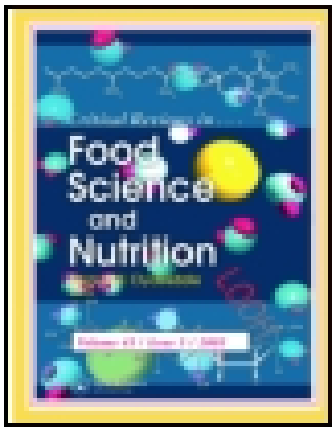

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Maximizing Shelf Life of Paneer- A Review

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Maximizing Shelf Life of Paneer- A Review

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Abstract. *Paneer resembling soft cheese is a well-known heat and acid coagulated milk product. It is very popular in Indian subcontinent and has also appeared in the western and Middle East markets. The shelf life of paneer is quite low and it loses freshness after 2-3 days when stored under refrigeration. Various preservation techniques including chemical additives, packaging, thermal processing and low temperature storage have been proposed by researchers for enhancing its shelf life. The use of antimicrobial additives is not preferred because of perceived toxicity risks. Modified atmosphere packaging (MAP) has been recommended as one of the best techniques for maximizing the shelf life of paneer.*

Key Words: Paneer, Coagulated dairy product, Shelf life, Soft cheese, Modified atmosphere packaging (MAP)

INTRODUCTION

India is the largest milk producer in the world. The milk production in India is approximately 114 million tones (Goyal and Goyal, 2012). Approximately 5% of milk produced in India is converted into paneer, which is a well-known heat and acid coagulated milk product (ICMR, 2000; Chandan, 2007). Paneer is similar to soft cheese, and is not only very popular in Indian subcontinent, but has also made appearance in western and Middle East markets. It is marble white, somewhat spongy with mildly acidic flavour and is generally prepared from buffalo milk (Patel, 1991). Paneer is of great value in diet because it is a rich source of high quality proteins, fat, minerals and vitamins (Shrivastava and Goyal, 2007). It forms base for a variety of culinary dishes, stuffing material for various vegetable dishes, snacks, and sweetmeats. However, the shelf life of paneer is quite low and it loses freshness after 2-3 days when stored at 10°C. Generally, surface spoilage of paneer limits its shelf life. Various preservation techniques including chemical additives, packaging, thermal processing, and low temperature storage have been tried by various workers to extend its shelf life.

PRESERVATION OF PANEER

Low Temperature Storage

A report suggested that the storage of paneer at subzero temperature, *i.e.*, ï 13°C and ï 32°C for 120 days did not affect its flavour and appearance, and the product was acceptable even up to 120 days, after frying. Further, the paneer made from 4, 5 and 6% fat milk could be stored for

not more than 6 days at 10°C, and for 120 days at ï 13°C and ï 32°C. A decrease in moisture content and increase in non protein nitrogen (NPN) was observed, but the decrease in moisture content was more for the samples stored at -13°C, while the increase in NPN was observed to be more for the product stored at ï 32°C. Storage at 10°C for 6 days, revealed no appreciable physico-chemical changes up to 6 days, but putrid flavour developed on the 7th day (Arora and Gupta, 1980).

Dehydration / Deep Freezing

Vishweshwaraiah (1987) studied the effect of dehydration or freezing on the shelf life of paneer. Fresh paneer had an average composition of 55% moisture and 45% total solids (TS). It was (i) cut into cubes and hot-air dried at 75 °C for up to 4 hr; (ii) extruded to increase surface area, then dried for up to 2 hr; (iii) or (iv) frozen at -9 or -15 ºC, respectively. After 4 hr drying, (i) had a moisture content of 15-18%; extruded paneer (ii) retained less moisture (5-9%) and drying was comparatively faster (<less or =>2 hr). Although, extruded paneer had a shelf life of up to 2 months vs. 3 days for the fresh product, but rehydration characteristics were poor and lacked cohesive properties. Frozen paneer had a shelf life of up to 8 days, but surface drying was observed. However, the sensory qualities of (iii) and (iv) were found to be almost comparable.

Heat Sterilization

Thermal sterilization of paneer at 15 psi for 15 min in tin cans kept the product well over a period of 50 days at room temperature, but slight browning and cooked flavour affected the organoleptic quality significantly. Paneer cubes fried prior to sterilization, however, spoiled

earlier due to the development of pronounced oxidised flavour after 40 days of storage (Sachdeva, 1983). Rao et al. (1984) developed a method, which extended the shelf life of paneer up to 3 months at 35 ºC. The process involved concentration of standardized milk (2% fat, 9.2% SNF) to 27% TS by ultrafiltration, followed by texturization at 118 ºC for 5 min, which also inactivated the microbial spores and yielded a long shelf-life product. The resultant product had a greater proportion of whey protein bound to the casein network than in traditional paneer. TS recovery was 95%, and overall acceptability score (9-point Hedonic scale) was 8.5.

Effect of Preservatives

Brine

Shukla et al. (1984) obtained a shelf life of 6 days at room temperature when raw paneer was dipped in 18% salt solution for 30 min, while Singh et al. (1988) claimed that the shelf life of paneer could be extended up to 16 days by dipping in brine (5%) and storing at refrigeration temperature, but the continuous dipping resulted in a very soft, fragile body, and dull yellow appearance of the product towards the end of 10 days of storage period.

Sorbic Acid, Irradiation and Benzoic acid

The experiments of Singh et al. (1989) revealed that the shelf life of paneer could be extended up to 36 days at room temperature by adding sorbic acid to milk (0.15%) and subsequent wrapping of paneer in sorbic acid coated butter paper. However, similar shelf life (36 days) of paneer was achieved at 5 ºC, when the product was prepared by adding of 0.05% sorbic acid to milk. The sorbic acid content in paneer varied from 0.15 to 0.3%. Singh et al. (1991) observed that

treatment of paneer with sorbic acid and/or gamma radiation reduced the microbial load. Combination treatment of 0.10% sorbic acid in milk and irradiation of the product at 2.5 Kilo Gray preserved the paneer samples for 30 days at ambient temperature (25-35 ºC). Modi and Jain (1988) reported the use of benzoic acid (1200 ppm = 0.12%) for enhancement of shelf life of paneer to 40 days at refrigerated temperature and 20 days at 37 °C.

Potassium Sorbate and Nisin

Incorporation of 0.1% potassium sorbate enhanced the shelf life of paneer from 6 days to 18 days, when stored at 5 °C (Rao et al., 1992). Thakral et al. (1990) could extend the keeping quality of paneer containing 0.1% potassium sorbate by 13, 3-4 and 1 day at 7, 22 and 37 ºC, respectively. However, the keeping quality was further improved by adding nisin together with the potassium sorbate.

Hydrogen Peroxide (H_2O_2) + Delvocid

Sachdeva and Singh (1990 a, b, c) observed that the fungicide (delvocid), when used in combination with a germicide (H_2O_2), kept paneer well for a period of 32 days at 8-10°C, but putrefactive odour and slight bitterness developed after 32 days, rendering the product unacceptable. Singh and Kanawjia (1990) were able to increase the shelf life of recombined milk paneer up to 50 days at 8±1 °C by dipping paneer blocks in 0.2% H_2O_2 + 0.5% delvocid at 8 ºC for 2 hr followed by vacuum packaging in polyethylene pouches.

Chlorinated, Acidified, and Buffered Water

Sachdeva and Singh (1990c) investigated the use of chlorinated water for shelf life extension of paneer. They showed that chlorinated water (35 ppm) did not favour the extension of shelf life. Rather, it had a deteriorating effect on the flavour score of paneer. Also, the use of acidified water (pH 5.5 and 2.5) had no effect on shelf life of paneer. The samples spoiled after a period of 6 days at refrigerated temperature. The deterioration at pH 2.50 was as rapid as at pH 5.50. The use of buffered water (pH 7.5) also did not produce any fruitful results. The buffering solution of sodium bicarbonate ($NaHCO_3$) and calcium phosphate ($Ca_3(PO_4)_2$) containing 2.5% of each of the salt by weight (pH 7.5), when used as the dipping medium, caused deterioration in paneer and the samples spoiled after 8 days of preservation.

Butylated Hydroxyanisole (BHA) and Tertiary Butyl Hydroquinone (TBHQ)

Kumar and Bector (1991) made paneer from buffalo milk (6% fat, 9% SNF) and added the antioxidant TBHQ and/or BHA to give concentration of 0.05% in the product. Paneer samples were analysed chemically, microbiologically and organoleptically throughout storage at 5, 15 and 25º C. Results showed that in general, titratable acidity, free fatty acid level, soluble N content and microbial counts increased at a slower rate in paneer containing TBHQ and/or BHA than in control paneer; TBHQ tending to have the greatest effect, and rates of change increasing with increase in storage temperature. The two antioxidants, either individually or together, were considered to be effective in increasing the shelf life of paneer to about 20, 7 days and 90 hr at 5, 15 and 25 °C, respectively vs. 10, 4 days and 48 hr for control paneer.

Lysozyme along with Lactoperoxidase (LP) System

Agrawal (2001) studied the effect of lysozyme and LP system on the enhancement of shelf life of paneer by dipping in two kinds of medium: (a) boiled and chilled distilled water in which LP system was activated, (b) LP system along with lysozyme (100 μg/ml). The ratio of paneer to dipping medium was nearly 1:1(w/v). At refrigeration temperature control paneer registered a shelf life of 8 days, while in case of LP system treated sample, the shelf life increased to 24 days. However, LP system and lysozyme treated paneer resulted in shelf life of 28 days.

Bacteriocin

The shelf life studies on the treatment of the paneer samples with pediocin along with 20mM EDTA/Na-citrate and 0.1% potassium sorbate were carried out at refrigeration temperature (5-7 ºC) by Malik et al. (2005). They observed that up to a period of 7 days at 5 ºC, the control untreated samples remained stable with no change in the organoleptic qualities. After 7 days mould, yeast and bacterial growth was clearly visible as coloured edges, accompanied by foul and acidic smell. Even though after 15 days, the treated samples had a higher total viable count than the 0 day control, their keeping and organoleptic qualities remained comparable to that of 0 day control. A prolonged shelf life of up to 59-60 days was obtained in the samples treated with the combination of bacteriocin consisting pediocin 34, EDTA and potassium sorbate. The bacteriocin preparations-pediocin, nisin and pediocin + nisin (50:50) in combination with NaCl (5%), potassium-sorbate (0.1%) and EDTA/sodium citrate (20mM) were found to be quite effective in enhancing the shelf life of paneer to about 75 days.

PACKAGING OF PANEER

Packaging means safely and cost- effectively delivering product to the consumer in accordance with the marketing strategy of the organization (Coles, 2003). The primary role of packaging is to protect the nutritional and sensory properties of milk and milk products from processing stage to the final consumption. Good packaging lowers product costs, reduces product wastage, helps consumers make purchase decisions, protects against tampering and spoilage. And above all, good packaging is essential to protect human health, and provide safety and comfort (Punjrath, 1995).

Goyal (1988) observed that the technology for production of paneer is well known for over a long time, but its proper packaging needs attention. Various materials have been used for the packaging of paneer (Table1). According to Aneja et al. (2002) paneer is highly susceptible to chemical and microbial changes, and emphasised that its packaging should protect against these changes, maintain quality, effective sales appeal, and add to consumer convenience. For the packaging and storage of paneer at refrigeration condition, they recommended coextruded laminates, polyethylene (PE) sachets, heat induced shrink film and wax coated parchment paper, polypropylene (PP) films of higher gauges and retort pouches for packaging of the long shelf life paneer.

Goyal and Paltani (2003) reported that paneer is commonly vacuum packaged in laminate of EVA /EVA/PVdC/EVA or cryovac / PE bags, and paneer curry in retort pouches. The study of Rai et al. (2008) revealed that when paneer was packaged in high barrier bags (LLD/ BA/Nylon ï 6/ BA/ LDPE) under 4 modified atmosphere, namely air (atm 1), vacuum (atm 2), 100% CO_2

(atm 3) and 100 % N_2 (atm 4) and stored at 7 ±1 ^{0}C, the atm3 was best, followed by atm 4 ≥ atm 2 ≥ atm 1, respectively in descending order. Karthikeyan et al. (2005) used PET/PE sachets for modified atmosphere packaging (MAP) of paneer.

PHYSICO- CHEMICAL CHANGES IN PANEER DURING STORAGE

Chemical Changes

Moisture

The effect of storage at 10 ºC, ï 13 ºC and ï 32 ºC on the moisture content of paneer was studied by Arora and Gupta (1980). The observations of their experiments indicated that the initial moisture content of 53.20% in fresh paneer increased to 54.36% and 54.61%, respectively on 3rd and 6th day when stored at 10 ºC, while at ï 13 ºC storage, the moisture content was observed to be 54.89%, 52.22%, 50.25% and 57.22%, respectively on 30th, 60th, 90th and 120th day of storage, but when the product was stored at ï 32 ºC, the moisture content decreased to 52.78%, 52.10%, 51.91% and 49.07% , respectively on 30th, 60th, 90th and 120th day of storage.

Rao et al. (1984) observed the reduction in moisture content of paneer when stored for 6 days at 5 ºC. Mistry et al. (1990) noted no significant change in moisture content on storage of paneer for 7 days under refrigeration. Pal et al. (1993) prepared low fat paneer from mixed milk (cow and buffalo milk, 1:1, fat 3.5%) and applied paraffin wax coating. Wax coated fresh paneer had 60.36% moisture, which decreased to 59.07% till 15th day of storage. Control fresh paneer had 55.78%, which decreased to 52.36% on 15th day. Pal (1998) observed that moisture content in fresh paneer prepared from standardized buffalo milk (3.5% fat) was 55.78%, which decreased to 54.85% on 5th, 53.74% on 10th and 52.36% on 15th day of storage.

Rai et al. (2008) studied the effect of MAP on the moisture content of paneer packed under 4 different atmospheres, namely air (atm 1), vacuum (atm 2), 100% CO_2 (atm 3) and 100 % N_2 (atm 4) at 7 ±1 ºC storage. The maximum loss in moisture content in the samples after 15 days of storage was observed in case of atm 1, followed by atm 2, atm 4 and atm 3, respectively. On further storage for 45 days, the initial moisture content of 51.60 % decreased to 51.16 % (atm 2), 51.21 % (atm 4) and 51.25 % (atm 3), indicating that the minimum moisture loss had been with the samples packaged under 100 % CO_2. Similar trend was observed by Shrivastava and Goyal (2009), when they stored paneer at 3±1 °C after packing under same modified atmospheres.

pH

The pH of paneer (prepared from standardized buffalo milk with 5% fat), decreased from 6.60 to 5.80 on 6th day of storage at 10º C (Bhattacharya et al., 1971). Arora and Gupta (1980) reported that there was an increase in the pH of paneer (6% fat) from 6.0 to 6.02 and 6.03 on 3rd and 6th day of storage at 10 ºC, while at ï 13 ºC pH was found to be 6.04, 5.99, 6.02 and 5.88, respectively on the 30th, 60th, 90th and 120th day of storage, and at -32 ºC storage the pH was 5.94, 6.00, 5.73 and 5.90, respectively on the 30th, 60th, 90th and 120th day. However, Mistry et al. (1990) noted no significant change in the pH of paneer stored at 7-10º C for 7 days. Pal et al. (1993) observed that the pH of wax coated fresh paneer decreased from 6.20 to 6.18 on the 5th day, and 6.01 on the 10th and 15th day, while the pH of control paneer 6.21 decreased to 5.73 on the 15th day. The work of Pal (1998) indicated that the pH of fresh paneer 6.21 decreased during storage at 8± 2 ºC to 6.04, 5.78 and 5.73, respectively on the 5th, 10th and 15th day.

Rai et al. (2008) found that on storage of paneer for 15 days at 7 ±1 ºC, the pH of paneer decreased from 5.92 to 5.61, 5.66, 5.71 and 5.63, respectively in the case of samples packaged

under atm 1 (air), atm 2(vacuum), atm 3 (100 % CO_2) and atm 4 (100 % N_2). The pH further decreased to 5.32, 5.36 and 5.30 in case of atm 2, atm 3 and atm 4, respectively after 45 days of storage, indicating that the maximum decrease had been with the product packaged under vacuum, and the minimum decrease was in samples packaged under 100% CO_2.

Titratable Acidity (TA)

The effect of storage on the TA has been studied by various workers. Bhattacharya et al. (1971) reported that the initial TA in terms of percent lactic acid (%LA) 0.15% in fresh paneer increased to 0.49% on 6th day when stored at 10 ęC. Haridas and Narayanan (1976) studied the effect of addition of 0.4% formalin on the TA of paneer. The average acidities (%LA) were observed to be 0.55, 0.55, 0.57, 0.61 and 0.66%, respectively for the samples stored for 0, 6, 7, 14 and 21 days. A steady increase in TA from 0.41 to 0.49 %, and rapid increase from 0.44 to 0.62 % after 3 days of storage of paneer at 15 ºC and room temperature, respectively was observed by Shukla et al. (1984). Pal and Garg (1989) reported an increase from 0.192 to 0.328 in TA of paneer samples stored at 7±1 ºC for 11 days. Mistry et al. (1990) also found significant increase in TA of paneer after 7 days of storage at 7-10º C. Contrary to these findings; Kumar and Bector (1991) noted no change in TA in paneer samples stored at 5 ºC for 14 days. However, at higher temperatures of 15 ºC and 25 ºC pronounced changes in TA were observed.

Pal et al. (1993) found that TA of wax coated fresh paneer was 0.15%, which increased to 0.25% on 15th day; whereas in control fresh paneer the TA was 0.14%, which increased to 0.16, 0.25 and 0.35% on 5th, 10th and 15th day respectively, when stored at 10±2 ºC. The investigation of Pal (1998) revealed that the TA of fresh paneer was 0.14%, which increased to 0.16% on 5th, 0.25%

on 10th, and 0.35% on 15th day of storage at 8±1 ºC. The experiments of Rai et al. (2008) indicated that the initial value for TA (% LA) of paneer gradually increased from 0.31 to 0.59, 0.46, 0.42, and 0.45, respectively in samples packed under atm 1 (air), atm 2(vacuum), atm 3 (100 % CO_2) and atm 4 (100 % N_2) after 15 days of storage. Further storage up to 45 days revealed that the TA increased to 0.69, 0.62 and 0.66, respectively in samples packaged under atm 2, atm3, and atm 4.

Free Fatty Acids (FFA)

The extent of lipolysis in fat rich dairy products is generally determined by estimating FFA. The FFA content of fresh buffalo milk paneer increased from 0.29 µeq/g to 0.90 µeq/g, and increase in cow milk paneer was from 0.25 µeq/g to 0.76 µeq/g after 30 days of storage at < 10 ºC (Sindhu et al., 2000). Kumar (1989) observed an increase in FFA content of paneer preserved with TBHQ and BHA after 90 hr of storage at ambient temperature, and progressively slower at 15ºC and 5 ºC. Boghra et al. (1997) observed that the increase in FFA content of paneer after 2 days was accelerated in the presence of iron, and copper had a greater effect.

The study of Rai et al. (2008) showed that the value for FFA (% oleic) of paneer stored for 15 days increased from 0.18 to 0.24, 0.21, 0.20 and 0.21, respectively in atm 1 (air), atm 2 (vacuum), atm 3 (100 % CO_2) and atm 4 (100 % N_2), indicating maximum lipolysis in case of air packed samples, and minimum for samples packaged under 100 % CO_2. Similar trend was observed when the product was stored for 45 days.

Tyrosine Content

Measurement of soluble tyrosine is an index of proteolysis. The tyrosine content (mg/100g) of fresh paneer increased from 13.84 to 41.53 on 10^{th}, and 64.97 on 15^{th} day when stored at 8±1 ºC (Pal et al., 1993; Pal, 1998). Sindhu et al. (2000) reported that the tyrosine content (mg/g) increased from 0.14 to 0.42, and from 0.12 to 0.47, respectively for buffalo and cow milk paneer stored for 30 days at <10 ºC.

Rai et al. (2008) studied the influence of MAP and storage on the tyrosine content of paneer. The results indicated that on storage for 45 days, the initial value of tyrosine content increased from 12.61 (mg/100 g) to 34.80, 29.18 and 33.21, respectively for the samples packaged under atm2 (vacuum), atm 3(100% CO_2) and atm 4 (100% N_2), suggesting that the minimum proteolysis had been in the samples packaged under 100 % CO_2, and maximum in samples packed under vacuum, establishing a very significant influence of MAP on the proteolysis of paneer during storage.

Peroxide Value (PV)

Sindhu et al. (2000) reported that peroxides were absent in fresh paneer, but appeared after 30 days of storage at < 10 ºC in buffalo milk paneer (0.4 meq/kg of fat) and cow milk paneer (0.34 meq/kg of fat). Boghra et al. (1997) studied the effect of added iron and copper on the PV of paneer. They observed that after 4 days, the PV of paneer increased more in paneer, which contained copper as compared to the samples having iron.

Electrophoretic Pattern of Proteins in Paneer

Sachdeva and Singh (1990c) studied the electrophoretic pattern of the proteins of fresh paneer and the paneer that had just spoiled after storage for a period of 8 days at refrigeration temperature. They observed that the extent of proteolysis, which took place in paneer during storage, was conspicuous. The Electrophoretic pattern of the proteins of fresh paneer indicated bands representing the ɔ, ɓ and Ŭ- casein fractions in order of increasing electrophoretic mobility. But in case of spoiled paneer sample, these bands faded away indicating a large extent of protein breakdown during storage. The protein fraction with the lowest electrophoretic mobility, which may be ɔ-casein, had completely disappeared in the case of spoiled sample. The area under the band representing ɓ ï casein had reduced considerably suggesting that the ɓ-casein fraction was also affected during storage of paneer. The Ŭ- casein fraction had also undergone maximum degradation and had broken down in several faster moving components indicated by the minor bands towards the anode, confirming that a great amount of protein degradation took place during storage of paneer.

Zanjad and Mathur (1994) investigated the elution profile and electrophoretic behaviour of casein using ion-exchange chromatography and polyacrylamide gel electrophoresis (PAGE) in order to determine the extent of storage-related changes in casein fractions present in a model sterilized paneer system obtained from vacuum concentrated and ultrafiltered (UF) buffalo milks. Paneer from fresh concentrated milk (CMP) and from UF milk (UFP), respectively resolved into 6 and 9 casein fractions, which included 1 and 3 ɓ -casein, 1 and 2 Ŭ -casein and 2 and 2 *k* -casein fractions. Changes in these casein fractions after 30 and 60 days storage at 35 and 45 ºC indicated substantial intermolecular rearrangement arising out of protein interactions, resulting in significant variations in concentrations of the various components. CMP and UFP showed

differences in susceptibility of the various protein complexes formed during processing to enzymatic degradation during storage.

The proteolysis in MAP paneer during storage was studied by Shrivastava and Goyal (2009) using SDS-PAGE (Sodium Dodecyl Sulphate Poly Acrylamide Gel Electrophoresis). The Electrophorogram prepared by using fresh paneer samples revealed three bands for acid casein sample and three bands for fresh paneer sample. During refrigeration storage (3±1 °C) of MAP paneer samples, the degradation of protein was first observed in two minor bands after 20 days, and the degradation in major band was seen in samples after 40 days of storage. The maximum proteolysis had been in case of paneer samples packed under air, followed by vacuum, 100% N_2 , 50% CO_2 /50 %N_2 , and 100% CO_2 in descending order. In case of air and vacuum-packed paneer, the bands faded away indicating a larger extent of protein breakdown as compared to modified atmosphere packed paneer.

Textural Changes in Paneer during Storage

Textural properties play an important role in the quality of paneer. The texture of paneer depends upon the status of components and the temperature of storage. Some of the textural properties such as hardness, cohesiveness, springiness, gumminess and chewiness have been studied by Kanawjia and Singh (1996) using an Instron Universal Testing Machine. The study revealed that the storage temperature and duration of storage had marked effects on the textural properties of paneer. The textural profile analysis showed that all textural properties of refrigerated paneer (stored at 6 to 8ęC) such as hardness, cohesiveness, springiness, gumminess and chewiness initially increased up to 15 days, and thereafter decreased appreciably till 45 days of storage.

Conversely, all textural properties of frozen samples (-28 to -30 ęC) decreased consistently throughout the storage period of 60 days. This may be due to the injury caused by the formation of ice-crystals and solidification of fat, which upon thawing disturb the casein matrix. Similar trends were observed in the case of gumminess and chewiness of paneer. This was expected, as these were secondary parameters derived from hardness, cohesiveness and springiness.

Khamrui et al. (2004) conducted experiments to investigate the effect of frying, freezing and rehydration on texture profile, and relationships between sensory and instrumental textural descriptors of paneer. Frying led to significant ($p<0.05$) increase in all the solid constituents and values of most of the textural profile parameters. Frying removed paneer's adhesiveness, but imparted fracturability to the product. Rehydration of fried Paneer by cooking in salt solution significantly decreased all the instrumental textural values except cohesiveness. Preceding or succeeding the freezing process to that of frying significantly affected the total solid content and most of the instrumental textural attributes, but had no definite effect on sensory textural attributes of rehydrated paneer except on gumminess. Though, sensory textural parameters exhibited significant correlations with instrumental measurements, the former was more efficient in registering changes in brittleness and stickiness attributes.

Pant et al. (1993) studied the effect of deep-frying in vegetable oil on texture of Tofu and paneer using texture profile analysis. The textural parameters namely hardness, cohesiveness, springiness, gumminess and chewiness were derived from texture profile curves. The observations revealed that unfried Tofu was softer than paneer, but exhibited greater chewiness, springiness and cohesiveness. Fried Tofu showed significantly greater hardness, springiness and chewiness than fried paneer. The differences in gumminess of unfried paneer and Tofu were

non-significant and remained non-significant even after frying. Cohesiveness of fried paneer was significantly higher than that of Tofu. Springiness of Tofu and paneer remained unaffected by frying. The results further indicated that the increase in hardness, gumminess and chewiness after frying was more pronounced in Tofu than in paneer, and the chewiness of the samples was directly proportional to gumminess. Effect of storage time on the instrumental texture profile of pasteurized Tofu was analysed by Bargale and Jha (1992). Their study led to conclusion that as the storage period increased; hardness, chewiness and gumminess increased significantly, while springiness and cohesiveness remained almost unchanged.

Rao and Patil (2006) observed that there was a decrease in hardness of paneer portion of ready-to-eat canned paneer curry stored at 15, 30 and 45 ęC. It may be due to increase in cohesiveness and springiness during storage. They also observed a steady increase in chewiness during storage period.

MICROBIOLOGICAL CHANGES IN PANEER DURING STORAGE

The microbiological quality of paneer is mainly affected by the conditions of manufacture, handling, storage and sale of the product. Paneer provides a favourable condition for the growth of a wide variety of organisms depending upon the temperature and the initial quality of product (Gupta, 1985; Ghodekar, 1989). Haridas and Narayanan (1976) observed mould growth in paneer samples after 2 ï 3 days of storage at 30 ºC, while Sachdeva (1983) noted increase in the total counts as well as yeast and moulds (Y & M) counts during storage of paneer up to 10 days at 5 ºC. Pal (1998) also noted that the total counts of mesophilic bacteria, Y & M and coliform increased during 15 days of storage of paneer at 8±2 ºC. Agnihotri and Pal (1996) observed

significantly higher total plate count, proteolytic, streptococci, psychotrophic, and Y & M counts in goat milk paneer after 3 days of storage under refrigeration.

Rajorhia et al. (1984) conducted a survey on the microbiological quality of paneer, and reported that the paneer samples collected from the experimental dairy of National Dairy Research Institute, Karnal, India had lower Y & M (132 /gm) and coliform count (20 x 10^2/gm) compared to the market samples of Delhi and Karnal, which had higher load of coliform, and Y & M. Bambha (1988) reported steady increase in psychrotrophic, proteolytic and lipolytic count in market paneer samples during storage at 7 ºC up to 7 days. On subsequent storage, the count increased tremendously. Several other workers (Gupta, 1985; Thakral, 1986; Parashar, 1987) observed that the spoilage of market paneer during storage was due to the growth of organisms on the surface of paneer.

Kumar (1989) reported no significant increase in total plate count and Y& M count in paneer containing antimicrobial agent like TBHQ and BHA, when stored at 5 ºC for 10 days. Singh et al. (1989) reported reduction in mesophilic count initially at 5 ºC stored paneer, but rapid increase was noticed after 4 days in unwrapped samples, and after 6 days in wrapped sorbic acid coated paper.

Sachdeva and Singh (1990b) dipped paneer in water containing various antimicrobial agents and stored at 8-10 ºC. The microbiological analysis revealed that the initial total plate count 10^3-10^5/g increased in all the paneer samples during storage, but at a faster rate in samples that were dipped in acidified, buffered, control or chlorinated water than in those dipped in brine or acidified brine. Dipping of paneer samples in H_2O_2 alone or followed by dipping in delvocid had the greatest bactericidal effect; the total count decreased during the 1st wk, then increased. The

initial Y & M count (10^2-10^3/g) decreased during the 1st wk of storage when the samples were dipped in H_2O_2 and/or delvocid. However, the rate of increase of Y & M count was greater in paneer dipped in plain, chlorinated, buffered or acidified water than in brine or acidified brine. Coliform counts were low in all the paneer samples, increasing from <5 to a maximum of 30-50/g during storage.

The experiments of Bector et al. (1999) showed continuous increase in the total plate count in paneer samples when packed in (i) LDPE 200 gauge, (ii) MXXQ 300 gauge and (iii) MST cellulose film 300 gauge, and stored under refrigeration. However, the samples packed in (ii) and (iii) showed less increase in microbial load as compared to that packed in (i).

Shrivastava et al. (2011) investigated the effect of MAP and storage on the microbial quality of laboratory made paneer by packing under 4 different atmospheres: atmospheric air (atm 1), vacuum (atm 2), 100% CO_2 (atm 3), 100% N_2 (atm 4), in presterilized high barrier bags consisting of LLD/BA/Nylon- 6/BA/LDPE, and stored at 7±1 ºC. The study revealed that the initial standard plate count (SPC) ($\log_{10}$) 3.462 increased to 4.962, 3.817 and 4.012, respectively in samples packaged under atm 2, atm 3 and atm 4, respectively after 45 days of storage, indicating that the minimum increase in the count had been with the samples packaged under 100 % CO_2 followed by atm 4 and atm 2, respectively in ascending order; suggesting bactericidal role of CO_2. The analysis showed that the samples packaged under air had maximum anaerobic count. Further storage up to 45 days revealed that the minimum growth had been in samples packaged under 100 % CO_2, followed by 100 % N_2 and vacuum, respectively in ascending order. The initial coliform count ($\log_{10}$) of 1.748 in air packed paneer samples increased to 3.953 after 15 days of storage. The paneer stored for 45 days revealed that coliform count had been

minimum in atm3 (2.141) followed by atm4 (2.944) and atm2 (3.772) respectively, in ascending order. However, the coliform count was found to decrease after 30 days of storage. The Initial mean value of Y & M count of paneer samples increased from 1.338 to 3.927 (atm 2), 3.109 (atm 3), and 3.468 (atm 4) respectively, after 45 days of storage, indicating that the minimum increase in Y & M count was with the samples packed under 100 % CO_2 establishing the bactericidal and fungicidal effect of CO_2.

SENSORY CHANGES IN PANEER DURING STORAGE

The data collected by Bhattacharya et al. (1971) on the changes in organoleptic quality of paneer prepared from milk containing 5% fat and stored at 10 ^{o}C revealed that the rating of the flavour and texture score decreased from ñvery goodò to ñgood ñ and ñfairò, respectively after 3 and 6 days of storage. However, slimy appearance at the top of the paneer samples was observed after 6 days of the storage.

Arora and Gupta (1980) observed that when paneer samples from milk containing 6% fat were stored at 10 ºC, the sensory scores were 98 and 95, each out of 100, respectively on 3rd and 6th day of storage. Storage of paneer at sub-zero temperature, *i.e.* at ï 13 and ï 32 ºC for 120 days did not affect its flavour and appearance but the body and texture of the product deteriorated and became crumbly and fluffy. The initial sensory scores for 4, 5 and 6% paneer were respectively 95, 96 and 98, which decreased to 88, 88 and 90 at ï 13 ^{o}C, and 89, 89 and 90 at ï 32 ^{o}C, respectively after 90 days of storage. It was observed that although the product was acceptable flavour wise, its freshness was lost. The body and texture properties were significantly affected

during storage. However, the appearance of the paneer was not affected significantly during storage.

Sachdeva and Singh (1990a) observed gradual deterioration in flavour score during storage of paneer dipped in plain water for 2 hr, packed in PE pouches. The product was rated unacceptable after 10 days due to the development of putrid odour, and an acidic and bitter taste. Slight decrease in body & texture score was also noted due to the loss of moisture, but when paneer was dipped in H_2O_2 solution (0.2%), a mouldy flavour developed after 22 days of storage at 10 ºC, and the product was evaluated as unacceptable. However, dipping of paneer in brine solution made the product more palatable, but levels >5% imparted a highly salty taste. Appearance scores, which were highest for paneer dipped in H_2O_2, declined during storage, and the spoiled samples dipped in antimicrobial agents exhibited non-uniform greenish yellow mouldy peaks, giving lower sensory scores to the samples.

Sensory-wise, the flavour of control paneer samples was found to be acceptable up to 7 days at 5 ºC before becoming slightly acidic and comparatively soft body & texture (Kumar and Bector, 1991), while the samples stored at 15 ºC resulted in stale flavour and slime development on the surface of paneer on the 10^{th} day of storage. However, organoleptically the product spoiled within 3 days at 15 ºC as the pleasant flavour turned putrid, with the development of yellowish discolouration and slime formation on the surface, while the samples containing TBHQ and BHA remained good for 7 days, but with slight acidic flavour. Agnihotri and Pal (1996) observed significant changes in organoleptic parameters such as appearance, colour, flavour and sliminess for paneer samples made from Barbari goat milk, after 3 days of storage at 4 ºC.

Rai et al. (2008) studied the effect of MAP and storage at 7±1 ºC on the sensory quality of laboratory made paneer by packing under 4 different atmospheres: atmospheric air (atm 1), vacuum (atm 2), 100% CO_2 (atm 3), 100% N_2 (atm 4), in presterilized high barrier bags comprising of LLD/BA/Nylon- 6/BA/LDPE. Their study led to the conclusion that from the consideration of sensory attributes namely appearance, flavour, body & texture and overall acceptability, the stored paneer samples packed under atm 3 were rated best followed by atm 4, atm 2 and atm 1, respectivly in descending order. In another study (Shrivastava and Goyal, 2009) in order to determine the least chemical changes in MAP paneer stored for various time intervals at 3±1 °C, the samples were submitted to 5 types of atmospheres (air, vacuum, 100% CO_2, 100% N_2 , and 50% CO_2 / 50% N_2). Amongst the five atmospheres studied the preservative effect of CO_2 was confirmed. From the investigation, it was concluded that paneer can be packaged in high barrier bags with 100% CO_2 atmosphere for least chemical changes during storage at 3±1 °C.

SHELF LIFE

The shelf life of paneer was reported to be only 6 days at refrigeration temperature (10 ºC) without much deterioration in quality but the freshness of the product was lost after 3 days; while at room temperature paneer did not keep well for more than one day (Bhattacharya et al., 1971). Gupta (1985) remarked that the shelf life of paneer largely depends upon the initial quality of the product. Arora and Gupta (1980) reported that the paneer prepared from milk having 4, 5 and 6 % fat could be stored for not more than 6 days at 10 ^oC, and for at least 120 days at -13 ^oC and ï 32 ^oC without much decrease in sensory quality.

Sachdeva (1983) observed 16 days shelf life for paneer samples tightly wrapped in heat shrink film (cryovac) and stored under refrigeration conditions. The researcher reported that paneer could be stored well over a period of 50 days at room temperature by sterilization. Rao et al. (1984) observed relatively less moisture loss in paneer packed in PE bags compared to parchment paper when the product was stored for 6 days under refrigeration conditions. Sachdeva and Singh (1990a) found that dipping of paneer samples in brine, acidified brine, H_2O_2, or H_2O_2 + delvocid extended the shelf-life to 22, 20, 22 and 32 days, respectively.

Ranawat et al. (1983) dipped paneer in sorbic acid solution (1000 ppm) and found that the paneer could be stored at 0 to 4 ºC up to 6 weeks. Pal and Garg (1989) reported that the shelf life of paneer was 7 days at 7 ºC, when made from sweet cream buttermilk, but the flavour, texture and appearance scores gradually declined, but still the paneer was acceptable up to 9 days with lower sensory scores. Zanjad and Mathur (1990) observed that paneer made by ñin-packagingò sterilization of ultrafiltered milk remained acceptable up to 2 months at 35 ºC, and up to 45 days at 45 ºC. The limited shelf life of paneer of 6 days under refrigeration conditions has been enhanced considerably by chemical treatment (dipping in 0.5% delvocid and 0.2% H_2O_2 solutions for 2hr) (Kanawjia and Singh, 1996). Kanawjia and Khurana (2006) reported that the limited keeping quality of paneer at refrigeration temperature can be enhanced by using antimicrobial substances and vacuum packaging.

In order to determine the shelf life of MAP paneer, Shrivastava (2007) subjected the samples to 5 types of atmospheres (air, vacuum, 100% CO_2, 100% N_2, and 50% CO_2 / 50% N_2) and stored at 3±1 °C. The shelf life of paneer increased significantly upto 30 days for the product packaged

under 100% CO_2, 100% N_2, and 50% CO_2 / 50% N_2. Under vacuum 20 days shelf life was achieved.

Agnihotri and Pal (1996) reported that goat milk paneer could be stored safely up to 3 days under refrigeration. Pal (1998) observed that the shelf life of low fat paneer coated with paraffin wax was more than 10 days at refrigeration temperature.

CONCLUSION

The shelf life of paneer is quite low and it loses freshness after 2-3 days when stored under refrigeration. Spoilage of paneer at surface decreases the shelf life. Various methods, *viz*., chemical additives, packaging, thermal processing, and low temperature storage have been applied by different researchers to maximize its shelf life. However, the use of antimicrobial additives has been discouraged because of perceived toxicity risks. Therefore, the use of MAP seems to be the best alternative for maximizing the shelf life of paneer.

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Table 1: Packaging Materials for Paneer

Packaging material	Reference
PE sachets	Arora and Gupta (1980), Rao et al. (1984), Shukla et al. (1984), Singh et al. (1988), Sachdeva and Singh (1990a), Chandan (2007)
Butter paper	Singh et al. (1989), Pal et al. (1993), Pal (1998)
Parchment paper	Bhattacharya et al.(1971), Rao et al. (1984)
Wax coated paper	Shukla et al. (1984)
Cryovac	Sachdeva (1983)
Saran coated films	Kanawjia and Singh (2000)
LLD/BA*/Nylon - 6/BA*/LDPE (*poly binding agent)	Rai et al. (2008), Shrivastava and Goyal (2009), Shrivastava et al. (2011)
Coextruded laminates, Heat induced shrink films	Chandan (2007)

