Journal of Sohag Agriscience (JSAS) 2023, 8(2): 269-281

ISSN 2311-1126
https://jsasj.journals.ekb.eg
JSAS 2023; 8(2): 269-281

Received: 11-11-2023
Accepted: 28-11-2023

Abd El-Aal A. Abd El-Khair
Amany G. Ahmed
Ateteallah H. Ateteallah

Dairy Sciences Department
Offered Subjects: Dairy sciences
Faculty of Agriculture
Sohag University
Sohag
82524
Egypt

Corresponding author:
Amany G. Ahmed
amany_ahmed@agr.sohag.edu.eg

Production and Evaluation of Soft Sheep's Milk Cheese Analogues Supplemented With Quinoa Seed Flour and Xanthan Gum

Abd El-Aal A. A. Abd El-Khair, Amany G. Ahmed and Ateteallah H. Ateteallah

Abstract

Sheep milk cheese analogues were made from whole sheep's milk with the addition of 0.03% Xanthan gum (XG) and Quinoa seed flour (QSF) at rates of 1, 2 and 3% (w/w). The chemical, rheological, sensory properties and yield of sheep milk cheese analogues were studied. The addition of QSF and XG reduced the moisture and fat content of sheep milk cheese analogues, while the protein content increased with the addition of QSF up to 2% and decreased slightly thereafter. The carbohydrate, crude fiber and ash content also increased significantly with the addition of QSF. The results also indicated a significant increase in the yield of cheese analogues with the increase in the level of QSF added. Texture profile analysis showed that the hardness, gumminess, and chewiness values generally increased with increasing levels of QSF added with xanthan gum, while cohesiveness and springiness values decreased in the cheese analogues compared to the control. Cheese analogues supplemented with 1% or 2% QSF with added xanthan gum received the highest scores for flavor, body, texture, appearance, and overall acceptability, while the addition of 3% QSF had the lowest overall acceptability score.

Keywords: Sheep milk cheese analogues, Quinoa seeds, Xanthan gum.

INTRODUCTION

Sheep milk has a high nutritional value and contains high levels of proteins, fats, minerals and vitamins, making it particularly useful for making cheese (Jooyandeh and Aberoumand, 2010). Furthermore, sheep's milk fat is mostly short- and medium-chain fatty acids that give it a unique flavour. Products made from sheep's milk, like cheese, have this flavor (Barlowska *et al.* 2011; Balthazar *et al.*, 2017). World-famous classic cheeses such as Roquefort, Pecorino, Manchego, Feta, and Halloumi are among the delicious and broad category of cheeses made from sheep's milk. However, the high price and scarcity of sheep's milk causes the cost of cheese made from it to rise, prompting customers to look for less expensive products (Rivas *et al*., 2019). One important strategy that can help expand the sheep milk cheese market is the availability of functional and healthy alternative products such as sheep milk cheese analogues. Cheese analogues are products that mimic or substitute traditional cheese; they are also referred to as imitation cheeses or cheese substitutes. In such products, the milk fat, milk protein, or both may be partially or completely replaced by non-dairy ingredients, usually of plant origin (Chavan and Jana, 2007). Cheese analogues have been manufactured primarily because of their cost-effectiveness and simplicity of manufacture (Cunha *et al.*, 2010). Currently, the production of cheese analogues is also focused on obtaining products that promote health or have new functional properties. Recent interest in plant-based products and healthier alternatives, especially those high in protein, has led to increased interest in developing cheese analogues (Solowiej *et al.*, 2015; Kamath *et al.*, 2022; Aschemann-Witzel *et al.*, 2021; McClements and Grossmann, 2021; Pua *et al*., 2022). Quinoa (*Chenopodium quinoa* Willd) is a pseudocereal of Chenopodiacee family which was cultivated and consumed since 5000 years ago by the indigenous Indian region populations (Vega-Galvez *et al.*, 2010). Quinoa has gained renewed interest as an alternative cereal crop due to its excellent nutritional value, and is regarded as a super food called the “golden grain”. Accordingly, the Food and Agriculture Organization of the United Nations (FAO, 2011) identified quinoa as “one of humanity's most promising crops” that can help achieve food security in the 21st century and declared 2013 the International Year of Quinoa. Quinoa is particularly rich in carbohydrates, proteins, lipids, minerals and vitamins, and significant amounts of other bioactive compounds, such as polyphenols and is also gluten-free. The protein content of quinoa seeds is higher than other cereals. Quinoa proteins are mainly albumin and globulin, with a better distribution of essential amino acids similar to casein. So, it can be used as an alternative to milk proteins (Gordillo-Bastidas *et al*., 2016; Angeli *et al*., 2020; Mu *et al*., 2023). However, the consumption of quinoa is limited due to its bitter and astringent taste, due to saponins (Suarez-Estrella *et al*., 2018). In addition, some sedimentation occurs due to the presence of large undissolved particles of quinoa seeds due to its high content of insoluble fiber and phytic acid. This is often overcome by adding some additives such as emulsifiers and stabilizers (Lamothe *et al*., 2015). Gums are one type of hydrocolloid that can be used to produce cheese analogues by acting as stabilizers, and water-binding agents (Badem, and Ucar, 2016; Solowiej and Nastaj, 2016). Therefore, the present study was conducted as an attempt to increase the quantities of cheese produced from sheep milk by manufacturing soft sheep milk cheese analogues of acceptable quality by adding different levels of Quinoa seed flour and Xanthan gum as functional ingredients.

MATERIALS AND METHODS

1. Materials

Whole sheep's milk used in this work (17.69% total solids, 6.40% fat, 5.85% protein, 4.52% lactose, 0.92% ash) was collected from the animal production farm of the Faculty of Agriculture, Sohag University, Egypt. Quinoa (*Chenopodium* quinoa, *Chenopodiaceae*) seeds were obtained from the Agricultural Research Centre, Giza, Egypt. Xanthan gum was supplied by Food chem. International Corporation, China.

2. Methods

2.1. Preparation of Quinoa seeds flour (QSF)

Quinoa seeds were washed several times and soaked for 4 h in distilled water at a 1:3 w/v ratio to remove saponins and bitterness then dried in an oven at 60°C for 12 h. The dried seeds were ground using a laboratory mill to obtain a fine powder. The seed flour was packed in a plastic container and kept at refrigerator temperature until use (Quispe-Fuentes *et al.*, 2013).

2.2. Preliminary experiments

In preliminary experiments, the appropriate level of XG to be used in the analogue cheese formulations was determined, which could trap insoluble suspended particles of QSF in the system and not settle under the force of gravity. XG of 0.03% (w/w) was most suitable (data not shown).

2.3. Manufacture of soft sheep's milk cheese analogues

Soft sheep's milk cheese analogues were manufactured following the method described by Abdelmontaleb *et al.* (2021), with some modifications. The sheep's milk was divided into four equal parts. The first part represents a control, and QSF was added to the remaining three parts at 1.0%, 2.0%, and 3.0% (w/w), respectively. XG was added at a rate of 0.03% (w/w) to each of the three treatments. To aid in the dissolution and hydration of the ingredients in milk, all treatments were continuously stirred for 45 minutes at 45°C, pasteurized for 30 minutes at 63°C, quickly cooled to 4°C, and maintained at this temperature overnight. The following day, all treatments were again pasteurized for 30 minutes at 63°C, cooled to 40°C, (microbial) and fresh liquid rennet (Reniplus 2000 IMCU/g, Spain) was added. The mixture was then incubated at 40°C for 1.5–2 hours. After complete coagulation, the resulting curds were sliced, poured into stainless steel molds lined with cheese cloth, and left for 18 hours to solidify under light pressure. After producing cheese analogues, the products were weighed, chopped, and packed into plastic containers with 5% saline solution. The containers were then kept refrigerated. Throughout a 60-day storage period, samples were examined every 15 days for sensory assessment as well as for chemical composition, texture, and yield while still fresh. Every analysis was carried out in triplicate.

2.4. Analytical Methods

2.4.1. Chemical analysis

Chemical analyses of sheep milk and cheese analogues including moisture, total solids, fat, ash, fiber and salt were determined according to AOAC (2012). Total nitrogen (TN) was determined by the semi-micro kjeldahl method. The protein content was obtained by multiplying the percentage of TN by 6.38. Carbohydrates content was calculated by difference using the formula: % Carbohydrates = 100 – (% moisture + % protein + % fat + % ash + % fiber).

2.4.2. Determination of cheese yield

According to Fox *et al.* (2000), the mass ratio between the curd obtained after the pressing stage and the weight of the milk was used to calculate the cheese yield. Every measurement was done three times.

2.4.3. Texture Profile Analysis

Three days after manufacture, cheese analogues underwent texture profile analysis (TPA) using the Mecmesin Multi Test 1-d Texture Analyzer (Slinfold, West Sussex, UK), and Specific Expression PC Software was used to compute the results. A compression test was used in the experiments to create a plot of force (N) versus time (sec). Samples were compressed twice at a rate of two centimeters per minute. From the obtained TPA curve, the following parameters were calculated: hardness (N), cohesiveness (B/A area), springiness (mm), gumminess (N), and chewiness (mJ). Three evaluations of each texture parameter were conducted according to IDF (1992).

2.4.4. Sensory assessment

Nine staff members of Dairy Science Department, Faculty of Agriculture, Sohag University/ Egypt, evaluated the cheese analogue samples based on their sensory evaluation according to the scheme described by

Nelson and Trout (1956). Taste received 50 points, body and texture received 35 points, and appearance received 15 points. The overall acceptability score was 100. Initial descriptions of sensory attributes were given by the subjects, followed by point values.

2.5. Statistical examination

The data obtained from the current study was analyzed by ANOVA. In all analyses, the data means test was utilized to assess the variation between the samples when a significant difference ($p < 0.05$) was found in a particular variable. The Statistical Analysis System for Windows software was utilized to analyze the data (SAS, 2008).

RESULTS AND DISCUSSIONS

1. Chemical composition of Quinoa seeds flour

The chemical composition of Quinoa seeds flour showed that the percentage of protein, fat, ash, carbohydrates, and crude fiber were 14.02%, 5.43%, 2.82%, 65.10%, and 7.05%, respectively (Table 1). These results are consistent with those previously reported in detail regarding the chemical composition of quinoa seeds (Pereira *et al*., 2019 and Olivera *et al*., 2022).

Table (1): Chemical composition of quinoa seed flour (g/100 g dry weight)

Nutrients (%)	**Sample***	**Literature**		
		Abugoch James (2009)	**Vilcacundo & Hernandez-Ledesma (2017)**	**Hussain et al. (2021)**
Protein	14.0	12–23	13.1–16.7	10–18
Fat	5.4	1.8-9.5	5.5–7.6	4.4–8.8
Ash	2.8	ND	ND	2.3–3.7
Carbohydrates	65.1	73.6–74.0	32–69	32–60
Crude fiber	7.1	7.0–9.7	7- 11.7	1.1% - 13.4

*Values are mean of three replicates
- ND: not detected

2. Chemical composition of cheese analogues:

The chemical composition of soft sheep's milk cheese analogues supplemented with XG and different levels of QSF is shown in Table 2. The results showed that the moisture content of cheese analogues decreased significantly ($P < 0.05$) with increasing percentages of QSF. This was accompanied by an increase in total solids in the cheese analogues in terms of carbohydrates, protein, ash and fiber. Khalifa *et al*. (2020) found that the addition of QSF to low-fat camel milk processed cheese spread at different levels (1%, 3%, and 5%) resulted in a significant increase in the content of total solids, protein, carbohydrates, and fiber compared to the control while moisture content decreased slightly with increasing QSF levels. Similar results were also noted by Abdelmontaleb *et al.* (2021), who found that adding QSF to UF-soft cheese at three different levels (1.0%, 2.0%, and 3.0%) significantly increased the dry matter content of the cheese in terms of fat, protein, ash, total dietary fiber, and carbohydrates while decreasing the moisture content in comparison to the control sample.

Table (2): Chemical composition of soft sheep's milk cheese analogues fortified with different levels of Quinoa seed flour and Xanthan gum during refrigerated storage

Constituents (%)	Storage period (days)	Control*	Treatments		
			QSF 1.0% + XG 0.03%	QSF 2.0% + XG 0.03%	QSF 3.0% + XG 0.03%
Moisture	1 15 30 45 60	59.54^{a} 58.51^{a} 57.93^{a} 57.78^{a} 57.11^{a}	59.02^{b} 57.67^{b} 57.08^{b} 56.77^{b} 56.51^{b}	58.24^{c} 56.91^{c} 56.17^{d} 55.62^{c} 55.35^{c}	57.89^{c} 56.92^{c} 56.64^{c} 56.35^{b} 56.20^{b}
Protein	1 15 30 45 60	15.48^{bc} 15.86^{b} 16.02^{c} 16.21^{c} 16.30^{c}	15.56^{b} 16.05^{a} 16.22^{b} 16.37^{b} 16.62^{b}	15.75^{a} 16.12^{a} 16.57^{a} 16.64^{a} 16.87^{a}	15.42^{c} 15.65^{c} 15.93^{d} 16.08^{d} 16.12^{d}
Fat	1 15 30 45 60	19.17^{a} 20.00^{a} 20.67^{a} 21.00^{a} 21.50^{a}	18.92^{a} 19.83^{a} 20.25^{b} 20.67^{a} 21.00^{b}	18.50^{b} 19.25^{b} 19.92^{b} 20.50^{a} 20.75^{c}	18.25^{b} 19.00^{b} 19.50^{c} 19.83^{b} 20.08^{d}
Ash	1 15 30 45 60	3.24^{c} 3.28^{c} 3.56^{bc} 3.71^{c} 3.93^{c}	3.27^{bc} 3.32^{c} 3.54^{c} 3.68^{c} 3.90^{c}	3.32^{b} 3.64^{a} 3.71^{a} 4.07^{a} 4.25^{a}	3.40^{a} 3.48^{b} 3.64^{ab} 3.79^{b} 4.12^{b}
Carbohydrate	1 15 30 45 60	2.57^{d} 2.35^{d} 1.82^{d} 1.30^{d} 1.16^{d}	3.12^{c} 2.92^{c} 2.54^{c} 2.05^{c} 1.40^{c}	3.90^{b} 3.74^{b} 3.15^{b} 2.58^{b} 2.11^{b}	4.63^{a} 4.48^{a} 3.71^{a} 3.14^{a} 2.56^{a}
Crude fiber	1 15 30 45 60	0^{d} 0^{d} 0^{d} 0^{d} 0^{d}	0.11^{c} 0.21^{c} 0.37^{c} 0.46^{c} 0.57^{c}	0.29^{b} 0.35^{b} 0.48^{b} 0.59^{b} 0.67^{b}	0.41^{a} 0.47^{a} 0.58^{a} 0.81^{a} 0.92^{a}
Salt	1 15 30 45 60	1.62^{a} 1.88^{b} 2.23^{ab} 2.52^{b} 2.85^{c}	1.60^{a} 2.03^{a} 2.35^{a} 2.82^{a} 3.25^{a}	1.54^{ab} 1.92^{b} 2.04^{c} 2.37^{c} 2.83^{c}	1.48^{b} 1.75^{c} 2.29^{ab} 2.80^{a} 3.06^{b}

Control*: Cheese made from sheep's milk without additives.
Values are mean of three replicates
The values with different superscript letters within the same row are significantly different ($p<0.05$)

From the results of the chemical composition of the Quinoa seed flour used in our study shown in Table (1), it is clear that the main component is carbohydrates, which constitute more than 65% of the total chemical composition of the Quinoa seed flour. Abugoch James (2009) stated that starch is the main carbohydrate component in quinoa, and is present at a rate ranging between 52.2% and 69.2%. Therefore, it has a high ability to absorb water and a great ability to swell. On the other hand, XG with its high water absorption capacity, likely contributes to this effect. Nateghi *et al.* (2012) found that by increasing the level of XG in reduced-fat cheddar cheese, the moisture and protein content increased significantly. According to the data in Table 2, the results also showed that compared with the control cheese, the protein content of the cheese analogs increased significantly ($P < 0.05$) with the addition of QSF up to 2% but slightly decreased with the addition of 3%, which may be related to the increased yield increase. Khalifa *et al.* (2020) and Abdelmontaleb *et al.* (2021) reported similar results. Conversely, Quinoa paste was found to significantly lower the protein content of processed cheese spread, according to El-Dardiry *et al*. (2017). The fat content of the cheese analogues decreased as the percentage of QSF added increased (Table 2). This may be due to the lower fat content of QSF (5.4%), as well as the increased yield of cheese analogues. These results are consistent with the results of Khalifa *et al.* (2020) who reported that the fat/DM content of low-fat camel milk processed cheese decreased significantly with increasing QSF addition. However, El-Dardiry *et al.* (2017) found that the fat/DM content of the obtained processed cheese spread was not affected by the addition of Quinoa paste. On the contrary, Abdelmontaleb *et al*. (2021) found that the addition of QSF significantly increased the fat content of UF-soft cheese. These conflicting results may be a result of differences in the type of milk used and its fat content. In our study, we used sheep's milk, which has a higher fat content (6.4%) compared to quinoa seeds (5.4%). As for the ash content, the data presented in Table (2) indicate that there was a significant increase ($P < 0.05$) in the ash content with an increase in the percentage of QSF added. This might be because QSF has more ash (2.8%) than sheep milk (0.92%). These findings align with the findings of Abdelmontaleb *et al.* (2021). However, research by El-Dardiry *et al*. (2017) and Khalifa *et al*. (2020) showed that the ash content decreased significantly as the amount of added quinoa increased. The salt content of fresh cheese analogues was significantly ($P < 0.05$) reduced by the addition of QSF (Table 2). El-Dardiry *et al*. (2017) achieved similar results. Table 2 shows that as the QSF ratio increased, the amount of crude fiber and carbohydrates in the cheese analogues increased significantly ($P < 0.05$). This can be attributed to the high carbohydrate and crude fiber content in QSF (65.1% and 7.1%, respectively). El-Dardiry *et al.* (2017) and Khalifa *et al.* (2020) obtained similar results. However, Abdelmontaleb *et al.* (2021) found that there were no statistically significant variations in total dietary fiber between 1.0% and 2.0% QSF treatments in UF-soft cheese with varying percentages of QSF. When compared to the other treatments, only the QSF 3.0% treatment exhibited statistically higher values. Quinoa is an excellent source of dietary fiber, which makes up 2.6% to 10% of the total weight of the grain. According to Gonzalez-Martin *et al*. (2014) and Lamothe *et al*. (2015), 22% of the fiber content is soluble and the remaining 78% is insoluble. From a health and nutritional perspective, it is critical to increase functional components like fiber in the resulting cheese analogues. Eating dietary fiber-rich flour is linked to reduced blood pressure, better glucose tolerance, and lowered cholesterol, which support healthy digestion and the prevention of some cancers, including colon cancer (Nirmala Prasadi and Joye, 2020). The results of the current study are consistent with those of El-Dardiry *et al*. (2017) who found that 38.82–42.45% dry matter, 17.57–18.39% fat, 9.5–13.27% protein, 2.01-3.74% ash, and 1.06–1.62% salt were present in processed cheese spread with different percentages of quinoa paste (10–40%). Khalifa *et al.* (2020) reported 40.09–42.84% dry matter, 8.80–10.10% fat, 10.62–11.24% protein, and 2.95–4.56% ash in processed low-fat cheese fortified with QSF

(1%–5%). Abdelmontaleb *et al.* (2021) found that UF-soft cheese with 1-3 percent added QSF had 35.02–36.81% dry matter, 17.5–18.0% fat, 10.67–11.21% protein, and 2.6–2.89% ash. According to a recent study by Guneser *et al.* (2023), processed cheese made with added (3%) QSF contains 37.10% dry matter, 18.31% fat, 11.93% protein, and 3.46% ash. Karimpour *et al*. (2023) found that the dry matter and fat content of imitation whey-less cheese increased while the moisture and protein content decreased as the amount of quinoa germs (3–9%) increased.

3. Yield of cheese analogues

The yield of soft sheep's milk cheese analogues is shown in Figure 1. The results showed that increasing the percentage of QSF and XG greatly increased the yields of cheese analogues. The yield of cheese analogues ranged from 30.25% to 33.17% with an increase in yield ranging from 8.89% to 19.40%. This may be because QSF has a high fiber and carbohydrate content, which could cause the resultant cheese analogues to bind more water than the control cheese (Ogungbenle, 2003). Similar results were reported by Abo Ali *et al.* (2022), who found that compared to control cheese, Kareish cheese fortified with varying concentrations (1, 3, and 5%) of germinated quinoa seed paste significantly increased in yield.

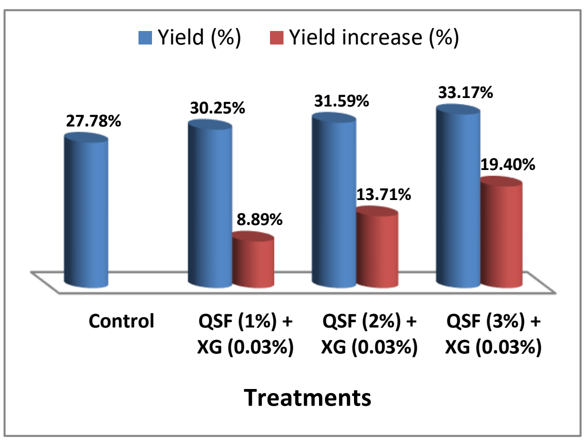

Fig. (1): Percentages of yield and yield increases in soft sheep's milk cheese analogues fortified with different levels of quinoa seed flour with xanthan gum.

As we mentioned previously, studies have shown that the primary ingredient in Quinoa seeds is starch, which makes up between 52.2% and 69.2% of the dry matter. Quinoa is also an outstanding source of soluble and insoluble dietary fiber, which consists of approximately 7% to 9.7% of the total seed (Abugoch James, 2009). Quinoa seeds have an average protein content of 13.8% to 16.5% (USDA, 2015). Therefore, the functional properties of starch, fiber, and protein contributed significantly to the increased yield of the resulting soft sheep's milk cheese analogues. Furthermore, xanthan gum has been shown to increase cheese yields. Shendi *et al.*(2010) reported that adding xanthan gum to cheese increases yield because the cheese retains a greater amount of water, due to the water absorption property of xanthan gum. Additionally, Nateghi *et al.* (2012) found that a higher xanthan gum content in reduced-fat cheddar cheese led to a significant increase in moisture and protein content, which was reflected in higher yield.

3.4. Textural characteristics of cheese analogues

Texture profile analysis (TPA) parameters of fresh soft sheep's milk cheese analogues are shown in Table 3. The hardness values increased significantly ($p<0.05$) with increasing QSF levels. This is explained by the high fiber and carbohydrate content of QSF. These results were in line with those of El-Dardiry *et al.* (2017) and Khalifa *et al*. (2020), who found that as QSF levels increased, the hardness of processed cheese increased significantly. Similar findings were also reported by Abdelmontaleb *et al*. (2021), who found that samples supplemented with QSF exhibited higher hardness and greater internal bond strength in comparison to the control. This is likely because QSF's high dietary fiber content forms a spongy network, and QSF also affects protein-protein interactions, which increases hardness and compression force. Compared with the control cheese, the cohesiveness and springiness values of the cheese analogues decreased significantly ($P<0.05$) with increasing QSF level (Table 3). These results are consistent with the findings of El-Dardiry *et al.* (2017) and Khalifa *et al*. (2020).

Table (3): Texture parameters values of fresh soft sheep's milk cheese analogues fortified with different levels of Quinoa seed flour and Xanthan gum

Treatments	Texture parameters				
	Hardness (N)	**Cohesiveness (B/A area)**	**Springiness (mm)**	**Gumminess (N)**	**Chewiness (mJ)**
Control*	3.80d	0.493a	0.677a	1.873c	1.268b
SM + 1.0 QSF + 0.03% XG	4.15c	0.442b	0.582b	1.834d	1.068d
SM + 2.0 QSF + 0.03% XG	5.70b	0.405c	0.579b	2.309b	1.337a
SM + 3.0 QSF + 0.03% XG	6.37a	0.374d	0.493c	2.382a	1.175c

Control*: Cheese made from sheep's milk without additives.
SM: Sheep's milk
Values are mean of three replicates
The values with different superscript letters within the same column are significantly different ($p<0.05$)

Gumminess and chewiness values of cheese analogues decreased with the addition of 1% QSF then increased with addition of 2% or 3% QSF (Table 3). These results are consistent with those of Abdelmontaleb *et al.* (2021), who found that samples with QSF added had chewiness and gumminess values that were higher than those of control cheese. They proposed that the stronger internal bonds in those samples were a result of their harder network. According to Abo Ali *et al*. (2022), Kareish cheese fortified with quinoa seed paste that had germinated exhibited high gumminess and chewiness values. In a recent study, Karimpour *et al*. (2023) found that the whey-less cheese containing quinoa germs had significantly lower cohesiveness and springiness values than control cheese. However, samples containing higher amounts of quinoa had higher values of gumminess and chewiness compared to those containing lower amounts of quinoa. On the other hand, Shendi *et al.* (2010) examined the effects of xanthan gum on the rheological properties and texture of low-fat Iranian white cheese and found that the cheese's texture improved with an increase in xanthan gum concentration. According to research by Nateghi *et al.* (2012), the hardness of reduced-fat cheddar cheese was reduced by adding a high concentration of xanthan gum (0.045%, w/w) to the cheese formulation. They reported that the addition of xanthan gum enhanced the protein matrix's ability to bind water, suggesting that changes in the pressure of the protein matrix were likely the cause of the cheese's decreased hardness. However, Salari *et al.* (2017) found that the cream cheese treatments with the highest fat content and the lowest amount of xanthan gum had the highest hardness.

5. Sensory properties

Table 4 shows a wide variation in sensory profile data for soft sheep's milk cheese analogues supplemented with different levels of QSF along with xanthan gum during refrigerated storage. Fresh cheese analogues showed that the addition of QSF resulted in lower flavor scores, especially as the addition level increased. The flavor became less palatable as the added level of QSF was increased to 3.0%. In UF-soft cheese produced with the addition of 1, 2, and 3% QSF, Abdelmontaleb *et al.* (2021) noticed the same pattern. However, Karimpour *et al.* (2023) found that quinoa additions up to 6% greatly enhanced the flavor of whey-less cheese. In our study, panelists described the flavor of the control cheese as tangy, while the cheese analogues were described as nutty with a slightly bitter aftertaste similar to delicious dark chocolate, with a slightly grainy texture, which may be due to the natural properties of QSF. The bitter aftertaste may be due to the presence of some residues of saponin, which is responsible for bitterness, in quinoa seeds. Table 4 also shows that the analogue cheese containing 1% and 2% QSF did not differ significantly ($p > 0.05$) in body and texture scores compared to the control cheese; however, the addition of 3% QSF resulted in a significant decrease in scores ($p < 0.05$). In contrast to our findings, Khalifa *et* *al*. (2020) found that high QSF levels (3% and 5%) improved the body and texture scores of low-fat camel milk processed cheese spread.

Table 4: Sensory properties of soft sheep's milk cheese analogues fortified with different levels of quinoa seed flour with xanthan gum during refrigerated storage

Attributes	Storage period (days)	Control*	Treatments		
			QSF 1.0% + XG 0.03%	QSF 2.0% + XG 0.03%	QSF 3.0% + XG 0.03%
Flavour (50)	1	37.3^{a}	36.3^{a}	32.7^{b}	25.1^{c}
	15	39.2^{a}	37.0^{ab}	34.6^{b}	28.7^{c}
	30	42.5^{a}	41.3^{a}	38.9^{a}	32.0^{b}
	45	44.8^{a}	43.1^{b}	41.2^{c}	36.5^{d}
	60	48.0^{a}	46.8^{a}	44.0^{b}	39.3^{c}
Body & Texture (35)	1	28.4^{a}	28.1^{a}	26.5^{a}	23.7^{b}
	15	28.9^{ab}	30.0^{a}	28.1^{b}	26.5^{c}
	30	30.6^{a}	30.2^{a}	29.1^{a}	27.3^{b}
	45	32.1^{a}	31.7^{a}	29.7^{b}	28.0^{c}
	60	33.7^{a}	32.9^{ab}	30.6^{b}	28.1^{c}
colour & Appearance (15)	1	11.7^{a}	10.5^{b}	10.1^{c}	8.2^{d}
	15	12.1^{a}	12.0^{a}	10.8^{b}	9.3^{c}
	30	12.9^{a}	12.7^{a}	11.7^{b}	9.6^{c}
	45	13.0^{a}	13.0^{a}	12.3^{b}	10.0^{c}
	60	13.6^{a}	13.3^{a}	12.5^{b}	10.1^{c}
Overall acceptability (100)	1	77.4^{a}	74.9^{b}	69.3^{c}	57.0^{d}
	15	80.2^{a}	79.0^{a}	73.5^{b}	64.5^{c}
	30	86.0^{a}	84.2^{a}	79.7^{b}	68.9^{c}
	45	89.9^{a}	87.8^{b}	83.2^{c}	74.5^{d}
	60	95.3^{a}	93.0^{a}	87.1^{b}	77.5^{c}

Control*: Cheese made from sheep's milk without additives.
Values are mean of three replicates
The values with different superscript letters within the same row are significantly different ($p<0.05$)

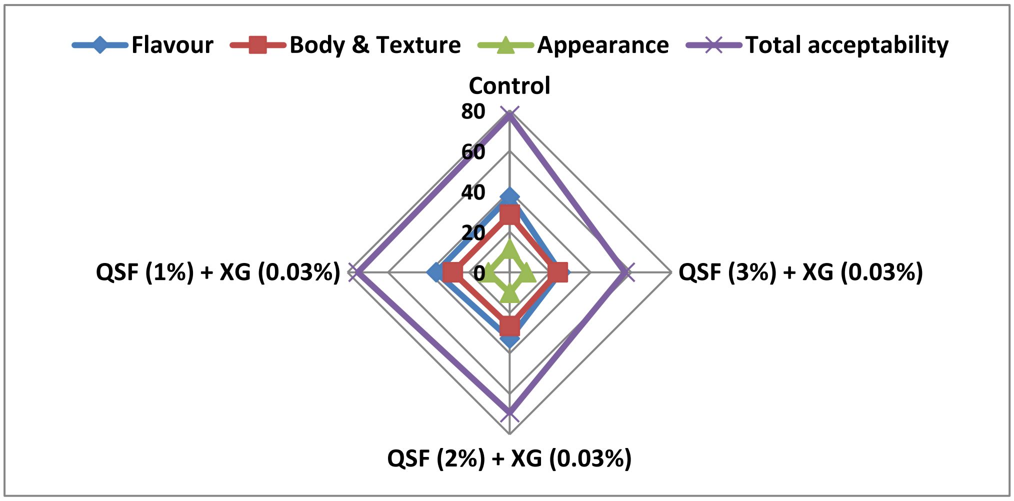

Fig. (2a): Comparative profilogram of attributes from the sensory evaluation of soft sheep's milk cheese analogues fortified with different levels of quinoa seed flour with xanthan gum when fresh.

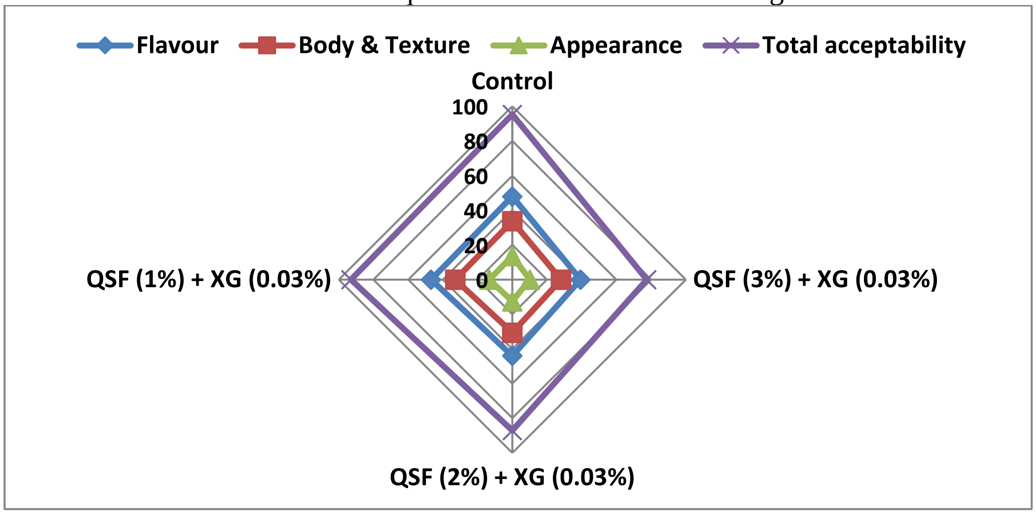

Fig. (2b): Comparative profilogram of attributes from the sensory evaluation of soft sheep's milk cheese analogues fortified with different levels of quinoa seed flour with xanthan gum at the end of the storage period.

Table 4 shows that as QSF levels increased the color and appearance values of the cheese analogues decreased. This may be due to the natural color of QSF. The same result was observed by Abdelmontaleb *et al.* (2021), who reported that the addition of QSF caused the color of the cheese samples to change. On the other hand, Shendi *et al.* (2010) observed that the xanthan gum addition resulted in more whey pockets in the cheese, which in turn enhanced the whiteness of low-fat white cheese. Overall acceptability scores indicated that cheese analogues containing 1.0% or 2.0% QSF were more acceptable than the sample containing 3.0% QSF (Table 4). This may be because this sample produces a slightly bitter taste and unsatisfactory color with the high QSF level. On the other hand, the inclusion of XG may have enhanced the sensory perception of the cheese analogues. Numerous studies have examined the impact of xanthan gum on the sensory characteristics of cheese. Shendi *et al.* (2010) found that low-fat white cheese treated with xanthan gum was the most desirable in terms of taste and texture, and had the greatest advantages in appearance and overall acceptability. Nateghi *et al.* (2012) reported that the addition of a high percentage of xanthan gum led to favorable economic outcomes, such as increased yields and acceptable textural characteristics of reduced-fat cheddar cheese. As the storage period progressed, the sensory attribute scores for all samples increased (Figures 2, A and B). Overall, the results showed that the most acceptable cheese analogues were produced by adding 1 and 2% QSF along with 0.03% XG.

CONCLUSION

This study concluded that adding 1% or 2% QSF with 0.03% XG to whole sheep milk can successfully produce functional analogues of soft sheep milk cheese with acceptable sensory properties, good health benefits, high nutritional value, high yield and low cost. This could serve as an expansion of the sheep milk cheese supply chain in the markets.

REFERENCES

Abdelmontaleb, H. S., Othman, F. A., Degheidi, M. A. and Abbas, K. A. (2021). The influence of quinoa flour addition on the physicochemical, antioxidant activity, textural, and sensory characteristics of UF-soft cheese during refrigerated storage. J. Food Process Preserv.; 45 (5):e15494.

Abo Ali, G., El-Dardiry, A. and El-rahmany, A. (2022). Study of the chemical, rheological, functional, microstructure, microbial, and sensory properties of Kareish cheese fortified with germinated quinoa seeds and processed using ultrasound technology. Egypt. J. Chem., 65 (11): 515-529.

Abugoch James, L. E. (2009). Quinoa (*Chenopodium quinoa* Willd.): Composition, chemistry, nutritional and functional properties. Adv. Food Nutr. Res.; 58:1-31.

Angeli, V.; Silva, P.; Massuela, D.; Khan, M.; Hamar, A.; Khajehei, F.; Graeff-Honninger, S. and Piatti, C. (2020). Quinoa (Chenopodium quinoa Willd.): An overview of the potentials of the "golden grain" and socio-economic and environmental aspects of its cultivation and marketization. Foods, 9 (2): 216.

AOAC (2012). Association of Official Analytical Chemists. 19th Ed. William Hornitz, (Ed) pub Association of official Agric. Chemists, Washington, D.C, USA.

Aschemann-Witzel, J., Gantriis, R. F., Fraga, P. and Perez-Cueto, F. J. A. (2021). Plant-based food and protein trend from a business perspective: markets, consumers, and the challenges and opportunities in the future. Crit. Rev. Food Sci. Nutr.; 61 (18):3119–3128.

Badem, A. and Ucar G. (2016). Cheese Analogues. Research & Reviews: Journal of Food and Dairy Technology; 4 (3): 44-48.

Balthazar, C. F., Pimentel, T. C., Ferrao, L.L., Almada, C. N., Santillo, A., Albenzio, M., Mollakhalili, N., Mortazavian, A. M., Nascimento, J. S., Silva, M. C., Freitas, M. Q., Sant Ana, A. S., Granato, D. and Cruz, A. G. (2017). Sheep milk: physicochemical characteristics and relevance for functional food development. Comprehensive Reviews in Food Science and Food Safety, 16 (2): 247-262.

Barlowska, J., Szwajkowska, M., Litwinczuk, Z. and Krol, J. (2011). Nutritional value and technological suitability of milk from various animal species used for dairy production. Comprehensive Reviews in Food Science and Food Safety, 10 (6): 291-302.

Chavan, R. and Jana, A. (2007). Cheese substitutes: an alternative to natural cheese—a review. Int. J. Food Sci. Technol. Nutr., 2 (2): 25–39.

Cunha, C. R., Dias, A. I. and Viotto, W. H. (2010). Microstructure, texture, colour and sensory evaluation of a spreadable processed cheese analogue made with vegetable fat. Food Res. Int. 43 (3): 723–729.

El-Dardiry, A. I., Al-Ahwall, R. I. and Gab-Allah, R. H. (2017). Preparation and properties of processed cheese spread containing quinoa paste. Egypt. J. Dairy Sci., 45 (2): 171-180.

FAO (2011). Quinoa : An ancient crop to contribute to world food security. Regional Office of Latin America and the Carribean.

Fox, P. F., Guinee, T. P., Cogan, T. M. and McSweeney, P. L. H. (2000). Fundamentals of cheese science, pp 1, 351 and 381. Gaithersburg, MD, USA: Aspen Publishers, Inc.

Gonzalez-Martin, M. I., Wells Moncada, G., Fischer, S. and Escuredo, O. (2014). Chemical characteristics and mineral composition of quinoa by near-infrared spectroscopy. J. Sci. Food Agric.; 94 (5): 876-881.

Gordillo-Bastidas, E., Diaz-Rizzolo, D. A., Roura, E., Massanes, T. and Gomis, R. (2016). Quinoa (*Chenopodium quinoa* Willd), from nutritional value to potential health benefits: An integrative review. J. Nutr. Food Sci.; 6 (3): 497.

Guneser, B. A., Aklale, B. and Guneser, O. (2023). Characterization of physicochemical, rheological, aroma and sensory properties of spreadable processed cheese supplemented with chia, quinoa, and teff seeds. Mljekarstvo, 73 (1): 22-37.

Hussain, M. I., Farooq, M., Syed, Q. A., Ishaq, A., Al-Ghamdi, A. A. and Hatamleh, A. A. (2021). Botany, nutritional value, phytochemical composition and biological activities of quinoa. Plants, 10 (11): 2258.

IDF. (1992). Rheological and fracture properties of cheese. Bulletin of the International Dairy Federation, (368), 1-67.

Jooyandeh, H. and Aberoumand, A. (2010). Physico-chemical, nutritional, heat treatment effects and dairy products aspects of goat and sheep milks. World App. Sci. J.; 11:1316–1322.

Kamath, R., Basak, S. and Gokhale, J. (2022). Recent trends in the development of healthy and functional cheese analogues-a review. LWT - Food Sci. Technol.; 155 (3):112991.

Karimpour, M., Javadi, A., Zomorodi, S. and Anarjan, N. (2023). The effect of quinoa germs on the quality of wheyless cheese. Food Hygiene, 12: (4): 1-15.

Khalifa, S. A., Abdeen, E. M. M., El-Shafei, S. M. S. and Mohamed, A. H. (2020). Effect of quinoa (Chenopodium quinoa) flour on the production and quality of low-fat camel milk processed cheese spread. Pak. J. Biol. Sci.; 23 (4): 439-453.

Lamothe, L. M., Srichuwong, S., Reuhs, B. L. and Hamaker, B. R. (2015). Quinoa (Chenopodium quinoa W.) and amaranth (Amaranthus caudatus L.) provide dietary fibres high in pectic substances and xyloglucans. Food Chem.; 167:490-496.

McClements, D. J. and Grossmann, L. (2021). A brief review of the science behind the design of healthy and sustainable plant-based foods. NPJ Science of Food, 5 (1):17

Mu, H.; Xue, S.; Sun, Q.; Shi, J.; Zhang, D.; Wang, D. and Wei, J. (2023). Research progress of quinoa seeds (Chenopodium quinoa Wild.): Nutritional components, technological treatment, and application. *Foods*; 12 (10):2087.

Nateghi, L., Roohinejad, S., Totosaus, A., Rahmani, A., Tajabadi, N., Meimandipour, A., Rasti, B., Manap, M. Y., Mirhosseini, H., Mustafa, S. and Omidizadeh, A. (2012). Physicochemical and textural properties of reduced fat cheddar cheese formulated with xanthan gum and/or sodium caseinate as fat replacers. J. Food Agric. Environ., 10 (2): 59-63.

Nelson, J. A. and G. M. Trout (1956). Judging Dairy products 4th Ed. The Olsen publishing Co. Milwaukee. Wis., 53212.

Nirmala Prasadi, V. P. and Joye, I. J. (2020). Dietary fibre from whole grains and their benefits on metabolic health. Nutrients 12 (10): 3045.

Ogungbenle, H. N. (2003). Nutritional evaluation and functional properties of quinoa (Chenopodium quinoa) flour. International Journal of Food Sciences and Nutrition, 54 (2): 153- 158.

Olivera, L., Best, I., Paredes, P., Perez, N., Chong, L. and Marzano, A. (2022). Nutritional value, methods for extraction and bioactive compounds of quinoa. In pseudocereals. IntechOpen.

Pereira E., Encina-Zelada C., Barros L., Gonzales-Barron U., Cadavez V. and Ferreira I. C. F. R. (2019). Chemical and nutritional characterization of *Chenopodium quinoa* Willd (quinoa) grains: a good alternative to nutritious food. Food Chem.; 280:110–114.

Pua, A., Tang, V. C. Y., Goh, R. M. V., Sun, J., Lassabliere, B. and Liu, S. Q. (2022). Ingredients, processing, and fermentation: Addressing the organoleptic boundaries of plant-based dairy analogues. Foods; 11(6):875.

Quispe-Fuentes, I., Vega-Galvez, A., Miranda, M., Lemus-Mondaca, R.A., Lozano, M. and Ah-Hen, K.S. (2013). A Kinetic approach to saponin extraction during washing of quinoa (Chinopodium quinoa Willd.) seeds. J. Food Process Eng., 36 (2): 202-210.

Rivas, M. C., Riocerezo, C. P., Vara, I. A., Gonzalez-Ronquillo, M., and Schilling, S. R. (2019). Production, processing, commercialization and analysis of customer preferences of sheep cheese in Chile. Milk Production, Processing and Marketing. DOI: 10.5772/intechopen.83806

Salari, S., Zanganeh, M., Fadavi, A. and Ahmadi, Z. (2017). Effect of xanthan gum and carboxymethyl cellulose on physical properties of cream cheese. Int. J. Adv. Technol., 8 (1): 176.

SAS. (2008). Statistical Analysis System, Version 9.2. Cary, USA: SAS Institute Inc. S.

Shendi, E. G.; Asl, A. K.; Mortazavi, A.; Tavakulipor, H.; Afshari, H. and Ebadi, A. G. (2010). The effect of xanthan gum using on improving texture and rheological properties of Iranian low fat white cheese. Middle East J. Sci. Res., 6 (4): 346-353.

Solowiej, B. and Nastaj, M. (2016). Relevance and production of dairy analogues and restructured dairy products. Reference Module in Food Science, 1st ed., Elsevier Inc., Amsterdam, 1-6.

Solowiej, B., Glibowski, P., Muszynski, S., Wydrych, J., Gawron, A., and Jelinski, T. (2015). The effect of fat replacement by inulin on the physicochemical properties and microstructure of acid casein processed cheese analogues with added whey protein polymers. Food Hydrocolloids, 44: 1-11.

Suarez-Estrella, D., Torri, L., Pagani, M. A. and Marti, A. (2018). Quinoa bitterness: causes and solutions for improving product acceptability. J. Sci. Food Agric.; 98 (11):4033-4041.

USDA (2015). United States Department of Agriculture. National Nutrient Database for Standard Reference Release, 28 (Basic Reports).

Vega-Galvez, A., Miranda, M., Vergara, J., Uribe, E., Puente, L. and Martinez E. A. (2010). Nutrition facts and functional potential of quinoa (Chenopodium quinoa Willd.), an ancient Andean grain: A review. J. Sci. Food Agric.; 90 (15): 2541-2547.

Vilcacundo, R. and Hernandez-Ledesma, B. (2017). Nutritional and biological value of quinoa (Chenopodium quinoa Willd.). Curr. Opin. Food Sci., 14: 1–6.

إنتاج وتقييم مشابهات جبن لبن الغنم المدعمة بدقيق بذور الكينوا وصمغ الزانثان

عبدالعال عابدين علي عبد الخير، أماني جابر محمود احمد، عطيت الله حسن عطيت الله
قسم علوم الالبان، كلية الزراعة، جامعة سوهاج

الملخص العربى

أجري هذا البحث بهدف دراسة إمكانية زيادة كميات الجبن المنتجة من لبن الغنم في محاولة للتغلب على مشكلة محدودية كميات لبن الغنم المنتجة عالمياً، وذلك من خلال إنتاج بعض مشابهات جبن لبن الغنم المدعمة بمصادر نباتية ذات القيمة الغذائية العالية والفوائد الصحية المميزة، مثل بذور الكينوا، وتقييم أثر ذلك على جودة مشابهات الجبن المنتجة، حيث تم تصنيع مشابهات جبن لبن الغنم بإضافة دقيق بذور الكينوا إلى لبن الغنم كامل الدسم بنسب 1، 2، و 3% مع إضافة صمغ الزانثان بنسبة 0.03%. كما تم تصنيع عينة من جبن لبن الغنم بدون أي إضافات للمقارنة. تم أخذ عينات من المنتج الطازج لتقدير التركيب الكيميائي والخصائص الريولوجية ونسبة التصافي، وتم تخزين العينات لمدة شهرين على درجة حرارة الثلاجة لتقييم الخصائص الحسية بشكل دوري. وقد أشارت النتائج إلى أن إضافة دقيق بذور الكينوا وصمغ الزانثان أدى إلى انخفاض نسبة الرطوبة والدهن، مع زيادة معنوية في نسبة الكربوهيدرات والألياف والرماد. وكان هذا النقصان أو الزيادة متناسبا مع معدل الإضافة ، بينما زادت نسبة البروتين مع إضافة الكينوا حتى 2%، ثم انخفضت مع زيادة نسبة الإضافة. كما لوحظ أن نسبة التصافي قد ارتفعت بشكل ملحوظ بزيادة النسب المضافة من بذور الكينوا مع صمغ الزانثان. وأظهرت نتائج الخصائص الريولوجية زيادة في قيم الصلابة وانخفاض في قوة التماسك والمرونة مع زيادة نسبة الكينوا المضافة. كما أشارت نتائج التقييم الحسي إلى أن مشابهات الجبن المصنعة بإضافة 1% أو 2% من دقيق بذور الكينوا مع صمغ الزانثان حصلت على درجات تقييم حسي جيدة من حيث النكهة والملمس سواء كانت طازجة أو أثناء التخزين. والخلاصة أنه من الممكن تصنيع مشابهات جبن لبن الغنم ذات الخصائص الغذائية والصحية والحسية الجيدة عن طريق إضافة دقيق بذور الكينوا بنسبة تصل إلى 2% مع إضافة 0.03% من صمغ الزانثان.