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Study of Rheological, Chemical, and Microbiological Properties of Chami, A Traditional Emirati Soft Chees

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STUDY OF RHEOLOGICAL, CHEMICAL, AND MICROBIOLOGICAL PROPERTIES OF CHAMI, A TRADITIONAL EMIRATI SOFT CHEESE

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This thesis is submitted in partial fulfilment of the requirements for the degree of Master of Science in Food Science

Under the Supervision of Professor Afaf Kamal-Eldin

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Declaration of Original Work

I, Aysha Othman Abdulla Al Katheeri, the undersigned, a graduate student at the United Arab Emirates University (UAEU), and the author of this thesis entitled *"Study of Rheological, Chemical, and Microbiological Properties of Chami, A Traditional Emirati Soft Cheese*", hereby, solemnly declare that this thesis is my own original research work that has been done and prepared by me under the supervision of Professor Afaf Kamal-Eldin, in the College of Food & Agriculture at UAEU. This work has not previously been presented or published or formed the basis for the award of any academic degree, diploma or a similar title at this or any other university. Any materials borrowed from other sources (whether published or unpublished) and relied upon or included in my thesis have been properly cited and acknowledged by appropriate academic conventions. I further declare that there is no potential conflict of interest concerning the research, data collection, authorship, presentation, and publication of this thesis.

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Abstract

In this work, ten Emirati Chami cheese samples were collected and analyzed to determine their chemical composition, texture, rheology, and microbiological properties. Chami cheeses showed large variations in moisture (60.9–84.1%), protein (7.5–14.6%), fat (0.5–7.8%), and ash (3.4–8.0%) contents as well as in pH (3.6–4.4), and water activity (0.977–0.999%). The variation in fat content of samples suggested that extra fat was added; this added fat was either butter or vegetable oil as indicated by the fatty acid composition. The different samples showed peaks of variable size for fat melting. The sodium content in the 10 cheese samples varied from 223–2410 mg/kg, with three samples showing very high contents of 1756, 2024, and 2410 mg/kg, indicating added salt. The sample with the lowest moisture content (60.9%) had the hardest texture among the cheeses. Rheological examination showed that Chami cheese samples were more elastic than they were viscous. Seven Chami samples contained lactic acid bacteria (6.5–9.1 log CFU/mL), while 5 samples showed yeast and mold growth (5.3–8 log CFU/mL). Six Chami samples showed the presence of *Staphylococcus* spp., while coliform bacteria were detected in 4 samples. All samples tested positive for *Salmonella* and 4 were positive for *Listeria*.

Keywords: Chami, Cheese, Chemical Composition, Rheology, Microbiology, Lactic Acid Bacteria, *Salmonella*, *Listeria*.

Title and Abstract (in Arabic)

دراسة الخصائص الريولوجية، الكيمائية، والمايكروبيولوجية للجبن التقليدي الإماراتي الجامي

ملخص

في هذا العمل، تم جمع عشرة عينات من جبن الجامي وتحليلها للخصائص الكيميائية، الريولوجية، والمايكروبيولوجية. كانت أنواع الجبن الجامي مختلفة في الرطوبة (60.9-84.1%) والبروتين (7.5-14.6%) والدهون (0.5-7.8%) والرماد (3.4-8.0%) ودرجة الحموضة (3.6-4.4 والماء النشاط (0.977-0.999%). بسبب وجود اختلاف في نسبة الدهون في عينات الجامي، تم إضافة الدهون الزائدة إما زبدة أو زيت نباتي كما هو مبين في تكوين الأحماض الدهنية. أظهرت العينات المختلفة ذروات ذات حجم متغير لذوبان الدهون. وتراوح محتوى الصوديوم في عينات الجبن العشر 223-2410 ملغم/ كغم مع ثلاث عينات احتوت على مستويات عالية 1756 و2024 و2410 ملغم/كغم تم إضافة الملح في العينات . عينة الجامي ذات محتوى رطوبة منخفض (60.9٪) هي الأكثر صلابة بين عينات الجامي. في تحليل الريولوجية تبين عينات الجامي تحتوي أكثر على معامل المرونة مقارنة بمعدل معامل اللزوجة. تبين وجود بكتيريا حمض اللاكتيك في سبع عينات (6.5-9.1 log cfu/ml) ووجود الخميرة والعفن في خمس عينات من الجامي (5.3-8.2 log cfu/ml). كما تبين وجود المكورات العنقودية في ست عينات والكوليفورم في أربع عينات من جبن الجامي. جميع عينات الجامي احتوت على السالمونيلا بينما احتوت أربع عينات على الليستيريا.

مفاهيم البحث الرئيسية: جبن الجامي، المكونات الكيميائية، الخصائص الريولوجية، الخصائص المايكروبيولوجية، بكتيريا حمض اللاكتيك، السالمونيلا، الليستيريا.

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Dedication

To my beloved parents and family

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List of Abbreviations

Aw	Water activity
CFU	Colony-forming unit
DSC	Differential scanning calorimetry
ICP-OES	Inductively coupled plasma atomic emission spectroscopy
kPa	Kilo Pascal unit
LAB	Lactic acid bacteria
NaCl	Sodium chloride (table salt)
pH	Hydrogen ion concentration
Tg	Glass transition temperature
UF	Ultrafiltration

Chapter 1: Introduction

1.1 Overview

Traditional foods are considered as essential components of culture and heritage worldwide. Traditional food was defined by Bertozzi (1998) as “a representation of a group, it belongs to a defined space, and it is part of a culture that implies the cooperation of the individuals operating in that territory”. Similarly, Jordana (2000) stated that “To be traditional, a product must be linked to territory and it must also be part of a set of traditions, which will necessarily ensure its continuity over time”. The methods of preparing traditional foods come from ancestors and are passed down through generations (Uzogara & Agu, 1990). Traditional foods are typically made and consumed by the local people in a specific region but are currently also considered as important touristic attractions. Some traditional foods may be further developed, industrialized, and commercialized to other communities (Kristbergsson & Oliveira, 2016).

Traditional foods represent an important part of the Emirati culture, identity, and heritage. Although the current diet of Emirati citizens incorporates many imported foods, traditional foods that are either prepared at home or purchased from restaurants contribute a significant proportion of the diet (Habib *et al*., 2011). Traditional Emirati dishes contain milk, rice, fish, and meat as the main ingredients, which have vibrant and unique tastes. Currently, traditional foods compete with ready-to-eat foods as well as foods served in restaurants and small outlets because their unique tastes and traditional values. Citizens attempt to preserve their traditional food knowledge and skills and encourage household production of traditional foods.

UAE is a cosmopolitan country that hosts millions of expats and offers various attractions for tourists from all over the world. The presentation and consumption of traditional Emirati foods are highly limited to home preparation by Emirati citizens, despite the social and nutritional benefits of these foods. Additionally, there is a need to maintain and expand the market share of traditional Emirati foods. Development of processes that ensure safety, sensory attraction, nutritional value, and convenience are needed.

One widely consumed Emirati food is Chami, which is a traditional fermented cheese produced at the household level. It is a type of soft fresh cottage cheese that has been drained (Yasin & Shalaby, 2013). It is similar in consistency to Petit Suisse cheese and has a weak gel structure (Pereira, 2016). The method of drainage allows the whey to remain in the product, leading to high protein content and giving the cottage cheese a white color. Lactic acid bacteria (LAB) in products such as Chami are thought to play an important role in improving the shelf life, sensory quality, and nutritional value of such foods. Chami cheese has different sweet tastes with slight acidity and a mild diacetyl flavor (Yasin & Shalaby, 2013).

The local people in UAE prefer to eat Chami with date fruit, rice, or bread. People also add ghee or clarified butter to the Chami to enhance its taste, while others add spices to the cheese. In the past, many families consumed Chami during. Chami is also consumed in dried form as Kami or Igt. Kami is the UAE name for sun-dried Chami, which is sold either in small flattened cakes that are 1–2 inches in diameter or as granular pieces of varying sizes. This product is hard and has a slightly musty aroma that is vaguely reminiscent of cheese, and its price varies from 10 to 20 Dirhams per kilo depending on the quality. Iqt or Yaqat is another product made by further dehydration of Chami into a very dry product that can be stored and used for a long time, particularly when traveling. Iqt is consumed after soaking in water and rehydration for at least 20 min.

The quality of Chami is primarily determined by the quality of the milk used and its level of freshness. Additionally, external processing factors such as exposure to heat, air, and light may change the quality of the food product during storage, leading to degradation or formation of undesirable flavors and tastes (Sung & Collins, 2000). Moreover, microbial spoilage can occur during storage depending on the initial microbial load and processing and storage conditions. Therefore, it is very important to examine the physicochemical characteristics and risks associated with the consumption of home-made Chami.

Studying the quality of Chami cheeses is important for protecting them as traditional foods and from adulteration and misbranding, and most importantly for ensuring their safety. Ensuring the safety of food is a major concern not only for consumers, but also for producers and distributors. Indeed, regulatory authorities, food processors, retailers, and consumer groups are interested in ensuring that foods are correctly labeled. The objectives of the present thesis are within this framework.

1.2 Problem Statement

The production and supply of many traditional foods faces challenges related to the assurance of safety, healthiness, and consistent quality. Development of these products requires the introduction of innovations that will enable these products to maintain and expand their market share in a highly competitive and increasingly global food market. However, it is important to gain insight into the quality characteristics and safety aspects associated with these products. This thesis aimed to collect commercial Chami samples and characterize their chemical, rheological, and microbiological properties.

1.3 Relevant Literature

1.3.1 Cheese: A Fermented Product for Milk Preservation

The production of cheese was spontaneously began by different populations to conserve milk. Depending on the surplus of products and climatic conditions, different soft and hard cheese types are produced. It has been estimated that 2000 different types have been developed and approximately 400 types have been described (Fox & MCsween, 2014). Broadly, cheese can be defined as the fresh or matured products obtained by the drainage of whey liquid after the coagulation of different types of creamy, skimmed, or partly skimmed milk, or a combination of these. Coagulation of milk is achieved using enzymes (rennet) or by acidification of milk using different combinations of LAB or acids (Kongo, 2013).

Cheeses are systematically classified based on composition, firmness, and maturation criteria. Table 1 refers to the ratio of water content to protein (mainly casein) content, both of which represent the major structural matrices of the cheese. The firmness of cheeses depends on this ratio but is also affected by other components such as fat.

1.3.2. Soft Cheeses

Cheese was produced as early as the times of ancient Egypt as evidenced by rock art dated to approximately 3000 BC in the Libyan desert which depict cattle being milked and bags of milk products, which may be cheese curd draining on rocks, as shown in Figure 2. The starter culture used in soft cheese production is *Lactococcus lactis* ssp. *lactis* and *Lactococcus lactis* ssp. *cremoris* (Abd El-Aziz *et al*., 2012). Cheese is stored at low temperatures with or without brine, and some cheeses can be stored at room temperature up to 38°C for up to 3 months depending on composition and microbial flora. Soft cheeses are produced by different traditional methods and stored at low temperature with or without brine (Dhuol & Hamid, 2013).

In the traditional processing of soft cheese, the milk is heated to kill harmful bacteria, followed by cooling and the addition of starter bacteria cultures. Alternatively, rennet may be added to the milk to coagulate proteins for conversion into curds and whey. Next, the curds and whey are heated to a high temperature, and salt is added to produce the correct texture and flavor. The cheese may then be pressed to remove some of the whey and to give the cheese its final shape. The cheese is left to mature or ripen to develop the desired flavor and aromas. Soft cheeses fall into two categories, ripened soft cheese such as brie, and fresh cheese and unripe cheese such as cottage cheese (Enwa *et al*., 2013).

Figure 1: Method for producing cheeses (Laponia, 2011)

Cottage cheese is a type of soft cheese that is slightly acidic and produced by heat coagulation of pasteurized skimmed milk (Guy, 1967). It has a granular texture with relatively uniform particle size and can be optionally mixed with a creamy liquid known as dressing. Typically, cottage cheese contains approximately 60–80% moisture (water activity >0.98) with a lactose content of approximately 4.5%, protein content of 11–21%, and fat content up to 10% (Dhuol & Hamid, 2013). The ash content is 3.7–5.4% and the final NaCl content is 2.3–3.5% w/w (Jesus *et al.* 2016). Fresh cheeses have pH values of 4.5–6.5 and a viscosity of 20 Pa (Dhuol & Hamid, 2013).

In addition to the water-to-protein ratio, cheese texture is determined by the levels of fat, NaCl, and pH, which affect the capillary permeability and cheese structure. For example, fat globules can block some of the capillaries to prevent salt penetration. Similarly, a high pH minimizes the absorption of salt into the cheese. Thus, cheese is hard and brittle at low pH (<5.0) and elastic at higher pH (>5.6) (Jesus *et al.*, 2016).

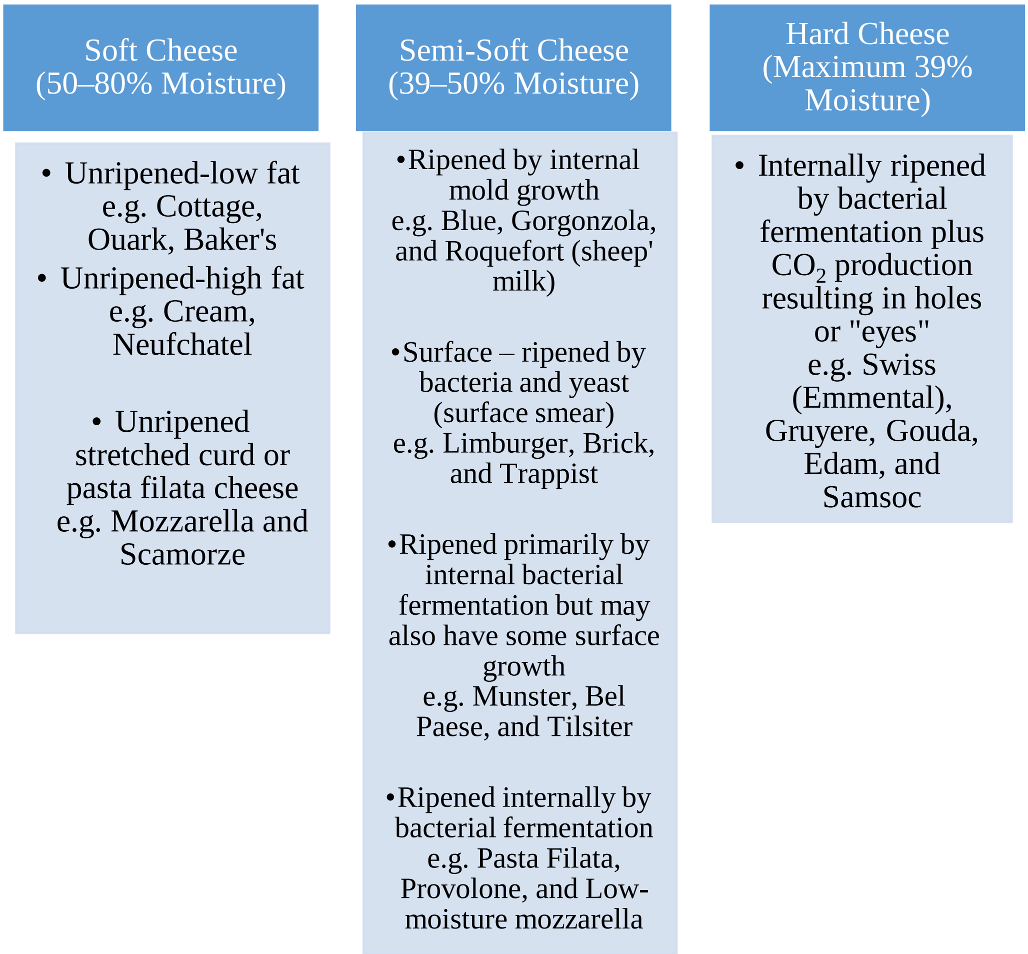

Figure 2: Schematic classification of cheeses according to moisture content, firmness, and maturation agents (Olson, 2017)

1.3.3 Selected Traditional Soft Cheeses Similar to Chami

There are many types of traditional cheese like the Chami in different countries, including Feta, Karish, Jammed, Koumiss, Jaben, Amasi, and Wara cheeses. Table 1 shows the compositional data of some soft cheeses that are similar to Chami.

(a) Feta Cheeses

Feta cheese is a type of traditional soft cheese produced using pasteurized or unpasteurized sheep or goat milk, with goat milk giving a harder texture and stronger flavor compared to sheep milk in Iran. Lactic acid culture is used to produce feta cheeses and calcium chloride is added to increase coagulation. The pH of feta cheese is higher than 6.5, while the acidity of the cheese is lower than 0.23%. The fat content in this cheese varies from 6.5 to 8% (Robinson & Tamime, 1991). The moisture range of the cheese is 48–54% and the protein content is 25.1% (Pitso, 1991). The hardiness and adhesiveness of feta cheeses is related to the milk ratio. Cheeses with a higher proportion of caprine milk have a more compact and less porous appearance than feta samples made with pure ovine milk. (Tsigkros *et al.*, 2003). The addition of whey or starch affects the softness of feta cheese. The addition of culture (*Streptococcus thermophilus* and *Lactobacillus delbrueckii*) and $CaCl_2$ cause the milk to coagulate in approximately 60 min (Jalili, 2016).

(b) Jeben Cheese

Jeben is a traditional fresh cheese made in Morocco and Tunisia from raw milk that is left to sour at room temperature followed by coagulation within 24–72 h (Guizani *et al*. 2001). Upon gelation, the product is named as rayeb and is separated into two products, Jeben and a raw butter known as zebdabeldia. Jeben cheese is processed in three stages: molding, draining, and conditioning. After coagulation, the curd is placed in small-perforated plastic molds and allowed to drain for 3–4 days (Benkerrouma & Tamime, 2004) or up to 10 days to produce firmer Jeben (Guizani *et al*. 2001). The pH of Jeben is approximately 4.2 and the titratable acidity is >0.9%; this cheese is typically consumed within 10–15 days after preparation.

(c) Cottage Cheeses

This cheese is produced from unpasteurized or pasteurized cow milk (Beukes *et al*., 2001). Cottage cheese is a type of soft cheese with the following proximate composition: 60–80% moisture, 10% fat, 11–21% protein, 3.5% lactose, 0.9% ash, and 0.4–0.8% salt (Dhuol & Hamid, 2013). The main steps in producing this cheese begin with adding a mesophilic starter to the milk followed by incubation for 5 h at 30°C (Boikhutso, 2010).

(d) Wara Cheese

Wara cheese is an unripe cheese made in West Africa by coagulating fresh cow milk mixed with a leaf extract of Sodom apple, *Calotropisprocera*, before fermentation by rennet enzymes and a rich consortium of microbes (Adetunji *et al*., 2008; Oladipo and Jadesimi, 2012). The optimum temperature for the coagulation activity of rennet is approximately 40°C. Fresh cow milk is placed in a 1 L clean metallic container that is heated to 50°C and starter culture is added to the mixture and incubated at 68°C for 20 min. Next, the mixture is cooled to 31°C, which is the most favorable temperature for the milk to coagulate (known as the renneting temperature). The whey is then separated from the curd and 150 mL of water is mixed with the curd and stirred continuously at 50°C for 45 min. The curd is placed on a sieve cloth and left for 15 min to drain the water and then pressed into molds to remove the water and yield the final Wara cheese product (Ayeni *et al*., 2014). The moisture, protein, ash, and fat contents of a Wara cheese sample were 70.75%, 6.2%, 20.5%, and 2.2–2.9%, respectively (Oladipo and Jadesimi, 2012). The pH of Wara cheese is 4.9 and total solid and lactose contents were 29.3% and 1.4%, respectively, while the sodium content was 3.4% (Omotosho *et al*., 2011).

Figure 3: Examples of soft cheeses similar to Chami

1. Chami cheese
2. Feta cheese www.diffen.com/difference/Feta_Cheese_vs_Goat_Cheese
3. Jeben cheese www.geniuskitchen.com/recipe/jben-moroccan-fresh-cheese-502807
4. Cottage cheese www.livestrong.com/article/502258-cottage-cheese-and-digestion/
5. Wara cheese http://funke-koleosho.blogspot.ae/2016/03/wara-milk-curds.html

Table 1: Description of example soft cheeses similar to Chami

Cheese	Origin	Milk Type	Starter culture	Processing	References
Feta	Iran	Pasteurized or unpasteurized sheep or goat milk	*Streptococcus thermophilus* and *Lactobacillus delbrueckii*	Pasteurized milk + adding culture + calcium chloride is added. Coagulation about 60 min and curd cut into small cubes and Darin is removed.	Jalili, 2016
Jeben	North Africa, Morocco, Tunisia	Raw milk	*Lactococcus* and *Leuconostoc species*	The molds are filled over a period of 3–4 days. The curd is then transferred to a muslin cloth bag that is tied and hung to drain for an additional 2–3 days. Firmer Jeben is achieved by extending the drainage period for up to 10 days	Guizani *et al*., 2001 Benkerrouma & Tamime, 2004
Cottage cheese	South Africa, Zimbabwe	Fresh cow milk Pasteurization	Mesophilic starter cultures	Mesophilic starter cultures are added to the milk followed by acid-induced coagulation. The milk is then incubated for 5 h at 30°C .	Dhuol and Hamid, 2013 Boikhutso, 2010
Wara	West Africa	Fresh cow milk	*Lactobacillus Plantarum*, *L. fermentum*, *Lactobacillus cellobiosus*	Fermentation is enhanced by the presence of a rich consortium of microbes. The optimum temperature established for rennet enzyme as coagulant is in the region of 40°C.	Oladipo and Jadesimi, 2012

1.3.4 Chemical Composition of Soft Cheeses Similar to Chami

Cottage cheese has a 60–80% moisture content (Aw >0.98), 4.5% lactose content, 11–21% protein content, 10% fat content (Dhuol & Hamid, 2013), 3.7–5.4% ash content, and 2.3–3.5% NaCl content (Jesus *et al.*, 2016). The pH values and viscosity of cottage cheese are 4.5–6.5 and 20 Pa, respectively (Dhuol & Hamid, 2013), as shown in Table 2.

The pH of feta cheese is higher than 6.5, while the acidity of the cheese is lower than 0.23%. The fat content in the cheese is 6.5–8% (Robinson & Tamime, 1991). The moisture range of this cheese is in the range of 48–54% and the protein content is 25.1% (Pitso, 1991). The pH of Wara cheese is 4.9. The total solid and lactose of Wara cheese is 29.3% and 1.4% respectively. No information is available regarding the acidity and viscosity of the product. The sodium content of this cheese is 3.4% (Omotosho *et al*., 2011), as shown in Table 2.

The total solids content of Jeben is the most relevant factor, as it highlights the degree of draining of the curd. The total solid content of Jeben is 45.6%, while the fat, protein, lactose, and moisture contents are 16.5%, 15.8%, 4.1%, and 62.5%, respectively (Benkerrouma & Tamime, 2004). Protein affects the cheese structure, with higher levels of proteins resulting in a harder texture of the product (Farahani *et al*., 2013). Some studies showed that the protein levels of white and cream cheese were 27.1% and 25.1%. According to a national standard, the lowest levels of protein in white cheese and cream cheese were 6% and 5.8%, respectively (Farahani *et al*., 2013). Another factor impacting the texture proprieties is the fat content, with a higher fat content resulting in a softer texture. Fat can have the highest impact on flavor and creamy taste. The fat content of different cheese samples was found to range from 12.4% to 25.0% (Farahani *et al.*, 2013), as shown in Table 2.

Soft cheeses such as Chami should not have a moisture level of more than 55% and milk fat should not be below 30%. The fat content can be adjusted by adding salt and nitrogen, which also improve spreading ability. Soft cheese may also contain gelling and emulsifying locust gum bean for thickening. Sorbic acid is also used in cheese in a limited amount of 3000 ppm (Haddad, 2017). In regular soft cheese, the pH value should be 4.6 and the amount of calcium can vary from 80 to 100 mg per gram of cheese. Fat content can be 30.3–33.6%, whereas the desired amount of protein is 8–10%. The properties of soft cheese are greatly affected by the lactate content, which should be 2–3% to ensure chemical bonding for consumable characteristics (Lacoite, 2016), as shown in Table 2.

Table 2: Proximate composition of soft cheeses similar to Chami

Cheese	Moisture (%)	Protein (%)	Fat (%)	Ash (%)	NaCl (%)	Lactose (%)	Reference
Feta	48–54	25.1	6.5–8	-	4–5	-	Robinson & Tamime, 1991 Pitso *et al*. 1991
Jeben	62.5	15.8	16.5	-	-	4.1	Benkerrouma & Tamime, 2004
Cottage cheeses	60–80	11-21	10	3.7–5.4	2.3–3.5	4.5	Dhuol & Hamid, 2013 Boikhutso, 2010
Wara	70.8	6.2	2.2–2.9	20.5	3.4	1.4	Oladipo and Jadesimi, 2012 Omotosho *et al*. 2011

1.3.5 Texture and Rheological Properties of Soft Cheeses

The texture of feta cheese changes the optimum ratio of fat to casein of feta cheese milk is altered. The texture of feta cheese was described as rubber-like (Pitso, 1991). The texture of cottage cheese is a smooth or chunky texture and is plain or combined with additives such herbs. The high moisture content of cheese gives it a smooth or chunky texture. Moreover, cheese texture is smooth in the absence of rennet or chunky with renneted firmer curds. The texture of cheeses differ with varying fat contents. Skim milk cheeses have higher protein contents compared to full-fat cheeses. Cottage cheeses exhibit properties such as white color, soft body, smooth texture, good spreadability, no signs of syneresis on the cheese surface, no dryness or grittiness, and mild to acidic flavor (Boikhutso, 2010). Salting and drainage time affect the properties of Jeben cheese. Fats and proteins are the main factors affecting the firm consistency of cheeses (Benyagoub *et al*., 2016). The texture of fresh Wara cheese is jiggly, soft, and quite delicate and can be disrupted by slight pressure (Hiya, 2016).

1.3.6 Texture and Sensory Properties of Soft Cheese

Most full-fat cream cheeses have higher values of hardness as measured by spreading ability compared to fat-free cheeses. Sensory analysis showed that full-fat cream cheeses were firmer, more difficult to dissolve and spread, more cohesive, and had a lesser ability to stick than fat-free cheeses. The greater hardness of full-fat cream cheese indicates a higher fat content because after homogenization of the cream cheese mix, fat globules are covered with casein and aggregate with the casein particles, reinforcing the structure of soft cheese (Brighenti *et al*., 2008).

1.3.7 Rheological Properties of Soft Cheese

Rheological properties of soft cheese must be determined to improve the textural qualities. Most full-fat cream cheeses show significantly higher G' values than fat-free cheeses at temperatures below 25°C during the heating cycle. Both full-fat cream and fat-free cheeses exhibit sharply decreased G' values during heating up to 40°C (Brighenti *et al.*, 2008). Thermosonication reduces the fat gobules in milk to increase the yield of soft cheese. Thermosonication of purified milk enhances the thermostability of soft cheese and prevents contamination by pathogens. In contrast, combinations of ultrasound technology may be useful for maintaining the rheological texture of soft cheese.

1.3.8 Microbiology of Soft Cheeses Similar to Chami

Microbiology analysis of feta cheese revealed non-starter LAB in the *Lactobacillus paracasei* ssp. including *Lactobacillus paracasei* and *Lactobacillus plantarum.* Strains of *Debaryomyces hansenii* were isolated from the brine, and both yeasts and the lactobacilli possessed enzymes that degrade fat or protein (Bintsis *et al*., 2000).

During fermentation of the soft cheese Jeben, some pathogens were detected, including species of *Listeria monocytogenes*, *Salmonella*, *Yersinia enterocolitica*, and *Staphylococcus aureus.* Although data regarding the incidence of staphylococcal infections from Jeben are not available. Type C enterotoxins were isolated from two of 30 Jeben samples (Hamama *et al*., 1989; Benkerrouma & Tamime, 2004). The total amount of LAB in Jeben samples was 10^8–10^9 CFU/g and mainly belonged to *L. lactis subsp. lactis*, *Leuconostoc mesenteroides* subsp. *lactis*, and *Lactobacillus casei* subsp. *casei*. Overall, a low number of lactobacilli was found in Jeben, while another genus of

LAB was present at high numbers. Moreover, the average counts of yeasts and molds were higher than 10^6 CFU/g (Benkerrouma & Tamime, 2004). Cottage cheese can be contaminated by psychrotrophs, coliforms, yeasts, molds, and microbial enzyme degradation (Loralyn et al., 2009). The Wara product has also been reported to be contaminated with pathogens like *S. aureus* and *Salmonella* (Callon *et al*., 2010). These bacteria can cause many diseases such as foodborne infections and enteric (internal) infections (Adetunji *et al*., 2008). Moreover, some potential pathogens such as *Streptococcus infantarius* subsp. *infantarius* were reported to be present in Wara.

Microbes were found in samples produced and stored without the use of refrigeration and heat treatments to eliminate microorganisms (Haddad, 2017). The milk could even trigger bacterial growth, whereas most microorganisms were LAB that can form the flora flesh of microbial cheese which is completely safe for human consumption. High levels of *Enterobacteriaceae* is related to fecal levels contaminating soft cheese, which create breeding conditions for pathogens and protozoa. *Aureus* should be separated from soft cheese to prevent contamination and ensure safety. The high amount of moisture in soft cheese limits its shelf life, increasing the probability of spoilage by microbial components (Almanza-Rubio, 2016). The presence of *Brucella* in soft cheese is related to the salt concentration and is higher in salted cheese, preventing contamination.

Chapter 2: Materials and Methods

2.1 Chemicals and Reagents

Boron trifluoride for fatty acid methylation, fatty acid standards for gas chromatography analysis, potassium hydroxide for saponification, sodium hydroxide and phenolphthalein for titration, and all other reagents were of analytical grade and were purchased from Sigma (St. Louis, MO, USA). Microbiological media (Violet Red Bile Agar (VRBA), Baird Parker Agar (BPA), deMan, Rogosa, Sharpe (MRS) Agar, and Rose Bengal Chloramphenicol Agar (RBCA) were purchased from Hi-Media (Mumbai, India).

2.2 Chami Cheese Samples

Ten commercial Chami samples were obtained from different suppliers in different Emirates (Abu Dhabi, Al Ain, Sharjah, and Fujairah). The samples were stored at -18℃ during the study period. The physicochemical and microbiological properties of these samples were evaluated as described below.

2.3 Proximate Composition

Chami cheese samples were homogenized with a mortar and pestle and analyzed for their proximate composition (fat content, total protein content, moisture, and ash) using the AOAC method (AOAC, 2000).

2.4 Fatty Acid Composition

Fatty acid methyl esters (FAME) were prepared from the extracted fat in four steps: saponification and esterification, extraction of FAMEs, washing the FAMEs with water, and drying of the FAMEs. Samples (10 mg) of the fat sample were placed into a reaction vial with 0.5 N alcoholic potassium hydroxide (1 mL), and the vial was sealed and placed in a hot oven at 100°C for 10 min to achieve saponification of the sample. The vial was cooled and BF_3 reagent (2 mL) was added, after which the vial was sealed and heated again for 10–15 min. The vial was cooled to room temperature and FAMEs were extracted twice in heptane (1 mL). The heptane extract was washed with water (1 mL) twice and then dried using anhydrous Na_2SO_4. The extract was concentrated to 0.5 mL and transferred to a clean GC vial for injection into the gas chromatograph (6500GC System, YL Instrument Co., Gyeonggi-do, Korea). The injection volume was 1 mL and the injector was set to 240°C in split mode (1:10). Separations were performed on a Varian Capillary column (50 m × 0.25 mm × 0.2 μm i.d., #CP7488, Palo Alto, CA, USA) programmed as follows: 80°C (2 min), 5°C/min, 190°C (5 min), 2°C/min, 210°C (5 min), 10°C/min, and 240°C (5 min). Helium was used as a carrier gas at a flow rate of 1.5 mL/min. Peaks were detected using a flame ionization detector set to 300°C and data were processed using software (YL-Clarity, Kunash Instruments, Mumbai, India). Khoury identification of peaks and method validation were conducted using Certified Reference Material (soya-maize oil).

2.5 pH and Titratable Acidity

The pH of homogenized Chami samples was measured using a pH meter (OHAUS Model®Starter 3100, Parsippany, NJ, USA). The titratable acidity of the samples was determined using a standard method by titrating the samples against sodium hydroxide (0.1 N) and phenolphthalein as an indicator. Titration acidity was determined using the following formula:

$$\text{Titratable acidity} = \frac{9 \times \text{volume of NaOH (mL)} \times \text{normality of NaOH}}{\text{Weight of sample (g)}}$$

2.6 Mineral Analysis

Mineral analysis was performed using an inductively coupled optical emission spectrometer (ICP-OES) that performs axial and radial view analysis simultaneously (model 710-Es, Varian). A microwave-accelerated reaction system (model Marrs 5, CEM Corporation, Matthews, NC, USA) was used to digest the samples by adding 10 mL of concentrated nitric acid (70% HNO_3) and 2 mL hydrochloric acid (37% HCl) in a closed vessel. After dissolution, the solutions was cooled and the volume was brought to 50 mL in a volumetric flask. After cooling, the vessel contents were filtered before analysis by ICP-OES.

2.7 Water Activity

The water activity of the different Chami samples was measured for homogenized samples at 20 ± 1°C using a pre-calibrated water activity-meter (Model: HC2-AW, Rotronic Instrument Corp., Hauppauge, NY, USA).

2.8 Differential Scanning Calorimetry (DSC)

The glass-transition temperature (T_g) and thermal behavior of homogenized Chami samples were measured by differential scanning calorimetry (DSC) (TA Instruments Q100, New Castle, DE, USA). A heat-cool-heat temperature programming protocol was used in DSC experiments to assess the behavior of Chami samples. The first heating step was conducted at 5°C/min, cooling was conducted at −30°C/min, and final heating was performed at 70°C/min. A heating rate of 5°C/min was chosen. The heating program was a conventional temperature ramp from −30°C to 70°C, as the expected thermal events (glass transition temperature and the melting point of fat are within this temperature range (Hjalmarsson, 2015).

2.9 Texture Profile Analysis

Instrumental texture profile analysis parameters were determined using a computerized TA-CT-PRO-AY, CT3 Texture Analyzer (Stable Microsystems, Surrey, UK) utilizing two cycles of compression-decompression. The load cell of measurement was up to 50 kg. The Chami sample (25 g) added to a cup. The instrument was set to zero before each measurement and compression mode was used for textural analysis. The texture profile analysis parameters were determined from force-time curves depending on the following attributes: peak force of the first compression cycle 1 (N); peak force of the second compression cycle 2 (N); adhesive forces; resilience, springiness, fracturability (N), cohesiveness, chewiness, and gumminess (Hjalmarsson, 2015).

2.10 Rheological Properties

Rheological measurements were performed using a DHR-2 hybrid rheometer (TA Instruments Ltd.). A representative portion of each sample was carefully removed and placed on the bottom plate of the rheometer. The top plate was slowly moved down until the space was 1 mm and excess sample was removed from the edges of the plate. The oscillatory trails were carried out with a frequency ranging from 0.01 to 10 Hz, with the same deformation (1%). The storage modulus (G’) and loss modulus (G’’) were recorded as a function of frequency. The temperature was set to 10°C during the tests.

2.11 Microbiological Examination

Chami samples were evaluated for their microbiological quality using plate count agar, coliforms count using VRBA, *S. aureus* by BPA, LAB by MRS agar, and yeast and mold by RBCA. For this, 10 g of Chami sample was aseptically transferred to a flask containing 90 mL sterile peptone water to prepare a 10^{-1} dilution. A series of dilutions was prepared by transferring 1 mL from each dilution into sterile test tubes containing 9 mL sterile peptone water to prepare dilutions of up to 10^{-9} (Harrigan, 1998).

The bacterial coliform count was determined using VRBA with the pour plating technique and plates were incubated at 37°C for 24 h (AOAC, 1995). Yeasts and molds counts were determined by RBCA with the spread plating technique, and the plates were incubated at 25°C for 5 days (AOAC, 1995). LAB were determined using MRS agar after incubation at 37°C for 48 h (Ramamoorthi *et al*., 2014). Isolation and differentiation of coagulase-positive staphylococci in Chami samples were carried out by BPA. The plates were incubated at 37°C for 48 h (Roberson *et al*., 1992). Chami samples were tested for the presence of *Salmonella* spp. and *Listeria* spp. using standard protocols (ISO 6579:2002 and ISO 11290-1:1996/1:2004). Bacterial counts are presented as log CFU/g in the Chami samples.

2.12 Statistical Analysis

All experiments were independently performed in either duplicate or triplicate. All data were expressed as a mean value or mean standard deviation. The differences in physicochemical properties of commercial Chami samples were analyzed by one-way analysis of variance. These data were analyzed using the Excel program. Pearson correlation was also determined. The data have been attached to the research report.

Chapter 3: Results and Discussion

3.1 Chami Cheese

Statistics regarding the dietary use of dairy products before the discovery of oil in 1976 informed revealed that total milk products from all sources were 15,300 tons, of which 3,500 tons were processed in the UAE. These products were consumed as fresh milk by humans or livestock (Philip, 2011). Chami is a traditional food made from fermented milk from goat, sheep, cow, and camel at the household level in the United Arab Emirates. It has a similar consistency to Jameed, a fresh cottage cheese in which the curd has been drained (Yasin & Shalaby, 2013), Petit Suisse cheese with a weak gel characteristic, or traditional homemade fresh goat cheese. Iqt is a product made by further dehydration of Chami, which results in a very dry product that can be stored and used for long periods and transported long distances. "Iqt" is consumed after soaking in water for at least 20 min. Local people prefer to eat Chami with date fruit, rice, and bread. Additionally, ghee or clarified butter may be added to Chami to enhance its taste. The production of Chami, as that of many other traditional fermented milk products, relies on spontaneous fermentation at the household level. Chami is poorly studied and requires extensive, physical, chemical, microbiological, and sensory characterization to enable the development of a favorable flavor profile and viable product that can be commercialized. Many parameters and variations must be measured, controlled, and evaluated to determine the optimum conditions for Chami production and develop a consistent method for scale-up. To expand and maintain the market of traditional food products, studies are needed to improve the quality, safety, and convenience of these foods. No studies have examined the chemical, physical, and microbiological properties of Chami.

During the preparation of this thesis draft, Alain Dairy Company began producing and commercializing fresh Chami using pasteurized full-cream milk and dairy culture supplemented with vitamins A and D. The advised shelf-life of the cheese at 0–4°C is 13 days. The components of this Chami cheese are fat (6 g/100 g), protein (6.6 g/100 g), and carbohydrate (8.8 g/100 g). No further information is available regarding this cheese.

3.2 Survey of Chami Cheeses

A study was conducted to survey the opinions of 150 females aged 16–31 years from the 7 Emirates, although most subjects were from Abu Dhabi (79%), as shown in Table 3. The results of the survey (Table 4) revealed that 75% of the participants prefer to consume Chami cheese on special occasions. Approximately 58% of the participants stated that the mother makes the Chami product at home, and 70% of the participants said that their family members enjoy consuming Chami cheese. The type and source of milk used to produce Chami was mostly full-fat cow milk. Different types of additives are used to make Chami, including salt, herbs, and ghee. The survey indicated that 69% of producers separate the fat and coagulate the milk by using Laban and that 74% of families add salt to Chami to enhance its taste. The whey is separated from the curd by centrifugation, sieving, or other means, with sieving as the preferred method. Most participants said that the product was edible/fresh for 1 week and that they stored Chami in the refrigerator. The participants reported the detection of spoilage of Chami by changes in its smell, taste, appearance, and color.

Table 3: Socio-demographic characteristics of 150 females who participated in the survey

Variable	Metric	Frequency	Percent (%)
Age (years)	16–20	58	39
	21–24	86	57
	≥25	4	4
Emirate of residence	Abu Dhabi	119	79
	Ras Al Khaimah	9	6
	Dubai	8	5
	Ajman	7	5
	Um Al Quwain	3	2
	Sharjah	2	1
	Fujairah	2	1

Table 4: Knowledge, experience, and attitude towards "Chami" production

Variable	Metric	Frequency	Percent (%)
How often do you consume Chami?	Daily	4	3
	Weekly	33	22
	Occasionally	113	75
What type of milk used to produce Chami?	Full-fat	124	83
	Skimmed	25	17
	Semi-skimmed	1	1
Source of milk used to produce Chami	Cow	122	81
	Camel	10	7
	Goat	18	12
Who makes or knows how to make Chami in your family?	Mother	87	58
	Grandmother	39	26
	sister	13	9
Do all family members eat Chami?	None	11	7
	Yes	105	70
What types of additive do you use?	None	45	30
	Salt	111	74
	Herbs	8	5
	Ghee	20	13
	Other	11	7
How do you coagulate?	Laban	103	69
	Yoghurt	44	29
	Other	3	2
How do you separate fat?	Centrifuge	103	69
	Washing machine	36	24
	Other	11	7
How do you separate whey?	Washing machine	56	37
	Sieving	80	53
	Other	14	9
How do you store Chami?	Room temperature	41	27
	Refrigerator	102	68
	Freezer	7	5
How long will the product be edible/fresh?	Unsure	11	7
	1–2	41	27
	3–4 days	30	20
	One week	63	42
	More than one week	5	3
How do you know if it is spoiled?	Unsure	8	5
	Smell	79	53
	Taste	29	19
	Color	18	12
	Appearance	16	11

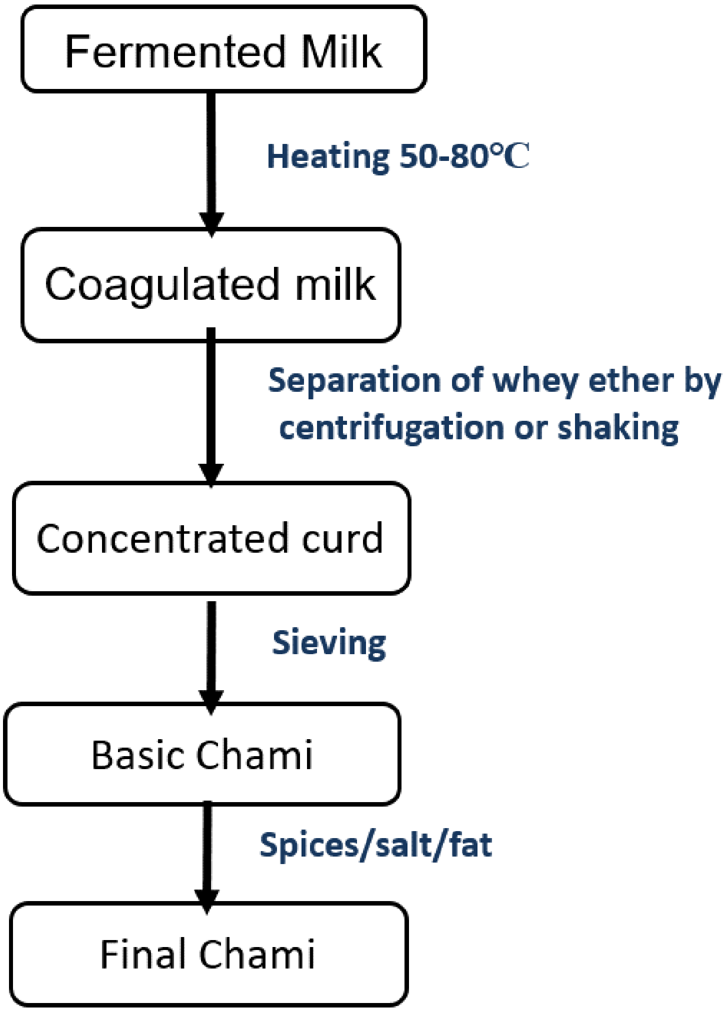

Figure 4: Flow chart of Chami processing

3.3 Proximate Composition of Chami Cheeses

The chemical composition of the analyzed Chami cheeses, presented in Table 5, showed the following ranges: moisture (60.9–84.1%), protein (7.5–14.6%), fat (0.5–7.8%), ash (3.4–8.0%), pH (3.6–4.4), acidity (0.033–0.144), and water activity (0.1–0.1). These values are comparable to other cheeses, such as cream cheese and pasteurized white cheese (feta with palm oil), which have moisture contents of 60% and cottage cheese which has moisture content of approximately 80% moisture (Yasin & Shalaby, 2013). The range of protein content in the Chami cheeses is comparable to those reported for other soft cheeses (11.2–21.4%) (Dhuol & Hamid, 2013; Yasin & Shalaby, 2013), Wara cheese (11.3%) (Oladipo and Jadesimi, 2012), and Jeben cheese (15.8%) (Benkerroum & Tamime, 2004). The range of fat content reported in the literature is 0.4–5.3% for cottage cheese (Yasin & Shalaby, 2013) and 1% for Wara cheeses (Oladipo and Jadesimi, 2012). The ash content of Chami cheeses is also comparable to those of other soft cheeses, such as cream cheese (7%) (Yasin & Shalaby, 2013) and cottage cheese (8.0%) (Yasin & Shalaby, 2013). Jeben cheese were reported to have an ash content of 4.2–4.5% (Benkerrouma & Tamime, 2004) and fresh cheese was 4.5–6.5% (Jesus *et al*., 2016). The titratable acidity of Chami is also comparable to those of other cheeses, particularly Jeben (Mazahreh *et al*., 2008; Yasin & Shalaby, 2013). The Chami cheese samples showed similar water activity values comparable as soft camembert cheese (0.987–0.910).

3.4 Fatty Acids

Table 6 shows that the fatty acid composition of seven Chami cheese included C: 4 to C: 12 fatty acids, which is similar to that of cow milk fat (Frelich *et al*., 2009).The myristic acid (C14: 0) content of Chami cheeses was 5.2–10%, while that for cow milk fat was 9.2–10.5% (Frelich *et al*., 2009). The palmitic acid (C: 16) content in Chami cheeses ranged between 21.3–35.1%, while the range for cow milk fat was 25.4–30.2% (Frelich *et al*., 2009). The oleic acid (C18: 1) content of Chami cheeses was 22.4–28.1%, which is higher than that reported for cow milk fat (3.1–5.5%) (Frelich *et al*., 2009). The highest relative percentages of (C18: 1) and (C18: 2) were 28.1% and 20.2%, respectively, in sample no. 4, indicating the addition of vegetable oil (Frelich *et al*., 2009).

Table 5: Major compositional characteristics of studied Chami cheeses

Sample	**Moisture (%)**	**Protein (%)**	**Fat (%)**	**Ash (%)**	**pH**	**Acidity (%)**	**Water activity (%)**
1	83.3	8.5	1.0	5.2	4.33	0.1	0.985
2	60.9	14.6	7.8	6.7	4.29	0.1	0.985
3	74.9	10.5	1.0	7.3	4.02	0.1	0.987
4	81.1	10.0	0.8	6.6	4.02	0.1	0.990
5	81.7	8.2	1.0	6.5	3.75	0.1	0.988
6	72.8	12.5	2.1	8.0	4.51	0.0	0.977
7	80.9	11.3	1.0	5.1	3.64	0.0	0.981
8	79.3	7.5	6.8	3.4	4.06	0.0	0.985
9	76.9	12.7	0.5	7.2	4.04	0.1	0.993
10	84.1	8.9	0.5	5.2	4.44	0.0	0.985
Range	60.9–84.1	8.2–14.6	0.5–7.8	5.1–8.0	3.64–4.44	0.0–0.1	0.977–0.993
Mean	77.6	10.4	2.3	6.1	4.1	0.0	0.9856
SD	6.5	2.3	2.6	1.4	0.3	0.0	0.0

Table 6: Fatty acid composition of Chami cheeses (relative %)

Fatty acids	2	3	4	5	6	7	10
C6:0	0.8	0.1	3	1	0.1	0.1	0.2
C8:0	0.7	1.1	0.1	0.9	0.9	1.1	0.1
C10:0	1.9	1.5	1.6	2.1	2.1	1.5	2.0
C11:0	N.D.	N.D.	N.D.	0.1	0.1	N.D.	0.1
C12:0	2.5	2.4	1.7	2.7	2.7	2.3	2.9
C14:0	10	8.9	5.2	9.5	9.4	8.9	10
C14:1	0.9	0.6	N.D.	0.7	0.7	0.6	0.5
C15:0	1.1	1.9	0.7	1.0	1.0	1.9	1.1
C15:1	0.1	0.1	N.D.	N.D.	N.D.	0.1	N.D.
C16:0	35.1	32.7	21.3	34.5	34.5	32.7	36.2
C16:1	2.0	1.6	1.5	1.5	1.5	1.6	1.3
C17:0	0.8	0.4	0.9	0.9	0.9	0.4	0.5
C17:1	0.4	0.5	0.6	0.4	0.4	0.5	0.3
C18:0	10.3	9.1	7.4	10.6	10.6	9.1	10.1
C18:1	23.2	22.4	28.1	25.2	24.7	23.4	24.6
C18:2	8	9.7	20.2	8	8	9.7	5.6
C20:0	0.6	0.9	0.1	0.5	0.5	0.9	0.3
C18:3	0.5	0.4	0.7	0.3	0.2	0.4	0.3
C20:1n9	N.D.	0.5	0.3	0.1	0.1	0.5	N.D.
C21:0	N.D.	0.7	N.D.	0.3	0.3	0.7	0.9
Others	2%	4.5	8.2	0.6	2.3	3.6	2.4

N.D. = Not detected

3.5 Minerals

Table 7 presents the level of minerals in the 10 Chami samples including calcium (Ca), potassium (K), magnesium (Mg), sodium (Na), phosphorous (P), sulfur (S), iron (Fe), manganese (Mn), and zinc (Zn). The sodium content in the 10 cheese samples was 223–2410 mg/kg, with three samples showing very high contents (1756, 2024, 2410 mg/kg), suggesting that NaCl was added during the production of these cheese samples. The addition of NaCl to cheese impacts the taste and texture of the cheese. Additionally, salt plays a very important role in preserving cheese and inhibiting the growth of spoilage bacteria. However, sodium (Na) and potassium (K) contents of the soft white cheese were similar (Dhuol & Hamid, 2013). The pH causes changes that lead to the movement of minerals from the center to the external layer of a cheese block or vice versa (Kwak, 2011), The coagulation method of cheese curd is impacted if the calcium in the milk is not in equilibrium. Bound phosphate is found in two forms, one as bound organic phosphate and the another as bound inorganic phosphate, which depends on the covalent attachment of phosphate with casein (Kwak, 2011).

Table 7: Mineral contents in Chami samples (mg/kg)

Sample	Na	K	Ca	Mg	Fe	Zn	P	S
1	389	1008	1213	100	2	5	1530	1081
2	2411	988	944	86	2	1.8	1603	1291
3	447	865	942	87	2	5	1213	772
4	668	864	1218	94	2	5	1426	910
5	223	695	812	76	2	7	1297	1009
6	263	816	959	87	1	7	1578	1214
7	2024	671	970	92	2	5	2018	1437
8	385	833	833	84	2	4	985	541
9	1756	736	736	83	1	4	1096	604
10	234	736	736	83	2	9	1481	1175
Range	223–2024	736–1008	736–1218	76–100	1–2	1.8–9	985–2018	541–1437
Mean	880	821.2	936.3	87.2	1.8	5.1	1422.7	1003.4
SD	841	115.0	171.0	7.0	0.4	2.0	295.0	296.0

3.6 DSC

The thermograms of three selected Chami samples evaluated by DSC are presented in Figure 5. DSC is used to study the melting characteristics of food samples.

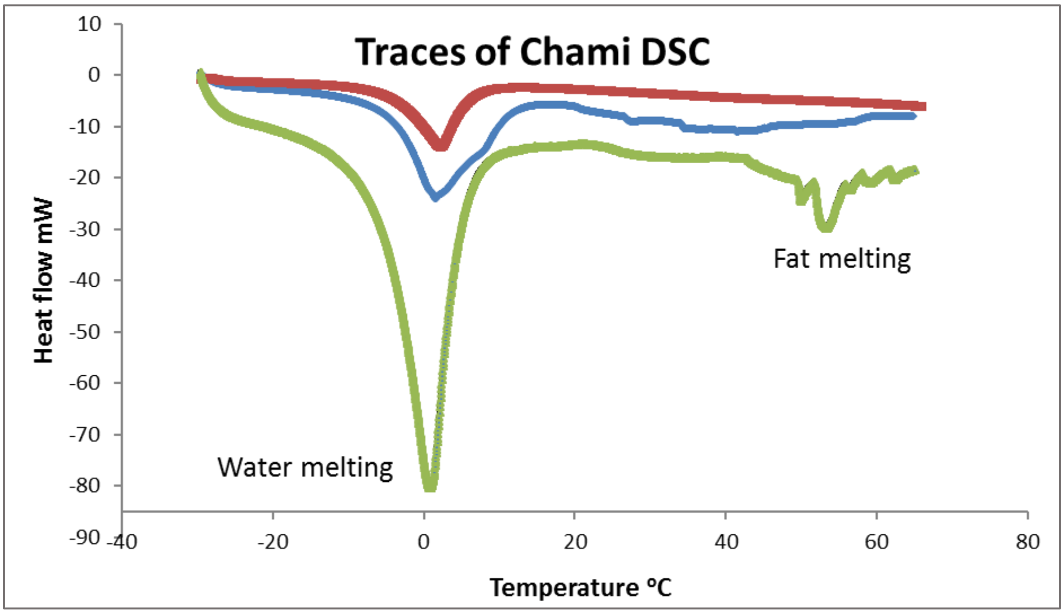

Figure 5: Differential scanning calorimetry (DSC) of Chami samples 9 (red), 8 (blue), and 2 (green)

According to Figure 5, all Chami samples showed a distinct peak at (0°C), which represents the melting point of ice water in the samples. Additionally, two samples (2 and 8) showed characteristic peaks associated with the melting temperature of fat. However, the peak sizes in one sample (6) were relatively smaller than those in other samples, which can be explained by its lower amount of fat. This result agrees with the findings of proximate composition analysis which showed that sample no. 1, 3, and 7 contained 1% fat. In contrast, sample no. 4, 9, and 10 showed values below 1%. Sample no. 6 contained 2.1% fat. Both sample no. 2 and 8 showed higher values compared to the others with values of 7.8% and 6.8%, respectively (Figure 5). The fat in sample no. 3 Chami sample had a higher melting point than the fat in sample no. 6 Chami, indicating that the added fats had different fatty acid compositions.

3.7 Texture Profile Analysis

A typical texture profile for the Chami cheeses is presented in Tables 9 shows that hardness cycles 1 and 2 were comparable, which is in accordance with the soft nature of the cheese. Hardness cycles 1 and 2 are highly correlated ($r = 0.970$, $p < 0.05$) and showed high and significantly correlations with respect to fracturability, gumminess, and chewiness (Table 10). At a higher hardness, a larger force is needed to resist deformation. The mean chewiness value of sliced cheese was 45%. A suitable chewiness provides a rich mouthfeel and enhances the taste of cheese (Zheng *et al*, 2016). Cohesiveness showed a weak negative correlation with gumminess and chewiness, which agrees with previous findings (Zheng *et al*, 2016) (Table 10).

Principal component analysis (PCA) transforms an initial set of factors describing a massive experimental data in a set of new factors, with each new factor showing a linear combination of the old factors. PCA of the texture profile of Chami cheese (Table 11) showed that three principal components (PCs) explained 97.3% of the variation: PC1 (65.85%), PC2 (22.95%), and PC3 (8.49%). In Figure 6, the scree plot shows the contribution of 9 principal components to the overall variability and the biplot displays the score and loading plots along PC1 and PC2, explaining 88.8% of the variance. Hardness cycle 1, hardness cycle 2, cohesiveness, chewiness, fracturability, and resilience were separated from adhesiveness and springiness along PC1, while PC2 separates cohesiveness, resilience, and springiness from the other parameters. As shown in Figure 7, the 10 samples showed variation in texture descriptors with some samples showing cohesiveness/resilience (sample no. 6 and 8), hardness, chewiness, gumminess, and fracturability (sample no. 3 and 2), adhesiveness (sample no. 1, 4, and 10), and springiness (sample no. 7 and 9)

Table 8 shows that the value of hardness cycle 1 was larger than that of hardness cycle 2. Hardness cycle 1 is the maximum force during the first compression cycle (N), hardness cycle 2 is the maximum force during the second compression cycle (N), adhesive force is the maximum force required to separate the teeth after biting the sample (N), resilience the ratio of the negative area to the positive area of the first compression cycle (A2/A1), springiness is the ratio between the second and first compression distances (D2/D1), and fracturability is the load force of the first significant peak (N).

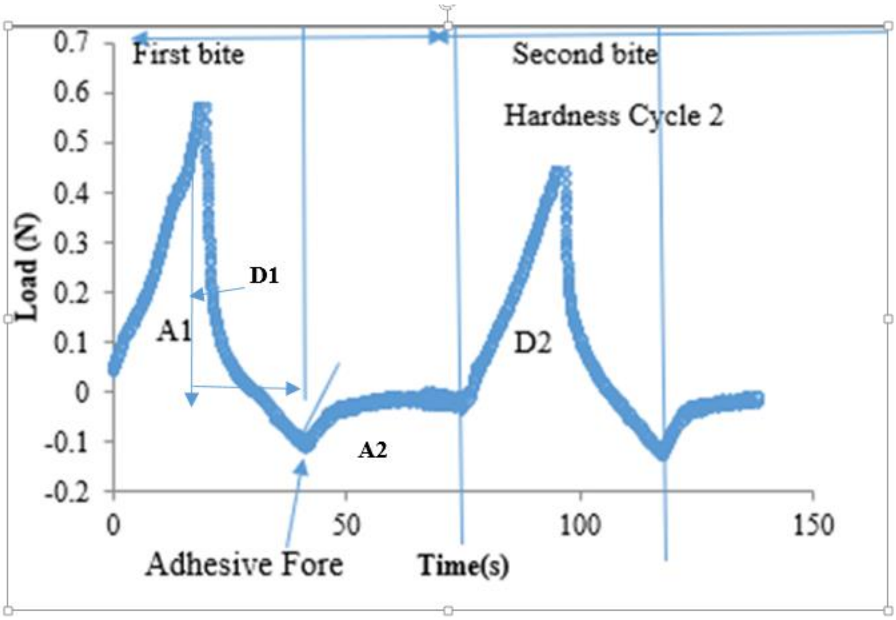

Figure 6: Typical texture profile of Chami cheese

(A1: First compression cycle, A2: Second compression cycle, D1: First compression distance, and D2: Second compression distance

Table 8: Definition of different texture attributes

Texture attributes	Definition
Hardness cycle 1	Peak force of the first compression cycle (N)
Hardness cycle 2	Peak force of the second compression cycle (N)
Springiness	Ratio of the second and first compression distances (D2/D1)
Fracturability	Load force of the first significant peak (N)
Cohesiveness	Degree to which the chewed mass sticks together
Adhesiveness	Degree to which the chewed mass sticks to the mouth surface; Adhesive force is the maximum force required to separate the teeth after biting the sample (N)
Chewiness	Product of hardness, cohesiveness, and springiness
Resilience	Ability of a substance or object to spring back into original shape (elasticity) measured as the ratio of the negative area to the positive area of the first compression cycle (A2/A1)

Source: Zheng *et al*, 2016

Table 9: Texture parameters of Chami samples

Sample	Hardness Cycle 1	Adhesiveness	Resilience	Fracturability	Hardness Cycle 2	Cohesiveness	Springiness	Gumminess	Chewiness
1	328	3.2	0.1	245	215	0.4	8.1	142	11.8
2	777	0.1	0.2	777	683	0.5	5.9	420	25.0
3	1166	0.3	0.2	1166	1030	0.5	4.8	603	36.2
4	423	1.8	0.1	391	174	0.5	5.1	193	12.1
5	133	0.9	0.1	33	117	0.6	7.4	77.3	5.7
6	632	0.1	0.3	632	572	0.6	6.3	383	25.0
7	409	0.1	0.2	340	368	0.6	6.5	246	16.0
8	510	0.3	0.2	438	466	0.6	6.3	304	18.8
9	458	0.1	0.2	458	407	0.5	4.1	220	12.0
10	632	0.1	0.3	632	572	0.6	6.3	383	25.0
Range	133–1166	0.1–3.2	0.1–0.3	33–1166	117–1030	0.4–0.6	4.8–8.1	77–603	5.7–36.2
Mean	521	0.68	0.2	479	437	0.5	6.2	281	17.7
SD	285	1.0	0.1	316	272	0.1	1.1	153	8.9

Table 10: T2 Pearson's correlation analysis of texture profile of Chami samples

Variables	Hardness Cycle 1	Adhesiveness	Resilience	Fracturability	Hardness Cycle 2	Cohesiveness	Springiness	Gumminess	Chewiness
Hardness Cycle 1	**1**								
Adhesiveness	-0.364	**1**							
Resilience	0.411	**-0.881**	**1**						
Fracturability	**0.996**	-0.380	0.423	**1**					
Hardness Cycle 2	**0.970**	-0.505	0.541	**0.963**	**1**				
Cohesiveness	-0.213	-0.578	0.594	-0.237	-0.055	**1**			
Springiness	**-0.638**	0.514	-0.370	**-0.674**	-0.563	0.266	**1**		
Gumminess	**0.981**	-0.484	0.555	**0.975**	**0.983**	-0.031	-0.594	**1**	
Chewiness	**0.968**	-0.412	0.530	**0.958**	**0.968**	-0.019	-0.504	**0.991**	**1**

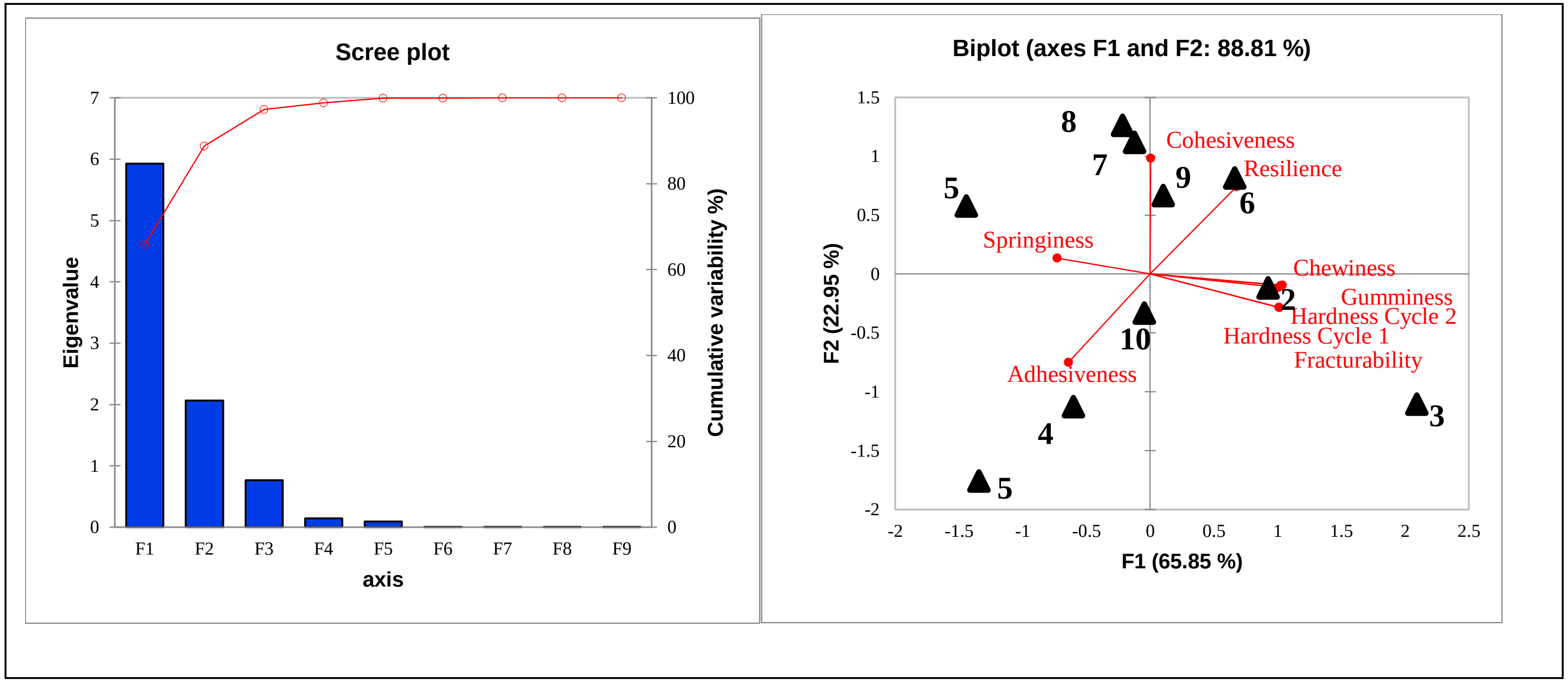

Figure 7: Principal component analysis of Chami cheese texture

The scree plot (left panel) shows the contribution of 9 principal components to the overall variability and the biplot displays the score and loading plots along PC1 and PC2 explaining 88.8% of the variance.

Table 11: Principal component analysis of texture profile

	F1	F2	F3	F4	F5	F6	F7	F8	F9
Eigenvalue	5.927	2.066	0.764	0.143	0.093	0.006	0.001	0.000	0.000
Variability (%)	65.852	22.953	8.489	1.590	1.031	0.063	0.014	0.005	0.002
Cumulative %	65.852	88.805	97.294	98.884	99.915	99.979	99.992	99.998	100.000

Cheese hardness is affected by the levels of moisture, proteins, fat, and salt in the product. In this set of cheese samples, hardness increased with decreased moisture content, as shown in figure 8.

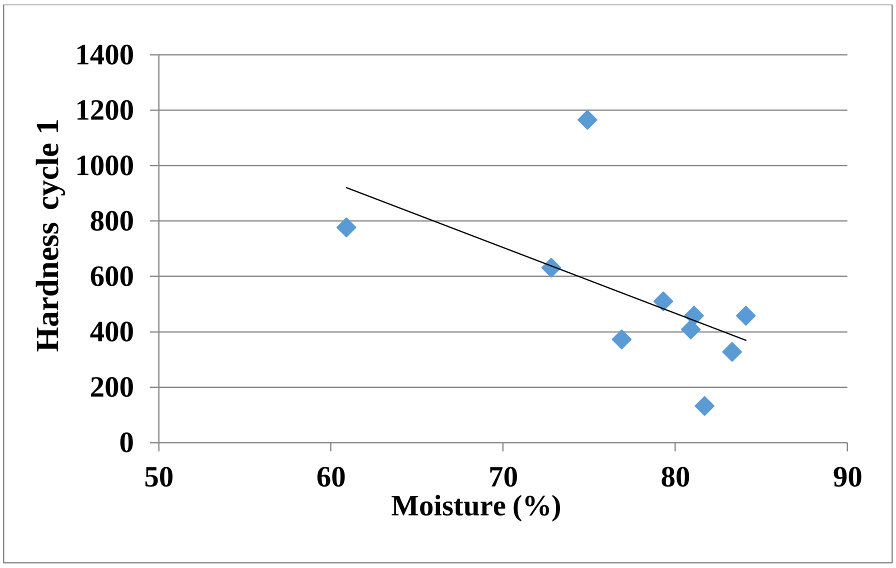

Figure 8: Correlation between hardness cycle 1 and moisture content

Cheese chewiness is negatively correlated with moisture content and positively correlated with the firmness of cheese products. In contrast, protein has a strong positive correlation with cheese hardness, chewiness, and gumminess, while fat content shows different correlations (Simoes *et al*., 2013). Low-fat cheese products show high chewiness values, while high-fat or high-moisture levels show reduced chewiness. Adhesiveness is also influenced by the fat content, which softens the cheese and leads to increased adhesiveness. Softening of feta cheese may occur because of the breakdown of casein (proteolysis) into small peptides and amino acids (Farbod *et al*., 2013). Fat content, particularly saturated fatty acids, is negatively correlated with resilience because the presence of fat in cheese leads to deformation of the product and a reduction in its resilience. A high NaCl content increases the possibility of Ca^{2+} replacement and reduces the firmness and resilience of cheese. A high moisture content can affect the gumminess, cohesiveness, and chewiness attributes (Simoes *et al*., 2013).

3.8. Rheological Analysis

Rheological analysis was performed to assess the viscoelastic properties of Chami samples. A frequency sweep test was conducted from 0.01 to 10 Hz at a fixed strain of 1%. The values of storage modulus (elastic; G´), loss modulus (viscous; G´´), apparent viscosity (η), and tan delta (δ) were determined. The elastic modulus G´ was higher than loss modulus G´´ for all Chami samples (Table 12), which is expected for solid and semi-solid samples. This indicates that all Chami samples were more elastic structure than viscous. Considering that Chami is a soft cheese, in which the casein protein forms cross-linkages, this may explain the viscoelastic characteristic. As shown in the table, most Chami samples showed similar values for the parameters studied with few exceptions (Ayyash *et al.*, 2008). Table 12 shows that the range of elastic modulus G' was 40–300 kPa. The elastic modulus G of low-fat akawi cheeses was 17.1–34.5 kPa at day 0 (Ayyash *et al.*, 2008). The range of viscous modulus G was 9.7–101 kPa. The elastic modulus G of low-fat akawi cheeses was 4.3–8.2 kPa at day 0 (Ayyash *et al.*, 2008). Sample no. 8 and 9 had similar viscoelastic properties at a frequency of 1 Hz. The range of apparent viscosity was 5–55 kPa/s; the table also shows the Tan delta (δ), which is the ratio of the loss modulus/elastic modulus. It is widely thought that Tan delta values less than one indicate the dominance of elastic behavior (solid-like), while values higher than one suggest viscous–dominance (liquid-like). According to the values presented in the table, all values were less than one except for sample no. 3, revealing that all Chami samples have more elastic behavior.

Table 12: Viscoelastic properties of Chami at a fixed frequency of 1 Hz

Chami cheese samples	**Elastic modulus G´ (kPa)**	**Viscous modulus G´´ (kPa)**	**Apparent viscosity η (kPa.s)**	**Tan delta (δ)**
1	40	9.7	5	0.24
2	300	90	40	0.3
3	200	50	25	0.25
4	100	30	19	0.3
5	33	8.5	7	0.25
6	300	100	51	0.3
7	89	20	15	0.22
8	250	71	40	0.28
9	250	60	30	0.24
10	301	101	55	0.3
Range	33–301	8.5–101	5–200	0.22–0.35
Mean	186	56.0	46.2	0.278
SD	110.1	36.4	56.8	0.040

3.9 Microbiology of Chami Cheese

Chami samples were evaluated for their microbiological quality by measuring the coliform count, *S. aureus*, LAB count, and yeast and mold. The range of LAB in Chami samples was 6.5–9.1 log CFU/mL. The highest average LAB was 9.1 log CFU/mL for Chami sample no. 9. One of the most important groups of acid-producing bacteria in the food industry is LAB, which are used to make starter cultures for dairy products. Several authors have demonstrated the predominance of LAB in traditionally fermented milk products (Bartoli *et al*., 2015). These results confirm the predominance of LAB in traditionally fermented milk, as reported by other researchers (Bartoli *et al*., 2015 and Mathara *et al*., 2004). Feta cheeses contain non-starter lactic acid bacteria, *L. paracasei* ssp., and *Lactobacillus plantarum* (Bintsis *et al*., 2000). The total load of LAB in Jeben samples was 10^8–10^9 CFU/g) and mainly belonged to the *L. lactis* subsp. *lactis*, *L. mesenteroides* subsp. *Lactis*, and *L. casei* subsp. *casei*. Overall, a low presence of lactobacilli was observed in Jeben, while other genera of LAB were present in high numbers. Sample no. 2, 8, and 10 did not contain LAB. This may be because of the post-fermentation heating of the milk samples, which is a general step in the production of Chami. Post-fermentation heat shock may have eliminated the natural flora of LAB in these samples.

Table 13 shows that the range of yeast and mold of samples was 5.3–8.2 log CFU/mL. Both sample no. 8 and 9 showed higher values of yeast and molds compared to other samples with values of 8.2 and 7.9 log CFU/mL, respectively. Yeast and mold were not observed in Chami sample no. 2, 5, 6, and 10, but yeast was present. The presence of yeasts indicates contamination of the product by air, water, or unhygienic practices during preparation and/or transportation. However, it is also possible that these yeasts play a key role in flavor development in Chami.

As a result, shown in Table 13, the range of the *Staphylococcus* spp. was 5.2–6.8 log CFU/mL. Sample no. 6 and 7 had the same value of 4.7 CFU/mL. The Wara cheeses have contaminated with pathogens like *Staphylococcus* spp. (Callon *et al*., 2010). These bacteria can cause many diseases such as foodborne infections and enteric (internal) infections (Adetunji *et al*., 2008). Moreover, some potential pathogens such as *S. infantarius subsp. infantarius* have been reported in Wara (Adetunji et al. 2008). The predominance of foodborne pathogens in Chami samples indicates potential health risks for consumers and the need for hygienic and manufacturing interventions. *Staphylococcus* species were not detected in Chami sample no. 1, 4, 7, and 8.

Coliform bacteria were detected seven Chami samples (3, 4, and 6–10) with varying proportions, indicating a serious hygiene issue during preparation. The range of coliform bacteria was 5.2–6.9 log CFU/mL. Thus, various contaminations of raw milk may affect the LAB counts during fermentation because of limited growth or inhibition (Ahmed *et al*., 2010). Cottage cheese can become contaminated with coliforms that cause microbial enzymatic degradation. Pasteurization of milk by heat treatment would eliminate these pathogens and extend the shelf-life of the products (Harding, 1999). There were no counts in sample no. 8–10.

All 10 Chami cheese samples tested were positive for *Salmonella* and four samples (sample no. 4–7) were positive for *Listeria*. These results indicate that contamination of home-made and commercialized Chami cheese poses a concern to human health. Chami cheese is susceptible to microbial growth because of its high moisture content and high pH, which negatively affect its hygiene and shelf life. Microbial growth and activity in cheese is affected by many factors such as the storage period, storage temperature, salt content, pH, packaging material, and nutrient content. Thus, cottage cheeses typically have a short shelf life of 3–4 weeks under refrigeration conditions.

The shelf life of cottage cheese was determined by the presence of spoilage organisms, such as coliforms and psychrotrophic *Pseudomonas* spp. and metabolites produced by spoilage microorganisms coliforms are commonly associated with post-pasteurization contamination during cheese preparation. The spoilage microbes can grow at low pH values of 4.0 while LAB, yeasts, and molds can grow at pH values below 5.0 (Boikhutso, 2010). The optimum water activity ranged from 0.920 to 0.990 for the growth of microorganisms and pathogens (Boikhutso, 2010).

Listeria monocytogenes is sometimes associated with soft cheeses made from cow's or goat's milk, as it can survive and grow during storage. It is relevant primarily to cheeses produced from raw milk (Morgan *et al*., 2001). Goat's milk is also a source of a pathogens such as enterotoxigenic *S. aureus*, which can lead to disease in humans. (JaNštoVá *et al*., 2010).

Table 13: Microbiology of Chami samples (log CFU/mL)

Sample	LAB	Yeast & Molds	*Staphylococcus*	*Coliforms*	*Listeria*	*Salmonella*
1	6.5	5.3	N.D.	N.D.	-	+
2	N.D.	4.7	6.8	N.D.	-	+
3	8.3	N.D.	5.7	8.1	-	+
4	6.6	N.D.	N.D.	6.3	-	+
5	7.6	N.D.	4.7	N.D.	+	+
6	6.7	N.D.	4.7	5.2	+	+
7	6.5	6.5	N.D.	6.9	+	+
8	N.D.	8.2	N.D.	N.D.	-	+
9	9.1	7.9	5.2	N.D.	-	+
10	N.D.	N.D.	6.7	N.D.	+	+

N.D.: Not detected
+/-: Positive/negative for the presence of bacteria

Chapter 4: Conclusion and Recommendation

Chami is a traditional fermented soft cheese product in the UAE. The whey is separated by centrifuging, shaking, and boiling. Next, the concentrated curd is sieved over a cloth and may be combined with additives. Ten Chami cheeses were studied and showed comparable chemical compositions except for 3 samples with high salt and 2 samples with high fat contents. Hardness cycle 1 and hardness cycle 2 were highly correlated ($p < 0.05$). The range of elastic modulus G was 40–300 kPa. The range of viscous modulus G was 9.7–101 kPa. The range of apparent viscosity was 5–55 kPa/s. All values of Tan delta of the samples were less than one, except sample no. 3, indicating that all Chami samples showed elastic behavior. The opposite correlation was obtained for the hardness with moisture content of Chami samples.

Seven Chami samples contained LAB, five samples contained yeast and molds, 6 samples contained *Staphylococcus*, and 4 samples contained coliforms. The results of this study showed that all 10 Chami cheese samples tested were contaminated with *Salmonella* and four were contaminated with *Listeria*. This requires further attention and studies by food control authorities.

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