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Manufacturing and Quality of Mozzarella Cheese: A Review

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ABSTRACT

Mozzarella cheese is a soft, unripened cheese variety of the Pasta-filata family which had its origin in the Battipaglia region of Italy. Mozzarella cheese was traditionally made from buffalo milk. It is made all over Italy, in other European countries and USA from cow milk, however the process needs to be modified accordingly. The finished cheese, lightly salted, is white, soft with a very lively surface sheen and has unique property of stretchability. Mozzarella cheese owes its characteristics mainly to the action of lactic acid on dicalcium-para-caseinate. Pure white color is the basic requirement of Mozzarella cheese, because of which buffalo milk is preferred over cow milk.. The current review discusses about the principle and chemistry of mozzarella cheese making, legal standards, mozzarella cheese manufacture, factors affecting quality of mozzarella cheese, composition of mozzarella cheese, value-added ingredients as additive,, equipment for mozzarella cheese manufacture, flavour of mozzarella cheese and the recent developments in mozzarella cheese manufacture. The microstructure and rheological characteristics of cheese, functional properties of mozzarella cheese for use on pizza, browning/blistering of mozzarella cheese, packaging, shelf life and storage changes of mozzarella cheese have been discussed at length in this review. Understanding the factors that determine the characteristics of the cheese product for its suitability for end usage can help the cheese makers to produce 'tailor-made' cheeses as per the whims and wishes of the food retailers and even the varied consumers.

Key words: Mozzarella cheese, variety, manufacture, functional properties, storage quality

INTRODUCTION

Mozzarella cheese is a soft, unripened cheese variety of the Pasta-filata family which had its origin in the Battipaglia region of Italy (Citro, 1981). Conventionally, Mozzarella cheese was made from buffalo milk. However, these days it is being manufactured in Italy, in other European countries and USA from cow milk which needs appropriate modifications (Ghosh *et al.*, 1990). The cheese is white, soft with a glossy surface and is valued for its stretch property. This makes it suitable for the preparation of lasagna, veal cutlet alla Parmigiana and as a topping on pizza (Kosikowski, 1982; Jana, 2001). Mozzarella cheese is used as a topping on pizza pie owing to its inherent stretching qualities. The popularity of pizza parlour, especially amongst youngsters has boosted the production of Mozzarella cheese. In Italy Mozzarella and pizza cheeses accounts for 78% of the total Italian cheese product (Merrill *et al.*, 1994).

Table 1: Prevention food adulteration act (India) requirements for Mozzarella and pizza cheese

Cheese type	Moisture (%)	Fat-on-dry matter (%)
Mozzarella	Max. 60.0	Min. 35.0
Pizza	Max. 54.0	Min. 35.0

Table 2: Microbial specifications of PFA for Mozzarella and pizza cheese

Microbial profile	Requirements
Total plate count/g, Max.	50,000
Coliform count	Absent in 0.1 g
E. coli	Absent in 1 g
Yeast and Mould count	Absent in 1 g
Anaerobic spore count	Absent in 1 g
Salmonella and Shigella	Absent in 25 g
Staph. aureus	Absent in 1 g
Listeria monocytogenes	Absent in 25 g

Table 3: Classification of Mozzarella cheese

Type of cheese	Moisture (%)	Fat-on-dry matter (%)
Mozzarella (Regular)	52.0-60.0	Min. 45.0
Mozzarella (Part skim)	52.0-60.0	30.0-45.0
Mozzarella (low moisture)	45.0-52.0	Min. 45.0
Mozzarella (low moisture, part skim)	45.0-52.0	30.0-45.0

In 'Pasta filata' principle of cheese making, the smooth texture and grain of the cheese is achieved through a skillful stretching of curd in hot water. The desirable characteristics of Mozzarella cheese is brought about by the action of lactic acid on dicalcium-para-caseinate, viz., the rennet cheese curd. At a pH of 5.2 to 5.4, much of this compound gets converted to mono-calcium paracaseinate which provides the strings and sheen to the cheese (Kosikowski, 1958). In India according to Prevention of Food and Adulteration (PFA) Act, there are two variants viz., Mozzarella and Pizza cheeses whose requirements are depicted in Table 1 and the microbial requirements of PFA are given in Table 2.

The Low Moisture, Part Skim Mozzarella (LMPSM) is considered suitable for use as pizza topping. New York state in USA specifies 52.0-58.0% moisture and a minimum fat content of 18.0% (for whole milk product) and a moisture content of 52.0-60.0% (for part-skim product) for Mozzarella cheese (Kosikowski, 1960). A maximum moisture content of 58.0% and minimum FDM of 28.0% is prescribed for such cheese in Sau Paulo state (Schiftan and Komatsu, 1979). In Italy, a minimum of 50% FDM and a maximum of 65.0% moisture are specified for buffalo whole milk Mozzarella cheese. When smoked, the cheese is marketed as Mozzarella di bufala affumicata (Anonymous, 1980; Cortesi and Maranelli, 1982). The Argentine Food Code specifies a minimum of 40.0% Dry Matter (DM) content and minimum of 35.0% FDM for Mozzarella cheese (Dianda, 1982).

Based on moisture and Fat-on-Dry Matter (FDM) content, Breseman (1973) suggested four classes of Mozzarella cheese as provided in Table 3.

MOZZARELLA CHEESE MANUFACTURE

Type of milk: Pure white color is the basic requirement of Mozzarella cheese which is lacking in cow milk cheese due to presence of carotene. Kosikowski (1975a) suggested use of neutralizing dyes (e.g., chlorophyll), benzoyl peroxide and titanium dioxide (@ 0.03%) to cheese milk, to overcome this problem. Buffalo milk is reported to be more suitable than cow milk for Mozzarella cheese due to high yield, its characteristic aroma and physical attributes (Bonassi *et al.*, 1982; Scott, 1986; El-Koussy *et al.*, 1995).

Bonassi *et al.* (1982) did not find any difference in taste, aroma or texture of Mozzarella cheese made from cow milk, buffalo milk or their combination (1:1). The cheese yield and fat content were significantly higher for buffalo milk product but the difference in pH, Titratable Acidity (TA), moisture, protein, soluble nitrogen and ash content were not significant. Singh and Ladkani (1984) standardized the method for Mozzarella cheese from cow and buffalo milk, with and without cheddaring. The stretchability was relatively inferior in buffalo cheese. Patel *et al.* (1986) standardized the Starter Culture (SC) and Direct Acidification (DA) method for the manufacture of Mozzarella cheese from buffalo milk.

The type of milk (viz., cow, buffalo and their admixture) used for Mozzarella had a profound influence on the cheese composition. The cheese obtained from a blend of cow and buffalo milk had superior organoleptic quality as well as meltability compared to those made from individual milks; buffalo cheese had superior nutritional value (Sameen *et al.*, 2008).

An initial fat level of 4.0% fat in buffalo milk gave best result; 0.75-0.80% lactic acid was found to be optimal for stretching operations yielding excellent melt and chewiness in resultant product (Anonymous, 1987). Casillo *et al.* (1984) suggested criteria such as fat content, C_{14}/C_{12} fatty acid ratio and electrophoretic mobility of αs_1-casein to detect adulteration of genuine buffalo milk Mozzarella cheese with cow milk. Buffalo milk mozzarella had higher protein content than cows' milk cheese. Rheological properties of cows' milk cheese were superior to those made from buffaloes' milk or mixture of cow and buffalo milk (1:1) (El-Batawy *et al.*, 2004a).

The meltability of ripened bovine and caprine milk cheeses were similar, when made from standardized milk. Bovine cheese exhibited more free oil compared to caprine cheese.

The bovine cheese underwent greater structural degradation during storage than the caprine cheese (Imm *et al.*, 2003).

Standardization of milk: Satisfactory quality Mozzarella cheese can be made from cow or buffalo milk standardized to 3.0-6.0% fat (Kosikowski, 1982; Patel *et al.*, 1986; Anonymous, 1987). However, use of lower fat content resulted in a harder texture and the cheese lost some of its milky, nutty flavor (Patel *et al.*, 1986). Sundar and Upadhyay (1990) obtained Mozzarella cheese with best sensory quality having superior attributes as a topping on pizza, when buffalo milk was standardized to casein/fat ratio of 0.7. The fat content, yield, meltability and fat leakage of cheese increased with increasing milk fat levels, whereas moisture and protein content tended to decrease. pH and stretchability were not influenced by the fat level in milk. A milk fat level of 2.5% was considered optimum for pizza making (Venkateswarlu *et al.*, 1999; Valle *et al.*, 2004). Mozzarella cheese made from 5.0% fat standardized milk was superior to those made from 0, 3.0 or 7.0% fat cow's milk; the former had cholesterol content of 87.51 mg/100 g of cheese on 30th day of refrigerated storage (Ali and Abdel-Razig, 2011).

Heat treatment of milk: Traditionally, Mozzarella cheese was manufactured from raw milk. However, pasteurization of milk is recommended for Mozzarella cheese that is to be consumed fresh, because the plasticizing process does not always destroy pathogens (Anonymous, 1977a; Caserio *et al.*, 1977). Heat treatment of milk (72°C, no hold) meant for Mozzarella cheese making improved protein and Total Solids (TS) recovery but decreased the fat recovery, gave soft-bodied cheese, improved flavor score and keeping quality and ensured public health safety (Patel *et al.*, 1986).

Schafer (1975) and Olson (1980) made satisfactory quality Mozzarella cheese from pasteurized and/or UHT treated milks with increased yield compared to the one made from raw milk. Partridge *et al.* (1982) did not find any significant difference in the quality of Mozzarella cheese made from fresh or stored (0-10 days) pasteurized milk. UHT heat treatment of milk resulted in greater recovery of the milk proteins in directly acidified Mozzarella cheese leading to 3.4% increase in cheese yield (Schafer and Olson, 1975).

Homogenization of cheese milk: Homogenization of milk in Mozzarella cheese manufacture led to whiter appearance and improved flavor (Kosikowski, 1958, 1960; Ernstrom, 1965; Jana and Upadhyay, 1992a, b), reduced fat losses in whey and moulding water (Maxcy *et al.*, 1955; Breene *et al.*, 1964; Quarne *et al.*, 1968a; Jana and Upadhyay, 1992a), increased cheese yield (Schafer and Olson, 1975; Jana and Upadhyay, 1992a,b) and reduced fat leakage during baking of cheese on pizza (Maxcy *et al.*, 1955; Breene *et al.*, 1964; Jana and Upadhyay, 1992a). However, it necessitated some modifications in the existing procedure of cheese manufacture (Anonymous, 1970a; Jana and Upadhyay, 1992c) and impaired the curd stretching (Kosikowski, 1960; Jana and Upadhyay, 1992a) as well as melting quality during baking trials (Breene *et al.*, 1964). Use of higher homogenization pressure (>50 kg/cm^2) resulted in greater fat recovery in cheese while protein recovery and curd stretching property were adversely affected (Jana and Upadhyay, 1992a). Milk homogenization (25 kg/cm^2, 60°C) increased cheese moisture, TA, Total Volatile Fatty Acid (TVFA) and cohesiveness but decreased stretchability, meltability, hardness, gumminess and chewiness. The flavour development was rapid in cheeses prepared from homogenized milk (El-Batawy *et al.*, 2004b). Homogenizing cheese milk did not exert any positive influence on cheese whereas homogenization of standardized milk helped in retarding free oil formation; the free oil was formed at lower temperature when cheese was made from homogenized milk (Tunick, 1994).

Miscellaneous process: Pre-culturing of milk resulted in reduced manufacturing time and increased yield (on DM basis) of cheese (Nilson *et al.*, 1979a; Radke *et al.*, 1979). Lactose hydrolysis of milk (>60%) in the manufacture of Mozzarella cheese resulted in reduction in period for acid development, curd treatment and ripening as well as improved curd characteristics and yield (Anonymous, 1977b). Use of lactoperoxidase thiocyanate treated buffaloes' milk in the manufacture of Mozzarella cheese increased acid production time from 6 to 8 h (Kumar and Mathur, 1986).

STARTER CULTURES

Traditionally used whey starters have been gradually replaced by more carefully maintained and cultivated starters. The starter used for fresh Italian Mozzarella is only *Streptococcus thermophilus*. To achieve consistent quality in the end product, the parameters to be controlled include avoiding batch-to-batch variation in the starter strain ratio and constant acidification (Sigsgaard, 1994).

Manufacture of high-moisture Mozzarella entails use of starters like *S. lactis*, *S. durans* or *S. faecalis*, whereas for low-moisture Mozzarella the starters recommended are *S. thermophilus*, *L. bulgaricus* and/or *L. helveticus* (Christensen, 1966; Anonymous, 1977a). Reinbold and Reddy

(1978) reported that use of culture composed of one or more of the species of *P. cerevisiae*, *L. plantarum*, *L. casei*, *S. faecalis* and *S. durans* in addition to the standard starter culture yielded cheese containing less than 0.3% lactose, helping in avoiding burning or blistering during baking on pizzas.

According to Ferris (1981), direct-to-vat starters such as 'Superstart' are used where cooking temperature does not exceed 39.4°C. For those using starters composed of *S. thermophilus* and *L. bulgaricus* which are necessary when cooking at temperatures of ≥40°C, the popularity of the bacteriophage-inhibiting medium 'Thermostar' is advisable.

Mozzarella cheese when made with the combination of *S. thermophilus* Non-Galactose (NG) and Galactose Fermenting (GF) strains and *L. helveticus* (GF) and *L. bulgaricus* (NG) reduced the incidence of non-enzymatic browning of Mozzarella cheese (Johnson and Olson, 1985; Hutkins *et al.*, 1986).

RENNETING OF CHEESE MILK

Various types of rennet i.e. of animal origin-Calf (Richardson *et al.*, 1967; Micketts and Olson, 1971; Bottazzi *et al.*, 1974; Citro, 1981), bovine (Bottazzi *et al.*, 1974), porcine pepsin (Quarne *et al.*, 1968b; Micketts and Olson, 1974; Bottazzi *et al.*, 1974), of vegetable origin-*Irpex lacteus* (Kikuchi *et al.*, 1988) and of microbial origin fungal rennet i.e., Meito, Marzyme and Surecurd (Richardson *et al.*, 1967; Quarne *et al.*, 1968b; Sandoval *et al.*, 1969, 1972). Christensen (1972) have been used successfully to produce Mozzarella cheese.

According to Quarne *et al.* (1968b) cheese made with porcine pepsin or fungal rennet gave an organoleptically superior product than veal rennet. Micketts and Olson (1974) found that cheese made with porcine pepsin was slightly softer than the one made using calf rennet. Christensen (1972) found identical result using Marzyme and calf rennet in cheese making.

Recovery of TS of cheese decreased when using *Mucor miehei* rennet, while the recovery of protein and fat content in cheese were nearly the same. *Mucor miehei* rennet exhibited greater rise in Soluble Nitrogen (SN) content than other coagulants. TVFA content increased with storage period and with increased fat content (1.5 vs. 3.0%) of the milk. The coagulant types did not affect the SN or TVFA. The type of coagulant had negligible effect on meltability, fat leakage and oiling-off of cheese. Mozzarella cheese made with *Mucor miehei* had the highest firmness. *Mucor miehei* rennet exhibited highest rate of proteolysis during storage and such cheeses were preferred over cheese made by other two coagulants (Ahmed *et al.*, 2011).

Mozzarella cheese prepared by SCM, using *E. parasitica* protease was softer in unmelted cheese texture, was more meltable and had lower apparent viscosity and more free oil release on melting than the cheese made using chymosin and *Mucor miehei* protease (Yun *et al.*, 1993a). Decreasing the concentration of chymosin coagulant by up to 40.0% had limited impact on the composition, proteolysis and functional characteristics during refrigerated storage of LMPSM cheese (Kindstedt *et al.*, 1995); the free oil formation was significantly affected.

The extract of dried berries of Withania coagulans of 0.85% strength was found suitable (@ 15 μL mL^{-1} of milk at 37°C) for preparation of Mozzarella cheese. The properties of this vegetable rennet compared well with those of calf rennet (Nawaz *et al.*, 2011). The yield, composition and properties of directly acidified Mozzarella cheese were not affected by the amount of single strength enzymes rennet or pepsin (Schafer and Olson, 1975).

LMPSM cheeses were made with Single Culture (SC) of *Streptococcus thermophilus* or Mixed Culture (MC) of *Streptococcus thermophilus* and *Lactobacillus helveticus* using chymosin or *Cryphonectria parasitica* (CP) coagulant. The melt area increased by ~2 times in cheeses made with SC as against 3-4 times for cheeses made with MC. The melt characteristics of 7 day old cheeses prepared with MC almost corresponded to that of 30 day old cheeses made with SC, suggesting faster ripening using MC. The degradation of total αs-casein was higher in the chymosin cheeses and that of β-casein in the CP cheeses. Meltability of Mozzarella cheese was better correlated to hydrolysis of β-casein and was comparable to SN but least to αs-casein (Dave *et al*., 2003a).

FACTORS AFFECTING QUALITY OF MOZZARELLA CHEESE

pH of whey: Mozzarella cheese was manufactured using Starter Culture Method (SCM) at different whey pH values viz., 6.2, 5.9, 5.6 and 5.3. Ash, calcium and phosphorus concentration of cheese decreased as the whey pH was lowered. A pH of 5.3 was beneficial with regard to cheese yield and calcium recovery. The meltability of cheese was improved when the calcium content of cheese was controlled (i.e., reduced). Fresh cheeses made by whey draining at pH 5.6 and 5.3 were preferred; the later cheese was rated inferior to the others at the end of 56 days of refrigerated storage (Kiely *et al*., 1992; Yazici and Akbulut, 2007). With regard to sensory score, the cheese made using 0.40% LA whey acidity was superior in terms of flavour and texture; it had maximum springiness. Cheese made from 0.50% whey acidity at draining was least acceptable (Sundar and Upadhyay, 1992).

Coagulant concentration and composition: Mozzarella cheeses with lower fat contents had the lowest moisture-in-nonfat-substance (MNFS) content which led to slower rate of proteolysis. The cheeses tended to become softer with progress of storage; the level of coagulant affected the same. There was a linear relation between melting of cheese and the milk fat content and coagulant levels (Dave *et al*., 2003b).

Cooking temperature: Higher cooking temperature (44°C vs. 38-41°C) produced cheese with lower moisture and decreased proteolysis during 50 days storage at 4°C. The firmness of melted cheese was greater when employing higher cooking temperatures. Cooking temperature did not significantly affect the meltability and free oil formation of cheese (Yun *et al*., 1993b).

Milling pH: Milling pH (5.1-5.4) affected the cheese pH and TA. The milling pH did not have any influence on the proteolysis of cheese during its refrigerated storage (Yun *et al*., 1993c).

Curd acidity at stretching: The optimum curd TA for cheese stretching was 0.8% LA. The sensory score of cheese increased with increasing curd acidity from 0.5 to 0.8% LA. Rise in curd acidity led to a decrease in cheese moisture and TS loss during stretching, while melting quality improved (Ghosh and Singh, 1996).

COMPOSITION OF MOZZARELLA CHEESE

The composition of Mozzarella cheese depends on the type of milk used for cheese making and the procedure used for cheese manufacture. According to IDF (1984) in India, the buffalo milk Mozzarella cheese contains 23.0-25.0% fat and 50.0% moisture on fat free cheese basis. The composition of Mozzarella cheese reported by few workers is depicted in Table 4.

Table 4: Composition of Mozzarella cheese

Constituents	El-Owni and Oswan (2009)	Jana (1992a)	Pizaia *et al.* (2003)
Moisture,%	48.59	50.51	49.30
Fat,%	27.25	26.34	25.85
Protein,%	20.06	20.48	20.83
Lactose,%	1.59	-	-
Ash,%	2.25	2.00	3.62
Salt (NaCl),%		0.90	2.17
Acidity (% LA)	0.66	0.61	0.76

VALUE-ADDED INGREDIENTS AS ADDITIVE

Concentrated buttermilk: Cheese milks were prepared by adding 0-6.0% (w/w) of Condensed Sweet Cream Buttermilk (CSCB) (34.0% TS, 9.0% casein) to part-skim milk and cream was added to obtain cheese milk with 11.2-12.7% TS and casein: Fat of 1.0. Use of CSCB resulted in a significant increase in cheese moisture. Fat and nitrogen recoveries in CSCB cheeses were slightly lower and higher, respectively, than the control cheeses. Cheeses containing CSCB (4.0-6.0%) showed less melt and stretch than control cheese. Addition of CSCB significantly lowered free oil at 1 week. Addition of CSCB at low (i.e., 2.0%) levels improved cheese yield without affecting the compositional, rheological and sensory properties of cheese (Govindasamy-Lucey *et al.*, 2007).

A washed, stirred-curd pizza cheese was manufactured using different types of concentrated (Cold Ultrafiltered (UF), cold Reverse Osmosis (RO) and Evaporation (EV)) Sweet Cream Buttermilk (SCB) as an ingredient in standardized milk. Cheese milks of casein:fat of 1.0 and casein content of 2.7% were obtained by blending UF-SCB retentate (19.9% solids), RO-SCB retentate (21.9% solids) or EV-SCB retentate (36.6% solids) with partially skimmed milk and cream (34.6% fat). SCB-fortified cheeses had 4.0-5.0% higher moisture (51.0-52.0%) than control cheese without SCB (47.0%). Fat recoveries were significantly lower in RO-and EV-SCB cheeses than in control or UF-SCB cheeses, when moisture was kept constant. The total phospholipid recovered in SCB cheeses (32.0-36.0%) was lower than control (41%). The SCB cheeses had lower meltability compared to control. The cheese made from milk fortified with UF-SCB had minimum free oil, when baked as a topping on pizza (Govindasamy *et al.*, 2006).

Milk protein concentrate: Addition of Milk Protein Concentrate (MPC) improved the yield of cheese from 10.34% for Control (C) to 14.50 and 16.65% for cheeses made from whole milk+MPC+culture (MP culture) and whole milk+MPC+direct acid (MP acid), respectively. TS recoveries were in the order MPculture>MPacid>C; fat and protein recoveries were not significantly affected. MPculture cheese had the highest Ca and lowest lactose content. MPacid cheese had the best meltability. Control cheese initially had better meltability than MPculture; however, the difference became insignificant after 28 days of storage at 4°C. MP directly acidified cheese had the softest texture and produced large-sized blisters when baked on pizza. The lowest and highest levels of proteolysis were found in MP culture and MP acid cheeses, respectively (Rehman *et al.*, 2003). Cold dispersible MPC containing 83.0% protein obtained by ultrafiltration process was used to standardize protein content of cheese milk to 4.0% (fat/protein = 1.0). There was an increase in the yield of cheese up to 16.7% (vs. 13.8% in control) as a result of high recovery of TS (i.e., 48.2%) and protein (78.3%) and slightly higher cheese moisture content (Francolino *et al.*, 2010).

Whey proteins: Heated (95°C at pH 4.6) whey protein homogenized dispersions added to standardized milk and reduced fat milk was used to enhance the yield of Mozzarella cheese. The retention of fat and yield of cheese was enhanced upon homogenization of whey proteins. The lower yield of reduced fat cheese was partially offset by adding whey proteins. Physical and sensory properties of reduced fat cheeses containing such whey proteins were similar to the full fat control (Punidadas *et al.*, 1999).

Inclusion of 0.1 or 0.2 w/w of heat denatured whey protein had no significant effect on the functionality of cheese compared with the control and helped in improving the water binding capacity of cheese (Mead and Roupas, 2001).

Ultrafiltration retentates: Pizza cheese were made from partially skimmed milk blended with cold processed UF retentates (13.5 and 15.2% TS). The fortified milk clotted faster than unfortified control milk. The fat recovery in cheese was in decreasing order viz., UF (13.5% TS) >control>UF (15.2% TS). The UF fortified cheese had higher nitrogen recovery too. Blending of cheese milk with cold UF retentate is beneficial in enhancing the cheese yield (Govindasamy-Lucey *et al.*, 2005).

METHODS OF MANUFACTURE OF MOZZARELLA CHEESE

The methods of manufacture of Mozzarella cheese varies considerably according to the market of the cheese.

Starter culture method: Traditional procedure (Starter culture technique) for manufacture of such cheese is described by several workers (Savini, 1950; Kosikowski, 1958; Reinbold, 1963; Davis, 1965; Reinbold and Reddy, 1978; Nilson *et al.*, 1979b; Thalmann, 1982; Singh and Ladkani, 1984; Scott, 1986). The stepwise description for preparation of Mozzarella cheese have also been reported by Mauk (1964), Christensen, (1966), Weckx and Delbeke (1971), Anonymous (1977c, 1982a), Muzzarelli (1977a, b), Nilson (1977), Ohashi (1981), Patel *et al.* (1986) and Sundar and Upadhyay (1990). The flow chart for preparation of Mozzarella cheese by Starter culture method is depicted in Fig. 1.

Pasteurized milk is incubated at 33°C with rennet and a starter comprising of lactobacilli and streptococci is used. The separated curd (pH 5.2) is heated in water at 80°C, kneaded and formed into 150-250 g balls which are cooled in running water at 10-12°C for 30 min followed by immersion in chilled (5°C) brine for 30 min (Weckx and Delbeke, 1971).

Direct acidification method: Direct Acidification (DA) technique has gained considerable commercial interest, as it does not rely on starter performance (unpredictable, risk of phage infection, milk contaminated with antibiotics) and helps towards mechanization of production (Fox, 1978). The manufacture of Mozzarella cheese using DA has been attempted by Schafer (1975), Ohashi (1981), Thalmann (1982), Demott (1983), Patel *et al.* (1986), Singh and Ladkani (1984), Anonymous (1985a) and Anonymous (1987).

The different types of acids employed in DA technique include hydrochloric acid, phosphoric acid, lactic acid, acetic acid, malic, citric acid and glucono-delta-lactone (Breene *et al.*, 1964; Shehata *et al.*, 1967; Quarne *et al.*, 1968a, b; Larson *et al.*, 1967, 1970; Keller *et al.*, 1974; Micketts and Olson, 1974; Patel *et al.*, 1986; Jensen *et al.*, 1987a). To circumvent the problem related to brine salting and to have close moisture control (i.e., 45.0-52.0%) in Mozzarella cheese, a stirred curd, no brine method was developed (Barbano *et al.*, 1994).

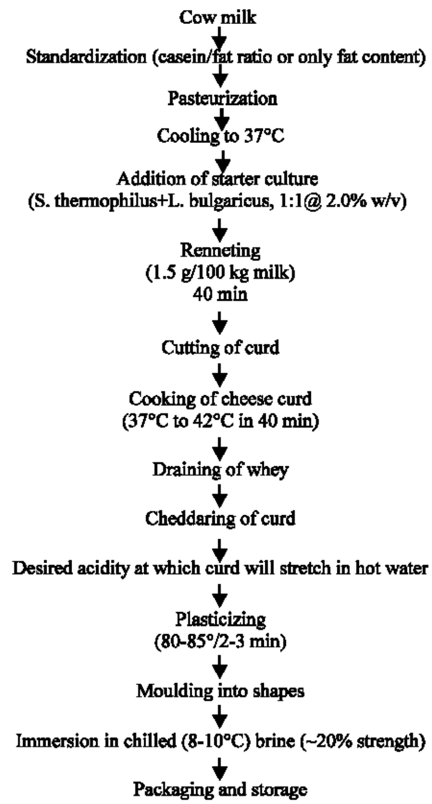

Fig. 1: Flow chart for preparation of Mozzarella cheese

Pizza cheese manufactured using citric acid as pH regulator had the highest calcium concentration and pronounced meltability and stretchability. No significant differences were noted with regard to fat and free oil contents when using acids such as citric, lactic acid, acetic acid, phosphoric and hydrochloric (Jian-Qiang *et al.*, 2011). A twin-screw extruder, fed with chilled curd, was used to stretch the cheese curd. The cheese made in such manner had lower meltability but no free oil compared with that made from a conventional stretcher (Apostolopoulos *et al.*, 1994).

The two methods employed utilizing DA techniques are:

- Direct acidification quiescent storage method (Breene *et al.*, 1964; Larson *et al.*, 1966, 1967; Quarne *et al.*, 1967; Patel *et al.*, 1986; Singh and Ladkani, 1984)
- Direct Acidification Continuous Agitation (DACA) method (Ernstrom, 1965; Larson, 1966; Larson *et al.*, 1970; Quarne *et al.*, 1967; Micketts and Olson, 1974; Kim and Yu, 1988)

DACA method involves use of continuous mixing, cooking, drawing, plasticizing, moulding, salting/brining and packaging machines which paves way for continuous production of Mozzarella cheese (Anonymous, 1970b, 1971, 1985a).

Keller (1978) and Wood (1987) prepared Mozzarella cheese by DA, with or without added microorganisms which yielded a quicker method of reaching the required pH value for stretching. Pizza cheeses made by conventional SC and DA method were compared. The recovery of fat and cheese yields was greater at pH 5.6 and 5.4 than at 5.9 and 5.2. Recovery of SNF and cheese hardness decreased, while moisture content, meltability and fat leakage increased, as pH decreased.

Meltability of DA cheeses was lower than that of SC, except for cheeses made with citric or malic acid at pH 5.2 and 5.4. Sensory scores of DA cheeses were highest at pH 5.4 and 5.6 and were best for cheese made with lactic or acetic acid compared to use of phosphoric, hydrochloric, malic or citric acids (Kim and Yu, 1988).

Mozzarella cheese from reconstituted milk: Cheese made with 40.0-60.0% reconstituted skim milk (10.0% solids) as blends with cows' fresh whole milk, had the best shredding, melting and stretching characteristics without oiling-off; highly acceptable for pizza topping. Higher substitution levels gave significantly higher moisture content and rigid curd. None of the LMPSM cheeses exhibited oiling-off; they had lower meltability but better shredding and stretching properties with longer strings than full-fat milk cheese, when baked (Davide *et al.*, 1993).

Mozzarella cheese has been made from reconstituted 'low-heat' dried skim milk and cream by Flanagan *et al.* (1978), Thompson (1978) and Demott (1983). Use of low-heat powder avoided a weak curd with poor stretch and melt characteristics. The cheese made by DA from reconstituted milk had higher protein and TS recoveries than that made from fluid milk (Demott, 1983). Leake and Nilson (1969) observed that fortifying part of skim milk with various levels of Non-Fat Dried Milk (NFDM) resulted in an increased cheese yield; the effect was marked with increasing rate of milk solids fortification. However, the cheese made from high solids milk required longer ripening period for required flavor development and melting qualities.

Mozzarella cheese made from recombined milk did not exhibit the characteristic stretch and melt behaviour of fresh milk cheeses. Such difficulty could be solved either by using low homogenization pressures in preparing recombined milk or by coating the fat with phospholipid in recombined milk emulsion and homogenizing at the usual pressure (Lelievre *et al.*, 1990).

Modified method of mozzarella cheese making: An alternative method for stretching the Mozzarella curd involved addition of 1-1.5% of emulsifying salts (tri-sodium citrate and disodium hydrogen phosphate; 1:1 or 2:1 w/w) to curd before heating to 65-70°C for 10-15 min, followed by moulding. Such cheese had improved melting characteristics, flavour and texture and recovery of milk constituents compared to control cheese made by conventional stretching in hot moulding water (Patel and Upadhyay, 1999).

Valle *et al.* (1979) suggested a modified process which overcomes the problem of curd becoming too acid for good plasticizing, especially when the milk had high lactose content (~5.0%). Likewise, Kielsmeier and Leprino (1970a,b) substituted the cheddaring step in the manufacture of Pasta filata cheese by a modified step which extracted most of the lactose and reduced the pH of the curd to 5.0-5.5, enabling the curd to possess the necessary plastic properties during the extrusion process. Shah *et al.* (2008) prepared pasteurized Mozzarella cheese (negative Alkaline phosphatase test) from raw milk (unpasteurized) just by employing boiling water for plasticizing the cheese curd.

Salting of cheese: The cheese maybe salted by methods such as (a) dry salting (b) brine salting and (c) hot brine salting. Direct salting of cheese involves stretching the cheese in hot water, draining the water followed by sprinkling salt (~1.6%) over the cheese during mixing (Ferris, 1981). Olson (1979) employed direct injection of salt solution (~6 MPa hydraulic pressures) into cheese. Use of dry salting, rather than brine salting (23% NaCl, pH 5.15, 0.02% calcium) or combined salting (dry+brine), resulted in a significantly higher cheese moisture and yield (Guinee *et al.*, 2000). According to Ferris (1981), the conventional method of salt brining is very costly, requires more space, exaggerates the problem of corrosion and poses difficulty in cleaning and disposing off the brine.

The brine-salted cheeses exhibited gradients of decreasing moisture from center to surface. The moisture loss from the cheese surface to the brine could be controlled through use of cold brining (Kindstedt, 2001). Reduction in the salt content of Mozzarella cheese led to slight decrease in the meltability and free oil of cheese.

EQUIPMENT FOR MOZZARELLA CHEESE MANUFACTURE

The mechanization in the manufacture of Mozzarella cheese includes the development of machines for forming and shaping cheese balls (Mongiello, 1957, 1959), moulding (Hannon and De Nucci, 1959; Elder and Pontecorvo, 1962; Langford, 1966; Mongiello, 1986), automatic plasticizing and stretching of curd (Pontecorvo and Shaffer, 1968, 1971; Kielsmeier and Leprino, 1973; Nilson and Samuel, 1975; Saal, 1975; Trauberman, 1975; Cosmi and De Stafeno, 1978; Meyer, 1983; Mongiello, 1985; Muzzarelli, 1985a), salting (Nilson and La Clair, 1975; Zahlaus, 1986, 1987), automatic moulder-cooling (Dzenis, 1976; Anonymous, 1979a; Volejnicek, 1981), moulding and hardening (Tomatis, 1987a, b), cheese compacting (Muzzarelli, 1985b), automatic brining and chilling of cheese (Anonymous, 1979b, c) and shredding (Saal, 1976). Schwartz and Schwartz (1957) evolved an apparatus to form strips from curd for subsequent immersion in hot water and stretching.

Mechanical mixers with single screw or twin screws, in conjunction with steam injection have been used for heating and stretching of the cheese. Typically, the water temperature used in cooker-stretcher ranges from 60-85°C and the cheese temperature as it exits the mixer ranges from 50-65°C (Renda *et al.*, 1997). Nilson (1977) recommended the use of curd milling and dicing machine prior to the mixer-stretcher operation.

Continuous production lines in mozzarella cheese manufacture: Continuous production lines for the manufacture of Mozzarella cheese involving all the traditional steps of the process have been described by several workers (Bottazzi *et al.*, 1974; Mongiello, 1957; Thalmann, 1982; Wood, 1987). DACA method of Mozzarella cheese manufacture greatly facilitates the mechanization and continuous production of curd. The reports pertaining to this are given by Larson *et al.* (1970), Nelles (1979), Kim and Yu (1988) and Anonymous (1987). The process mainly involves use of continuous mixing, cooking, drawing, plasticizing, moulding, salting/brining and packaging machines. Kerrigan and Norback (1986) have shown the utility of linear programming in the allocation of milk resources for Mozzarella cheese making to maximize net returns and cheese yield or minimize cost.

FLAVOUR OF MOZZARELLA CHEESE

Mozzarella cheese has lower Free Fatty Acids (FFA) concentration and milk flavor and except for C_4, the role of FFA in the characteristic flavor of this cheese was not apparent. It is considered that branched short chain fatty acids are important for the flavor of Mozzarella cheese (Lindsay, 1983; Woo and Lindsay, 1984). According to Micketts and Olson (1971, 1974) use of reduced amount of rennet (calf and pepsin) prevented bitter flavor in Mozzarella cheese. The key amino acids in bitter peptides were leucine, phenylalanine, proline and valine (Kim and Lee, 1985).

SURVIVAL OF MILK CLOTTING ENZYME IN CHEESE

Micketts and Olson (1974) and Matheson (1981) studied the survival of milk clotting enzymes in the manufacture of Mozzarella cheese. The residual coagulant activity of 0.004 RU g^{-1} and 1.0-7.7% of total activity has been reported which contributed to the overall proteolysis in cheese (Kikuchi *et al.*, 1988). The casein hydrolysis by plasmin in Mozzarella cheese is less extensive than in Cheddar or Gouda cheese (Creamer, 1976; Lawrence *et al.*, 1983).

KEEPING QUALITY AND STORAGE CHANGES

Rossi (1972), Matteo *et al.* (1982), Patel *et al.* (1986) and Mikacic (1986) studied the changes during storage of Mozzarella cheese. Mozzarella cheese kept in brine with 1.0% NaCl had the highest sensory score and had excellent quality, even after 12 days. Storage of Mozzarella cheese at 4°C over 4 weeks decreased the apparent viscosity; the rough fibrous texture changed to a smooth one and changes also occurred in cheese melting and stretching characteristics (Kindstedt and Guo, 1997a, b, 1998). Patel *et al.* (1986) reported that cheeses made by DA method had lower shelf life (1 week) as compared to those prepared by starter method (>2 weeks), when stored at 8°C. The unsalted cheese packaged in polyethylene pouch had a shelf life of 3 months at 8-10°C (Ghosh and Kulkarni, 1996). Soluble Nitrogen (SN) and soluble tyrosine and tryptophan contents elevated with increasing storage period. Advancement of cheese storage led to an increase in the meltability of cheese (Ahmed *et al.*, 2011).

MICROBIOLOGICAL PROFILE OF CHEESE

Several workers studied the microbiological aspects of Mozzarella cheese during manufacture, as well as of market samples (Sforzolini *et al.*, 1956; Kosikowski, 1960; Catellani and Giordano, 1962; Nilson and La Clair, 1976; Caserio *et al.*, 1977; Nieradka *et al.*, 1979; Ottogalli *et al.*, 1979; Asperger, 1982; Asperger and Brandl, 1982). A decrease of about 2 log of *Listeria monocytogenes* was observed after stretching of the curd in hot water (95°C).Listeria could not survive in cheese after 24 h when stored in the conditioning liquid (skim water from stretch, pH ~4.0) (Villani *et al.*, 1998). Stretching of Mozzarella cheese curd at 66°C for 5 min or 77°C for 1 min can effectively control *L. monocytogenes* during the production of Mozzarella cheese; brining too had a lethal effect but less effective than stretching treatment (Kim *et al.*, 1998). The US Food and Drug Administration permits addition of mould inhibiting ingredients, upon declaration on the label, during kneading and stretching process or applying it to the surface of the cheese (FDA, 1977). Few reports dwell on the effects of storage on the microbiological quality of the product (Rossi, 1972; Costamagna, 1976; Asperger, 1982; Asperger and Brandl, 1982; Mikacic, 1986).

PROCESSED MOZZARELLA CHEESE

Kosikowski (1957) and Kosikowski and Silverman (1954) manufactured processed cheese using Mozzarella cheese curd. The product resembled Mozzarella cheese in physical properties and flavor but did not 'string out' well. The young Cheddar cheese component of the processed cheese blend could be substituted by Mozzarella cheese up to an extent of 25.0-40.0% level, without adversely affecting the composition and sensory characteristics of the product (Patel *et al.*, 1986; Jana, 1992b).

DEVELOPMENTS IN MOZZARELLA CHEESE MANUFACTURE

Membrane process in cheese production: Reviews pertaining to the manufacture of Mozzarella cheese from ultrafiltrated milk are given by Mann (1982), Pal and Cheryan (1987), Jensen *et al.* (1987b) and Jana (1992a). Some manufacturing lines like Firma Pasilac (Anonymous, 1982b), Ridgeway Foods (Morris, 1984; Anonymous, 1985b), Alfa-Laval Alcurd continuous coagulator (Vincens, 1986) and Maubois, Mocquot and Vassal (M.M.V.) process (Kosikowski, 1986) utilizes the Ultrafiltration (UF) process in the manufacture of Mozzarella cheese on commercial basis.

The principle behind the manufacture involves separation of milk, UF of skim milk, cream concentration and mixing retentate with the cream before culturing and renneting (Chandan, 1982). In order to obtain quality product, the important parameters include UF of milk to 39-40% TS, followed by conventional evaporation to 52-54% TS (Covacevich, 1981); supplementation of cheese milk with retentate and hot brine stretching (Fernandez and Kosikowski, 1984, 1986a), addition of freeze dried retentate to fresh liquid retentate (Fernandez and Kosikowski, 1984) and diafiltration with brine during UF with/without simultaneous fermentation of the retentate (Covacevich, 1975; Kosikowski, 1975b; Covacevich and Kosikowski, 1975, 1978; Maubois and Kosikowski, 1978; Friis, 1981). A volume concentration ratio of 1.75:1 was found optimum for Mozzarella cheese manufacture (Fernandez and Kosikowski, 1986b, c). UF cheeses exhibited lower stretchability, higher oiling off and greater increase in hardness during storage than non-UF cheeses (El-Batawy *et al.*, 2004a).

Ultrafiltered whole milk retentates (Volume Concentration Ratio (VCR) of 1.4:1, 1.7:1 and 2:1) were made into Mozzarella cheese by DA with 10% glacial acetic acid. Low concentrate retentates showed improved physical properties over that of non-retentate control whole milk. Excellent melting Mozzarella cheese was attained and increases in cheese yield were related directly to retentate concentration. Yield efficiency, based on casein recovery, was higher in retentate cheese than in controls (Fernandez and Kosikowski, 1986a).

Retentate supplementation (4.5:1 retentate supplementing milk to 1.2:1 fat and 1.4:1 protein) improved LMPSM cheese yield. Retentate supplemented cheese had higher protein and fat and lower moisture than control (Fernandez and Kosikowski, 1986b). Increased output per vat, higher yield efficiency and good melting properties were observed in retentate cheese made using thermophilic starter over control; optimum retentate VCR was 1.75:1 (Fernandez and Kosikowski, 1986a). Mozzarella cheese prepared from UF retentate (VCR of 2.34:1) had higher total protein, ash and pH but lower fat, FDM, salt and TA than control cheese (Pizaia *et al.*, 2003).

Mozzarella cheese making from UF milk was advantageous with regard to yield (>20%),plant capacity and reduced usage of starter and rennet. It also facilitated fully automated continuous working with cleaning-in-place techniques,, standard cheese quality, labour saving and more rapidly developed flavor. Nonetheless, impaired stretching properties and low meltdown characteristics in the resultant cheese are the difficulties encountered.

Drying of cheese: The process of drying Mozzarella cheese has been described by Costamagna (1976), Sozzi (1978) and Singh and Tiwari (1986). Dried cheese can be used for flavouring certain food items.

Low-fat Mozzarella cheese: Owing to the awareness among people regarding fat intake (especially milk fat) and health, the dairy industry has shown increasing interest in producing low-fat and fat-free dairy products, including Mozzarella cheese.

Low-fat (6.0% fat) Mozzarella cheeses was made by pre-acidification of milk (pH 6.1) with citric acid, using encapsulated ropy exopolysaccharide (EPS) producing *Streptococcus thermophilus*.

Pre-acidification of milk helped in reducing the hardness and increase meltability of low fat cheeses. Use of capsular (30.45 mg g^{-1} cheese) and ropy-EPS (30.55 mg g^{-1} cheese) aided increased moisture retention (2.0% higher moisture) in cheese, making them softer but exhibited lower springiness. The cheeses containing EPS exhibited improved shred fusion, meltability and reduced surface scorching upon baking in oven (Zisu and Shah, 2007). Low-fat (6.0%) cheese made with the EPS starter cultures exhibited slightly higher meltability than control cheese made using non EPS starter (Perry *et al.*, 1998).

Carrillo *et al.* (2005) prepared low fat Pasta filata cheese from milk standardized to 1.6 and 3.2% milk fat by DA method. Reducing the fat content in LMPSM below the US legal minimum of 30.0% FDM resulted in a product with textural and meltability characteristics comparable to those of a full-fat low moisture Mozzarella (Tunick *et al.*, 1991).

MICROSTRUCTURE AND RHEOLOGICAL CHARACTERISTICS OF CHEESE

The microstructure of Mozzarella cheese was studied by Kalab (1977), Taranto *et al.* (1979) and Taranto and Yang (1981). It basically exhibited large fat globules uniformly scattered throughout the compact protein matrix with little aggregation.

The effects of type of milk (Masi and Addeo, 1984), standardization of milk for fat or casein/fat (C/F) ratio (Patel *et al.*, 1986; Sundar and Upadhyay, 1991), heat treatment of milk (Patel *et al.*, 1986), homogenization (Jana and Upadhyay, 1992a), milk coagulant (Micketts and Olson, 1971), method of manufacture (Patel *et al.*, 1986), type of acid and pH at coagulation (Keller *et al.*, 1971, 1974; Chen *et al.*, 1979; Yang and Taranto, 1982), whey draining acidity (Sundar and Upadhyay, 1990), composition (Chen *et al.*, 1979; Yang and Taranto, 1982; Cervantes *et al.*, 1983; Tunick *et al.*, 1991) and proteolysis during storage (Kindstedt *et al.*, 1993) on the rheological properties of Mozzarella cheese has been reported. Cheese made using the lowest C/F ratio milk (0.50) had lower hardness, cohesiveness, springiness, chewiness and gumminess than cheeses made from milk with higher C/F ratios (up to 0.90) (Sundar and Upadhyay, 1991).

Mozzarella cheese behaves like a visco-elastoplastic material (semisolid) at room temperature which exhibiting visco-elasticity (as liquid) at about 60°C. Its yield stress gradually decreases with increase in temperature of texture measurement using capillary rheometer (Muliawan and Hatzikiriakos, 2007). Mozzarella cheese exhibited poor meltdown, fat leakage, acid flavor, free surface moisture, poor cohesiveness and bleached discolouration after thawing but normal characteristics regained in 1-3 weeks of tempering, after thawing (Ghosh *et al.*, 1990). On decreasing the fat content (3.5 to 2.0%) of the cheese milk, the cohesiveness, gumminess and chewiness of the cheese increased, whilst elasticity decreased (Valle *et al.*, 2004). Lee *et al.* (1978) tried to correlate the objectively assessed rheological parameters of Mozzarella cheese with their sensory characteristics.

FUNCTIONAL PROPERTIES OF MOZZARELLA CHEESE

The important characteristics of Pizza cheese are: (i) it should possess a moderate toughness and an adequate stringiness; (ii) it should shred, grind and slice with a minimum of matting. Pizza retailers reported flavour, meltability and shredability as the most important attributes for customer satisfaction. Mozzarella cheese manufacturers considered meltability, stretchability, elasticity, stringiness and shredability to be important for customer satisfaction. Few Mozzarella manufacturers were of the opinion that frozen storage adversely affected cheese quality (McMahon *et al.*, 1993; Savage and Mullan, 1996; Jana, 2001).

Since Mozzarella cheese is used mostly for pizza and related foods, it must possess specific functional properties in both melted and unmelted states. Fresh Mozzarella is not suitable for pizza application since it melts to a tough, elastic and granular consistency exhibiting limited stretch. On ageing of cheese under refrigeration for a few weeks, the unmelted cheese becomes softer and the melted cheese becomes viscous, less elastic and attains greater stretch. The aged cheese now has adequate functionality for use on pizza. Further storage of cheese makes it excessively soft and fluid when melted thereby making it unsuitable for pizza (Kindstedt, 1991, 1993).

With ageing of cheese there was an increase in the stretchability and flow ability of cheese. Changes in functionality were as a result of change in pH, proteolysis, protein-bound water and free oil in the cheese. On prolonged storage, shredded cheese developed susceptibility to clumping/balling and baked cheese tended to exude excess free oil and lost its desired level of chewiness (Guinee *et al.*, 2001). Melting tended to increase during storage of fat containing cheese, however there was hardly any change observed in the non-fat (0% fat) cheese (Dave *et al.*, 2003b).

BROWNING, BLISTERING AND BURNING OF MOZZARELLA CHEESE

Low-browning Mozzarella cheeses were made using thermophilic streptococcal cultures capable of fermenting galactose. Such cheese when compared with conventional Mozzarella cheese as pizza toping, the judges could distinguish between the light and dark colours; however, there was no significant sensory difference between the two products (Matzdorf *et al.*, 1994).

Galactose accumulated in Mozzarella when either strain (nongalactose (Gal^-) and galactose fermenting (Gal^+) strains) of *Str. thermophilus* was used. Galactose was found in all Mozzarella cheese regardless of the culture used. The temperature and time during stretching of the curd inhibited fermentation of the residual galactose. The fermentation of accumulated galactose was the result of metabolism by *Lactobacillus helveticus*. There was a positive correlation between galactose content and brown color intensity in heated Mozzarella cheese (Johnson and Olson, 1985).

Mozzarella cheese having reduced lactose (<0.3%) content is a key factor in order to avoid burning or blistering of cheese during baking of pizzas. This could be accomplished by using 0.5-3.0% of a culture composed of one or more of the species *Pediococcus cerevisiae, Lactobacillus plantarum, Lactobacillus casei, Streptococcus faecalis* and *Streptococcus durans* in addition to the standard culture (Reinbold and Reddy, 1978; Jana, 1992c). Mozzarella cheese obtained by conventional method was more prone to blistering than cheese made from UF retentate during the first month of storage; both cheeses exhibited similar behavior during subsequent storage (Pizaia *et al.*, 2003).

Covering the cheese surface with a hydrophobic or physical barrier (i.e., pizza topping) affected melting and browning behaviour of Mozzarella cheese on pizza. The barrier blocked moisture loss and subsequent skin formation that limited melting and allowed scorching of fat-free and low-fat cheese during pizza baking (Rudan and Barbano, 1998).

STRETCH TESTING METHODS

Stretchability of Mozzarella cheese has been evaluated through fork test, the imitative tensile stretch test and the 3-pronged-hook probe tensile test. An objective test based on the principle of the Ring-and-Ball method helped to measure the softening point of polymers; the technique controls temperature and moisture loss during stretch testing. The method could distinguish between the cheeses of variable age (Hicsasmaz *et al.*, 2004).

SHREDDED MOZZARELLA CHEESE

Application of anti-caking agents for shredded cheese helped in retarding clumping and enhanced the appearance of cheese shreds.

PACKAGING OF MOZZARELLA CHEESE

The effectiveness of some antimicrobial (viz., lemon extract combined with brine and gel solution made of sodium alginate) packaging systems on the microbial quality decay kinetics was assessed; the treatment led to an increase in the shelf life of active packaged Mozzarella cheeses (Conte *et al.*, 2007). Mozzarella cheese has been successfully packaged in polyethylene (300 gauge) and Cryovac packed in polyvinylidene chloride (PVDC) film (150 gauge) with or without vacuum packaging (Ghosh and Singh, 1992a, b).

SHELF LIFE OF CHEESE

The Mozzarella cheese when packaged in cryovac package in PVDC film and stored under refrigeration (5°C) and deep freeze kept well for 42 and 90 days, respectively (Ghosh and Singh, 1992). The storage changes in Mozzarella cheese packaged without a liquid was studied (Coppola *et al.*, 1995). A lactic acid/chitosan solution (0.075% chitosan strength) was added to the starter used for Mozzarella cheese. Spoilage microorganisms like coliform and Pseudomonas were inhibited in presence of chitosan; it did not influence the growth of Micrococcaceae but somewhat stimulated lactic acid bacteria (Altieri *et al.*, 2005).

STORAGE CHANGES IN CHEESE

During refrigerated (4°C) storage of Mozzarella cheese for 50 days, the textural characteristics viz., hardness, cohesiveness and springiness of unmelted cheese decreased, meltability increased, apparent viscosity of melted cheese decreased and free oil formation from melted cheese increased (Yun *et al.*, 1993c). During storage there was an increase in the water holding capacity of the cheeses (Yazici and Akbulut, 2007). With advancement in ripening time of LMPSM, there was a significant decrease in the concentration of intact casein, firmness, melt time and apparent viscosity. Nevertheless, the flowability and stretchability of the molten cheeses were found to increase significantly during storage (Guinee *et al.*, 2001). There was a slight continual decrease in moisture of cheese during refrigerated storage; the pH decreased from initial 5.36 to 5.16 in 49 days, while TA showed a linear increase (Ghosh and Singh, 1992). Refrigerated storage of Mozzarella cheese led to significant decrease in the moisture content culminating in increased fat, cholesterol and protein content; TVFA also showed an increasing trend. The pH of cheese decreased with increase in storage period of Mozzarella cheese (Ali and Abdel-Razig, 2011).

The soluble nitrogen of LMPSM increased significantly during 7 weeks of ripening but at different rates for different coagulants (*Endothia parasitica*, *Mucor miehei* or chymosin). Substantial breakdown of caseins was evident during ripening. Texture characteristics, meltability, apparent viscosity and free oil formation changed significantly during ripening; the rate of change differed among coagulants and corresponded with proteolysis rates (Kindstedt *et al.*, 1993). The melting and fat leakage characteristics increased while stretch tended to decrease with advancement in storage period of Mozzarella cheese (Ghosh and Singh, 1992). The Mozzarella cheese obtained from UF retentate exhibited lower proteolysis and melt capacity during storage than the one made from normal unconcentrated milk (Pizaia *et al.*, 2003).

FILLED MOZZARELLA CHEESE AND SUBSTITUTES

The products resembling Mozzarella cheese include the Filled, Imitation Mozzarella cheese, Mozzarella analogue or the Cheese extender. Such products are made from non-dairy ingredients like hydrogenated, soya or cottonseed oil as a fat source, Na-and Ca-caseinates or soya proteins as protein source along with flavouring agents (Anonymous, 1981). Such products have been claimed to possess several advantages such as low price, positive flavor control, improved product consistency, excellent keeping quality and reliability of supply of raw materials (Vernon, 1972). Ghosh and Kulkarni (1996) standardized a method for manufacture of low cholesterol Mozzarella cheese from filled milk containing 3% sunflower oil employing direct acidification; citric acid produced a softer cheese than acetic acid at similar pH.

Several reports are available on manufacturing and compositional aspects of imitation Mozzarella cheese (Anonymous, 1970a; Vernon, 1972; Kasik and Peterson, 1975; Fox, 1978; Rule and Werstak, 1978; Taranto and Yang, 1981; Yang and Taranto, 1982; Yang *et al.*, 1983; Christiansen *et al.*, 1986; Toppino *et al.*, 1988).

Natural vs. Imitation mozzarella cheeses: Differential scanning calorimetry is one classical method that can be used to distinguish natural Mozzarella cheese from imitation Mozzarella made with Ca-caseinate. This is due to a decrease in the enthalpy of milk fat melting transition at 18°C with concomitant rise in the caseinate concentration. Scanning electron microscopy exhibited agglomerated lipids in the imitation samples, whereas uniform dispersion of fat globules was evident in the natural cheese (Tunick *et al.*, 1989).

CONCLUSION

Mozzarella cheese is a soft, unripened cheese variety of the Pasta-filata family which had its origin in the Battipaglia region of Italy. Mozzarella cheese was originally manufactured from high fat buffalo milk. However, it is made all over Italy, in other European countries and USA from cow milk with certain modifications. The finished cheese, lightly salted, is white, soft with a very lively surface sheen and has unique property of stretchability. Mozzarella cheese owes its characteristics mainly to the action of lactic acid on dicalcium-para-caseinate. Pure white color is the basic requirement of Mozzarella cheese which is lacking in cow milk cheese due to presence of carotene. Understanding the factors that determine the characteristics of the cheese product for its suitability for end usage can help the cheese makers to produce ‘tailor-made’ cheeses as per the whims and wishes of the food retailers and even the varied consumers.

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