Indian J Dairy Sci 76(5): 458-465
https://doi.org/10.33785/IJDS.2023.v76i05.006

RESEARCH ARTICLE

Physicochemical, colour, textural, rheological and sensory properties of goat milk mozzarella cheeses as affected for acidulants

Arun K Verma (✉), **Tarun Pal Singh, V Rajkumar, K Gururaj, MK Singh and Tanuja Kushwah**

Received: 15 November 2022 / Accepted: 26 April 2023 / Published online: 23 October 2023
© Indian Dairy Association (India) 2023

Abstract: The present study aimed at investigating the effect of four acidulants, *viz.,* acetic acid (CAA), citric acid (CCA), hydrochloric acid (CHA) and lactic acid (CLA) on quality and acceptability of goat milk mozzarella cheese. Four different treatments were prepared using 25% (w/v) of acidulants and their physicochemical, functional, colour, textural, sensory and rheological properties were evaluated. No significant difference in cheese yield, pH, protein and fat were observed among treatments. However, titratable acidity for CCA was significantly higher ($p<0.05$) than for other treatments. Moisture and ash contents in CAA were significantly higher ($p<0.05$) than in CLA and CHA. Cheese CAA had significantly lower ($p<0.05$) meltability than the other treatments. The fat leakage for treatment CCA was significantly higher ($p<0.05$) as compared to other cheeses. The Hunter colour redness (a^*) value for CAA was significantly higher ($p<0.05$) compared to the other treatments. The yellowness (b^*) value of treatment CAA was significantly higher ($p<0.05$) than the treatment CLA. The hardness and chewiness values for the treatments CAA and CHA were significantly higher ($p<0.05$) compared to the other two treatments. Cohesiveness and gumminess values were the highest for the treatment CAA, while these were the lowest for the treatment CLA. The evaluation of frequency and temperature sweeps of cheese samples revealed that the storage modulus (G') and loss modulus (G") for the treatment CHA was the highest, while the treatment CLA had the lowest values. The sensory characteristics of the cheeses from different treatments were statistically similar ($p>0.05$) except colour and appearance score, which was the highest for CCA. It can be concluded that though the type of acidulants had significant effects on various quality parameters of goat milk mozzarella cheese, their overall acceptability remained unaffected.

Keywords: Acidulants; Goat milk; Mozzarella cheese; Rheological behaviour; Sensory evaluation; Texture profile

ICAR-Central Institute for Research on Goats, Makhdoom, Farah-281 122, Mathura, Uttar Pradesh

Arun K Verma (✉)
*E-mail: arun.lpt2003@gmail.com

Introduction

Mozzarella cheese is one of the most consumed cheeses worldwide since it is relished by consumers when eaten alone and as a pizza ingredient (Francolino et al. 2010). Acidification is a critical stage in cheese making that ensures the desired cheese curd characteristics. Because it does not depend on starter efficiency, the direct acidification method for cheese production has gained significant commercial interest (Seth and Bajwa, 2015). The chemical composition and structure of the para-casein matrix obtained during the manufacturing process have a significant impact on the properties of mozzarella cheese (Martínez-Martínez and Vélez-Ruiz, 2019). Also, it has been reported that the type of acid used for pre-acidification affects curd characteristics, rate of curd formation, milk coagulation from the rennet, the recovery of milk solid-not-fat, yield, moisture content, mineral retention, elasticity, textural and rheological properties of cheese (Breene et al. 1964; Ernstrom, 1965; Quarne et al. 1968; Keller et al. 1974; Najafi et al. 2006). Different acids/acidulants, such as lactic acid, acetic acid, hydrochloric acid, phosphoric acid, citric acid, malic acid and glucono-delta-lactone have been used for the preparation of mozzarella cheese (Breene et al. 1964; Quarne et al. 1968; Keller et al. 1974; Patel et al. 1985; Dave et al. 2003; Najafi et al. 2006). Seth and Bajwa (2015) used acetic acid, citric acid and lactic acid as acidulants for the preparation of buffalo milk mozzarella cheese. Moreover, Abd El Aziz and Abo-sera (2015) used organic acids and fruit juices for direct acidification while preparing cow milk mozzarella cheese.

Buffalo milk is generally used to prepare mozzarella cheese, however, now it is also produced from cow milk in many countries. Goat milk can also be attempted for the preparation of high-quality mozzarella cheese, as goat milk products receive special preferences due to their characteristic flavour, texture and delicacy.

The recent trend of growth in the consumption of goat milk and milk products is driven by their beneficial effects such as lower allergenicity, better digestibility and many shared anecdotal health claims on human health (Hanelein, 2004; Lima et al. 2018). The preparation of mozzarella cheese from goat milk either alone or in combination with buffalo milk has been attempted in the past with limited studied parameters (Sabikhi and Kanawjia, 1992; Pal and Agnihotri, 2000). However, to the best of our knowledge, there is no report on the application of different acidulants for the preparation of goat milk mozzarella cheese. Since goat milk has compositional differences from cow and buffalo milk as far as protein and fat are concerned, it would be interesting to investigate the processing approach and the quality of goat milk mozzarella cheeses prepared using different acidulants. Therefore, the present study was envisaged to use acetic acid, citric acid, hydrochloric acid and lactic acid as an acidulant in the preparation of goat milk mozzarella cheese and observe their effect on physicochemical, colour, textural, rheological and sensory properties of the products.

Materials and Methods

Ingredients

The fresh goat milk (Fat: 4.5%; SNF: 9.37%) was procured from the Jamunapari unit of the ICAR-Central Institute for Research on Goats, Makhdoom and brought to the laboratory. The milk was filtered, pasteurized at 72 ºC for 30 sec and cooled down to below 10 ºC. The pasteurized milk was used for the preparation of mozzarella cheeses. Analytical grade acidulants like acetic acid, citric acid, hydrochloric acid and lactic and other analytical chemicals and reagents were procured from the standard firm. Microbial Meito® rennet in powder form having an activity of 300,000 Mu/g was purchased from Meito Sangyo Co., Ltd. (Nishi-ku Nagoya 451–8520, Japan) for cheese preparation.

Experimental details

In the present study, the rennet concentration and the process (pre-acidification pH, renneting temperature, coagulation time, cooking/scalding time and plasticization temperature) for the preparation of goat milk mozzarella cheese were standardized. This was followed by the preparation of goat milk mozzarella cheese using a 25% concentration of different acidulants, namely acetic acid, citric acid, hydrochloric acid and lactic acid. The prepared mozzarella cheeses were packed in low-density polyethylene (LDPE) pouches and analysed for the physicochemical, colour, textural, rheological and sensory properties.

Preparation of mozzarella cheese

Pasteurized goat milk (Fat: 4.5%; SNF: 9.37%) was taken and pre-acidified to pH 5.40±0.02 using acetic acid (CAA), citric acid (CCA), hydrochloric acid (CHA) and lactic acid (CLA). This was followed by the addition of rennet (40mg/L) into the milk and proper mixing. The milk was left undisturbed for setting at 31ºC for 1h. Thereafter, the curd was cut into 1 cm^3 pieces. The temperature of the cheese vat having curd pieces was gradually raised from 31ºC to 39ºC in 40-45 min with simultaneous stirring. After cooking whey was drained off through a strainer and the cheese curd was subjected to manual plasticization at 72±2 ºC. Subsequently, plasticized cheese was dipped into a brine solution (6%) and then dried at a refrigerated temperature. The weight of the prepared mozzarella cheese was recorded and packed in an LDPE for further study.

Product analyses

Cheese yield, pH and acidity

The cheese yield was measured by dividing the weight of the cheese by the total weight of the milk.

$$\text{Cheese yield (\%)} = \frac{\text{Weight of cheese}}{\text{Weight of milk}} \times 100$$

The pH of cheese samples was determined by homogenizing 10 g of the sample with 20 ml of distilled water, and the reading was recorded at 25 °C using a microprocessor-controlled pH analyser (Mettler Toledo®, Ohio, USA). The titratable acidity of the cheese, expressed as a lactic acid (% by weight), was evaluated by mixing 10 g of grated cheese with 90 ml distilled water, and subsequent titration of the filtrate.

Proximal composition

The moisture, fat, protein and ash content of the grated cheese samples were determined using a moisture analyser, Gerber method, Kjeldahl assembly, and Muffle furnace, respectively as per methods described by IS: SP18(Part XI) 1981.

Functional properties

The meltability of cheese samples was determined by the method of Savello et al. (1989). Here, a pyrex glass tube (25cm long and 3cm diameter) was taken and the grated cheese was plugged at one end. After incubation at 30 °C for 2 h, the tube with cheese was heated at 110°C for 50 min in a horizontal posture, and the distance travelled by molten cheese from the reference line was measured in centimetres. The fat leakage or oiling off property of cheese was determined by the method of Breene et al. (1964). The percentage area ratio of the cheese disc and oil ring was calculated as the fat leakage.

Hunter colour parameters

The colour values of the cheese samples were recorded by evaluating Hunter lightness (L^*), redness (a^*) and yellowness (*b**) values using Color Tec PCM+ (ColorTecAssociates, Inc., Clinton, NJ) at six different places of samples.

Texture profile analysis

The Stable Micro System (Model TA.XT 2i/25 Surrey, U.K.) was used to assess the textural properties of goat milk mozzarella cheeses. The analysis was carried out using the central cores of two pieces of each sample (1.5 cm^3), that were compressed twice to 60% of their original height. A 75 mm compression platen (P75) connected to a 30 kg load cell was applied at a crosshead speed of 2 mm/s to press the samples.

Rheological property

The rheological properties of goat milk mozzarella cheese samples were assessed using a dynamic rheometer (MCR72, Anton Paar Ltd., Austria) connected to a 25 mm diameter parallel stainless steel plate geometry with a 2 mm gap (Sharma et al. 2016). The cheese samples were placed on the platform and equilibrated at the test temperature for 2 min. To prevent moisture loss during measurements, vegetable oil was applied around the sample. The linear viscoelastic (LVE) limit of the cheeses was determined using strain amplitude sweeps ranging from 0.01 to 100% at 1 Hz and 70 °C. The frequency sweeps of the cheese samples were measured at 70 °C using 0.2% strain amplitude and frequencies ranging from 100 Hz to 0.01 Hz. The temperature sweeps of the samples were determined by increasing the temperature from 20 ºC to 90 ºC, and amplitude and frequency were kept fixed at 0.2% and 1 Hz, respectively.

Sensory properties

Sensory analysis of mozzarella cheese samples was carried out by a panel of 8 panellists comprised of scientists and students aged between 20 to 60 years. After briefing the panellists about the experiment they were requested to rate the coded cheese samples on the sensory evaluation proforma using a 9-point hedonic scale (1 = extremely dislike and 9 = extremely like) for different sensory attributes like colour and appearance, flavour, body and texture and overall acceptability.

Statistical analysis

The experiment was independently replicated thrice to generate the data and each analysis was performed in duplicate (n=3). Eight trained sensory panellists were selected for the organoleptic evaluation of the cheese during each experimental trial (n=24). The generated data were analysed using one-way analysis of variance (ANOVA) in SPSS for Windows (version 17.0, SPSS, Inc., Chicago, IL) to determine the mean and standard error (SE) for each parameter. The obtained means were compared by Duncan's multiple range test, considering significant differences when $p< 0.05$.

Results and Discussion

Cheese yield, pH and acidity

The yields of mozzarella cheese prepared with different acidulants were statistically similar and ranged from 11.91% to 12.69% (Table 1). This is probably because of the use of the same milk and processing approach for all the treatments. Lower total solids (13.26%) in goat milk than in buffalo milk might have contributed to the lesser cheese yield. Similar to our finding, Martínez-Martínez and Vélez-Ruiz (2019) reported a yield of 11.7 to 13.1% for cheeses manufactured following different formulations. Chatli et al. (2019) also observed the yield of low-fat and full-fat buffalo milk mozzarella cheeses in the range of 8.90-13.81%. However, a comparatively lower product yield (7.71-9.44%) for low-fat mozzarella cheeses was obtained by Zisu and Shah (2005). There were no significant differences in the pH value (5.94-5.98) among treatments. However, treatment CCA had a slightly lower pH value as compared with other treatments. Guinee et al. (2002) reported pH values in the range of 5.4-5.9 for low-moisture mozzarella cheeses. Titratable acidity for treatment CCA was significantly higher ($p<0.05$) in relation to other treatments, which could be attributed to the non-significantly lower pH value for the mozzarella cheese prepared using citric acid.

Proximal composition

The analysis of the proximate composition of the mozzarella cheeses prepared using four acidulants showed that treatment CAA had significantly higher ($p<0.05$) moisture content compared with the treatment CLA (Table 1). The moisture content (50.82%-52.01%) reported in the present study is in agreement with the findings of Abd El Aziz and Abo-srea (2014) in cow milk mozzarella cheese. Seth and Bajwa (2015) observed a significant effect of acidulants on moisture and moisture in non-fat substances contents of mozzarella pre-cheeses. There were no significant differences in the protein (19.02%-20.77%) and fat (21.50%-21.83%) contents among the four treatments. This could be attributed to similar protein and fat recovery in all the treatments, as followed processing conditions were alike for all the cheeses. Similar fat content was reported by Abd El Aziz and Abo-srea (2014) in cow milk mozzarella cheese. The treatments CHA and CLA had significantly lower ($p<0.05$) ash contents than the treatment CAA. The ash content (2.37-2.72%) recorded in the present study is lower than the values (2.9-3.0%) reported by Seth and Bajwa (2015) in buffalo milk mozzarella cheese prepared by using different acidulants. A significantly higher moisture and ash contents for the treatment CAA could be due to more uptake of brine. The treatment CCA had statistically similar ash content to other treatments.

Functional properties

The functional attributes of mozzarella cheese important for pizza include the desired degrees of flow and stringiness on baking (Guinee et al. 2002). Cheese meltability is an important functional attribute, particularly for cheese used in food eaten after heating (Altan et al. 2005), and it is directly influenced by calcium, fat content, moisture content, pH, and nitrogen fractions (Machuca et al. 2015; Zisu and Shah, 2005). The meltability of cheese prepared using acetic acid was significantly lower ($p<0.05$) than cheeses from other treatments (Table 1). However, the meltability of the mozzarella cheese from treatments CCA, CHA and CLA were statistically similar. A significantly higher meltability for the treatments CAA, CHA and CLA might be attributed to a larger decrease in the Ca and Ca: protein during pre-acidification by citric acid, HCl and lactic acid as compared to acetic acid, as the differences in the binding affinity of calcium for the acidulants have been previously reported (Inczéy, 1976). Keller et al. (1974) also observed a significant effect of the type of acidulants on cheese meltability. The meltability recorded in the present study (17.17-21.37 cm) was much higher than the values (5.1-12.2 cm) reported by Abd El Aziz and Abo-srea (2014) in cow milk mozzarella cheese.

Table 1 Effect of different acidulants on physicochemical, functional, Hunter colour, textural and sensory properties of goat milk mozzarella cheese

Parameter	CAA	CCA	CHA	CLA
		Physicochemical properties		
Cheese Yield (%)	12.06±0.29	11.91±0.25	12.69±0.06	11.98±0.41
pH	5.98±0.01	5.94±0.04	5.97±0.00	5.98±0.01
TA (% by wt)	0.33±0.01^{b}	0.37±0.01^{a}	0.31±0.01^{b}	0.32±0.01b^{b}
Moisture (%)	52.01±0.24^{a}	51.62±0.27^{ab}	51.08±0.32^{ab}	50.82±0.45^{b}
Protein (%)	20.77±0.64	19.02±0.93	19.18±0.11	20.10±0.44
Fat (%)	21.83±1.28	21.50±1.43	21.67±0.61	21.83±0.98
Ash (%)	2.72±0.07^{a}	2.57±0.12^{ab}	2.49±0.03^{b}	2.37±0.04^{b}
		Functional properties		
Meltability (cm)	17.17±0.95^{b}	20.75±0.31^{a}	21.37±0.23^{a}	20.97±0.07^{a}
Fat leakage (%)	105.03±1.39^{c}	135.14±2.33^{a}	113.36±2.44^{b}	107.58±1.38^{c}
		Hunter colour and Texture profile analysis		
Lightness (L*)	83.93±0.27	83.02±1.07	83.28±0.31	83.26±0.31
Redness (a*)	3.60±0.19^{a}	2.46±0.12^{c}	2.94±0.11^{b}	2.93±0.15^{b}
Yellowness (b*)	17.89±0.71^{a}	16.25±0.52^{ab}	16.90±0.67^{ab}	15.96±0.11^{b}
Hardness (N/cm^2)	51.01±2.03^{a}	41.45±2.85^{b}	52.08±2.07^{a}	38.32±1.32^{b}
Adhesiveness (Ns)	-0.38±0.11	-0.69±0.11	-0.27±0.10	-0.25±0.07
Springiness (cm)	0.81±0.03^{a}	0.72±0.02^{b}	0.84±0.03^{a}	0.87±0.02^{a}
Cohesiveness (ratio)	0.54±0.01^{a}	0.54±0.02^{a}	0.49±0.02^{ab}	0.46±0.02^{b}
Gumminess (N/cm^2)	27.41±1.52^{a}	22.61±2.02^{b}	25.53±0.83^{ab}	17.54±0.65^{c}
Chewiness (N/cm)	22.13±0.76^{a}	16.39±1.63^{b}	21.38±1.03^{a}	15.19±0.42^{b}
		Sensory properties*		
Colour & appearance	8.08±0.14^{ab}	8.25±0.17^{a}	7.71±0.16^{b}	7.81±0.17^{ab}
Flavour	8.13±0.17	8.27±0.15	7.85±0.18	7.86±0.18
Body & Texture	7.75±0.20	8.04±0.20	7.69±0.14	7.89±0.16
Overall acceptability	7.98±0.16	8.17±0.21	7.76±0.15	7.80±0.16

n=6; *n=24; Means bearing different superscripts in a row differ significantly ($P<0.05$)

CAA: Mozzarella cheese with acetic acid; CCA: Mozzarella cheese with citric acid; CHA: Mozzarella cheese with hydrochloric acid; CLA: Mozzarella cheese with lactic acid

Heat influences fat leakage, which is affected by heating temperature and time. When cheese is heated, it melts and releases fat, which can coalesce and result in fat separation from the protein matrix. Fat leakage, like meltability, is an important factor to consider if cheese is going to be consumed after heating. A moderate oiling off is preferable because it protects the cheese shreds from surface dehydration, case hardening, and scorching during pizza baking, whereas excessive free oil may appear greasy and unappealing melt (Kindstedt, 2007). The fat leakage for the treatment CCA was significantly higher ($p<0.05$) than the cheeses from other treatments (Table 1). Also, fat leakage for the treatment CHA was significantly higher ($p<0.05$) as compared to treatments CAA and CLA. The fat leakage (105.03-135.14%) for the different cheeses observed in the present study was lower than the average value (163%) reported in four mozzarella cheeses by Wang and Sun (2004).

Hunter colour parameters

The Hunter colour parameters of prepared cheeses were evaluated to know the effect of the studied acidulants and are presented in table 1. The lightness or brightness (*L*)* values (83.02-83.93) of cheeses among treatments did not differ significantly. Martínez-Martínez and Vélez-Ruiz (2019) also observed high luminosity in fresh cheese with lightness values greater than 78. According to Alvarez et al. (2007), the high moisture content in the cheeses was related to their increased luminosity. There were significant differences ($p<0.05$) in the Hunter colour redness (a^*) values of different treatments, and the redness value of different cheeses decreased in the following order CAA>CHA=CLA>CCA. The yellowness (b^*) for the treatment CAA was significantly higher ($p<0.05$) than the treatment CLA. However, yellowness values for treatments CAA, CCA and CHA were statistically similar. Also, there were no significant differences in the yellowness values of treatments CCA, CHA and CLA. Martínez-Martínez and Vélez-Ruiz (2019) reported the redness value of the cheese systems in the negative (green) and yellowness value in the positive. Although, the redness values of the studied cheeses were low (2.46-3.60), these values were not on the negative side to consider the colour green.

Texture profile analysis

The texture profile analysis of goat milk mozzarella cheese revealed that hardness values for treatments CAA and CHA were significantly higher ($p<0.05$) in relation to treatments CCA and CLA, indicating that cheeses prepared using the citric acid and lactic acid were softer (Table 1). The lower hardness values for mozzarella cheeses prepared using citric acid and lactic acid might be ascribed to low calcium content and a high degree of casein hydration (Lawrence et al. 1984). According to Metzger et al. (2001), calcium plays a crucial role in cheese texture by crosslinking protein, and a reduction in cheese calcium decreases crosslinking among protein fibres, resulting in softer texture. Among treatments, no significant differences in adhesiveness values were observed. The springiness value for the treatment CCA was significantly lower ($p<0.05$) than for other treatments. However, the differences in the springiness values of treatments CAA, CHA and CLA were non-significant. The springiness values (0.72-0.87) of the mozzarella cheeses observed in the present study were higher than the values (0.41-0.73) observed by Martínez-Martínez and Vélez-Ruiz (2019). The treatment CLA had a significantly lower ($p<0.05$) cohesiveness value as compared to CAA and CCA. However, the cohesiveness values of CHA and CLA were statistically similar. In agreement with our results, Martínez-Martínez and Vélez-Ruiz (2019) reported the cohesiveness value of functional mozzarella cheese in the range of 0.41-0.73. However, Zisu and Shah (2005) reported a higher cohesiveness value (0.63-0.74) for low-fat mozzarella cheese. Gumminess and chewiness values are secondary data and they varied according to the values of hardness, cohesiveness and springiness. The gumminess and chewiness values for the treatment CAA were the highest, while treatment CLA had the lowest value. Seth and Bajwa (2015) reported significantly different gumminess and chewiness values for the cheeses prepared using three acidulants.

Rheological

According to Keller et al. (1974), the type of acid used to prepare direct acid low-moisture part-skim mozzarella affects cheese calcium content and rheological characteristics. They further stated that the type of acid used for pre-acidification is important as it may influence the functionality of low-fat mozzarella cheese. The strain sweeps of mozzarella cheeses from different treatments showed that the limit of linear viscoelastic (LVE) was about 1 % (Fig. 1a). The application of strain beyond LVE resulted in a gradual decrease in the value of storage modulus (G') for all the cheeses. The storage modulus for the treatment CCA was lower than other treatments. Frequency sweeps of mozzarella cheeses exhibit how viscous and elastic properties change with the rate of applied strain or with a timescale of deformation. The storage (G') and loss (G") moduli for all the treatments increased with increasing frequency from 0.01 to 100 Hz (Fig. 1b, 1c). The dynamic moduli (G' and G") for the treatment CHA was the highest, whereas for the treatment CLA was the lowest throughout the studied frequency range. Temperature sweeps in the range of 20-90 °C were used to study the viscoelastic properties of goat milk mozzarella cheeses during melting (Fig. 1d). Across the entire test temperature range, the dynamic moduli decreased with increasing temperature in all treatments. There was a steep decrease in the storage modulus of all the treatments as the temperature was raised from 20ºC to about 40-45ºC, and this was followed by a more gradual decline in its values, to the lowest at 90ºC. The initial decline in the value of G' reflects softening of the cheese probably due to liquefaction of the lipid phase, which is fully liquid at about 40°C. Storage and loss moduli values represent the extent and strength of protein-protein bonds in the

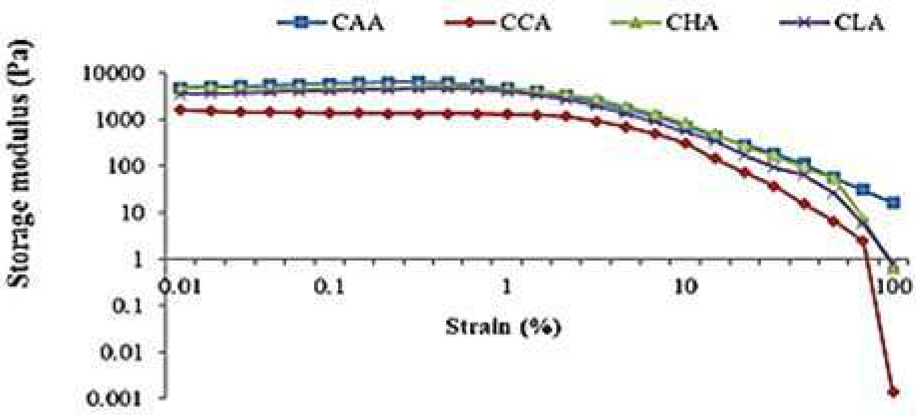

Fig. 1a Strain sweep of goat milk mozzarella cheese prepared by different acidulants

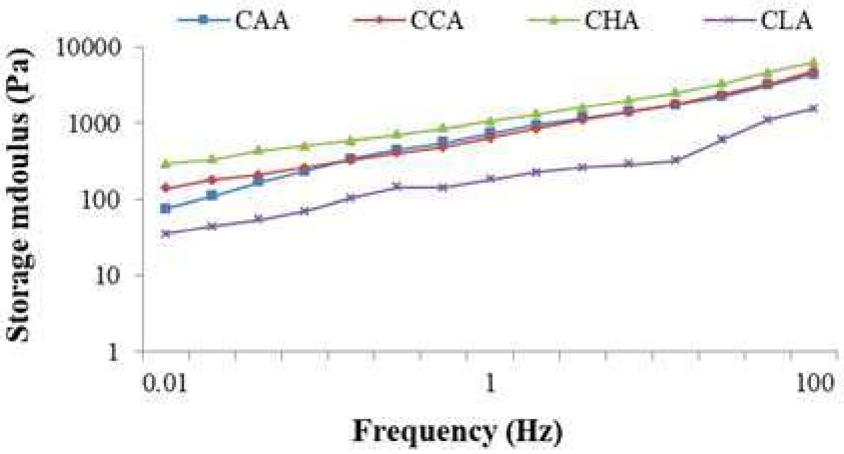

Fig. 1b Storage modulus of goat milk mozzarella cheese prepared by different acidulants as a function of frequency

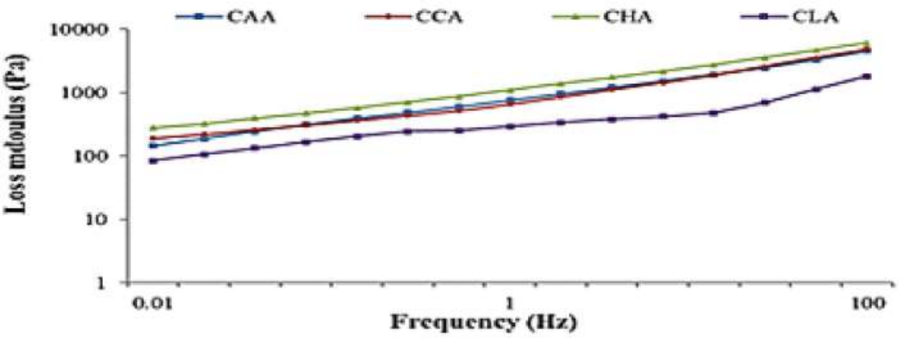

Fig. 1c Loss modulus of goat milk mozzarella cheese prepared by different acidulants as a function of frequency

cheese, so a decrease in their values indicates weak protein-protein interactions. Similar to the frequency sweeps, the dynamic moduli for the treatment CHA was the highest, while for the treatment CLA was the lowest throughout the studied temperature range. The heat-induced changes in the viscoelastic property of cheeses suggest the alteration in their structure, and the cheese showing a lesser degree of structural modifications in the studied temperature range is expected to have low functional properties (Guineeet al. 2002).

Sensory properties

The organoleptic evaluation of the goat milk mozzarella cheeses showed that treatment CCA had significantly higher ($p<0.05$) colour and appearance score than CHA (Table 1). The treatment CHA had a colour and appearance score statistically similar to treatments CAA and CLA. Similarly, differences in the colour and appearance scores of treatments CAA, CCA and CLA were non-significant. There were no significant differences in the flavour, body and texture, and overall acceptability scores among treatments. However, the scores for these sensory parameters for the treatment CCA were non-significantly higher than other treatments. In their study on buffalo milk mozzarella cheese, Seth and Bajwa (2015) also found that products prepared using citric

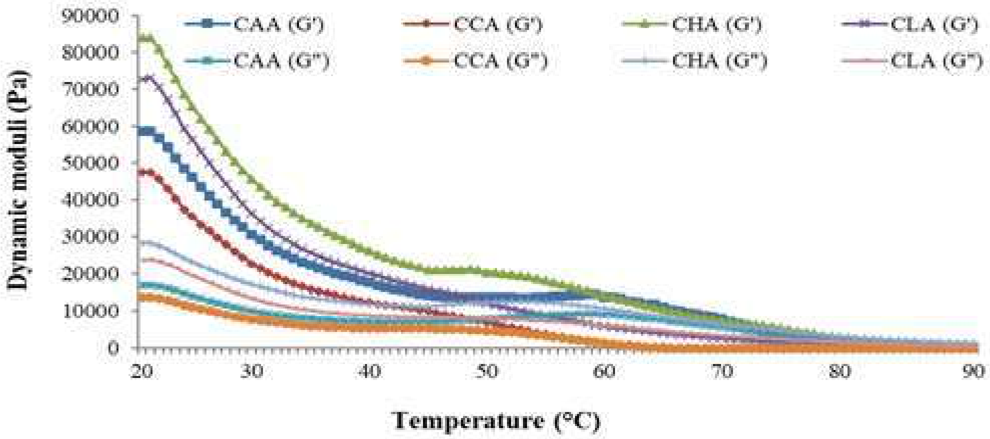

Fig. 1d Temperature sweeps of goat milk mozzarella cheese prepared by different acidulants

acid had a higher appearance and overall acceptability scores as compared to cheeses made with acetic acid and lactic acid.

Conclusions

The findings of the present study showed that the acidulants used for pre-acidification of milk to prepare goat milk mozzarella cheese had significant effects on acidity, moisture, ash, meltability and fat leakage. Hunter colour parameters, especially redness and yellowness values were affected by the used acidulants. Also, acidulants had a significant effect on the textural properties of the mozzarella cheese, and cheeses prepared with acetic acid and hydrochloric acid were harder in relation to citric acid and lactic acid. The evaluation of the rheological parameters of cheeses revealed a similar pattern of structural changes in applied frequency and temperature range. Although cheeses from all the treatments were highly acceptable as rated by the panellists, the assessment of functional and textural properties showed that treatments CCA and CLA were superior to others.

Acknowledgements

The authors express their gratitude to the Director of this Institute for providing the necessary facilities to carry out the research. Rajendra Singh, Suneel, and Khem Chand's technical assistance and support is also gratefully acknowledged.

References

Abd El Aziz ME, Abo-srea MM (2014) The effect of direct acidification by different acidulants on the properties of mozzarella cheese. J Food Dairy Sci 5: 7-13

Altan A, Turhan M, Gunasekaran S (2005) Comparison of covered and uncovered Schreiber test for cheese meltability evaluation. J Dairy Sci 88: 857-861

Álvarez S, Rodríguez V, Ruiz ME, Fresno M (2007) Correlations between instrumental texture and colour with chemical composition of Canarian goat cheeses. Arch Zootec 56: 663–666

Breene WM, Price WV, Ernstrom CA (1964) Manufacture of pizza cheese without starter. J Dairy Sci 47: 1173-1180

Chatli MK, Gandhi N, Singh P (2019) Quality of low-fat mozzarella cheese with different fat replacers. Acta Aliment 48: 441-448

Dave RI, McMahon DJ, Oberg CJ, Broadbent JR (2003) Influence of coagulant level on proteolysis and functionality of mozzarella cheeses made using direct acidification. J Dairy Sci 86: 114-126

Ernstrom CA (1965) Mechanized pizza cheese making by means of a continuous direct acidification method. Mfd Milk Prod J 57: 7–11

Francolino S, Locci F, Ghiglietti R, Iezzi R, Mucchetti G (2010) Use of milk protein concentrate to standardize milk composition in Italian citric mozzarella cheese making. LWT-Food Sci Technol 43: 310-314

Guinee TP, Feeney EP, Auty MAE, Fox PF (2002) Effect of pH and calcium concentration on some textural and functional properties of mozzarella cheese. J Dairy Sci 85: 1655-1669

Haenlein GFW (2004) Goat milk in human nutrition. Small Rumin Res 51: 155-163

Inczéy DS (1976) Analytical applications of complex equilibria. John Wiley & Sons Inc., New York, NY

IS: (SP: 18) 1981 ISI Handbook of Food Analysis, Part XI, Dairy Products. Bureau of Indian Standards, Manak Bhavan, New Delhi

Keller B, Olson NF, Richardson T (1974) Mineral retention and rheological properties of mozzarella cheese made by direct acidification. J Dairy Sci 57: 174-180

Kindstedt PS (2007) Low-moisture mozzarella cheese. In: McSweeney PLH (ed) Cheese problems solved, CRC Press LLC, Boca Raton, FL, pp 298–329

Lawrence RC, Heap HA, Gilles J (1984) A controlled approach to cheese technology. J Dairy Sci 67: 1632-1645

Lima MJR, Teixeira-Lemos E, Oliveira J, Teixeira-Lemos LP, Monteiro A, Costa JM (2018) Nutritional and health profile of goat products: focus on health benefits of goat milk. Goat Science. Intech Open 189-232

Machuca LM, Rodriguez YE, Guastavino Meneguini DE, Bruzzo ME, Acuña Ojeda MF, Murguia MC (2015) Production and sensory evaluation of novel cheeses made with prebiotic substances: inulin and oligofructose. Food Nutri Sci 6: 1489- 1495

Martínez-Martínez M, Vélez-Ruiz JF (2019) Development and physicochemical characterization of a functional mozzarella cheese added with agavin. J Food Sci Nutri Res 2: 87-107

Metzger LE, Barbano DM, Kindstedt PS, Guo MR (2001) Effect of milk preacidification on low fat mozzarella cheese: II. Chemical and functional properties during storage. J Dairy Sci 84: 1348-1356

Najafi MBH, Asianfar H, Ghoddosi HB (2006) Study on physico-chemical, rheological and sensory properties of mozzarella cheese by direct acidification. Am Eurasian J Agric Environ Sci 1: 268-272

Pal UK Agnihotri MK (2000) Quality and shelf-life of direct acid goat milk mozzarella cheese at refrigeration temperature. Indian J Anim Sci 15: 57-61

Patel GC, Vyas SH, Upadhyay KG (1986) Evaluation of mozzarella cheese made from buffalo milk using direct acidification technique. Indian J Dairy Sci 39:394–403

Quarne EL, Larson WA, Olson NF (1968) Recovery of milk solids in direct acidification and traditional procedures of manufacturing pizza cheese. J Dairy Sci 51: 527-530

Sabikhi L, Kanawjia SK (1992) Effect of admixing of goat and buffalo milks on sensory, compositional and textural characteristics of direst acid mozzarella cheese. Indian J Dairy Sci 45: 562-562

Savello PA, Ernstrom CA, Kalab M (1989) Microstructure and meltability of model process cheese made with rennet and acid casein. J Dairy Sci 72: 1-11

Seth K, Bajwa U (2015) Effect of acidulants on the recovery of milk constituents and quality of mozzarella processed cheese. J Food Sci Technol 52: 1561-1569

Sharma P, Munro PA, Dessev TT, Wiles PG (2016) Shear work induced changes in the viscoelastic properties of model mozzarella cheese. Int Dairy J 56: 108-118

Wang HH, Sun DW (2004) Evaluation of the oiling off property of cheese with computer vision: Correlation with fat ring test. J Food Eng 61: 47-55

Zisu B, Shah NP (2005) Textural and functional changes in low-fat mozzarella cheeses in relation to proteolysis and microstructure as influenced by the use of fat replacers, pre-acidification and EPS starter. I Dairy J 15: 957-972