The Impact of Partial Replacement of UF-Skim Milk Retentate by Denatured Salt Whey Protein Paste on The Quality of Feta Cheese Analogue

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ABSTRACT

The present investigation was conducted to study the effect of partial substitution of UF-retentate of skimmed cow's milk with the denatured salt whey protein past (DSWPP) aiming to obtain the optimal formulation of the two ingredients for manufacturing of feta cheese analogue. In this study, the ratios of substitution were 5, 10, 15 and 20% (wt/wt). Physicochemical properties, texture profile, organoleptic properties, microbial quality and economic efficiency of the UF-FCA were studied along 60 days of refrigeration storage (6±2°C). Inclusion of DSWPP caused significant differences ($p \leq 0.05$) in physicochemical properties of UF-FCA. Dry matter content and pH values were decreased, while significant increase was observed in total protein, water soluble nitrogen, and titratable acidity values as compared to control. Moreover, significant differences were observed in texture parameters among all UF-FCA treatments. The values of hardness, springiness, cohesiveness, gumminess and chewiness were decreased, whereas adhesiveness values were increased as compared to control. Organoleptic properties of UF-FCA with or without DSWPP were acceptable by the panelists. Cheese samples contained 15% DSWPP were the most preferred among all treatments. The microbial quality was satisfactory for all cheese treatments. The cold storage for 60 days led to different changes in UF-FCA properties. The economic study efficiency indicates that the additional ratio of DSWPP up to 20% (wt/wt) as partial replacer for UF-skim milk retentate in the production of UF-FCA resulted in a decrease in the total production cost.

Keywords: Feta cheese analogue, cheese byproducts, economic study.

INTRODUCTION

Cheese, a diverse group of fermented dairy products, is produced globally in a wide array of flavors, textures, and forms, influenced by regional conditions and optimized production technology (Fox *et al.,* 2000 and Isam *et al.,* 2010). The technology of ultrafiltration (UF) in cheese production has undergone thorough investigation and review (El-Zahar, 2009), as highlighted in Lawrence (1989). This attention stems mainly from its capacity to enhance yield by recovery of whey proteins in the cheese, particularly when the milk or retentate, is subjected to a high heat treatment, as noted by Marshall (1986).

Feta cheese is a soft and spreadable cheese variety made by concentrating milk through ultrafiltration to achieve 35% total solids, followed by enzymatic coagulation of the concentrated milk. Feta cheese and Feta-type cheese can be produced from whole milk, partially skimmed, or skim milk (Hamdy *et al.,* 2021). This type of cheese typically contains 45-60% fat (on a dry basis), 28% protein (on a dry basis), maximum 3% salt, and has a final pH of 4.8 after 72 hours of production can be consumed directly after production. The shelf life of this type of cheese is maximum two months (Abd El-Salam *et al.,* 1993 and Ramadan *et al.,* 2014). Cheese analogue is typically produced using a combination of dairy and non-dairy proteins, various edible fats or oils, different types of starches, additional ingredients, and water. Compared to natural cheeses, analogue cheeses offer advantages such as lower cost and relatively higher functional stability during storage (Fox *et al.,* 2000 and Guinee, 2007).

Approximately 50% of overall milk production of Egypt is used for commercial cheese production. In 2001, the total cheese production reached 480,000 metric tons, representing 2.9% of the global cheese production. During the 1990s, Egypt experienced a consistent annual increase of approximately 6% in whey production. By the year 2000, the whey production had reached 1,452,500 metric tons (Zhang *et al.,* 2003).

Whey is separated during the cheese-making process. This liquid remaining after milk is coagulated and strained to remove curd. It comprises proteins, lactose, vitamins, minerals and small amounts of fat (Krissansen, 2007). Every day, the global production of whey is growing. Castillo *et al.* (2020) reported that the world production of whey in 2020 was 183 million tons. It is widely recognized that the discharge of whey from the dairy industry as waste leads to significant pollution because of its high biological oxygen demand (BOD) levels, which range from 35 to 40 g/l (Zayed and Winter, 1995). Salt whey is a byproduct that is obtained during the production of certain cheeses, including Domiati, Ras, and Cheddar. The salt content in whey derived from Domiati cheese typically ranges from 8% to 15%, whereas in whey from Ras and Cheddar cheese, it is only about 2% to 5%. Unlike sweet whey, salt whey

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poses challenges for convenient processing due to its elevated salinity and its high biological and chemical oxygen demand. Therefore, the processing of salt whey is more difficult compared to that of sweet whey (Sanderson *et al.,* 1996).

Until 1980, approximately half of the total whey produced was dumped as waste product into local waterways. However, two significant developments altered the treatment of whey. Firstly, stricter environmental regulations prohibited the routine disposal of industrial byproducts. Secondly, researchers began exploring the various benefits of whey, leading to its recognition as a new revenue source (Geiser, 2003). The identification of whey as a functional food with nutritional applications elevated whey to a co-product in cheese manufacturing (Walzem *et al.,* 2002). In Egypt, many cheese manufacturing facilities currently resort to land spreading as a disposal method for salt whey. However, this practice has negative consequences as it raises the chloride levels in the soil, posing a risk of crop damage. To address the environmental impact and effectively utilize whey, various methods and technologies have been developed. One of the latest proposed applications for salt whey is its incorporation as an ingredient in process cheese production, offering a new avenue for whey utilization and reducing or eliminating its disposal into the environment (Awad *et al.,* 2013). Whey proteins possess numerous functional characteristics, including excellent solubility, dispersibility, water binding, foaming, whipping, emulsification, gelation, and buffering power, making them commonly utilized in various food applications (Evans *et al.,* 2009).

Presently, concepts like sustainable consumption, green economy, and eco-consumption carry significant importance. The advocacy for sustainable consumption stands as a cornerstone in attaining minimal environmental impact, ensuring sustainable food security, and enhancing public health (Kulyk *et al.,* 2020). In fact, the 2030 agenda for sustainable development proposed to achieve responsible consumption and production (Partiti and Arcuri, 2021). Consequently, reducing waste by the inclusion of cheese by-products (whey) in food formulation seems to contribute to this goal. The findings of this study are expected to contribute to the development of a more efficient utilizing of salted whey resulting from Ras cheese manufacture to making denatured salt whey protein paste (DSWPP). Moreover, the utilization of DSWPP in the production of ultrafiltration- feta cheese analogue (UF-FCA) could offer an innovative approach for sustainable utilization of salt whey. Therefore this study aims to explore the benefits of replacement the UF-skim milk retentate by DSWPP at levels (5,10,15 and 20% (wt/wt)) in the production of UF-FCA and analyze its impact on the quality of the final product (physicochemical properties, texture profile, organoleptic properties, microbial quality and economic efficiency) during refrigerated storage (6±2˚C) for two months.

MATERIALS AND METHODS

Materials:

Fresh cow skim milk and Ras cheese whey were obtained from El-Nada Company for Food Industries (REFY), which is located in Elnobaria City, El-beheria Governorate, Egypt. Palm oil shortening (melting temperature 36-38˚C) was acquired from Intercontinental Specialty Fats Sdn. Bhd- Malaysia. Food-grade salt was procured from El-Nasr Company of Alexandria, Egypt. Microbial rennet was sourced from CAGILO STAR, Spain. Stabilizers (Lacta–815, 825) were obtained from Misr Food Additives (MIFAD) Company in Badr city, Egypt. Glucono delta lactone (GDL) was obtained from Roquette Freres Company in Lille, France. Potassium sorbate was acquired from Pfizer, a pharmaceutical company.

Table 1. Chemical composition of dairy-raw materials, according to AOAC (2000)

Ingredients	Total solids %	Fat %	Protein %	Lactose %	pH- value	Salt %
Fresh skim milk	8.84	0.4	3.22	4.52	6.58	-
UF retentate of skim milk	24.50	1.3	15.65	6.11	6.53	-
DSWPP*	24.55	0.9	16.51	3.27	5.59	2.8

*DSWPP**:** Denatured salt whey protein paste

Methods:

Preparation of denatured salt whey protein paste (DSWPP):

Denatured salt whey protein paste was prepared as described by Ismail *et al.* (2011). Ras cheese whey (pH 5.85) was skimmed and collected in stainless steel tank, then heated with direct steam injection to 90±5˚C for 20-25 min. with continuous agitation to promote the denaturation of whey proteins, and obtain a thicker whey concentrate. Heating step helps in the formation of a paste-like consistency. Once the desired consistency is achieved, salted whey leaved to cool and flocculated denatured salted whey proteins were recovered by straining through cloth bags at room temperature for 2-3 hrs. The precipitate was transferred to stainless steel frames and pressed overnight to obtain the DSWPP (24.55% total solid, 0.9% fat, then storage refrigerated at (5±1˚C) until use.

Manufacture of UF- feta cheese analogue (UF-FCA):

The production of UF-FCA followed the method described by Bachmann (2001) with some modifications. The quantities of ingredients for manufacturing process as illustrated in Table (2) were calculated in order to fulfill the requirements of the Egyptian Standards (No,1867/2005) for the final product, which aimed for approximately 38% dry matter (DM) and 40% fat/dry matter (F/DM). Fresh cows skim milk was subjected to ultrafiltration unit to obtain the retentate of skim milk (TS 24.5%). The UF retentate of skim milk was partially substituted with DSWPP in different ratios(w/w), as indicated in the Table (1). The UF-FCA was made as follows: UF retentate of skim milk and DSWPP were mixed in a 50 kg processing tanks (3000 rpm) at 50˚C for 3 min and the melted palm oil was added with continuous stirring. The blends were heated at 75±1˚C approximately for one min, and subsequently cooled to around 45˚C. Then, as shown in Table (2) GDL, $CaCl_2$, salt, potassium sorbate and stabilizers (lacta 815) were added after dissolved in boiling water. After complete mixing, the blends were filled in stainless steel trays and rennet was added. The pre-cheese was incubated at the 40±1˚C for 20-25 min to complete coagulation process. The trays were then removed from the incubator and kept refrigerated at (6±2˚C) overnight. Subsequently, cheese was cut into 10cm X10cm cubes, covered with low density polyethylene bags (LDPE), packed in plastic jars 0.5 kg capacity without brine solution and stored at 6±2˚C for a period of two months. The UF-FCA samples were subjected to chemical, rheological and organoleptic analysis at five different intervals: 1, 15, 30, and 60 days.

Methods of Analysis

Physicochemical parameters:

Dry matter, fat, ash and total protein contents of UF-FCA samples were determined according to AOAC (2000). pH value of the samples was measured using glass electrode pH meter, type-digital (model HANNA HI9321 microprocessor) according to the British standard institution (B.S.I) bulletin no. 770 (1952). Salt contents of ingredients were estimated using Volhard method according to Richardson (1985). Titratable acidity in terms of % lactic acid and water-soluble nitrogen (WSN) of cheese was determined according to Ling (1963).

Table 2.The ingredients percent (%) used in UF-FCA making

Ingredients (%)	Treatments*				
	Control	T_1	T_2	T_3	T_4
UF retentate of skim milk	81.25	77.19	73.13	69.06	65
DSWPP	0	4.06	8.12	12.19	16.25
Palm oil	14.4	14.4	14.4	14.4	14.4
Salt	1.75	1.64	1.52	1.41	1.3
GDL	2	2	2	2	2
Stabilizers	0.6	0.6	0.6	0.6	0.6
$CaCl_2$	0.02	0.02	0.02	0.02	0.02
Pot. Sorbate	0.05	0.05	0.05	0.05	0.05
Microbial rennet	0.0045	0.0045	0.0045	0.0045	0.0045

* **Treatments code**:
Control: UF-FCA(100% UF retentate of skim milk);
T_1: UF-FCA(95% UF retentate of skim milk +5% DSWPP);
T_2: UF-FCA(90% UF retentate of skim milk +10% DSWPP);
T_3: UF-FCA(85% UF retentate of skim milk +15% DSWPP);
T_4: UF-FCA(80% UF retentate of skim milk +20% DSWPP)

Texture Profile Analysis (TPA):

Texture profile analysis (being the most commonly used method for assessment of cheese texture) has been found to be effective for evaluating cheese texture. A two-bite compression test was performed using the Texture Analyzer. Samples for texture profile analysis (TPA) were obtained from the middle of the whole cheese block rather than from the surface to avoid surface effects. A two-bite penetration test was performed using the Texture Analyzer Pro CT V1.2 Build 9 (TA1000, CNS-Brookfield, England) with the TA 11 probe (30˚ and 25 mm diameter) and operated at a crosshead speed of 0.5 $mm\cdot s^{-1}$ and penetration distance of 10mm. Hardness, springiness, cohesiveness, adhesiveness, gumminess, and chewiness were evaluated in triplicate according to the definitions given by IDF (1991).

Sensory Attributes:

Ten staff members from the Food, Dairy Science and Technology Department, Faculty of Agriculture, Damanhour University, sensory evaluated cheese samples. The samples of UF-FCA were assessed based on flavor (50 points), body and texture (35 points), and color and appearance (15 points), resulting in a total score of 100 points.

Microbiological examinations:

The UF-FCA samples were examined for total viable counts (TVC), yeasts and molds count (YM), coliform group (CG), which were detected by using an enrichment technique following the procedure outlined in Anonymous (1998) and ISO (2001). Aseptically, 25 g of the samples were transferred to a stomacher bag (Sewared, London, UK), and homogenized with 225 ml of sterile peptone solution (0.1% w/v) for 60 s at room temperature. Serial dilutions of peptone water (0.1% w/v) were prepared and duplicate of 1 ml or 0.1 ml samples from appropriate dilutions were poured or spread onto selective or non-selective agar plates. The following microbial counts and growth conditions were used: total viable counts enumerated on plate count agar medium (Merck, 1.05463) at 32˚C for 48 h; yeasts and moulds grown on Rose Bengal Chloramphenicol Agar medium (Lab M, 36, supplemented with chloramphenicol, X009) at 25˚C for 5 days; coliform group enumerated on Violet-Red Bile agar medium at 37˚C for 24 h according to Difco's (1984).

Statistical Analysis:

Statistical analysis of the obtained results was conducted using a software package (SAS, 1991) that utilized analysis of variance. In cases where the F-test yielded significant results, a least significant difference (LSD) was computed following Duncan's method (1955) for comparing means. The data shown in the tables represent the mean values (with standard deviation ±) derived from three experiments.

RESULTS AND DISCUSSION

Changes in physicochemical properties of UF-FCA.

The dry matter, fat, salt, total protein and water-soluble nitrogen contents in UF- feta cheese analogue made from UF retentate of skim milk and DSWPP with different levels 5, 10, 15 and 20% (wt/wt) are illustrated in Table (3). There was a slight difference in dry matter of final UF-FCA samples, and replacement of UF retentate of skim milk with DSWPP caused significant decreased ($p \leq 0.05$) in dry matter content as compared with control. In the same time the decrease in dry matter was increment gradually with increase replacement ratio. The DM content of UF-FCA ranged from 38.29% to 38.65% for control and $T_{4,}$ respectively. This decrease may due to the high-water holding capacity of DSWPP which may increase the moisture holding in cheese curd. The TP/DM content of UF-FCA made with UF retentate of skim milk and DSWPP were significantly different ($p \leq 0.05$). The control samples had the lowest value of TP/DM with 32.92%, while the highest TP/DM content was found in T_4 (.33.56%). The TP/DM and WSN contents were increased with addition ratios of DSWPP, and because of high protein content of DSWPP (16.51%), it is expected to raise the TP and WSN values of cheese samples. On the other hand, F/DM and Salt/DM were not significantly different ($p \leq 0.05$) in all the UF-FCA treatments.

In general, significant differences ($p \leq 0.05$) were detected with prolonged of cold storage period (60 days), gradually increased in DM, F/DM, TP/DM, Salt/DM, and WSN contents of UF-FCA samples. The increase in WSN and NPN values could be attributed to the breakdown of proteins in the cheese facilitated by milk and rennet enzymes, as well as other microbial activities, as suggested by El-Zeini *et al.* (2007). This is possibly attributed to moisture evaporation, Kebary *et al.* (2006) observed a significant decrease in the moisture content of Domiati cheese as the pickling period progressed, whereas the total solids (TS) values increased significantly. As outlined by Schar and Bosset (2002), the primary determinants affecting cheese alterations during storage are product composition, processing techniques, packaging methods, and storage conditions (including duration and temperature).

Table 3. The effect of partial replacement of UF retentate of skim milk with different levels of DSWPP on the chemical composition of UF-FCA during refrigerated storage (6±2°C) for two months

Composition	Storage periods (days)	Treatments*				
		Control	T_1	T_2	T_3	T_4
Dry matter (DM) %	1	38.65±0.06^{gh}	38.57±0.1^{hi}	38.42±0.08^{ij}	38.33±0.06^{j}	38.29±0.1^{j}
	15	38.97±0.08^{f}	38.9±0.05^{f}	38.85±0.05^{fg}	38.64±0.04^{ghi}	38.63±0.08^{hi}
	30	39.54±0.08^{de}	39.6±0.03^{d}	39.42±0.07^{de}	39.32±0.04^{e}	39.03±0.07^{f}
	60	40.15±0.11^{a}	40.05±0.06^{ab}	39.94±0.08^{abc}	39.82±0.07^{c}	39.85±0.05^{bc}
Fat/DM %	1	40.03±0.06^{g}	40.07±0.05^{g}	40.17±0.05^{fg}	40.27±0.06^{fg}	40.4±0^{efg}
	15	40.17±0.05^{fg}	40.23±0.06^{fg}	40.23±0.06^{fg}	40.4±0.02^{efg}	40.57±0.05^{cdef}
	30	40.47±0.05^{defg}	40.57±0.06^{cdef}	40.63±0.11^{cdef}	40.77±0.06^{bcde}	40.9±0.1^{bcd}
	60	40.76±0.06^{bcde}	40.93±0.05^{bcd}	41±0.17^{abc}	41.17±0.05^{ab}	41.46±0.05^{a}
Salt /DM %	1	4.57±0.04^{e}	5.59±0.06^{e}	4.64±0.08^{de}	4.64±0.07^{de}	4.7±0.01^{cde}
	15	4.64±0.03^{de}	4.67±0.02^{cde}	4.68±0.03^{cde}	4.69±0.01^{cde}	4.7±0.02^{cde}
	30	4.76±0.02^{bcd}	7.79±0.02^{bc}	4.78±0.02^{bcd}	4.8±0.01^{bc}	4.74±0.03^{cd}
	60	4.89±0.03^{ab}	4.98±0.01^{a}	4.95±0.09^{a}	5.02±0.04^{a}	4.95±0.03^{a}
Total Protein/DM %	1	32.92±0.03^{m}	33.05±0.05^{l}	33.29±0.04^{ij}	33.47±0.03^{gh}	33.56±0.05^{fg}
	15	33.03±0.02^{l}	33.14±0.03^{kl}	33.43±0.03^{h}	33.59±0.02^{efg}	33.69±0.02^{de}
	30	32.22±0.03^{jk}	33.38±0.03^{hi}	33.64±0.02^{ef}	33.8±0.02^{cd}	33.87±0.03^{bc}
	60	33.43±0.02^{h}	33.58±0.07^{efg}	33.76±0.06^{cd}	33.97±0.04^{b}	34.11±0.04^{a}
WSN %	1	1.287±0.006^{k}	1.361±0.01^{ghi}	1.355±0.006^{hi}	1.376±0.008^{fgh}	1.392±0.005^{def}
	15	1.311±0.009^{j}	1.383±0.006^{efg}	1.388±0.009^{ef}	1.395±0.005^{def}	1.430±0.004^{bc}
	30	1.319±0.007^{j}	1.400±0.005^{de}	1.399±0.009^{de}	1.414±0.008^{cd}	1.444±0.005^{b}
	60	1.352±0.009^{i}	1.425±0.007^{bc}	1.443±0.01^{b}	1.435±0.008^{bc}	1.472±0.007^{a}

*Treatments: see codes below **Table (2)** WSN: water soluble nitrogen - Values are presented as means ± SD
- Differences in the superscript letters indicate significance ($p \leq 0.05$) between means.

Titratable acidity and pH values of UF-FCA samples were shown in Figs. (1&2), UF- Feta cheese analogue made using partial replacement of UF retentate of skim milk with DSWPP (T_1, T_2, T_3 and T_4) was relatively high acidic as compared to that made using UF retentate of skim milk (control). The UF-FCA (control) samples had the lowest acidity (0.83%) and highest pH value (5.85) and the UF-FCA with 20% DSWPP (T4) had the highest acidity (1.55%) and lowest pH value (5.66). These findings align with those reported by Tashakori *et al.* (2013), indicating that the Feta cheese sample manufacture with 1.5% whey protein concentrate exhibited the highest acidity and lowest pH, contrasting with the control white Feta cheese sample which had the lowest acidity and highest pH. As the storage duration progressed (Figs. 1&2), the acidity of cheese in all treatments exhibited a significant gradual rise ($p \leq 0.05$), accompanied by a significant decrease in pH values. Additionally, the data presented in the same Figs. (1&2) indicate a rapid rise in acidity within the initial 15 days of storage, followed by a slight and gradual increase in titratable acidity throughout the remaining storage period. This phenomenon could be attributed to the fermentation process converting lactose into lactic acid. Similar findings were reported by Hamad and Ismail (2009).

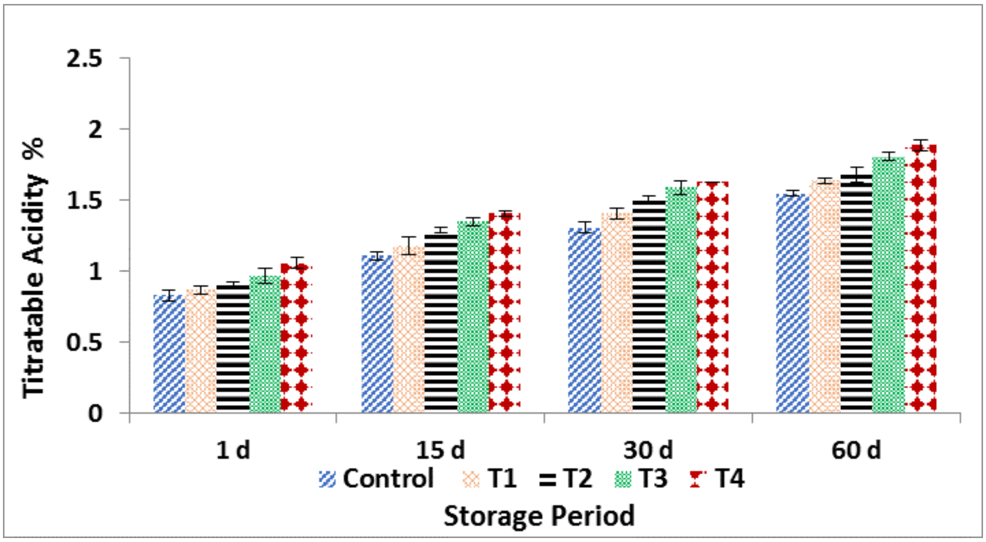

Fig.1. The effect of partial replacement of UF retentate of skim milk with different levels of DSWPP on the acidity(%) of UF-FCA during refrigerated storage (6±2°C) for 60 days

*Treatments: see codes below **Table (2)**

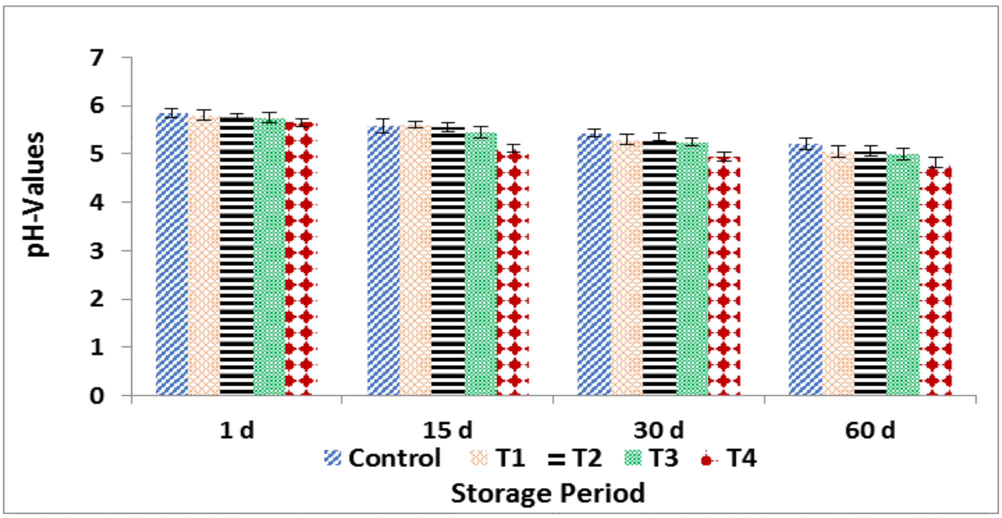

Fig.2. The effect of partial replacement of UF retentate of skim milk with different levels of DSWPP on the pH-values of UF-FCA during refrigerated (6±2°C) for 60 days

*Treatments: see codes below **Table (2)**

Changes in the texture profile of UF-FCA.

Texture plays a pivotal role in defining the identity of a product and the attributes of food materials, particularly in the context of cheese, as it results from a combination of physical and chemical properties (Quigleya *et al.,* 2011). The texture of cheese is significantly influenced by both compositional and processing parameters (Sattar *et al.,* 2018). The parameters representing the texture profile reflect the structural composition of the cheese matrix. These parameters include hardness, springiness, cohesiveness, adhesiveness, gumminess, and chewiness. Data illustrated in Table (4) indicated the effect of addition of DSWPP on instrumental texture characteristics of UF-FCA samples.

Hardness refers to the amount of force needed to compress a sample between the molars, Bourne (2002). The data presented in Table (4) show significant differences ($p \leq 0.05$) in the hardness of UF-FCA samples based on the UF retentate of skim milk replacement process. Partial replacement of UF retentate of skim milk with DSWPP resulted in the softest cheeses compared to the control, and the hardness of cheese samples observed significant decreased ($p \leq 0.05$) with the increase of the DSWPP ratio. The UF-FCA samples including a 20% of DSWPP as UF retentate of skim milk replacer had the lowest hardness (408 g) as compared to control (649 g). The differences in hardness values between UF-FCA samples maybe due to the content casein and fat. The low-fat cheeses are harder than full-fat types because of higher casein content. The fat in cheese plays as a lubricant and can break up the protein matrix so that cheese becomes softer (Koca and Metin, 2004). Moreover, ultrafiltration leads to the complete recovery of whey proteins, constituting 20% of the total proteins in cheese, within the cheese matrix. This results in a softer cheese with reduced shear stress. Additionally, as all caseins accumulate in the ultrafiltration retentate of skim milk, the gel strength is correspondingly enhanced (Hinrichs, 2001). Singh and Waungana (2001) demonstrated that incorporating whey proteins into the UF cheeses resulted in a loose, pasty and cracked texture. The high water binding capacity of whey proteins in the UF cheeses resulted in a poor consistency/texture, which is expected to improve with continued ripening (Lopez and Dufour, 2001).

Springiness, according to Bourne (2002), refers to the speed at which a deformed material reverts to its initial shape upon removal of the force causing the deformation. The data obtained indicated that the process of UF retentate of skim milk replacement significantly ($p \leq 0.05$) influenced the springiness of the cheese. With 15% UF retentate of skim milk replacement by DSWPP resulting in the lowest springiness among all fresh cheese samples. The springiness values of all UF-FCA samples decreased gradually during the cold storage period, likely due to proteolysis, which enlarges the fat voids within the cheese matrix, this results in agreement with those reported by Elazhry *et al.* (2019).

Cohesiveness, as defined by Bourne (2002), refers to the strength of the internal bonds that constitute the structure of the product. The results revealed that, the UF-FCA which made without UF retentate of skim milk replacement possessed the highest cohesiveness of all cheese samples. while, replacement of UF retentate of skim milk with DSWPP led to significant decrease ($p \leq 0.05$) in cohesiveness values. This could be attributed to the higher porosity of the protein matrix in the UF-FCA samples where UF retentate of skim milk was replaced, likely caused by the presence of DSWPP.

Adhesiveness refers to the work necessary to counteract the bonding forces between a food's surface and other materials it encounters. It is determined by assessing the negative area during the initial bite, which represents the force needed to separate a compressing probe from the food (Bourne, 2002). replacement of UF retentate of skim milk with different ratio of DSWPP led to significant increase in adhesiveness value of UF-FCA. Also, T_1 observed the highest adhesiveness value among all treatments. In the same time, cold storage observed decrease in the adhesiveness values of all UF-FCA samples.

Gumminess is defined as the energy needed to disintegrate a semisolid food until it becomes ready for swallowing as explained by Bourne (2002). As shown in Table (4) DSWPP had significant effects on the gumminess of cheese samples. Gumminess values of UF-FCA samples were significantly decreased ($p \leq 0.05$) when DSWPP was used as UF retentate of skim milk replacer in the production of UF-FCA, control cheese samples showed the highest gumminess among all cheese samples. Moreover, DSWPP increased moisture of UF-FCA samples and disrupted protein matrix of cheese so that less force was needed to disrupt the texture of cheese in compression stage. Extending the cold storage period led to a significant increase ($p \leq 0.05$) in gumminess for all UF-FCA samples, attributed to the rise in their hardness.

Chewiness is defined as the number of masticates required for a certain amount of sample in order to satisfactorily decrease the consistency for swallowing (Nateghi *et al.*, 2012). As well as gumminess, the minimum chewiness was observed when DSWPP was used as partial replacer for UF retentate of skim milk in the UF-FCA production. Control cheese samples showed the highest chewiness among all cheese samples, this finding showed that this levels of the DSWPP was able to loosen the structure of the protein matrix of cheese. Therefore, less energy is needed for chewing of the cheese in the mouth and preparing it for being swallowed. The chewiness of all cheeses raised gradually during cold storage of 60 days, likely due to increase in the hardness as well as gumminess.

Therefore, DSWPP were able to increase or reduce texture parameters based on their substitution ratio because of the significant interactions**.**

Table 4. The effect of partial replacement of UF retentate of skim milk with different levels of DSWPP on the texture characteristics of UF-FCA during refrigerated storage at (6±2°C) for two months

Properties	Storage periods (days)	Treatments*				
		Control	T_1	T_2	T_3	T_4
Hardness (g)	1	649^{ed}	581^{gf}	572^{g}	484^{h}	408^{i}
	15	715^{b}	607^{cb}	582^{cd}	508^{g}	475^{g}
	30	731^{b}	695^{cb}	668^{cd}	565^{g}	558^{g}
	60	853^{a}	713^{b}	673^{cd}	616^{ef}	637^{ed}
Springiness (mm)	1	3.98^{a}	3.91^{a}	3.76^{b}	3.11^{g}	3.66^{cb}
	15	3.26^{f}	3.6^{cd}	3.13^{gf}	3.5^{ed}	3.75^{b}
	30	2.63^{i}	3.24^{gf}	2.61^{i}	2.95^{h}	3.44^{e}
	60	2.15^{j}	2.95^{h}	2.7^{i}	2.25^{j}	3.23^{gf}
Cohesiveness	1	0.47^{fg}	0.33^{h}	0.35^{gh}	0.27^{i}	0.45^{ed}
	15	0.56^{abc}	0.39^{efgh}	0.37^{fgh}	0.38^{fgh}	0.5^{dc}
	30	0.58^{ab}	0.43^{ef}	0.41^{efg}	0.45^{ed}	0.57^{ab}
	60	0.6^{a}	0.52^{bc}	0.54^{abc}	0.53^{bc}	0.59^{ab}
Adhesiveness (mj)	1	0.6^{c}	1^{a}	0.8^{b}	0.5^{cd}	0.9^{ab}
	15	0.4^{de}	0.8^{b}	0.6^{c}	0.5^{cd}	1^{a}
	30	0.5^{cd}	0.8^{b}	0.4^{de}	0.4^{de}	0.4^{de}
	60	0.3^{e}	0.5^{cd}	0.4^{de}	0.3^{e}	0.3^{e}
Gumminess (g/sec)	1	279.07^{fghi}	191.73^{l}	200.0^{kl}	130.68^{m}	183.6^{l}
	15	400.4^{bc}	236.73^{ghi}	215.34^{ijk}	193.04^{jkl}	237.5^{fghi}
	30	423.98^{b}	298.85^{fgh}	273.88^{ghi}	254.25^{hij}	318.06^{efg}
	60	511.8^{a}	370.76^{cd}	363.42^{cde}	326.48^{def}	375.83^{cd}
Chewiness (g/sec)	1	1110.7^{bc}	749.66^{d}	752.75^{d}	406.41^{e}	671.98^{d}
	15	1305.3^{a}	852.23^{c}	674.01^{d}	675.64^{d}	890.63^{c}
	30	1115.07^{bc}	968.27^{c}	714.83^{d}	750.04^{d}	1094.13^{bc}
	60	1100.37^{bc}	1093.74^{bc}	981.23^{c}	734.58^{d}	1213.93^{ab}

*Treatments: see codes below **Table (2)** - Values are presented as means ± SD.
- Differences in the superscript letters indicate significance ($p \leq 0.05$) between means.

Changes in the organoleptic properties of UF-FCA:

The scores of organoleptic attributes of UF- feta cheese analogue samples are showed in Table (5), all UF-FCA cheese treatments were acceptable by panelists. Feta cheese is traditionally recognized for its white appearance, and the incorporation of DSWPP primarily alters the color and appearance of the cheese without significant differences ($p \leq 0.05$). The color and appearance scores of both the control and various treatments were similar in both fresh and stored cheese. The effect of DSWPP on the flavor score was not significant ($p \leq 0.05$) as shown in Table (5). The panelists stated that the UF-FCA samples containing DSWPP had favorable and dairy taste, therefore, the cheese samples with 5% DSWPP had a highest flavor score (34) as compared with control (33.9), while cheese samples contain 20% DSWPP gained the lowest flavor score among all cheese samples. Different proportions of DSWPP yielded UF-FCA with different body and texture scores.

Texture is defined as the combination of sensory elements resulting from physical properties perceived by the senses of light and touch (Fox *et al.,* 2000). Scores of body and texture of UF-FCA made with or without partial substitution of UF retentate of skim milk with DSWPP were similar when fresh. The UF-FCA samples made with 5% DSWPP had a lowest score (48.1), while cheese made with 15% DSWPP gained the highest body and texture score (48.5). The majority of sensory evaluation judgment revealed that at 20% DSWPP substitution, it could be presented as spreadable more than classic cheese. In this case, spreadable UF-FCA made by adding 20% DSWPP presents a new acceptable dairy product. Ismail (2012) reported that addition of whey proteins to milk or curd slightly raised scores of organoleptic properties of Ras cheese. The overall acceptability scores were ranged between 95.3

and 96.5 for T_4 and T_3, respectively. Also, at the end of storage periods, cheese samples T_3 gained the highest scores (89.6) as compared to control (89.1), and cheese samples T_4 which made by replacement of UF retentate of skim milk with 20% DSWPP gained the lowest score (88.9, 88). During cold storage, a slight insignificant decrease has been occurred in the scores of organoleptic properties for all UF-FCA samples within the initial 15 days of storage. However, significant differences were observed, followed by a slight and gradual decrease in organoleptic properties scores throughout the remaining storage period. Finally, it is concluded that UF-FCA with acceptable properties to 60 days of cold storage could be made from partial replacement of UF retentate of skim milk with denatured salt whey proteins paste ratio up to 15%. Hamad and Ismail (2013) reported similar findings, indicating a gradual decreased in sensory evaluation scores for all white cheese spread treatments during the storage period, particularly evident in cheese stored at room temperature.

Microbiological quality of UF-FCA:

The data illustrated in Table (6) showed that the mean counts of total viable bacteria, yeasts and moulds, and coliform group bacteria were nearly similar in all UF-FCA samples with or without partial substitution by DSWPP. The mean log count of TVC were ranged between 3.62 and 4.11 log cfu/g for T_3 and T_2, respectively. Moreover, the mean log count of yeasts and moulds were ranged from 1.98 to 2.36 log cfu/g for T_2 and T_3, respectively. In the same time, coliform testing may be used as a method for assess the efficiency of cheese milk and to monitor post-pasteurization contamination in cheese milk, as indicated by Chappel and Bigalke (1987), the presence of coliform group in UF-FCA samples were detected with very small numbers at the beginning of the storage period, and it ranged between (< 10) to (< 30) cfu/g, then not detected as the storage period progresses. These findings align with those reported by Majali *et al.* (2015). The absence of coliform group bacteria may be attributed to the effective heat treatment and stringent sanitation practices employed during the production and storage of cheese samples.

Table 5.The effect of partial replacement of UF retentate of skim milk with different levels of DSWPP on the organoleptic properties of UF-FCA during refrigerated storage at (6±2°C) for two months

Properties	Storage periods (days)	Treatments*				
		Control	T_1	T_2	T_3	T_4
Appearance & color (15)	1	$13.9±0.74^{abc}$	$13.8±0.42^{abcd}$	$13.8±0.42^{abcd}$	$14.1±0.32^{a}$	$14±0.32^{ab}$
	15	$13±0.67^{abcde}$	$12.9±0.88^{abcdef}$	$13.2±0.42^{abcdef}$	$13.2±0.63^{abcd}$	$13.1±0.74^{abc}$
	30	$12.8±0.42^{defgh}$	$12.6±0.52^{cdefgh}$	$12.7±0.48^{abcdefg}$	$13±0.67^{abcdefg}$	$13.1±0.57^{bcdefgh}$
	60	$12.4±0.51^{fgh}$	$12.2±0.42^{h}$	$12.3±0.48^{gh}$	$12.5±0.53^{efgh}$	$12.4±0.7^{fgh}$
Falvor (50)	1	$33.9±0.57^{a}$	$34±0.47^{ab}$	$33.9±0.74^{a}$	$33.9±0.32^{a}$	$33±0.47^{a}$
	15	$32.9±0.73^{a}$	$32.8±0.63^{a}$	$33±0.66^{a}$	$32.9±0.74^{a}$	$32.3±0.48^{ab}$
	30	$32.3±0.82^{ab}$	$32.2±0.79^{ab}$	$32.2±0.79^{ab}$	$32.4±0.69^{ab}$	$31.7±0.67^{b}$
	60	$31.4±0.51^{c}$	$31.7±0.82^{c}$	$31.4±0.84^{c}$	$31.5±0.85^{c}$	$31±0.82^{c}$
Body & Texture (35)	1	$48.3±0.4^{ab}$	$48.1±0.32^{a}$	$48.3±0.67^{ab}$	$48.5±0.71^{ab}$	$48.3±0.48^{abc}$
	15	$47.5±0.71^{abc}$	$47.8±0.42^{abc}$	$47.7±0.67^{abc}$	$47.6±0.7^{abc}$	$47.1±0.57^{c}$
	30	$46.3±0.48^{bc}$	$46.4±0.69^{c}$	$46.3±0.67^{abc}$	$46.4±0.7^{bc}$	$45.8±0.63^{cd}$
	60	$45.3±0.48^{de}$	$45±0.81^{de}$	$45.6±0.52^{de}$	$45.6±0.7^{de}$	$44.6±0.97^{e}$
Overall acceptability (100)	1	$96.1±0.88^{a}$	$95.9±0.88^{a}$	$96±1.15^{a}$	$96.5±0.97^{a}$	$95.3±0.82^{ab}$
	15	$93.4±0.97^{ab}$	$93.5±1.18^{ab}$	$93.9±1^{ab}$	$93.7±1.42^{ab}$	$92.5±1.08^{ab}$
	30	$91.4±1.17^{bc}$	$91.2±1.14^{bc}$	$91.2±1.4^{bc}$	$91.8±1.13^{bc}$	$90.6±1.35^{c}$
	60	$89.1±0.87^{d}$	$88.9±1.1^{d}$	$89.3±1.34^{d}$	$89.6±1.58^{d}$	$88±2.11^{d}$

*Treatments: see code below **Table (2)** - Values are presented as means ± SD.
- Differences in the superscript letters indicate significance (p≤0.05) between means.

Table 6. Microbiological properties (Log cfu/g) of UF-FCA manufacture by partial replacement of UF retentate of skim milk with different levels of DSWPP during refrigerated storage at (6±2°C) for two months

Properties	Storage periods (days)	Treatments*				
		Control	T_1	T_2	T_3	T_4
Total viable bacteria	1	3.99	3.67	4.11	3.62	3.93
	15	3.87	3.59	3.95	3.58	3.89
	30	3.79	3.49	3.90	3.52	3.83
	60	3.62	3.38	3.80	3.44	3.74
Yeasts & Molds	1	2.18	2.24	1.98	2.36	2.16
	15	2.12	2.13	1.74	2.23	2.05
	30	1.86	1.90	1.51	1.97	2.02
	60	< 30	1.58	< 30	1.89	1.86
Coliform group	1	< 10	< 30	< 30	< 10	< 30
	15	< 10	< 10	< 10	< 10	< 10
	30	N.D	N.D	N.D	N.D	N.D
	60	N.D	N.D	N.D	N.D	N.D

*Treatments: see code below **Table (2)** cfu/g: colony forming unit per gram
N.D: not detected in 1g of sample

Throughout the storage period, the count of various microbial groups in cheese notably declined, reaching their lowest numbers by the end of the storage period. The refrigerated storage of UF-FCA samples led to a decrease in the count of all tested microbial groups, likely due to the influence of acidity, salt and cold storage on microbial activity. This reduction can be clearly attributed to the rise in titratable acidity, which regulated the rate of bacterial growth or served as a bactericidal agent, as suggested by El-Abd *et al.* (2003). Meanwhile, counts of TVC, yeasts and molds, and coliform group in all UF-FCA samples were satisfactory, which is much lower than allowed by the Egyptian standard No,1867/2005.

Economic efficiency study:

The data illustrates in Table (7) showed the impact of incorporating DSWPP as partial replacer for UF retentate of skim milk in the manufacture of UF-FCA on various economic factors. These factors include the UF retentate of skim milk cost, DSWPP cost, other ingredients cost, e.g. (shortening, salt, GDL, stabilizers, rennet, $CaCl_2$, potassium sorbate), processing cost, total production cost, rates of UF retentate of skim milk cost reduction and rates of production cost reduction. The results of this economic study indicate that the addition of 5, 10, 15, and 20% of DSWPP resulted in decrease in the rates of total production cost 2.57, 5.16, 7.78 and 10.34% respectively, compared to the control. These findings highlight the positive impact of incorporating DSWPP in terms of profitability in the production of UF-FCA.

Table 7. The economic efficiency of using DSWPP in the production of UF-FCA

Ingredients	Treatments*				
	Control	T_1	T_2	T_3	T_4
UF retentate of skim milk cost (L.E)	2547	2420	2293	2165	2038
DSWPP cost (L.E)	0	27	53	79	106
Other ingredients cost (L.E)	950	950	950	950	950
Processing cost (L.E)	400	400	400	400	400
Total production cost of 100 kg cheese (L.E)	3897	3797	3696	3594	3494
Rates of UF retentate of skim milk cost reduction %	-	3.93	7.89	11.9	15.82
Rates of production cost reduction %	-	2.57	5.16	7.78	10.34

*Treatments: see code below **Table (2)**

CONCLUSION

The findings of this study demonstrate the successful production of UF- feta cheese analogue by substituting a portion of UF retentate of skim milk with denatured salt whey protein paste at a ratio up to 15%. The resulting UF-FCA exhibited satisfactory quality characteristics and increased the percent of revenue. It could be concluded that dairy companies waste (salted whey resulting from Ras cheese manufacture) could be used as a cheap ingredient in the production of UF-FCA, in addition to preserving the environment.

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الملخص العربي

تأثير الاستبدال الجزئي لمركز الترشيح الفوقى للبن الفرز بعجينة بروتينات الشرش المالح المدنتر على جودة مشابه جبن الفيتا

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أجريت الدراسة بهدف الوصول لأفضل تركيبة تستخدم في صناعة مشابه الجبن الفيتا من خلال الاستبدال الجزئي لمركز الترشيح الفوقى للبن البقرى الفرز بعجينة بروتين الشرش المالح المدنتر. تم تقييم تأثير الاستبدال بنسب ٥، ١٠، ١٥، ٢٠% (وزن/ وزن) بعجينة بروتين الشرش المالح المدنتر، وتأثير ذلك على الخصائص الطبيعية، الكيميائية، الريولوجية، الحسية، والجودة الميكروبية لمشابه جبن الفيتا الناتج على مدى ٦٠ يوم من التخزين المبرد (٦±٢ درجة مئوية). وكذلك دراسة الكفاءة الاقتصادية. وأظهرت النتائج أن الاستبدال الجزئي لمركز الترشيح الفوقى للبن الفرز بعجينة بروتين الشرش المالح المدنتر أدى إلى حدوث فروق معنوية ($p \leq 0.05$) في قيم الخواص الطبيعية والكيميائية لمشابه جبن الفيتا، حيث حدث انخفاض معنوي في محتوى الجبن من المادة الجافة وكذلك قيم الأس الهيدروجيني، بينما حدثت زيادة معنوية في محتوى الجبن من البروتين الكلى والنيتروجين الذائب وكذلك قيم الحموضة مقارنة بالكنترول. كذلك، لوحظت فروق معنوية في صفات القوام بين جميع المعاملات، حيث انخفضت قيم الصلابة والمرونة والتماسك والصمغية والمضغية، في حين زادت قيم الالتصاق مقارنة بالكنترول. وأظهرت نتائج التقييم الحسى لعينات مشابه جبن الفيتا كانت جميعها مقبولة من قبل المحكمين، ولكن عينات الجبن التي تحتوي على ١٥% من عجينة بروتين الشرش المالح المدنتر كانت الأكثر تفضيلاً بين جميع المعاملات، وكانت الجودة الميكروبية مقبولة لجميع المعاملات. أدى التخزين البارد لمدة ٦٠ يومًا إلى حدوث تغييرات مختلفة في خصائص الجبن. وتشيرنتائج دراسة الكفاءة الاقتصادية إلى أن استخدام عجينة بروتين الشرش المالح المدنتر بنسب تصل إلى ٢٠% (وزن/وزن) كبديل جزئي لمركز الترشيح الفوقى للبن البقرى الفرز في إنتاج مشابه جبن الفيتا أدت إلى انخفاض تكلفة الإنتاج وزيادة الربحية.