Egypt. J. Chem. Vol. 67, SI: M. R. Mahran, pp**. 1761 - 1771** (2024)

Egyptian Journal of Chemistry

http://ejchem.journals.ekb.eg/

Properties and quality of Mozzarella cheese made from cow's and goat's milk

Arafat Qabaha*, Mohamed Nagib, Ahmed Emam

Dairy Science Department, Faculty of Agriculture, Cairo University

Abstract

This study aimed to investigate the influence of milk type on the chemical, rheological, and sensory properties of Mozzarella cheese. Three cheese sample were manufactured from cow, goat and their mixture at 1:1. Fresh and stored cheese samples were analyzed for chemical, sensory, rheological, and structural properties using electron microscopy were studied when fresh and after stored at 5 ± 2C° for 30 days. The whey and kneading water from each treatment were also analyzed. The results showed that the loss of components in the whey and kneading water was higher for goat's milk cheese. Cow's milk cheese exhibited higher fat and protein retention compared to goat's milk cheese, resulting in improved meltability and lower fat separation. Blending the milk improved these properties in goat milk cheese. Goat's milk cheese had a denser protein matrix (observed by electron microscopy) and higher hardness, springiness, chewiness, and gumminess were compared to cow milk cheese. During storage, hardness, chewiness, and gumminess were decreased while springiness increased in all cheeses. Sensory evaluation indicated that cow's milk cheese received the highest scores for texture, structure, appearance, and flavor. These findings suggest that milk type significantly impacts Mozzarella cheese characteristics, adding cow's milk to goat's milk also improved the quality of the resulting cheese.

Keywords: Mozzarella cheese, cow's milk cheese, goat's milk cheese, physicochemical properties, rheological properties, electron microscopy, sensory properties..

1. Introduction

Mozzarella cheese is a product with a rich history that can be traced back to the abundance of water buffalo milk in Southern Italy. Initially, this cheese was crafted exclusively from the high-fat content of buffalo milk, but this tradition later expanded to include cow milk, which gained widespread acceptance among Italians [1]. However, the limited availability of buffalo milk in many regions has made cow milk the predominant choice for Mozzarella cheese production worldwide. Interestingly, in the Middle East, particularly in Syria, a variation of Mozzarella known as "El-Medaffarah" is predominantly crafted using ewe's milk, sometimes with the addition of goat's milk [2]. Belonging to the pasta filata family, Mozzarella cheese originates from the Battipaglia region of Italy [3]. As highlighted by [4]**,** Mozzarella possesses unique characteristics that set it apart. Its soft, typically white texture allows for easy and uniform distribution, complemented by a fibrous structure. Known for its exceptional melting and stretching capabilities, it offers a mild aroma and flavor profile. Commonly used in its melted state, Mozzarella is a popular choice, especially as a traditional pizza topping. While existing research has primarily focused on the production of Mozzarella cheese from cow's milk, with minimal attention given to the potential of goat and ewe milk as viable alternatives. Milk is widely regarded as a key agricultural product in Palestine, and the livestock industry is experiencing continuous growth in milk production. This increase can be attributed mainly to new dietary trends, a favorable climate, abundant agricultural lands, and water availability [5]. Goat and ewe farming, which are low-cost alternatives for dairy production, are widely practiced in Palestine, similar to that in developing countries [6]. Additionally, dairy cow farming has seen a notable shift towards large-scale, organized operations, leading to the establishment of numerous model farms throughout the region. Despite the widespread production of cheese from cow's milk, many countries are aiming to increase their output of unique cheeses and decrease imported quantities. In Palestine, the dairy industry primarily focuses on the production of fermented dairy products and soft white cheese from cow, ewes, and goat milk. However, hard and semi-hard cheeses are not locally produced and must be imported. The utilization of primitive and traditional methods for the production of soft white cheese leads to losses for farmers due to production loss. Despite its high demand, Mozzarella cheese has not yet been produced from goat milk, making it a potential commercial investment. We

*Corresponding author e-mail: arafatkabaha1976@gmail.com (Arafat Qabaha)
Receive Date: 19 May 2024, Revise Date: 09 June 2024, Accept Date: 20 June 2024
DOI: 10.21608/ejchem.2024.290974.9738

hope that our research will contribute to the development of a sustainable and profitable dairy industry in Palestine, and support the local production of high-quality Mozzarella cheese from goat milk using appropriate methods and techniques that align with available resources.

1. MATERIALS AND METHODS

Fresh cow's and goat's milk used for mozzarella cheese production were obtained from family farms in Ramallah, Palestine. As shown in Table 1, the analysis of the cow's and goat's milk used is provided. Calf rennet powder and the starter culture series DVS-TCC were purchased from Chr. Hansen's Laboratories in Denmark. Starter complex blend consists of thermophilic strains and *Lactobacillus bulgaricus*, imparting the finished cheese with a traditional Mediterranean type of pasta filata flavor. Lactic acid, fine grade calcium chloride, dry fine crystal salt, nisin 2.5% (E234), and natamycin (E-235) were all obtained from Sun pharm drug stores, in Palestine.

Cheese-making procedure:

Mozzarella cheese was produced using cow's and goat's milk following the method described by [7]. The process of manufacturing Mozzarella cheese through direct acidification involves lowering the pH using lactic acid. This technique aids in eliminating variability in acid production by bacteria, prevents issues caused by bacteriophages, slow starters, and other contaminants, provides better control over pH variations, and reduces manufacturing times. In the present study, the manufacturing process is provided in Figure 1. Three distinct cheese treatments were prepared using full-fat milk sourced from Palestine: Palestinian Cow milk (PCC), Palestinian Goat milk (PGC), and their mixture milk 1:1 cow’s milk: goat’s milk (PCGC). The resulted cheeses were analyzed for chemical composition, rheological properties, microstructure, and sensory characteristics, when fresh and after 30 days of storage at 5 ± 2°C.

Methods of analysis

pH values were measured using a digital meter (WTW 720, Germany) and electrode (SenTix 81, Germany). Fat, moisture, ash, lactose and water-soluble nitrogen content were determined according to [8]. Total nitrogen (TN) was determined by Kjeldahl methods according to [9]. Salt content according to the method described by a modified Volhard method [10]**.** Meltability and fat leakage (oiling off) were assessed according to [11]. Cheese microstructure was analyzed using Scanning Electron Microscopy (SEM) according to [12]**.** Textural properties were measured using a texture analyzer (TA. XT plus, Stable Micro Systems, UK) with probe A/BE-d40 on 30mm x 30mm cheese samples [13]. The organoleptic evaluation was done using a 100-point scoring system for flavor (50 points), body & texture (35 points), and appearance (15 points) by 10 well-trained panelists from the dairy science department, at Cairo University. Data were statistically analyzed using IBM SPSS Statistics 28 with the least significant difference (LSD) test for significance [14].

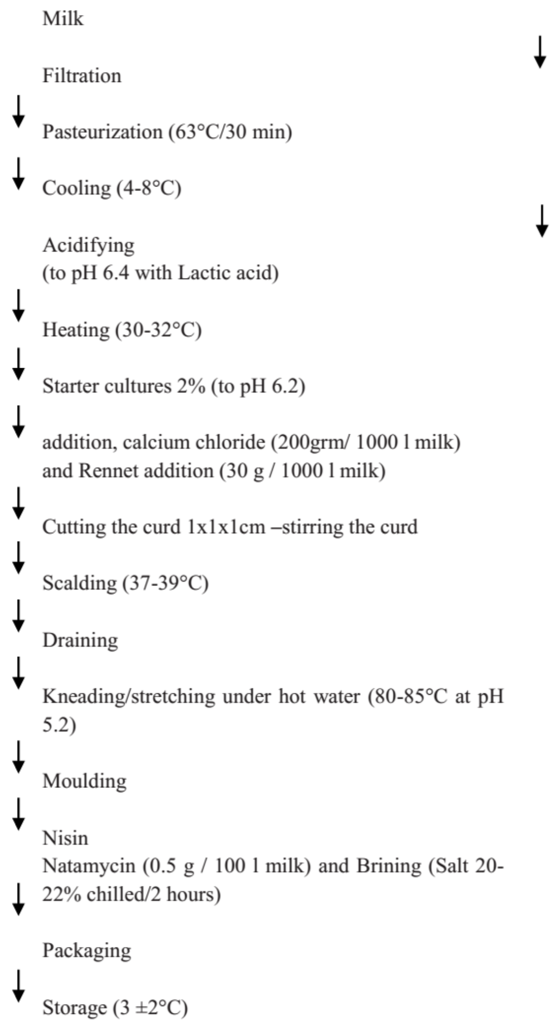

Figure (1): Flow chart of mozzarella cheese production.

2. RESULTS AND DISCUSSIONS

Chemical composition of cheese milk.

Table (1) summarizes the chemical composition of various cheese milk types, revealing significant differences were noticed in all milk components across the milk samples. Full-fat goat milk had the highest content of total solids, fat, and protein, and the lowest lactose content. This aligns with previous studies by [15, 16, 17]**,** which emphasizes the inherent compositional variations between different milk types. The observed discrepancies in total solids content within the treatments likely stem from the varying proportions of each milk type used in the treatments.

Table (1): Chemical composition of cheese milk.

Component %	Cow's milk	Goat's milk	Cow's and Goat's milk	Sig.	LSD
TS	$12.57^{c} \pm 0.05$	$12.97^{a} \pm0.02$	$12.79^{b} \pm0.03$	0.000****	0.06
Fat	$3.65^{c} \pm 0.04$	$4.19^{a} \pm 0.03$	$4.05^{b} \pm 0.02$	0.000****	0.06
Protein	$3.31^{c} \pm 0.03$	$3.53^{a} \pm 0.02$	$3.40^{b} \pm0.02$	0.000****	0.04
Lactose	$4.77^{a} \pm 0.01$	$4.22^{c} \pm0.02$	$4.44^{b} \pm0.04$	0.000****	0.05
Ash	$0.73^{b} \pm 0.01$	$0.77^{a} \pm0.02$	$0.78^{a} \pm0.01$	0.003**	0.02
Acidity	0.15 ±0.01	0.16 ±0.00	0.16 ±0.00	0.079 ns	0.01
pH	$6.67^{a} \pm0.01$	$6.60^{c} \pm0.00$	$6.62^{b} \pm0.00$	0.000****	0.01

ns= not significant ** $p \leq 0.01$ **** $p \leq 0.0001$; (a,b,c) Means having different superscript letters by row are ignificantly different ($P \leq 0.05$)

Effect of milk type on the chemical composition of cheese whey.

The chemical composition of cheese whey was analyzed after scalding the curd at 37-39°C for 50 minutes. As shown in (Table 2) a lower percentage of total solids and fat were noted in cow cheese whey compared to goat cheese whey. Notably, adding cow milk to goat milk (1:1 ratio) further reduced fat (27.1%) and protein (5.4%) loss compared to using goat milk alone. This suggests a potential synergy between cow and goat milk in minimizing losses during cheese making. The statistical analysis of whey cheese revealed significant differences in all measured parameters.

Our results were similar to [18]**,** who found that milk type and GDL use to influence whey composition. Our results showed higher fat content in goat cheese whey than cow chees whey. The total solids and protein content of the whey fell within the range reported by [19,20] for mozzarella cheese whey made with mixed milk.

Table (2): Chemical composition of cheese whey.

Component %	PCC	PGC	PCGC	Sig.	LSD
TS	$6.386^{c} \pm0.028$	$7.245^{a} \pm0.11$	$6.974^{b} \pm0.04$	0.000****	0.14
Fat	$0.680^{c} \pm2.70$	$1.557^{a} \pm 3.39$	$1.135^{b}\pm1.76$	0.000****	0.07
Protein)	$0.854^{b} \pm2.29$	$0.993^{a} \pm4.51$	$0.939^{a} \pm2.42$	0.012*	0.08
Lactose	$4.500^{a} \pm0.05$	$4.137^{c} \pm0.02$	$4.363^{b} \pm 0.05$	0.000****	0.08
Ash	$0.523^{b} \pm 0.01$	$0.613^{a} \pm0.01$	$0.577^{a} \pm0.04$	0.017*	0.05
Acidity	$0.340^{b} \pm 0.00$	$0.350^{a} \pm0.00$	$0.343^{b} \pm0.01$	0.027*	0,01
pH	$5.473^{a} \pm0.006$	$5.377^{c} \pm0.01$	$5.397^{b} \pm 0.02$	0.000****	0.02

* $p \leq 0.05$ **** $p \leq 0.0001$
PCC **=** Palestinian Cow milk PGC = Palestinian Goat milk PCGC = Palestinian cow and goat cheese in a 1:1 ratio; (a,b,c) Means having different superscript letters by row are significantly different ($P \leq 0.05$)

Impact of milk type on the chemical composition of cheese kneading water.

Table 3 presents the chemical composition of cheese kneading water. Significant variations in fat and total solids loss were noticed depending on the milk type. The analysis showed the highest loss of fat (0.975%) and total solids (1.228%) in cheese produced from goat milk. Cow milk cheese exhibited the lowest loss of fat (0.500%) and total solids (0.840%). This difference may be due to the smaller fat globules in goat milk (0.73 to 8.58m) than cow milk (0.92 to 15.75m). Interestingly, using a 1:1 blend of cow and goat milk significantly reduced component loss during kneading. Fat loss decreased by approximately 23.36% (from 0.957% to 0.735%), while total solids loss declined by 26.79% (from 1.228% to 0.900%). These findings suggest that combining cow and goat milk can improve cheese production efficiency by minimizing component loss during kneading.

Table (3): Chemical composition of kneading water.

kneading water Type	TS (%)	Fat (%)	Protein (%)
PCC	$0.840^{c} \pm 0.004$	$0.500^{c} \pm0.010$	$0.259^{c} \pm 0.007$
PGC	$1.228^{a} \pm 0.018$	$0.957^{a} \pm 0.045$	$0.331^{a}\pm 0.009$
PCGC	$0.900^{b} \pm 0.005$	$0.735^{b} \pm 0.023$	$0.298^{b} \pm 0.018$
Sig.	0.000****	0.000****	0.001***
LSD	0.02	0.06	0.02

*** $p \leq 0.001$ **** $p \leq 0.0001$
PCC **=** Palestinian Cow milk PGC = Palestinian Goat milk PCGC = Palestinian cow and goat cheese in a 1:1 ratio; (a,b,c) Means having different superscript letters by column are significantly different ($P \leq 0.05$).

Impact of milk type on fat and protein recovery in Mozzarella cheese.

Figures 2 and 3 illustrate the diverse fat and protein recovery in Mozzarella cheese derived from different milk types. It is clear that the cheese made from goat milk exhibited the lowest fat and protein retention rate (38.59 and 73.26 %, respectively), while cow milk cheese showed the highest (70.4 and 74.8%, respectively). Incorporating cow's milk with goat milk increased fat recovery to 47.7% (a 22.9% increase). Protein recovery was not significantly affected by the addition process. These findings align with [20].

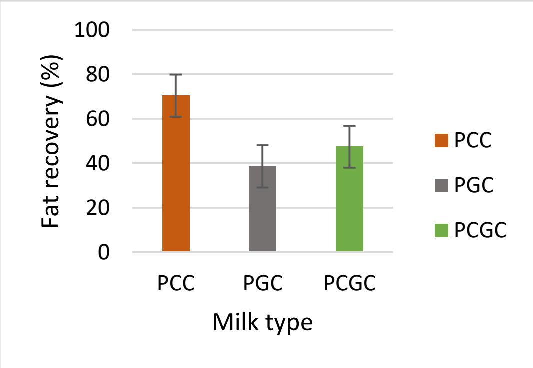

Figure (2): Impact of milk type on the fat recovery of cheese.

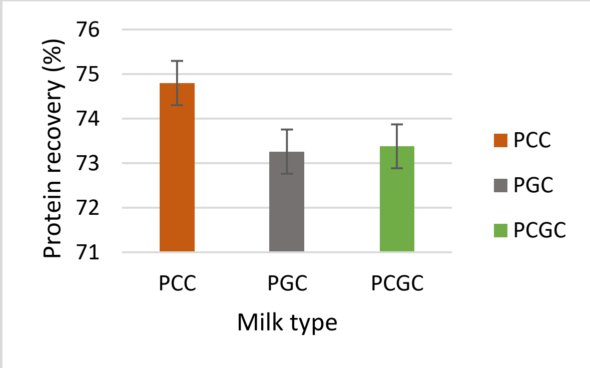

Figure (3): Impact of milk type on the protein recovery of cheese.

Effect of milk type on the cheese actual yield.

Optimizing yield is crucial for economic efficiency in various industries. **Table 4** highlights the impact of milk type on cheese yield. Goat milk cheese exhibiting the lowest and significant yield due to higher component losses in whey (7.25%) and kneading water (1.228%) compared to cow milk cheese whey (6.39%) and kneading water (0.840%). This is according with [18,21]. Encouragingly, incorporating cow milk with goat milk led to a marked improvement in both actual and adjusted yields. Compared to using goat milk alone, adding cow milk increased the cheese yield by 5.4%. This finding is further supported by [20], who achieved a yield percentage of 11.63% for Mozzarella cheese made with a blend of cow and goat milk.

Table (4): Actual yield of Mozzarella cheese.

Milk Type	Actual Yield (%)
PCC	$11.12^{a} \pm 0.36$
PGC	$9.99^{b} \pm 0.63$
PCGC	$10.53^{ab} \pm 0.41$
Sig.	0.004**
LSD	0.84

** $P \leq 0.01$, PCC = Palestinian Cow milk PGC = Palestinian Goat milk PCGC = Palestinian cow and goat cheese in a 1:1 ratio

Impact of milk type on the chemical composition of Mozzarella cheese

The effects of milk type on the chemical composition, pH and titratable acidity of the resultant cheese are presented in Tables 4and5. While no significant differences in pH were observed (likely due to the kneading process standardizing pH around 5.2), titratable acidity levels varied significantly. Cow milk cheese exhibited the highest acidity (0.87%), followed by the blend (0.85%) and then goat milk cheese (0.73%). The typical pH range for making pasta filata cheeses like Cheddar, Oaxaca, and Mozzarella from various milks is between 4.9 and 5.8 [22,23]. These findings align with the observed pH values in this study. Similar results were observed by [24]. Storage time led to increased acidity and decreased pH in the cheese. [21] reported much lower acidity values in both cow and goat milk Mozzarella cheese, while [25] found higher acidity in cow milk cheese. These contrasting findings highlight the need for further research to understand the interplay between milk type, storage conditions, and starter cultures on cheese acidity.

Table (5): Effect of milk type and storage period on pH-value and titratable acidity % of Mozzarella cheese during storage at 5±2°C.

Milk Type	Storage Period (Day)	pH	Acidity
PCC	**Fresh**	$5.21^{a} \pm 0.01$	$0.87^{b} \pm 0.01$
	30	$4.94^{b} \pm 0.01$	$1.11^{a} \pm 0.03$
PGC	**Fresh**	$5.21^{a} \pm 0.03$	$0.73^{c} \pm 0.03$
	30	$4.95^{b} \pm 0.03$	$0.88^{b} \pm 0.03$
PCGC	**Fresh**	$5.22^{a} \pm 0.01$	$0.85^{b} \pm 0.03$
	30	$4.95^{b} \pm 0.02$	$1.09^{a} \pm 0.05$
Sig.		0.000****	0.000****
LSD		0.04	0.05

**** $p \leq 0.0001$

PCC = Palestinian Cow milk PGC = Palestinian Goat milk PCGC = Palestinian cow and goat cheese in a 1:1 ratio; (a,b,c) Means having different superscript letters by column are significantly different ($P \leq 0.05$).

From Table (6), it is clear that the lowest DM, fat and F/DM content was observed in cheese made from goat milk, in contrast it had the highest protein (25.92%). This can likely be attributed to higher whey loss during processing, as goat milk whey has a higher solid/fat content compared to cow milk whey.

Interestingly, adding cow milk to goat milk increased the DM, fat, and F/DM content (from 47.62% to 48.57%, 16.18% to 18.23%, and 33.97% to 37.53%, respectively) while decreasing the protein content (from 25.92% to 23.63%). These findings are consistent with studies by [26]**,** who reported similar trends in cheese composition when using blends of cow and goat milk. [27] reported that Mozzarella cheese using goat and cow milk containing 4% fat, had a DM, fat and protein content of 54.44,22.9 and23.67% and 53.44,22.7and23.29%, respectively. These values were higher than the values content obtained in the present study. However, our results differ from those of [7]**,** who reported a lower DM, fat, and protein content in goat milk cheese. These discrepancies highlight the potential influence of various factors, such as animal breed, feed composition, and cheese-making techniques, on the final composition of Mozzarella cheese.

Table (6): Effect of milk type and storage period on the chemical composition of Mozzarella cheese during storage at 5±2°C.

Milk Type	Storage Period (Day)	TS	Fat	F/DM	Protein
PCC	**Fresh**	$49.19^{b} \pm 0.16$	$23.08^{a} \pm 0.20$	$46.92^{a} \pm 0.56$	$22.26^{f} \pm 0.10$
	30	$50.47^{a} \pm 0.16$	$23.41^{a} \pm 0.25$	$46.39^{a} \pm 0.44$	$22.65^{e} \pm 0.10$
PGC	**Fresh**	$47.62^{c} \pm 0.24$	$16.18^{e} \pm 0.09$	$33.97^{c} \pm 0.72$	$25.92^{b} \pm 0.21$
	30	$49.25^{b} \pm 0.29$	$16.96^{d} \pm 0.46$	$34.44^{c} \pm 1.06$	$26.39^{a} \pm 0.22$
PCGC	**Fresh**	$46.97^{d} \pm 0.43$	$18.23^{c} \pm 0.12$	$38.82^{b} \pm 0.47$	$23.63^{d} \pm 0.23$
	30	$47.98^{c} \pm 0.13$	$18.86^{b} \pm 0.25$	$39.30^{b} \pm 0.56$	$24.03^{c} \pm 0.18$
Sig.		0.000****	0.000****	0.000****	0.000****
LSD		0.46	0.54	1.19	0.32

**** $p \leq 0.0001$

PCC = Palestinian Cow milk PGC = Palestinian Goat milk PCGC = Palestinian cow and goat cheese in a 1:1 ratio; TS = total solids F/DM = fat/dry matter; (a,b,c,d,e,f) Means having different superscript letters by column are significantly different ($P \leq 0.05$)

The percentage composition of salt and ash in cheese are considered interrelated parameters. This relationship justifies the combined presentation and interpretation of their data, including calcium content. **Table 7** shows the changes observed in the salt, ash, and calcium content of various cheeses influenced by milk type. No statistically significant differences in salt content were observed among the different treatments. The data indicates significant increase in the ash, salt, and calcium content in all treatments throughout the storage period. This rise can be attributed to the reduction in moisture content. The ash content in fresh samples of Mozzarella cheese in treatments PCC, PGC, and PCGC were 2.64, 2.80 and 2.76, % respectively. These findings align with previous research conducted by [28,29,30], which posits that the rise in ash and total calcium content during the storage of Mozzarella cheese can be attributed to changes in cheese moisture and dry matter content.

The type of milk used influenced the calcium and ash content of the cheese, with calcium/ash contents of 0.634/2.64, 0.718/2.80, and 0.678/2.76 for PCC, PGC, and PCGC respectively when fresh. These findings are consistent with [26]**,** who reported that cow milk Mozzarella exhibited slightly higher ash (3.42%) and lower calcium (0.610%) content compared to goat milk Mozzarella (3.41% ash and 0.768% calcium). Conversely, cow milk cheese displayed a lower salt concentration (1.7%) compared to goat milk cheese (1.8%).

The role of the water-soluble nitrogen (WSN) in cheese flavor development is not fully understood, but it's believed to contribute to the background profile. As shown in Table (7) a significant increase in WSN during refrigerated storage. This aligns with findings by [30]**,** who reported that WSN content typically reflects the rate of proteolysis even under refrigeration (4°C). Statistical analysis of our WSN values revealed significant differences between treatments. PCC cheese had the highest WSN content (0.358%), while PGC cheese had the lowest (0.317%) after 30 days of storage.

Cheese meltability reflects the ability of cheese particles to flow past one another when heated. For optimal meltability, a strong interaction between protein and moisture in the cheese structure is essential. Upon heating, the protein matrix expands and becomes more hydrated, leading to enhanced melting [32]. **Table 8** presents the meltability values of Mozzarella cheese treatments. It is clear that the type of milk used in cheese production also had a significant effect on meltability values.

The findings demonstrated that meltability significantly impacts the overall quality of Mozzarella cheese and is influenced by multiple variables. The study showed that there are with a noticeable increase in meltability during the storage period of Mozzarella cheese across all treatments.

Table (7): Effect of milk type and storage period at 5±2°C on salt, ash, calcium and WSN content of Mozzarella cheese.

Milk Type	Storage Period (Day)	Salt	Ash	Calcium	WSN
PCC	**Fresh**	1.00[b] ± 0.04	2.64[d] ± 0.01	0.634[e] ± 0.01	0.275[d] ± 0.006
	30	1.24[a] ±0.02	3.16[b] ± 0.04	0.647[d] ± 0.01	0.358[a] ± 0.005
PGC	**Fresh**	1.04[b] ± 0.05	2.80[c] ± 0.02	0.718[b] ± 0.01	0.253[e] ± 0.008
	30	1.24[a] ± 0.06	3.32[a] ± 0.02	0.731[a] ± 0.01	0.317[c] ± 0.008
PCGC	**Fresh**	1.01[b] ± 0.03	2.76[c] ± 0.04	0.678[c] ± 0.01	0.262[e] ± 0.005
	30	1.22[a] ± 0.08	3.28[a] ± 0.03	0.681[c] ± 0.01	0.337[b] ± 0.007
Sig.		0.000****	0.000****	0.000****	0.000****
LSD		0.06	0.05	0.12	0.01

**** p ≤ 0.0001
PCC = Palestinian Cow milk PGC = Palestinian Goat milk PCGC = Palestinian cow and goat cheese in a 1:1 ratio; WSN = water soluble nitrogen**;** (a,b,c,d,e) Means having different superscript letters by column are significantly different (P ≤ 0.05)

Initially, the fresh cheese exhibits a firm texture with poor melting properties, despite being somewhat stretchable. In this respect, [33] found that the cheese softens significantly and demonstrates a marked improvement in meltability during the aging process that spans 1-3 weeks. This enhanced melting capability is attributed to the dislodgement of the para-casein matrix within the cheese structure [34]. The type of milk used in cheese production also had a significant effect on meltability values. Mozzarella cheese made from cow's milk exhibited the highest meltability, while cheese made from goat's milk exhibited the lowest. When cow milk was blended with goat milk, a substantial increase in meltability was noted compared to cheeses produced solely from goat. The results are consistent with those of [25]**,** who found that cow's milk Mozzarella cheese exhibits superior meltability compared to goat's milk Mozzarella cheese.

Oiling off, refers to the separation of liquid fat from the cheese body into oil pockets, is a significant quality issue in Mozzarella cheese, particularly when it is melted on pizza. **Table 8** shows the fat leakage (oiling off) percentages for Mozzarella cheese stored at 5 ±2°C. The type of milk used plays a critical role in the occurrence of oiling. Cow's milk cheese exhibited the lowest value (1.52%), whereas goat's milk cheese had the highest (3.47%). The mixed milk cheese displayed an intermediate oiling-off value of 2.72%. As storage time increased, oiling off increased for all treatments, which is in line with the findings of [18,27]. Blending cow's milk with goat's milk significantly affected the oiling-off properties of the cheese resulted in a reduction in oiling off from 3.47% to 2.72% (21.62% reduction).

Table (8): Effect of milk type and storage period on meltability and oiling off of Mozzarella cheese during storage at 5±2°C.

Milk Type	Storage Period (Day)	Meltability (mm)	Oiling off (%)
PCC	**Fresh**	140.67[c] ± 2.52	1.52[f] ± 0.04
	30	197.00[a] ± 3.46	4.32[c] ± 0.10
PGC	**Fresh**	78.33[f] ± 3.06	3.47[d] ± 0.06
	30	130.30[d] ± 1.53	5.37[a] ± 0.08
PCGC	**Fresh**	94.00[e] ± 5.00	2.72[e] ± 0.05
	30	163.00[b] ± 6.00	4.94[b] ± 0.13
Sig.		0.000****	0.000****
LSD		6.93	0.15

**** p ≤ 0.0001
PCC = Palestinian Cow milk PGC = Palestinian Goat milk PCGC = Palestinian cow and goat cheese in a 1:1 ratio; (a,b,c,d,e,f) Means having different superscript letters by column are significantly different (P ≤ 0.05)

Textural Profile Analysis of Mozzarella Cheese Produced from Different Milk type.

Tables 9 & 10 presents the changes in primary textural parameters, including hardness, adhesiveness, cohesiveness, and springiness, as well as secondary parameters such as gumminess and chewiness, of the experimental cheeses after 30-day storage period. The textural attributes of foods play a significant role in consumer appeal, buying decisions, and eventual consumption. Texture is generally limited to the sensations experienced when masticating, suggesting the predominant role of mechanical properties. Texture Profile Analysis (TPA) is the key instrumental method used to correlate with sensorial textural parameters [35].

It is clear that the cow milk cheese exhibited the lowest values of hardness, cohesiveness, springiness, gumminess and chewiness (2404.73g, 0.79, 4.83mm, 1899.74 g/sec and 9175.73g/sec respectively) while the goat milk cheese exhibited the highest values. The incorporation of cow's milk with goat's milk led to a 4.07% decrease in hardness (2495.95g), 4.71% decrease in cohesiveness (0.81), 32.58% decrease in springiness (5.38 mm), 8.2% decrease in gumminess (2028.9 g/sec) and 38.11 decrease in chewiness (10910.79 g/sec).

These findings align with the notion that cheese hardness, gumminess and chewiness increases as the total filler content, which is the combined proportion of fat and moisture decreases, and protein content increases [36]. This is in according with [37] who reported that reducing fat content from 50.4% w/w (full-fat) to 13.5% (low-fat) during the production of Gaziantep cheese (pasta filata cheese) led to increased textural parameters, including hardness, gumminess, cohesiveness, and springiness in the final cheese product. The hardness, gumminess and chewiness values of all cheese formulations were observed to decrease significantly ($p < 0.05$) throughout the storage period. The fresh cheese exhibited hardness measurements ranging from 2404.73 to 2600.00 g, while the cheese stored for 30 days showed values ranging from 2220.03 to 2553.31 g.

The initial stages of cheese ripening are marked by a noticeable decrease in hardness, characterized by a shift from a firm, rubbery texture to a smoother and softer product [38]. This textural transformation can be attributed to the confluence of various biochemical and physical processes occurring at the microscopic level.

One of the key factors contributing to the softening of cheese is the breakdown of the casein network, which is the primary protein structure in cheese. This process, known as proteolysis, is facilitated by rennet enzymes, which cleave peptide bonds within the casein molecules [39]. The resulting fragments are smaller and less capable of forming a rigid network, leading to a softer texture. Another factor influencing cheese texture is protein hydration. As the cheese curds absorb serum from the surrounding fat-serum channels, increasing the water content within the protein matrix [40,41]. This increased hydration disrupts the intermolecular interactions within the casein network, promoting further softening. In addition, the solubilization of colloidal calcium phosphate (CCP) leads to a softer cheese texture [39].

Table (9): Effect of milk type and storage period on hardness, cohesiveness, and Adhesiveness of Mozzarella cheese during storage at 5±2°C.

Milk Type	Storage Period (Day)	Hardness (g)	Cohesiveness (Ratio)	Adhesiveness
PCC	**Fresh**	$2404.73^{c} \pm 46.06$	$0.85^{b} \pm 0.01$	$-50.59^{c} \pm 4.59$
	30	$2220.03^{d} \pm 67.89$	$0.88^{a} \pm 0.01$	$-59.10^{d} \pm 3.07$
PGC	**Fresh**	$2600.00^{a} \pm 67.39$	$0.79^{e} \pm 0.01$	$-18.74^{a} \pm 2.18$
	30	$2553.31^{ab} \pm 42.47$	$0.81^{d} \pm 0.01$	$-21.08^{a} \pm 0.82$
PCGC	**Fresh**	$2495.95^{bc} \pm 7.07$	$0.81^{d} \pm 0.01$	$-36.34^{b} \pm 2.18$
	30	$2229.96^{d} \pm 69.02$	$0.84^{c} \pm 0.01$	$-36.62^{b} \pm 1.78$
Sig.		0.000****	0.000****	0.000****
LSD		97.14	0.01	4.81

**** $p \leq 0.0001$

PCC = Palestinian Cow milk PGC = Palestinian Goat milk PCGC = Palestinian cow and goat cheese in a 1:1 ratio; (a,b,c,d) Means having different superscript letters by column are significantly different ($P \leq 0.05$)

Table (10): Effect of milk type and storage period on springiness, gumminess, and chewiness of Mozzarella cheese during storage at 5±2°C.

Milk Type	Storage Period (Day)	Springiness (mm)	Gumminess (g/sec)	Chewiness (g/sec)
PCC	**Fresh**	$4.83^{f} \pm 0.02$	$2054.44^{a} \pm 54.98$	$9927.86^{c} \pm 306.93$
	30	$5.07^{e} \pm 0.19$	$1945.73^{b} \pm 36.40$	$9861.41^{c} \pm 368.12$
PGC	**Fresh**	$7.98^{b} \pm 0.08$	$2044.21^{a} \pm 59.14$	$16318.14^{a} \pm 611.91$
	30	$8.16^{a} \pm 0.05$	$2076.67^{a} \pm 35.58$	$16946.23^{a} \pm 353.89$
PCGC	**Fresh**	$5.38^{d} \pm 0.03$	$2028.90^{a} \pm 18.59$	$10910.79^{b} \pm 127.95$
	30	$5.65^{c} \pm 0.09$	$1865.68^{b} \pm 56.86$	$10544.51^{bc} \pm 489.27$
Sig.		0.000****	0.001***	0.000****
LSD		0.17	81.83	720.92

*** $p \leq 0.001$ **** $p \leq 0.0001$

PCC = Palestinian Cow milk PGC = Palestinian Goat milk PCGC = Palestinian cow and goat cheese in a 1:1 ratio; (a,b,c,d,e,f) Means having different superscript letters by column are significantly different ($P \leq 0.05$).

Scanning electron microscopy (SEM) of Mozzarella cheese.

The microstructure of cheese is crucial in determining its texture and functional properties [42]. Scanning electron microscopy (SEM) is a well-established technique for investigating the cheese microstructure, during SEM analysis, a focused beam of electrons interacts with the sample surface, resulting in the generation of a high-resolution image [43]. The rheological properties of cheese, both in its solid and melted states, are significantly influenced by its microstructure [44].

Scanning electron micrographs of experimental cheese are shown in Figure (4). Understanding the microstructure of Mozzarella cheese, particularly how the casein and fat interact during and after manufacture can provide valuable insight into what constitutes a quality product. As presented in Figure 4, the solid background of each micrograph represents the protein matrix and the empty black areas represent air sacs, originally occupied by fat cells. The goat milk cheese (Figure 4 (a) magnitude 1500X; at 20 kV) was found to be less porous when compared with the cheese made from the cow milk. This is likely to be a result of the different protein and fat concentrations in the original bovine milks. A higher protein concentration lowers the volume fraction of the aqueous phase, which consequently lowers mean distance between casein micelles and so increases the extent of their subsequent aggregation. Additionally, starter strains (not shown), may be due to embedding in the protein matrix. A less compact, inhomogeneous, and contained large pores and short individualized casein filaments was observed in the cow Mozzarella cheese. Furthermore, the surface of the protein matrix appeared to be coarse and the matrix itself was less compact. Qualitatively, there was no clear distinction between the microstructure of the mixed milk Mozzarella and cow milk Mozzarella (Figure 4 b, c respectively).

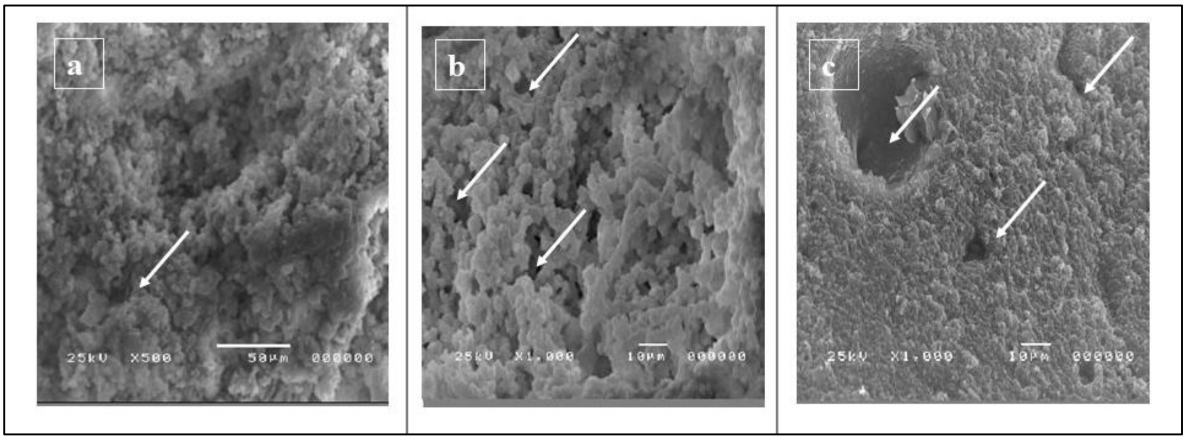

Figure 4. Scanning electron micrographs (1000 x) of Mozzarella cheese treatments; (a) goat milk Mozzarella, (b) Cow milk Mozzarella, (c) mixed milk Mozzarella. Void spaces (marked with white arrows), Scale bar is 10 µm .

Sensory evaluation of Mozzarella cheese as affected by milk type during storage at at 5±2°C.

Data presented in table (11) summarize the organoleptic assessment of the three types of Mozzarella cheese. The Mozzarella cheese assessment revealed a clear difference between the appearance of cheese and the stored one after 30 days, with no significant difference in all Mozzarella cheeses. While with body and texture, the values increased by storage and cow Mozzarella cheese recorded the highest value being 34, while Goat Mozzarella cheese recorded the lowest value 32. The mixed are recorded intermediate value being 33.

No significant difference on the case of both cow and mixed milk cheese while significant difference detected in the case of Goats milk. Concerning Cheese flavor, both cow and mixed cheeses recorded high values with no significant differences between fresh and stored one, on the other hand, goat cheese recorded the lowest values being 39.7 and 41.3 when fresh and after 30 days. In conclusion cow cheese got the highest total score, followed by mixed milk cheese then goat's cheese with significant differences.

fresh cow's milk Mozzarella received the highest and significant score (88 points), compared to goat's milk cheese which received the lowest score (80.7 points). Notably, blending cow's milk with goat's milk significantly improved the sensory score (85.7 points) compared to cheese made solely from goat milk (6.2% increase).

As the storage period of mozzarella cheese increased, the total score for all treatments increased to 94.3, 85.3 and 90 points out of 100 for cow's milk cheese, goat's milk cheese, and mixed milk cheese, respectively. These results are consistent with those of [26,32], who found that cheese scores increased positively with storage period.

Among sensory attributes, flavor is considered the most important factor in determining consumer response. The flavor of all treatments improved with storage because the metabolic processes are responsible for the basic flavor and texture changes. As biochemical reactions continue during cheese ripening, the breakdown of fat and protein by microbial and residual rennet enzymes produces more flavoring compounds and hydrolyzes casein, resulting in a smooth texture [45].

Table (11): Sensory evaluation of Mozzarella cheese as affected by milk type and storage period at 5±2°C.

Milk Type	Storage Period (Day)	Appearance (15)	Body &Texture (35)	Flavor (50)	Total (100)
PCC	**Fresh**	11.7±0.6	32.3±0.6	44.0^{bc} ±1.0	88.0^{b} ±2.2
	30	13.0±1.0	34.0±1.0	47.3^{a} ±2.1	94.3^{a} ±3.5
PGC	**Fresh**	11.0±1.0	30.0±1.0	39.7^{d} ±1.5	80.7^{c} ±3.5
	30	12.0±1.0	32.0±2.6	41.3^{cd} ±2.1	85.3^{bc} ±5.7
PCGC	**Fresh**	10.7±0.6	32.3±1.2	42.7^{bc} ±1.5	85.7^{bc} ±3.3
	30	12.0±1.0	33.0±1.0	45.0^{ab} ±1.0	90.0^{ab} ±1.0
Sig.		0.078 ns	0.073 ns	0.001***	0.002**
LSD		1.57	2.48	2.84	5.05

ns= not significant ** $p \leq 0.01$ *** $p \leq 0.001$

PCC **=** Palestinian Cow milk PGC = Palestinian Goat milk PCGC = Palestinian cow and goat cheese in a 1:1 ratio; (a,b,c) Means having different superscript letters by column are significantly different ($P \leq 0.05$)

4. Conclusion

This study has elucidated the significant impact of milk type on the chemical, rheological, and sensory properties of Mozzarella cheese. The analysis of fresh and stored cheese (at 5 ± 2°C for 30 days) highlighted several key differences influenced by the type of milk used. Cow's milk cheese demonstrated superior fat and protein retention compared to goat's milk cheese, which translated into better meltability and lower fat separation. In contrast, goat's milk cheese had a denser protein matrix, resulting in higher hardness, springiness, chewiness, and gumminess. Blending cow's milk with goat's milk improved the quality of goat milk cheese by enhancing its meltability and reducing fat separation. Cold storage affected all cheese treatments by decreasing hardness, chewiness, and gumminess, while increasing springiness. Sensory evaluation favored cow's milk cheese, which received the highest scores for texture, structure, appearance, and flavor. This result supports the potential for diversifying Mozzarella cheese production in regions like Palestine, where goat milk is abundant. Such diversification could meet local demand and reduce reliance on imported cheeses, contributing to a more sustainable and profitable dairy industry. Future research should focus on optimizing the blend ratios and processing conditions to maximize the quality of Mozzarella cheese made from different milk types.

REFERENCES

1-Kosikowski, F. V. (1986). New cheese making procedures utilizing ultrafiltration Food Technol. C.f. Egyptian J. Dairy Sci.,20, 201-218.

2-Darwish, M. Y. H. (1977). Sheep breeding and production. Dar-El- Maaref. Cairo, Egypt (In Arabic) (C.F. Abou-Donia and Abdel-Kader, 1979).

3-Citro, V. (1981). Atypical local product obtained from buffalo milk. Scienza-e-Tecnica-Lattiero- Casearia, 32:263-273.

4-Ahmed, K. (2004). Palm based mozzarella cheese as pizza topping Malaysian palm oil board, Ministry of plantation industries and commodities Malaysia, P.O. Box 10620, 50720 kuala lumpur, malaysia.

5-Barlowska, J.; Pastuszka, R.; Rysiak, A., Król, J.; Brodziak, A.; Kedzierska-Matysek, M.; Wolanciuk, A. and Litwinczuk, Z. (2018). Physicochemical and sensory properties of goat cheeses and their fatty acid profile in relation to the geografic region of production. International Journal of Dairy Technology, 71(3): 699-708.

6-Schwarz, D. G. G.; Lima, M. C.; Barros, M.; Valente, F. L.; Scatamburlo, T. M.; Rosado, N.; Oliveira, C. T. S. A. M.; Oliveira, L. L. and Moreira, M. A. S. (2017). Passive shedding of Mycobacterium avium ssp. paratuberculosis in commercial dairy goats in Brazil. Journal of Dairy Science, 100(10): 8426-8429.

7-Verma, A.K.; Pal-Singh, T.; Rajkumar, V.; Guruaj, K.; Sinh, M.K.; and Kushwah, T. (2023). Physicochemical, color, textural, rheological and sensory properties of goat milk mozzarella cheese as affected for acidulates. Indian Dairy Association. 76(5), 458-465.

8-A.O.A.C. (2020). Official methods of analysis. A.O.A.C. Association of official analytical chemists. Washington D.C.I., U.S.A.

9-Ling, E. R. (1963). A text book of dairy chemistry. Vol. 2. 3rd ed., Chapman and Hall, London.

10-Kosikowski, F.V. (1970). Cheese and Fermented Milk Product 2nd edn., Edwards Brothers Inc., Am. Arbor, Michigan, USA.

11-Nilson, K. M. and LaClair, F. A. (1976). A national survey of the quality of Mozzarella cheese. Manuf. Milk Rod. Suppl. Am. Dairy Rev., 38: 18.

12-Kalab, M.; Yun, J.; Yiu, S. H. (1987). Textural properties and microstructure of processed cheese food rework. Food Microstruct., 6: 181–92.

13-Bourne, M. (1978). Texture Profile Analysis. Food Technol., 32:62– 66, 72.

14-SPSS, I. (2021). IBM SPSS Statistics for windows, version 28. Armonk, NY: IBM Crop.

15-Park, Y. W.; Juárez M.; Ramos M. and Haenlein G. F. W. (2007). Physico-chemical characteristics of goat and sheep milk. Small Rum. Res., 68: 88- 113.

16-Raynal-Ljutovac, K.; Lagriffoul, G.; Paccard, P.; Guillet, I.; and Chilliard, Y. (2008). Composition of goat and sheep milk products: An update. Small Ruminant Research, 79(1): 57-62.

17-Sumarmono, J. (2022). Current goat milk production, characteristics, and utilization in Indonesia IOP Conference Series: Earth and Environmental Science 1041.

18-Ismail, M. M., Ayyad, K. M., and Hamad, M. N. (2007). Manufacture of Mozzarella cheese using glucono-delta-lactone. In The 10th Egyptian Conference for Dairy Science & Technology (pp. 415-432). Cairo, Egypt.

19-El-Zoghby, A. S. (1994). Studies on Mozzarella cheese. Ph. D. Thesis, Fac. of Agric. Zagazig Univ., Egypt.

20-Abd El-Kader, Y.I and Ismail, M. M. (2006). Effect of using glucono-deltalactone as acidulant on the chemical and rheological properties of Mozzarella cheeses made from different types of milk. J. Agric. Sci. Mansoura Univ., 31(4):2193-2203.

21-Sulieman, A. M. E.; Mohamed, A. R. A. and Razig, K. A. A. (2012). Production and effect of storage in the chemical composition of Mozzarella cheese. Int. J. Food Sci. Nutr. Eng. 2: 21-26.

22-Zisu, B. and Shah, N.P. (2005). Low-Fat Mozzarella as Influenced by Microbial Exopolysaccharides, Preacidification, and Whey Protein Concentrate. Journal of Dairy Science, 88: 6,1973-1985.

23-Yazici, F.; Dervisoglu M.; Akgun A. and Aydemir O. (2010). Effect of whey pH at drainage on physicochemical, biochemical, microbiological, and sensory properties of Mozzarella cheese made from buffalo milk during refrigerated storage. Journal of Dairy Science, 93: 5010–5019.

24-Sabikhi, L. and Kanawjia,S. K. (1992). Effect of admixing of goat and buffalo milks on sensory, composition and textural characteristics of direct acid Mozzarella cheese. Indian J. Dairy Science, 45(10): 562-567.

25-El-Tahra, M. A., M. A. Ammar, M. M. Ismail and R. L. El-Metwally. (2008). Chemical, rheological and organoleptic properties of mozzarella cheese made from goat's milk and whey protein. J. Agric. Sci. Mansoura Univ. 33: 4321-4338.

26-Raquib, M.; Borpuzari1, T.; Hazarika1, M.; Laskar,S. K; Saikia, G.K. and Hazarika, R.A.(2022). Effect of coagulating enzymes and types of milk on the physico-chemical, proximate composition and sensory attributes of iron fortified Mozzarella cheese. Emirates Journal of Food and Agriculture. 34(3): 180-187.

27-El-Metawally, R.I.M. (2008). Manufacture of mozzarella cheese by using different type of milk. Ph.D. Thesis. Faculty of Agriculture, Mansoura University, Egypt.

28-Abbas, K.A. (2003). Studies on Mozzarella cheese. M. Sc. Thesis, Fac. of Agric. Fayoum, Cairo Univ., Egypt.

29-Helal, A. M. I. (2006). Manufacturing of Mozzarella Cheese from Cow's and Buffaloe's Milk with Complete Substitution of Milk Fat with Vegetable Oils. Ph. D. Thesis, Fac. of Agric. (damanhour), Alex. Univ., Egypt.

30-Abd El-Hamid, L.B.; Awad, R.A.; Zedan, M.A. and Salama, W.M. (2006). Functional properties of buffalo Mozzarella cheese as affected by enzymatic casein modification. Egyptian J. Dairy Sci., 34: 69-79.

31-Zedan, I.A.; Abou-Shaloue, Z. and Zaky, S.M. (2014). Quality Evaluation of Mozzarella Cheese from Different Milk Types. Alexandria Science Exchange Journal, 35(3): 146-158.

32-McMahon, D.J.; Fife, R.L. and Oberg, C. J. (1999): Water partitioning in Mozzarella cheese and its relationship to cheese meltability. J. Dairy Science. 82: 1361369.

33-Rowney, M.; Roupas, R.; Hickey, M. W. and Everett, D. W. (1999). Factors affecting the functionality of Mozzarella cheese. Aust. J. Dairy Technol. 54: 94-102.

34-Sheehan, J.J. and Guinee, T.P. (2004). Effect of pH and calcium level on the biochemical, textural and functional properties of reduced-fat Mozzarella cheese. Int. Dairy J. 14 (2): 161-172.

35-Awad, S. (2011). Texture and Microstructure: in Practical Food and Research pp. 361-391 (ed. Rui M. S. Cru), Nova Sci. publishers, Inc.

36-Awad, S.; Hassan, A. N. and Muthukumarappan, K. (2005). Application of exopolysaccharide producing cultures in reduced fat cheddar cheese: texture and melting properties. J. Dairy Sci., 88:4204 – 4213.

37-Kahyaoglu, T.; Kaya, S. and Kaya, A. (2005). Effect of fat reduction curd dipping temperature on viscoelasticity, texture and appearance of Gaziantep cheese. Food Sci. Technol. Int., 11: 191-198.

38-Lawrence, R. C.; Creamer, L. K. and Gilles, J. (1987). Texture development during cheese ripening. J. Dairy Sci., 70:1748- 1760.

39-Lucey, J. A.; Johnson, M. E. and Horne, D. S. (2003). Invited Review: Perspectives on the basis of the rheology and texture properties of cheese. J. Dairy Sci., 86: 2725–2743.

40-McMahon, D. J., Alleyne, M. C., Fife, R. L. and Oberg, C. J. (1996). Use of Fat Replacers in Low Fat Mozzarella Cheese' J Dairy Sci 79:1911-1921.

41-Guinee, T.P.; Feeney E.P.; Auty, M.A.E. and Fox PF. (2002). Effect of pH and calcium concentration on some textural and functional properties of mozzarella cheese. J Dairy Sci.; 85:1655–69.

42-Joshi, N. S.; Muthukumarappan, K. and Dave, R.I. (2003). Understanding the role of calcium in functionality of part skim Mozzarella cheese. J. Dairy Sci., 86: 1918-1926.

43-McMahon, D. J. (1995). How the microstructure of Mozzarella cheese is related to functional properties.

32nd Annual Marschall Italian Speciality Cheese Seminar, Madison, WI.

44-Gunasekaran, S. and Mehmet, M.A.K. (2003). Cheese rheology and texture: CRC Pree LLC New York, USA Chapter, 9: 377-397.

45-Barbano D. M.; Chu, K.Y.; Yuri J.J. and Kindstedt, P.S. (1993): Contri - bution of coagulant, starter and milk enzymes to proteolysis and browning in Mozzarella cheese. In: Proc. 30th Marshall Italian and Specialty Cheese Seminars, Rhodia-Marshall, Madison, USA, 65–79