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Research Article
Low-fat Processed Cheese Spread with Added Inulin: Its Physicochemical, Rheological and Sensory Characteristics

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Abstract

Background and Objective: The reduction of fat content in dairy products particularly processed cheese varieties is highly recommended to avoid health problems related to milk fat. Unfortunately, the removal of fat from cheese causes many functional and organoleptic defects. The main objective of this study is to investigate the impact of inulin addition on the physicochemical, rheological and sensory characteristics of low-fat processed cheese spread. This study also aims at evaluating the stability or change of these characteristics under cold storage conditions. **Materials and Methods:** In this study, inulin was added to the low fat processed cheese spread blends for enhancing both texture and sensory acceptances. Inulin was added at levels of 5, 7 and 9% (w/w) and its amounts were reduced from total protein contents. Two control samples, full fat (C1) and low fat free of inulin (C2)) were also carried out for comparison. All produced processed cheese spreads were investigated for their physicochemical, rheological and sensory characteristics when fresh and after 60 days of cold storage. **Results:** Replacing of milk protein in low-fat processed cheese spread with 5% inulin had lowered the hardness and increased the adhesiveness of processed cheese with added inulin than low-fat cheese free of inulin. Inulin also showed a positive effect on the mean of spread ability and sensory acceptance of the low-fat processed cheese spreads. **Conclusion:** Inulin percent is highly affected by processing conditions during the production of processed cheese. The processing conditions negatively affected inulin stability in the final product. The physicochemical, rheological and sensory characteristics of low fat processed cheese spreads were dramatically enhanced by inulin addition especially at low concentration (5%) level to be close to those in full-fat processed cheese spread.

Key words: Low fat processed cheese spread, inulin, physicochemical, rheological, sensory characteristics

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

INTRODUCTION

In recent years, the areas of research of nutritionists and food companies have responded to consumers demand and preference. They have begun to look at food not only as a source of energy but also for health benefits[1]. Processed cheese is a useful vehicle for such studies because the sensory profiles of commercial samples of processed cheese spreads (full- and low-fat) have already been characterized[2]. Moreover, in the 20 year period to 1994, production of processed cheese in Europe, North America, New Zealand and Japan has increased by 20%, European countries account for the majority of international exports[2]. In Egypt, the production of processed cheese products is in a continuous increase and has received much attention[3]. Recently, processed cheese spreads have become a popular variety of processed cheese products science it has a wide range of food applications[4].

The high fat content in most of cheese verities (about 50% of cheese solid) are mainly associated with an increase in the risk for obesity, high blood cholesterol and coronary heart disease[5]. As a result, more attempts were made to produce reduced-or low fat processed cheese[6]. The Codex Commission on International Trade has set a maximum limit of 50% reduction in fat for a cheese to be labelled as reduced fat[7]. Nevertheless, in Europe, cheese can be labelled as reduced-fat cheese when the reduction in fat content is at least 30% compared with a similar product[6]. Although, the reduction of fat content in processed cheese spread is one of the main recommended ways to achieve this target[8]. Unfortunately, the removal of fat from cheese causes many functional and organoleptic defects[9,10]. With a consequent of reducing fat content in the processed cheese blend, an increase in protein network and a decrease in lubrication provided by fat occurs[11] which results in a firm, rubbery texture and poor meltability[12]. Sensory defects such as lack of flavor, bitterness, off-flavor and undesirable color are also appeared[6]. These defects can be enhanced by the addition of water, protein and/or protein fractions or other additives such as gums, stabilizers or fat replacers[13,14]. As a result, improve in the acceptability of low fat processed cheese can be achieved[15,16]. Among these functional ingredients, inulin became the most promising added material. It presents as an odorless[17], low calorie soluble dietary fiber[18] with an interesting technological properties: bulking agent, fat mimic and texture modifier[19].

Inulin is a storage polysaccharide found in different parts in many plants[20]. Because of its technological and nutritional properties and beneficial effects for human health[6], it is accepted in most countries as food ingredients that can be used without restrictions in food formulations[21]. It is Generally Recognized as Safe (GRAS) in the USA by the Food and Drug Administration (FDA) and in most of the European countries, it is recognized as "Natural food ingredients"[22]. Although, inulin can be successfully used to produce fat like mouth feel and texture enhancer in liquid dairy foods but not in dry food products its breakdown as a result of heating temperature over time and pH during processing were observed and studied[20,23,24]. Its crystallization and crystallinity characteristics and crystal morphology under processing conditions were also investigated[18].

Thus, this study aimed to investigate the impact of inulin addition at different levels on the physicochemical, rheological and sensory characteristics of low-fat processed cheese spreads. The stability of added inulin after the processing of different cheese blends and during storage of produced low-fat cheese spreads for 60 days under cooling conditions were also investigated.

MATERIALS AND METHODS

Raw materials: To manufacture full fat or low fat processed cheese spread samples, the following ingredients were used: fresh buffalo's skimmed milk obtained from the herd of the Faculty of Agriculture, Cairo University, Giza, Egypt was used to produce rennet curd. Ras cheese was purchased from the Egyptian local market. Emulsifying salt (S9 special) was obtained from JOHA BK Ladenburg, Germany. Liquid calf rennet and buffalo's butter (80% fat) were obtained from Dairy unit, Dairy Science Department, Faculty of Agriculture, Cairo University. Milk protein concentrate (MPC 70% protein) was imported from Fonterra's Ltd., 9 Princes St., Auckland, New Zealand. Skim milk powder (SMP) with 1.25% fat, 36% protein, 51% lactose and 4% moisture was obtained from Arla Foods, Sweden. Inulin (Frutafit®TEX) extracted from chicory root was imported from Sensus (Netherlands).

Manufacture of rennet curd: The curd was made up of fresh buffalo's skimmed milk by rennet coagulation[6]. The produced curd was analyzed for its chemical composition before manufacture of processed cheese spreads.

Manufacture of processed cheese spread blends: The full fat and low fat processed cheese spread blends were prepared under the guide lines recommended by the Egyptian Organization for Standardization and quality (ES: 999-2/2005) for processed cheese spread as follows: (59% moisture, 41%TS, 20.5% fat and 50% F/DM) for full fat and (65% moisture, 35%TS, 7% fat and 20% F/DM) for low fat.

Table 1: Composition of different processed cheese spread blends

	Ingredient (g kg^{-1})							
Treatments[a]	Ras cheese	Rennet curd	Butter	Emulsifiers	MPC	SMP	Water	Inulin
C1	100	400	203.5	27	18.5	25.0	226.0	-
C2	100	400	35.0	27	61.0	64.5	312.5	-
T1	100	400	35.0	27	35.5	40.0	312.5	50
T2	100	400	35.0	27	25.0	30.0	313.0	70
T3	100	400	35.0	27	15.0	20.0	313.0	90

[a]Treatment, C1: Full-fat processed cheese spread (control 1), C2: Low-fat processed cheese spread (control 2), T1: Low-fat processed cheese spread with 5% inulin, T2: Low-fat processed cheese spread with 7% inulin, T3: Low-fat processed cheese spread with 9% inulin

Ras cheese (24.41% moisture, 40% fat, 27.37% protein, 4.28% soluble protein, 3.9% salt, 5.47% ash and 5.2pH), rennet curd (74.41% moisture, 1% fat, 21.19% protein, 2.11% soluble protein, 1.99% ash and 6.17 pH) and other ingredients (g kg^{-1}) used in the manufacture of processed cheese spread blends are illustrated in Table 1. The different blends were manufactured in which each blend was cooked in laboratory processing kettle (Thermomix 3000-1, Vorwerk France S.A. Paris) at 80°C for 5 min. The mixture was hot filled into plastic cups and then cooled rapidly. Samples from each blend were divided into two groups. The first one was analyzed as fresh sample, the second was stored at refrigerator 6±1°C for 2 months before they were analyzed.

Analytical methods

Chemical analysis and pH: The moisture, ash, fat and total nitrogen were determined[25]. Salt content of Ras cheese was determined using the Mohr titration method[26]. The soluble nitrogen was determined following the procedure described by Innocente[27]. For pH measurement, pH meter (JENWAY 3505, Made in the UK) was used after calibration at pH 7.0 then 4.0 using buffer solutions. Carbohydrate content was calculated by difference.

Texture profile analysis: Texture profile analysis (TPA) was conducted using TMS-Pro Texture Analyzer (stable Micro system, USA) fitted with a 25 N force load cell. Each sample (6.5 cm in diameter and 5 cm in height) was compressed twice using Cone Probe of 25 mm diameter. Optimized test condition were 60 mm back- off distance to sample, ratio of deformation 35%, test speed 60 mm min^{-1} and trigger force 0.15 N. Cheese samples were evaluated for hardness, adhesiveness, cohesiveness, springiness, gumminess and chewiness using TL-Pro software. All measurements were performed at 20°C.

Meltability: Meltability of processed cheese spread samples was measured in duplicates by using the meltability test apparatus as outlined by Olson and Price[28]. The distance of flow from the cheese was quickly measured and recorded in centimeter as "Cheese Flow" or as "Cheese Meltability".

Inulin determination by High performance liquid chromatography (HPLC): Cheese samples were prepared[29] and the HPLC, smart line, Knauer, Germany, equipped with binary pump, Column used Phenomenex® Rezex RAM- Carbohydrates, 300×7.8 mm operated at 65°C was used for inulin determination. The separation is achieved using isocratic elution by HPLC grade water with flow rate 0.6 mL min^{-1}. The injected volume was 20 µL. Detection: Refractive Index (RI detector) data injection by claritychrom@ software.

Sensory evaluation: Sensory evaluation of full and low-fat processed cheese spreads were carried out using the method of Giri *et al.*[30]. It was performed by 10 trained panelists from the staff members of Dairy Science Department, Faculty of Agriculture, Cairo University.

Statistical analysis: A randomized complete block design with 2 factor was used for analysis all data with three replications for each parameter. The treatment means were compared by least significant difference (L.S.D.) test as given by Snedecor and Cochran[31] using assistant program.

RESULTS

Chemical analysis, pH and inulin determination: The chemical composition of manufactured processed cheese spread samples when fresh and after 60 days of storage at 6±1°C was determined and presented in Table 2. Among all processed cheese spreads the minimum percentage of moisture was observed for the full-fat sample (C1). The opposite trend was observed for total solids percentage which is negatively proportional with the level of fat in all

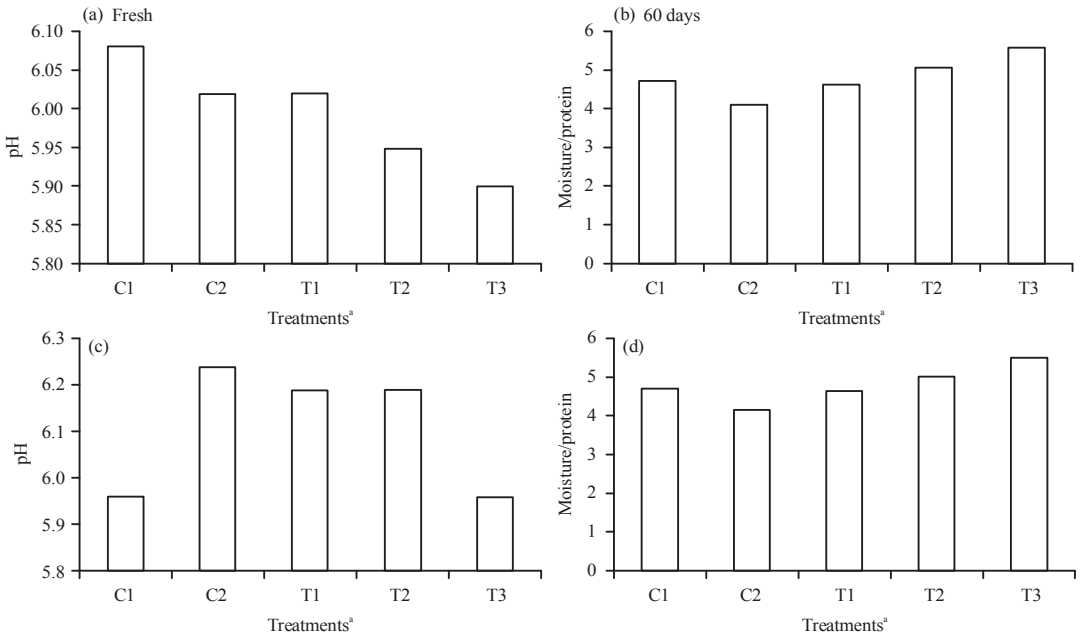

Fig.1(a-d): Changes in moisture/protein ratio and pH of produced processed cheese spreads as affected by inulin addition when (a, c) Fresh and (b, d) After 60 days of cold storage

[a]Treatments, C1: Full-fat processed cheese spread (Control 1), C2: Low-fat processed cheese spread (Control 2), T1: Low-fat processed cheese spread with 5% inulin, T2: Low-fat processed cheese spread with 7% inulin, T3: Low-fat processed cheese spread with 9% inulin

Table 2: Chemical analysis of produced processed cheese spreads as affected by inulin addition when fresh and after 60 days of cold storage

Treatments	Age	Moisture (%)	Total solids(%)	Fat (%)	Protein (%)	Carbohydrates (%)	Ash (%)
C1	Fresh	59.78±0.05^{d}	40.23±0.05^{b}	20.50±0.5^{a}	12.59±0.03^{e}	03.08±0.52^{f}	04.06±0.01^{de}
	60 days	59.01±0.12^{e}	40.99±0.12^{a}	20.50±1.0^{a}	12.47±0.08^{e}	03.86±0.02^{f}	04.16±0.01^{cd}
C2	Fresh	65.57±0.04^{a}	34.43±0.04^{e}	07.00±0.1^{b}	15.82±0.02^{a}	06.88±0.17^{e}	04.73±0.01^{a}
	60 days	64.54±0.11^{c}	35.46±0.11^{c}	07.00±0.1^{b}	15.65±0.01^{b}	07.98±0.21^{d}	04.83±0.01^{a}
T1	Fresh	64.57±0.02^{c}	35.43±0.02^{c}	07.00±0.2^{b}	13.90±0.01^{c}	09.99±0.13^{c}	04.52±0.02^{b}
	60 days	64.31±0.41^{c}	35.69±0.41^{c}	07.00±0.1^{b}	13.89±0.01^{c}	10.32±0.39^{bc}	04.48±0.11^{b}
T2	Fresh	65.43±0.05^{a}	34.57±0.05^{e}	07.00±0.4^{b}	12.89±0.10^{d}	10.53±0.43^{bc}	04.15±0.02^{cd}
	60 days	64.79±0.01^{bc}	35.21±0.01^{cd}	07.00±0.3^{b}	12.93±0.03^{d}	10.99±0.02^{b}	04.29±0.08^{c}
T3	Fresh	65.24±0.10^{ab}	34.76±0.10^{de}	07.00±0.2^{b}	11.63±0.01^{f}	12.19±0.31^{a}	03.94±0.01^{e}
	60 days	64.41±0.07^{c}	35.59±0.07^{c}	07.00±0.1^{b}	11.76±0.01^{f}	12.80±0.03^{a}	04.03±0.01^{de}

Means in the same column with different superscript letters are significantly different at $p \leq 0.05$. [a]Treatment, C1: Full-fat processed cheese spread (control 1), C2: Low-fat processed cheese spread (control 2), T1: Low-fat processed cheese spread with 5% inulin, T2: Low-fat processed cheese spread with 7% inulin, T3: Low-fat processed cheese spread with 9% inulin

cheese samples represents slight significant differences between all cheese samples with the same level of fat when fresh or at the end of storage period.

As a result of fat reduction, data shows a significant increase in both protein and carbohydrates contents in C2 when compared with C1. The low-fat processed cheese spreads with added different inulin levels (5, 7 and 9%) exhibited a significant decrease in protein contents and a significant increase in carbohydrate contents at $p \leq 0.05$ when compared with low-fat cheese sample free of inulin without any remarkable effect to the storage condition. As for the ash percentage, there is a significant deference between all fresh treatments and these changes were in parallel to the changes in protein percentage. No remarkable effect for cold storage was observed in all cheese samples.

Changes in pH values as well as moisture/protein ratios for all processed cheese spread samples (fresh and after 60 days) were presented in Fig. 1. The reduction in fat led to a decrease in moisture/protein ratio. Moreover, the reduction in the moisture/protein ratios in fresh (04.14) and stored low fat control sample (04.12) lead to an increase in pH values. Also, it is well observed that because of the reduction in protein content in the inulin added samples (T1, T2 and T3), the moisture/protein ratios were increased and the pH

values were decreased. The same trends in moisture/protein ratios and pH values were also observed in stored cheese samples with no remarkable differences between fresh and stored samples.

Inulin determination in produced processed cheese spreads: Inulin was added to the blends of low-fat processed cheese spreads at ratio 5, 7 and 9% to produce T1, T2 and T3 cheese samples, respectively. After one day of processing, inulin was determined using HPLC. Determination of inulin in processed cheese spread samples after processing (Table 3) showed a decrease in its contents than amounts previously added to the blends, where it was observed that the percentage of inulin loss was 38.00, 51.43 and 44.44% for T1, T2 and T3, respectively.

Texture profile analysis (TPA): To examine the effect of inulin addition on the properties of the low-fat processed cheese spread samples, the TPA of the cheeses were exploited. The results of the TPA test presented in Table 4 indicated that were significant changes in the texture parameters between controls (C1 and C2) as well as treated samples (T1, T2 and T3). It was also observed that the hardness value significantly ($p \leq 0.05$) increased from 04.92 N in fresh full-fat control sample to be 12.17 N in stored low-fat control sample.

Table 3: Content of inulin (g/100 g sample) in low fat processed cheese spreads when fresh and after 60 days of cold storage as determined by HPLC

	Treatments[a]		
Age	T1	T2	T3
Fresh	01.90	03.60	04.00
60 days	01.92	03.60	03.90
Loss (%)	38.00	51.43	44.44

[a]Treatment, T1: Low-fat processed cheese spread with 5% inulin, T2: Low-fat processed cheese spread with 7% inulin, T3: Low-fat processed cheese spread with 9% inulin

The increase in adhesiveness value of full-fat control sample (C1) than in low-fat control sample (C2) allowed it to melt better and thus increase the adhesiveness. The highest value of adhesiveness was recorded for the low-fat processed cheese spread with 5% inulin (T1) compared to other samples. The adhesiveness was significantly decreased in cheese samples with added inulin at levels 7 and 9% (T2 and T3, respectively). The addition of inulin to low-fat processed cheese spread decreased the cohesiveness values gradually, making them more similar to full-fat control cheese. It was observed that measurements of springiness and chewiness are decreased in low-fat processed cheese spread (C2) compared to full-fat one (C1), while there was no significant difference between them in respect of gumminess. However, it was found that the lowest level of inulin addition (5%) significantly increase some of TPA parameters (gumminess and chewiness). In contrast, more inulin addition (7 and 9%) led to decrease all of these parameters.

Meltability: The changes in meltability (cm) of produced processed cheese spreads, depending on the fat content and inulin percentage are shown in Fig. 2. The meltability of fresh low-fat processed cheese spread samples (C2, T1,T2 and T3) were decreased significantly ($p \leq 0.05$) when compared to full-fat processed cheese sample (C1). The same trend in the meltability reduction was also observed at the end of second month of cold storage period for each sample except T3 as the meltability significantly increased. Regarding the effect of inulin addition to the low-fat processed cheese spreads data in Fig. 2 show that there is a positively significant effect in meltability of cheese samples compared to low-fat sample free of inulin (C2).

Sensory evaluation: An overall look to the data presented in Table 5 clearly indicates that the full-fat control treatment (C1)

Table 4: Texture profile analysis of produced processed cheese spreads as affected by inulin addition when fresh and after 60 days of cold storage

Treatments[a]	Age	Hardness (N)	Adhesiveness (mJ)	Cohesiveness (Ratio)	Springiness (mm)	Gumminess (N)	Chewiness (mJ)
C1	Fresh	04.92±0.03^{f}	19.35±0.03^{b}	00.84±0.03^{ab}	11.22±0.06^{c}	04.14±0.16^{c}	46.48±0.02^{c}
	60 days	06.06±0.03^{d}	10.01±0.02^{e}	00.62±0.03^{e}	10.05±0.06^{f}	03.74±0.03^{e}	37.64±0.05^{d}
C2	Fresh	08.11±0.12^{c}	11.55±0.03^{d}	00.52±0.03^{f}	08.70±0.03^{h}	04.19±0.04^{c}	36.47±0.08^{e}
	60 days	12.17±0.03^{a}	07.65±0.06^{g}	00.68±0.04^{de}	11.29±0.02^{b}	08.33±0.04^{a}	94.00±0.03^{a}
T1	Fresh	05.23±0.04^{e}	21.55±0.05^{a}	00.81±0.02^{b}	12.54±0.04^{a}	04.24±0.03^{c}	53.23±0.03^{b}
	60 days	09.61±0.02^{b}	06.55±0.05^{hi}	00.47±0.02^{f}	08.00±0.03^{i}	04.54±0.03^{b}	36.26±0.03^{f}
T2	Fresh	01.56±0.04^{i}	06.70±0.02^{h}	00.79±0.01^{bc}	10.40±0.03^{e}	01.24±0.03^{g}	12.90±0.10^{i}
	60 days	04.39±0.06^{g}	12.76±0.03^{c}	00.91±0.03^{a}	08.85±0.03^{g}	03.97±0.02^{d}	35.13±0.14^{g}
T3	Fresh	01.48±0.02^{i}	06.30±0.31^{i}	00.73±0.04^{cd}	10.60±0.07^{d}	01.08±0.04^{g}	11.43±0.03^{j}
	60 days	03.10±0.03^{h}	09.29±0.01^{f}	00.73±0.04^{cd}	10.03±0.06^{f}	02.26±0.04^{f}	22.67±0.03^{h}

Means in the same column with different superscript letters are significantly different at $p \leq 0.05$, [a]Treatments, C1: Full-fat processed cheese spread (Control 1), C2: Low-fat processed cheese spread (Control 2), T1: Low-fat processed cheese spread with 5% inulin, T2: Low-fat processed cheese spread with 7% inulin, T3: Low-fat processed cheese spread with 9% inulin

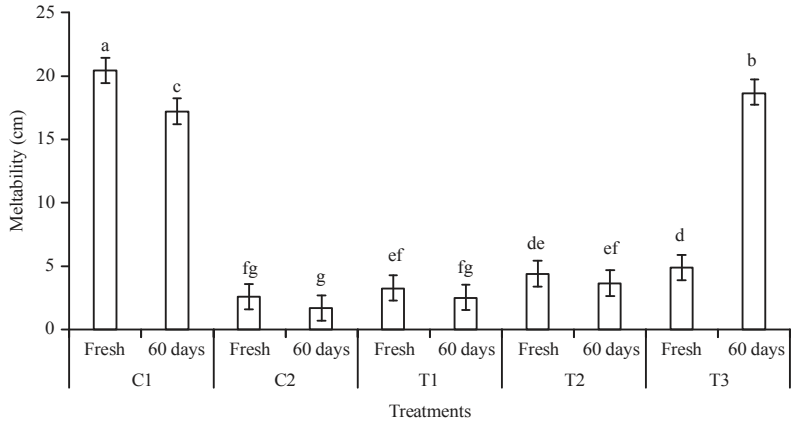

Fig. 2: Meltability (Mean±SD) of produced processed cheese spreads as affected by inulin addition when fresh and after 60 days of cold storage

[a]Treatments, C1: Full-fat processed cheese spread (Control 1), C2: Low-fat processed cheese spread (Control 2), T1: Low-fat processed cheese spread with 5% inulin, T2: Low-fat processed cheese spread with 7% inulin, T3: Low-fat processed cheese spread with 9% inulin

Table 5: Sensory evaluation of produced processed cheese spreads as affected by inulin addition when fresh and after 60 days of cold storage

Treatments[a]	Age	Flavor (45)	Body and texture (30)	Color and appearance (10)	Spread ability (15)	Total score (100)
C1	Fresh	44.00±1.0^{a}	29.00±0.6^{a}	10.00±0.6^{a}	14.00±0.6^{a}	97.00±1.2^{a}
	60 days	44.00±1.0^{a}	27.00±1.0^{bc}	10.00±0.6^{a}	14.00±1.0^{ab}	95.00±2.1^{a}
C2	Fresh	40.00±2.0^{cd}	27.00±1.0^{bc}	07.00±1.0^{b}	12.00±0.6^{c}	86.00±3.2^{c}
	60 days	39.00±1.0^{d}	22.00±1.0^{d}	07.00±1.0^{b}	09.00±1.0^{d}	77.00±2.0^{d}
T1	Fresh	43.00±0.6^{ab}	29.00±1.0^{a}	09.00±1.0^{a}	14.00±0.6^{a}	95.00±1.0^{a}
	60 days	41.00±1.0^{bc}	26.00±0.6^{c}	09.00±1.0^{a}	12.00±1.0^{c}	88.00±1.5^{bc}
T2	Fresh	39.00±1.5^{cd}	28.00±1.2^{ab}	09.00±1.0^{a}	13.00±1.0^{bc}	90.00±2.3^{b}
	60 days	36.00±1.0^{e}	23.00±1.2^{d}	09.00±1.0^{a}	10.00±1.0^{d}	78.00±0.6^{d}
T3	Fresh	41.00±1.0^{bc}	30.00±0.6^{a}	09.00±1.0^{a}	10.00±1.0^{d}	90.00±1.2^{b}
	60 days	31.00±1.0^{f}	20.00±1.2^{e}	09.00±1.0^{a}	07.00±1.0^{e}	67.00±0.6^{e}

Means in the same column with different superscript letters are significantly different at $p \leq 0.05$, [a]Treatments, C1: Full-fat processed cheese spread (control 1), C2: Low-fat processed cheese spread (control 2), T1: Low-fat processed cheese spread with 5% inulin, T2: Low-fat processed cheese spread with 7% inulin, T3: Low-fat processed cheese spread with 9% inulin

recorded the highest total score either when fresh or after 60 days of storage. The other 5 treatments could be arranged in the following descending order when fresh T1>T2 = T3>C2 and in the following descending order after 60 days of storage T1>T2>C2>T3.

The flavor of all studied processed cheese spread samples were to some extent similar when they were fresh while it was slightly decreased after 60 days of storage in samples with high levels of inulin (T2 and T3).

The flavor of fresh low-fat processed cheese spread supplemented with 5% inulin was close to full-fat processed cheese spread. After cold storage, the flavor of low-fat processed cheese spread containing inulin was significantly different than full-fat processed cheese spread.

There was no significant difference in the body and texture of fresh control sample (C1) and the samples with inulin but after storage, there was a significant decrease. The body and texture of fresh low-fat processed cheese spread supplemented with 5% inulin was close to full-fat processed cheese spread.

No statistical differences were found on the mean scores for color and appearance of low-fat processed cheese spread containing inulin and full-fat sample except for low-fat processed cheese spread free of inulin which showed a significant difference in the color and appearance score.

Regarding the spread ability, no significant difference was observed between fresh low-fat processed cheese spread with 5% inulin and C1 but at 7 and 9% inulin addition, it decreased significantly.

DISCUSSION

The reduction in fat content of low-fat processed cheese samples (Table 2) led to a slightly significant increase in the moisture percentage with a little decrease as a result of storage conditions in most of the samples.

The processing conditions negatively affect inulin stability in the final product. While, there were no differences in its contents after storage. The reduction in inulin percentage after processing of cheese blends (Table 3) can be supported by the results of Glibowski and Wasko[32]. They investigated the changes in inulin structure after heating the high polymerized inulin solutions at different pH. Their results revealed that heating inulin solution at pH3 and 80°C caused the 49% decrease in inulin concentration and that those conditions caused inulin to be partially hydrolyzed which led to an increase in shorter chain and simple sugars concentration. In contrast, Glibowski and Bukowska[24] reported that no degradation was found regardless of thermal processing (up to 100°C for 55 min) at pH≥5.

It is not a surprising result to observe an increase in hardness value in low-fat control sample than full-fat one (Table 4). Fat breaks up the protein matrix and plays the role of lubricant to provide smoothness and a softer texture [33]. The decrease in fat/protein ratio in low-fat control sample made it firmer than full-fat control sample. This is compatible with Rogers *et al.*[34], who reported that removal of fat is associated with a lower fat to protein ratio, resulting in a more dense protein structure, thus making the cheese firmer. Although hardness values started to decrease gradually as a result of inulin addition, it started to increase again as a result of storage in each sample separately but still significantly less hard than low-fat control sample. These results as well as the moisture/protein ratio presented in Fig. 1 are previously explained by Koca and Metin[35], who reported that, the softening effect observed in inulin-containing cheese could be attributed to an increase in filler volume and higher moisture/protein ratio, which lowered matrix protein levels. Adhesiveness is a texture parameter correlated negatively with protein content and positively with fat in cheeses[36]. The lower protein and higher fat contents make the adhesiveness value higher in fresh full-fat control sample than low-fat control sample (Table 2 and 4). The reduction in adhesiveness in cheese samples with added inulin especially at 7 and 9% may be possibly due to the gelling properties of inulin at high levels, as mentioned by Akalin *et al.*[37]. The cohesiveness refers to the strength of internal bonds especially the protein-protein interactions[38]. Data presented in Table 4 was parallel to the finding of Glibowski and Kowalska[39], who found a reduction in cohesiveness with the addition of inulin in kefir.

Meltability is the most important functional property determines the quality of processed cheese spread. It is dependent on both the thermal phase change characteristics of the solid cheese and the property of the melt which they mainly depend on the composition and texture of the cheese[40,41]. Increasing of meltability in cheese samples containing inulin were clearly engaged with both the decrease in fat and increase in protein contents (Table 2) as well as the significant decrease in hardness (Table 4) when compared to low-fat sample free of inulin (C2). Sołowiej *et al.*[41] reported that meltability of processed cheese analogues decreased significantly with increase of protein concentration. This reduction in meltability may be due to the interaction occurred between κ-casein and β-lactoglobulin as a result of high temperature[42] and that the more the protein content, specially whey proteins, in processed cheese structure the more the reduction in meltability of the final product[43].

It was clearly observed that inulin providing a fat-like Mouthfeel in low fat product[44,45] and provides them nearly the same sensory characters as of full fat products[46-48]. The reason behind decreasing total sensory score for low-fat samples containing inulin than full or low-fat samples free of inulin was due to the formation of crystals that caused after taste during sensory evaluation. The enhancement in body and texture in samples containing 5% may be due to that inulin particularly mimics fat in low-fat cheeses as it may contribute to an improved creaminess and mouth feel[49,50].

Giri *et al.*[30] studied the effect of inulin at 4, 6 and 8% on the sensory characteristics of processed cheese spread and observed that though up to 6% inulin addition, spread ability score was similar as compared to the control but at 8% inulin addition, it decreased significantly ($p<0.05$) referring to the water binding property of inulin, at higher level (8%) may have reduced the softness of spread that caused poor spread ability. The color's defect in low-fat processed cheese sample (Table 5) comparing to other treatments may be attributed to the absence of inulin particles which can act as light-scattering centers and increase the opaqueness of cheeses[6].

CONCLUSION

This study has investigated the effect of inulin addition on some characteristics of low-fat processed cheese spread. Although the inulin stability was negatively affected by the processing conditions in fresh samples, its addition positively enhanced the characteristics of the final product in terms of physicochemical, rheological and sensory properties especially at level of 5% when compared to other treatments.

SIGNIFICANT STATEMENT

This study revealed the significance of using inulin in the production of low-fat processed cheese spread. This study will

help the researcher to exploit these findings to improve the quality of low-fat processed cheese spread with excellent sensory characteristics, thus increase the consumer demand for the product and take advantages of the nutritional and health benefits of the processed cheese.

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