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Review paper

Paneer - Unripe Variety of Soft Cheese-A Review

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ABSTRACT

Paneer is similar to tofu is most popular indigenous dairy product which is also identified as South Asian variety of soft cheese obtained by acid and heat coagulation it is similar to unripe variety of soft cheese which is used in preparation of different culinary dishes and snacks. It is a rich source of high quality animal protein, fat, minerals and vitamins. *Paneer* is marble white appearance having firm, cohesive and spongy body with a close knit texture and a sweetish acidic nutty flavor. About 4-5 % of the total milk produced in India is converted into *paneer*. Annual production of *paneer* is estimated at 0.2 million tones having the market value of ₹ 18 × 10^9. It is confined to unorganized sector. Now a day it is possible to manufacture *paneer* by using different types of milk along with different composition like cow milk, buffalo milk, got milk, or blends of these milks, skimmed milk whole milk, butter milk. Along with cow and buffalo milk the *paneer* is also prepared from soymilk, groundnut milk, peas milk, blends of soy-cow milk, soy-buffalo milk, flavored tofu by incorporating carrot, soy-groundnut milk and spices incorporation and different techniques have been developed for the production of *paneer* as per requirement of the consumer with appreciable improvement in yield and other quality characteristics such as physiochemical microbiological and sensory quality of the product. The *chhana*, a het-acid coagulated product of milk, is used as base material for production of *paneer*. For production of *chhana*, milk is heated to near a boiling temperature, followed by cooling and coagulation at 70-75 °C by using 1-2% citric acid, calcium sulphate and magnesium chloride as a coagulants or sour whey. Free whey is drain off to obtain coagulum further, coagulum is pressed to get firm, cohesive and spongy body *paneer*. *Paneer* block of required size are packed in laminated plastic pouches, preferably vacuum packaged, heat sealed and stored under refrigeration. *Paneer* keeps well for about a day at ambient temperature and for about a week under refrigeration (7 °C), through its freshness lost within 3 days. The spoilage of *paneer* is mainly due to bacterial action. Hence, to increase the shelf-life and storability of *paneer* the *paneer* is incorporated with spices like turmeric, clove, cinnamon, black *papper* and cardmom which helps in enhancing shelf-life of *paneer*. Among the spices studied cardmom was found to be the best spices to improve shelf-life of *paneer* up to 28 days of storage at 7± 1°C. Microwave convective drying of paneer also helps in enhancing self-life up to 118 days along with good color, rehydration ratio without appreciable loss of quality in HDPP pouches under acceleration condition of storage (38±2°C, 90% RH).

Keywords: *Paneer*, Soymilk, Groundnut milk, Chhana, Calcium Sulphate, Magnesium Chloride, Spices, Microwave convective dryer, Packaging, Shelf-life, Coagulant, Preservatives, Sensory quality

Milk has occupied an exalted position in India since early times. Its roots go back some 6000 years when milch animals were domesticated. Simple processes were developed to preserve milk's nutritive goodness as a means to protect and promote health. *Paneer* is one such product, a soft, unripe 'home-made cheese' (cottage cheese like product moulded into large chunks), and is traditionally made by acid

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precipitation of cows or buffalo milk or a combination of both and pressing the resulting curd into blocks or cubes. The product has a shelf-life of 6 days at 10°C (Jagannath *et al.* 2001). Paneer consist usually of the protein and nearly all the insoluble salts and colloidal materials, together with part of the moisture of serum of the original milk in which are contained lactose whey proteins, soluble fats, vitamins and other milk components. It contains approximately 53-55% moisture, 23 -26% fat, 17-18 % protein, 2-2.5% carbohydrates and 1.5-2.0% minerals (Kanawjia & Singh, 2000). It is mostly consumed in a fried form, and the manufacture of paneer at pilot level was first standardized by (Bhattacharya *et al.* 1971). It has led India to emerge as the largest milk producer in the world, transcending a record level of 104.8 million metric tones (MMT) in 2008 accounting for 15% of the world's total milk production (NDDB, 2009; Bhasin, 2009). An estimated 5% of milk produced in india is converted to paneer (ICMR, 2000; Chandan, 2007a); production figure being 3,959 metric tones in the year 200-03, which increased to 4,496 metric tones in the year 2003-2004 (Joshi, 2007; Shrivastav & Goyal, 2007) exhibiting a growth of 13%. Approximately 85% of total milk used for the manufacturing of cheese/ paneer is discarded/drained off as whey (Sooch *et al.* 2002; Balasubramanyam *et al.* 1989). In 2001, the 'paneer' whey generated only in India, was around 2.58×10^6 tones (Aneja *et al.* 2002).

Various source used to manufacture paneer by using different types of milk along with blends like cow milk, Soy- buffalo milk, goat milk, soymilk, groundnut milk, peas milk, blends of soy-cow milk, soy buffalo milk, flavoured tofu by incorporating carrot, soy ground nut milk and spices incorporation, or blends of these milks, skimmed milk, whole milk, butter milk. The developed product has good consumer acceptability and other quality characteristics such as physiochemical, microbiological etc. (Eresam *et al.* 2015; Mhatre *et al.* 2008; Raja *et al.* 2014; Buch, 2010; Agnihotri *et al.* 1996; Kumar *et al.* 2011; Uprit and Mishra, 2003; Sharma *et al.* 1998; Das *et al.* 2009; Khan and Pal, 2011; Butool *et al.* 2015 and Khodke *et al.* 2014).

Paneer is rich source of animal protein available at a comparatively lower cost and forms an important source of animal protein for vegetarians (Khan *et al.* 2011). General procedure for production of paneer, for channa the milk is heated to near boiling temperature, followed by cooling and coagulation at 80-85°C by using 1-2% citric acid or sour whey (Bandyopadhyay *et al.* 1987). Free whey is drained off to obtain the coagulum, which is a casein- whey protein complex with entrapped fat. About 90% fat and protein, 10% lactose and 50-60% minerals of original milk are recovered in channa (De, 1980). Recovery of milk solids in channa varies between 63% and 67% (Chandan, 2007a). When chhana is pressed, matting of the coagulum takes place due to change in viscoelastic properties under pressure. Pressed chhana blocks are immersed in chilled water at 4-6°C for 2-3 h. the product obtained is called paneer.

According to PFA, 2010 good quality of paneer characterized by a marbal white colour, sweetish, mildly acidic taste, nutty flavour, spongy body and closely knit smooth texture. The PFA predicts paneer is a "product obtained from cow or buffalo milk or combination of thereof, by precipitation with sour milk, lactic acid or citric acid. The moisture contain should not be more than 70% and fat content should not be less than 50% expressed on dry matter". Bureau of Indian Standards BIS, 1983 imposed maximum of 60% moisture and minimum of 50% of fat in dry matter of paneer. The production of paneer has been largely confined to the unorganized dairy sector which employs traditional inefficient method of manufacture. Pioneering work for the upgradation of the traditional methods of paneer manufacture was carried out by (Bhattacharya *et al.* 1971).

Due to the high cost of paneer, that has restricted its use to mainly the elite and upper middle class of society and poses a great hurdle in its popularization particularly among the middle class and the poor. Milk fat is one of the major factors for high cost of paneer with its possible dietary risk factor in causing coronary heart disease (CHD). In view of high cost and increasing occurrence of coronary complications there is considerable interest to reduce/replace the milk fat in paneer. This amount to the manufacture of paneer like products utilizing non-conventional food solids, which are not only cheaper but also can be converted into product that resembled closely to paneer in textural and nutritional characteristics. Soybean is one such food material, which is popular for producing low cost high nutritional value product. Soybean products represent an inexpensive and abounded source of protein. Replacing a part of milk used in making paneer with soybean milk could give economical and nutritious product. Addition of the soy solids in milk influences textural and sensory characteristics of paneer. Many researchers have recommended blending of soy milk with buffalo milk for the preparation of paneer and cheese (Vijayalaxmi *et al.* 1982; Restogi *et al.* 1998 and Kumar *et al.* 1997).

Addition of soymilk to buffalo milk up to 20% had no adverse effect on quality of paneer, which resembles with milk paneer in taste, colour and springiness (Babaje *et al.* 1992). Fortification of milk with soy and groundnut were reported to decrease hardness of paneer (Roy, 1990). Mixing of soymilk with cow milk during cheese making resulted in products with higher moisture content and weaker body and texture as compared to those made from the cow milk only (Metwalli *et al.* 1982 and Abou El-Ella, 1980). In order to prepare soy fortified paneer (SFP) of a desired sensory and textural quality the selection of a proper blend of soy milk and buffalo milk as well as their composition is very important.

Historical Vista

The nomads of south west Asia first to develop several distinctive heat and acid coagulant varieties of cheese (Mathur *et al.* 1986). In the period 75-300AD the people of Kusana and Saka Satavahana used to consume the solid mass prepared from mixture of warm milk and curd, which resembles paneer (Mathur,1991). Kradi cheese- a semi-soft dried cheese found in Jammu Kashmir is quite similar to paneer (Punoo *et al.* 2007). The nomads of South West Asia developed distinct heat/acid varieties of *cheese* (Mathur, 1991). In South Asia and Central South and Lain America the cheese is manufactured by heat-acid precipitation without starter culture (identical to Indian paneer). The several distinctive varieties of cheese were developed in south West Asia regions. *Paneer-khikhi* is one of the most popular variety of cheese in Iran. It was originally developed by the well known 'Bakhtiari' tribe the resides in summer and Sharz in winter. The literal meaning of paneer is container and '*khikhi*' is skin. They started version of *paneer-khikhi* was known as '*Paneer-e-shour*. In Afghanistan 'paneer-e-khom' and '*paneer-e-pokhta*' are two varieties of paneer made from boiled milk (Chandan, 2007a). A product similar to paneer is also found in Mexico and Caribbean Island (Nayak *et al.* 1998).

Paneer was first introduce in India by Persian and Afghan invaders. This could be the reason for its wide popularity in North Western Part of India and Southern regions of Jammu and Kashmir. Science from last few decades paneer has spread to other parts of India probably due to wide migration of people from one place to another.

Different source of Paneer

The main raw material used for preparation of paneer is milk. Now days some additives are also used to improve the quality characteristics of paneer. Various types of milk are used for manufacture of paneer. The quality of paneer is determined by the quality of milk from which it is produced (Nayak *et al.* 1998).

(a) Buffalo milk

For making good quality paneer, buffalo milk is considered more suitable than cow milk (Bhattacharya *et al.* 1971; Sachdeva *et al.* 1985 & Singh *et al.* 1988). Ghodekar, (1989) reported that higher amounts of casein and minerals (calcium, phosphorus) were responsible for imparting firm and rubbery body to buffalo milk paneer. Fat globules and casein micelles of bigger size and higher concentration of fat, casein, calcium, phosphorus and lower voluminosity and salvation properties of casein micelles in buffalo milk compared to cow milk makes it better suited to paneer making with spongy character (Sindhu, 1996; Ramasamya *et al.* 1999 & Masud, 2002) advocated use of buffalo milk having 6% fat for preparation of best quality paneer. Several workers recommended buffalo milk standardized to 5–6% fat for paneer manufacture (Bhattacharya *et al.* 1971; Arora *et al.* 1980; Rao *et al.* 1984; Chawla *et al.* 1987; Sachdeva *et al.* 1988a; Singh *et al.* 1990 & Kumar *et al.* 2008a).

(b) Cow milk

Good quality paneer can be obtained from cow milk using certain modifications in the manufacturing process or through use of additives (Vishweshwaraiah *et al.* 1986; Singh *et al.* 1988; Sachdeva *et al.* 1991; Arya *et al.* 1992 & Jadhavar *et al.* 2009). The paneer conformed to the PFA standards can be obtained from cow milk standardized to 4.5% fat (Vishweshwaraiah, 1986) and also by using crossbred cows (HF × Sahiwal) milk having 3.7% fat and 8.25–8.42% SNF (Pruthi *et al.* 1989). However, cow milk yields inferior quality paneer especially in sensory characteristics compared to buffalo milk. Such effect could be ascribed to different make-up of casein micelles and lower protein and calcium contents in cow milk compared to buffalo milk (Sindhu, 1996).

(c) Mixed milk

Mixed cow and buffalo milk (1: 1) with 5% fat yielded a superior paneer than cow milk alone (Shukla *et al.* 1984). Sachdeva and Singh (1985) suggested substitution of one third of buffalo milk with cow milk without any adverse effect on the sensory quality of paneer. Singh and Kanawjia (1990) recommended using admixture of buffalo and cow milk (65:35) having 5.18% fat for manufacture of acceptable quality paneer. Pal and Yadav (1991) suggested use of buffalo: cow milk (1:1) with fat level of 3.5% for production of low-fat paneer. However, Chavan *et al.* (2007) recommended addition of 20 parts of buffalo skim milk to 80 parts of cow whole milk for production of better quality paneer.

(d) Goat milk/sheep milk

Use of goat milk resulted in paneer that lacked compactness (Shukla *et al.* 1988). Prasad and Sinha 1990 made paneer from goat milk with acceptable characteristics and without any goaty odour. Agnihotri and Pal (1996) prepared good quality creamy white paneer, free from ‘goaty’ smell or salty taste, from Barbari goat milk with 4.86% fat and 8.96% SNF employing coagulation temperature of 87–88 °C using 0.15% citric acid. Sheep milk could be used to manufacture paneer which resembled buffalo milk paneer (Kale *et al.* 2008). Pal *et al.* (2008) standardized the processing variables (heat treatment of 90 °C, coagulation temperature of 90 °C and coagulant strength of 2% citric acid) for the manufacture of paneer from ewe’s milk with 6.94% fat.

(e) Low fat milk (Low fat paneer)

Acceptable quality low fat paneer with 42% fat on dry matter (FDM) was made from buffalo milk standardized to 3.5% fat. Cow or buffalo milk with fat levels lower than 3.5% resulted in product with unacceptable flavour (not having typical flavour) and body and texture (lacked softness) (Chawla *et al.* 1985; Chawla *et al.* 1987 & Arya *et al.* 1992). The modifications like coagulation temperature of 60°C and addition of cultured skim milk (2.5%) and use of additives like NaCl (0.25%) prior to coagulation of buffalo milk (2% fat, 9% SNF) will obtain reduced fat paneer (30% FDM) with acceptable quality (Sanyal *et al.* 2000a & Sanyal *et al.* 2000b). Good quality paneer can be made from milk standardized to even 3.5% fat without resorting to addition of any additives (Chandan, 2007b).

Low fat paneer of acceptable quality can be produced from cow milk standardized to a fat content of 3.5% (Vishweshwaraiah *et al.* 1986). The paneer with 24% FDM reports the acceptable quality in western countries (Aneja, 2007; Chandan, 2007a).

(f) Dried milk

The yield of paneer was increased from 18.3% to 24.4% by using buffalo milk with not fat dry milk (NFDM) (Chawla *et al.* 1987). Unfermented reconstituted skim milk and fruit juices were used for manufacture of ‘fruit paneer’ (Nakazawa *et al.* 1989). The process for production of paneer from recombined milk (with addition of 0.15% calcium chloride to it) using cow skim milk powder and butter oil is standardized process for manufacture of paneer (Singh *et al.* 1991). Singh and Kanawjia (1992) manufactured paneer from buffalo whole milk powder reconstituted to different levels of total solids (15–25% TS) and concluded that paneer obtained from reconstituted whole milk with 15% TS was the best in terms of yield, TS recovery and sensory characteristics of paneer.

Types of Paneer

In the last few decades, consistent efforts have been made for the manufacture of different types of paneer like low fat paneer, recombined and reconstituted milk paneer, dietary fiber enriched low fat paneer, soy paneer, filled paneer, vegetable impregnated paneer and UF paneer. A brief description of such types of paneer is given below.

(a) Conventional paneer

Preparation of conventional paneer is an old age practice which is generally adopted by halwais in the cities and towns. For preparation of this type of paneer, generally buffalo milk having a fat to SNF ratio of 1:1.65 is preferred. Such paneer is quite rich in fat content (Kumar *et al.* 2014)

(b) Low fat paneer

Generally, health conscious people do not like to consume conventional paneer because of its high fat content. Therefore, efforts have been made to develop low fat paneer without significantly compromising the sensory and textural characteristics. Good quality low fat paneer has been developed at National Dairy Research Institute, Karnal from milk having as low as 3.0% fat (Kanawjia *et al.* 2006). Kanawjia and Singh (2000) reported that fortification of low fat milk with soya solids improved its rheological and sensory quality along with reduction in the cost of production. Chandan, (2007a) reported that skim milk paneer and low fat paneer having 13% and 24% fat, respectively on dry matter basis are available in the western countries. Out of these, former had a chewy, rubbery texture and hard body.

(c) Recombined and reconstituted milk paneer

During summer season there is a drastic curtailment in the supply of milk due to reduction in milk production, whereas demand is more during these days. As a result, the price of paneer goes up. To overcome the seasonal variation, efforts have been made to develop paneer from milk powder and a fat source. Appropriate technology has been developed for the manufacture of acceptable quality paneer from whole milk powder and also from skim milk powder and butter oil (Kanawjia *et al.* 2006).

(d) Dietary fiber enriched low fat paneer

With increase in the awareness about the health risks associated with consumption of dietary fat and cholesterol intake, there is an increase in the demand of fiber enriched low fat or non fat food products. Since paneer prepared from low fat milk result in hard body, coarse, rubbery and chewy texture, bland flavor, poor mouth feel as well as mottled colour and appearance (Chawla *et al.* 1985), low fat paneer with an improved quality in terms of sensory, rheological and nutritional attributes has been developed by using soy fiber and inulin (Kanawjia *et al.* 2006). These fibers besides improving the texture and sensory properties of low fat paneer, improves the bowel movement and reduces the chances for colorectal cancer.

(e) Soy paneer

Day by day increase in the cost of milk products has put pressure on researchers for the development of products with high nutritive value but low cost. Soy protein is an outcome of this strategy. This product can be utilized for preparation of various culinary dishes. Babaje *et al.* (1992) studied the effect of blending soy milk with buffalo milk on the quality of paneer. They observed that coagulation of soy milk results into a white, soft gelatinous mass. The product had bland taste, unique body and texture. Soy paneer is a cheaper source of good quality paneer. They also noticed that addition of soy milk up to 20% to buffalo milk had no adverse effect on the quality of paneer and resembles almost that of milk paneer in colour, taste and springiness. Acceptability of soy paneer can be further enhanced by addition of sodium caseinate.

(f) Filled paneer

During flush season, the rate of the milk goes down and farmers feel difficulty in selling milk at normal price. Under such circumstances, milk fat is generally recovered as cream which is subsequently utilized either for the production of butter or ghee but skim milk does not get right price. To overcome this problem, skim milk can be utilized for preparation of filled paneer. For this skim milk is blended with vegetable oils/vanaspati or coconut milk. Blending of 10% coconut milk with skim milk resulted in the manufacture of filled paneer with highly acceptable sensory attributes (Bajwa *et al.* 2005).

(g) Vegetable impregnated paneer

Impregnation of vegetables not only reduces the cost of paneer but also provides functional properties to it. Bajwa *et al.* (2005) manufactured vegetable impregnated paneer by incorporating coriander and mint leaves from 5 to 30% in buffalo milk having 5% fat. They reported that yield, ash, crude fiber, ascorbic acid, iron and calcium content of the paneer increased with increase in the level of impregnation whereas fat content decreased. A decrease in the level of sensory scores was noticed with increase in the level of vegetables impregnation although all the samples were very well acceptable.

(h) UF paneer

Membrane technologies can be greatly exploited for the manufacture of paneer. It not only improves the quality and shelf-life of paneer but also reduces energy losses. Ultrafiltration process permits retention of greater amount of whey solids in paneer and consequently gives higher yields. The process involves standardization of pasteurized milk to a fat content of 1.5% and SNF to 9.0%, followed by ultrafiltration to a total solids content of 30%. To this glucono-δ-lactone is added @ 0.9% prior to filling in retortable metalized polyester pouches. These pouches were then autoclaved for 15 min during which concomitant thermal texturization also took place resulting in formation of long shelf life product (Aneja *et al.* 2002). UF paneer was reported to a shelf-life of 3 months at 35 °C and overall acceptability of 8.5 on a 9-point hedonic scale.

Paneer Manufacturing

Bhattacharya *et al.* (1971) standardized the process for manufacturing paneer on a pilot plant scale. Buffalo milk having 6% fat content was heated at 82 °C in a cheese vat for 5 min and cooled to 70 °C, and was coagulated with citric acid (1% solution), which was added slowly to the milk with continuous stirring until a curd and clear whey separated out. The mixture was allowed to settle down for 10 min and the whey was drained out through a muslin cloth. During this time, the temperature of whey was maintained above 63 °C. The curd was then collected and filled in a hoop (35 × 28 × 10 cm) lined with a clean and strong muslin cloth. The hoop had a rectangular frame with the top as well as bottom open. The frame was then rested on a wooden plank and filled with the curd before covering with another plank on the top of the hoop by placing a weight of 45 kg for about 15–20 min. The pressed block of curd is removed from the hoop and cut into 6–8″ pieces and immersed in pasteurized chilled water (4–6 °C) for 2–3 h. The chilled pieces of paneer are then removed and placed on a wooden plank for 10–15 min to drain occluded water. Afterwards, these pieces were wrapped in parchment paper, and stored at refrigeration temperature (4 ± 1 °C). A schematic approach for the manufacture of paneer is depicted in Fig. 1.

Physico-chemical changes during paneer manufacture

The physical and chemical changes in casein are brought about by the combine effect of heat and acid during coagulation process. The large structural aggregates of casein are formed by normal colloidal dispersion of discrete casein micelles, in which milk fat and coagulated serum protein get entrapped along with some whey. During this stage, two major changes occurs (i) removal of tricalcium phosphate from the surface of casein and its conversion into monocalcium phosphate and soluble calcium salt and (ii) calcium gets free from calcium hydrogen caseinate to form soluble calcium salt and free casein. When the pH of the milk system drops, the colloidal particles becomes isoelectric i.e. the net electric charge becomes zero to form "Zwiter ion" under such circumstance the dispersion is no longer stable; the casein gets precipitated and forms a coagulum (Walstra *et al.* 1983).

Fresh buffalo milk
↓
Filtration
↓
Standardization (Fat: SNF 1:1.65 using buffalo skim milk)
↓
Heating (82°C, 5 min)
↓
Cooling (70°C)
↓
Addition of coagulant (1% Citric acid ($C_6H_8O_7$) at 70°C)
↓
Continuous stirring till clear whey separates out
↓
Settling for 10 min
↓
Draining of whey
↓
Pressing the coagulum after filling in muslin cloth lined hoops
↓
Removal of blocks and cutting into desired size
↓
Immersion of paneer blocks in chilled water (4°C)
↓
Draining of water and wiping surface
↓
Packaging and storage at 4°C

Fig. 1: Flow chart for manufacture of paneer (Kumar *et al.* 2011)

Caseins exist in large colloidal micelles with calcium phosphate. These micelles are highly hydrated (average 3.7 g water per gram casein protein) with large voluminosity of about 4.4 ml/ g protein. The size of micelles ranges from 500 to 3000 A with maximum distribution at a diameter of about 800 A, and a weight average mol. wt. of 2.5 × 108. Casein are phosphorproteins precipitated from raw milk at pH 4.6 at 20°C. They comprise approximately 80% of the total protein content in milk. The principal proteins in this group are classified according to the homology of their primary structure into α_{s1}, α_{s2}, β- casein and κ-caseins. The complete amino acid sequence with more acidic amino acid of bovine α_{s1}- Caseins is known. The β variant consists of 199 amino acid residues with calculated molecular weight of 23,614 (Mercier *et al.* 1971). The α_{s2}-caseins contain the major α_{s2}-CN A-13P, and the minor components α_{s2}-CN A-12P, α_{s2}-CN A-IIP, and α_{s2}-CN A-10P, which were classified as α_{s2}, α_{s3}, α_{s4}, and α_{s6}, respectively. The α_{s5}-casein is a dimer of disulfide- linked α_{s2}-CN A-12P and α_{s}-CN A11P. The complete amino acid sequence of α_{s2}-CN A-11P consists of 207 residues giving a calculated molecular weight of 24,350 (Brignon *et al.* 1977). β- Casein constitutes 30 to 35% of the total caseins. The β-CN A1-5P is a single polypeptide chain of 209 residues with molecular weight of 23,982 (Ribadeau-Dumas *et al.* 1972 & Grosclaude *et al.* 1973). κ-Casein constitutes about 15% of the total caseins and it is only casein containing cysteine. The major casein, κ-CN B-P1, consist of 169 amino acid residues with a calculated molecular weight of 19, 023 (Brignon *et al.* 1972 & Mercier, 1972).

(a) Casein Micelle Models

The Casein micelles comprise 93% (w/w) caseins with the α_{sl}- to α_{s2}- to β- to κ-caseins in the proportion of 3:1:3:1 weight ratio. The remaining 7% consists of inorganic calcium (2.87%), phosphate (2.89%), citrate (0.40%), and small amounts of magnesium, sodium, and potassium (Schmidt, 1980). A casein micelle is regarded as a core consisting of a mixture of α_{s}- and β-caseins stabilized by a surface coat of κ-casein. Slattery and Evard, (1973) proposed the model of a micelle composed of submicelles in which the hydrophobic regions of the casein molecules are oriented in the interior and the hydrophilic regions are located on the surface. The κ-caseins, due to self-association, are restricted to one area on the surface of the submicelle. Therefore, on the surface of the submicelle, there are two separate regions: a hydrophilic macropeptide portion of associated κ-caseins and a phosphate-rich (phosphoserine residues) area of the other caseins. The phosphate groups on the surface interact with calcium to form calcium phosphate bridges. The shielding effect of the calcium renders a portion of the micelle surface available for hydrophobic interactions (Slattery, 1976 & Slattery, 1977). In building up a micelle, the hydrophobic interactions among the submicelle surfaces orient the submicelles with the hydrophobic regions pointing inward. Eventually, the resulting micelle must contain a highly hydrophilic surface rich in κ-casein. The size of the micelle is therefore dictated by the relative concentration of κ-caseins in the submicelle. The κ-casein-rich submicelles tend to limit growth at the micelle surface.

A later modification of the Slattery model consists of the binding of submicelles by electrostatic interactions via colloidal calcium phosphate instead of by hydrophobic interactions (Fig. 2 (Schmidt *et al.* 1976, Schmidt, 1980, Schmidt, 1982). The binding of submicelles occurs between the negatively charged ester phosphate group of casein and the colloidal

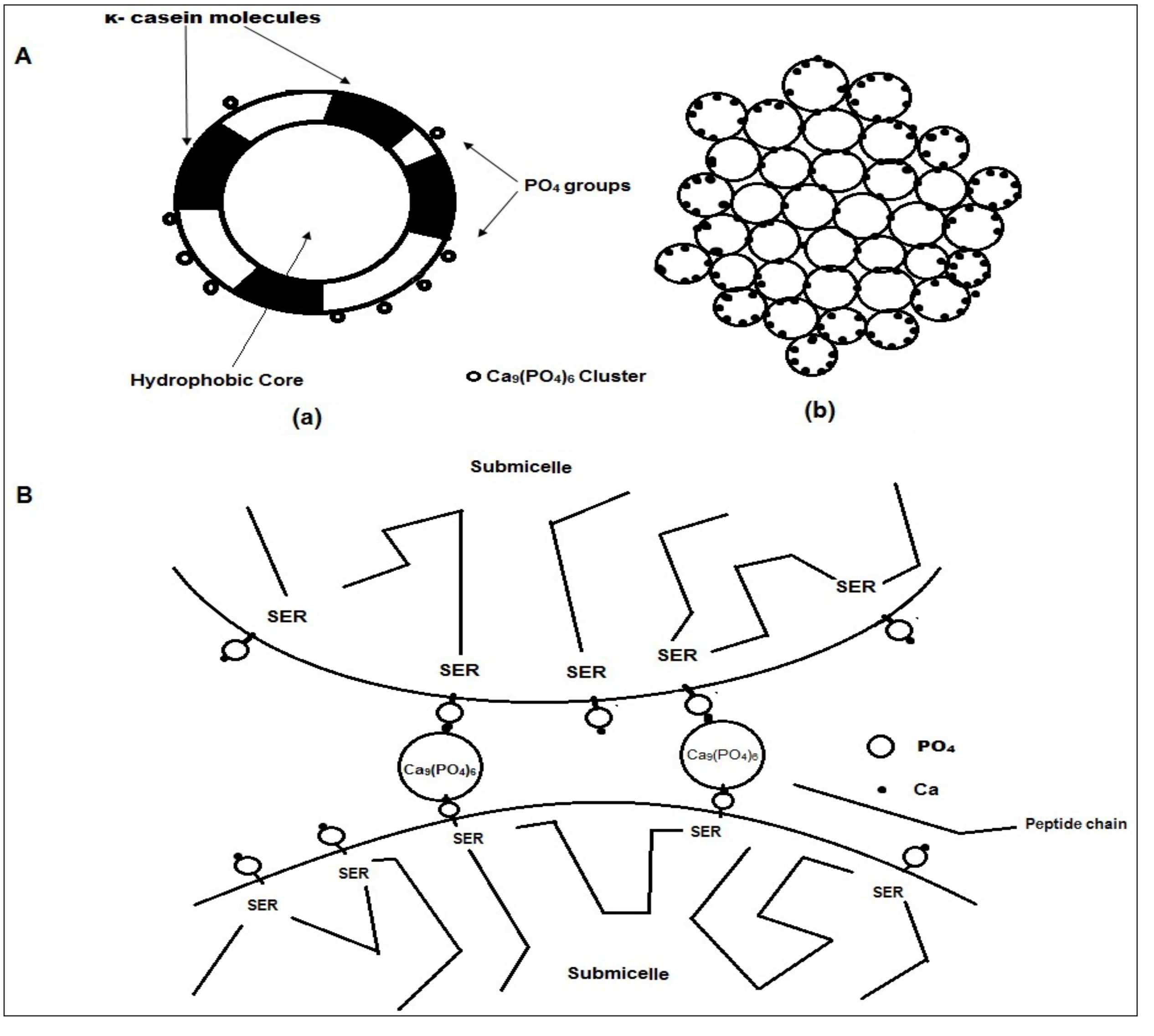

Fig. 2: (A) Schematic representation of a submiceile (a) and a casein micelle composed of submicelles (b). **(B)** Schematic diagram of the binding of two submicelles via $Ca_9(PO_4)_6$ clusters. (Schmidt, 1982)

calcium phosphates in the form of $Ca_9(PO_4)_6$ clusters of tricalcium phosphate, $Ca_3(PO_4)_2$ which are positively charged by adsorption of two calcium ions. Because κ-casein is almost phosphate free, submicelles with low κ-casein content are buried in the interior of the micelle structure. As the micelle grows, the κ-casein on the shell surface increases, with decreasing content of the phosphoserine residues (from the a- and P-caseins) for $Ca_3(PO_4)_2$ clusters. Micellar growth stops when the micelle surface is predominantly occupied by κ-casein.

(b) Heat Induced Changes in Milk Preceding Coagulation

In modern dairy technology, milk for all products is subjected to heat treatment which may range from mild for cheese milk to severe for ultra-high temperature (UHT) products and sterilized concentrated milks. The milk protein system is remarkably heat stable but shows marked natural variation, and it may be necessary to select milk for particular applications. However, natural heat stability may be modified by a variety of additives and process manipulations (Fox, 1981). Fox, (1981) studied the principal changes induced in milk on heating at elevated temperatures (~140°C) for extended periods. Table 1 shows some heat-induced changes in milk likely to lead to protein coagulation.

Nutritional importance of paneer

Paneer is of great value in diet, especially in the Indian vegetarian context, because it contains a fairly high level of fat and proteins as well as some minerals, especially calcium and phosphorus. It is also a good source of fat soluble vitamins A and D. So its food and nutritive value is fairly high. Superior

Table 1: Some heat-induced changes in milk likely to lead to protein coagulation

Changes occur	**Consequences**
Decrease in pH	The pH of unaltered milk decreases to 5.5 to 6.0 at coagulation. Three principal reactions account for the decline in pH. (1) Production of organic acids, principally formic, from lactose, (2) precipitation of primary and secondary calcium phosphate as tertiary phosphate with concomitant release of H +, and (3) hydrolysis of organic (casein) phosphate and its subsequent precipitation as $Ca_3(PO_4)_2$ with release of H +.
Precipitation of calcium phosphate	The solubility of calcium phosphate decreases with increasing temperature and increasing pH; at 120°C there appears to be a sharp decrease in solubility at % pH 6.8.
Maillard browning	Considerable browning occurs on heating milk at 140°C especially at the upper end of the pH range. The reduction in dye-binding capacity of milks heated at 140°C at pH 6.7 and 7.2 which presumably reflects the nonavailability of lysine as a result of interaction with lactose. Approximately 15% and 25% of the lysine groups were rendered unavailable on heating at pH 6.7 and 7.2, respectively, in 20 min.
Modification of casein:	
Dephosphorylation	The total dephosphorylation of sodium caseinate occurs in 5 h. The release of (*Trichloroacetic acid*) TCA-soluble phosphorus is rapid than formation of TCA-soluble nitrogen. Suggesting that the increase in TCA-soluble Phosphorous is not due to proteolysis. Partially dephosphorylated casein is, *inter alia,* much more heat-labile than casein and is capable of binding less Ca^{2+}. It was considered that these two factors were largely responsible for the heat-coagulation of casein.
Changes in micclar structure:	
Zeta potential	The rennet hydrolysis of κ-casein reduces the zeta potential of the micelles and probably leads to coagulation possibly through van der Waals attractive forces. If pH of milk decreases during heating, these results suggest that, at constant pH, the zeta potential actually increases and the heat-induced coagulation of casein micelles is not because of charge neutralization but probably involves hydrophobic or van der Waals interactions.

Hydration changes	Micellar hydration is dependent on and closely related to zeta potential. There is a substantial reduction in hydration which appears to be at variance with reported changes in zeta potential.
Association – dissociation	Casein micelles disperse on heating milk at ~90°C for 30 min as evidenced by the formation of nonsedimentable (105,000 × g 30 min) casein. It was suggested that ispersion was due to removal of micellar calcium by soluble citrate which is neutralized normally by soluble calcium but which is rendered "free" by precipitation of calcium phosphate on heating. Because of its high pH, the free citrate dissolves colloidal calcium. Intermolecular protein reactions, as well as solubilization of micellar calcium, were considered responsible for micellar dissociation.

Fox, 1981.

nutritive value of paneer is attributed to the presence of whey proteins that are rich source of essential amino acids. Due to its high nutritive value, paneer is an ideal food for the expectant mothers, infants, growing children, adolescents and adults. Paneer is also recommended by the clinicians for diabetic and coronary heart disease patients (Chopra *et al.* 1995).

The protein efficiency ratio (PER) and biological value (BV) of paneer prepared from buffalo milk and cow milk is 3.4, 2.3; 86.56 and 81.88, respectively. The digestibility coefficient values for both types of paneer were nearly identical. Buffalo milk paneer had higher net protein utilization (83.10) as compared to cow milk paneer (78.28) (Shrivastava *et al.* 2007).

Factors affecting quality of Paneer

(a) Type of milk Buffalo milk

Type of milk Buffalo milk is better suited for making paneer compared to cow because the latter produces soft, weak and fragile product that is considered unsuitable for cooking purposes. The superior quality of paneer from buffalo milk is due to its unique physico-chemical properties as compared to those of cow milk. Buffalo milk has larger fat globules and casein micelles, higher concentrations of solid fat, casein, calcium, phosphorus, and lower voluminosity and salvation properties of casein micelles compared to cow milk (Sindhu, 1996). Cow milk paneer has a soft and spongy body and a relatively open texture whereas, buffalo milk paneer has firm and spongy body and a close texture.

Of all the milk constituents, fat exerted the greatest influence on the quality of paneer. Normally, 5% fat in milk is required for making paneer, which complies with the PFA standards. Bhattacharya *et al.* (1971) and Kumar *et al.* (2008a) reported that the good quality paneer could be made from buffalo milk containing 6% fat. However, an acceptable quality paneer was made from milk containing 3.5% fat (Chawla *et al.* 1985). Mixed milk (cow: buffalo; 1:1) having 5% fat yielded superior paneer than cow milk alone. About one third of buffalo milk could be substituted with cow milk without compromising on flavour, body and texture of resultant paneer (Sachdeva *et al.* 1985).

(b) Quality of milk

Vishweshwaraiah and Anantakrishnan (1985a) noticed that homogenization of cow milk improved the yield and organoleptic score of paneer. They also reported that the milk with Clots-On-Boiling (COB) test positive or milk having high acidity was not suitable for paneer making. Chawla *et al.* (1985) reported that the use of homogenized buffalo milk, or homogenized buffalo skim milk mixed with unhomogenized cream, did not improve the flavour of low fat paneer. Vishweshwaraiah and Anantakrishnan (1986) reported that fat loss in whey increased with increase in fat content of milk and total solids recovery was highest in paneer from lower fat milk.

(c) Type, strength and amount of coagulant required

Various coagulants were used, over the years including aged whey (Singh *et al.* 1984; Sachdeva *et al.* 1985 & Vishweshwaraiah, 1985a), citric acid

(Vishweshwaraiah, 1985a & Sachdeva *et al.* 1985), whey cultured with *Lactobacillus acidophilus* (Sachdeva *et al.* 1985), lactic acid (Kumar *et al.* 2008b) and alum (Kumar *et al.* 2008c). Grover *et al.* (1989) prepared soya paneer using citric, tartaric, lactic and acetic acid as coagulant. Paneer made from tartaric acid had the highest acceptability amongst the coagulants. Citric acid as 1% solution is most widely used coagulant for making a good quality paneer (Singh *et al.* 1988 & Sachdeva *et al.* 1988a). Vishweshwaraiah and Anantakrishnan (1985a) advocated use of 2% citric acid solution for paneer making from cow milk. The acid (citric/lactic) requirement was 2.34 g for coagulating 1 kg of milk. The quantity of coagulant required was slightly more in case of homogenized milk compared to unhomogenized cow milk (Chawla *et al.* 1985). The amount of acid required was highest in case of hydrochloric acid and lowest in case of phosphoric acid and acidophilus whey. Citric, tartaric, lactic and sour whey did not show much variation in their requirement to coagulate a given quantity of milk (Sachdeva *et al.* 1987).

Pal and Yadav (1991) utilized 1.41 and 1.52 g of citric acid per kg of buffalo milk and cow milk, respectively for complete coagulation, while Chawla *et al.* (1987) advocated 1.95 g citric acid (1%) for making paneer from 1 kg of cow milk regardless of its fat content. About 1.5 g of hydrochloric acid (0.6%) is sufficient to coagulate buffalo milk for paneer making (Sachdeva *et al.* 1987). Rao *et al.* (1984) made paneer from standardized (6% fat) buffalo milk using three different strengths (0.3, 0.4 and 0.5% solution). The moisture content and thus yield of paneer decreased while acidity and fat losses in whey increased with increasing strength of citric acid solution. Milk heat treated at 85 °C and coagulated with 0.3% citric acid solution gave best result for paneer. Arya and Bhaik (1992) reported that good quality paneer could be made from cow milk (4.5–5.2% fat) by incorporating 0.10% $CaCl_2$ into milk prior to its coagulation.

(d) Heat treatment of milk and coagulation temperature

Heat treatment of milk causes destruction of microorganisms, denaturates whey proteins and retards colloidal calcium phosphate solubility (Ghodekar, 1989). Acidification precipitates casein micelles along with denatured whey proteins and insoluble calcium phosphate (Rose *et al.* 1959; Brule *et al.* 1978 and Walstra *et al.* 1983). The temperature-time combinations for heating milk for paneer making advocated by various researchers are: 80 °C without holding (Vishweshwaraiah *et al.* 1985a), 82 °C for 5 min (Bhattacharya *et al.* 1971), 85 °C without holding (Rao *et al.* 1984), 85 °C for 5 min (Singh, 1991) and 90 °C without holding (Sachdeva *et al.* 1988b). Coagulation temperature influences the moisture content, fat and TS recovery and thereby the yield of paneer; it also influences its body and texture characteristics. An increase in the temperature from 60 to 86 °C decreased the moisture content of paneer from 59 to 49%. Bhattacharya *et al.* (1971) recommended cooling of heated (82 °C for 5 min) milk to 70 °C for coagulation. Use of coagulation temperature greater than 70 °C resulted in hard and dry paneer while free surface moisture was evident when coagulated at lower (<70 °C) temperatures (Sachdeva *et al.* 1988a). Coagulation temperature of 70 °C has been widely practiced and reported to give desired frying quality in terms of shape retention, softness as well as integrity (Rao *et al.* 1984 & Chawla *et al.* 1985). Vishweshwaraiah and Anantakrishnan (1985a) reported that satisfactory quality paneer can be obtained by employing coagulation temperature of 80 °C from both buffalo and cow milk.

(e) pH of coagulation

De, (1980) reported that the moisture retention in paneer decreased with fall in pH, which consequently decreased the yield. Vishweshwaraiah and Anantakrishnan (1985a) reported that paneer made by coagulating cow milk at coagulation pH 5.0 was sensorily scored superior to the one coagulated at pH of 5.5. Sachdeva *et al.* (1991) advocated optimum coagulation pH of 5.2–5.25 for paneer to be prepared from cow milk. Sachdeva and Singh (1988a) noticed that the optimum coagulation pH was 5.35 for paneer obtained from buffalo milk with regard to TS recovery and product quality.

Additives

Various types of food grade additives have been incorporated into the milk during paneer production in order to improve a few parameters such as yield, sensory characteristics and shelf life as well as to reduce the cost of production.

(e) Calcium compounds

Calcium helps in building the cross linkages during the formation of curd and thus helps in increasing the recovery of milk solids, yield and improves body and texture and overall acceptability scores of paneer. Cow milk paneer has softer body than buffalo milk paneer since cow milk is lower in calcium content. In order to produce good quality cow milk paneer, calcium chloride at the rate of 0.08–0.15% was used to get better quality paneer (Sachdeva *et al.* 1991 & Arya *et al.* 1992). Singh and Kanawjia 1988 observed that use of 0.1% $CaCl_2$ to milk prior to coagulation increased total solids recovery, yield and all the sensory characteristics. Singh and Kanawjia (1991) recommended addition of 0.15% $CaCl_2$ for paneer to be made from recombined cow milk. A combination of disodium phosphate and calcium chloride has been used in western countries for preparation of low-fat cheese. It increased the softness and elasticity of curd due to the formation of colloidal calcium phosphate (Teknotext, 1995).

Calcium phosphate addition to the milk can help in the coagulation of whey proteins thereby increasing the yield of curd (Dybing *et al.* 1998). Calcium ions help in neutralization of milk protein charges and induce aggregation and precipitation of casein. The calcium phosphate microcrystals formed when using phosphate salt in milk, provides a substrate for protein adsorption, with subsequent cross-binding of the casein micelles to form sturdy aggregates of co-precipitated calcium phosphate and casein (Guo *et al.* 2003). Hill *et al.* (1982) recommended use of high temperature and $CaCl_2$ for getting better yield through co-precipitation of casein and whey proteins. Arora *et al.* (1996) observed that addition of $CaCl_2$ increased fat, protein, TS, pH and TS recovery and thus yield of paneer made from diluted milk which is most commonly encountered in un-organized sector. Kanawjia and Rizvi (2003) recommended use of 0.15% $CaCl_2$ to microfiltered milk retentate prior to acidification in paneer manufacture.

(f) Herb impregnation

Kaur *et al.* (2003) and Bajwa *et al.* (2005) reported that incorporation of coriander and mint at level of 10% by weight in paneer improved the overall acceptability score and yield of product.

(g) Vegetable oil

Low-cost, low-calorie, health promoting paneer can be made using skim milk added with vegetable oil. Hydrogenated vegetable oil and groundnut oil proved to be better than soya oil; the later product was unacceptable. Higher fat level (i.e. 5.5 vs. 3.5%) resulted in better acceptability of the resulting filled-paneer (Roy *et al.* 1999). Kanawjia and Singh (2000) found that paneer obtained from skim milk and vanaspati (HVO) resulted in quite acceptable paneer.

(h) Coconut milk

Venkateswarlu *et al.* (2003) opined that addition of 10% of coconut milk (25% fat) to skim milk resulted in highly acceptable quality paneer.

(i) Protein enrichment

The protein content of paneer can be increased using non-conventional low cost proteins to improve its nutritional value and to achieve economy. They were also used to improve the sensory characteristics of low fat paneer thus making it ideally suited for dietary management of consumers suffering from protein malnutrition and coronary complications. Incorporation of whey solids raised the yield of paneer by 20.9%, though recovery of milk solids decreased (Singh *et al.* 1991). Kanawjia and Singh (2000) found that incorporation of low cost calcium salt of groundnut protein isolates to skim milk and vegetable fat mixture produced nutritionally superior paneer than the conventional paneer. Salve *et al.* (2007) advocated use of 2.0% whey protein concentrate (72% protein) to buffalo milk with only

4% fat for improving the quality attributes of low fat paneer (<50% FDM). Sivakumar *et al.* (2007) found that the inclusion of 0.2% soy protein isolate (SPI) to buffalo milk with 4% fat increased the yield of low-fat paneer containing around 40% FDM, at the same time improving its texture, juiciness and overall acceptability when compared to paneer devoid of added SPI. SPI was mainly added as a fat replacer. Paneer was prepared by incorporating 3, 5 or 10% of either soymilk, buttermilk or skimmed milk to buffalo milk. In all cases, oil uptake on frying with groundnut oil was not appreciably different from that of the control up to the 5% level of incorporation but, at 10%, the oil uptake was higher than the control. Paneers with buttermilk and soy milk had softer textures than the control (Sharma *et al.* 1998).

(j) Buttermilk

Buttermilk, a by-product of butter industry which can be utilized in the manufacture of paneer. Buttermilk is of two types, sweet and sour buttermilk. Pal and Garg (1989) proposed two additional manufacturing steps for the manufacture of paneer from sour buttermilk, i.e., neutralization of sour butter milk to 0.15% titratable acidity by sodium bicarbonate and washing of curd with hot water (72 °C) before pressing to mitigate the problems of self-coagulation of milk during heating, development of acidic smell, sour taste and grainy texture in paneer. Shoekand *et al.* (1990) found that fresh cream buttermilk can be used for standardizing the buffalo milk upto casein to fat ratio of 0.70 (4.47% fat, 3.97% protein) without affecting its quality and acceptability.

(k) Sodium compounds

Chawla *et al.* (1987) found that addition of 0.1% sodium citrate or 0.5% sodium chloride to milk helped in increasing the moisture content of low fat paneer and thereby yield of the product. Yadav *et al.* (1994) found that use of common salt (0.5%) in milk led to an improvement in the body and texture characteristics and yield of low-fat buffalo milk paneer, besides enhancing its shelf life (i.e. 2 days at room temperature). Incorporation of small amounts of cultured skim milk (2.5%) and salt (0.05%) helped to improve the moisture, yield and sensory quality of reduced-fat paneer (Sanyal *et al.* 2000a, 2000b & Mendiratta *et al.* 2004). Kaur *et al.* (2003) found that dipping of paneer blocks in brine solution (1–5%) decreased its moisture and water activity while the flavour and overall acceptability were enhanced when 3% brine solution was used.

(l) Emulsifying salts

Pal and Kapoor (2000) used various emulsifying salts namely monosodium phosphate, disodium phosphate, trisodium citrate, tetrasodium pyrophosphate, sodium tripolyphosphate and sodium hexametaphosphate (1–3%) for preparation of processed paneer. None of the emulsifying salts had any significant influence on the chemical composition in the product. Although, such salts are not permitted by PFA in India but they are permitted by codex alimentarius in directly acidified cheeses and other similar type of dairy products. These were used to make processed paneer which could be similar to processed cheese, which is very popular in western countries. But the addition of such salts proved to be of no significance in paneer.

(m) Hydrocolloids

Sachdeva and Singh (1988a) observed increase in moisture retention and thus yield of paneer when sodium alginate, carrageenan or pre-gelatinized starch at levels of 0.10, 0.15 and 0.15% respectively were used as hydrocolloids. Roy and Singh (1994) reported that addition of 0.1% pre-gelatinized starch coupled with use of higher coagulation temperature (90 °C) improved the body and texture as well as yield of filled paneer; sodium alginate at 0.1% level did not exert any beneficial effect. Sharma *et al.* (1999) used Carboxymethyl cellulose (CMC) as an additive for oil reduction in deep-fat fried paneer and found that it appreciably reduced the oil uptake by paneer on frying.

(n) Dietary fibre

The use of soy fibre and inulin (1%) resulted in an improvement in the sensory, rheological and nutritional properties of low-fat paneer which otherwise was criticized for having hard, coarse, rubbery and chewy body and texture (Kanawjia *et al.* 2006). Kantha and Kanawjia (2007) utilized 0.56% of soya fibre in the manufacture of low-fat paneer.

(o) Fruit juices

Nakazawa *et al.* (1989) added fruit juices to reconstituted skim milk for obtaining 'fruit flavoured paneer' having desired sensory characteristics.

Chemical composition of paneer

1. Chemical composition of paneer prepared from different composition of cow milk, buffalo milk and soymilk.

Paneer consist of different chemical constitutents as protein, fat, moisture, lactose, ash etc. the chemical composition of paneer varies with composition of milk, methods of preparation and loss of milk solids in whey. The report of chemical composition of paneer prepared from cow milk, buffalo milk, soymilk and its blends of various workers is Presented in Table 2.

2. Effect of different coagulants on chemical composition of paneer

Khan *et al.* (2011) conducted the study to determine the effect of different types of acids viz., citric acid, tartaric acid, malic acid each at 2, 3 and 5% concentration on the chemical composition of paneer made using reconstituted milk. Paneer was evaluated for moisture, fat, protein, ash and pH as per AOAC, (2003) guideline for cheese. It was observed that the moisture content of paneer decrease progressively with increase in strength of coagulant from 2 to 5% irrespectively of the type of the coagulant. These results were found to be at approximation with the result of (Sachdeva *et al.* 1988b). The moisture content exhibited significant variation ($p \leq 0.05$) with the type of coagulant used. The moisture content was higher in case of malic acid paneer followed by tartaric and at last citric acid paneer. The higher moisture content in malic acid paneer could be the result of milder effect of malic acid on milk protein as malic acid has higher pKa values which resulted in realease of H^+ ions from the acid solution which could have resulted in milder level of denaturation of milk proteins thus retaining higher hydration capabilities compared to citric acid or tartaric acid (Pal *et al.* 1999). In case of fat content the highest fat content was noticed in case of citric acid paneer ($p \leq 0.05$) followed in order by tartaric and malic acid paneer. The decrease in fat content was due to decrease in fat recovery from citric acid through tartaric acid to malic acid paneer. The paneer prepared from 5% acid had significantly higher protein ($p \leq 0.05$) values than either 2% or 3% coagulant paneer. However it was found that the protein content of paneer made using citric acid and tartaric acid were comparablr and both had significantly higher ($p \leq 0.05$) values than malic acid paneer. The lower value of malic acid was due to poor recovery of milk solids as well higher moisture content which results in decrease in protein content proportion. The ash content did not showed any variation ($p \leq 0.05$) among the three concentration of coagulants. However, citric acid and tartaric acid resulted in significantly higher ($p \leq 0.05$) ash content than malic acid paneer. Analysis of data revealed that the TS recoveries were inversely related to the concentration of coagulant, so with the increase in concentration of coagulant, so with the increase in concentration from 2% to 5%, the TS recovery decreased, although 2% to 3% paneer samples were comparable statistically at 5% level of significance. The results were compared successfully with the results of (Sachdeva *et al.* 1987; Sachdeva *et al.* 1988b) who also find that TS recovery varied inversely with the concentration of the coagulant solution. Table 3 shows the effect of different coagulant at various concentration on the physico-chemical quality of reconstituted milk paneer.

3. Effect of soy protein isolates (SPI) incorporation on physic-chemical properties of low fat paneer

Kumar *et al.* (2011) prepared low fat paneer using soy protein isolate (SPI) as fat replacer was investigated. The physiological and sensory characteristics of 4 types of paneer made of low-fat milk (3% milk fat (MF)) and 10% solids not fat (SNF)) and SPI of 0 (T_1),

Table 2: Chemical compostion of paneer

Types of milk used for paneer making	Constituents (%)					Reference
	Moisture	Fat	Protein	Lactose	Ash	
BM (3.5% fat)	56.99	18.10	18.43	—	—	Chawla *et al.* (1987)
BM (4% fat)	54.05	23.27	16.78	2.96	2.20	
BM (5% fat)	56.77	22.30	—	—	—	Bhattacharya *et al.* (1971)
BM (5% fat)	52.75	25.64	15.62	2.68	2.14	Kumar *et al.* (2008b)
BM (6% fat)	54.76	25.98	—	—	—	Bhattacharya *et al.* (1971)
BM (6% fat)	51.54	26.54	—	—	—	Sharma *et al.* (1989)
BM (97%) + Skim milk (3%)	51.77	25.69	—	—	—	
BM (95%) + Skim milk (5%)	51.81	25.19	—	—	—	
BM (90%) + Skim milk (10%)	52.64	23.72	—	—	—	
BM (97%) + Bt (3%)	51.77	25.81	—	—	—	
BM (95%) + Bt (5%)	52.12	25.40	—	—	—	
BM (90%) + Bt (10%)	53.14	24.25	—	—	—	
BM (97%) + SyM (3%)	51.88	26.47	—	—	—	
BM (95%) + SyM (5%)	53.08	25.97	—	—	—	
BM (90%) + SyM (10%)	54.12	24.82	—	—	—	
BM (50%) and SyM (50%)	54.60	18.33	19.81	—	1.68	Babaje *et al.* (1992)
BM (5.8% fat)	50.72	27.13	17.99	2.29	1.87	Rajorhia *et al.* (1984)
BM (5.5% fat)	55.19	23.80	17.99	—	—	Chawla *et al.* (1987)
BM (5.8% fat)	54.10	23.50	18.20	2.40	1.80	Sachdeva *et al.* (1987)
BM (6% fat)	50.98	27.97	14.89	2.63	2.08	Kumar *et al.* (2008b)
Whole BM	51.52	27.49	17.48	2.28	2.18	Das *et al.* (1999)
Toned BM	54.40	22.00	15.00	—	2.00	Butool *et al.* (2015)
Cow milk (3.5% fat)	55.97	18.89	20.93	2.01	1.45	Mistry *et al.* (1992)
Cow milk (5% fat)	53.90	24.80	17.60	—	—	Singh *et al.* (1988)
Cow milk (4.5% fat)	55.26	24.15	18.43	—	—	Syed *et al.*. (1992)
SyM (100%)	88.68	1.85	7.6	—	1.87	Raja *et al.* (2014)
SyM (100%)	76.00	5.44	9.40	—	1.5	Butool *et al.* (2015)
SyM (100%)	71.40	3.52	15.79	—	1.33	Khodke *et al.* (2014)
SyM (50%) and Skimmed milk (50%)	85.32	1.70	8.80	3.80	0.38	Raja *et al.* (2014)
SyM (75%) and Skimmed milk (25%)	82.65	2.55	9.60	4.70	0.47	
Goat milk (4.86 % fat)	46.94	—	19.99	—	1.93	Agnihotri *et al.* (1996)
SyM (90%) + Groundnut milk (10%)	68.00	3.50	15.50	—	1.24	Khodke *et al.* (2014)
SyM (80%) + Groundnut milk (20%)	69.75	3.65	14.40	—	1.25	
SyM (70%) + Groundnut milk (30%)	71.50	3.74	13.70	—	1.29	
SyM (60%) + Groundnut milk (40%)	72.45	4.60	12.90	—	1.31	
SyM (50%) + Groundnut milk (50%)	73.80	4.80	12.30	—	1.32	
SyM (100%)	—	1.40	3.10	1.00	—	Jain *et al.* (2009)
SyM (25%) + Toned Milk (75%)	—	2.00	3.10	3.40	—	
SyM (50%) + Toned Milk (50%)	—	1.80	3.20	2.20	—	
SyM (75%) + Toned Milk (25%	—	1.60	3.20	1.20	—	
Toned Milk (100%)	—	3.00	3.20	4.60	—	
Peanut milk	51.22	20.85	19.92	—	1.22	Chauhan *et al.* (2015)

BM= Buffalo milk; Bt= Butter milk; SyM= Soymilk.

Table 3: Effect of different coagulant at various concentration on the physico-chemical quality of reconstituted milk paneer

Physico-chemical quality	Conc. of Coagulants (%)	Coagulants		
		Citric acid	Tartaric acid	Malic acid
Moisture (%)	2%	57.4±0.49	58.3±0.45	60.66±0.40
	3%	57.1±0.23	57.9±0.43	60.4±0.47
	5%	56.1±0.33	56.9±0.49	59.0±0.09
Fat (%)	2%	19.1±0.13	18.5±0.10	17.2±0.19
	3%	19.2±0.09	18.6±0.21	17.3±0.20
	5%	19.2±0.09	18.6±0.21	17.8±0.17
Protein (%)	2%	18.1±0.18	17.9±0.12	16.6±0.15
	3%	18.2±0.21	18.0±0.19	16.6±0.21
	5%	18.7±0.26	18.5±0.13	17.3±0.12
Ash (%)	2%	1.9±0.04	1.9±0.02	1.8±0.05
	3%	1.9±0.03	1.9±0.01	1.8±0.10
	5%	2.0±0.02	2.0±0.03	1.8±0.03
Total Solid Recovery (%)	2%	58.7±0.31	58.0±0.47	56.9±0.13
	3%	58.4±0.42	57.7±0.12	56.6±0.44
	5%	57.1±0.39	56.6±0.54	55.6±0.36

Khan et al. 2011.

0.1 (T_2), 0.2 (T_3), 0.3% SPI (T_4) were compared with high fat paneer (T_c) made of high fat milk (6% milk fat (MF) and 9% (SNF)). $CaCl_2$ (0.2% w/v) was used as a coagulant at 75±1°C. Protein (micro-Kjeldahl method), fat ISI, (1981), lactose ISI, (1973) moisture, ash and titratable acidity AOAC, (1995) and pH of paneer (O'keeffe *et al.* 1976) were determined. The processing parameters such as yield, frying loss were determined by weighing samples. Increased level of SPI in paneer increased yield, protein, ash, moisture content and decreased fat, moisture protein ratio, lactose and calorie contents. In the following Table 4 reveals that fat and fat on dry matter has been reduced ($p \leq 0.05$) from TC to T_1-T_4. Lower fat and lactose contents in T_2, T_3, and T_4 as compared to T_1 may be due to increased yield. Similar findings were reported in paneer (Chawla *et al.* 1987 & Singh *et al.* 1991). Protein and ash contents of T_1, T_2, T_3, and T_4 were higher ($p \leq 0.05$) than TC due to increase in SNF content as well as incorporation of higher SPI levels. The moisture protein ratio was higher ($p \leq 0.05$) in TC than in T_1, T_2, T_3, and T_4. Moisture content in T_1, T_2, T_3, and T_4 was higher ($p \leq 0.05$) than in TC. Thus moisture and protein contents increased with decrease in fat content of paneer. Similar findings were reported in paneer by (Ashraf *et al.* 1992 & Singh *et al.* 1988). Higher fat in milk results in lower moisture retention in the final product of paneer. The titratable acidity and pH showed no significant difference for different samples. The paneer yields in T_1-T_4 were comparable to TC. Lactose content was in the range of 2.3–2.4% in all samples. Similar findings were reported in paneer by (Ghodekar, 1989). The calorie content was lower ($p \leq 0.05$) in (Soy low fat paneer) SLFP than in (High fat paneer) HFP. The frying losses were lower with the decrease of paneer fat content is given in Table 4.

4. Chemical composition of Vegetable impregnated and spices incorporated paneer

Eresam *et al.* (2015) prepared paneer with incorporation of spices as black pepper, cardamom, Cinnamon and clove tested for their relatively efficacy in improving shelf life of paneer. All the spices were incorporated in paneer @ 0 (control), 0.2, 0.4, 0.6, 0.8 and 1.0% by wt. of expected yield of paneer. The chemical characteristics at a regular interval of 7 days during

Table 4: Effect of soy protein isolate (SPI) incorporation on the physico-chemical attributes of low fat paneer

Physico-chemical attributes	High Fat paneer (Tc)	SPI level %			
		0 (T_1)	0.1 (T_2)	0.2 (T_3)	0.3 (T_4)
Moisture	54.8±0.45[b]	57.7±0.52[a]	57.7±0.58[a]	57.8±0.39[a]	57.90±0.21[a]
Fat (% w/w)	23.1±0.79[a]	13.2±1.02[b]	13.0±0.85[b]	12.7±0.54[bc]	12.4±0.32[c]
Fat (% db)	56.8±0.41[a]	31.1±0.90[b]	30.7±0.84[b]	30.0±0.81[c]	29.3±0.71[c]
Protein (%)	17.7±0.38[c]	23.90±0.51[b]	24.4±0.32[ab]	24.7±0.47[a]	24.9±0.37[a]
Ash (%)	02.2±0.23[b]	02.5±0.21[ab]	02.5±0.21[a]	02.5±0.33[a]	02.5±0.39[a]
Lactose (%)	02.3±0.33[b]	02.4±0.23[a]	02.4±0.15[a]	02.4±0.23[a]	02.3±0.23[ab]
Moiasture /Protein Ratio	03.1±0.06[a]	02.4±0.06[b]	02.4±0.10[b]	02.3±0.09[bc]	2.3±0.11[c]
Calorie (Kcal)	287.3±1.24[a]	236.2±0.79[b]	223.9±0.86[c]	222.1±0.86[c]	220.1±0.86[c]
Titrable acidity, % lactic acid	00.23±0.02	00.24±0.01	00.23±0.04	00.23±0.01	00.24±0.03
pH	05.5±0.08	05.5±0.07	05.5±0.06	05.5±0.05	05.5±0.04
Frying loss %	14.2±0.35[a]	13.0±0.18[b]	13.1±0.12[b]	13.1±0.21[b]	13.2±0.27[b]
Yield, %	21.0±0.76[a]	19.0±0.74[c]	19.5±0.61[b]	20.3±0.48[b]	20.5±0.36[a]

Kumar et al. 2011.

Mean with different superscript in the same row differs significantly (p≤0.05) (n=6).

the storage of paneer were determined. Moisture content in paneer was determine according to BIS, (1983) procedure specified for paneer under IS:10484. Fat content of paneer was estimated by following the method described for cheese (ANON, 1972). Protein content was determined by Kjeldahl method as described by (Horwitz, 1980). Lactose content in paneer was estimated by difference. The ash content of the paneer sample was estimated by the method of BIS, (1981). The acidity of the paneer sample was estimated according to BIS, (1983) procedure specified for paneer under IS:10484. Free fatty acid content of paneer was estimated using the method described for cheese (Thomas *et al.* 1954). The soluble nitrogen content of the paneer sample was estimated by Kjeldahlhod as described by (Kosikowaski, 1970). The study paneer was prepared by incorporating black paper, cardamom and clove i.e., Bp, Ca and Cl @0.6% and cinnamon Ci @ 0.4% by wt. of expected yield of paneer. The effect of incorporating spices on the yield and chemical composition of paneer is presented in Table 5. There was a significant ($p \leq 0.05$) difference in moisture, fat, FDM and protein content of samples. The lactose content of sample varied from 1.67 (control) to 2.0% (Bp and Ci) and the ash content varied from 1.67 (control) to 1.71 (Bp and Ci). The yield of control was maximum i.e. 18.01% and Ci was minimum i.e., 17.50%. Even though the difference in yield was only 0.5%, control had significantly ($p \leq 0.05$) higher yield compared to all the other experimental samples.

Butool *et al.* (2015) prepared carrot incorporated soypaneer, the principle ingredients used were carrot and soybean and citric acid. Carrot pulp was incorporated in two different ratios of 10% and 20%. A carrot incorporated paneer improved colour, appearance, flavor, texture and nutritional properties. The soypaneer incorporation with 20% carrot has almost equal acceptance to the milk paneer in terms of taste, nutritional value and acceptability. Table 5 shows the effect of addition of selected spices and carrot incorporation on chemical compostion of paneer.

Processing parameters

1. Heat treatment of milk

Heat treatment of milk has a profound effect on physico-chemical, sensory and microbiological properties of paneer. It also affects TS recovery

Table 5: Effect of addition of selected spices and carrot incorporation on chemical composition of paneer

Sample	Moisture (%)	Fat (%)	Protein (%)	Ash (%)	References
Mixed Milk (5.5% fat)	50.21	29.02	17.19	—	Sivakumar *et al.* (2007)
Mixed Milk Bp (0.6% fat)	49.81	29.85	17.68	—	
Mixed Milk Ca (0.6% fat)	49.71	29.69	17.57	—	
Mixed Milk Ci (0.4% fat)	49.52	29.85	17.68	—	
Mixed Milk Cl (0.6% fat)	49.70	26.69	17.59	—	
Toned milk + Carrot (10%)	75.60	04.90	09.60	1.9	Butool *et al.* (2015)
Toned Milk + Carrot (20%)	74.80	04.70	09.60	2.30	

Bp= Black pepper; Ca= Cardamom; Cl= Clove; Ci= Cinnamon.

Table 6: Recommended time-temperature combination for heating milk prior to acid coagulation

Temperature-Time combination	Effect on paneer	Reference
80°C/ no hold	Suitable for paneer making from cow milk	Vishweshwaraiah *et al.* (1985b)
82°C/5 min	Good quality paneer from cows milk	Bhattacharya *et al.* (1971)
85° C/No hold	Paneer from crossbred cow milk	Arya *et al.* (1992) & Bajwa *et al.* (2005)
85° C/No hold	Suitable for paneer from buffalo milk	Rao *et al.* (1984)
85 °C/5 min	Suitable for paneer from buffalo milk	Masud *et al.* (2007)
95 °C/10 min	Suitable for buffalo milk paneer	Chawla *et al.* (1985)
90 °C/No hold	Suitable for buffalo milk paneer	Sachdeva *et al.* (1988b)
Heating momentarily to 90^{o}C or 118 C	Suitable for low-fat paneer from mixed (cow : buffalo; 1:1) having 3.5% fat	Pal *et al.* (1991)
96 °C/No hold	Suitable for skim milk paneer	Mendiratta *et al.* (2007)
80°C/15 min	Suitable for soymilk and skimmed milk paneer	Raja *et al.* (2014)
70°C/No hold	Suitable for buffalo milk paneer (normally used by industry)	Sharma *et al.* (1989)
87-88°C/No hold	Suitable for goat milk paneer	Agnihotri *et al.* (1996)
70°C/No hold	Suitable for soy-groundnut paneer	Khodke *et al.* (2014)
90°C/No hold	Suitable for peanut paneer	Chauhan *et al.* (2015)
90°C/No hold	Suitable for paneer from reconstituted milk	Khan *et al.* (2011)
60°C/No hold	Suitable for SPI (Soy protein isolate) incorporated low fat paneer	Kumar *et al.* (2011)
90°C/No hold	Suitable for soypaneer	Uprit *et al.* (2004)

and thus yield of paneer. Heat treatment of milk is essential to destroy the pathogenic as well as spoilage micro-organisms. It also denaturates whey proteins, reduces solubility of colloidal calcium phosphate, thus co-precipitating them along with the casein upon acidification of milk. These constituents increase the yield of curd, which are otherwise lost in whey (Rose *et al.* 1959; Fox *et al.* 1977; Brule *et al.* 1978 & Walstra *et al.* 1983). Heat treatment at 90 °C for 10–15 min was necessary to achieve desired yield (Muller *et al.* 1967). Different time-temperature combinations adopted by various workers are detailed in Table 6.

2. Type and strength of coagulant

Paneer manufacture involves the coagulation of milk proteins to form curd. During this process large clumps of proteins are formed in which fat and other colloidal and dissolved solids get entrapped. The coagulation of milk occurs when pH of milk reaches 4.6 which is the isoelectric point of its major protein, casein. The type and concentration of the acid and the mode of delivery into the hot milk influence the moisture level and product yield.

Several coagulants have been tried namely lemon juice, citric acid, tartaric acid, lactic acid, malic acid, hydrochloric acid, phosphoric acid, acetic acid, fermented milk, sour/cultured whey, yoghurt and lactic cultures. Calcium lactate has also been used as coagulant (Sachdeva *et al.* 1987; Kumar *et al.* 1998 & Deshmukh *et al.* 2009).

The concentration of coagulant has a profound effect on the body and texture of paneer. Low acid strength results in soft body and smooth texture, while high acid strength results in hard body. The strength of coagulant adopted by different workers for paneer manufacture is delineated in Table 7.

Table 7: Strength of coagulants used for paneer making

Coagulant strength	References
1% (w/v) citric acid for buffalo milk coe milk	Bhattacharya *et al.* (1971); Chawla *et al.* (1985); Singh *et al.* (1988)
1.0% (tartaric acid/citric acid/lactic acid) and acidophilus whey (1.22% TA) for buffalo milk. Acidophilus whey resulted in highest TS recovery (66.4%)	Sachdeva *et al.* (1987)
2.0% (w/v) citric acid for cow milk and low fat milk (2.2% fat)	Vishweshwaraiah *et al.* (1985b) & Arya *et al.* (1992)
2.0% (w/v) citric acid for cow and buffalo milk mix (1:1) 3.5% fat	Pal *et al.* (1991)
2.5% citric acid solutuion for cow milk	Sharma *et al.* (2002)
1% (w/v) citric acid solution and cultured whey in ratio of 3:1 for skim milk paneer	Mendiratta *et al.* (2007)
10.0% lactic acid for buffalo milk	Masud *et al.* (2007)
2% (w/v) citric acid solution for ewe's milk	Pal *et al.* (2008)
1% (w/v) citric acid solution for soy and cow milk mix (1:1)	Jadhavar *et al.* (2009)
1.5%(w/v) citric acid for Coagulation of soymilk	Raja *et al.* (2014)
2% (w/v) citric acid solution for reconstitute milk	Khan *et al.* (2011)
2% (w/v) tartaric acid for reconstituted milk	
1% (w/v) citric acid solution for buffalo milk, buffalo milk+skimmed milk, soymilk and butter milk (97:3, 95:5, 90:10)	Sharma *et al.* (1998)
0.15% (w/w) citric acid granules for goat milk	Agnihotri *et al.* (1996)
1% (w/v) calcioun sulphate for peanut paneer	Chauhan *et al.* (2015) & Sharma *et al.* (1999)
2% (w/v) citric acid for toned buffalo milk, soymilk, soymilk + carrot incorporation (10%, 20%)	Butool *et al.* (2015)
2% % citric acid solution for soy-groundnut milk	Khodke *et al.* (2014)
1% (w/v) citric acid solution for buffalo milk	
1% (w/v) citric acid solution for soymilk + buffalo milk (15:85)	Uprit *et al.* (2003)
2% (w/v) $CaCl_2$ for SPI (soy protein isolate) incorporated low fat paneer	Kumar *et al.* (2011)
1% (w/v) citric acid solution for full cream milk (6.0% fat, 9.0 % SNF)	Buch *et al.* (2010)
2% (w/v) for soymilk	Parmar *et al.* (1989)
0.5% (w/v) calcium sulphate for dairy milk	Jain *et al.* (2009)
0.5% (w/v) calcium sulphate for soymilk	Parmar *et al.* (1989)
1% (w/v) citric acid solution for soymilk	Uprit *et al.* (2004)

The amount of coagulant required for coagulation of milk depends upon the type of milk, buffering capacity of milk, type of coagulant and the coagulation temperature employed is given in Table 7.

3. Temperature of coagulation

The temperature and pH of coagulation have a significant effect on the body and texture, TS recovery and yield of paneer. The optimum temperature of coagulation differs for different types of milk and their composition, including fat. Coagulation temperature influences moisture retention in paneer. An increase in temperature of coagulation from 60 to 90 °C decreased the moisture content of paneer from 59.0 to 49.0%. Paneer obtained by coagulating milk at 70 °C had the best organoleptic quality and had desired frying quality namely integrity/shape retention and softness (Sachdeva *et al.* 1988b & Chandan *et al.* 2007).

A coagulation temperature of 70 °C has been recommended for paneer making from buffalo milk (Bhattacharya *et al.* 1971 & Sachdeva *et al.* 1988b). Temperatures higher than this resulted in dry and hard paneer while lower temperature yielded product having very moist surface (Sachdeva *et al.* 1988b). Masud, (2002) and Bajwa, (2005) recommended use of higher (85 °C) and lower (72 °C) coagulation temperature for buffalo milk paneer. Chawla *et al.* (1985) recommended coagulation temperature of 85 °C for low-fat buffalo milk.

To obtain good quality paneer, most workers recommended higher coagulation temperature for cow milk. The suggested coagulation temperature for obtaining good quality paneer from cow milk was 80–85 °C (Vishweshwaraiah *et al.* 1985b; Mistry *et al.* 1992; Arya *et al.* 1992 & Sharma *et al.* 2002). Coagulation temperature of 90o and 70 °C has been recommended when preparing paneer from ewe's milk and mixed milk (cow: buffalo; 1:1) respectively (Chavan *et al.* 2007 & Chawla *et al.* 1985). Singh and Kanawjia (1991) suggested 90 °C of coagulation temperature for making paneer from recombined cow milk. Low coagulation temperature of 60 °C has been used by Sanyal and Yadav (2000a) for preparing reduced-fat paneer.

4. pH of coagulation

Variation in the pH of coagulation has a significant effect on the body and texture, flavour, quality and yield of paneer. According to De, (1980) and Sachdeva and Singh (1988b), with the fall in pH (5.5-5.0), the moisture retention and yield of paneer decreased. Paneer made from cows' milk coagulated at pH 5.0 was sensorily superior to the one coagulated at pH 5.5 (Vishweshwaraiah *et al.* (1985b). However, at coagulation pH of 5.0 the moisture, TS recovery and yield were lower. The moisture content and yield of paneer increased from 50 to 58.6% and from 20.8 to 24.8% respectively, when coagulation pH increased from 5.1 to 5.4. Sensory quality was best at pH 5.3–5.35 which is recommended for paneer making from buffalo milk Sachdeva *et al.* (1988b). Sachdeva *et al.* (1991) recommended the pH range of 5.20–5.25 for cow milk paneer.

5. Whey drainage

After coagulation of milk, the curd is allowed to settle down for 5 min without stirring. During this period the temperature should not be allowed to drop below 63 °C. Thereafter, the curd along with the whey was transferred in a hoop lined with muslin cloth to remove the whey (Bhattacharya *et al.* 1971).

6. Hooping and pressing

The curd is transferred to hoops lined with muslin cloth and subjected to pressing to obtain a compact block of paneer. Different workers have used different pressure for varied time period for paneer manufacture. Bhattacharya *et al.* (1971) and Sachdeva *et al.* (1991) applied pressure of 40–45 kg for 10–15 min for paneer hoop sized 35 × 28 × 10 cm for buffalo milk paneer with moisture around 56%. De *et al.* (1980) and Vishweshwaraiah *et al.* (1986) employed a pressure of 2 kg/cm^2 for 25 min on wooden hoop (4 × 4 × 4 inches) to obtain paneer with 55.0% moisture, while Kulsheshtha *et al.* (1987) suggested applying a pressure of 1 kg/cm^2 and found moisture level in paneer was inversely related to the pressure applied. Kumari and Singh (1992) used 0.08 kg/cm^2 for paneer preparation from cow and buffalo milk which resulted in paneer with 47.9 and 42.7% moisture respectively. Aneja *et al.* (2002) recommended higher weights of 70–100 kg on hoops for 10–15 min.

Drying of Paneer

Uprit *et al.* (2003) successfully investigated the microwave convective drying characteristics of SFP (soy fortified paneer) cubes at different temperature of hot air and microwave power level. The drying rated increased with increased in drying temperature and microwave power level, thus reducing drying time. Diffusivity analysis revealed that moisture diffusivity varied with moisture content and the change in product temperature during drying. An increase in diffusivity was observed with an increase in hot air temperature and microwave power. A drying air temperature of 53.5°C (air velocity 2m/s) and microwave power of 111.5W was considered as optimum for the production of quality dried SFP cubes. The obtained product had good colour, rehydration ratio and had a shelf-life of 118 days without appreciable loss of quality in HDPP (High density polypropylene 115×127 mm) pouches under acceleration condition of storage (38±2°C, 90% RH).

Packaging

Paneer being a perishable commodity is highly susceptible to physico-chemical and microbiological changes. Therefore, its packaging must provide protection against these damages while maintaining its quality, sales appeal, and freshness and consumer convenience. Various packaging material utilizes for packaging of paneer include polythene sachets, cioextruded films, laminates, prachment paper etc. Most of the paneer produces in organized sector is packaged in polythene bags because of its better barrier properties in respect of loss of moisture. These bags prove to be a superior packaging material for paneer compared to vegetable prachment paper (Rao *et al.* 1984). Packaging of chemical preservatives treated paneer with and without vaccum extended its shelf life up to 35 and 50 days, respectively at 8°C (Singh *et al.* 1990). Vaccum packaging of cow milk paneer is reported to have enhanced its shelf life from 1 week to more than 30 days at 6 °C (Sachdeva *et al.* 1992). Paneer packaging in high barrier film (EVA/EVA/PVDC/EVA) under vaccume and heat treated at 90°C for 1 min had a shelf life of 90 days under refrigeration. Rao *et al.* (1984) prepared paneer from satandardized buffalo milk having 6% fat and packaged in polyethylene and vegetable prachment paper and then stored at 6-8 °C. They found that decrease in moisture content of paneer was more in the samples packaged in vegetable parchment paper than in polyethylene. The titratable acidity was found to be slightly more in parchment paper packed samples than in other packaging materials.

Shelf-life

A relatively shorter shelf life of paneer is considered to be a major hurdle in its production at commercial level. It cannot be stored for more than 1 day at room temperature in tropical countries. Bhattacharya *et al.* (1971) reported that paneer could be stored for only 6 days at 10 °C without much deterioration in its quality, though the freshness of the product was lost after 3 days. It has been noticed that the spoilage in paneer occurs due to growth of microorganisms on the surface. A greenish yellow slime formation on the surface of paneer and the discolouration is accompanied with off flavour. Therefore, efforts have been made to curb the surface growth of microorganisms and thereby increase the shelf life of paneer. Dipping of paneer in brine solution may increase the shelf-life of paneer from 7 days to 20 days at 6–8 °C (Kanawjia *et al.* 2006). Arora and Gupta (1980) reported that during storage at −13 °C or −32 °C for 120 days, moisture content tended to decrease, non-protein nitrogen increased and significant changes in fat, total nitrogen content and pH occurred. Storage of paneer at these temperatures did not affect the flavour and appearance significantly but body and texture was deteriorated.

CONCLUSION

Paneer represents a variety of Indian soft cheese, which is used as a base material for the preparation of a large number of culinary dishes and is highly nutritious and wholesome. Most of the paneer is produced in unorganized sector in very small quantities using traditional methods. Reluctance to use modern technological processes has hampered the organized production, profitability and export performance of paneer. Recently some of the organized dairies have taken trials to produce paneer in continuous machines on commercial scale. Shelf-life limitation is a major constraint for its large scale production as it is spoiled within 2 days at room temperature or 7–10 days under refrigeration. Use of antimicrobials and natural antioxidants and vacuum packaging of paneer in nylon pouches reasonably increased the shelf life and facilitated distribution and marketing of product..

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