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RESEARCH ARTICLE

Comparison of acid casein-based Mozzarella cheese analogue with natural Mozzarella cheese during refrigerated storage

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Abstract: Mozzarella cheese analogue was prepared using acid casein and partially hydrogenated palm kernel oil as protein and fat source respectively and compared with natural Mozzarella cheese during refrigerated storage. Moisture and soluble nitrogen of analogue and natural cheese were statistically similar while analogue had higher pH and acid degree value. Moisture of the samples reduced during storage while pH, soluble nitrogen and acid degree value increased. Hardness and cohesiveness of both the samples were similar. Natural cheese had higher springiness and chewiness while analogue showed higher gumminess and adhesiveness. Hardness, gumminess and chewiness reduced during storage while other textural characteristics remained unaffected. Natural cheese had better functional characteristics such as shredability, meltability, fat leakage and stretchability. Meltability, fat leakage and stretchability improved during storage while shredability deteriorated. Natural cheese showed superior sensory characteristics, viz. appearance, flavour, melting, stringiness and chewiness throughout the storage.

Keywords: Mozzarella cheese; Mozzarella cheese analogue; physico-chemical characteristics; textural characteristics; functional characteristics; sensory characteristics

Introduction

Cheese analogue is generally defined as a product prepared by blending different constituents, including non-dairy fat and protein, either singly or in combination and producing a product similar to cheese. The production of cheese analogue is increasing globally because of continuous increase in consumer demand since the consumers want a product which possesses appreciable functional characteristics and acceptable sensory characteristics. The manufacturers are also interested in developing cheese analogues due to ease of production and cost-effectiveness (Dharaiya et al. 2019).

Refrigerated storage of Mozzarella cheese and its analogues results in some desirable changes such as mellowness, melt and stretch as well as undesirable changes such as sliminess on surface, poor shredability, excessive fat leakage etc. which are mainly result of proteolytic changes. The starter culture as well as rennet has been implicated in leading to such storage changes in natural Mozzarella cheese. Plasmin has been implicated for the changes observed in the functional properties of Mozzarella cheese analogue. Storage stability of cheese product is important from the perspective of the pizza makers, so that the desired functional properties may be maintained during its estimated usage period (Alinovi et al. 2020).

Therefore, the aim of current investigation is to observe the changes taking place in physico-chemical, textural, functional and sensory properties of Mozzarella cheese and its analogue

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during refrigerated storage and to recommend optimum period of storage to obtain suitable characteristics for pizza-making.

Materials and Methods

Acid casein (87.12% protein) was obtained from M/s. Mahaan Protein Ltd., Kosikalan, India. Specialty palm kernel oil (partially hydrogenated) based vegetable fat (Melting point – 32°C) was obtained from M/s. Kamani Oil Industries Pvt. Ltd., Mumbai, India. Calcium chloride, dihydrate; di-sodium hydrogen orthophosphate, dihydrate; tri-sodium citrate, dihydrate; anhydrous citric acid; lactic acid and lecithin were procured from M/s. Loba Chemie Pvt. Ltd., Mumbai, India. Pre-gelatinized starch (Pregenil XT) was obtained from M/s. Madhu Hydrocolloids Pvt. Ltd., Ahmedabad, India. Mozzarella cheese flavouring paste was supplied by M/s. Adare Food Ingredients Pvt. Ltd., Vitthal Udyognagar, India. Vacuum-evaporated salt (*Tata* brand) and fresh pre-baked pizza loaves were obtained from a local market. Rennet (*Maxiren* brand) was supplied by DSM Food Specialities Ltd., Mumbai, India.

Preparation of natural Mozzarella cheese: Mozzarella cheese was prepared using the method standardized by Chavhan et al. (2015).

Preparation of Mozzarella cheese analogue

Mozzarella cheese analogue (MCA) was prepared as per the method described by Dharaiya et al. (2021). The formulation of Mozzarella cheese analogue is depicted in Table 1.

Chemical analysis

Mozzarella cheese and analogue samples were analysed for moisture, soluble nitrogen (by semi-micro Kjeldahl method) and acid degree value using the method prescribed by FSSA (2015) as well as pH (Dharaiya et al. 2021).

Texture profile analysis

Texture of the experimental cheese samples was analysed using the method described by Dharaiya et al. (2021).

Functional characteristics

The experimental cheese samples were evaluated subjectively for shredability, considering ease of shredding, length and thickness of shreds and the behaviour of shreds after shredding. A stainless-steel shredder with pore size diameter of 3 mm was used for shredding. Meltability of experimental samples, stretchability and fat leakage was analysed using the methods described by Dharaiya et al. (2019).

Sensory evaluation of cheese as a pizza topping

The experimental cheese samples were examined for pizza making by conducting baking trials as per the method described by Dharaiya et al. (2021).

Statistical analysis

In each part of the study, data obtained from 4 independent trials were statistically analyzed using completely randomized design. Statistical analysis was carried out using one-way ANOVA through MS-Excel.

Results and Discussion

Chemical changes in analogue and natural Mozzarella cheese during storage

The changes in the physico-chemical properties during refrigerated storage of Mozzarella cheese and its analogue have been shown in Table 2.

Moisture

Moisture content of experimental cheese samples reduced significantly ($P<0.05$) during storage, though there was no significant difference between natural and analogue cheese samples but period of storage (P) and interaction between type of cheese and period of storage (C×P) significantly ($P<0.05$) decreased moisture content of cheese samples.

Moisture loss during storage of cheese due to evaporation is a common phenomenon. Such reduction in the moisture content of Mozzarella cheese during refrigerated storage has also been reported by Ehsannia and Sanjabi (2016) and Jana and Tagalpallewar (2017).

pH

The type of cheese (C) and the interaction between type of cheese and period of storage (C×P) had a significant (P d" 0.05) influence on the pH values of the product. The pH of analogue and natural cheeses increased progressively with increase in the

Table 1: Formulation of Mozzarella cheese analogue

Ingredients	Rate of addition (%)
Vegetable fat	15.00
Acid casein	21.30
Tri-sodium citrate	0.90
Disodium hydrogen phosphate	1.60
Lecithin	0.15
Citric acid	0.18
Calcium chloride	0.30
Pre-gelatinized starch	2.00
Cheese flavouring	3.00
Common salt	1.00
Water	54.57

storage period. The rise in pH of analogue was greater up to 21st day, thereafter it tended to stabilize while the pH was of natural cheese increased linearly through-out the storage period. However, such change in the pH was non-significant. Cheese analogue had higher initial pH values than that of natural cheese due to presence of emulsifying salts; such higher pH values associated with analogue was maintained throughout the storage period. (Goncalves and Cardarelli, 2021)

Soluble nitrogen (SN)

The type of cheese (C) failed to exert significant impact on soluble nitrogen while period of storage (P) and interaction between them (C×P) had significant (P<0.05) impact. The fresh cheeses (0 day) were statistically identical in their SN content. SN increased progressively during storage. The increase in SN content at 35th day over the initial content was greater in case of natural cheese (i.e. 1.26%) than in that of analogue (i.e. 1.07%). The lower magnitude of rise in SN content in analogue compared to natural cheese could be due to absence of residual rennet activity and the varying pH conditions in cheese. A similar trend has been reported by several researchers in analogue and natural Mozzarella cheese (Alinovi et al, 2020); processed Mozzarella cheese (Khetra et al. 2015) and processed cheese analogue (Ehsannia and Sanjabi, 2016).

Acid degree value (ADV)

There was a significant (P≤0.05) influence of type of cheese (C), storage period (P) as well as their interaction (C x P) on the ADV of cheeses. ADV increased significantly (P≤0.05) especially from 28th day of refrigerated storage. Fresh natural cheese showed lower ADV. An increase in ADV and Free Fatty Acids (FFA) content of natural cheese during refrigerated storage has also been reported by Jeewanthi and Paik (2018).

Textural changes in analogue and natural Mozzarella cheeses during refrigerated storage

The changes in textural characteristics during refrigerated storage of natural cheese and analogue is presented in Table 3.

Hardness

The type of cheese (C) failed to influence the hardness of cheeses, while the period of storage (P) and the interaction between type of cheese and period of storage (C×P) had a significant (Pd"0.05) influence on the hardness of cheeses. The hardness of analogue gradually increased till 21st day of storage, followed by a gradual decrease till the end (35th day) of storage while natural cheese showed a gradual decrease in its hardness throughout the storage period. In spite of lower moisture content

Table 2: Changes in physico-chemical properties of analogue and natural Mozzarella cheese during refrigerated storage

Cheese samples	0 day	7 days	14 days	21 days	28 days	35 days	Average
			Moisture content (%)				
ACMCA	53.42±0.35^{a}	53.32±0.29^{a}	53.24±0.31^{a}	53.11±0.39^{a}	52.92±0.25^{b}	52.75±0.31^{b}	53.13
NMC	53.65±0.30^{a}	53.41±0.33^{a}	53.27±0.34^{a}	53.14±0.28^{a}	53.04±0.22^{a}	52.89±0.24^{b}	53.23
Average	53.54^{p}	53.37^{p}	53.26^{p}	53.13^{p}	52.98^{q}	52.82^{q}	
CD (0.05)	Cheese type (C)=NS; Period of storage (P)=0.45; C x P=0.67						
			pH				
ACMCA	5.89±0.07^{a}	5.91±0.05^{a}	5.94±0.06^{a}	5.98±0.08^{a}	6.01±0.07^{a}	6.04±0.09^{a}	5.962^{x}
NMC	5.41±0.05^{b}	5.41±0.06^{b}	5.42±0.04^{b}	5.42±0.08^{b}	5.43±0.07^{b}	5.44±0.09^{b}	5.422^{y}
Average	5.65	5.66	5.68	5.70	5.72	5.74	
CD (0.05)	Cheese type (C)=0.12; Period of storage (P)=NS; C x P=0.29						
			Soluble nitrogen (% of total nitrogen)				
ACMCA	1.24±0.14^{a}	1.44±0.18^{a}	1.66±0.21^{a}	1.81±0.15^{a}	2.06±0.14^{a}	2.31±0.15^{b}	1.753
NMC	1.28±0.23^{a}	1.53±0.18^{a}	1.71±0.21^{a}	1.98±0.15^{a}	2.35±0.19^{b}	2.54±0.17^{b}	1.898
Average	1.260^{p}	1.485^{p}	1.685^{p}	1.895^{q}	2.205^{q}	2.425^{q}	
CD (0.05)	Cheese type (C)=NS; Period of storage (P)=0.48; C x P=0.88						
			Acid degree value				
ACMCA	0.58±0.14^{a}	0.63±0.11^{a}	0.72±0.10^{b}	0.79±0.12^{b}	0.85±0.15^{b}	0.96±0.13^{b}	0.755^{x}
NMC	0.19±0.13^{a}	0.22±0.14^{a}	0.25±0.09^{a}	0.29±0.11^{a}	0.34±0.13^{a}	0.39±0.11^{a}	0.280^{y}
Average	0.385^{p}	0.425^{p}	0.485^{p}	0.540^{p}	0.595^{p}	0.675^{q}	
CD (0.05)	Cheese type (C)=0.19; Period of storage (P)=0.23; C x P=0.46						

ACMCA-Acid casein based Mozzarella cheese analogue; NMC – Natural Mozzarella cheese; x & y shows significant difference in type of cheese; p & q shows significant difference during storage; a & b shows significant difference for interaction between type of cheese and period of storage

in analogue, it possessed lower hardness which could be ascribed to the differences in the protein structure and hydration of protein. The increase in the hardness of cheeses during storage could be attributed to a concomitant decrease in the moisture content (Table 2) and possible increase in the water holding capacity (WHC) of proteins, whereas decline in the hardness at a later stage of storage could be ascribed to the proteolytic changes (Table 2) which shadowed the effect of decrease in moisture

Table 3: Changes in textural properties of analogue and natural Mozzarella cheese during refrigerated storage

Cheese samples	0 day	7 days	14 days	21 days	28 days	35 days	Average
			Hardness (N)				
ACMCA	14.48±1.21^{a}	16.50±1.54^{b}	18.44±1.42^{b}	19.09±1.16^{b}	15.93±1.35^{b}	12.57±1.61^{a}	16.17
NMC	18.22±1.53^{b}	16.72±1.42^{b}	15.21±1.62^{a}	14.80±1.16^{a}	14.51±1.23^{a}	12.79±1.09^{a}	15.38
Average	16.35^{p}	16.61^{p}	16.83^{p}	16.95^{p}	15.22^{p}	12.68^{q}	
CD (0.05)	Cheese type (C)=NS; Period of storage (P)=1.85; C x P=3.71						
			Cohesiveness				
ACMCA	0.354±0.07	0.361±0.09	0.380±0.11	0.387±0.08	0.390±0.09	0.396±0.07	0.378
NMC	0.398±0.06	0.387±0.09	0.368±0.10	0.343±0.08	0.321±0.05	0.310±0.09	0.354
Average	0.376	0.375	0.374	0.365	0.356	0.353	
CD (0.05)	Cheese type (C)=NS; Period of storage (P)=NS; C x P=NS						
			Springiness (mm)				
ACMCA	3.66±0.19^{a}	3.77±0.24^{a}	3.81±0.30^{a}	3.89±0.22^{a}	3.72±0.27^{a}	3.51±0.31^{a}	3.73^{x}
NMC	5.12±0.25^{b}	5.28±0.27^{b}	5.35±0.32^{b}	5.36±0.24^{b}	5.20±0.21^{b}	5.03±0.19^{b}	5.22^{y}
Average	4.390	4.525	4.580	4.625	4.460	4.270	
CD (0.05)	Cheese type (C)=0.31; Period of storage (P)=NS; C x P=0.76						
			Gumminess (N)				
ACMCA	511.10±9.73^{a}	594.16±7.53^{b}	703.05±6.69^{b}	740.48±8.41^{b}	621.87±7.52^{b}	497.74±8.95^{a}	611.40^{x}
NMC	725.02±8.12^{b}	648.10±9.04^{b}	453.46±7.68^{a}	389.94±8.22^{a}	389.22±7.65^{a}	367.79±7.69^{a}	495.58^{y}
Average	618.06^{p}	621.13^{p}	578.26^{p}	565.21^{p}	505.55^{q}	432.76^{q}	
CD (0.05)	Cheese type (C)=68.05; Period of storage (P)=83.02; C x P=166.04						
			Chewiness (N-mm)				
ACMCA	18.63±1.31^{a}	22.53±1.63^{b}	26.35±1.52^{b}	28.34±1.95^{b}	23.14±1.72^{b}	17.50±2.31^{a}	22.75^{x}
NMC	37.04±2.21^{c}	34.22±1.95^{c}	24.25±2.04^{b}	20.92±1.62^{a}	20.28±1.88^{a}	15.46±1.84^{a}	25.36^{y}
Average	27.84^{p}	28.38^{p}	25.30^{q}	24.63^{q}	21.71^{q}	16.48^{r}	
CD (0.05)	Cheese type (C)=2.52; Period of storage (P)=3.89; C x P=6.76						
			Adhesiveness (N-mm)				
ACMCA	0.276±0.07	0.290±0.08	0.295±0.10	0.285±0.06	0.282±0.11	0.258±0.09	0.281^{x}
NMC	0.206±0.06	0.213±0.07	0.228±0.05	0.227±0.09	0.223±0.07	0.218±0.10	0.219^{y}
Average	0.241	0.252	0.262	0.256	0.252	0.238	
CD (0.05)	Cheese type (C)=0.15; Period of storage (P)=NS; C x P=NS						

ACMCA-Acid casein based Mozzarella cheese analogue; NMC – Natural Mozzarella cheese; x & y shows significant difference in type of cheese; p, q & r shows significant difference during storage; a, b & c shows significant difference for interaction between type of cheese and period of storage

content of cheeses. Jeewanthi et al. (2016) reported reduction in the expressible serum in Mozzarella cheeses during their refrigerated (4°C) storage; such phenomena are indicative of increase in the water holding capacity of proteins. Similar findings were reported by Jeewanthi and Paik (2018).

Cohesiveness

None of the parameters studied i.e. type of cheese (C), period of storage (P) and their interaction (C×P) had any significant influence on the cohesiveness of the cheeses. Similar results were obtained by Jeewanthi and Paik (2018).

Springiness

The springiness of cheeses was significantly (Pd"0.05) affected the type of cheese (C) and the interaction between type of cheese and period of storage (C×P); the springiness of cheeses remained unaffected by the period of storage (P). Natural cheese had significantly (P<0.05) higher springiness than analogue which could be ascribed to the reduced fat particle size in case of natural cheese resulting in more extensive protein-protein and protein-fat interaction yielding product having desired springiness. The varying rate of hydration of casein in analogue and natural cheese also might have led to the observed difference in the springiness. The dehydrated casein is rehydrated during preparation of cheese analogue while it is naturally hydrated in milk (Badem and Ucar, 2016).

Gumminess

The gumminess values were significantly (P<0.05) affected by the type of cheese (C), the period of storage (P) and their interaction (C x P). The gumminess of analogue was significantly (P<0.05) higher than that of natural cheese. Since gumminess value is derived as a product of hardness and cohesiveness, the trend shown by hardness and cohesiveness is also reflected in the values of gumminess. Higher gumminess is not a desirable characteristic. During storage of Mozzarella cheese, the gumminess was reported to increase initially, followed by a decrease during subsequent storage (Rizwan-ur-Rehman et al. 2017).

Chewiness

The chewiness of experimental cheeses was significantly (P<0.05) influenced by the type of cheese (C), the period of storage (P) as well as their interaction (C×P). Since chewiness is product of springiness and gumminess, the trend exhibited by gumminess and springiness is reflected in the values of chewiness. The mellowing in the structure of Mozzarella cheese during ageing, as a result of proteolytic changes and possibly increased water holding capacity of protein, has a favourable influence on the perceived chewiness of cheese (Jana and Tagalpallewar, 2017).

Adhesiveness

The type of cheese (C) had a significant (P≤0.05) effect on the adhesiveness of product, while the period of study (P) and their interaction (C×P) failed to influence the adhesiveness of cheese appreciably. The difference in the type and proportion of emulsifying salts and the difference in the micro-structure of cheese matrix must have led to the observed differences in the adhesiveness of cheese samples (Jana and Tagalpallewar, 2017).

Changes in the functional characteristics of analogue and natural Mozzarella cheeses during refrigerated storage

Since the analogue and natural Mozzarella cheeses have application mainly as a pizza topping, both the type of cheeses was evaluated for their pizza related baking qualities at an interval of 7 days till 35th day of refrigerated storage (7±1°C). The results related to the changes in the baking qualities of cheeses are presented in Table 4.

Shredability

The shredding property of analogue was found superior to that of natural cheese in the beginning of the storage but with progress of the storage period, the shredability of analogue deteriorated while that of natural cheese improved initially and deteriorated after 21 days of storage. The lower moisture content and presence of emulsifying salts in analogue resulted in better shredability. The improvement in the shredability of natural cheese initially could be attributed to absorption of free moisture into the block of cheese (Banville et al. 2013). The deterioration of shredability towards the end of storage could be due to proteolysis. Similar trend has been observed by Dharaiya et al. (2019).

Meltability and melting time

The meltability of cheeses was significantly (P≤0.05) affected by the cheese type (C), period of storage (P) and their interaction (C×P). The meltability of both types of cheeses increased progressively with the advent of storage. The meltability of Mozzarella cheese increases during storage due to hydrolysis of β-casein and it is correlated with the soluble nitrogen content of cheese (Liu et al. 2024). Meltability of cheese is associated with its moisture in non-fat substances (MNFS) and cheese pH; lowering in pH improves cheese meltability. The progressive increase in proteolysis during ageing of cheese also promotes its meltability, while in case of analogue raising the levels of emulsifying salts (Kamath et al. 2022) and adjusting higher pH value tended to improve the meltability of product. An increase in the meltability of natural cheese and analogue during refrigerated storage has been reported by most researchers (Alinovi et al. 2020).

Owing to the improvement in melting property of cheese, the time required for the product to melt in the baking oven (at 230°C)

tended to decrease progressively with the advancement in the storage period. An inverse relation has been noted between meltability and melting time in the oven.

Fat leakage

The storage period (P) failed to exert any significant influence on the fat leakage of cheeses, while the type of cheese (C) and interaction (C×P) had a significant (P<0.05) influence on it. A gradual decrease in the fat leakage of analogue was noticed during the refrigerated storage. Contrary to this, natural cheese showed gradual increase in the fat leakage throughout the storage period of 35 days. Emulsifying salts used in cheese analogue preparation are known to modify the proteins to emulsify the fat in the cheese matrix (Arief and Manab, 2024). The pH of cheese analogue was higher than that of natural cheese resulting in reduced fat leakage. The increase in the fat leakage in natural cheese could be associated to the difference in the emulsification of milk fat in cheese matrix and the lower pH. The plasticizing treatment given to cheese curd in case of natural cheese might be making the cheese matrix porous and reducing the emulsified state of milk fat contributing to the greater fat leakage. The increase in the fat leakage in natural cheese during refrigerated storage has also been reported by several workers (Alinovi et al. 2020).

Stretchability

The type of cheese (C), the period of storage (P) and their interaction (C×P) were significantly (Pd"0.05) affected the stretchability of stored cheese samples. There was an increase in the stretchability of analogue up to 21 days followed by decline. In case of natural cheese, the stretchability gradually increased throughout the storage period up to 35 days. The fresh analogue cheese stretched to a greater extent than did fresh natural cheese. The initial improvement in the stretchability of Mozzarella cheese with ageing was ascribed in part to the age-related reduction in the concentration of intact para-casein as a result of proteolytic changes taking place during aging (Table 2). Such changes led to product having improved water binding capacity, getting progressively mellowed in body which thus must have led to permitting longer strands of cheese when stretched, post baking (Zedan et al. 2014; Goncalves and Cardarelli, 2021; Guo et al. 2023).

Table 4: Changes in functional properties of analogue and natural Mozzarella cheese during refrigerated storage

Cheese samples	0 day	7 days	14 days	21 days	28 days	35 days	Average
			Shredability*				
ACMCA	Very good	Very good	Good	Good	Fair	Poor	---
NMC	Good	Very good	Very good	Good	Fair	Fair	---
			Meltability#				
ACMCA	2.28±0.24^{a}	2.88±0.29^{a}	3.51±0.26^{a}	4.19±0.31^{a}	4.75±0.27^{a}	5.13±0.30^{b}	3.79^{x}
NMC	3.47±0.32^{a}	4.05±0.30^{a}	4.78±0.28^{a}	5.40±0.24^{b}	5.78±0.29^{b}	6.12±0.27^{b}	4.93^{y}
Average	2.875^{p}	3.465^{p}	4.145^{p}	4.975^{q}	5.265^{q}	5.625^{q}	
CD (0.05)			Cheese type (C)=0.98; Period of storage (P)=1.36; C x P=2.62				
			Melting time (sec)				
ACMCA	470.0±7.32^{a}	462.5±8.14^{a}	432.5±7.91^{a}	390.0±6.45^{a}	365.0±7.29^{b}	322.5±7.85^{b}	407.08^{x}
NMC	440.0±7.83^{a}	430.0±7.54^{a}	392.5±8.19^{a}	352.5±7.12^{b}	332.5±7.80^{b}	300.0±7.22^{b}	374.58^{y}
Average	455.00^{p}	446.25^{p}	412.50^{p}	371.25^{q}	348.75^{q}	311.25^{q}	
CD (0.05)			Cheese type (C)=22.29; Period of storage (P)=34.51; C x P=79.02				
			Fat leakage (cm^{2})				
ACMCA	3.86±0.18^{a}	3.40±0.22^{a}	3.14±0.29^{a}	2.90±0.25^{a}	2.59±0.26^{a}	2.36±0.19^{a}	3.042^{x}
NMC	4.19±0.21^{a}	4.91±0.25^{b}	5.51±0.23^{b}	6.05±0.28^{b}	6.75±0.29^{b}	7.54±0.21^{b}	5.825^{y}
Average	4.025	4.155	4.325	4.475	4.670	4.950	
CD (0.05)			Cheese type (C)=0.61; Period of storage (P)=NS; C x P=2.29				
			Stretchability (cm)				
ACMCA	14.5±1.29^{a}	17.5±1.35^{a}	19.5±1.94^{b}	22.5±1.75^{b}	20.0±1.23^{b}	14.0±1.64^{a}	18.0
NMC	12.5±1.52^{a}	15.0±1.98^{a}	17.5±2.05^{a}	20.75±1.63^{b}	22.75±1.41^{b}	24.75±1.56^{c}	18.875
Average	13.5^{p}	16.25^{p}	18.5^{q}	21.625^{r}	21.375^{r}	19.375^{q}	
CD (0.05)			Cheese type (C)=NS; Period of storage (P)=2.84; C x P=5.08				

ACMCA-Acid casein based Mozzarella cheese analogue; NMC – Natural Mozzarella cheese; x & y shows significant difference in type of cheese; p, q & r shows significant difference during storage; a, b & c shows significant difference for interaction between type of cheese and period of storage; *Subjective analysis; # Arbitrary value

Changes in the sensory quality of stored analogue and natural Mozzarella cheeses as pizza topping

The type of cheese (C) as well as the interaction between type of cheese and period of storage (C×P) significantly (P<0.05) affected all sensory parameters while period of storage (P) failed to significantly influence when judged as a pizza topping (Table 5).

Appearance

The appearance of Mozzarella cheese on pizza pie takes into consideration the melted cheese appearance, fat leakage and browning aspects. The appearance score for natural Mozzarella cheese was significantly (P<0.05) higher than that of analogue. The appearance score for both the samples were increased during first 21 days followed by a decrease. Natural cheese was whiter in colour and glossier. The analogue had a transparent appearance after melting which led to visibility of the pizza base beneath. Dharaiya et al (2021) also reported superior appearance score for natural cheese over analogue.

Flavour

Natural cheese possessed characteristic Mozzarella flavour with slight salty and acidic taste while analogue had characteristics sour taste even though pH was adjusted to higher level. The flavour score of analogue increased upto 21 days while that of natural cheese increased for initial 14 days followed by a decrease. Several researchers reported superior flavour of natural cheese over analogue (Dharaiya et al. 2021; Short et al. 2021).

Melting

Cheese is a network of interconnecting molecules of casein, hence, the hydrolysis of casein molecules influenced melting behaviour of Mozzarella cheese. The analogue sample had

Table 5: Changes in sensory characteristics of analogue and natural Mozzarella cheese during refrigerated storage

Cheese samples	7 days	14 days	21 days	28 days	35 days	Average
			Appearance score			
ACMCA	7.14±0.25^{a}	7.16±0.29^{a}	7.21±0.26^{a}	6.93±0.36^{a}	6.75±0.19^{a}	7.038^{x}
NMC	7.39±0.31^{a}	7.74±0.26^{b}	7.95±0.21^{b}	7.72±0.18^{b}	7.25±0.24^{a}	7.610^{y}
Average	7.27	7.45	7.58	7.33	7.00	
CD (0.05)			Cheese type (C)=0.33; Period of storage (P)=NS; C x P=0.69			
			Flavour score			
ACMCA	6.58±0.19^{a}	6.64±0.16^{a}	6.85±0.24^{a}	6.47±0.21^{a}	5.93±0.18^{a}	6.494^{x}
NMC	7.95±0.21^{b}	8.10±0.20^{b}	7.90±0.29^{b}	7.70±0.22^{b}	7.50±0.24^{b}	7.830^{y}
Average	7.26	7.37	7.38	7.09	6.71	
CD (0.05)			Cheese type (C)=0.65; Period of storage (P)=NS; C x P=1.45			
			Melting score			
ACMCA	7.21±0.29^{a}	7.41±0.25^{a}	7.32±0.30^{a}	7.01±0.26^{a}	6.52±0.24^{a}	7.09^{x}
NMC	7.08±0.21^{a}	7.59±0.26^{a}	7.89±0.28^{b}	7.63±0.19^{a}	7.47±0.23^{a}	7.53^{y}
Average	7.15	7.50	7.61	7.32	6.99	
CD (0.05)			Cheese type (C)=0.38; Period of storage (P)=NS; C x P=1.26			
			Stringiness score			
ACMCA	7.17±0.32^{a}	7.31±0.36^{a}	7.01±0.31^{a}	6.84±0.39^{a}	6.58±0.27^{a}	6.98^{x}
NMC	7.43±0.28^{b}	7.62±0.31^{b}	7.95±0.24^{b}	7.77±0.35^{b}	7.54±0.34^{b}	7.66^{y}
Average	7.30	7.46	7.48	7.31	7.06	
CD (0.05)			Cheese type (C)=0.36; Period of storage (P)=NS; C x P=0.80			
			Chewiness score			
ACMCA	7.27±0.41^{a}	7.37±0.35^{a}	7.06±0.21^{a}	6.93±0.29^{a}	6.73±0.31^{a}	7.07
NMC	7.14±0.37^{a}	7.41±0.31^{a}	7.68±0.26^{b}	7.27±0.24^{a}	7.02±0.32^{a}	7.30
Average	7.21	7.39	7.37	7.10	6.87	
CD (0.05)			Cheese type (C)=NS; Period of storage (P)=NS; C x P=0.72			
			Overall acceptability			
ACMCA	7.07±0.34^{b}	7.18±0.41^{b}	7.09±0.36^{b}	6.82±0.44^{a}	6.49±0.39^{a}	6.93^{x}
NMC	7.40±0.28^{b}	7.64±0.35^{c}	7.84±0.36^{c}	7.62±0.33^{c}	7.29±0.29^{b}	7.56^{y}
Average	7.24	7.41	7.47	7.22	6.89	
CD (0.05)			Cheese type (C)=0.36; Period of storage (P)=NS; C x P=0.48			

ACMCA-Acid casein based Mozzarella cheese analogue; NMC – Natural Mozzarella cheese; x & y shows significant difference in type of cheese; a & b shows significant difference for interaction between type of cheese and period of storage

suboptimal melting with non-uniform matting of the cheese shreds on pizza pie while natural cheese had uniform melting and fusion of cheese shreds. The melting behaviour of analogue improved during initial 14 day of storage while that of natural cheese increased during initial 21 days followed by deterioration. The improvement in the meltability of NMC during refrigerated storage has already been established (Sheikh et al. 2023).

Stringiness

Natural cheese reported superior stringiness than analogue. Natural cheese had thinner and non-fibrous strands while analogue had thicker and fibrous strands. Superior stringiness of natural cheese could be attributed to use of rennet in the preparation while acid casein based analogue is devoid of rennet. The stringiness of analogue improved up to 14th day of refrigerated storage while that of natural cheese improved up to 21st day of the storage followed by deterioration. Similar findings were reported by Short et al. (2021).

Chewiness

The type of cheese (C) and the period of storage (P) could not influence chewiness while their interaction (C x P) had significant ($P<0.05$) influence. In case of natural cheese, chewiness score increased during initial 21 days followed by deterioration while in case of analogue, it increased for initial 14 days and then deteriorated. The judges liked moderate chewiness in case of Mozzarella cheese. The cheese samples were very chewy at the end of storage. Sheikh et al. (2023) also had similar observations.

Overall acceptability

The period of storage (P) could not influence overall acceptability score while type of cheese (C) and the interaction (C x P) had significant ($P<0.05$) influence on it. Analogue had statistically ($P<0.05$) similar score during initial 21 days and then decreased while in case of natural cheese, overall acceptability score improved on 14th day and was statistically ($P<0.05$) similar up to 28th day and then decreased. The maximum score was observed for natural cheese on 21st day of refrigerated storage.

Conclusion

Mozzarella cheese analogue was associated with higher pH and acid degree value than that of natural cheese during refrigerated storage while moisture and soluble nitrogen were almost similar. Moisture of cheese samples reduced with advancement of storage while soluble nitrogen and acid degree value increased. Analogue had lower springiness, chewiness and adhesiveness while higher gumminess compared to its natural counterpart. Hardness, gumminess and chewiness of experimental samples reduced with progression of storage. Shredability of analogue deteriorated as the storage period advanced while that of natural cheese increased up to 14 days and then deteriorated. Analogue had comparatively lower meltability and fat leakage than that of natural cheese. Meltability and stretchability of cheese samples increased with storage. Sensory characteristics of analogue improved up to 14 days followed by deterioration while those of natural cheese improved up to 21 days of storage and then deteriorated.

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