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INFLUENCE OF REPLACING MILK FAT WITH N-LITE D ON THE QUALITY OF LOW-FAT MOZZARELLA CHEESE

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ABSTRACT: The possibility of making good-quality low-fat mozzarella cheese was evaluated. Five treatments of mozzarella cheese were made from mixed milk (40% cow's and 60% buffalo's milk). Control cheese treatment (c) was made from mixed standardized to 3% fat. The other four treatments were made from mixed milk standardized to 2.25, 1.50, 0.75, and 0.00% fat milk, adding N-Lite D at the ratio of 0.75,1.50,2.25, and 3.00% respectively (T1, T2, T3, and T4). The obtained results revealed that replacement of milk fat with N-lite -D caused a significant increase of titratable acidity, moisture and all texture parameters (hardness, Cohesiveness, Springiness, Gumminess, and chewiness), while declined fat, acidity, fat, protein and ash content, meltability, stretchability and oiling off increased as storage period proceeded, while moisture content decreased. The change of cheese quality during storage at 5±1°C was more evident than that during storage at -18 ±2°C. Total scores of cheese organoleptic properties of cheese treatments C, T1, T2, T3, and T4 were not significantly different from each other, which means it's possible to replace up to 75% of milk fat with N-Lite D without detrimental effect on the organoleptic properties of mozzarella cheese.

Key words: Mozzarella – fat replacer – meltability – stretchability.

INTRODUCTION

Mozzarella cheese is a semi-hard, unripen cheese variety and a prominent member of the paste filate, or stretched curd, cheeses that originated in Italy. Pasta filata cheese is distinguished by a unique plasticizing and kneading treatment of the fresh curd in hot water, imparting its fibrous structure, melting, and stretching properties to the finished cheese. Thus, pasta filata differs from other cheese varieties in several essential respects, which explains why they have been traditionally grouped as a distinct category (Fox, 1993).

Milk fat plays crucial roles in developing the texture, color, flavor perception, flavor stability, flavor generation, and the overall sensation of dairy products (Abbas *et al*., 2024) because of the health problems associated with fat such as diabetes, hypertension, atherosclerosis, gallbladder disease, liver, morbidity of many cancers, coronary heart disease, stroke, obesity and diabetes ADA 2005. Many studies have been carried out to reduce fat content. However, because of the essential and key role of fat in developing the texture and flavor, fat content removal or reduction causes many defects in the product's final quality (Hamed *et al.,* 2014; Kebary *et al.,* 2015). The removal of fat in Mozzarella cheese can result in low moisture, making the cheese hard, rubbery, and causing poor meltability (Poduval and Mistry, 1999). A promising approach to produce low-fat cheese, while keeping the same functional and organoleptic properties as full-fat cheese, is using fat replacers. Many efforts have been devoted to reducing the intake of milk fat and utilizing the fat replacers in manufacturing dairy products (Kebary & Hussein, 1999; Akbari *et al*., 2016).

A fat replacer is an ingredient that can be used to provide some or all of the functions of fat, yielding fewer calories than fat. Fat replacers must replicate all or some of the functional properties of fat in fat-modified food (Schwenk and Guthrie, 1997). McMahon *et al*. (2020) and Abbas *et al*. (2024) found several categories of fat replacers.

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N-Lite D is one of the main carbohydrate-based fat replacers. It is produced from waxy maize maltodextrins and has been successfully developed to imitate specific sensory and functional properties of dairy fats, especially in fermented products and frozen dairy desserts (Sandrou and Arvanitoyannis, 2000).

This study aims to evaluate the possibility of making good-quality, low-fat mozzarella cheese, study the effect of replacing milk fat with N-lite-D, and monitor the changes in cheese quality during storage.

MATERIAL AND METHODS

1. Materials

1.1. Source of milk

Cow and buffalo milk were obtained from the private farm Quoter in Al-Gharbia Governorate, Egypt. Both milks were standardized to 3.0% fat.

Table 1: Chemical composition of standardized cow and Buffalo milk.

	Components (%)				
Type of milk	**TS**	**Fat**	**Protein**	**Ash**	**Acidity**
Cow's	12.61	3	3.93	0.76	0.15
Buffalo's	14.22	3	4.62	0.93	0.16

Eco Milk Analyzer MILKANA KAM98-2A.

1.2. Rennet

Rennet produced by *Muccor Miehei* (cHr-Hansens Lab, Copenhagen, Denmark) was obtained from the Local market. It was added to the milk at 1 g / 20 kg.

1.3. Salt

Dry commercial food-grade sodium chloride obtained from El-Nasr Salines Company, Egypt.

1.4. N-lite D (can be hydrated based on fat replacers)

National Starch and Chemical Company, Bridgewater, New Jersey, USA, gratefully provided N-lite- D. The composition is 94% total carbohydrates, 4-6% moisture, <0.5% fat, and <1.0% ash.

1.5. Bacterial strains and propagation

Streptococcus thermophiles (EMCC 1043), *Lactobacillus delbrueckii* subsp. *bulgaricus* (EMCC 1102) were obtained from Cairo Mircen, Ain Shams University, Egypt. *Streptococcus thermophiles* and *Lactobacillus bulgaricus* were activated individually by three successive transfers in sterile 10% reconstituted non-fat dry milk.

1.6. Chemicals

All chemicals used were analytical grade.

2. Methods

2.1. Mozzarella cheese making

All cheese treatments were made in a private factory at Quoter, Al-Gharbia Governorate, Egypt. Fresh morning whole cow's and buffalo's milk were separated skim cow's and buffalo's milk were mixed at the ratio 2:3 (cow's to buffalo's milk). Also, the resulting cream from both milks was mixed with the same ratio, 2:3. Control cheese was made from mixed milk standardized to 3.0%. The other four treatments were made from mixed milk standardized to 2.25, 1.5, 0.75, and 0.0% fat, and adding 0.75, 1.5, 2.25, and 3.0% N-lite D. Mozzarella cheese treatments were made according to the method described by Kosikowski (1982). N-Lite-D was added and mixed thoroughly. All milk batches were heated to 65 °C for 30 min, then cooled to 37°C, and then yoghurt starters and $CaCl_2$ were added to the milk at 1.0 and 0.02%, respectively. Rennet was added at 1 g / 20 kg of milk. The curd was cut into cubes using American knives. The whey was drained when its pH reached 5.5, and the curds were gently collected together and kept in the warm cheese vat (38±2 °C) till the curd pH reached 5.2.

The string test gives a rope of 3 meters. At this point, the curd block was cut into small pieces, cooked at 80-85° C, and appropriately mixed for about 5-10 min. Using a wooden paddle until a smooth plastic mass is obtained and formed into blocks. The cheese was salted in a 5% cold brine solution for 24 hr. The cheese blocks are removed from the brine, dried on muslin, and packaged in polyethylene bags. The resultant cheese was analyzed fresh and stored at 5±1°C and -18°C for chemical, rheological, and sensory evaluation. The whole experiments were duplicated.

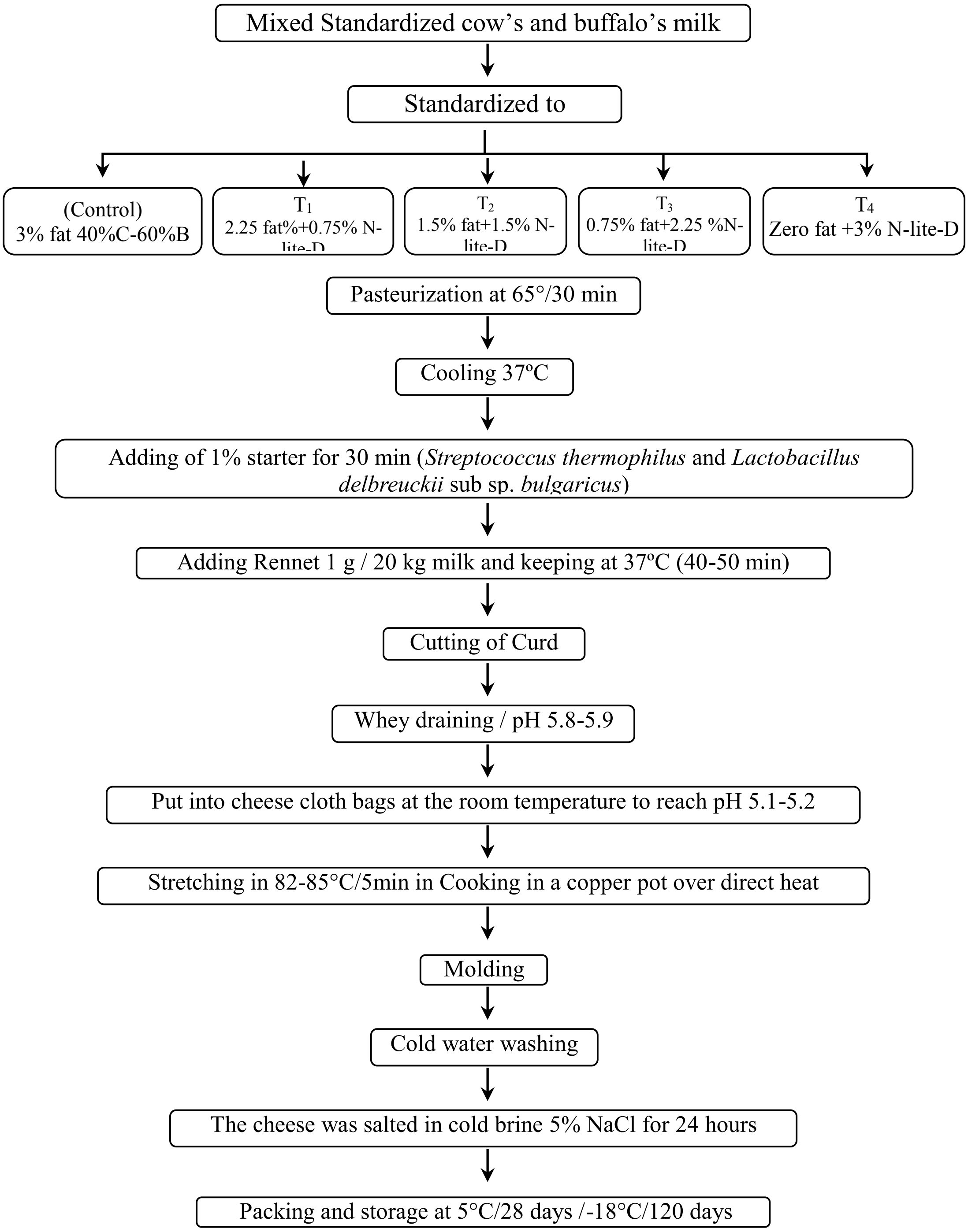

Fig. 1: Flow sheet of Mozzarella cheese manufacture.

2. Physicochemical analysis

2.1. Using the Eco milk analyzer MILKANA KAM98-2A, milk samples were analyzed for titratable acidity, total solids, fat, and total protein.

2.2. Moisture, ash, and total protein content

They were determined according to A.O.A.C. (2012).

2.3. Fat content

Fat content was determined by the original Gerber's method according to A.O.A.C. (2010).

2.4. Titratable acidity (TA)

It was determined and expressed as lactic acid percent according to Ling (2008).

3. Rheological analysis

The meltability (mm) of cheese was measured in duplicate using the melting test tube as described by Olson and Price (1958), which was modified by Rayan *et al.* (1980). Sabikhi and Kanawjia (1992) evaluated the mozzarella cheese's stretchability test (cm).

Oiling-off (ratio): Ghosh and Singh's (1992) method was used to determine the oiling-off percentage (fat leakage).

Texture profile analysis was conducted according to

4. Organoleptic properties judging

Samples from fresh and stored Mozzarella cheese were organoleptically evaluated according to the scheme described by Nelson and Trout (1956). The scoring sheet for Mozzarella cheese was follows: Flavour (50 points), Body & texture (35 points), and Appearance (15 points). The evaluation was carried out by regular scoring panel (8-10 panelists) of staff members at Food Science Department, Faculty of Agriculture, Ain Shams University and Dairy Research Dept., Food Technology Research Institute, Agricultural Research Center.

5. Statistical analysis

Data were analyzed using a 2 × 3 factorial design. Newman-Keuls' Test was used to make the multiple comparisons (Steel and Torrie, 1980) using the CoStat Software program, Version 6.4 (2008). Significant differences were determined at $P \leq 0.05$.

RESULTS AND DISCUSSION

1. Chemical properties

1.1. Titratable acidity

The results in Fig. 2 and Table 4 show that the titratable acidity of cheese was the lowest among fresh cheeses for all cheese treatments. The average values of fresh cheese treatments were 0.52, 0.50, 0.50, 0.46, and 0.43% for C, T1, T2, T3, and T4% treatments, respectively. The values were 1.18, 1.19, 1.13, 1.06, and 1.03% at 120 days in the same order. Titratable acidity of all cheese treatments increased throughout the storage period. Cheese acidity increased markedly ($P \leq 0.05$) during storage at 5±1°C, while it increased slightly during storage at -18 ±2°C (Fig. 2 and Table 4). The titratable acidity of cheese treatments at 120 days significantly differed ($P \geq 0.05$) from that of cheese treatments at 90 days. The increase of cheese acidity during storage at -18±2°C was less evident than that during storage at 5±1°C. These results follow those of Hassan & Abdel-Kader (2000) and Badawi *et al.* (2004, who found that cheese acidity increased as the storage period advanced. Replacement of milk fat with N-lite (Awad,2008, and Elgaml *et al.*, 2024), a carbohydrate-based fat, significantly increased the titratable acidity of the resulting mozzarella cheese treatments. This increase was proportional to the amount added from N-lite D. These results might be due to the higher moisture content that enhances the growth of cheese macroflora and consequently increases the development of acidity (El-Hawary *et al.,* 2009, and Chatli *et al*., 2019).

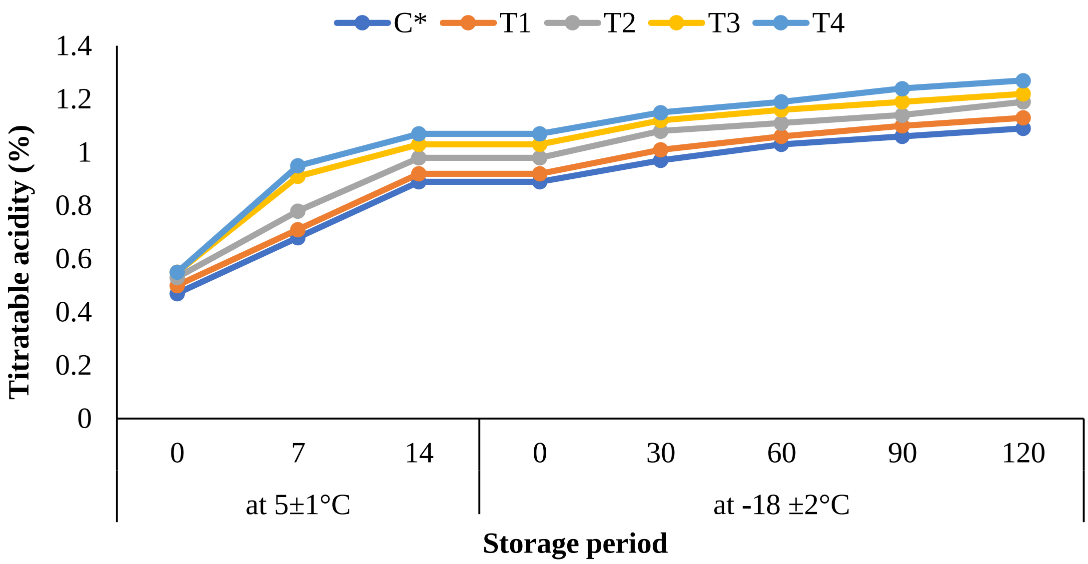

Fig. 2: Effect of partial replacement of cow's milk with buffalo's milk on Acidity content (%) of mozzarella cheese.

C*: Control cheese made from mixed milk (40% cow's milk + 60% buffalo's milk) stored at 5±1°C for 14 days and then 120 days at -18±2°C.

T_1: Mozzarella cheese made from mixed milk standardized to 2.25% fat and adding 0.75 N-lite-D stored at 5±1°C for 14 days and then 120 days at -18±2°C.

T_2: Mozzarella cheese made from mixed milk standardized to 1.50% fat and adding 1.5% N-lite-D stored at 5±1°C for 14 days and then 120 days at -18±2°C.

T_3: Mozzarella cheese made from mixed milk standardized to 0.75% fat and adding 2.25% N-lite-D stored at 5±1°C for 14 days and then 120 days at -18±2°C.

T_4: Mozzarella cheese made from skim mixed milk and adding 3.0% N-lite-D stored at 5±1°C for 14 days and then 120 days at -18±2°C.

1.2. Moisture content

The results presented in Fig. 3 and Table 4 show that the moisture content of cheese treatments was the highest when fresh for all cheese treatments. The average values of fresh cheese were 48.91, 48.68, 48.31, 47.53, and 45.16 for C, T1, T2, T3, and T_4 treatments, in the same order. The corresponding values were 45.22, 45.03, 44.91, 43.96, and 43.09 at 120 days. It is evident that as the storage period advanced, the moisture content decreased. The decrease in moisture content of all cheese treatments was more obvious during storage at 5±1°C than during storage at -18±2°C. Similar trends were reported by Abdel-Razig (2000) and Elgaml *et al*. (2024), who noted that cheese weight loss during storage was due to the loss of its moisture content due to curd contraction and water expulsion. Similarly, O'Connor (1994) added that cheese loses its moisture during storage if not adequately wrapped, thus reducing its yield. Nasr (2015) reported that the moisture content in all Mozzarella cheese treatments decreased slightly during storage. Data presented in Fig. 3 and Table 4 revealed that there was a positive correlation between the rate of replacing milk fat with milk N-lite D, which means that as the concentration of added N-lite D increased, the moisture content increased (Kebary *et al*., 1998; Koca & Metain, 2004, and Chatli *et al*., 2019). Cheese treatment T_4, which was made by adding 3% N-lite D, contained the highest moisture content, while cheese treatment (C), which was made from mixed milk containing 3% fat, contained the lowest moisture content. These results could be attributed to the higher holding capacity of N-lite D than that of fat and/or the interference with the strikes of casein matrix by lowering the deriving force, which helps to expel the whey from cheese curd (McMahon *et al*., 1996).

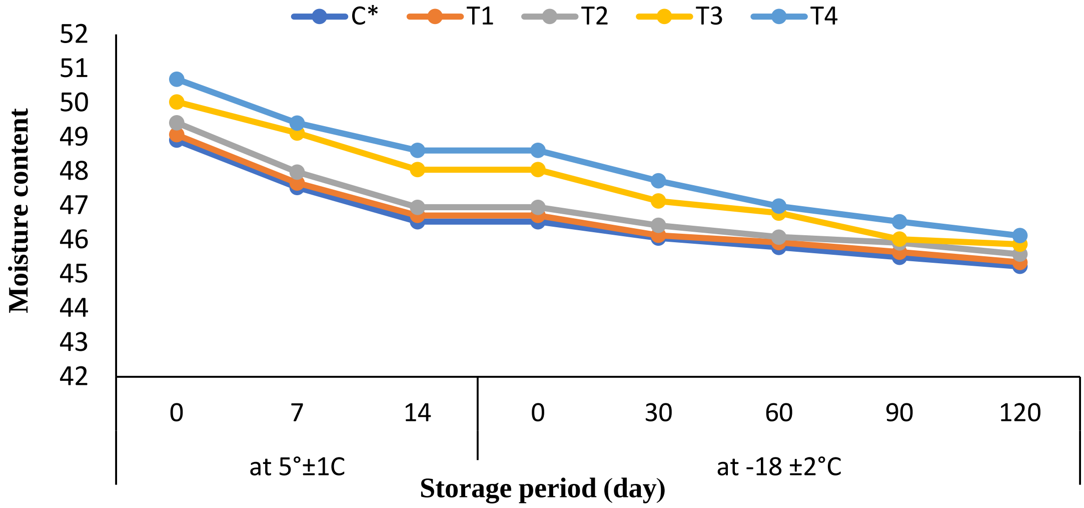

Fig. 3: Effect of partial replacement of cow's milk with buffalo's milk on the moisture content of mozzarella cheese.

See the legend of Fig. (2).

1.3. Fat content

The results in Fig. and Table 4 show that the fat contents of cheese were the lowest at zero time for all cheese treatments. The average values for fresh cheese treatments were 20.09, 16.8, 11.5, 7.8, and 1.0% for C, T1, T2, T3, and T_4 treatments, respectively. The values were 22.10, 18.3, 12.3, 8.6, and 1.0% for C, T1, T2, T3, and T_4 treatments at 120 days in the same order. Fat contents of all cheese treatments increased throughout storage period Fig. (4). Helal (2006), Amer *et al.* (1998) and Zedan *et al.* (2014), who observed that increasing of fat content during storage of mozzarella cheese, which might be due to the gradual loss of moisture content during storage. The increase of fat content during storage at 5±1°C was more evident than during storage at -18±2°C. Replacement of milk fat with N-lite D caused a significant reduction of fat content of the resultant mozzarella cheese treatments, and this decrease was proportional to the replacement rate (Fig. and Table 4). Cheese treatment $T_{4,}$ which is made from skimmed mixed milk and contains the highest ratio of N-lite D, contained the lowest fat content, while cheese treatment C that made from 3% fat mixed milk contained the highest fat content, which may be due to the fat content of milk used in cheese making (Sameen *et al.*, 2010; Chatli *et al.*, 2019 and Ahmed *et al.*, 2023).

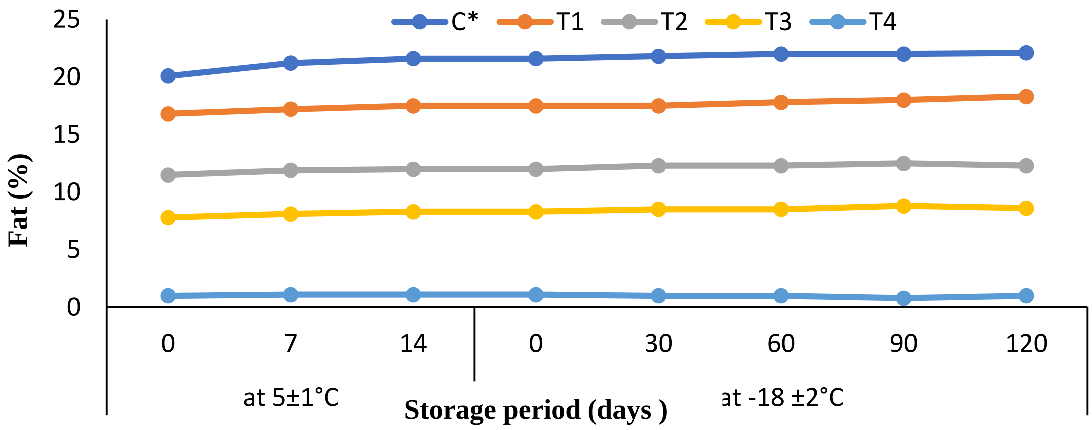

Fig. 4: Effect of partial replacement of cow's milk with buffalo's milk on the Fat content of mozzarella cheese.

See the legend of Fig. 2.

1.4. Protein content

The results in Fig. 5 show that the Protein content was the lowest at zero time for all treatments. The average values of fresh cheese were 22.15, 22.20, 22.11, 22.19 and 22.23% for C, T_1, T_2, T_3 and T_4 treatments, respectively, the values of protein content at the end of storage period (120) days were increased to 23.28, 23.41, 23.35, 23.28 and 23.35% for the same treatments. Protein content of all cheese treatments increased markedly ($p \leq 0.05$) during storage at 5±1°C, while it increased slightly during storage at-18±2°C (Fig. 5 and Table 4). These results came in agreement with the data obtained by Rudan *et al*. (1998) and Stevens & Shah (2002), who illustrated that low fat Mozzarella cheese being made with fat replacers contained higher protein content, these results might be due to the losses of moisture and consequently increasing of total solids and protein content. El-Koussy *et al*. (1995) reported a similar increase in protein content during the storage of Mozzarella cheese (Sameen *et al*., 2010; Zedan *et al*., 2014; and Elgaml *et al.,* 2024). El-Batawy *et al.* (2004) reported that Mozzarella cheese made from cow milk tends to be softer, which may also influence moisture retention and protein expression over time. However, disagreed with those of Bhaskaracharya and Shah (2001), who stated that the protein contents of cheeses made with fat replacers were lower than those of control cheeses.

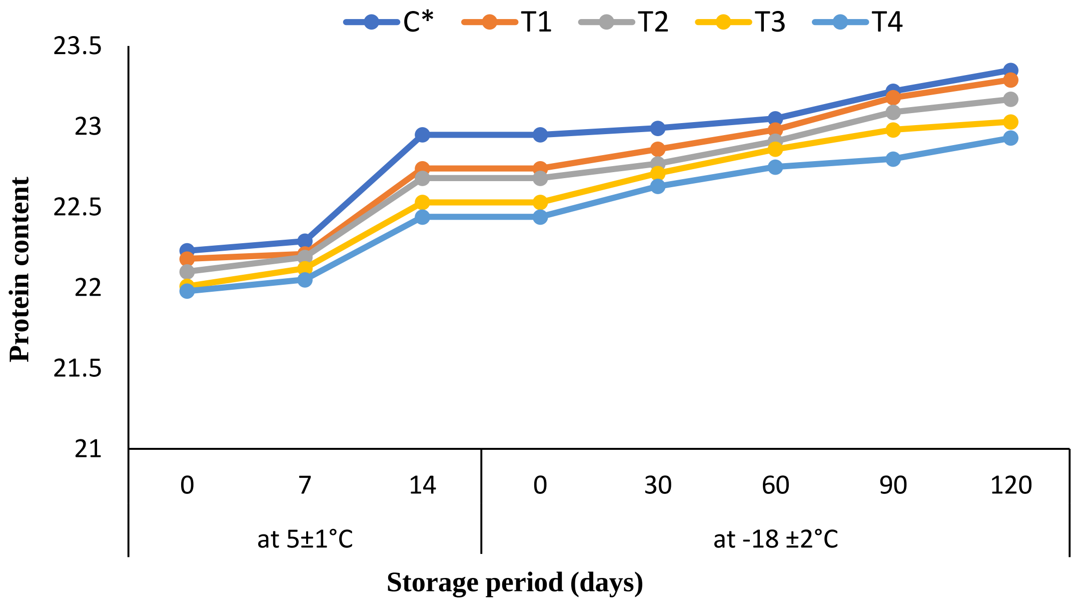

Fig. 5: Effect of partial replacement of cow's milk with buffalo's milk on the Protein content of mozzarella cheese.

See the legend of Fig. 2.

1.5. Ash content

Fig. 6 and Table 4 illustrate the Ash content of mozzarella cheese treatments. Ash content of cheese treatments was the lowest among all fresh cheese treatments. The average values for fresh cheese treatments were 2.75, 2.69, 2.71, 2.69, and 2.74% for C, T1, T2, T3, and T4 treatments, respectively. In the same order, the corresponding values increased to 2.93, 2.99, 2.93, 2.91, and 2.96% on 120 days of storage. Ash content of all mozzarella cheese treatments increased slightly throughout the storage period (Fig. 6 and Table 4). This increase in ash content of all cheese treatments during the storage period might be due to decreased moisture content, consequently increasing the total solids of cheese and ash content (Zedan *et al.,* 2014; Elgaml *et al*., 2024).

The obtained results revealed that all cheese treatments were not significantly (P>0.05) different from each other, which means that replacement of milk fat without means that replacement of milk fat with N-lite D which is a carbohydrate -based fat replace did not have significant (P>0.05) effect on the ash content of cheese treatments (Fig. 6 and Table 4).

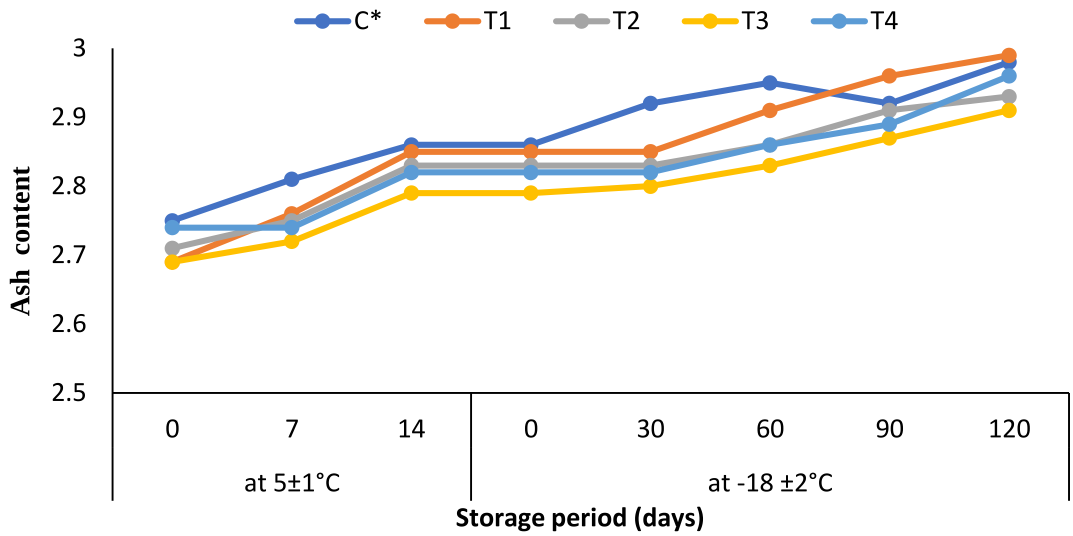

Fig. 6: Effect of partial replacement of cow's milk with buffalo's milk on Ash content of mozzarella cheese.

See the legend of Fig. 2.

2. Functional properties of Mozzarella cheese

2.1. Meltability (mm)

The results in Fig. (7) and Table (4) indicated that the meltability of all mozzarella cheese treatments increased progressively during storage, whether cheese stored at 5±1°C or stored at -18±2°C (Ghosh & Singh, 1992; Fife *et al.*, 1996; Amer *et al.*, 1998; El-Zeina *et al.*, 2007 and Zedan *et al.*, 2014), who suggested that proteolysis and protein breakdown with in the cheese matrix, as well as calcium solubilization due to increasing acidity, contribute to the increase of meltability over time (MacMahon *et al.*, 1996; Yun *et al.*, 1998; Rudan *et al.*, 1998 and Paduvol & Mistry, 1999). The increase of meltability was more pronounced during storage of cheese treatment at 5±1°C than those during storage at -18±2°C (Fig. 7). Concerning the effect of both milk fat and adding fat replacer on the meltability of mozzarella cheese, there are main two factors, which are the reduction of fat content of milk used in the manufactures of mozzarella cheese, which adversely affected the meltability of cheese and caused a significant decrease of meltability values and the addition of fat replacers those improved the meltability of cheese and increased its values (Sundar & Upadhyay, 1991; Tunick *et al.*, 1991; El-Hawary *et al.*, 2009; Chatli *et al.*, 2019 and Ahmed *et al.*, 2023). This might be due to water retention in cheese curd (Perry *et al.*, 1997).

Results presented in Fig. 7 and Table 4 indicated that the meltability of mozzarella cheese treatments decreased significantly (p≤0.05) by replacing milk fat with N-lite D. This decrease was proportional to the rate of replacement (Fig. 7). This decrease in meltability might be due to the effect of reducing fat, on which meltability was more effective than that of adding fat replacers (N-lite D), which improves the cheese meltability. Cheese treatment T_4 made from skim milk and adding 3% N-lite D exhibited the lowest value of meltability, while control value of meltability, while control cheese exhibited the highest values (Fig. 7).

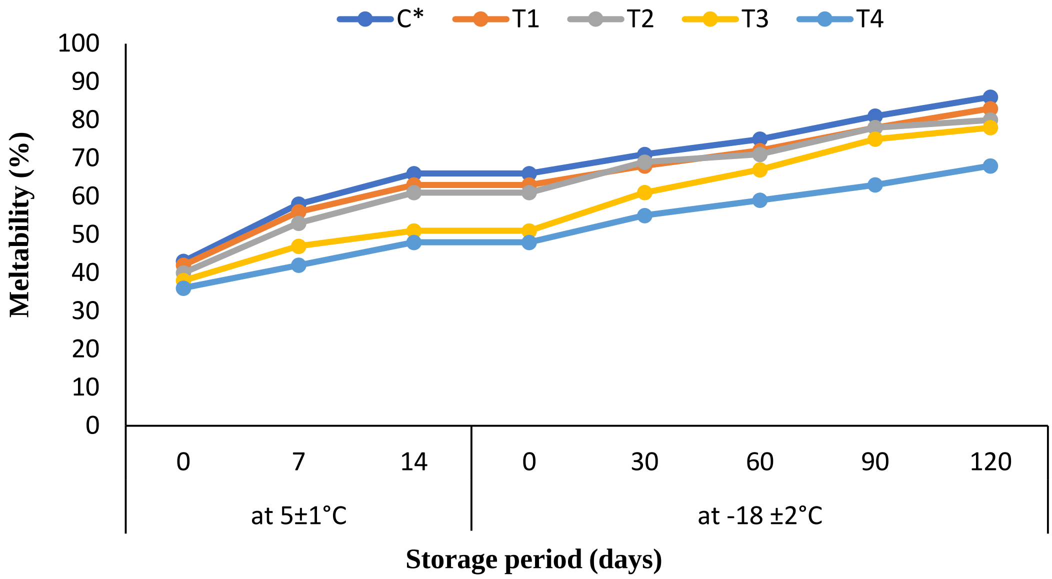

Fig. 7: Effect of partial replacement of cow's milk with buffalo's milk on Meltability (mm) of mozzarella cheese.

See the legend of Fig. 2.

2.2. Stretchability of cheese

The values of Stretchability of fresh mozzarella cheese treatments were 33, 33, 31, 29 and 25 cm for treatments C, T_1, T_2, T_3 and T_4, respectively, while the corresponding values at the end of storage period were 68, 66, 63, 61 and 54 cm successively (Fig. 8 and Table 4). The obtained results indicated that the Stretchability of all mozzarella cheese treatments increased significantly ($P \leq 0.05$) as the storage period progressed. The increase of Stretchability of all cheese treatments was less pronounced during storage of cheese treatments at -18±2°C than during storage of cheese at 5±1°C. These results agree with those reported (El-Zeini *et al.*, 2007; Zedan *et al.*, 2014; and Elgaml *et al.*, 2024). The increase in Stretchability during storage of mozzarella cheese treatments may be partly attributed to the age-related reduction in concentration of intact para-casein and the increased water binding capacity of the casein. An increase in the water binding capacity of the para casein is expected to enhance functionality as it is conductive to greater retention of moisture during baking of the Pizza, which in turn limits the occurrence of defects associated with excessive dehydration, such as, burning, crusting and poor flowability (Zedan *et al.*, 2014).

It has been reported that the reduction of milk fat caused a significant decrease in cheese stretchability, while adding fat replacers significantly increased the values of cheese stretchability (Sattar et al., 2018; Ahmed et al., 2020, and Ahmed *et al.*, 2023). Ahmed *et al.* (2020) reported that the stretch quality in low-fat cheese was lower than that of high-fat cheese. The results revealed a negative correlation between the rate of replacing milk fat with N-lite D and the values of cheese treatment (Fig. 8 and Table 4), which means decreasing the cheese stretchability values by increasing the replacement rate. These results could be attributed to the effect of reducing fat, which was more effective than the effect of adding fat replacer. The obtained results are in accordance with those reported by Gunasekaran and Kuo, (2002), who concluded that cheese with greater meltability had the higher stretchability.

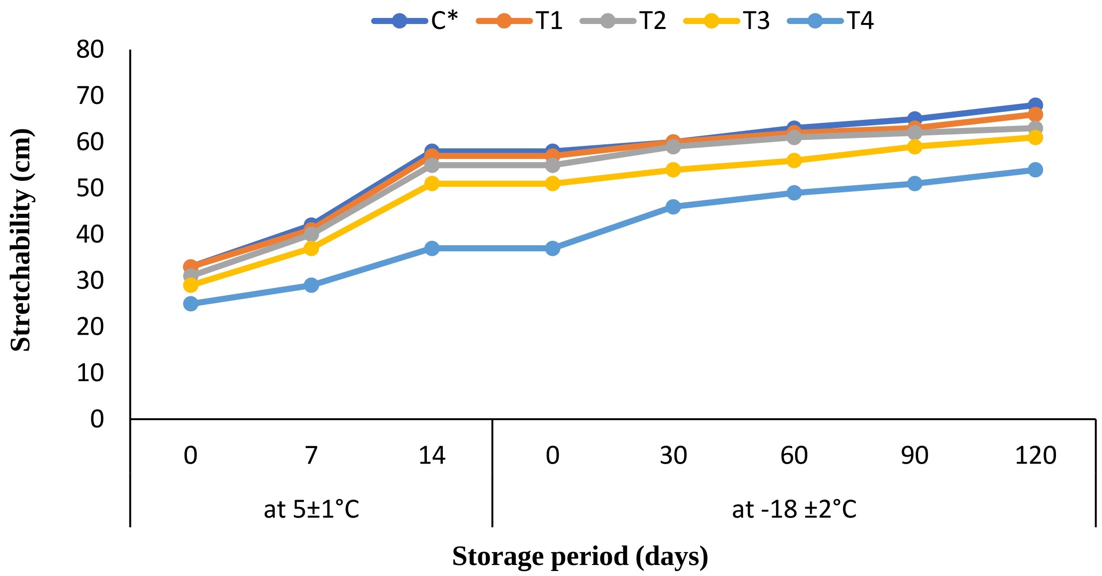

Fig. 8: Effect of partial replacement of cow's milk with buffalo's milk on Stretchability (cm) of mozzarella cheese.

See footnote Fig. (2).

2.3. Oiling off

Oiling off is considered one of the essential defects of this type of cheese when melted on top of a pie. Fat leakage in Mozzarella cheese is a significant quality problem (El-Zoghby, 1994; Abbas, 2003). The effects of replacing milk fat with N-lite D and storage conditions on oiling off of mozzarella cheese treatments are illustrated in Fig. 9. These results revealed that the values of oiling off% % of all cheese treatments increased significantly ($P \leq 0.05$) as the storage period progressed (Fig. 9 and Table 4). Oiling off% of all cheese treatments increased markedly during storage at 5±1°C, while it increased slightly during storage of all cheese treatments at -18±2°C (Amer *et al.,* 1998; Abbas, 2003; Zedan *et al.,* 2014, and Elgaml *et al.*, 2024). These results could be due to the increase in meltability and the change of the polymorphic structure of milk fat during storage of mozzarella cheese and/or the casein breakdown that allows fat globules dispersed in the protein matrix (Tunick *et al.,* 1997). Also, Amer *et al.* (1998) reported that the increase of cheese oiling off (%) during storage in a freezer could be due to the denaturation of protein and/or the formation of ice crystals that rupture the fat globule membrane. Replacement of milk fat with N-lite D caused a significant reduction in the oiling off of mozzarella cheese treatments. This decrease was proportional to the rate of replacing milk fat with N-lite D (Fig. 9). These results might be due to the reduction of fat content in cheese (Kindstedt & Rippe, 1990 and Kindstedt, 1993) and/or fat replacer may act as emulsifying that help to retention and bunding the fat lightly in cheese matrix. Rudan *et al.* (1998) reported that low-fat mozzarella cheese containing a fat replacer had lower values of free oil than the cheese without adding a fat replacer. Cheese treatment T_4, which was made from skim milk and added the highest ratio of N-lite D 3%, did not exhibit fat leakage, while the control cheese, which was made from mixed milk containing 3%, showed the highest value of oiling off (Fig. 9 and Table 4). Tunick (1994) found that refrigerated storage of Mozzarella cheese increased free oil because of proteolysis.

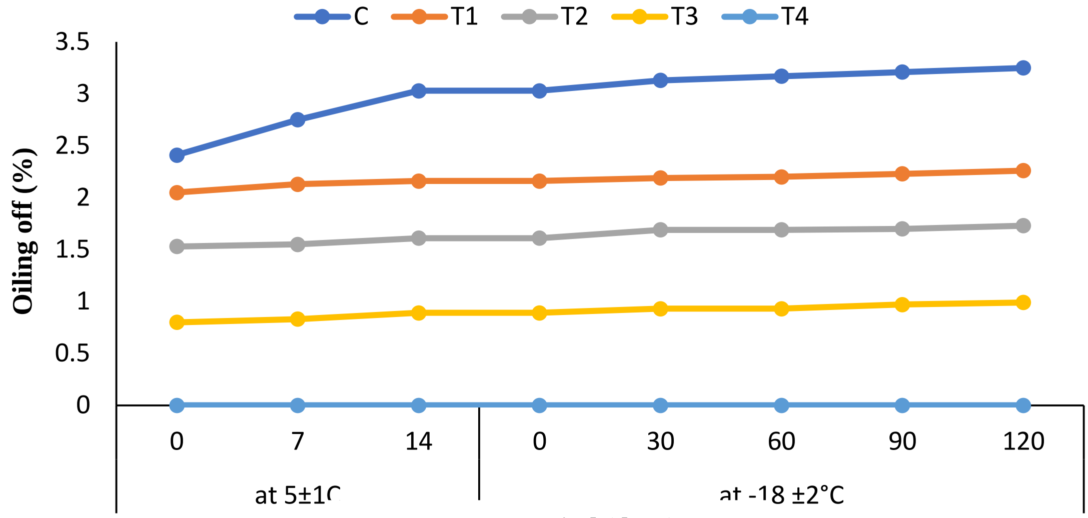

Fig. 9: Effect of partial replacement of cow's milk with buffalo's milk on Oiling off (%) of mozzarella cheese.

See footnote Fig. (2).

3. Rheological properties of Mozzarella cheese

3.1. Texture profile analysis for Mozzarella cheese

Determining the texture parameters has been of concern because texture is one of mozzarella cheese's most critical quality attributes. All cheese treatments ' texture parameters (Hardness, cohesiveness, springiness, Gumminess, and chewiness) followed similar trends (Table 2). All texture parameters of mozzarella cheese treatments increased significantly as the storage period advanced (Abdel-Hamid et al., 2001; Mailam, 2015; Nasr, 2019), which might be due to the loss of moisture and consequently an increase in total solids and protein content (Abdel-Hamid et al., 2001; Mailam, 2015). Also, Romeih (2006) and El-Zeini *et al*. (2007) found that adhesiveness of cheese treatments increased as the storage period progressed, which may be attributed to proteolysis during the storage period. It is noticed the increases of texture parameters of (values) of mozzarella cheese treatments were less obvious during cheese storage at -18±2°C than those during storage of cheese treatments at 5±1°C (Table 2), which might be due to the differences of the rate of losing moisture and increasing the total solids and protein content.

It has been reported that these are the two main factors affecting the texture of low-fat mozzarella cheese; the first one is the fat content of cheese, which adversely affects the hardness and other texture parameters, while the second one is the temperature of the cheese, which increases all texture parameters. This might be due to the high fat content of cheese acting as a weak point in the protein matrix, which makes it less hard than the cheese matrix without fat, and also fat plays the role of liberation to provide smoothness and a softer texture (Romih *et al*., 2002; Ahmed *et al*., 2023 and Chatli *et al*., 2019). The second factor is the addition of fat replacers, which decreases the hardness and other texture parameters, acting as flavor and increasing the water holding capacity of cheese, consequently reducing the hardness of cheese (Koka & Metin, 2004; Chati et al., 2019; and Ahmed *et al*., 2023). Date in Table (2) indicated that there were a positive correlation among the rate of replacing milk fat with N-lite D and the values of texture parameters, which means that as the rate of replacement increased the values of all texture parameters increased, which might be due to the effect of reducing fat content of cheese was more effective than the effect of adding N-lite D. Cheese treatment T_4 that made from skim milk and adding the highest amount from N-lite D (3%) exhibited the highest values of hardness and other texture parameters. In comparison, the control cheese treatment (C), which was made from mixed milk containing 3%, exhibited the least hardness and other texture parameters.

Table 2: Effect of partial replacement of fat milk on rheological parameters of mozzarella cheese.

Property Treatments		Storage period (days) at 5±1°C			Storage period (days) at -18±2°C					Means**
		Fresh	7	14	Fresh	30	60	90	120	
Hardness (g)	C*	6.12	6.85	8.17	8.17	8.21	8.26	8.28	8.31	7.796^{c}
	T_1	6.10	6.81	8.09	8.09	8.12	8.18	8.21	8.27	7.733^{c}
	T_2	6.22	6.95	8.22	8.22	8.25	8.31	8.36	8.39	7.865^{c}
	T_3	6.43	7.15	8.82	8.86	8.96	9.09	9.13	9.18	8.452^{b}
	T_4	6.65	7.63	9.11	9.11	9.18	9.24	9.31	9.39	8.702^{a}
Means**		6.304^{f}	7.078^{e}	8.49^{d}	8.49^{d}	8.544^{c}	8.616^{b}	8.658^{b}	8.708^{a}	
Cohesiveness (g/mm)	C*	0.401	0.426	0.448	0.448	0.459	0.471	0.482	0.499	0.454^{a}
	T_1	0.409	0.431	0.449	0.449	0.461	0.482	0.491	0.498	0.458^{a}
	T_2	0.418	0.447	0.456	0.456	0.467	0.486	0.493	0.501	0.465^{a}
	T_3	0.425	0.459	0.468	0.468	0.475	0.488	0.496	0.513	0.474^{a}
	T_4	0.449	0.469	0.485	0.485	0.497	0.509	0.518	0.529	0.492^{a}
Means**		0.420^{b}	0.446^{b}	0.461^{b}	0.461^{b}	0.471^{b}	0.487^{b}	0.496^{b}	0.508^{a}	
Springiness (mm)	C*	6.43	7.09	7.98	7.98	8.12	8.25	8.33	8.49	7.833^{c}
	T_1	6.39	7.12	7.85	7.85	8.09	8.22	8.29	8.43	7.78^{c}
	T_2	6.41	7.15	7.92	7.92	8.17	8.35	8.41	8.56	7.861^{c}
	T_3	6.56	7.33	8.09	8.09	8.26	8.44	8.59	8.73	8.011^{b}
	T_4	6.69	7.55	8.43	8.43	8.57	8.71	8.82	8.89	8.261^{a}
Means**		6.496^{e}	7.248^{d}	8.054^{c}	8.054^{c}	8.242^{b}	8.394^{b}	8.488^{b}	8.62^{a}	
Gumminess (N)	C*	2.45	2.92	3.66	3.66	3.77	3.89	3.99	4.15	3.561^{b}
	T_1	2.49	2.94	3.63	3.63	3.74	3.94	4.03	4.12	3.565^{b}
	T_2	2.60	3.11	3.75	3.75	3.82	4.04	4.12	4.21	3.675^{a}
	T_3	2.73	3.28	4.15	4.15	4.26	4.44	4.53	4.71	4.031^{c}
	T_4	2.96	3.56	4.42	4.42	4,56	4.70	4.82	4.97	4.264^{c}
Means**		2.646^{e}	3.162^{d}	3.922^{c}	3.922^{c}	3.8975^{c}	4.202^{b}	4.298^{b}	4.432^{a}	
Chewiness (g/mm.)	C*	15.75	20.70	29.21	29.21	30.61	32.09	33.24	35.23	28.255^{d}
	T_1	15.91	20.43	28.50	28.50	30.26	32.39	33.41	34.73	28.016^{d}
	T_2	16.67	22.24	29.70	29.70	31.21	33.73	33.13	33.92	28.787^{c}
	T_3	17.91	24.04	33.53	33.53	35.19	37.47	38.91	41.12	32.712^{b}
	T_4	19.80	26.88	37.26	37.26	39.08	40.94	42.51	44.18	35.988^{a}
Means**		17.208^{g}	22.858^{6}	31.64^{e}	31.64^{e}	33.27^{d}	35.324^{c}	36.24^{b}	37.836^{a}	

See the legend of Fig. 2.

● For each effect, the letters in the same row mean the multiple comparisons are different; letter A is the highest mean, followed by B, C, etc.

* Significant at 0.05 level ($P \leq 0.05$)

4. Sensory evaluation

Scores of organoleptic properties (Flavor, appearance, body, and texture, and total scores) of mozzarella cheese are illustrated in Table 3. These organoleptic properties followed almost similar trends. Total scores of all cheese treatments increased significantly ($P \leq 0.05$) throughout the storage period, which might be due to the hydrolysis of protein and fat during storage (Sameen *et al*., 2008). Similar trends were reported by El-Batawy *et al*. (2004), Sameen et al. (2008), and Zedan *et al*. (2014). The enhancements in organoleptic property scores during the storage of cheese treatments at -18 ±2°C were less pronounced than those observed during storage at 5 ±1°C.

On the other hand there were no significant differences among cheese treatments C, T_1, T_2 and T_3, which means replacing of milk fat up to 75% with N-lite D, which is a carbohydrate based fat replacer did not have significant (P>0.05) effect on the organoleptic properties of Mozzarella cheese, while increasing the rate of replacing milk fat with N-lite D caused a significant (P≤0.05) decline of the total organoleptic properties scores (Table 3), which might because this cheese was made from skim mixed milk (Table 3) (Sameen *et al*., 2010 and Chatli *et al*., 2019), who reported that fat reduction adversely affected all sensory attributes, while adding fat replacers improved the organoleptic properties of low fat mozzarella cheese.

Table 3: Effect of storage temperature on Organoleptic Analysis of Mozzarella cheese.

Property Treatments		Storage period (days) at 5±1°C			Storage period (days) at -18±2°C					Means**
		Fresh	7	14	Fresh	30	60	90	120	
Flavor (50)	C*	41	41	42	42	43	43	43	42	42^{a}
	T_1	42	42	42	42	43	43	44	43	43^{a}
	T_2	41	41	42	42	42	42	43	43	42^{a}
	T_3	40	40	41	41	41	41	42	42	41^{a}
	T_4	37	38	41	41	38	39	39	40	38^{b}
Means**		40.2^{c}	40.4^{c}	41.6^{b}	41.6^{b}	41.4^{b}	41.6^{b}	42^{a}	42^{a}	
Body & texture (35)	C*	30	30	31	31	32	32	33	32	31^{a}
	T_1	30	30	30	30	31	30	30	31	30^{a}
	T_2	30	31	31	31	31	31	31	30	31^{a}
	T_3	30	30	30	30	31	31	31	31	31^{a}
	T_4	27	27	28	28	29	29	29	30	28^{b}
Means**		29.4^{c}	29.6^{c}	30^{b}	30^{b}	30.8^{a}	30.6^{a}	30.8^{a}	30.8^{a}	
Appearance (15)	C*	11	11	12	12	12	12	12	12	12^{a}
	T_1	12	12	13	13	13	13	12	13	12^{a}
	T_2	11	11	12	12	12	12	13	12	12^{a}
	T_3	11	11	12	12	12	12	12	12	12^{a}
	T_4	10	11	11	11	11	11	11	11	10^{b}
Means**		11^{b}	11.2^{b}	12^{a}	12^{a}	12^{a}	12^{a}	12^{a}	12^{a}	
Total (100)	C*	82	82	85	85	87	87	88	86	85^{a}
	T_1	84	84	85	85	87	86	86	87	85^{a}
	T_2	82	84	85	85	85	85	87	85	85^{a}
	T_3	81	83	84	83	84	84	85	85	85^{a}
	T_4	74	76	77	77	78	80	80	82	78^{b}
Means**		80.8^{e}	82.2^{d}	83.2^{c}	83.2^{bc}	84.2^{c}	84.2^{ab}	85.2^{a}	85^{a}	

See the legend of Fig. 2.

● For each effect, the letters in the same row mean the multiple comparisons are different; letter A is the highest mean, followed by B, C, etc.

* Significant at 0.05 level (P ≤ 0.05).

Table 4: Effect of partial replacement of cow's milk with buffalo's milk on the quality of low-fat Mozzarella cheese.

Low-fat Mozzarella cheese properties.	Multiple comparisons●						Multiple comparisons●								
								at 5±1°C			at 18±2°C				
	Mean squares	C	T_1	T_2	T_3	T_4	Mean squares	0	7	14	0	30	60	90	120
Titratable acidity (%)	0.035*	C	B	B	A	A	0.038*	E	D	C	C	B	B	A	A
Moisture (%)	0. 047*	C	C	C	B	A	0.019*	A	B	C	C	D	D	E	E
Fat (%)	6.114*	A	B	C	D	E	0.026*	D	C	BC	BC	B	AB	A	A
Protein (%)	79.153*	A	B	C	D	D	1392.28*	D	D	C	C	BC	B	AB	A
Ash (%)	0.074	A	A	A	A	A	2147.735*	C	C	B	B	B	AB	A	A
Meltability (mm)	4.236*	A	AB	B	C	D	1196.051*	D	F	E	E	D	C	B	A
Stretchability (cm)	306.349*	A	A	B	C	D	2493.96*	F	F	E	E	D	C	B	A
Oiling off	583.854*	A	B	C	D	E	60.964*	E	D	C	C	B	AB	AB	A

See the legend of Fig. (2).

● For each effect, the letters in the same row mean the multiple comparisons are different; letter A is the highest mean, followed by B, C, etc.

* Significant at 0.05 level ($P \leq 0.05$).

Conclusion

It could be concluded that acidity, fat, total protein, ash content, meltability, stretchability, oiling-off, and texture parameters increased, while moisture decreased during storage. These changes were more obvious in cheese stored at 5±1°C than in cheese stored at -18±2°C.

The total scores of organoleptic properties of cheese treatments C, T_1, T_2, and T3 were not significantly different from each other, which means replacing up to 75 % of milk fat with N-lite D did not adversely affect the sensory attributes of mozzarella cheese.

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تأثير استبدال دهن الحليب بـ N-lite D على جودة جبن الموزاريلا قليل الدسم

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الملخص العربي

تم تقييم إمكانية صنع جبن موزاريلا قليل الدسم عالي الجودة. تم صنع خمس معاملات لجبن الموزاريلا من الحليب المختلط (40٪ حليب بقري و 60٪ حليب جاموسي). تم صنع معاملة الجبن الكنترول من حليب مختلط 3٪ دهن. تم صنع المعاملات الأربع الأخرى من حليب مختلط 2.25 و 1.50 و 0.75 و 0.00٪ حليب دهن مع إضافة N-Lite D بنسبة 0.75 و 1.50 و 2.25 و 3.00٪ على التوالي (T1 و T2 و T3 و T4). أظهرت النتائج التي تم الحصول عليها أن استبدال دهن الحليب بـ N-lite -D تسبب في زيادة كبيرة في الحموضة والرطوبة وجميع معايير الملمس (الصلابة والتماسك والمرونة واللزجة والمضغ)، بينما انخفض محتوى الدهون والحموضة والدهون والبروتين والرماد وقابلية الذوبان وقابلية التمدد والزيت مع استمرار فترة التخزين، بينما انخفض محتوى الرطوبة. كان التغير في جودة الجبن أثناء التخزين عند 5 ± 1 درجة مئوية أكثر وضوحًا من التغير في جودة الجبن أثناء التخزين عند -18 ± 2 درجة مئوية. لم تختلف الدرجات الإجمالية للخصائص الحسية للجبن لمعاملات الجبن C و T1 و T2 و T3 و T4 بشكل كبير عن بعضها البعض، مما يعني أنه من الممكن استبدال ما يصل إلى 75٪ من دهن الحليب بـ N-Lite D دون تأثير ضار على الخصائص الحسية لجبن الموزاريلا.

الكلمات المفتاحية: موزاريلا – بديل الدهون – قابلية الذوبان – قابلية التمدد.