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Research Article
Manufacture of Functional and Healthy Probiotic Frozen Goat's Yoghurt Using Chia Flour

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Abstract

Background and Objective: Chia seed is a good source of polyunsaturated fatty acid, dietary fiber, antioxidant activity and it can form mucilage so, its use as stabilizers and emulsifiers. Goat's milk has many nutritional and therapeutic properties. The objective of this study was to manufacture healthy and functional probiotic frozen goat's yogurt using chia flour (CF). **Materials and Methods:** Three types of probiotic frozen goat's yogurt were manufactured using full fat (4% fat) without CF as control, low-fat (2% fat) and non-fat (0.5% fat) goat's milk containing probiotic bacteria and using chia flour (CF) at different levels (1, 2 and 3%) as a fat replacer and stabilizers. The physiochemical, overrun, antioxidant activity, rheological, microbiological, sensory properties and fatty acid profile of goat's frozen yogurt determined when fresh and after15 and 30 days of frozen storage at -18°C. **Results:** The results showed that the specific gravity and the melting resistance of resultant low-fat and non-fat probiotic frozen goat's yogurt decreased as the CF level increased. The low-fat probiotic frozen goat's yogurt had higher overrun than non-fat and control. The antioxidant activity, Oleic and linoleic fatty acids of low-fat and non-fat probiotic frozen goat's yogurt had significantly ($p \leq 0.05$) increased as CF level increased than control. The total bacterial count, *L. bulgaricus*, *S. thermophilus*, *L. acidophlius* and *B. bifudium* were increased as CF level increased. **Conclusion:** The addition of CF at levels (1, 2 and 3%) increased the development of low-fat and non-fat probiotic frozen goat's yogurt flavor also, improved the functional, healthy and acceptability than the control.

Key words: Frozen yogurt, goat's milk, fat-replacer, stabilizer, chia flour, probiotic

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Competing Interest: The author has declared that no competing interest exists.

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

INTRODUCTION

Frozen yogurt is often considered a healthy different to plain ice cream. It's a delicious dessert that combines the texture of ice cream with the nutritious and healthy characteristics of yoghurt[1]. Frozen yogurt quality has enhanced and continues to grow; making it one in every of the foremost oftentimes consumed frozen desserts around the world consequently, makers are endlessly investigating value-added ingredients to stimulate health-conscious consumers[2]. It is worth mentioning frozen yogurt is often classified into three categories: soft, hard or mousse[3]. Nowadays, there is growing consumer interest in functional food products (i.e., beneficial compounds or foods containing microorganisms) that can provide health benefits[4]. The frozen dairy desserts might be a good source for probiotic cultures, due to their composition and low storage temperatures. *Bifidobacterium* is an important group of probiotic cultures and commonly used in fermented dairy products that contribute a major part in the human intestinal microbes in healthy humans. They are considered to provide many beneficial effects including improvement of lactose digestibility, ant-carcinogenic activity, reduction of serum cholesterol level, synthesis of B vitamins and facilitation in calcium absorption supplementation with *Bifidobacterium* spp. has been found to exert a little effect on flavor or compositional characteristics of frozen yoghurt[5-6]. Recently, consumers shift their dietary habits towards healthier food choices, particularly those that convey associate degree adequate intake of nutrients and present therapeutic effects. Chia (*Salvia hispanica* L.) is an annual herbaceous plant that belongs to the Lamiaceae family, chia is native from southern Mexico and northern Guatemala. Recently chia has been cultivated for commercial purposes practically for human consumption as food supplements[7]. The chia seeds are usually consumed grounded or as a whole grain in food industries such as fruit juices, beverages, milk and salad. Chia flour incorporated in diets and earned good quality because of its technological, healthy, nutritional and functional properties, which include fat-binding and gelatin[8-9].

Chia seeds have high contents of dietary fiber, proteins, minerals, vitamins, amino acids and polyunsaturated fatty acids, mainly α-linolenic acid, linoleic and oleic acids. Also, it has high contents of bioactive compounds of antioxidant activity, mainly polyphenols and tocopherols. Also, Chia seeds are used because of its healthy beneficial effect on the anti-carcinogenic, anti-inflammatory, anti-obesity and antiradical activities, control of dyslipidemia due to low-density lipoprotein (LDL) and triglycerides contents reduction and additionally high-density lipoprotein (HDL). These seeds can absorb water and form mucilage which might be used in food technology as a substitute for stabilizers and emulsifiers[10].

In the last years, utilization of the goat milk for product manufacturing increased because of its known functional properties and health benefits. Goat milk has been recognized as unique lipid and protein with unique health benefits. Goat milk contains a higher amount of calcium, magnesium and phosphorus than cow and human milk[11]. Goat milk is a good source for those who are suffering from anemia, osteoporosis and malabsorption and allergy or intolerance to cow milk. Many products are manufactured from goat milk such as cheese, yogurt, UHT and evaporated milk, pasteurized beverages, ice-cream, milk powder because of the functional and nutraceutical properties of goat milk[12]. Therefore, the objective of this work was to investigate the influence of using chia flour at different levels (1, 2 and 3%) as a fat replacer and stabilizers on the manufacture of three types of probiotics goat's frozen yogurt. Full-fat (4% fat) probiotics frozen goat's yogurt without chia flour as control, low-fat (2% fat) and non-fat (0.5% fat) probiotics frozen goat's yogurt. Physiochemical, overrun, antioxidant activity, rheological, microbiological and sensory properties and fatty acid profile were determined during frozen storage at -18°C when fresh then after 15 and 30 days.

MATERIALS AND METHODS

Fresh whole goat's milk (12.6% total solids, 4% fat, 3.70% protein, 0.77% ash, 0.16% acidity and pH value 6.66) was obtained from the herds of Desert Research Center, Ministry of Agriculture, Cairo, Egypt. Probiotic starter culture ABT-2 which consists of *Streptococcus thermophilus* ST-20Y, *Lactobacillus acidophilus* LA-5 and *Bifidobacterium bifidium* BB-12 and freeze-dried culture of *Lactobacillus bulgaricus* and *Streptococcus thermophilus* (1:1) were obtained from Chr. Hansen's laboratories, (Denmark). Chia flour (96.5% total solids, 35% fat, 23% protein, 3.63% ash and 34.8% dietary fiber). Skim milk powder (1.32% fat, 96.15% total solids and 32% protein) were obtained from the local market, Fresh goat's cream containing 40% fat was obtained by separating of fresh goat's milk using the cream separator. Carboxymethyl cellulose (CMC) was obtained from Misr Food Additives-MIFAD, Bader City, commercial-grade sugar (sucrose) and vanilla were obtained from the local market. 2, 2-diphenyl-1-picrylhydrazyl (DPPH) was obtained from Sigma-Aldrich, (Germany).

Table 1: Formulation of ingredients of probiotic frozen goat's yogurt using chia flour

	Treatments						
	Full fat (4% fat)	Low-fat (2% fat)			Non-fat (0.5% fat)		
Ingredients (g kg^{-1})	Control	T1	T2	T3	T4	T5	T6
Goat's milk (4%)	793.7	-	-	-	-	-	-
Goat's milk (2% fat)	-	808.1	798.6	789.1	-	-	-
Goat's milk (0.5% fat)	-	-	-	-	817.2	915	812
Skim milk powder	34.2	32.4	32.4	32.4	30.6	30.6	30.6
Cream (40% fat)	17.1	-	-	-	-	-	-
Chia flour(35% fat)	-	9.5	19.0	28.5	2.2	4.4	6.6
Sugar	150	150	150	150	150	150	150
Stabilizer (CMC)	5	-	-	-	-	-	-
Total	1000	1000	1000	1000	1000	1000	1000

Control: Full-fat probiotic frozen goat's yogurt (4% fat) without chia flour (CF), low-fat (2% fat) probiotic frozen goat's yogurt T1: 1% CF, T2: 2% CF, T3: 3% CF, non-fat (0.5% fat) probiotic frozen goat's yogurt, T4: 1% CF, T5: 2% CF, T6: 3% CF

Study area: This study was carried out in the laboratories of Desert Research Center (Mataria, Egypt) and the Faculty of Agriculture (Zagazig University) during the period November, 2018 till February, 2019.

Preparation of chia flour: Chia flour was prepared according to Abd El Fatah Faid[13]. The chia seeds were milled and ground into flour and sieving through 40 mesh screens using a hammer mill. Then the resultant chia flour was packed and kept in the refrigerator temperature until used.

Experimental analysis: Formulation of different treatments (7 treatments) is illustrated in Table 1. Three replicates were made from each treatment and analyzed each in duplicate.

Preparation of probiotic frozen goat's yogurt using chia flour: Probiotic frozen goat's yogurt was prepared according to Goda *et al.*[14]. Seven treatments of frozen yogurt mixes were prepared by blending the ingredients shown in Table 1. All treatments standardized to give 12% SNF, 15% sugar, 0.1 vanillas and 0.5% stabilizer.

The fat standardized as follow:

- The control treatment was standardized to give full fat (4% fat) without chia flour (CF) addition, the low-fat treatments were standardized to give (2% fat) with 1, 2 and 3% CF and non-fat treatments were standardized to give (0.5% fat) with 1, 2 and 3% CF. The mixes were homogenized at 250 kg cm^{-2}, heated at 85°C/15 min and cooled to 42°C. Yogurt starter cultures were added at the ratio of 2 and 5% of ABT-2 probiotics starter, mixes were incubated at 42°C until desired titratable acidity was reached to 0.4-0.5%. Then mixes were cooled to 5°C. Sugar and stabilizer were added then all mixes were aged at 5°C overnight prior to whipping and freezing. The aged mixes were frozen in an ice cream freezing machine (Punto Dolce gel M2, Staff Ice system, Rimini, Italy). The resultant frozen yogurt was packaged into a plastic cup (150 mL) and stored at -18°C for hardening according to Marshall *et al.*[15]. The resultant probiotic frozen goat's yogurt was analyzed for physicochemical, microbiological, antioxidant activity and sensory properties when fresh and then after 15 and 30 days

Physico-chemical analysis: The total solids, fat, protein, acidity, ash and fiber of goat's milk, dried skim milk and chia flour were determined by AOAC[16]. The pH value was determined using a pH meter (Persica model pH 900, Switzerland). Apparent viscosity measurements of the apparent viscosity of aged probiotics frozen goat's yogurt mixes were carried out according to Mitschka[17], with some modifications. Brook field Programmable Rheometer (Model RVDV-III Ultra, Brookfield Engineering Laboratories, Stoughton, MA, USA) was used for viscosity measurements. All mixes were tempered for 5 min at 20±1°C in a concentric cylinder with RV spindle number 3 at 40 rpm. Rheocalc software (ver. 2.5, Brookfield Engineering Laboratories, Inc.) was used to collect the values of apparent viscosity. Plastic viscosity, yield stress, flow behavior index and consistency coefficient index were drowning from measured values of shear stresses and apparent dynamic viscosity.

Probiotics frozen goat's yogurt mixes and resultant probiotics frozen goat's yogurt were analyzed for specific gravity, weight per gallon (kg) and freezing point according to Marshall and Arbuckle[18]. The overrun of probiotics frozen goat's yogurt was analyzed by Marshall *et al.*[15]. The melting resistance of probiotic frozen goat's yogurt samples was determined according to Segall and Goff[19]. Probiotics frozen goat's yogurt (30 g in weight at -18°C was placed on a Buchner funnel at ambient temperature (25°C). The weight of the melted material was recorded after 15 min past and expressed as percentage weight melted. The color estimation of probiotics frozen goat's yogurt samples was measured using the Hunter Lab color Flex. The L, a and b values were recorded, with L denoting lightness on a 0-100 scale from black to white; a, red (+) or green (-) and b, yellow (+) or blue (-) as described by CIE[20]. Acetaldehyde contents (μ mg^{-1}) were analyzed according to Lee and Jago[21].

Total phenolic and antioxidant activity analysis

Preparation of chia seeds extract: The milled chia seeds were weighed and added solvent (hydroethanolic solution 80%) in a 1:10 (1 g chia seed and 10 mL solvent), to obtain the extract. Thereafter, the extracts subjected to constant stirring (80 rpm) using a mechanical stirrer (Marconi MA-039, Piracicaba Brazil) for 60 min then filtered through qualitative filter paper No. 1 and centrifuged at 3000 rpm for 20 min. The extracts had their volumes completed with distilled water, packed and stored in amber bottles in a freezer (-20°C) until analysis Reyes-Caudillo *et al.*[22]

Determination of total phenolic content (TPC): Total phenolic content (TPC) was determined according to Jayaprakasha *et al.*[23] by using Folin-Ciocalteu reagent. The 0.5 mL of sample was mixed with 0.5 mL of 10-fold-diluted Folin-Ciocalteu reagent. After 3 min, 4 mL of 7.5% sodium carbonate was added. The mix was allowed to stand for 30 min in the dark at room temperature before the absorbance was measured at 765 nm using a spectrophotometer (model 2010, Cecil Instr. Ltd., Cambridge, UK). The final results were expressed as milligrams gallic acid of equivalent per gram of dry weight (DW).

Determination of radical scavenging activity (RSA %): Free radical scavenging activities (RSA %) of the samples were measured using the method of Brand-Williams *et al.*[24] An aliquot 100 μL of the sample solution was mixed with 2.9 mL of 1, 1-diphenyl-2-picrylhydrazyl (DPPH) in methanol. The mix was shaken vigorously and left to stand for 30 min. The absorbance of the resulting solution was measured at 517 nm by a UV-visible spectrophotometer. The antioxidant activity was calculated using the following equation:

$$\text{Antioxidant activity (\%)} = \left[1 - \frac{\text{Abs sample}}{\text{Abs control}} \times 100\right]$$

Fatty acid profile: Fatty acid profile was determined according to Qian[25] by transforming the fat to fatty acid methyl esters, which were prepared by reacting 50 mg fat with 2 mL (15% methanolic HCl, Fluka) at 100°C, for 1 h, then the tubes were cooled to room temperature, 2 mL n-hexane and 2 mL deionized water was added, vortexes at 500×g for 2 min. Test tubes were allowed to stand for 15 min, the supernatant was transferred to GC vials, injected to GC-MS (7890 A GC System Agilent) fitted MSD detector, using ZB-5 fused silica capillary column (Zebron Phenomenex, 30 m×0.25 mm).

Microbiological analysis: The total bacterial count of probiotics frozen goat's yogurt was determined according to Marshall[26] numeration of *S. thermophilus*, diluted samples were plated on M17 agar (Oxide Ltd) and incubated at 37°C for 48-72 h under aerobic conditions while *L. delbrueckii* subsp. *Bulgaricus* was determined using MRS-agar Rybka and Kailasaphaty[27] *L. acidophilus* counts were determined using MRS-sorbitol agar according to Dave and Shah[28] *Bifidobacterium bifidium* was plated on MRS-NNLP medium. The plates of *L. acidophilus* and *Bifidobacterium bifidium* were anaerobically (Anaerocult A system; Merck, Darmstadt, Germany) incubated at 37°C for 72 h Gueimonde *et al.*[29] Coliform bacteria and mold and yeasts were analyzed according to IDF[30-31] respectively.

Sensory evaluation: The sensory evaluation of probiotics frozen goat's yogurt were determined by a test panel of 10 panelists of the staff member of Animal and Poultry Breeding Department, Desert Research Centre for flavor (45 point), body and texture (35 point), color and appearance (10 points), melting quality (10 points) and overall acceptability as described by Salama[32]. The probiotics frozen yogurt was taken out from frozen storage period 18°C after 24 h post hardening and promptly offered to the panelists.

Statistical analysis: The data related to the three replications were obtained by applying a three-factor completely randomized block design with the results being analyzed through SPSS software. Analysis of variance along with significant difference ($p \leq 0.05$) were accomplished through Duncan's multiple range test Steel *et al.*[33]. Excel software was employed to plot curves.

RESULTS

Pilot experiments were carried out to study the influence of different levels (1, 2, 3, 4, 5 and 6%) of chia flour (CF) as a fat replacer and stabilizer on the quality of probiotic frozen goat's yogurt. The obtained results showed that chia flour (CF) could be successfully used at the levels (1, 2 and 3%) to improve the functional, nutritional and health benefits of probiotic frozen goat's yogurt.

Physical properties of probiotic frozen goat's yogurt mixes

Specific gravities and weight per gallon values: The results in Table 2 showed that specific gravities and weight per gallon values decreased ($p\leq0.05$) significantly with the increase of CF levels up to 3%. Results showed that higher values of specific gravity and weight per gallon values recorded in non-fat (0.5% fat) T4, T5 and T6 followed by low-fat (2% fat) probiotic frozen goat's yogurt mixes T1, T2 and T3 while the full-fat (4% fat) without CF as control record lowest values. Also, specific gravity and weight per gallon values increased ($p\leq0.05$) significantly with the decrease in the fat percentage.

Freezing point: Results from Table 2 showed that the freezing point decreased ($p\leq0.05$) significantly with the increase of CF up to 3%. Non-fat (0.5% fat) probiotic frozen goat's yogurt mixes T4, T5 and T6 recorded lowest values followed by low-fat (2% fat) probiotic frozen goat's yogurt mixes T1, T2 and T3, respectively while full-fat (4% fat) probiotic frozen goat's yogurt mix without CF as control record highest value.

pH values: The pH values significantly ($p\leq0.05$) decreased with the increase in the levels of CF. Non-fat (0.5% fat) probiotic frozen goat's yogurt mixes T4, T5 and T6 recorded the lowest pH values followed by low-fat (2% fat) probiotic frozen goat's yogurt mixes T1, T2 and 3,while full fat (4% fat) probiotic frozen goat's yogurt mix without CF as control record highest pH value it was 6.63±0.50.

Rheological properties: Results from Table 2 illustrate that the apparent viscosity, plastic viscosity, yield stress and consistency coefficient index increased ($p\leq0.05$) significantly in low-fat (2% fat) followed by non-fat (0.5% fat)) probiotic frozen goat's yogurt mixes than the full-fat (4% fat) probiotic frozen goat's yogurt mixes without CF as control. Also, it could be noticed that T3, T2 and T1 recorded highest values of apparent viscosity, plastic viscosity, yield stress and consistency coefficient index followed by T6, T5 and T4 while full fat (4% fat) without CF as control recorded lowest values. On the other hand; the flow behavior index of the three types of probiotic frozen goat's yogurt mixes took an opposite trend to different properties.

Biochemical properties of resultant probiotic frozen goat's yogurt

Specific gravity: The results from Table 3 showed that the specific gravity of fresh low fat (2% fat) and non-fat (0.5% fat) probiotic frozen goat's yogurt were decreased ($p\leq0.05$) significantly with the increase of the CF levels up to 3%. Non-fat (0.5% fat) probiotic frozen goat's yogurt T4, T5 and T6 had highest specific gravity followed by low-fat (2% fat) probiotic frozen goat's yogurt T3, T2 and T1, respectively, while full fat (4% fat) probiotic frozen goat's yogurt without CF as control recorded the lowest value it was 0.638±0.50. On the opposite hand, specific gravity decreased ($p\leq0.05$) significantly in all treatments during the frozen storage period.

Table 2: Physical, rheological properties and pH values of probiotic frozen goat's yogurt mixes using CF

	Treatments						
	Full-fat (4%)	Low-fat (2% fat)			Non-fat (0.5% fat)		
Properties	Control	T1	T2	T3	T4	T5	T6
Specific gravity (g mL^{-1})	1.0855 ± 0.30^{g}	1.1175 ± 0.50^{f}	1.1166 ± 0.50^{e}	1.1147 ± 0.50^{d}	1.1205 ± 0.50^{c}	1.1194 ± 0.49^{b}	1.1180 ± 0.50^{a}
Weight per gallon (kg)	4.117 ± 0.50^{g}	4.239 ± 0.50^{f}	4.235 ± 0.50^{e}	4.228 ± 0.50^{d}	4.250 ± 0.50^{c}	4.245 ± 0.50^{b}	4.241 ± 0.50^{a}
Freezing point (°C)	-2.3 ± 0.48^{g}	-2.35 ± 0.50^{f}	-2.37 ± 0.50^{e}	-2.39 ± 0.50^{d}	-2.40 ± 0.43^{c}	-2.45 ± 0.42^{b}	-2.48 ± 0.43^{a}
pH-value	6.63 ± 0.50^{e}	6.50 ± 0.50^{c}	6.48 ± 0.50^{b}	6.44 ± 0.50^{a}	6.38 ± 0.50^{g}	6.35 ± 0.50^{f}	6.31 ± 0.50^{d}
Apparent viscosity (mPas)	144.7 ± 0.50^{g}	198.9 ± 0.36^{c}	217.4 ± 0.50^{b}	320.2 ± 0.50^{a}	146.0 ± 0.50^{f}	150.5 ± 0.50^{e}	187.8 ± 0.76^{d}
Plastic viscosity (mPas)	97.0 ± 0.40^{g}	132.2 ± 0.50^{c}	144.9 ± 0.50^{b}	195.1 ± 0.26^{a}	99.2 ± 0.50^{f}	106.4 ± 0.50^{e}	130.6 ± 0.50^{d}
Yield stress (N m^{-2})	4.39 ± 0.43^{g}	4.73 ± 0.50^{c}	4.89 ± 0.50^{b}	4.95 ± 0.50^{a}	4.43 ± 0.50^{f}	4.57 ± 0.50^{e}	4.62 ± 0.50^{d}
Flow behavior index	0.551 ± 0.50^{a}	0.518 ± 0.50^{e}	0.502 ± 0.50^{f}	0.493 ± 0.50^{g}	0.546 ± 0.50^{b}	0.540 ± 0.50^{c}	0.537 ± 0.50^{d}
Consistency coefficient (mPas)	119.9 ± 0.50^{g}	156.2 ± 0.50^{c}	167.1 ± 0.50^{b}	178.7 ± 0.29^{a}	121.8 ± 0.50^{f}	138.9 ± 0.50^{e}	145.5 ± 0.50^{d}

Means within a row with different superscripts are significantly different (p<0.05), Control: Full-fat probiotic frozen goat's yogurt (4% fat) without chia flour (CF), low-fat (2% fat) probiotic frozen goat's yogurt T1: 1% CF, T2: 2% CF, T3: 3% CF, Non-fat (0.5% fat) probiotic frozen goat's yogurt, T4: 1% CF, T5: 2% CF, T6: 3% CF

Table 3: Physical and biochemical properties of probiotic frozen goat's yogurt using different level of CF during the frozen storage period

Properties/ storage period (days)	Treatments: Full-fat (4%)	Low-fat (2% fat)			Non-fat (0.5% fat)		
	Control	T1	T2	T3	T4	T5	T6
Specific gravity							
Fresh	0.638 ± 0.50^{g}	0.680 ± 0.50^{d}	0.665 ± 0.50^{e}	0.650 ± 0.50^{f}	0.798 ± 0.50^{c}	0.782 ± 0.50^{b}	0.765 ± 0.50^{a}
15	0.625 ± 0.50^{e}	0.653 ± 0.50^{ga}	0.645 ± 050^{f}	0.631 ± 0.50^{d}	0.783 ± 0.50^{c}	0.770 ± 0.50	0.751 ± 0.50^{a}
30	0.603 ± 0.50^{e}	0.637 ± 0.50^{g}	0.625 ± 0.50^{f}	0.611 ± 0.50^{d}	0.765 ± 0.50^{c}	0.751 ± 0.50^{b}	0.739 ± 0.50^{a}
Overrun (%)							
Fresh	50.320 ± 0.50^{g}	73.890 ± 0.50^{c}	75.690 ± 0.50^{b}	77.790 ± 0.50^{a}	57.450 ± 0.50^{f}	60.250 ± 0.50^{e}	69.210 ± 0.50^{d}
15	47.020 ± 0.50^{g}	69.550 ± 0.50^{d}	70.110 ± 0.50^{c}	74.700 ± 0.57^{e}	55.640 ± 0.50^{k}	56.820 ± 0.50^{i}	50.920 ± 0.50^{m}
30	44.800 ± 0.50^{i}	66.980 ± 0.50^{hi}	67.220 ± 0.50^{g}	69.390 ± 0.50^{f}	45.040 ± 0.40^{n}	47.410 ± 0.50^{m}	49.120 ± 0.50^{i}
Acetaldehyde							
Fresh	272.000 ± 0.50^{g}	351.000 ± 0.50^{f}	360.000 ± 0.50^{e}	372.000 ± 0.50^{d}	377.000 ± 0.50^{c}	380.000 ± 0.50^{b}	392.000 ± 0.50^{a}
15	212.000 ± 0.50^{s}	309.000 ± 0.50^{n}	318.000 ± 0.50^{m}	325.000 ± 0.50^{i}	358.000 ± 0.50^{h}	374.000 ± 0.50^{e}	383.000 ± 0.50^{b}
30	189.000 ± 0.50^{t}	280.000 ± 0.50^{q}	298.000 ± 0.50^{p}	305.000 ± 0.50^{o}	339.000 ± 0.50^{k}	355.000 ± 0.50^{i}	374.000 ± 0.50^{e}
Melting loss (%) (resistance)							
Fresh							
30 min	9.720 ± 0.50^{de}	7.250 ± 0.50^{e}	6.830 ± 0.50^{e}	4.980 ± 0.50^{a}	8.850 ± 0.50^{e}	8.150 ± 0.50^{e}	7.800 ± 0.50^{e}
60 min	65.110 ± 0.50^{be}	62.810 ± 0.50^{be}	62.500 ± 0.50^{be}	60.260 ± 0.50^{be}	63.910 ± 0.50^{be}	63.770 ± 0.50^{be}	63.160 ± 0.50^{be}
90 min	72.540 ± 0.50^{be}	70.750 ± 0.69^{be}	70.760 ± 0.52^{be}	0.030 ± 0.50^{be}	71.680 ± 0.50^{be}	71.450 ± 0.50^{be}	71.220 ± 0.50^{be}
15							
30 min	11.250 ± 0.50^{de}	8.980 ± 0.50^{e}	8.860 ± 0.50^{e}	7.940 ± 0.50^{e}	9.480 ± 0.50^{de}	9.340 ± 0.50^{de}	9.270 ± 0.50^{e}
60 min	75.780 ± 0.50^{bcd}	70.770 ± 0.50^{be}	71.190 ± 0.50^{be}	70.460 ± 0.50^{be}	71.930 ± 0.50^{be}	71.690 ± 0.50^{be}	71.480 ± 0.50^{be}
90 min	85.660 ± 0.50^{b}	81.570 ± 0.50^{b}	81.350 ± 0.50^{b}	79.100 ± 0.50^{bc}	84.790 ± 0.50^{b}	84.670 ± 0.50^{b}	83.360 ± 0.50^{b}
30							
30 min	12.940 ± 0.50^{cde}	11.590 ± 0.50^{de}	11.400 ± 0.50^{de}	9.810 ± 0.50^{de}	12.520 ± 0.50^{de}	12.320 ± 0.50^{de}	12.080 ± 0.50^{de}
60 min	82.120 ± 0.50^{b}	79.830 ± 0.50^{b}	79.650 ± 0.50^{b}	79.390 ± 0.50^{bc}	80.780 ± 0.50^{b}	80.410 ± 0.50^{b}	80.160 ± 0.50^{b}
90 min	97.580 ± 0.50^{b}	90.910 ± 0.50^{b}	90.630 ± 0.50^{b}	90.150 ± 0.50^{b}	93.000 ± 0.50^{b}	92.790 ± 0.50^{b}	92.590 ± 0.50^{b}

Means within a row with different superscripts are significantly different ($p<0.05$), Control: Full-fat probiotic frozen goat's yogurt (4% fat) without chia flour (CF), low-fat (2% fat) probiotic frozen goat's yogurt T1: 1% CF, T2: 2% CF, T3: 3% CF, Non-fat (0.5% fat) probiotic frozen goat's yogurt T4: 1% CF, T5: 2% CF, T6: 3% CF

Overrun: The results from Table 3 showed that the overrun for fresh low-fat (2% fat) probiotic frozen goat's yogurt were significantly ($p\leq0.05$) increased with the increase of CF levels up to 3% followed by non-fat (0.5% fat) probiotic frozen goat's yogurt. Noticed that T3, T2 and T1 had higher overrun followed by T6, T5 and T4 while full-fat (4% fat) without CF as control recorded lowest overrun. Whereas, overrun decreased ($p\leq0.05$) significantly in all probiotic had frozen goat's yogurt treatments during frozen storage.

Acetaldehyde: Also, the results from Table 3 illustrated that the acetaldehyde content was significantly ($p\leq0.05$) increased with the increase of CF levels up to 3%. Fresh non-fat (0.5% fat) T6, T5 and T4 followed by T3, T2 and T1 low-fat (2% fat) probiotic frozen goat's yogurt recorded higher acetaldehyde content. Whereas the full-fat (4% fat) without CF as control recorded the lowest value. Also, acetaldehyde content decreased ($p\leq0.05$) significantly during 15 days of frozen storage and so it decreased ($p\leq0.05$) gradually during the frozen storage period altogether resultant probiotic frozen goat's yogurt treatments.

Melting resistance: The results from Table 3 showed that the melting resistance increased with the increase of CF levels up to 3% in low-fat (2% fat) and non-fat (0.5% fat) probiotic frozen goat's yoghurt than the full-fat (4% fat) probiotic frozen goat's yoghurt without CF as control. The low-fat (2% fat) probiotic frozen goat's yoghurt recorded highest melting resistance followed by non-fat (0.5% fat) probiotic frozen goat's yoghurt that took an extended period to begin the melting process than the full-fat (4% fat) probiotic frozen goat's yoghurt without CF as a control. Moreover, the amount of melted probiotic frozen goat's yoghurt samples were less at the end of the analysis period (90 min). These results showed that the highest melting resistance the higher overrun of low-fat (2% fat) probiotic frozen goat's yoghurt followed by non-fat (0.5% fat).

Radical scavenging activity (RSA %) and total phenolic compounds (TPC)

Radical scavenging activity: Results from Fig. 1a showed that the radical scavenging activity (RSA%) of low-fat (2% fat) and non-fat (0.5% fat) probiotic frozen goat's yogurt had

Table 4: Color changes of probiotic frozen goat's yogurt using different level of CF during the frozen storage period

Properties/ storage period (days)	Treatments Full-fat (4%)	Low-fat (2% fat)			Non-fat (0.5% fat)		
	Control	T1	T2	T3	T4	T5	T6
L							
Fresh	80.86 ± 0.50^{b}	78.03 ± 0.50^{d}	73.65 ± 0.50^{g}	65.28 ± 0.50^{l}	73.90 ± 0.50^{fg}	72.81 ± 0.50^{h}	69.92 ± 0.50^{j}
15	81.79 ± 0.50^{a}	79.56 ± 0.50^{c}	74.69 ± 0.50^{ef}	66.89 ± 0.50^{k}	74.55 ± 0.50^{f}	73.62 ± 0.50^{gh}	70.98 ± 0.50^{i}
30	82.45 ± 0.50^{a}	80.12 ± 0.50^{bc}	75.38 ± 0.50^{e}	69.74 ± 0.50^{j}	75.39 ± 0.50^{e}	74.22 ± 0.50^{fg}	71.38 ± 0.50^{l}
a							
Fresh	-3.41 ± 0.50^{f}	-0.89 ± 0.29^{ae}	-1.16 ± 0.50^{ae}	-1.35 ± 0.50^{cde}	-1.85 ± 0.50^{e}	-1.41 ± 0.50^{de}	-0.91 ± 0.50^{ad}
15	-1.33 ± 0.50^{be}	-0.71 ± 0.50^{abc}	-0.94 ± 0.50^{ad}	-1.09 ± 0.50^{ae}	$-1.56^{\pm}0.50^{de}$	-1.56 ± 0.50^{be}	-0.82 ± 0.50^{ad}
30	-1.00 ± 0.67^{ad}	-0.53 ± 0.50^{ab}	-0.80 ± 0.50^{ad}	-0.04 ± 0.27^{a}	-1.13 ± 0.50^{e}	-0.89 ± 0.50^{ad}	-0.69 ± 0.50^{abc}
b							
Fresh	10.98 ± 0.50^{i}	12.53 ± 0.50^{gh}	12.75 ± 0.50^{gh}	12.94 ± 0.50^{g}	12.04 ± 0.50^{h}	12.72 ± 0.50^{gh}	12.86 ± 0.50^{gh}
15	12.72 ± 0.50^{gh}	15.10 ± 0.50^{f}	15.87 ± 0.50^{def}	16.02 ± 0.50^{de}	16.15 ± 0.50^{e}	16.09 ± 0.50^{de}	16.59 ± 0.50^{gh}
30	15.42 ± 0.50^{ef}	17.35 ± 0.50^{bc}	17.95 ± 0.50^{ab}	18.35 ± 0.50^{a}	17.47 ± 0.50^{b}	17.97 ± 0.50^{ab}	18.75 ± 0.50^{a}

Means within a row with different superscripts are significantly different ($p<0.05$), Control: Full-fat probiotic frozen goat's yogurt (4% fat) without chia flour (CF), low-fat (2% fat) probiotic frozen goat's yogurt T1: 1% CF, T2: 2% CF, T3: 3% CF, Non-fat (0.5% fat) probiotic frozen goat's yogurt T4: 1% CF, T5: 2% CF, T6: 3% CF

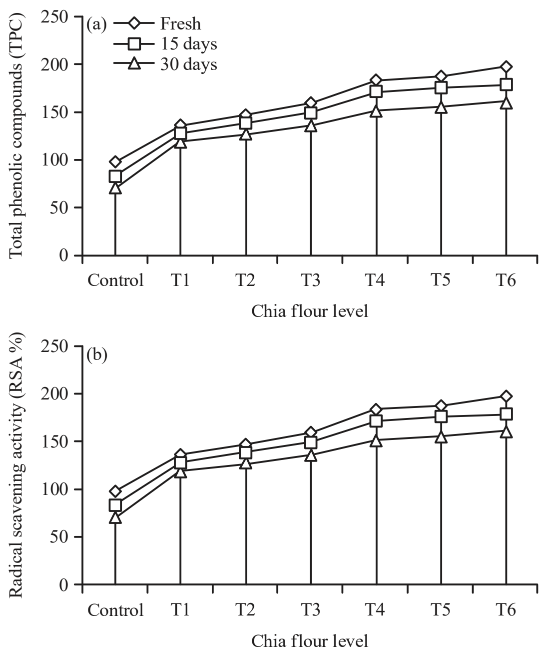

Fig. 1(a-b): RSA (%) and TPC of probiotic frozen goat's using different level of CF during the frozen storage period
Control: Full-fat probiotic frozen goat's yogurt (4% fat) without chia flour (CF), low-fat (2% fat) probiotic frozen goat's yogurt T1: 1% CF, T2: 2% CF, T3: 3% CF, Non-fat (0.5% fat) probiotic frozen goat's yogurt T4: 1% CF, T5: 2% CF, T6: 3% CF

significantly ($p\leq0.05$) increased with the increase of CF levels up to 3% than the full-fat (4% fat) probiotic frozen goat's yogurt without CF as control. It could be noticed that the non-fat (0.5% fat) probiotic frozen goat's yogurt recorded highest values than low-fat (2% fat) probiotic frozen goat's yogurt whereas T6 recorded the highest value followed by T5, T4, T3, T2 and T1 whereas full-fat (4% fat) probiotic frozen goat's yogurt without CF as control recorded the lowest (RSA%). On the opposite, gradually reduced within the (RSA%) was detected after 15 days during the frozen storage period.

Total phenolic compounds: Also, results from Fig. 1b showed that the total phenolic compounds (TPC) of low-fat (2% fat) and non-fat (0.5% fat) probiotic frozen goat's yogurt were highly significant ($p\leq0.05$) increased in TPC than full-fat (4% fat) without CF served as control. It could be noticed that the non-fat (0.5% fat) probiotic frozen goat's yogurt recorded highest level of radical scavenging activity (TPC) than low-fat (2% fat) probiotic frozen goat's yogurt whereas T6 recorded highest value followed by T5, T4, T3, T2 and T1 whereas full-fat (4% fat) probiotic frozen goat's yogurt without CF as control samples recorded the lowest (TPC). A clear decrease in TPC showed in all probiotic goat's frozen yogurt after 15 days of frozen storage period.

Color changes: The color changes are illustrated in Table 4. A significant difference ($p\leq0.05$) in color between the resultant low-fat (2% fat), non-fat (0.5% fat)probiotic frozen goat's yogurt using CF up to 3% and full-fat (4% fat) probiotic frozen goat's yogurt without CF as control. Results from Table 4 showed that T3 and T6 given lower L* values ($p\leq0.05$) than control in fresh and during the frozen storage period. These might be associated with the addition of different levels of CF that accomplished in lighting in low-fat (2% fat) and non-fat (0.5% fat) probiotic frozen goat's yogurt, in color analysis, the L* parameter indicates lightness and reflect light on a scale ranging from 0 to 100. Significantly higher a* values ($p\leq0.05$) were found in T4 and T1 than the control in fresh and during

Table 5: Main fatty acids composition in chia flour

Fatty acids	Fatty acids (%) in chia flour
Palmitic acid C16:0	7.55
Stearic acid C18:0	2.80
Oleic acid C18:1 ω9	6.13
Vaccenic acid C18:1 ω7	0.82
Linoleic acid C18:2 ω6	19.20
Linolenic acid C18:3 ω3	63.40
Arachidic acid C20:0	0.23

the frozen storage period. The b* values (yellow component) were found to be higher in T6 and T3 in fresh and during the frozen storage period whereas the control recorded the lowest value.

Fatty acids profile: The characterization of the fatty acid profile of the chia flour was summarized in Table 5. Palmitic and stearic are saturated fatty acids (SFA). Oleic acid is monounsaturated fatty acids (MUFA), linoleic acid (LA) and linolenic acids (ALA) are polyunsaturated fatty acids (PUFA) were determined as they had previously been investigated. Palmitic acid was found to be 7.55% in the chia flour. Stearic acid was found to be 2.80% in the chia flour's fat content, which agrees with the (range 2.8-3.2%). The oleic acid content was 6.13% which is within the range; (6.2-8.2%), linoleic acid and linolenic acid content were 19.2 and 63.4%, respectively.

The profiles of fatty acid compositions of the three types of resultant probiotic frozen goat's yogurt are listed in Table 6. All the resultant probiotic frozen goat's yogurt contained 21different fatty acids from butyric acid (C4:0) to arachidonic acid (C20:4 ω6). The highest concentration of fatty acid was palmitic acid (C16:0), followed by oleic acid (C18:1), linoleic (C18:1) and myristic acid (C14:0).

The high levels of the medium-chain fatty acids (C12:0 and C14:0) found in the probiotic frozen goat's yogurt using different levels of CF up to 3%.

Oleic acid (C18:1) was recorded at the highest level among the unsaturated fatty acids in all probiotic frozen goat's yogurt treatments. It could noticed that non-fat(0.5%fat)probiotic frozen goat's yogurt T4, T5 and T6 respectively, contained significantly ($p\leq 0.05$) higher Oleic acid (C18:1 ω9) than that of low-fat (2% fat) probiotic frozen goat's yogurt T1, T2 and T3 and full fat (4% fat) probiotic frozen goat's yogurt without CF as a control. Linoleic acid (C18:2 ω6) and linoleic acid (C18:3 ω3) were increased ($p<0.05$) significantly with the increase of CF levels up to 3%. All of the long-chain fatty acids were significantly (p<r0.05) higher in full-fat (4% fat) probiotic frozen goat's yogurt without CF as control than those in low-fat (2% fat) and non-fat (0.5% fat) probiotic frozen goat's yogurt, except the Arachidic acid C20:0 and Arachidonic acid C20:4 ω6.

Furthermore, Σ of saturated fatty acid of non-fat (0.5% fat) T4, T5and T6 probiotic frozen goat's yogurt contained significantly ($p\leq 0.05$) lowest value followed by low-fat (2% fat) probiotic frozen goat's yogurt T1, T2 and T3 while, full fat (4% fat) probiotic frozen goat's yogurt without CF as control recorded the highest value. Also, results from Table 6 show that Σ unsaturated fatty acid of non-fat (0.5% fat) and low-fat (2% fat) probiotic frozen goat's yogurt significantly ($p\leq 0.05$) increased with the increase of CF level than that of full-fat (4% fat) probiotic frozen goat's yogurt without CF as control.

The ΣPUFA ω6/ΣPUFA ω3 ratio decreased ($p\leq 0.05$) significantly with the increase of CF levels up to 3%. The ΣPUFAω6/ΣPUFAω3 ratio of low-fat (2% fat) and non-fat (0.5% fat) probiotic frozen goat's yogurt decreased significantly ($p\leq 0.05$) with the increase of CF up to 3%. While, the ΣPUFA ω6/ΣPUFA ω3 of full-fat (4% fat) probiotic frozen goat's yogurt without CF as control recorded the highest value. The fatty acids were decreased ($p\leq 0.05$) significantly in all probiotic frozen goat's yogurt treatments during the frozen storage period up to 30 days.

Microbiological properties of resultant probiotic frozen goat's yogurt: Microbiological properties are shown in Fig. 2a. The total bacterial count of non-fat (0.5% fat) and low-fat (2% fat) probiotic frozen goat's yogurt significant ($p\leq 0.05$) increased gradually with the increase of CF levels up to 3%. The total bacterial count of T6 and T5 recorded the highest count followed by T3 and T2 while, the total bacterial count of full-fat (4% fat) probiotic frozen goat's yogurt without CF as control recorded the lowest count. Whereas the total bacterial counts in all probiotic frozen goat's yogurt were significantly ($p\leq 0.05$) decreased gradually till the end of the frozen storage period up to 30 days. Among probiotic frozen goat's yogurt treatments T6, T5 and T3 had the highest count after 30 days of storage. In general results from Fig. 2b and c showed that *L. bulgaricus* and *S. thermophilus* were increased significantly ($p\leq 0.05$) with the increase of adding levels of CF up to 3%. Fresh non-fat (0.5% fat) and low-fat (2% fat) probiotic frozen goat's yogurt had the highest count than full-fat (4% fat) probiotic frozen goat's yogurt without CF as control. Whereas a significant ($p\leq 0.05$) decreased occurred in the count of *L. bulgaricus* and *S. thermophilus* after 30 days of storage. The full-fat (4% fat) probiotic frozen goat's yogurt without CF as control and T1 recorded the lowest counts. Whereas, results from Fig. 2d and e showed that the highest count of the viable count of *L. acidophlius* and *B. bifudium* were found in T6, T5, T3 and T2 therefore the lowest count was found in the full-fat (4% fat) probiotic goat's frozen yogurt

Table 6: Fatty acids profile of probiotic frozen goat's yogurt using different level of CF during the frozen storage period

Properties/ storage period (days)	Treatment						
	Full-fat (4%)	Low-fat (2% fat)			Non-fat (0.5% fat)		
	Control	T1	T2	T3	T4	T5	T6
Butyric acid C4:0							
Fresh	1.41±0.50[a]	1.41±0.50[a]	1.38±0.50[a]	1.36±0.50[a]	1.38±0.50[a]	1.37±0.50[a]	1.33±0.50[a]
30	1.39±0.50[a]	1.40±0.50[a]	1.36±0.50[a]	1.27±0.50[a]	1.34±0.50[a]	1.31±0.5[a]	1.25±0.50[a]
Caproic acid C6:0							
Fresh	1.79±0.50[a]	1.77±0.50[a]	1.65±0.50[a]	1.51±0.50[a]	1.94±0.50[a]	1.94±0.5[a]	1.92±0.50[a]
30	1.78±0.50[a]	1.76[a]±0.50[a]	1.63±0.50[a]	1.49±0.50[a]	1.91±0.50[a]	1.87±0.5[a]	1.85±0.50[a]
Caprylic acid C8:0							
Fresh	1.65±0.50[a]	1.64±0.50[a]	1.51±0.50[a]	1.42±0.50[a]	1.86±0.50[a]	1.83±0.5[a]	1.81±0.50[a]
30	1.63±0.50[a]	1.63±0.45[a]	1.46±0.50[a]	1.37±0.50[a]	1.82±0.50[a]	1.81±0.5[a]	1.78±0.50[a]
Capric acid C10:0							
Fresh	4.62±0.50[ab]	4.60±0.29[a]	3.97±0.50[ad]	3.35±0.50[de]	4.45±0.50[abc]	3.80±0.50[be]	3.19±0.50[de]
30	4.50±0.50[abc]	4.45±0.50[abc]	3.50±0.62[de]	3.30±0.50[de]	4.41±0.50[abc]	3.76±0.50[cde]	3.12±0.50[e]
Undecanoic acid C11:0							
Fresh	0.22±0.27[a]	0.23±0.28[a]	0.21±0.27[d]	0.22±0.28[a]	0.20±0.27[a]	0.21±0.27[a]	0.20±0.27[a]
30	0.21±0.27[a]	0.22±0.27[a]	0.20±0.26[d]	0.22±0.27[a]	0.20±0.26[a]	0.21±0.27[a]	0.20±0.26[a]
Lauric acid C12:0							
Fresh	3.07±0.50[b]	3.04±0.5[b]	2.97±0.50[b]	2.80±0.50[b]	4.22±0.50[a]	4.15±0.50[a]	3.97±0.50[a]
30	2.96±0.50[b]	2.98±0.50[b]	2.93±0.50[b]	2.77±0.50[b]	4.20±0.50[a]	4.13±0.50[a]	3.96±0.50[a]
Myristic acid C14:0							
Fresh	9.50±0.50[abc]	10.15±0.50[a]	9.41±0.50[abc]	8.47±0.50[de]	9.95±0.50[ab]	7.72±0.50[ef]	6.18±0.50[g]
30	9.11±0.50[cd]	10.05±0.50[ab]	9.31±0.50[bc]	8.37±0.50[def]	9.45±0.50[abc]	7.62±0.50[f]	6.08±0.50[g]
Tetradecenoic acid CC14.1ω5							
Fresh	0.16±0.25[a]	0.16±0.25[a]	0.16±0.25[a]	0.15±0.25[a]	0.12±0.25[a]	0.12±0.25[a]	0.11±0.25[a]
30	0.15±0.25[a]	0.15±0.25[a]	0.15±0.25[a]	0.14±0.25[a]	0.11±0.25[a]	0.11±0.25[a]	0.10±0.25[a]
Pentaenoic acid C15:0							
Fresh	2.09±0.50[a]	1.89±0.50[ab]	1.86±0.50[ab]	1.82±0.50[ab]	1.39±0.50[ab]	1.25±0.50[b]	1.08±0.50[b]
30	2.07±0.50[a]	1.68±0.50[ab]	1.85±0.50[ab]	1.80±0.50[ab]	1.38±0.50[ab]	1.24±0.50[b]	1.06±0.50[b]
Palmitic acid C16:0							
Fresh	27.13±0.50[a]	25.26±0.50[cd]	23.34±0.50[ef]	23.27±0.50[fg]	25.91±0.25[ab]	24.12±0.50[de]	23.45±0.29[fg]
30	25.71±0.50[cd]	24.13±0.50[de]	23.27±0.50[fg]	22.86±0.50[g]	24.18±0.50[bc]	24.01±0.50[de]	23.19±0.50[eg]
Palmitoleic acid C16:1 ω7							
Fresh	1.47±0.50[a]	1.44±0.50[a]	1.40±0.50[a]	1.39±0.50[a]	1.12±0.50[a]	1.06±0.50[a]	0.96±0.50[a]
30	1.45±0.50[a]	1.43±0.50[a]	1.39±0.50[a]	1.38±0.50[a]	1.11±0.50[a]	1.04±0.50[a]	0.94±0.50[a]
Heptadecanoic acid C17:0							
Fresh	1.93±0.50[a]	1.77±0.50[abc]	1.21±0.50[ad]	0.69±0.50[d]	1.08±0.50[bcd]	0.89±0.50[d]	0.67±0.50[d]
30	1.91±0.49[ab]	1.76±0.50[abc]	1.20±0.50[ad]	0.64±0.50[d]	1.06±0.50[cd]	0.87±0.50[d]	0.66±0.50[d]
Stearic acid C18:0							
Fresh	11.39±0.50[a]	11.16±0.50[a]	10.06±0.50[a]	9.96±0.50[a]	10.03±2.78[a]	9.96±6.11[a]	9.58±0.50[b]
30	11.31±0.49[a]	11.11±0.50[a]	10.86±0.50[a]	9.74±0.50[a]	9.85±0.50[b]	9.80±0.50[b]	8.44±0.50[b]
Oleic acid C18:1							
Fresh	23.86±0.50[ef]	25.63±0.50[e]	26.51±0.50[e]	27.41±0.50[d]	29.04±0.50[bc]	29.35±0.50[ba]	29.89±0.50[a]
30	23.79±0.50[h]	25.18±0.50[g]	25.06±0.50[fg]	26.79±0.50[e]	27.64±0.50[d]	27.74±0.50[d]	28.33±0.50[cd]
Vaccenic acid C18:1 ω7							
Fresh	1.97±0.50[a]	1.00±0.50[bc]	1.13±0.50[bc]	1.78±0.50[ab]	0.45±0.00[c]	1.10±0.50[bc]	1.60±0.50[ab]
30	1.96±0.50[a]	0.99±0.50[bc]	1.15±0.50[bc]	1.77±0.50[ab]	0.48±0.44[c]	1.02±0.50[bc]	1.59±0.50[ab]
Linoleic acid C18:2 ω6							
Fresh	5.61±0.50[gh]	6.48±0.50[fg]	8.25±0.45[cd]	9.22±0.50[ab]	7.57±0.50[de]	8.55±0.50[bc]	9.51±0.50[a]
30	5.60±0.50[i]	6.47±0.50[hi]	7.28±0.54[ef]	9.04±0.5[cde]	5.90±0.50[g]	6.38±0.50[e]	7.09±0.50[cd]
Linolenic acid C18:3 ω3							
Fresh	1.34±0.48[fg]	2.18±0.50[e]	4.19±0.50[d]	4.73±0.50[cd]	2.53±0.50[e]	5.64±0.50[b]	7.53±0.50[a]
30	0.94±0.50[g]	1.88±0.50[ef]	6.90±0.50[a]	4.45±0.50[d]	2.23±0.50[e]	5.47±0.51[bc]	7.25±0.50[a]
Stearidonic acid C18:4 ω3							
Fresh	0.35±0.35[a]	0.14±0.25[a]	0.18±0.26[a]	0.22±0.27[a]	0.11±0.25[a]	0.14±0.25[a]	0.16±0.25[a]
30	0.33±0.34[a]	0.13±0.25[a]	0.17±0.26[a]	0.21±0.25[a]	0.10±0.25[a]	0.13±0.25[a]	0.15±0.25[a]
Arachidic acid C20:0							
Fresh	0.24±0.28[a]	0.44±0.24[a]	0.44±0.24[a]	0.44±0.24[a]	0.51±0.50[a]	0.50±0.50[a]	0.52±0.50[a]
30	0.23±0.28[a]	0.43±0.23[a]	0.43±0.23[a]	0.43±0.23[a]	0.50±0.50[a]	0.50±0.49[a]	0.51±0.50[a]

Table 6: Continued

Properties/ storage period (days)	Treatments: Full-fat (4%)	Low-fat (2% fat)			Non-fat (0.5% fat)		
	Control	T1	T2	T3	T4	T5	T6
Arachidonic acid C20:4 ω6							
Fresh	0.21±0.27[a]	0.16±0.25[a]	0.17±0.26[a]	0.19±0.26[a]	0.36±0.37[a]	0.36±0.37[a]	0.39±0.40[a]
30	0.20±0.26[a]	0.15±0.26[a]	0.16±0.25[a]	0.18±0.26[a]	0.35±0.36[a]	0.35±0.36[a]	0.38±0.39[a]
Σ saturated							
Fresh	66.43±0.50[a]	64.42±0.50[b]	59.13±0.50[e]	56.01±0.50[g]	59.43±0.50[e]	54.43±0.50[h]	50.40±0.50[j]
30	65.91±0.50[c]	64.23±0.50[cd]	61.70±0.50[d]	57.13[h]±0.50[h]	58.02±0.50[f]	53.40±0.50[i]	49.38±0.50[k]
Σ unsaturated							
Fresh	33.57±0.50[i]	35.58±0.50[h]	40.87±0.50[f]	43.99±0.50[d]	40.57±0.50[f]	45.57±0.50[c]	49.60±0.50[a]
30	28.134±0.50[k]	33.52±0.50[j]	37.91±0.50[g]	41.20±0.50[f]	37.66±0.50[g]	42.46±0.50[e]	46.56±0.50[b]
ΣPUFA ω-6/Σ PUFA ω-3							
Fresh	4.19±0.50[a]	2.97±0.50[b]	1.96±0.50[c]	1.95±0.50[c]	2.99±0.50[b]	1.52±0.50[c]	1.26±0.50[c]
30	2.86±0.51[a]	2.81±0.50[b]	1.81±0.50[c]	1.80±0.50[c]	2.87±0.50[b]	1.38±0.50[c]	1.15±0.50[c]

Means within a row with different superscripts are significantly different ($p<0.05$), Control: Full-fat probiotic frozen goat's yogurt (4% fat) without chia flour (CF), low-fat (2% fat) probiotic frozen goat's yogurt T1: 1% CF, T2: 2% CF, T3: 3% CF, non-fat (0.5% fat) probiotic frozen goat's yogurt T4: 1% CF, T5: 2% CF, T6: 3% CF

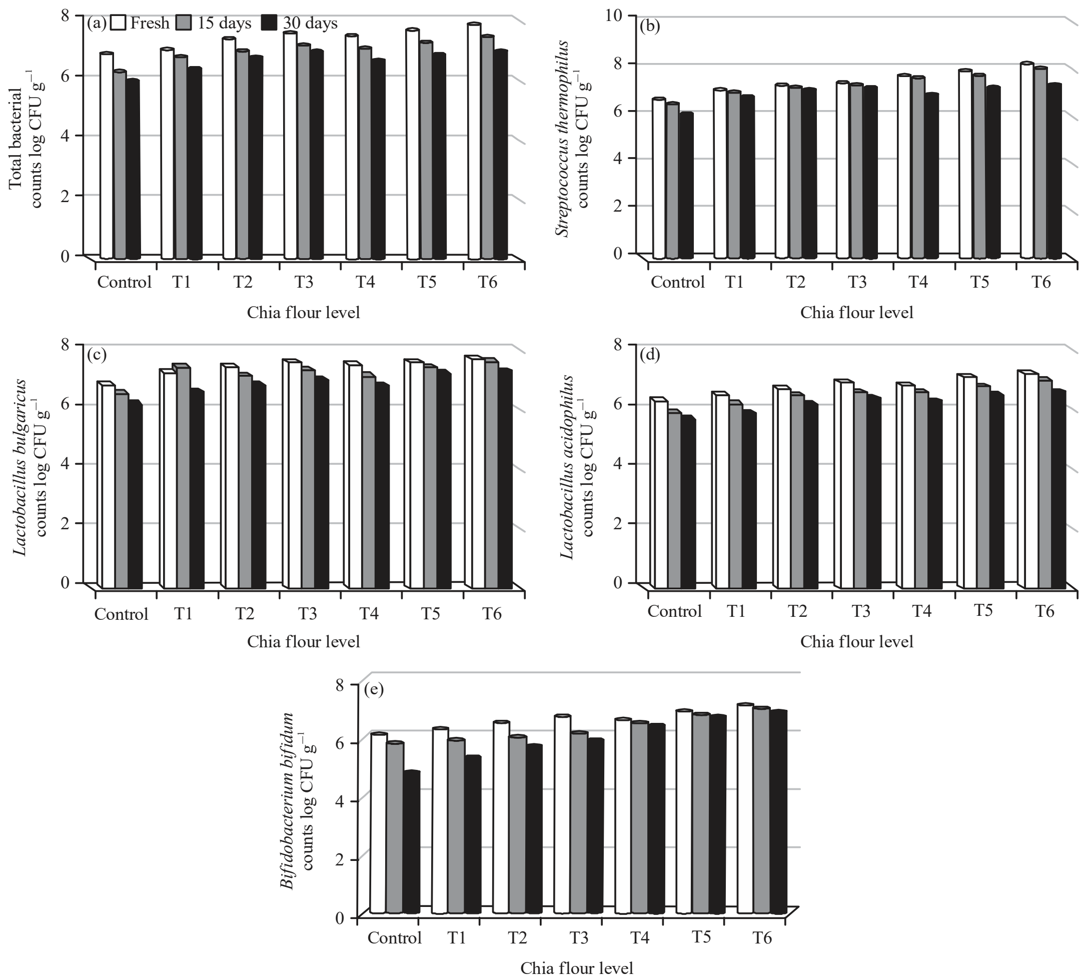

Fig. 2(a-e): Microbiological changes of probiotic frozen goat's yogurt using different level of CF during the frozen storage period, (a) Total bacterial, (b) *Streptococcus thermophilus*, (c) *Lactobacillus bulgaricus*, (d) *Lactobacillus acidophilius* and (e) *Bifidobacterium bifidum*

Control: Full-fat probiotic frozen goat's yogurt (4% fat) without chia flour (CF), low-fat (2% fat) probiotic frozen goat's yogurt T1: 1% CF, T2: 2% CF, T3: 3% CF, Non-fat (0.5% fat) probiotic frozen goat's yogurt T4: 1% CF, T5: 2% CF, T6: 3% CF

Table 7: Sensory properties of probiotic frozen goat's yogurt using different level of CF during the frozen storage period

Properties/ storage period (days)	Treatments						
	Full-fat (4%)	Low-fat (2% fat)			Non-fat (0.5% fat)		
	Control	T1	T2	T3	T4	T5	T6
Flavour (50)							
Fresh	44.00 ± 0.50^{f}	46.00 ± 0.50^{d}	48.00 ± 0.50^{b}	45.00 ± 0.50^{e}	45.00 ± 0.50^{e}	46.00 ± 0.50^{g}	43.00 ± 0.50^{i}
15	43.00 ± 0.50^{g}	47.00 ± 0.50^{c}	48.00 ± 0.50^{b}	46.00 ± 0.50^{d}	46.00 ± 0.50^{e}	47.00 ± 0.50^{f}	44.00 ± 0.50^{h}
30	42.00 ± 0.50^{h}	46.00 ± 0.50^{b}	47.00 ± 0.50^{a}	45.00 ± 0.50^{c}	45.00 ± 0.50^{f}	46.00 ± 0.50^{e}	43.00 ± 0.50^{g}
Body and texture (40)							
Fresh	35.00 ± 0.50^{e}	38.00 ± 0.50^{b}	39.00 ± 0.50^{a}	37.00 ± 0.29^{cd}	36.00 ± 0.50^{d}	37.00 ± 0.50^{c}	35.00 ± 0.50^{e}
15	35.00 ± 0.50^{e}	38.00 ± 0.50^{b}	39.00 ± 0.50^{a}	37.00 ± 0.50^{c}	37.00 ± 0.50^{c}	38.00 ± 0.50^{b}	36.00 ± 0.50^{d}
30	34.00 ± 0.50^{f}	37.00 ± 0.50^{c}	38.00 ± 0.50^{a}	36.00 ± 0.50^{b}	36.00 ± 0.76^{bc}	37.00 ± 0.50^{e}	35.00 ± 0.50^{c}
Melting quality (10)							
Fresh	7.00 ± 0.87^{b}	8.00 ± 0.50^{a}	8.50 ± 0.50^{a}	9.00 ± 0.50^{a}	7.00 ± 0.50^{b}	7.50 ± 0.50^{b}	8.00 ± 0.50^{b}
15	6.00 ± 0.50^{c}	7.00 ± 0.50^{a}	8.00 ± 0.50^{a}	8.50 ± 0.50^{a}	6.50 ± 0.50^{b}	7.00 ± 0.50^{b}	7.50 ± 0.50^{c}
30	5.00 ± 0.50^{d}	7.00 ± 0.50^{a}	7.50 ± 0.50^{a}	8.00 ± 0.50^{b}	6.00 ± 0.50^{c}	6.50 ± 0.50^{c}	7.00 ± 0.50^{d}
Total scores (100)							
Fresh	86.00 ± 0.36^{cd}	92.00 ± 0.50^{ab}	95.50 ± 0.50^{a}	91.00 ± 0.50^{de}	88.00 ± 0.50^{hi}	90.50 ± 0.50^{efg}	86.00 ± 0.50^{ghi}
15	84.00 ± 5.50^{fh}	92.00 ± 0.50^{bc}	95.00 ± 0.50^{ab}	91.50 ± 0.50^{efg}	89.50 ± 0.50^{def}	92.00 ± 0.50^{fg}	87.50 ± 0.50^{i}
30	81.00 ± 0.50^{ghi}	90.00 ± 0.50^{cd}	92.50 ± 0.50^{ab}	89.00 ± 0.50^{ghi}	87.00 ± 0.50^{ghi}	89.50 ± 0.50^{i}	86.00 ± 0.36^{j}

Means within a row with different superscripts are significantly different ($p<0.05$), Control: Full-fat probiotic frozen goat's yogurt (4% fat) without chia flour (CF), low-fat (2% fat) probiotic frozen goat's yogurt T1: 1% CF, T2: 2% CF, T3: 3% CF, Non-fat (0.5% fat) probiotic frozen goat's yogurt T4: 1% CF, T5: 2% CF, T6: 3% CF

without CF served as control. Among probiotic frozen goat's yogurt treatments T6, T5 and T3 had the highest count of *L. acidophlius* and *B. bifudium* after 30 days of storage.

Sensory properties: Sensory properties are shown in Table 7. The results indicated that flavor and body and texture of low-fat (2% fat)and non-fat (0.5% fat) probiotic frozen goat's yogurt were recorded highest score than full-fat (4% fat) probiotic frozen goat's yogurt without CF as control. Also, noticed that T2 and T1 followed by T5 and T4 recorded the highest score of flavor and body and texture than the full-fat (4% fat) probiotic frozen goat's yogurt without CF as control. T6 and T3 recorded the lowest score. The melting quality increased ($p\leq0.05$) significantly with the increase in the levels of CF up to 3%. Noticed that T3, T2 and T1 had the highest score of melting quality followed by T6, T5 and T4 than control. Moreover, the melting quality probiotic frozen goat's yogurt samples were decreased ($p\leq0.05$) significantly at the end of the frozen storage period 30 days. The overall score points of low-fat (2% fat) and non-fat (0.5% fat) probiotic frozen goat's yogurt were recorded highest score than full-fat (4% fat) probiotic frozen goat's yogurt without CF as control. T2 and T1 recorded the highest score followed by T5 and T4 than the control. While T6 and T3 recorded a lower score. Also, during frozen storage period T2 and T1 followed by T5 and T4 gained the best scores among alternative treatments and control at the end of the storage period.

DISCUSSION

Chia (*Salvia hispanica* L.) is a good source of lipids, dietary fiber, protein, phenolic compounds and the high concentration of essential fatty acids particularly unsaturated fatty acid[34]. According to results of the present study, a significant ($p\leq0.05$) increased on the specific gravity and weight per gallon of non-fat (0.5% fat) followed by low-fat (2% fat) probiotic frozen goat's yogurt mixes than the full-fat (4% fat) probiotic frozen goat's yogurt mixes without CF as control. These results might be due to the higher specific gravity of chia flour compared thereupon of milk fat and lower fat contents of those mixes[35,36].

The freezing point decreased ($p\leq0.05$) significantly with the increase of CF levels up to 3% due to the soluble fiber and soluble carbohydrates of CF which lowering the freezing point. Additionally, the removal of fat from frozen dairy products and replaced with soluble substances such as soluble fiber and soluble carbohydrates due to lower the freezing point[37,38].

A significant decrease of pH values recorded of low-fat (2% fat) followed by non-fat (0.5% fat) than the full-fat (4% fat) probiotic frozen goat's yogurt mixes without CF as control. Earlier studies suggested that CF had higher titratable acidity. So, adding of *Bifidobacteria* led to lower pH[39-40].

The apparent viscosity, plastic viscosity, yield stress and consistency coefficient index of low (2% fat) and non-fat (0.5%fat) probiotics frozen yogurt mixes recorded higher values than the control without CF. On the other hand, the flow behavior index of the three types of probiotic frozen goat's yogurt mixes took an opposite trend to different properties. These results may due to the lowest fat content and the influence of CF which improved the viscosity characteristic of mixes. CF has a high content of a soluble deity fiber and gum used in food industries because of its functional properties[41,42]. The effect of CF not only physiological functionality but also technological functionality which mostly depends on hydration properties[43,44].

The specific gravity decreased ($p \leq 0.05$) significantly on the resultant low-fat (2%fat) and non-fat (0.5% fat) probiotic frozen goat's yogurt. These results due to the freeze and hardening as a result of incorporated air into the mix throughout whipping also, the higher specific gravity of CF and milk fat[36,45]. Changes in overrun percentages of low-fat (2% fat) and non-fat (0.5% fat) probiotic frozen goat's yogurt can be associated with the different additional levels of CF which contain high fiber dietary that acts as a fat replacer and to the characteristic of chia mucilage. On the opposite, overrun decreased ($p \leq 0.05$) significantly in low-fat (2% fat) and non-fat (0.5% fat) probiotic frozen goat's yogurt during frozen storage period[36,45].

Acetaldehyde decrease ($p \leq 0.05$) significantly as the CF level increased because of the incontestable ability of various lactic acid and probiotic bacteria to convert the acetaldehyde to ethanol[46]. These results showed that using CF improved probiotic frozen goat's yogurt as it may serve as prebiotics[47,13].

The melting resistance reduced as a result of CF addition. The amount of melted of low-fat (2% fat) and non-fat (0.5% fat) probiotic frozen goat's yogurt were less at the end of the analysis period (90 min) than control. The melting resistance increased in all probiotic frozen goat's yogurt during the frozen storage period. These results attribute to use CF as dietary fiber which increased the water holding capacity and increases the viscosity it improves the melting characteristics[48]. Additionally, the amount of air incorporated the character of the crystal ice and therefore the network of fat globules shaped during freeze process[35].

The radical scavenging activity (RSA%) and total phenolic compounds (TPC) of non-fat (0.5% fat) and low fat (2% fat) probiotic frozen goat's yogurt recorded high values than the control. These results could be due to using the different levels of CF which has a high content of antioxidant compounds that reduce the risk of chronic disease and diabetes[49-51]. On the opposite, gradually reduced within the (RSA %) and (TPC) was detected after 15 days during the frozen storage period[51,52].

The color change has been observed in probiotic frozen yogurt. it can notice that the lower L* values ($p \leq 0.05$) of low (2% fat) and non-fat (0.5% fat) probiotic frozen yogurt than full fat (4% fat) without CF as control. These might be associated with the addition of CF that accomplished in lighting, in colour analysis, the L* parameter indicates lightness and reflects light on a scale ranging[53] from 0-100.

Also, the higher a* values (green component) in goat dairy could be attributed to their fatty acids profiles. Additionally, the goat has the ability to convert β-carotene into vitamin A. These results could be due to using the different levels of chia flour that contains a high content of phenolic compounds and antioxidant activity[54-56]. The increase in b* values was also associated with the addition of a different level of CF. Amarowicz *et al.*[49] reported that the color developed by the chia mucilage because of the passage of pigments or tannic substances from the seed coat the ultimate color is dark yellow[48].

Fatty acids are essential nutrients for many lactic acid bacteria and supplementation of growth medium with fatty acid can influence the membrane composition and growth rate[57]. The medium-chain fatty acids (C12:0 and C14:0) recorded a high level in low (2% fat) and non-fat (0.5%fat) probiotic frozen goat's yogurt it might have been derived from the CF. Also, Oleic acid (C18:1) and linoleic acid (C18:2) recorded the highest level among the unsaturated fatty acids in non-fat (0.5% fat) and low-fat (2% fat) probiotic frozen than the control. these results due to chia seeds contain significant amounts of oleic and linolenic acids[58-60]. Aguiar *et al.*[61] reported that linolenic acid (ω-3) and linoleic acid (ω-6) are described as essential fatty acid because the human body cannot be synthesized it, therefore, must be obtained through the diet. In general, the beneficial health effects of omega-3 fatty acids are to improve general health and reducing the risk of disease[62]. The ΣPUFA ω6/ΣPUFA ω3 ratio decreased ($p \leq 0.05$) significantly with the increase of CF levels up to 3%. Attalla and El-Hussieny[63] reported that the ratio ω-6/ω-3 from 4:1 reaches to 1:1 as a perfect ratio in human diets to forestall the event of vessel diseases and a few chronic diseases as well as cancer[64]. The fatty acids content slight ($p \leq 0.05$) decreased in all probiotic frozen goat's yogurt during the frozen storage period up to 30 days[65,66]. These results due to the oxidative changes during the frozen storage period.

The total bacterial, *L. bulgaricus*, *S. thermophilus*, *L. acidophlius* and *B. bifudium* count of non-fat (0.5% fat) and low-fat (2% fat) probiotic frozen goat's yogurt increased gradually with the increase of CF up to 3%. These results due to the addition of CF as prebiotics stimulated the growth of probiotic bacteria[67,68]. The results showed that probiotic counts in frozen yogurt decreased during storage significantly ($p<0.05$). The previous results indicated that the count of *L. acidophlius* and *B. bifudium* in all probiotic frozen goat's yogurt maintained acceptable values ($\geq$6 CFU g^{-1}) to attain the functional impact of those probiotics till the end of frozen storage period[67,69]. Coliform bacteria and Yeasts and moulds counts were not detected in any probiotic frozen goat's yogurt samples when fresh and during the frozen storage period. This indicates the good sanitary conditions during the preparation of the probiotic frozen goat's yogurt. Regarding the sensory evaluation, the addition of probiotic bacteria can enhance the sensory features of frozen goat's yogurt it may be due to use goat milk as a probiotic carrier[70,71]. also, results showed that using CF at levels 2 and 1% increased the development of non-fat (0.5% fat) and low-fat (2% fat) probiotic frozen goat's yogurt flavor, body and texture, improved the functional, acceptability and covert goaty flavor of goat's probiotic frozen goat's yogurt than full-fat (4%fat) probiotic frozen goat's yogurt without CF as control that, maybe due to the impact of the phenolic compound and its nutty flavor[72].

Finally, these results indicate that the possibility to use CF as a fat replacer and stabilizers to produce functionally and healthy fermented frozen products. These products containing probiotic bacteria that are vital to health. Moreover, this kind of product rich in unsaturated fatty acid, omega-3 and antioxidant compounds that can prevent the dangers of many diseases, such as heart disease, diabetes and obesity. Furthermore, using chia flour improved the technological properties and acceptability of goat's milk, as it enhances its flavor.

CONCLUSION AND FUTURE RECOMMENDATION

Overall, the results in this study showed the possibility to use chia flour successfully at different levels (1, 2 and 3%) as a fat replacer and stabilizers with goat's milk contain probiotic bacteria to produce probiotic frozen goat's yoghurt. This fortification provides health and nutritional probiotic frozen goat's yoghurt. The resultant probiotic frozen goat's yoghurt had the highest content of antioxidant compounds, unsaturated fatty acid mainly oleic fatty acid and omega-3 fatty acid. Also, the observation indicated that chia flour addition at levels (2 and 1%) improved the functional, health benefit and the acceptability of low-fat (2% fat) and non-fat (0.5% fat) probiotic frozen goat's yoghurt.

From previous results can be recommended using chia flour as fat replacer and stabilizers to produce functionally and healthy fermented frozen yogurt. Also, recommended using chia flour incorporated with probiotic bacteria to produce low fat and non-fat dairy products is advised to use it instead of full-fat products. So, this kind of product rich in unsaturated fatty acid, omega-3 and antioxidant compounds that can prevent the dangers of many diseases. Furthermore, using chia flour improved the technological properties and acceptability of goat's milk, as it enhances its flavor.

SIGNIFICANCE STATEMENT

This study discovered the importance of using chia flour as a fat replacer and stabilizer in the production of three types of probiotic frozen goat's yogurt. This study can be beneficial to improve the functional, nutritional, quality and acceptability of probiotic frozen goat's yogurt.

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