

**THE IMPACT OF APPLICATION OF SOME NATURAL
HYDROCOLLOIDS AS FAT REPLACERS IN REDUCED-FAT
UF-FETA CHEESE PRODUCTION**

Othman, Eman K.¹, Awad, S.A.², Abd Elhamid, A.M.¹, Yacoub, S.S.¹

¹Food, Dairy Science and Technology Department, Faculty of Agriculture,
Damanhour University, Egypt. ²Dairy Science and Technology Department,
Faculty of Agriculture, Alexandria University, Egypt.

Corresponding author: emankhaled@agr.dum.edu.eg; Cell: +201207938574



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ABSTRACT

The current research aimed to comprehensively evaluate the effects of using some types of hydrocolloids, namely xanthan gum (XG), locust bean gum (LBG), and basil seed gum (BSG), each at a concentration of 0.3%, either individually or in combination, as fat replacers, on physicochemical, rheological, sensory, and microbiological properties of low-fat UF-Feta cheese (LFC) during 60 days of cold storage $5\pm 2^{\circ}\text{C}$. The results indicated The results showed that there was a significant ($P\leq 0.05$) decrease in the content of dry matter, fat/dry matter, and titratable acidity values in all LFC treatments compared with the full-fat cheese (FFC). Meanwhile, LFC treatments containing gums, either individually or in combination, exhibited a lower dry matter content than the LFC (control). In contrast, the LFC treatments showed a significant ($P\leq 0.05$) increase in pH values, as well as higher contents of protein, salt, ash, and carbohydrates (on basis of dry matter) compared with the FFC. During storage, a gradual increase in acidity and dry matter components due to moisture loss, while a significant decrease in pH values was observed in all FFC and LFC samples.

The addition of gums improved the textural properties of LFC, as evidenced by a significant reduction in hardness and cohesiveness values compared with the LFC (control). This imparted the cheese with textural characteristics comparable to those of FFC. The use of hydrocolloids in binary or ternary mixtures resulted in a better balance between hardness and cohesiveness, reflecting a synergistic interaction among the different types of gums. The LFC samples treated with gums received significantly higher scores for sensory attributes including appearance, flavor, texture, and overall acceptability compared to the LFC (control), and were closer in their sensory profile to the FFC. This was particularly evident in samples containing BSG and LBG, whether used individually or in combination. A gradual decline in sensory scores for all treatments during storage. Microbiological analyses showed that all feta cheese samples maintained acceptable microbiological quality, and the use of gums had no noted effect in this regard. During storage period, yeasts, molds, and coliform bacteria were not detected, while a gradual reduction in sporeforming bacteria counts was observed. Overall, the study demonstrated that natural gums (XG, LBG and BSG) contributed to the improvement of cheese characteristics, making them effective fat replacers in the production of low-fat UF-Feta cheese.

Keywords: Feta Cheese, Low Fat Cheese, Fat Replacers, Hydrocolloids, Xanthan Gum, Locust Bean Gum, Basil Seed Gum.

INTRODUCTION

Cheese represents one of the most diverse and complex categories within the dairy product sector that enjoys many varieties traded and marketed worldwide (Xue *et al.*, 2022). White soft cheese is recognized as the most popular and commonly consumed cheese in Mediterranean countries, especially in Egypt. It is widely consumed and available in many

varieties depending on the manufacturing techniques, fat content, and salt percentage (**Hegazy *et al.*, 2012**). Egypt exhibits the highest cheese consumption rate in North Africa, supported by the wide diversity of cheese varieties available in the market, including soft, brined, salted, semi-soft, and hard cheeses (**Abed *et al.*, 2021**). White soft cheese represents the dominant segment of Egypt's cheese industry, contributing nearly 75% of the total national cheese production.

Feta cheese is a widely consumed soft white cheese across Africa, Europe, and several other regions. Traditionally, it was produced from goat's milk; however, in contemporary manufacturing practices, a variety of milk sources sheep, cow, and buffalo milk are now utilized to produce Feta cheese. Depending on the desired fat content and product characteristics, Feta cheese can be manufactured from whole, partially skimmed, or skimmed milk (**Hamdy *et al.*, 2021**). The application of ultrafiltration (UF) technique in cheese making offers numerous technological and economic advantages. It enhances cheese yield, reduces production costs, and facilitates the manufacture of products with improved nutritional and functional properties. Moreover, the UF technique effectively addresses the environmental and operational challenges associated with whey disposal, which remain a major drawback of traditional cheese-making methods (**Wedad *et al.*, 2017; Kravtsov *et al.*, 2020**).

As a globally popular, nutrient-dense, and flavor-rich dairy product, cheese contains approximately 3–40% protein and 4–48% fat, depending on its type and manufacturing process (**McCarthy *et al.*, 2013**). From a sensory perspective, fat plays a pivotal role in determining product quality, contributing to the desirable aroma, creaminess, and lubricity that define consumer acceptance. The global demand for low-fat cheese has risen significantly, driven by growing public awareness of health and nutrition-related concerns. Excessive fat consumption has been associated with an increased risk of obesity, cardiovascular diseases, and hypertension; therefore, there is a growing global interest in the production

of low-fat food products (**Kavas *et al.*, 2004; Rashidi *et al.*, 2015**). Nonetheless, fat replacement has emerged as a major focus in food product innovation due to multiple converging factors. Growing public concern regarding body weight management has significantly expanded the market for low-calorie and reduced-fat foods over the past decade (**Rios *et al.*, 2014**). In parallel, global environmental sustainability considerations have prompted a shift toward plant-based ingredients, which are increasingly regarded as more sustainable alternatives to those of animal origin (**McClements and Grossmann, 2021**). Moreover, it is a practical approach when taking into account the economic implications and affordability related to the extensive use of milk fat in both industrial production and consumer products (**Ahsan *et al.*, 2024**).

The global definition of low-fat cheese, as mandated by the CODEX Commission on International Trade, requires a minimum 50% reduction in fat content compared to a reference variety. Fat reduction in cheese formulations leads to substantial alterations in the compositional and structural balance, which adversely affect the textural, functional, and sensory properties of the final product. Reduced-fat cheeses are often characterized by poor meltability, a firm or rubbery texture, diminished flavor intensity, off-tastes, and occasionally an undesirable color appearance, all of which contribute to lower consumer acceptability (**Sun *et al.*, 2021**). One of the primary challenges in producing low-fat cheese is maintaining its texture. Consumers expect reduced-fat cheeses to exhibit sensory and functional properties comparable to those of full-fat varieties. Consequently, the development of low-fat cheese that maintains the same quality attributes as its high-fat counterpart has been a major focus of research and industrial innovation in the global dairy sector for many years. One of the most effective approaches to overcoming the negative effects of fat reduction in cheese is the use of fat mimetics and replacers, which can help maintain the desirable texture, mouthfeel, and flavor profile of low-fat cheese (**Kavas *et al.*, 2004; Rout and Saha, 2025**).

Fat replacers are specialized ingredients formulated to partially or completely substitute natural fats in food products, thereby reducing their overall caloric content. In cheese manufacturing, these replacers not only contribute to calorie reduction but also enhance moisture retention and disrupt the protein matrix, leading to improved texture and sensory properties in low-fat cheese (**Rashidi *et al.*, 2015**). The incorporation of fat substitutes into reduced-fat or low-fat cheese formulations is considered an effective approach to enhance the textural properties and sensory attributes of the final product (**Ganesan *et al.*, 2014**). In the food processing industry, hydrocolloids are extensively employed as carbohydrate-based fat substitutes to mitigate the adverse effects associated with fat reduction and to enhance the functional properties of food products (**Udo *et al.*, 2023**). The most commonly used fat replacers are derived from hydrocolloids, whose functional properties such as thickening, texturizing, and water-holding capacity (WHC) enable them to effectively mimic the physical characteristics of fat in dairy products (**Razavi and Behrouzian, 2018**).

The term "gum" refers to a class of hydrophilic or amphiphilic polysaccharides with high molecular weight, as well as their derivatives, which possess the ability to form gels or viscous solutions in specific solvents even at low concentrations (**Zare *et al.*, 2019; Barak *et al.*, 2020**). Based on their origin, structural composition, and functional characteristics, gums can be classified into several categories: plant-derived gums (e.g., seed gums, guar gum, and locust bean gum), secretion-derived gums (e.g., gum Arabic and tragacanth gum), mucilage-based gums (e.g., psyllium gum), seaweed-derived gums (e.g., alginate and carrageenan), and microbial-derived gums (**Ahmad *et al.*, 2019**). Xanthan gum is an anionic polysaccharide produced by microbial fermentation, known for its high viscosities that stabilize food systems even at low concentrations (**Krempel *et al.*, 2019**). Locust bean gum, a galactomannan derived from the seed endosperm of the carob tree, is widely used in the food industry as a thickener and stabilizer to enhance the textural function (**Barak and Mudgil, 2014; Nasrallah *et al.*, 2024**). Basil seeds (*Ocimum basilicum* L.) contain mucilaginous polysaccharides within their testa cells, which, upon

hydration, rapidly absorb water and swell to form a highly viscous hydrogel (Shahrajabian *et al.*, 2023).

Therefore, the aim of this study was to evaluate the effects of using some hydrocolloids (xanthan gum, locust bean gum, and basil seed gum), individually and in combination at percent 0.3%, as fat replacers, on physicochemical, rheological, sensory, and microbiological properties of low-fat UF-Feta cheese during 60 days of cold storage ($5 \pm 2^{\circ}\text{C}$).

MATERIALS AND METHODS

Materials

Fresh cow's milk, skimmed milk powder, and butter oil were obtained from El-Nada Company for Food Industries (REFY), Ltd. (El-Nobaria City, Egypt). Xanthan gum and locust bean gum (powdered form) were purchased from El-Gomhoria Company for Drugs and Chemicals (Cairo, Egypt). Basil seeds were purchased from a local market (Nasr City, Cairo Governorate, Egypt). Commercial stabilizers (Lacta-815 & Lacta-825) were obtained from Misr Food Additives Company (MIFAD) located in Badr City, Egypt. Glucono delta lactone (GDL) was procured from Sigma Chemical Company (St. Louis, Mo., USA). Potassium sorbate was obtained from Jiangbei Additive Co., Ltd., China. Salt was procured from El-Madina for the Salt Industry Company of Alexandria, Egypt. Microbial rennet (750 IMCU/ml) was obtained from CAGILO STAR, Spain. All other chemicals used in this study were of analytical grade.

Preparation of basil seed gum (BSG)

Basil seeds were washed several times with ethanol to remove contaminants, then filtered and dried in an oven at 50°C to evaporate remaining ethanol. The purified seeds were immersed in distilled water at $50\text{--}55^{\circ}\text{C}$ (seed-to-water ratio of 1:30), and the pH was adjusted to 8 using 0.2 M NaOH or instead of and HCl. The mixture was stirred at 50°C for 2

h using a magnetic stirrer (Lab ART/SH-5, Turkey). Subsequently, the dispersion was stirred at 1500 rpm for 10 min to facilitate the detachment of mucilage from the seed surface. It was subsequently centrifuged at 9000 rpm for 15 min (Nüve-NF 800R, Türkiye) to separate the mucilage from the seeds. The mucilage collected from the upper layer was oven-dried (Nüve KD 200, Türkiye) at 50 °C for 24 h. The dried mucilage was blended with 95% ethanol (1:3 gum:ethanol) and kept overnight at 4 °C to obtain pure BSG. The gum solution was filtered using a 200 mesh kitchen sieve, and the sieve was rinsed with pure water to recover all remaining gum. The filtrate obtained was oven dried at 50 °C for 18 hours, ground into powder, and stored in plastic bags at +4 °C until use. The extraction yield of BSG was determined to be 20.2% (Oraç *et al.*, 2023).

UF-Feta cheese manufacture

The chemical composition of the raw materials and ingredients used in the manufacture of UF-Feta cheese were illustrated in **Table (1)**.

Table 1: The chemical composition and pH value of the raw materials used in the manufacture of UF-Feta cheese

Ingredients	Component (%)					pH
	DM	Fat	Protein	Lactose	Carbohydrates	
Fresh cow's milk	12.03	3.50	3.15	5.02	-	6.68
Skimmed milk powder	97.00	0.88	35.5	50.00	-	6.37
Butter oil		99.10	-	-	-	6.60
Retentate	23.50	8.75	7.84	6.30		6.63
Xanthan gum	88.00	-	0.50	-	87.00	6.00
Locust bean gum	89.00	-	5.00	-	75.00	5.50
Basil seed gum	89.00	-	7.00	-	80.00	6.00

UF-Feta cheese was prepared following the traditional method described by **Tamime and Kirkegaard (1991)**, with minor modifications to

suit the objectives of the present study. Fresh cow's milk was pasteurized at 72°C for 15 sec, then ultra-filtered at 50°C (3 folds). Thirty six kg of resultant retentate were divided into nine equal portions (4 kg each). The first portion (Control-1) was obtained by standardizing a portion of the retentate with butter oil as a full-fat UF-Feta cheese (FFC). The remaining eight portions were produced from the same retentate but standardized with skimmed milk powder (SMP) as a low-fat UF-Feta cheese (LFC). Dry matter and fat/dry matter ratio were optimized in FFC and LFC to comply

Table 2: Formulations (1: control (Ctrl-1), 2: control (Ctrl-2), 3:XG, 4: LBG, 5:BSG, 6:XG-LBG, 7: XG-BSG, 8:LBG-BSG, 9:XG-LBG-BSG) of UF-Feta cheese made with Xanthan, Locust bean, and basil seed gums as fat replacers.

Component *	Treatments								
	FFC	LFC							
	1	2	3	4	5	6	7	8	9
Retentate (kg)	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00
SMP (kg)	-	0.80	0.80	0.80	0.80	0.80	0.80	0.80	0.80
Butter oil (kg)	0.80	-	-	-	-	-	-	-	-
Salt (g)	70.0 0	70.0 0	70.0 0	70.0 0	70.0 0	70.0 0	70.0 0	70.0 0	70.0 0
CaCl ₂ (mg)	0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.40
Pot. Sorbate (g)	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00
GDL (g)	90.0 0	90.0 0	90.0 0	90.0 0	90.0 0	90.0 0	90.0 0	90.0 0	90.0 0
Microbial rennet (g)	0.18	0.18	0.18	0.18	0.18	0.18	0.18	0.18	0.18
Lacta815 - Lacta825 (50:50%)	10.0 0	10.0 0	10.0 0	10.0 0	10.0 0	10.0 0	10.0 0	10.0 0	10.0 0
XG (mg)	-	-	12.0 0	-	-	6.00	6.00	-	4.00
LBG (mg)	-	-	-	12.0 0	-	6.00	-	6.00	4.00
BSG (mg)	-	-	-	-	12.0 0	-	6.00	6.00	4.00

*FFC: full-fat UF-Feta cheese (Ctrl-1), LFC: low -fat UF-Feta cheese (Ctrl-2), XG: Xanthan gum, LBG: Locust bean gum, BSG: Basil seed gum, XG, LBG, BSG: refer to low-fat UF-Feta cheese produced using hydrocolloids individually, each at a concentration of 0.3%. XG-LBG, XG-BSG, LBG-BSG, XG-LBG-BSG: refer to low fat UF-Feta cheese made using combination of hydrocolloids at total concentration of 0.3%, mixed in respective ratios of 1:1, 1:1, 1:1, and 1:1:1, respectively. SMP: skimmed milk powder.

Approximately with the **Egyptian Standard Specification (No:1008-12/2005)** for Feta cheese. One of last eight portions was considered as low-fat UF-Feta cheese (control-2). At the same time the other seven portions of retentate were incorporated with gums as detailed in **Table 2** and mixed thoroughly until complete dissolution. Subsequently, all treatments were incorporated with Lacta815-Lacta825 (0.25%), CaCl_2 (0.01%), potassium sorbate (0.05%), GDL (2.25%), and salt (1.75%) then mixed. The mixtures were transferred quickly into stainless steel trays containing rennet then mixed and incubated at 35 °C for 20 min to achieve complete coagulation. The curd obtained was cooled for 6 h, then cut into blocks sized 8cm x 8cm x 15cm, then packing in plastic containers (Food Grade) and stored refrigerated at 5 ± 2 °C for 60 days. UF-Feta cheese treatments were performed to analysis when fresh and after 15, 30, and 60 days for chemical, rheological, microbiological, and sensory properties.

Physicochemical parameters

Dry matter, ash, protein, fat, salt and contents were determined according to **AOAC (2000)**, while titratable acidity were examined according to **Ling (1963)**. The values of carbohydrate were achieved by calculation $\% \text{Carbohydrates} = 100 - (\text{Moisture} + \text{Fat} + \text{Protein} + \text{ash})$, according to the method reported by **(Cebeci *et al.*, 2020)**. The pH value of feta cheese samples was determined using a digital glass electrode pH meter (Model HI9321, HANNA Instruments, Woonsocket, RI, USA), following the method described by **the BSI (1952)**.

Rheological properties

UF-Feta cheese samples for texture profile analysis (TPA) were obtained from the middle of the whole cheese 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/s and penetration distance of 10mm. Hardness, Consistency, and adhesiveness were evaluated in triplicate according to the definitions given by **IDF (1991)**.

Sensory evaluations

All samples of UF-Feta cheese were assessed by fifteen of the staff members of the Food and Dairy Science Departments, Faculty of Agriculture, Damanhour University. Samples were evaluated for appearance (15 points), body and texture (50 points) and flavor (35 points) to be 100 points for the total scores. according to **Hassan *et al.* (1983)**.

Microbial examinations

Microbiological analyses of the UF-Feta cheese samples were conducted throughout the cold storage period up to 60 days. Duplicate samples from each treatment were collected at each sampling interval, and 10 g of each cheese sample were aseptically weighed for analysis (both surface and interior), diluted in 90 ml of a sterile sodium citrate solution 2% (w/v) (Sigma, St. Louis, MO, USA), the samples then were homogenized for (60 sec.) at room temperature using a Stomacher (Model 400, Seward Medical, London, UK). Serial dilutions were prepared under aseptic conditions, and the pour plate technique was employed for microbial enumeration according to the method described by **APHA (2004)**. For counting mesophilic sporeformers, samples were heated at 80°C for 10 min then cooled to the room temperature. Enumeration was done on plate count agar at 32°C/48h (**Matrh, 2010**). Yeasts and molds

enumeration was carried out on dichloran rose-bengal chloramphenicol agar medium (Oxoid, England), and plates were incubated at 25°C for 5 days (ISO 215271, 2008). Coliforms were counted on violet red bile agar medium (Oxoid, England), and plates were incubated at 30°C for 24 h (ISO 4832, 2006).

Statistical analysis

The collected data were statically analyzed using factorial analysis of variance (ANOVA) following the procedures as outlined by **Gomez and Gomez (1984)**, to evaluate the effects of treatments, storage conditions, and their interaction. Differences among treatment means were evaluated using Tukey's Honestly Significant Difference (HSD) test at a 5% significance level ($p \leq 0.05$). All statistical analyses were performed using the SAS software, version 9.4 (SAS Institute Inc., Cary, NC, USA).

RESULTS AND DISCUSSION

Physicochemical properties of UF-Feta cheese

The effect of incorporating gums individual and combined as fat replacers on the approximate chemical composition of all UF-Feta cheese samples is presented in **Tables (3-8)**. Increasing moisture content is a key strategy to improve low-fat cheese properties. The use of fat replacers retards curd syneresis during cheese-making, as water binds directly to fat replacers, which interfere with casein matrix shrinkage and reduce the driving force for whey expulsion (**McMahon *et al.*, 1996**).

In the current study, full-fat cheese (control-1) exhibited the highest dry matter (DM) content ($38.31 \pm 0.06\%$) on day one, which significantly increased to $41.2 \pm 0.01\%$ after 60 days. A significant difference ($P \leq 0.05$) was observed between Control-1 and all low-fat cheese treatments as shown in **Table 3**. Low-fat cheese (control-2) exhibited significantly lower DM values (37.86 ± 0.01 to $40.98 \pm 0.06\%$) than full-fat cheese (control-

1), due to its higher protein content, which enhanced the water-binding capacity of the cheese matrix, contributing to improved moisture retention and texture stability (Romeih *et al.*, 2002; Ali *et al.*, 2016; Alnemr *et al.*, 2016). All hydrocolloid-treated cheese showed the lowest DM compared with both controls, as the replacement of fat with hydrocolloids (gums) containing hydroxyl groups increased water retention, resulting in lower DM. These data suggest that the use of fat replacers like xanthan, locust bean, and basil seed gum (individually or in combination) Under the current experimental conditions, an increase in the moisture and protein contents of UF-Feta cheese was observed, likely attributed to the hygroscopic nature of the incorporated hydrocolloids. Similar effects have been previously reported in various types of low-fat cheeses (Romeih *et al.*, 2002; Nateghi *et al.*, 2012; Ali *et al.*, 2016; Alnemr *et al.*, 2016; Alzamili *et al.*, 2022).

Table 3: Effect of incorporating gums individual and combined as fat replacers on dry matter content (%) of UF-Feta cheese during cold storage for 60 days

Trts.	Storage periods	Day-1	Day-15	Day-30	Day-60
FFC	Control-1	38.31±0.06 ^K	39.16±0.01 ^G	40.30±0.01 ^D	41.2±0.01 ^A
	Control-2	37.86±0.01 ^L	38.68±0.02 ^J	39.90±0.10 ^E	40.98±0.06 ^B
LFC	XG	37.78±0.03 ^L	38.58±0.03 ^J	39.60±0.02 ^F	40.95±0.07 ^B
	LBG	37.85±0.07 ^L	39.01±0.08 ^{GH}	40.19±0.03 ^D	40.95±0.02 ^B
	BSG	37.73±0.04 ^L	38.70±0.01 ^J	39.90±0.10 ^E	40.60±0.01 ^C
	XG-LBG	37.82±0.09 ^L	38.88±0.10 ^{HI}	39.55±0.01 ^F	40.62±0.08 ^C
	XG-BSG	37.82±0.02 ^L	38.72±0.01 ^{IJ}	39.96±0.06 ^E	40.87±0.03 ^B
	LBG-BSG	37.85±0.05 ^L	39.05±0.05 ^G	40.49±0.02 ^C	40.97±0.06 ^B
	XG-LBG-BSG	37.83±0.03 ^L	38.16±0.05 ^K	39.99±0.01 ^E	40.87±0.03 ^B

*FFC: full-fat UF-Feta cheese (Ctrl-1), LFC: low -fat UF-Feta cheese (Ctrl-2), XG: Xanthan gum, LBG: Locust bean gum, BSG: Basil seed gum, XG, LBG, BSG: refer to low-fat UF-Feta cheese produced using hydrocolloids individually, each at a concentration of 0.3%. XG-LBG, XG-BSG, LBG-BSG, XG-LBG-BSG: refer to low fat

UF-Feta cheese made using combination of hydrocolloids at total concentration of 0.3%, mixed in respective ratios of 1:1, 1:1, 1:1, and 1:1:1, respectively. Values are presented as means $\pm$ SD, Differences in the superscript letters indicate significance ($P \leq 0.05$) between means.

As expected, the fat in dry matter (F/DM) of UF-Feta cheese was significantly ($p \leq 0.05$) higher in full-fat cheese (Control-1), ranging from $60.39 \pm 0.01\%$ to $62.16 \pm 0.03\%$. In contrast, all low-fat cheese treatments showed substantially lower F/DM values, ranging from 21.79% for (XG and XG-LBG) to 22.62% for (Control-2), as illustrated in **Table (4)**.

Table 4: Effect of incorporating gums individual and combined as fat replacers on fat/dry matter (%) of UF-Feta cheese during cold storage for 60 days

Trts.	Storage periods	Day-1	Day-15	Day-30	Day-60
FFC	Control-1	60.39 ± 0.01^D	60.91 ± 0.03^C	61.60 ± 0.03^B	62.16 ± 0.03^A
	Control-2	21.90 ± 0.01^{PQR}	22.11 ± 0.01^{LMN}	22.38 ± 0.02^{GHI}	22.62 ± 0.01^E
	XG	21.79 ± 0.01^S	21.96 ± 0.01^{OPQ}	22.19 ± 0.01^{LM}	22.49 ± 0.02^{FGH}
	LBG	21.8 ± 0.01^{RS}	22.06 ± 0.03^{MNO}	22.31 ± 0.02^{IJK}	22.49 ± 0.02^{FG}
	BSG	22.00 ± 0.01^{NOP}	22.19 ± 0.01^{JKL}	22.46 ± 0.03^{FG}	22.61 ± 0.01^E
	XG-LBG	21.79 ± 0.08^{RS}	22.03 ± 0.01^{NOP}	22.17 ± 0.02^{LM}	22.41 ± 0.04^{GHI}
	XG-BSG	21.90 ± 0.01^{PQRS}	22.09 ± 0.01^{LMN}	22.37 ± 0.01^{GHI}	22.57 ± 0.01^{EF}
	LBG-BSG	21.90 ± 0.05^{PQR}	22.17 ± 0.13^{KLM}	22.49 ± 0.01^{FG}	22.59 ± 0.02^{EF}
	XG-LBG-BSG	21.86 ± 0.02^{QRS}	21.94 ± 0.04^{LMN}	22.34 ± 0.03^{HIJ}	22.54 ± 0.03^{EF}

*FFC: full-fat UF-Feta cheese (Ctrl-1), LFC: low -fat UF-Feta cheese (Ctrl-2), XG: Xanthan gum, LBG: Locust bean gum, BSG: Basil seed gum, XG, LBG, BSG: refer to low-fat UF-Feta cheese produced using hydrocolloids individually, each at a concentration of 0.3%. XG-LBG, XG-BSG, LBG-BSG, XG-LBG-BSG: refer to low fat UF-Feta cheese made using combination of hydrocolloids at total concentration of 0.3%, mixed in respective ratios of 1:1, 1:1, 1:1, and 1:1:1, respectively. Values are presented as means $\pm$ SD, Differences in the superscript letters indicate significance ($P \leq 0.05$) between means.

The F/DM ratio decreased in all hydrocolloid-treated compared with low-fat cheeses (Control-2), this suggests that the increase in moisture content of low-fat cheeses results in a relative reduction in fat concentration, consequently leading to a decrease in the fat-in-dry-matter (F/DM%) content. Similar findings were reported by **Aminifar *et al.* (2014)**, who attributed the reduction in fat content of low-fat cheese incorporating xanthan gum to its higher moisture content. Therefore, the reduction in fat content observed in cheeses formulated with other hydrocolloids could also be related to their enhanced moisture content.

Table 5: Effect of incorporating gums individually and combined as fat replacers on protein /dry matter (%) of UF-Feta cheese during cold storage for 60 days

Trts.	Storage periods	Day-1	Day-15	Day-30	Day-60
FFC	Control-1	16.49±0.02 ^Q	16.63±0.03 ^P	16.82±0.03 ^O	16.97±0.03 ^O
	Control-2	31.52±0.01 ^{KL}	31.83±0.01 ^{EF}	32.21±0.02 ^C	32.55±0.01 ^A
	XG	31.33±0.01 ^N	31.58±0.01 ^N	31.90±0.01 ^{LMN}	32.33±0.03 ^{KLM}
	LBG	31.35±0.01 ^N	31.72±0.04 ^{HI}	32.09±0.03 ^D	32.34±0.03 ^B
	BSG	31.33±0.01 ^{MN}	31.67±0.02 ^{JK}	32.05±0.05 ^{FGH}	32.27±0.02 ^E
	XG-LBG	31.34±0.01 ^N	31.67±0.02 ^K	31.89±0.03 ^{IJ}	32.23±0.06 ^{EF}
	XG-BSG	31.37±0.01 ^N	31.65±0.01 ^{IJ}	32.04±0.01 ^D	32.33±0.01 ^B
	LBG-BSG	31.38±0.01 ^N	31.75±0.01 ^{GHI}	32.21±0.02 ^C	32.36±0.03 ^B
	XG-LBG-BSG	31.36±0.06 ^N	31.46±0.02 ^{HI}	32.04±0.04 ^D	32.32±0.04 ^{BC}

*FFC: full-fat UF-Feta cheese (Ctrl-1), LFC: low -fat UF-Feta cheese (Ctrl-2), XG: Xanthan gum, LBG: Locust bean gum, BSG: Basil seed gum, XG, LBG, BSG: refer to low-fat UF-Feta cheese produced using hydrocolloids individually, each at a concentration of 0.3%. XG-LBG, XG-BSG, LBG-BSG, XG-LBG-BSG: refer to low fat UF-Feta cheese made using combination of hydrocolloids at total concentration of 0.3%, mixed in respective ratios of 1:1, 1:1, 1:1, and 1:1:1, respectively. Values are presented as means ± SD, Differences in the superscript letters indicate significance ($P \leq 0.05$) between means.

Similarly, as shown in **Table 5**, protein content in dry matter (P/DM%) was significantly higher in LFC ($p \leq 0.05$) during 60 days of

storage. Full-fat cheese (control-1) had the lowest P/DM% (16.49 ± 0.02 to 16.97 ± 0.03). The increase in P/DM% in low-fat cheeses can be attributed to the fat reduction and subsequent concentration of protein in the dry matter. The present results are in line with those reported by **Sattar *et al.* (2015)** and **Moghiseh *et al.* (2021)**, who discovered that reducing fat content in cheese formulations led to an increase in total protein and moisture levels due to the higher proportion of non-fat solids and enhanced water retention in the cheese matrix.

Low-fat cheese (control-2) recorded the highest P/DM% (32.55 ± 0.01 at day-60), followed by hydrocolloid-treated. The addition of hydrocolloids slightly reduced P/DM% compared with LFC, which may be owing to the hydrocolloid's water-binding ability (**Ali *et al.*, 2016**; **Murtaza *et al.*, 2024**). It was also noticed from **Table 3**.

Table 6: Effect of incorporating gums individual and combined as fat replacers on salt /dry matter (%) of UF-Feta cheese during cold storage for 60 days

Trts.	Storage periods	Day-1	Day-15	Day-30	Day-60
FFC	Control-1	$4.83 \pm 0.02^{\text{K}}$	$4.87 \pm 0.01^{\text{JK}}$	$4.92 \pm 0.03^{\text{FGHIJ}}$	$4.97 \pm 0.01^{\text{CDEFGH}}$
LFC	Control-2	$4.91 \pm 0.01^{\text{HIJ}}$	$4.96 \pm 0.02^{\text{DEFGH}}$	$5.02 \pm 0.06^{\text{ABCD}}$	$5.07 \pm 0.02^{\text{A}}$
	XG	$4.88 \pm 0.01^{\text{IJK}}$	$4.92 \pm 0.01^{\text{GHIJ}}$	$4.97 \pm 0.01^{\text{BCDEFGH}}$	$5.04 \pm 0.02^{\text{AB}}$
	LBG	$4.88 \pm 0.01^{\text{IJK}}$	$4.94 \pm 0.01^{\text{EFGHI}}$	$5.00 \pm 0.01^{\text{BCDE}}$	$5.04 \pm 0.01^{\text{AB}}$
	BSG	$4.88 \pm 0.01^{\text{IJK}}$	$4.92 \pm 0.01^{\text{FGHIJ}}$	$4.98 \pm 0.02^{\text{BCDEFG}}$	$5.02 \pm 0.01^{\text{ABCD}}$
	XG-LBG	$4.88 \pm 0.01^{\text{IJK}}$	$4.93 \pm 0.01^{\text{EFGHIJ}}$	$4.97 \pm 0.01^{\text{CDEFGH}}$	$5.02 \pm 0.01^{\text{ABCD}}$
	XG-BSG	$4.88 \pm 0.01^{\text{IJK}}$	$4.93 \pm 0.01^{\text{FGHIJ}}$	$4.99 \pm 0.01^{\text{BCDEFG}}$	$5.03 \pm 0.01^{\text{ABC}}$
	LBG-BSG	$4.88 \pm 0.01^{\text{IJK}}$	$4.94 \pm 0.01^{\text{EFGHI}}$	$5.01 \pm 0.01^{\text{ABCD}}$	$5.04 \pm 0.01^{\text{AB}}$
	XG-LBG-BSG	$4.88 \pm 0.01^{\text{IJK}}$	$4.90 \pm 0.01^{\text{EFGHI}}$	$4.99 \pm 0.01^{\text{BCDEF}}$	$5.03 \pm 0.01^{\text{ABC}}$

*FFC: full-fat UF-Feta cheese (Ctrl-1), LFC: low -fat UF-Feta cheese (Ctrl-2), XG: Xanthan gum, LBG: Locust bean gum, BSG: Basil seed gum, XG, LBG, BSG: refer to

low-fat UF-Feta cheese produced using hydrocolloids individually, each at a concentration of 0.3%. XG-LBG, XG-BSG, LBG-BSG, XG-LBG-BSG: refer to low fat UF-Feta cheese made using combination of hydrocolloids at total concentration of 0.3%, mixed in respective ratios of 1:1, 1:1, 1:1, and 1:1:1, respectively. Values are presented as means $\pm$ SD, Differences in the superscript letters indicate significance ($P \leq 0.05$) between means.

Table 7: Effect of incorporating gums individually and combined as fat replacers on ash /dry matter (%) of UF-Feta cheese during cold storage for 60 days

Trts.	Storage periods	Day-1	Day-15	Day-30	Day-60
FFC	Control-1	5.28 $\pm$ 0.05 ^{DK}	5.33 $\pm$ 0.12 ^{DK}	5.37 $\pm$ 0.02 ^{FGHIJ}	5.52 $\pm$ 0.02 ^{CDEFGH}
LFC	Control-2	5.36 $\pm$ 0.01 ^{HIJ}	5.45 $\pm$ 0.05 ^{DEFGH}	5.57 $\pm$ 0.05 ^{ABCD}	5.67 $\pm$ 0.02 ^A
	XG	5.33 $\pm$ 0.03 ^{IJK}	5.40 $\pm$ 0.01 ^{GHIJ}	5.50 $\pm$ 0.01 ^{BCDEFGH}	5.63 $\pm$ 0.02 ^{AB}
	LBG	5.37 $\pm$ 0.04 ^{IJK}	5.44 $\pm$ 0.08 ^{EFGHI}	5.55 $\pm$ 0.05 ^{BCDE}	5.64 $\pm$ 0.01 ^{AB}
	BSG	5.36 $\pm$ 0.01 ^{IJK}	5.41 $\pm$ 0.04 ^{FGHIJ}	5.52 $\pm$ 0.07 ^{BCDEFG}	5.60 $\pm$ 0.02 ^{ABCD}
	XG-LBG	5.33 $\pm$ 0.08 ^{IJK}	5.43 $\pm$ 0.05 ^{EFGHIJ}	5.50 $\pm$ 0.03 ^{CDEFGH}	5.61 $\pm$ 0.03 ^{ABCD}
	XG-BSG	5.33 $\pm$ 0.03 ^{IJK}	5.43 $\pm$ 0.05 ^{FGHIJ}	5.55 $\pm$ 0.01 ^{BCDEFG}	5.63 $\pm$ 0.06 ^{ABC}
	LBG-BSG	5.33 $\pm$ 0.06 ^{IJK}	5.49 $\pm$ 0.08 ^{EFGHI}	5.56 $\pm$ 0.02 ^{ABCD}	5.63 $\pm$ 0.05 ^{AB}
	XG-LBG-BSG	5.33 $\pm$ 0.03 ^{IJK}	5.40 $\pm$ 0.02 ^{EFGHI}	5.54 $\pm$ 0.05 ^{BCDEF}	5.62 $\pm$ 0.02 ^{ABC}

*FFC: full-fat UF-Feta cheese (Ctrl-1), LFC: low -fat UF-Feta cheese (Ctrl-2), XG: Xanthan gum, LBG: Locust bean gum, BSG: Basil seed gum, XG, LBG, BSG: refer to low-fat UF-Feta cheese produced using hydrocolloids individually, each at a concentration of 0.3%. XG-LBG, XG-BSG, LBG-BSG, XG-LBG-BSG: refer to low fat UF-Feta cheese made using combination of hydrocolloids at total concentration of 0.3%, mixed in respective ratios of 1:1, 1:1, 1:1, and 1:1:1, respectively. Values are presented as means $\pm$ SD, Differences in the superscript letters indicate significance ($P \leq 0.05$) between means.

According to data in **Table 6**, the salt/DM content (%) showed significant variations ($P \leq 0.05$) among treatments and storage periods. Full-fat cheese consistently exhibited the lowest salt content throughout cold storage ($4.97 \pm 0.03\%$ after 60 days), whereas low-fat cheese (control-2) recorded the highest values ($5.07 \pm 0.02\%$ after 60 days). All hydrocolloid-

treated cheeses presented intermediate values, with slight differences between individual and combined gum applications. A significant increase in ash/DM content was observed in low-fat cheese (control-2) compared with full-fat cheese (control-1). Conversely, cheeses containing hydrocolloids showed lower ash/DM values than Control-2, depending on the hydrocolloid type (**Table 7**). This could be attributed to the higher protein content of LFC compared with FFC and the higher moisture content of hydrocolloid-treated cheeses than LFC (**Ali *et al.*, 2016**). Based on data in **Table 8**, the total carbohydrate content revealed significant ($p \leq 0.05$) variations among the different treatments throughout the storage period. Full-fat cheese (Control-1) recorded the lowest values (17.82 ± 0.01 to $18.34 \pm 0.02\%$), while all cheeses containing hydrocolloids, whether used individually or in combination, exhibited markedly higher carbohydrate content throughout storage at ($5 \pm 2^\circ\text{C}$). A gradual increase in carbohydrate content was observed, which may be due to moisture loss and the resulting concentration of solids.

Table 8: Effect of incorporating gums individually and combined as fat replacers on carbohydrates /dry matter (%) of UF-Feta cheese during cold storage for 60 days

Trts.	Storage periods	Day-1	Day-15	Day-30	Day-60
FFC	Control-1	17.82 ± 0.01^N	17.97 ± 0.01^{MN}	18.18 ± 0.02^{LM}	18.34 ± 0.02^L
	Control-2	17.82 ± 0.01^N	17.97 ± 0.01^{MN}	18.18 ± 0.02^{LM}	18.34 ± 0.02^L
LFC	XG	40.63 ± 0.01^K	41.02 ± 0.01^{JK}	41.52 ± 0.04^{GHJ}	41.96 ± 0.02^{DEFGHI}
	LBG	41.14 ± 0.05^{FGHI}	41.47 ± 0.05^{CDEFGH}	41.89 ± 0.05^{ABCDE}	42.46 ± 0.07^A
	BSG	41.15 ± 0.01^{FGHI}	41.62 ± 0.06^{BCDEF}	42.11 ± 0.03^{ABC}	42.45 ± 0.04^A
	XG-LBG	40.80 ± 0.01^{JK}	41.15 ± 0.02^{IJ}	41.64 ± 0.06^{EFGHI}	41.93 ± 0.02^{CDEFG}
	XG-BSG	41.14 ± 0.01^{FGHI}	41.58 ± 0.01^{CDEFG}	41.86 ± 0.04^{ABCDE}	42.31 ± 0.07^{AB}
	LBG-BSG	40.97 ± 0.01^{IJ}	41.34 ± 0.02^{FGHI}	41.85 ± 0.02^{BCDEF}	42.23 ± 0.03^{ABCD}
	XG-LBG-BSG	40.97 ± 0.01^{HIJ}	41.47 ± 0.01^{EFGHI}	42.06 ± 0.02^{ABCDE}	42.26 ± 0.03^{ABC}

*FFC: full-fat UF-Feta cheese (Ctrl-1), LFC: low -fat UF-Feta cheese (Ctrl-2), XG: Xanthan gum, LBG: Locust bean gum, BSG: Basil seed gum, XG, LBG, BSG: refer to low-fat UF-Feta cheese produced using hydrocolloids individually, each at a concentration of 0.3%. XG-LBG, XG-BSG, LBG-BSG, XG-LBG-BSG: refer to low fat UF-Feta cheese made using combination of hydrocolloids at total concentration of 0.3%, mixed in respective ratios of 1:1, 1:1, 1:1, and 1:1:1, respectively. Values are presented as means $\pm$ SD, Differences in the superscript letters indicate significance ($P \leq 0.05$) between means.

The pH and titratable acidity values showed slight variations throughout storage, with no significant differences ($P \leq 0.05$) between full-fat cheese (Control-1), low-fat cheese (Control-2), and hydrocolloid-treated cheeses (**Figs. 1 and 2**). The pH of FFC (control-1) remained higher than that of LFC, both with and without hydrocolloids, indicating an inverse relationship between pH and moisture content. The lower pH values observed in low-fat cheeses, particularly those containing hydrocolloids, may be attributed to their higher moisture and protein content. These findings are agreement with the results reported by **Kavas *et al.* (2004)**.

The pH and titratable acidity of full-fat (FFC), low-fat control (LFC), and low-fat UF-Feta cheese samples containing different hydrocolloids as fat replacers (xanthan gum, locust bean gum, basil seed gum, and their binary and ternary combinations) over the storage period at 5 ± 2 °C are shown in **Figs. (1 and 2)**. The results indicated that the use of hydrocolloids as fat replacers had no significant ($p \leq 0.05$) effect on the acidity of UF-Feta cheese, similar results were reported other authors (**Portaghi *et al.*, 2023; Ali *et al.*, 2016**). On day-1, the pH values of all cheese samples were relatively similar, ranging between $4.85 \pm 0.02\%$ (control-1, XG-LBG, XG-BSG) and $4.96 \pm 0.03\%$ (control-2, LBG), with no significant differences among full-fat, low-fat, and hydrocolloid-containing treatments.

Throughout the 60 days of cold storage, a gradual and consistent decrease in pH was observed across all samples, reflecting the ongoing fermentation and lactic acid production during ripening. After 60 days, the pH reached $4.79 \pm 0.02\%$ in full-fat cheese (control-1) and ranged between

4.61 $\pm$ 0.02% (BSG) and 4.82 $\pm$ 0.02% (LBG) in the hydrocolloid treatments. Among the binary combinations, XG-LBG and XG-BSG samples showed slightly lower pH values (4.70–4.72%), whereas the ternary combination (XG-LBG-BSG) exhibited an intermediate value (4.76 $\pm$ 0.03%).

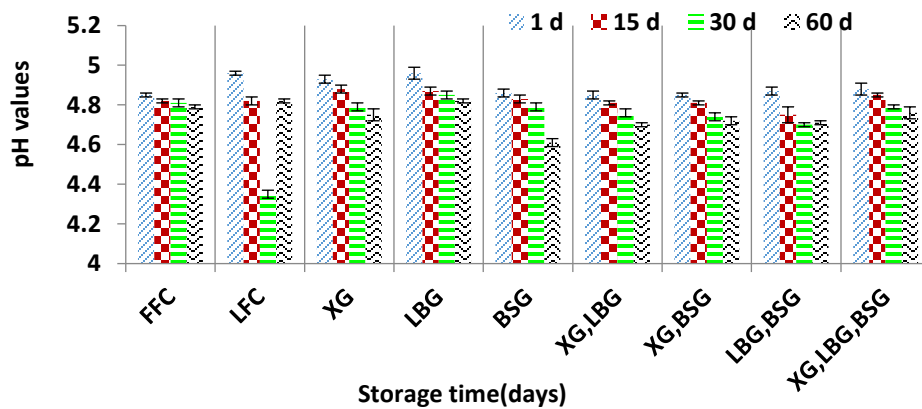


Fig. 1: Effect of incorporating gums individual and combined as fat replacers on pH values of UF-Feta cheese during storage at 5±2°C for 60 days.

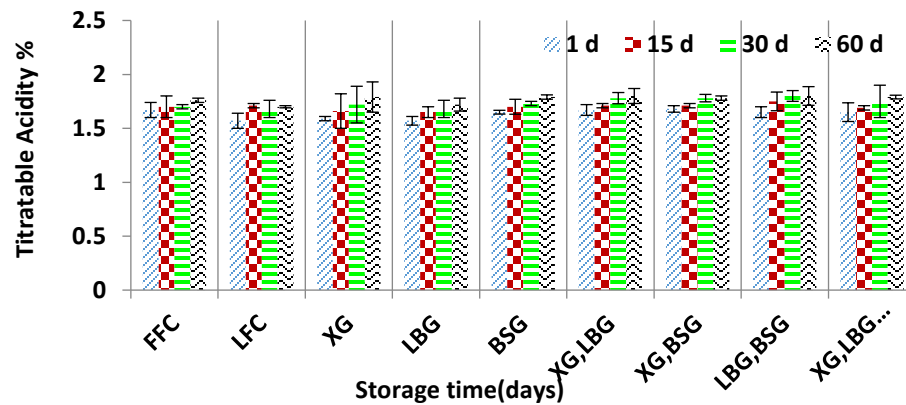


Fig. 2: Effect of incorporating gums individual and combined as fat replacers on acidity (%) of UF-Feta cheese during storage at 5±2°C for 60 days. FFC: full-fat

UF-Feta cheese (Control-1), LFC: low -fat UF-Feta cheese (Control-2), XG: Xanthan gum, LBG: Locust bean gum, BSG: Basil seed gum. XG; LBG, BSG: refer to low-fat UF-Feta cheese produced using hydrocolloids individually, each at a concentration of 0.3%. XG-LBG, XG-BSG, LBG-BSG, XG-LBG-BSG: refer to low fat UF-Feta cheese made using combination of hydrocolloids at total concentration of 0.3%, mixed in respective ratios of 1:1, 1:1, 1:1, and 1:1:1, respectively. Values are presented as means $\pm$ SD.

Regarding acidity values, an inverse trend was observed **Fig. 2**. There was a slight variation with not statistically significant ($p \leq 0.05$) differences were detected in the acidity values between the full-fat and low-fat cheeses, as well as LFC with hydrocolloids. The initial acidity values of UF-Feta cheese ranged between 1.57 ± 0.05 and 1.68 ± 0.02 , with the low-fat cheese (Control-2) showing the lowest acidity (1.67 ± 0.07) on day-1. All low-fat treatments exhibited slightly acidity values. As storage progressed, acidity values increased gradually in all treatments, reaching their maximum after 60 days (ranging from 1.70 ± 0.01 in Control-2 to 1.80 ± 0.07 in LBG and LBG-BSG). The lower acidity values observed in low-fat cheeses, particularly those containing hydrocolloids, may be attributed to their higher moisture and protein content. These results are in line with the findings reported by **Kavas *et al.* (2004)**. **Nateghi *et al.* (2012)** examined the impact of incorporating sodium caseinate and xanthan gum as fat replacers in low-fat Cheddar cheese and observed that their addition did not cause significant changes in either pH or titratable acidity. In other words, if the added gum does not enhance acidification, it will have no significant effect on the acidity or pH of the cheese (**Lobato-Calleros *et al.*, 2001**).

Rheological properties of UF-Feta cheese:

The incorporation of hydrocolloids as fat replacers significantly influenced the rheological characteristics of UF-Feta cheese during cold storage. As presented in **Table (9)**, the effects of individual and combined hydrocolloid treatments on hardness values over a 60-day storage period at $5 \pm 2^\circ\text{C}$. Hardness values demonstrated considerable variation among

treatments throughout the storage period. At day-1, the full-fat cheese (Control-1) exhibited the lowest hardness value (126.86 g), while the low-fat cheese (Control-2) showed the highest value (350.32 g). At the same time, hydrocolloid treatments exhibited hardness values ranging between 138.37g and 297.94g for XG-LBG-BSG and LBG-BSG combination treatments, respectively. This is in agreement with the results of **Akın and Kirmaci (2015)**; **Baghdadi et al. (2018)**, who found that the low-fat control cheese exhibited significantly harder than the full-fat control cheese due to its high protein content.

Table 9: Effect of incorporating gums individual and combined as fat replacers on hardness values (g) of UF-Feta cheese during cold storage for 60 days.

Trts.	Storage periods	Day-1	Day-15	Day-30	Day-60
FFC	Control-1	126.86 ^J	145.12 ^H	214.45 ^Y	213.32 ^Z
LFC	Control-2	350.32 ^N	373.55 ^I	353.39 ^M	409.99 ^D
	XG	148.83 ^F	190.61 ^A	356.01 ^L	378.59 ^H
	LBG	240.19 ^V	273.03 ^U	295.45 ^R	308.42 ^P
	BSG	214.91 ^X	279.91 ^S	363.14 ^J	389.43 ^F
	XG-LBG	157.26 ^E	162.74 ^D	329.68 ^O	422.10 ^C
	XG-BSG	234.95 ^W	278.24 ^T	382.17 ^G	356.11 ^K
	LBG-BSG	297.94 ^Q	395.10 ^E	431.54 ^B	547.27 ^A
	XG-LBG-BSG	138.37 ^I	145.53 ^G	170.67 ^C	178.45 ^B

FFC: full-fat UF-Feta cheese (Control-1); LFC: low-fat UF-Feta cheese (Control-2); XG: Xanthan gum; LBG: Locust bean gum; BSG: Basil seed gum. XG; LBG; BSG: refer to low-fat UF-Feta cheese produced using gums individually, each at a concentration of 0.3%. XG-LBG; XG-BSG; LBG-BSG; XG-LBG-BSG: refer to low fat UF-Feta cheese made using combination of gums at total concentration of 0.3%, mixed in respective ratios of 1:1, 1:1, 1:1, and 1:1:1, respectively.

The observed increase in the textural hardness of cheese resulting from fat reduction may be attributed to the absence of fat globules between casein particles, leading to greater protein-protein interactions and enhanced matrix compression. In cheese structure, fat globules and

moisture function as filler components within the casein network, contributing to the softness and smoothness of the final product (**Madadlou *et al.*, 2005**). In low-fat cheese formulations, the reduction of fat is not proportionally compensated by an increase in moisture; consequently, the filler phase within the protein matrix diminishes, resulting in a denser and more compact microstructure (**Romeih *et al.*, 2002**), and consequently, a harder texture is obtained.

The observed reduction in hardness of low-fat cheese following the incorporation of gums, either individually or in combination, may be attributed to the superior water-binding capacity of these hydrocolloids. Consequently, the absorbed water, in conjunction with the gums, mimics the functional role of fat within the cheese matrix. This interaction allows water and gum molecules to occupy spaces between protein chains, thereby preventing excessive aggregation of protein molecules and maintaining a softer texture. This results in softening the texture of low-fat cheeses, which is consistent with our findings (**Aminifar *et al.*, 2014; Rashidi *et al.*, 2015; Ribas *et al.*, 2019; Sharafi *et al.*, 2019; Portaghi *et al.*, 2023**), the authors reported that the incorporation of different fat replacers, including xanthan gum, novel galactomannans, and basil seed gum, led to a reduction in cheese hardness.

Polysaccharide-based fat replacers, including xanthan gum, guar gum, carrageenan, alginate, sodium alginate, and β -glucan, are capable of mechanically entrapping water and inhibiting casein–casein interactions through either segregate or associative mechanisms, involving hydrogen bonding, electrostatic interactions, or hydrophobic interactions between the polysaccharide and casein molecules. These effects contribute to higher moisture retention, a softer texture, improved lubrication, and enhanced creaminess in low-fat cheese (**Ouyang *et al.*, 2022**). In contrast to our findings, **Hosseini-Parvar *et al.* (2015)** reported that increasing the level of basil seed gum led to greater hardness in processed cheese. Similarly, the addition of tragacanth gum to Lighvan cheese, as well as konjac and xanthan gums to spreadable processed cheese, was shown to increase

hardness and firmness, suggesting that the effect of hydrocolloids on cheese texture can be highly dependent on the type of cheese and formulation (Milani *et al.*, 2017, Ghods Rohani & Rashidi, 2019).

During the extended cold storage period, hardness generally increased across all treatments, with the LBG-BSG combination reaching 547.27 g at day-60, representing the maximum hardness value, while the triple combination treatment XG-LBG-BSG showed the lowest hardness value (178.45 g) among all treatments at the final storage point. The progressive hardness increase during cold storage reflects typical cheese aging behavior, accelerated by hydrocolloid incorporation. This phenomenon is attributed to hydrocolloids' water-binding capacity, creating a more structured protein-polysaccharide network over time. Fat replacers can decrease cheese stability during processing and storage.

The consistency values of UF-Feta cheese exhibited significant variations depending on the type of hydrocolloid treatment and storage duration, **Fig. (3)**. On day-1, the low-fat cheese demonstrated the highest consistency value (4670.00 g.sec), which was substantially higher than the full-fat cheese (Control-1, 1116.84 g.sec), indicating that fat reduction inherently increases cheese firmness due to reduced lubrication effects and altered protein matrix structure (Portaghi *et al.*, 2023). Individual hydrocolloid treatments showed moderate consistency values, with xanthan gum (XG) exhibiting 2344.73 g.sec, locust bean gum (LBG) 1727.96 g.sec, and basil seed gum (BSG) 1681.81 g.sec. The combined hydrocolloid treatments demonstrated interesting patterns throughout storage, with XG-LBG showing the most changes. among the hydrocolloid combinations.

By day-60, the consistency values generally stabilized or slightly decreased, with LFC (Control-2) maintaining high values (7328.53 g.sec) and LBG-BSG showing the highest consistency (5780.37 g.sec) among combined treatments. This storage-related increase in consistency can be attributed to progressive protein aggregation, moisture redistribution, and strengthening of hydrocolloid networks over time. Hydrocolloids function

as multifunctional biopolymers in food formulations, exhibiting gelling behavior, thickening capacity, and stabilization of biphasic systems (foams, emulsions, dispersions). Their influence on final product consistency derives from their hydration characteristics and ability to form structured three-dimensional matrices (Li *et al.*, 2024).

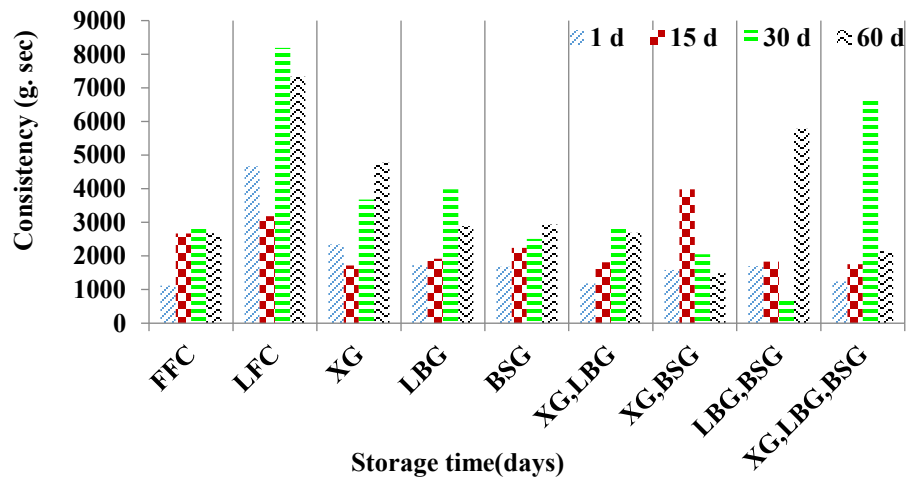


Fig. 3: Effect of incorporating gums individual and combined as fat replacers on consistency values (g/sec) of UF-Feta cheese during storage at $5\pm 2^{\circ}\text{C}$ for 60 days.

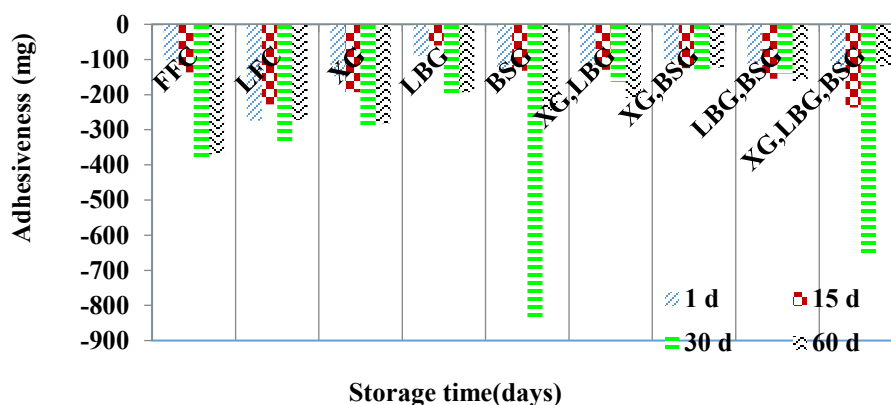


Fig. 4: Effect of incorporating gums individual and combined as fat replacers on adhesiveness values (mg) of UF-Feta cheese during storage at $5\pm 2^{\circ}\text{C}$ for 60 days. FFC: full-fat UF-Feta cheese (Control-1); LFC: low -fat UF-Feta cheese (Control-2); XG: Xanthan gum; LBG: Locust bean gum, BSG: Basil seed gum. - XG; LBG;BSG: refer to low-fat UF-Feta cheese produced using hydrocolloids individually, each at a concentration of 0.3%. - XG-LBG; XG-BSG; LBG-BSG; XG-LBG-BSG: refer to low fat UF-Feta cheese made using combination of hydrocolloids at total concentration of 0.3%, mixed in respective ratios of 1:1, 1:1, 1:1, and 1:1:1, respectively.

Adhesiveness values of both fresh and store UF-Feta cheese samples (60 days) are presented in **Fig. (4)**. On the day one, LFC (Control-2) exhibited the highest value (-274.22 mg), followed by XG (-147.73 mg) and BSG (-134.99 mg), the full-fat cheese (Control-1) showed the lowest initial adhesiveness value (-102.32 mg). The low-fat cheese (LFC) without added gum exhibited higher adhesiveness than the full-fat counterpart, which can be attributed to its elevated protein content and the resulting denser protein network (Nateghi *et al.*, 2012).

Adhesiveness values presented insignificant decrease with the addition of individually or in combination hydrocolloids compared with LFC (Control-2). Similar to our finding, Baghdadadi *et al.* (2018) stated that

samples formulated with basil seed gum led to a reduction in adhesiveness. These findings are also in agreement with **Portaghi *et al.* (2022)** who reported that the incorporation of basil seed gum and xanthan gum in low-fat cream cheese led to a reduction in adhesiveness. In contrast to our findings, **Ghods Rohani and Rashidi (2019)** reported that the addition of konjac and xanthan gums to spreadable processed cheese resulted in increased adhesiveness. These values increased as the storage period progressed, which may be attributed to proteolytic activity occurring during storage (**El-Zeini *et al.*, 2007; Ibrahim *et al.*, 2018**).

Sensory properties of UF-Feta cheese

The sensory attributes of UF-Feta cheese, which are influenced by the incorporation of individual and combined hydrocolloids as fat replacers, were evaluated over a 60-day cold storage period at $5\pm 2^{\circ}\text{C}$, as shown in **Figs. 5-8**. All sensory attributes (appearance, flavor, body and texture, and overall acceptability) remained significantly higher ($P\leq 0.05$) in FFC than in all LFC, irrespective of whether with or without fat replacer. The low-fat cheese (Control-2) exhibited the poorest appearance scores, declining significantly from 12.4 ± 0.84 to 11.0 ± 0.82 during storage, as shown in **Fig. 5**. Among the fat-reduced formulations, Fat reduction primarily affected the color and appearance of the cheese, as the absence of fat increases opacity and alters its visual characteristics.

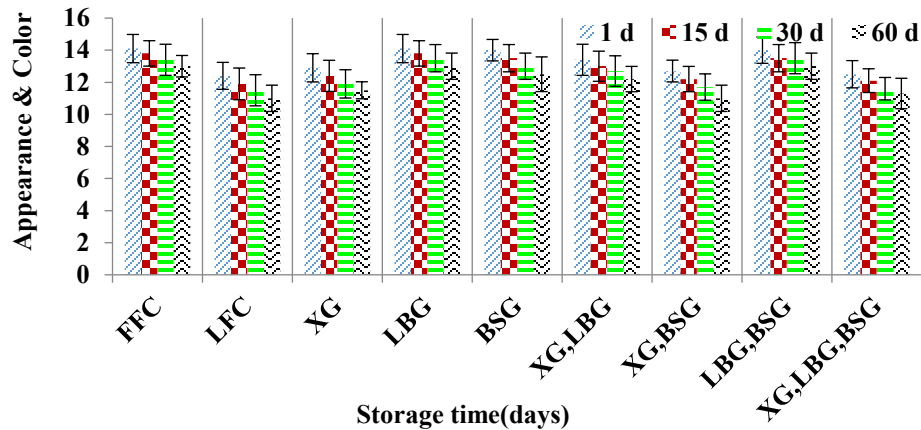


Fig. 5: Effect of incorporating gums individual and combined as fat replacers on appearance and color score of UF-Feta cheese during storage at $5\pm 2^{\circ}\text{C}$ for 60 days.

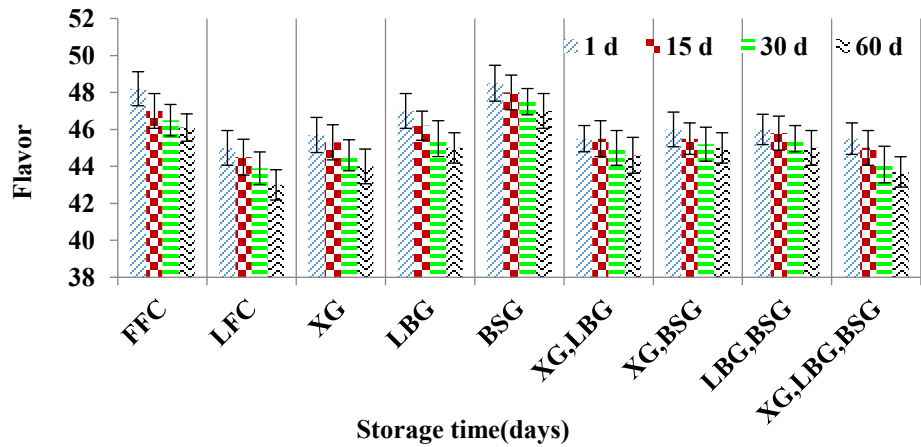


Fig. 6: Effect of incorporating gums individual and combined as fat replacers on flavor score of UF-Feta cheese during storage at $5\pm 2^{\circ}\text{C}$ for 60 days. FFC: full-fat UF-Feta cheese (Control-1); LFC: low -fat UF-Feta cheese (Control-2); XG: Xanthan gum; LBG: Locust bean gum, BSG: Basil seed gum. - XG; LBG, BSG: refer to low-fat UF-Feta cheese produced using hydrocolloids individually, each at a concentration of 0.3%. XG-LBG, XG-BSG, LBG-BSG, XG-LBG-BSG: refer to low fat UF-Feta cheese made using combination of hydrocolloids at total

concentration of 0.3%, mixed in respective ratios of 1:1, 1:1, 1:1, and 1:1:1, respectively. - Values are presented as means $\pm$ SD

By adding hydrocolloids, the appearance of low-fat white soft cheese was developed and scored higher points than that of its LFC control. (Ali *et al.*, 2016). The gradual decline in appearance scores across all treatments during storage reflects natural aging processes, including moisture migration and surface changes, which are commonly observed in cheese systems during refrigerated storage.

Flavor scores, representing the most critical sensory parameter (50 points maximum), revealed significant differences among treatments throughout cold storage (**Fig. 6**). The BSG achieved superior flavor scores, starting at 48.5 ± 0.97 and declining to 47 ± 0.94 after 60 days. The LFC showed the poorest flavor development, 45.0 ± 0.94 to 43.0 ± 0.82 during cold storage. Low-fat cheeses typically exhibit a less pronounced flavor compared to full-fat counterparts, which may result from flavor dilution due to higher moisture content (Sipahioglu *et al.*, 1999) and the reduced presence of fat-soluble compounds that contribute significantly to the overall flavor profile. Fat plays a major role in carrying flavor compounds in cheese, and a reduction in fat content consequently leads to a diminution of the overall cheese flavor. (Baghdadi *et al.*, 2018). Among fat-reduced treatments, BSG demonstrated the best flavor retention (48.5 ± 0.97 initially, declining to 47.0 ± 0.94), followed by LBG (47.0 ± 0.94 to 45.0 ± 0.82). These findings are consistent with previous research. For instance, Aydinol and Ozcan (2018) reported that the incorporation of inulin and oat β -glucan into reduced-fat Labneh cheese improved flavor compared to other low-fat variants.

Body and texture scores (35 points maximum) showed substantial variations among treatments (**Fig. 7**), with LBG achieving the highest scores throughout storage (34.5 ± 0.71 to 33.5 ± 0.5), followed by FFC (Control-1), (33.8 ± 0.79 to 32.5 ± 0.85). closely followed by BSG (33.6 ± 0.7 to 32.2 ± 0.92). The LFC exhibited the poorest textural characteristics,

declining from 29.5 ± 0.97 to 27.0 ± 0.94 during storage. The gradual decline in textural scores during storage reflects typical changes in cheese structure, including protein rearrangement and moisture redistribution.

Overall acceptability scores (100 points maximum) integrated all sensory parameters and revealed clear preferences among treatments, as shown in **Fig.(8)**. On day one FFC (Control-1) and BSG maintained the highest acceptability (96.1 ± 0.1), followed closely by LBG (95.6 ± 0.1). at the day of 60 BSG achieved the highest value 91.7 ± 0.1 . The LFC (Control-2) showed the lowest acceptability, declining from 86.9 ± 0.1 to 81.0 ± 0.1 during cold storage. Notably, BSG treatment achieved acceptability scores statistically equivalent to the full-fat control, demonstrating its effectiveness as a fat replacer. These findings corroborate recent research by **Portaghi et al. (2023)**, who reported that basil seed gum can successfully replace fat in dairy products while maintaining consumer acceptability. Previous research has showed a decline in sensory attributes for low-fat cheeses, including diminished flavor, texture, and overall acceptability (**Sharafi et al., 2019**).

The hydrocolloid combinations showed intermediate acceptability scores, with LBG-BSG performing better (92.5 ± 0.1 to 89.0 ± 0.1) than binary combinations. This suggests that triple combinations may provide more balanced sensory characteristics through complementary functional properties of different hydrocolloids. The storage-related decline in acceptability across all treatments reflects natural cheese aging processes, including flavor development, textural changes, and appearance modifications. Recent comprehensive studies by **Ahmad et al. (2024)** on hydrocolloid applications in reduced-fat dairy products support these observations, indicating that while individual hydrocolloids can effectively replace fat functionality, their performance varies significantly based on the specific hydrocolloid type and concentration used, with basil seed gum showing particular promise in maintaining overall product quality and consumer acceptance.

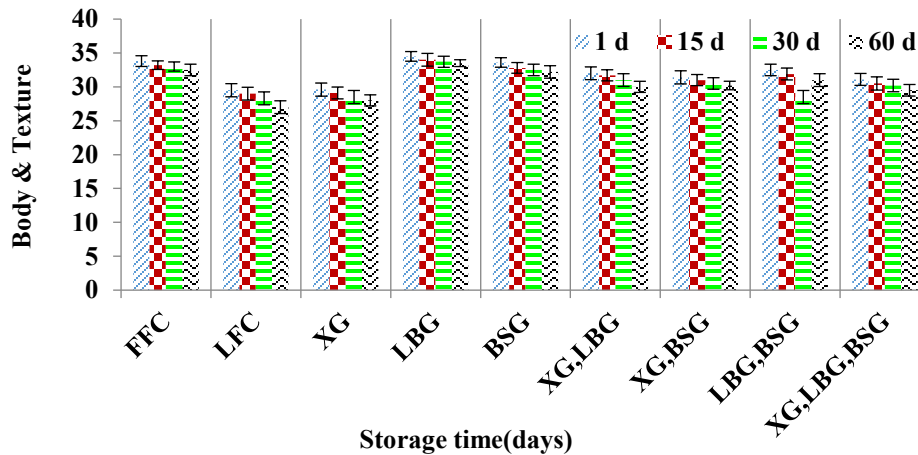


Fig. 7: Effect of incorporating gums individual and combined as fat replacers on body and texture score of UF-Feta cheese during storage at $5\pm 2^{\circ}\text{C}$ for 60 days.

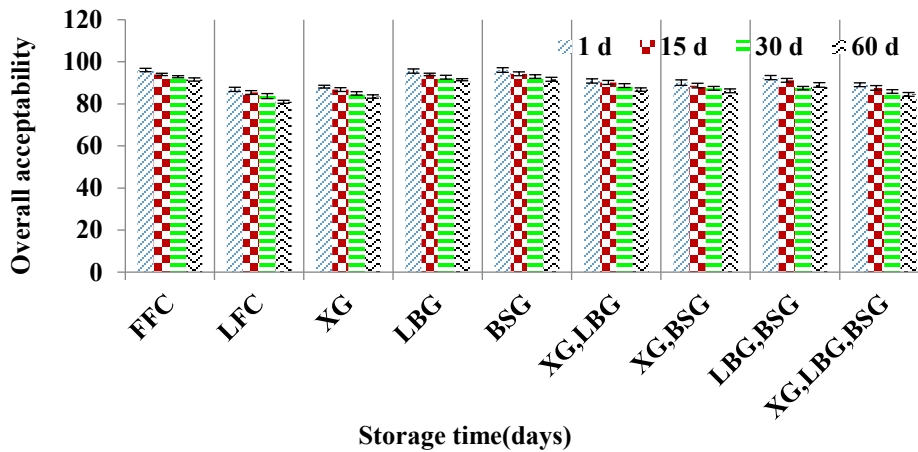


Fig. 8: Effect of incorporating gums individual and combined as fat replacers on overall acceptability score of UF-Feta cheese during storage at $5\pm 2^{\circ}\text{C}$ for 60 days. FFC: full-fat UF-Feta cheese (Control-1); LFC: low -fat UF-Feta cheese (Control-2); XG: Xanthan gum; LBG: Locust bean gum; BSG: Basil seed gum. - XG; LBG;BSG: refer to low-fat UF-Feta cheese produced using hydrocolloids individually, each at a concentration of 0.3%. XG-LBG; XG-BSG, LBG-BSG; XG-LBG-BSG: refer to low fat UF-Feta cheese made using combination of

hydrocolloids at total concentration of 0.3%, mixed in respective ratios of 1:1, 1:1, 1:1, and 1:1:1, respectively. Values are presented as means $\pm$ SD.

Similar observations were reported by (Sharafi *et al.*, 2019; Portaghi *et al.*, 2023). Fat reduction in cheese has been shown to negatively affect taste, mouthfeel, appearance, and overall acceptability. Indeed, existing studies have consistently reported a decline in sensory properties in low-fat cheese formulations. This deterioration in appearance is consistent with previous findings by Ali *et al.* (2016) who reported that the reduction in fat content significantly affected the appearance, texture, flavor and the overall acceptability of the cheese. Adding hydrocolloids to milk significantly improved all sensory parameters to gain higher total scores.

Microbial properties of UF-Feta cheese

The incorporation of hydrocolloids as fat replacers in dairy products significantly influences not only the physicochemical and textural properties but also affects the microbial characteristics during storage, which is crucial for food safety and shelf-life determination. The microbial properties of UF-Feta cheese of individual and combined hydrocolloids as fat replacers, were evaluated over a 60-day cold storage period at $5\pm 2^{\circ}\text{C}$, as shown in **Table 10**. Mesophilic spore-forming bacteria counts showed a gradual decline during 60 days of storage at $5\pm 2^{\circ}\text{C}$ across all cheese treatments. Initial counts ranged from 2.05 to 2.93 Log_{10} cfu/g on day-1, with the XG-BSG treatment having the highest and the XG-LBG treatment the lowest counts. By day-60, the lowest counts were recorded in the FFC (1.85 Log_{10} cfu/g) and XG-LBG treatment (1.78 Log_{10} cfu/g), indicating the antimicrobial efficacy of hydrocolloids, particularly combinations like XG-LBG, which consistently inhibited bacterial growth more effectively than individual gums (Buehner *et al.*, 2014; Nassib *et al.*, 2018). These effects are likely due to the reduced water activity and acidic microenvironment formed by hydrocolloid gels, limiting spore germination and bacterial proliferation (Scrocco *et al.*, 2005; Watterson *et al.*, 2014). Moreover, spore-forming bacteria are heat-resistant and often survive

pasteurization, so their reduction over extended refrigerated storage confirms the value of hydrocolloids in enhancing microbiological quality (**Miller *et al.*, 2015**). Mold and yeast counts were initially low to moderate (>10 to >30 cfu/g) but dropped to non-detectable levels (ND) by day-30 onwards for most treatments, with the XG-LBG and XG-LBG-BSG combinations showing complete inhibition as early as day-15. This strong antifungal effect highlights hydrocolloids' ability to create an environment unfavorable for fungal growth, attributed to moisture binding and film-forming properties that reduce surface exposure and oxygen availability (**Chang *et al.*, 2021; Jahdkaran *et al.*, 2021**). The synergistic effects of combined hydrocolloids enhance these preservative qualities, consistent with reports on xanthan's inherent antimicrobial activity complemented by locust bean gum's gel stabilization (**Maleki *et al.*, 2019; Vilas *et al.*, 2020**). These findings reinforce the potential of hydrocolloids as natural preservatives enhancing shelf stability and safety of low-fat dairy products (**Belasli *et al.*, 2020**).

Coliform bacteria were detected at low levels (>10 cfu/g) only at day 1 and remained undetectable from day 15 through day-60 in all treatments. This suggests excellent hygienic quality and effective microbial control, likely due to ultrafiltration combined with antimicrobial properties of hydrocolloids (**Brooks *et al.*, 2010; Mohamed *et al.*, 2022**). The absence of coliforms is a critical indicator of sanitary processing, reflecting minimal fecal contamination risk and proper microbial stability (**Synge, 2000**). The sustained absence throughout storage illustrates the combined effect of strict processing hygiene and hydrocolloid addition in maintaining product safety superior to conventional UF-Feta cheese (**Montanari *et al.*, 2004**).

Table 10: Effect of incorporating gums individual and combined as fat replacers on microbial properties (Log_{10} cfu/g) of UF-Feta cheese

Storage periods (days)	FFC	LFC							
	Ctrl-1	Ctrl-2	XG	LBG	BSG	XG-LBG	XG-BSG	LBG-BSG	XG-LBG-BSG
Mesophilic spore-forming bacteria									
1	2.11	2.6	2.37	2.55	2.32	2.05	2.93	2.25	2.47
15	2.03	2.45	2.36	2.34	2.28	2.00	2.51	2.17	2.34
30	2.01	2.39	2.25	2.35	2.21	1.87	2.45	2.08	2.32
60	1.85	2.25	2.22	2.27	2.09	1.78	2.38	1.98	2.16
Mold & Yeasts									
1	30<	10<	30<	30<	30<	10<	30<	30<	10<
15	10<	10<	10<	10<	30<	ND	10<	30<	ND
30	ND	ND	ND	ND	ND	ND	ND	ND	ND
60	ND	ND	ND	ND	ND	ND	ND	ND	ND
Coliform group bacteria									
1	10<	10<	<10	<10	<10	<10	<10	<10	<10
15	ND	ND	ND	ND	ND	ND	ND	ND	ND
30	ND	ND	ND	ND	ND	ND	ND	ND	ND
60	ND	ND	ND	ND	ND	ND	ND	ND	ND

- FFC: full-fat UF-Feta cheese (Control-1); LFC: low-fat UF-Feta cheese (Control-2). XG, LBG, BSG: refer to low-fat UF-Feta cheese produced using hydrocolloids individually, each at a concentration of 0.3%. XG-LBG, XG-BSG, LBG-BSG, XG-LBG-BSG: refer to low fat UF-Feta cheese made using combination of hydrocolloids at total concentration of 0.3%, mixed in respective ratios of 1:1, 1:1, 1:1, and 1:1:1, respectively. Cfug: colony forming unit/gram. N.D: Not Detected.

CONCLUSION

In recent years, consumer demand for health-promoting foods has surged as people become more aware of the connection between diet and health. Additionally, the sensory attributes of the product play a crucial role in determining its acceptance among consumers. This study successfully developed low-fat UF-Feta cheese with improved physicochemical, textural, and sensory properties through the incorporation of different gums (xanthan gum, locust bean gum, basil seed gum, and their binary and ternary combination). Low-fat UF-Feta cheese without gums showed a loss in texture and sensory quality. Among the gums tested, basil seed gum and its combination with locust bean gum demonstrated the most promising improvements. Therefore, xanthan, locust bean, and basil seed gums are recommended as functional fat replacers to produce healthier low-fat UF-Feta cheese at commercial scale with desirable quality attributes and extended shelf life.

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ETHICAL APPROVAL

The Scientific Research Ethics Committee of the Faculty of Agriculture, Damanhour University, Egypt (DUFA-2025-T10) authorized all experimental techniques.

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الملخص العربي

تأثير تطبيق بعض الغرويات الطبيعية كبدايل للدهون في صناعة جبن الفيتا منخفض الدهن
المنتج بالترشيح الفائق

إيمان خالد عثمان^١ ، سامح على عوض^٢، عبير محمد عبدالحميد^١ ، سامح سعيد يعقوب^١
^١ قسم علوم وتكنولوجيا الأغذية والألبان ، كلية الزراعة ، جامعة دمنهور ، مصر. ^٢ قسم علوم
وتقنية الألبان ، كلية الزراعة ، جامعة الإسكندرية ، مصر.

تم إجراء هذا البحث بهدف دراسة تأثير استخدام بعض أنواع الغرويات وهى (صمغ الزانثان، صمغ حبوب الخروب، وصمغ بذور الريحان) بنسبة ٠,٣٪ في صورة منفردة أو في صورة مخلوط كبدايل للدهن في صناعة جبن الفيتا منخفض الدهن المنتج بواسطة الترشيح الفائق على خصائص الجودة (الطبيعية، الكيميائية، الريولوجية، الحسية، والجودة الميكروبية)، وذلك خلال التخزين المبرد على درجة حرارة 2 ± 5 درجة مئوية لمدة ٦٠ يوماً. وأظهرت النتائج أنه من ناحية الخصائص الكيميائية والطبيعية، لوحظ وجود انخفاض معنوي ($P \leq 0.05$) في محتوى المادة الجافة والدهن/المادة الجافة، وكذلك قيم الحموضة لكل معاملات جبن الفيتا منخفض الدهن مقارنة بالجبن كامل الدهن، في حين أظهرت معاملات الجبن منخفض الدهن المحتوية على الصمغ في صورة مفردة أو مخلوط محتوى منخفض من المادة الجافة مقارنة بالجبن منخفض الدهن (الكنترول). كما أظهرت معاملات الجبن منخفض الدهن زيادة معنوية ($P \leq 0.05$) في قيم الأس الهيدروجيني، ومحتواها من حيث البروتين، الملح، الرماد، والكربوهيدرات منسوبة إلى المادة الجافة مقارنة بالجبن كامل الدهن. أدى التخزين المبرد لمدة ٦٠ يوماً إلى حدوث زيادة تدريجية في قيم الحموضة في محتوى الجبن من المادة الجافة ومكوناتها نتيجة لفقد الرطوبة، بينما أدى إلى حدوث انخفاض معنوي في قيم الأس الهيدروجيني وذلك لكل معاملات جبن الفيتا منخفض وكامل الدهن. بالنسبة للخواص الريولوجية، أظهرت النتائج أن إضافة الصمغ حسنت من خصائص القوام للجبن المنخفض الدهن، حيث أدى حدوث انخفاض معنوي في قيم كل من الصلابة والتماسك مقارنة بالجبن منخفض الدهن (الكنترول)، مما أعطى الجبن خصائص قوام مشابه للجبن كامل الدهن. أدى استخدام الصمغ في صورة مخاليط ثنائية أو ثلاثية في تحقيق توازن أفضل بين الصلابة والتماسك، وهو ما يعكس وجود تأثير تآزري بين أنواع الصمغ المختلفة. فيما يتعلق بالتقييم الحسي، سجلت عينات الجبن المنخفض الدهن المعاملة بالصمغ تقييمات حسية مرتفعة معنوياً في صفاتها الحسية مثل المظهر، النكهة، القوام، والقبول العام مقارنة بالجبن المنخفض الدهن (الكنترول)، وكانت أقرب في صفاتها الحسية للجبن كامل الدسم، خاصة المعاملات المستخدم فيها صمغ بذور الريحان وصمغ الخروب سواء بصورة مفردة أو مخلوط، كما لوحظ أن التخزين المبرد لمدة ٦٠ يوم أدى انخفاض قيم التقييم الحسي لكل المعاملات. أظهرت نتائج الاختبارات

الميكروبية أن جميع معاملات جبن الفيتا ذات جودة ميكروبية مقبولة ، كما أظهرت النتائج عدم وجود تأثير ملحوظ من استخدام الصمغ. بامتداد فترة التخزين المبرد لم تُكتشف الخمائر والفطريات أو بكتيريا القولون ، كما أدى الى حدوث انخفاض تدريجي في أعداد البكتيريا المكونة للجراثيم. بصفة عامة أوضحت الدراسة أن الصمغ الطبيعية (الزانتان، حبوب الخروب، بذور الريحان) قد ساهمت في تحسين خصائص الجبن مما يجعلها تُعد بدائل للدهن فعالة في إنتاج الجبن الفيتا منخفض الدهن والمصنع بطريقة الترشيح الفوقي.

الكلمات الدالة: جبن الفيتا- الجبن منخفض الدهن – بدائل الدهن – الغرويات – صمغ الزانتان – صمغ الخروب – صمغ بذور الريحان

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