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REVIEW

Paneer production: A review

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Abstract Paneer represents a South Asian variety of soft cheese prepared by acid and heat coagulation of milk. It is popular throughout South Asia and used in the preparation of a number of several culinary preparations and snacks. It is a rich source of high quality animal protein, fat, minerals and vitamins. Due to availability of different types of milk and variation in milk composition, various techniques have been developed for the production of paneer as per the requirements of the consumers with appreciable improvement in the yield and other quality characteristics. Some of the modifications recommended in the preparation of paneer are discussed in this review. Examples of some 'value-added' paneer have been dealt.

Key words Paneer · Coagulants · Preservatives · Heat treatment · Chemical composition · Sensory quality

Introduction

India has witnessed a remarkable growth in milk production during the last few decades due to the success of the Operation Flood programme, which is one of the world's largest and successful integrated dairy development programs initiated in 1970s. It has led India to emerge as the largest milk producer in the world, transcending a record level of 104.8 million metric tonnes (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 tonnes in the year 2002–03, which increased to 4,496 metric tonnes in the year 2003–04 (Joshi 2007; Shrivastava and Goyal 2007) exhibiting a growth of 13%.

Paneer is a South Asian variety of soft cheese obtained by acid and heat coagulation of milk. It is a non-fermentative, non-renneted, non-melting and unripened type of cheese. Paneer is popular throughout South Asia, used in raw form or in preparation of several varieties of culinary dishes and snacks. The production of paneer is now spreading throughout the world. The ability of paneer to be deep fried is one feature that has led to its wider acceptance and a favourite for making snacks, *pakoras* or fried paneer chunks (Aneja 2007).

Paneer is a rich source of animal protein available at a comparatively lower cost and forms an important source of animal protein for vegetarians. Over and above its high protein content and digestibility, the biological value of protein in paneer is in the range of 80 to 86 (Shrivastava and Goyal 2007). In addition, paneer is a valuable source of fat, vitamins and minerals like calcium and phosphorus. It has a reasonably long shelf life under refrigeration.

Good quality paneer is characterized by a marble white colour, sweetish, mildly acidic taste, nutty flavour, spongy body and closely knit, smooth texture. According to the PFA (2010), paneer means "product obtained from cow or buffalo milk or combination thereof, by precipitation with sour milk, lactic acid, or citric acid. It shall contain not more than 70% moisture and the fat content should not be less than 50% expressed on dry matter". Milk solids may also be used in preparation of paneer. Bureau of Indian Standards (BIS 1983) imposed maximum of 60% moisture and minimum of 50% fat in dry matter for paneer. Paneer is used in a variety of forms viz. base for variety of culinary

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dishes, ingredient for various vegetable dishes (especially *matar paneer* and *palak paneer*), snacks, etc.

The production of paneer has been largely confined to the unorganised dairy sector which employs traditional, inefficient methods 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 ever growing demand for paneer, researchers were encouraged to develop new techniques for the manufacture of paneer. Researchers recommended varied processing conditions for the preparation of varieties of paneer using different types of milk.

Historical perspective

It is believed that the nomads of south west Asia were the first to develop several distinctive heat and acid coagulated varieties of cheese (Mathur et al. 1986). The people of *Kusana* and *Saka Satavahana* periods (AD 75-300) used to consume the solid mass prepared from mixture of warm milk and curd, which resembles paneer (Mathur 1991). *Kradi* cheese—a semisoft dried cheese found in Jammu and Kashmir is quite similar to paneer (Punoo et al. 2007).

Paneer Khiki is one of the unique Iranian nomadic cheese, developed by Bakhtiari tribe of Iran (Rao et al. 1992); when salted it is known as *paneer-e-shour.* The literal meaning of word paneer (Persian) is container and that of *'khiki'* is skin. Paneer is also the Hindi name of *Withania coagulans*, a vegetable rennet that yields bitter curd. The nomads of Afghanistan developed two distinct varieties of white paneer viz., *paneer-e-kham* from raw milk and *paneer-e-pokhta* from boiled milk. Sour milk, pieces of a creeper called *putika*, bark of palasa tree or *Kuyala (jujuka)* might have been used for the coagulation of milk.

Paneer was probably first introduced into India by Persian and Afghan invaders. This could be the reason for its wide popularity in the North Western parts of India and Southern regions of Jammu and Kashmir. However, it was only during the last five decades that paneer has spread to other parts of India probably due to wide spread migration of people from one region to another.

Diversification

Due to the ever growing demand of paneer by varied health conscious consumers, researchers were encouraged to develop new types and varieties of paneer. Examples of these include skim milk paneer, low-fat paneer, reduced-fat paneer, fibre enriched low-fat paneer, low-fat paneer enriched with whey protein concentrate/soy protein isolate, soy paneer, filled paneer, protein-enriched filled paneer, microfiltered paneer, ultrafiltered paneer, vegetable impregnated paneer, paneer curry, paneer spreads, paneer pickles, spiced paneer, masala paneer, fruit paneer, processed paneer, long-life paneer, Kradi cheese and the list goes on.

White cheese varieties made without any starter culture using high heat and acid precipitation are popular in South and Central America, Mexico and Caribbean islands. They are quite similar to paneer. Some fresh unripened cheese varieties which are quite similar to paneer are *Kareish* in Egypt, *Armavir* in Western Caucasus, *Zsirpi* in the Himalayas, *Feta* in Balkans and Queso Criollo, Queso Llanero and Queso blanco in Latin America, *Anari* in Cyprus, Farm cheese in western countries, *Beyaz paneer* in Turkey (Torres and Chandan 1981; Wikipedia 2010).

Raw materials for paneer

The main raw material which is used for preparation of paneer is milk. Now-a-days some additives are also used to improve the quality characteristics of paneer.

Type of milk

Various types of milk have been used for the manufacture of paneer. The quality of paneer is determined by the quality of milk from which it is produced (Nayak and Bector 1998).

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 and Kanawjia 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 solvation 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) and 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 and Gupta 1980; Rao et al. 1984; Chawla et al. 1987; Sachdeva and Singh 1988b; Singh and Kanawjia 1990; Kumar et al. 2008a).

Cow milk Good quality paneer can be obtained from cow milk using certain modifications in the manufacturing process or through use of additives (Vishweshwaraiah and Anantakrishnan 1986; Singh and Kanawjia 1988; Sachdeva et al. 1991; Arya and Bhaik 1992; Jadhavar et al. 2009a). Vishweshwaraiah and Anantakrishnan (1986) reported that paneer obtained from cow milk standardized to 4.5% fat conformed to the PFA standards. Pruthi and Koul (1989) also found that paneer made from crossbred cows (HF x Sahiwal) milk having 3.7% fat and 8.25–8.42% SNF conformed to the PFA standards. 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).

Mixed milk Mixed cow and buffalo milk (1: 1) with 5% fat yielded a superior paneer than cow milk alone (Shukla et al. 1984). On the other hand, Sachdeva et al. (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.

Goat milk/sheep milk Use of goat milk resulted in paneer that lacked compactness (Shukla et al. 1988). Prasad et al. (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.

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, 1987' Arya and Bhaik 1992). Sanyal and Yadav (2000a, b) proposed certain modifications like coagulation temperature of only 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) to obtain reduced fat paneer (30% FDM) with acceptable quality. 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 and Anantakrishnan 1986). Aneja (2007) and Chandan (2007a) reported that acceptable quality paneer with 24% FDM is available in western countries.

Dried milk Chawla et al. (1987) used buffalo milk fortified with not fat dry milk (NFDM) for paneer manufacture to increase its yield to 24.4% from 18.3%. Nakazawa et al. (1989) used unfermented reconstituted skim milk and fruit juices for manufacture of 'fruit paneer'. Singh and Kanawjia (1991) standardized the process for production of paneer from recombined milk using cow skim milk powder and butter oil. They recommended addition of 0.15% calcium chloride to recombined milk for paneer manufacture. 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.

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.

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 and Bhaik 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 and Smith 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.

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.

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 and Singh 1999). Kanawjia and Singh (2000) found that paneer obtained from skim milk and vanaspati (HVO) resulted in quite acceptable paneer.

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.

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. 1991b). 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).

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.

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 and Yadav 2000a, b; 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.

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.

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.

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 and Khurana 2006). Kantha and Kanawjia (2007) utilized 0.56% of soya fibre in the manufacture of low-fat paneer.

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

Paneer making employing membrane processes

Membrane technology like reverse osmosis, ultra-filtration and microfiltration has a wide range of applications in food industry. The dairy industry is probably the largest user of membrane separation processes owing to their unique advantages such as high recovery of solids, low energy requirements, reduced bulk and minimal thermal degradation of milk constituents. Membrane processed milk has been applied in paneer manufacture too.

Ultrafiltration Concentration of standardized milk (2% fat, 9.2% SNF) to 27% TS through use of ultrafiltration for the manufacture of paneer resulted in a greater proportion of whey proteins bound to the casein network than the paneer made from unconcentrated milk, giving 95.0% TS recovery on the basis of ultrafiltrate; it led to increase in the yield of paneer by 25%. The paneer also had a superior sensory quality (Rao and Mathur 1990; Kanawjia and Singh 2000). Sivakumar et al. (2005) found that concentration of skim milk up to four times (4X) by ultrafiltration along with the addition of 2.5% starter culture and 0.5% salt can reduce the hardness of paneer made from skim milk.

Microfiltration Microfiltration (MF) technology was employed for selective fractionation and concentration of standardized cow milk. The MF retentate can be utilized for the manufacture of paneer, provided calcium chloride was added to the retentate at a level of 0.15%. Such additive helped in improving the organoleptic and textural properties of resultant paneer (Kanawjia and Rizvi 2000). Kanawjia and Rizvi (2003) used microfiltration to develop paneer from skim milk concentrate utilizing three fat sources viz. butter oil, cooking butter and plastic cream which were incorporated into skim milk retentate using homogenization. Plastic cream performed better than the other two fat sources.

Reverse osmosis/Nanofiltration Gupta and Pal (1995) observed that paneer made from milk concentrated by reverse osmosis to 1.5x (25% TS) and 2x (33% TS) resulted in higher yield by 2–3% on original milk amount basis compared to control without affecting its sensory properties. Pal et al. (2002) conducted a study in which they concentrated cow milk to about 1.5 and 2.0 folds using NF membrane system at 50 °C and found that the NF reduced the salt content of cow milk up to 74% in 1.5 fold concentration without affecting other major constituents. Paneer prepared from normal cow milk had hard, compact and dry characteristics. NF of cow milk though helped overcoming these defects and produced better quality paneer imparted excessive brittleness.

Milk composition and standardization

In order to obtain the product with uniform composition and maximum yield, milk needs to be standardized. Standardization also enables the manufacturer to conform to PFA requirements for paneer. Various researchers suggested use of buffalo milk standardized to 5–6% fat to get product complying with the PFA standards (Bhattacharya et al. 1971; Arora and Gupta 1980; Rao et al. 1984; Singh and Kanawjia 1990). Sachdeva and Singh (1988a) recommended standardizing buffalo milk to 5.8% fat and 9.5% SNF (Fat: SNF; 1: 1.65) for paneer making. Good quality paneer was also made from buffalo milk with lower levels of fat (3.5%); paneer did not comply with the PFA standards (Vishweshwaraiah and Anantakrishnan 1985a; Chawla et al. 1985, 1987).

Cow milk from crossbred (HF x Sahiwal) with lower solid level (3.7% fat, 8.4% SNF) enabled preparing paneer conforming to the PFA standards (Pruthi and Koul 1989). Vishweshwaraiah and Anantakrishnan (1986) advocated standardizing cow milk to 4.5% fat level. Mistry et al. (1992) suggested adjusting both fat and SNF levels in milk for paneer manufacture.

Processing parameters

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 and thus yield of paneer. Heat treatment of milk is essential to destroy the pathogenic as well as spoilage microorganisms. 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 and Tessier 1959; Fox and Morrissey 1977; Brule et al. 1978; Walstra and Jenness 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 1.

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 and Singh 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 2.

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 (Table 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 and Singh 1988b; Chandan 2007b).

A coagulation temperature of 70 °C has been recommended for paneer making from buffalo milk (Bhattacharya et al. 1971; Sachdeva and Singh 1988b). Temperatures higher than this resulted in dry and hard paneer while lower temperature yielded product having very moist surface (Sachdeva and Singh 1988b). Masud (2002) and Bajwa et al. (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 and Anantakrishnan 1985a; Mistry et al. 1992; Arya and Bhaik 1992; Sharma et al. 2002). Coagulation temperature of 90^{o} and 70 °C has been recommended when preparing paneer from ewe's milk and mixed milk (cow: buffalo; 1:1) respectively (Pal et al. 1991, 2008). 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.

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 and Anantakrishnan 1985a). 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 and Singh 1988b). Sachdeva et al. (1991) recommended the pH range of 5.20–5.25 for cow milk paneer.

Table 1 Recommended time-temperature combinations 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 and Anantakrishnan (1985a)
82 °C/5 min.	Good quality paneer from cow's milk	Bhattacharya et al. (1971); Mistry et al. (1992)
85 °C/No hold	Paneer from crossbred cow milk	Arya and Bhaik (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 and Singh (1988b)
Heating momentarily to 90° 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)

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).

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 35x28x10 cm for buffalo milk paneer with moisture around 56%. De et al. (1971) and Vishweshwaraiah (1986) employed a pressure of 2 kg/cm^2 for 25 min on wooden hoop (4x4x4 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.

Preservation

Paneer is a highly perishable product. It was reported that the freshness of paneer remains intact only for 3 days at refrigeration temperature (Bhattacharya et al. 1971). At room temperature paneer does not keep good for more than one day. In order to increase the shelf life of paneer,

Table 2 Strength of coagulants used for paneer making

Strength of coagulant solution	Reference
1% citric acid for buffalo milk cow milk	Bhattacharya et al. (1971); Chawla et al. (1985); Singh and Kanawjia (1988); Sachdeva and Singh (1988b)
0.6% (HCl/phosphoric acid/citric acid in sour whey) for buffalo milk. First two were economical	Sachdeva and Singh (1987)
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 and Singh (1987)
2.0% citric acid for cow milk and low fat milk (2.2% fat)	Vishweshwaraiah and Anantakrishnan (1985a); Arya and Bhaik (1992)
2.0% citric acid for cow and buffalo milk mix (1:1) 3.5% fat	Pal et al. (1991)
2.0% of citric or malic acid for buffalo milk	Pal et al. (1999)
2.5% citric acid solution for cow milk	Sharma et al. (2002)
1% 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% citic acid for ewe's milk	Pal et al. (2008)
1% citric acid for soy and cow milk mix (1:1)	Jadhavar et al. (2009a)

Table 3 Level of addition of acid per 1.0 kg of milk for paneer making

Quantity of coagulant per 1.0 kg milk	Reference
3 g citric acid for buffalo milk	Rao et al. (1984)
2.34 g citric or lactic acid for cow milk	Vishweshwaraiah and Anantakrishnan (1985a)
2.04 g citric acid (homogenized) and 1.90 g citric acid (unhomogenized) cow milks	Vishweshwaraiah and Anantakrishnan (1985a)
1.95 g citric acid for buffalo milk	Chawla et al. (1987)
1.53 g HCl, 1.14 g phosphoric acid and 2.00 g citric acid for buffalo milk	Sachdeva and Singh (1987)
205 ml of sour whey with citric acid (1.79% TA) and 190 ml of acidophilus whey (1.22% TA)	- do -
2.1 g lactic acid	- do -
2.1 g citric acid for buffalo milk	Sachdeva and Singh (1988b)
1.41 g citric acid (buffalo) and 1.52 g citric acid (cow milk)	Pal and Yadav (1991)
2.03 g of citric acid and 2.00 g of malic acid for buffalo milk	Pal et al. (1999)
2.27 g of lactic acid for buffalo milk	Masud (2002)
1.68 g citric acid for buffalo skim milk	Sivakumar et al. (2005)
0.2% citric or lactic acid by weight of buffalo milk	Kumar et al. (2007, 2008b)

additives, modification in paneer manufacturing process, surface treatments and packaging materials have been recommended by various workers. Singh et al. (1988) dipped paneer blocks of 1.5 kg each in 5% brine, chilled water and acidified water (pH 5.0) to enhance their shelf life (up to 12 days at refrigeration temperature). Singh et al. (1989) found that addition of 0.15% sorbic acid to milk for paneer preparation or wrapping the paneer in sorbic acid-coated butter paper (2 g/m^2) extended its shelf life to 30 days at ambient temperature.

Vishweshwaraiah (1986) observed that dehydration of paneer cubes (2 cm^3) to 15% moisture by keeping them in hot air drier at 75 °C for 4 h and deep freezing at −9 and −15 °C led to shelf life of 2 months and 8 days respectively. A low shelf life of only 8 days on deep freezing (at −15 ° C) was probably due to surface drying, which limited its usage, as samples were kept without packaging material. Reduced fat paneer (30–42% FDM) had higher shelf life than full fat (>50% FDM) paneer as paneer with lower fat content underwent less deteriorative changes due to lipolysis (Ghodekar 1989). Sachdeva and Singh (1990) found that dipping of paneer in 5% brine, acidified brine (5% NaCl, pH 5.5) and hydrogen peroxide solution (0.2%, v/v) with or without delvocid (0.5%, w/v) extended the shelf life of paneer cubes of small size (1.0×0.25×0.5 inches) to 22, 20, 32 and 22 days respectively compared to 10 days for control at 8–10 °C; smaller paneer size helped in better diffusion of the solution and thus longer shelf life.

Rao et al. (1992) utilized hurdle technology involving mild heat treatment, minor reduction in water activity and acidification (pH 5.0) to extend their shelf life of paneer to 14 days at 30 °C. Pal et al. (1993) observed that paraffining of low-fat paneer cubes (1 inch cubes) increased the shelf life by over 10 days compared to unparaffined ones. Rao and Patil (1999a) used 1% each of sodium chloride, sucrose and glycerol to decrease the water activity of paneer which led to shelf life extension. Rao and Patil (1999b) developed paneer curry using hurdle technology. The product was so formulated as to have a water activity of 0.95, pH of 5.0, potassium sorbate content of 0.1%. The product kept well for about 1 month and had better quality than the heat-sterilized product stored under similar conditions (30 °C). Singh and Rai (2004) used hot (60 °C for 5 min) and cold (8–10 °C for 6 h) diffusion of paneer cubes with sodium chloride and potassium sorbate and subsequent microwave drying to extend their shelf life. Singh et al. (1991a) found that use of 0.10% sorbic acid in milk coupled with irradiation of the product at 2.5 KGy increased the shelf life of paneer to 30 days at ambient temperature. However, irradiation is not permitted so far by the PFA. In case of paneer, PFA only allows use of sorbic acid and its sodium, potassium or calcium salts at the rate of 2,000 ppm and nisin at the rate of 12.5 ppm for preservation purposes. Punjrath et al. (1997) used blast freezing (−20 °C) to enhance the shelf of paneer blocks (1.5 cm^3) to more than 1 year at a storage temperature of below −19 °C.

Packaging

Use of packaging significantly increased the shelf life of paneer. The type of packaging material also played an important role in enhancement of shelf life. Normally, paneer blocks of required size/weight are packaged in polyethylene pouches, heat sealed and stored under refrigeration conditions. Alternatively, they are vacuum packaged in laminated or co-extruded films. Use of saran-coated packaging films (saran is a polyvinylidene chloride which is a synthetic polymer having low permeability to a wide range of gases and vapors thus making it most valuable for use in food packaging) helped in enhancing the shelf life of paneer to a great extent (Sachdeva and Singh 1990). A paneer-like product was developed by Rao and Mathur (1990) adapting in-package process. The process involved concentration of milk to 27% total solids by UF followed by filling the concentrated milk in retortable pouches and subjecting to texturization process at 118 °C for 5 min. The shelf life of in-packaged paneer was reported to be 3 months at 35 °C. Sachdeva et al. (1991) reported that paneer packaged in laminated pouches had a shelf life of about 30 days at refrigerated storage (6+1 °C). Rao (1996) used moralized polyester pouches (which have barrier layer on exposed surface) for packing of paneer made from UF concentrated milk followed by texturising process at 115 °C, which also led to sterilization of paneer. It resulted in longer shelf life. Paneer packaged in high barrier film (EVA/EVA/PVDC/EVA) under vacuum and heat treated at 90 °C for one min was reported to have a shelf life of 90 days under refrigeration (Punjrath et al. 1997).

Heat sterilization led to considerable extension of shelf life of paneer. Paneer packed in tins along with water/brine and sterilized in autoclave at 1 kg/cm^2 for 15 min could stay well for 4 months at room temperature (Kanawjia and Singh 2000). Use of concentration by thermal evaporation under vacuum or ultrafiltration to a level of total solids desired in the final product. (approx. 50–55%), followed by acidification to desired pH (5.4) and in-package thermal texturization at 115 °C, which also led to sterilization of paneer, resulting in shelf life of about 3 months at ambient temperature (Rao 1996; Kanawjia and Khurana 2006).

Mechanization of paneer making

Batch production at a small scale employing the traditional process often results in an inconsistent product. Use of modern mechanized process offers advantages of uniform quality, improved shelf life, increased yield and a nutritionally better product. The process developed by Sachdeva et al. (1993) involved standardization and heating of milk followed by UF. The concentrated mass, which had about 40 per cent total solids, was cold acidified to get the desired pH. Till this point, the product was flowable and could be easily dispensed into containers with automatic dispensing machines. The filled containers were then subjected to texturisation by microwave heating in a domestic microwave oven. This could also be achieved in a continuous process by using microwave tunnels. Such tunnels comprise of a series of magnetrons under which the product moved continuously on the conveyor belts. The resulting product had typical characteristics of normal paneer. In another approach, an in-package process was developed using UF process for manufacturing long shelf life paneer-like product (Rao 1996). Standardized buffalo milk is concentrated partly by vacuum concentration process and partly by employing UF to a level of total solids desired in the final product. After packing in moralized polyester pouches, product was formed by a texturising process at 115 °C, which also led to sterilization. The process permitted greater product yield due to retention of whey solids, being 35 per cent as compared to 15 per cent obtained by conventional batch process.

A continuous paneer-making system was also developed at National Dairy Research Institute, Karnal by Agrawala et al. (2001). In this system, the unit operations involved in paneer making were mechanized. The continuous paneer making machine was designed to manufacture 80 kg paneer per hour by employing twin-flanged apron conveyor cum filtering system for obtaining the desired moisture content and texture attributes. Das and Das (2009) used an impact type device for manufacture of paneer. For the pressing, curd was kept in cages made from a special type of screen and the cages were subjected to impact forces for preparation of paneer. Rate of change in moisture content, hardness and solid loss was closely related to energy imparted.

Yield of paneer

The yield of paneer is dictated by the composition of milk used (type of milk, standardization for fat or fat and SNF), heat treatment given to milk, type and strength of coagulant, losses incurred after coagulation (based on pH and temperature of coagulation) and moisture content of resultant paneer after pressing (Bhattacharya et al. 1971; Chawla et al. 1985, 1987; Sachdeva and Singh 1987, 1988a, b; Sharma et al. 2002). According to Chandan (2007a), the yield of paneer was dependent on the fat and SNF content of the milk used, fat and protein recovered in paneer and its moisture content. A yield of around 21–23% for paneer containing 51–54% moisture can be obtained from buffalo milk, while yield from cow milk is about 17–18%.

Sharma et al. (2002) reported that the composition of milk, which changes with the seasons of the year, had profound effect on the yield of paneer. Milk obtained during winter season gave highest yield (15.5%) while rainy season led to least yield (14.79%). Muller et al. (1967) recommended that adequate heat treatment to milk so as to have desired protein denaturation was necessary to enhance the yield of paneer. Co-precipitation of casein and whey protein through acidification in presence of calcium chloride (0.15%) led to enhanced yield of paneer (Hill et al. 1982; Singh and Kanawjia 1988; Arora et al. 1996; Makhal and Kanawjia 2005). The yield of paneer from buffalo milk decreased with an increase in coagulation temperature (Sachdeva and Singh 1988b), while for cow milk it increased (Singh and Kanawjia 1988).

Rao et al. (1984) suggested that higher yield of paneer could be obtained by heating milk to 85 °C and coagulating milk using 0.3% citric acid solution at 70 °C. Sachdeva and Singh (1987) found that the yield of paneer was 21.8, 21.7, 22.6, 22.8, 23.4, 23.2 and 22.7% respectively when using 1.0% citric acid, 1.0% tartaric acid, 1.0% lactic acid, 0.6% phosphoric acid, 0.6% HCl and 0.6% citric acid in naturally soured whey and whey cultured with *Lactobaccillus acidophilus*. Higher fat levels in initial milk gave higher yield of paneer (Chawla et al. 1987; Pal and Yadav 1991). Yield of paneer was greater when using 2% malic acid rather than 2% citric acid solution as coagulant (Pal et al. 1999). Jadhavar et al. (2009b) obtained 14.2% yield of paneer from cow milk, standardized to 4% fat. Deshmukh et al. (2009) observed that use of acidified and cultured whey helped in increasing the yield of paneer.

Homogenization increased the yield of paneer significantly (Vishweshwaraiah and Anantakrishnan 1985a). Chawla et al. (1987) observed that the incorporation of sodium chloride (0.5%) and NFDM dramatically improved the yield of paneer. Sanyal and Yadav (2000b) found that addition of 0.25% common salt along with 2.5% cultured skim milk increased the yield of reduced-fat paneer. Sanyal et al. (2004) observed that the addition of common salt at the rate of 0.75% to milk increased the yield of reduced-fat paneer by 19.59% above that of control. Addition of 7.5% of whey solids (obtained by heating cheese whey to 85–87 °C at pH 4.8 followed by filtration) to milk increased yield by about 21.0% (Singh et al. 1991b). Incorporation of hydrocolloids like 0.10% Na-alginate, 0.15% carrageenan or 0.15% pre-gelatinized starch helped in increasing the yield of paneer by retaining more moisture (Sachdeva and Singh 1988a). Gupta and Pal (1995) observed that paneer made from reverse osmosis retentate (25 and 33 TS%) resulted in higher moisture retention, culminating in higher yield by 2–3% on original milk quantity basis compared to control. Kaur and Bajwa (2003) found that reduction of the size of leaves by chopping or grinding and stage of incorporation significantly affected the yield and moisture content of herb impregnated paneer. Kantha and Kanawjia (2007) observed that both fat level in milk and incorporation of soy fibre had a significant effect on the yield of paneer; fat level of 2.5% and soy fibre level of 0.56% was found to be optimal.

Quality characteristics of paneer

Chemical composition of paneer A wide variation in the composition of paneer has been reported by several workers. This is mainly due to differences in the initial composition of milk, methods of manufacture and milk solid losses in whey. The chemical composition of paneer reported by different workers is furnished in Table 4.

Sensory quality of paneer The ultimate aim of any food item is not only to provide nutrients but also to give sense of delight to consumers by virtue of desired color, flavour and texture. The quality of paneer depends upon the quality of milk from which it was made. Milk fat exerts significant effect on the organoleptic quality of paneer. The sensory score increased with increasing fat (4 to 6%) levels (Arora and Gupta 1980). Low fat paneer with acceptable organoleptic quality was made from cow milk with 3.5% fat (Vishweshwaraiah and Anantakrishnan 1986). Chawla et al. (1985) reported that acceptable quality paneer could be obtained from milk possessing 3.5–6.0% fat. Singh and Kanawjia (1988) observed that the sensory score of cow milk paneer improved with increase in coagulation temperatures (i.e. 75–90 °C). Such high temperature of coagulation also held true for paneer obtained from recombined milk added with 0.15% $CaCl_2$ (Singh and Kanawjia 1991). A coagulation temperature of 85 °C has been recommended for paneer making from reconstituted milk (15.0% TS) (Singh and Kanawjia 1992).

Sachdeva et al. (1991) observed that incorporation of 0.08% $CaCl_2$ in manufacture of cow milk paneer helped in improving the sensory score for appearance, flavour, body and texture compared to milk without added calcium salt. They reported maximal sensory score when pH of coagulation was 5.20-5.25. Pal et al. (1991) observed that the sensory score of low-fat paneer was greater when milk was heat treated at 118 °C rather than at 90 °C. Pal and Yadav (1991) observed that paneer made from mixed milk of buffalo and cow in the ratio of 3:1 or 1:1 had superior sensory characteristics than that made using 1:3 ratio or cow milk. Singh et al. (1991b) observed that the overall 9-point hedonic scores of paneer made with 0, 5, 7.5 and 10% whey solids (which were obtained by heating cheese whey to 85–87 °C at pH 4.8 followed by filtration) were 8.4, 8.1, 7.2 and 6.4 for raw paneer, and 8.7, 8.4, 7.7 and 7.6 for fried paneer respectively. Kumar et al. (1998) found that the body and texture and overall acceptability scores of paneer made using calcium lactate coagulant were better than those obtained for the product made using citric acid or sour whey.

Arya and Bhaik (1992), found that paneer made from cow milk (2.2% fat) resulted in a product lacking in softness and typical flavour. Syed et al. (1992) found that the total sensory score of paneer made using different milks tended to decrease in the following order: Paneer from buffalo milk with 6.0% fat (93.33 score)>Paneer from cow milk with 4.5% fat (88.97 score)>Paneer from skim milk

Table 4 Proximate composition of paneer

Milk fat (%)	Constituents in Paneer (%)					References
	Moisture	Fat	Protein	Lactose	Ash	
Buffalo milk						
3.5	56.99	18.10	18.43	–	–	Chawla et al. (1987)
5.0	56.77	22.30	–	–	–	Bhattacharya et al. (1971)1)
5.0	56.43	22.50	–	–	–	Shukla et al. (1984)
5.5	55.19	23.80	17.99	–	–	Chawla et al. (1987)
5.8	50.72	27.13	17.99	2.29	1.87	Rajorhia et al. (1984)
5.8	54.10	23.50	18.20	2.40	1.80	Sachdeva and Singh (1987)
5.9	51.12	26.86	17.38	–	2.00	Pal and Garg (1989)
5.9	55.10	23.47	19.92	3.09	2.43	Pal et al. (1999)
6.0	54.76	25.98	–	–	–	Bhattacharya et al. (1971)
6.0	53.51	24.12	16.44	2.60	1.88	Pal and Kapoor (2000)
6.0	47.05	23.00	19.77	–	2.75	Masud et al. (2007)
7.57	51.93	26.17	15.74	2.71	1.80	Pal and Yadav (1991)
Cow milk						
3.5	55.97	18.98	20.93	2.01	1.45	Mistry et al. (1992)
4.4	56.0	22.0	18.5	2.1	1.4	Sachdeva et al. (1991)
4.5	55.26	24.15	18.43	–	–	Syed et al. (1992)
4.57	59.31	17.9	17.34	2.43	1.38	Pal and Yadav (1991)
5.0	53.90	24.80	17.60	–	–	Sachdeva and Singh (1988b)
Mixed cow and buffalo						
3.5	55.06	18.40	20.75	2.43	1.90	Pal et al. (1991)
5.0	57.14	22.32	–	–	–	Shukla et al. (1984)
Skim milk						
0.1	62.14	4.0	27.48	–	–	Syed et al. (1992)
–	62.47	1.96	28.64	–	2.55	Sivakumar et al. (2005)
Goat/Ewe's milk						
Goat milk (4.86% fat)	46.94	26.95	19.99	–	1.93	Agnihotri and Pal (1996)
Ewe milk						
(6.94%)	55.08	23.50	15.75	2.73	2.93	Pal et al. (2008)
Reconstituted/Recombined milk						
Reconstituted WMP (15%TS)	57.30	17.40	22.80	–	–	Singh and Kanawjia (1992)
Recombined cow milk	57.40	22.92	16.16	–	–	Singh and Kanawjia (1991)

with 0.1% fat (84.87). Arora et al. (1996) observed that use of 0.05% $CaCl_2$ in milk diluted with water to 4.6% fat and 8.0% SNF resulted in paneer comparable to that made from normal milk (5.5% fat and 9.0% SNF).

Citric acid yielded sensorily superior paneer compared to malic acid; the body and texture of paneer obtained using malic acid was quite poor (Pal et al. 1999). The sensory attributes of paneer made by coagulating milk at 80 °C using either cultured whey of *Lactobacillus acidophilus* and *Streptococcus lacti*s or acidified whey at 1.0% did not differ from one another; however, use of cultured whey with *Streptococcus lacti*s resulted in paneer with lower scores for body and texture. The use of whey cultured with *Streptococcus lactis* resulted in paneer with a soft and loose body and open texture, which was unsuitable for sale (Deshmukh et al. 2009).

Kaur et al. (2003) found that paneer dipped in 3% brine had a good sensory score. They also reported that the use of mint (*Mentha spicata*) and coriander (*Coriandrum sativum*) improved the flavour of paneer. Sanyal et al. (2004) observed that desired sensory quality of reduced fat paneer could be obtained through use of 0.25% sodium chloride in milk for paneer making. Bajwa et al. (2005) advised heating temperature of 85 °C, coagulation temperature of 72 °C and immediate straining to yield highly acceptable paneer at all the levels of herb impregnation. The overall acceptability score was the highest at 10.0% incorporation of coriander and mint leaves. Paneer made from buffalo milk heated at 85 °C yielded sensorily superior product then when heated at 80 or 90 °C (Masud et al. 2007). Kantha and Kanawjia (2007) reported that acceptable paneer could be obtained from milk having 3.0% fat and 0.25% soy fibre. Chavan et al. (2007) found that paneer made from blend of buffalo skim milk and cow milk (20:80) was comparable to that of standard buffalo milk containing 5.5% fat. Kumar et al. (2007, 2008b) found that the sensory score of paneer decreased with an increase in the level of incorporation of the coagulant i.e. from 0.2 to 0.6%. Pal et al. (2008) found that acceptable paneer could be obtained from ewes' milk by coagulating the milk at 90 °C using 2.0% strength of citric acid solution.

Microbiological quality of paneer The microbiological quality of paneer depends on the microbiological quality of milk, and the hygiene exercised during manufacture of paneer and its subsequent handling, packaging and storage. Microorganisms such as coliforms, yeasts and moulds that might be present in raw milk get destroyed completely, when milk is heated at 82 °C for 5 min. But these microbes may contaminate the product through a number of sources like air, water, equipment, knife, muslin cloth and persons handling the products (Aggarwal and Srinivasan 1980). These microbes can cause proteolytic and lipolytic changes, discolouration and other defects in the product (Thakral et al. 1986). Vishweshwaraiah and Anantakrishnan (1985b) suggested that SPC lower than 5,000/g and greater than 2 lakhs/g could be rated as 'Excellent' and 'Poor' respectively.

Bureau of Indian Standards (BIS 1983) set limits for microbial count viz., total plate count $<5\times10^5$/g, yeast and mould count <250/g, and coliform count of <90/g. Rajorhia et al. (1984) observed that paneer made at pilot scale level at National Dairy Research Institute, Karnal had lower yeast and mould, and coliform count than paneer obtained from market (Delhi, Karnal). Such a finding for laboratory and market paneer was also observed by several workers (Vishweshwaraiah and Anantakrishnan 1985b; Das and Ghatak 1999; Goyal et al. 2007; Singh and Singh 2000). Such a difference in SPC was also noted in products sold by local and standard shops in India (Kumari and Kalimuddin 2002). Higher counts in the market samples points at lack of adequate sanitary practices during manufacture and storage. Kalhan and Grover (1984) observed that fresh paneer prepared under hygienic conditions did not show any pathogenic microorganisms. Singh et al. (1989) reported microbial profile of fresh paneer as SPC—2.3×10^3, proteolytic bacteria—7.4×10^2, lipolytic bacteria—4.9×10^2 and fungi—10/g. Pal et al. (1993) found that the SPC, yeast and mould and coliform count of paneer were 3.03, 1.90 and 0.86 log cfu/g, respectively. Nath et al. (2007) observed SPC of 5.4×10^3 and yeast and mould count of 260/g in freshly prepared paneer. Ghodekar (1989) observed that the market paneer was contaminated with yeast and mould which led to deterioration in sensory quality of paneer during storage due to proteolytic and lipolytic changes. Such products become unacceptable and potentially injurious to the health of consumers. Kumar and Sinha (1989) observed that more than 60.0% of paneer samples from organized dairies and markets in India were contaminated with coliforms.

Vaishnavi et al. (2001) obtained SPC in the range of 3×10^2 to 9.7×10^{10} cfu/g in paneer samples sold in Chandigarh. A few workers reported that majority of market paneer (Ranchi, Gwalior) samples were contaminated with *Bacillus cereus* and *Pseudomonas aeruginosa* respectively (Kumari and Kalimuddin 2003; Bharadwaj et al. 2007); aflatoxin contamination in market panner was also observed (Choudhary et al. 2007). Chhabra (2008) observed yeast count in the range of 24–180 cfu/g in paneer.

Textural properties Desai et al. (1991) studied the textural properties of paneer procured from six different sources in Karnal. Instron Universal testing machine fitted with a 100 N load cell was used for the study. They observed that the hardness, gumminess and chewiness of raw paneer varied significantly, whereas cohesiveness and springiness did not differ among the market paneer samples. They concluded that the hardness was inversely related to the moisture content and directly related to the calcium content of paneer.

Syed et al. (1992) observed that the hardness of paneer was highest for skim milk paneer when compared to cow and buffalo milk paneer. Kumari and Singh (1992) found that cow milk paneer had higher values for cohesiveness, gumminess and chewiness than buffalo milk paneer, whereas the hardness and springiness were greater in buffalo milk paneer. However, the paneer or channa from buffalo milk have been found to produce harder and chewy texture due to higher concentration of casein in the micelle state with bigger size, harder milk fat due to larger proportion of high melting triglycerides in it and higher content of total and colloidal calcium (Sindhu 1996). Kanawjia and Singh (1996) observed values of 13.2 N, 0.68, 7.8 mm, 9.8 N and 71 N-mm respectively for hardness, cohesiveness, springiness, gumminess and chewiness when measured using Instron Texture machine using 1000 N load cell.

Commercial production of paneer by popular dairy brands

Many of India's top dairy brands launched paneer on commercial scale. The paneer is currently marketed by many brands such as Amul, Britannia, Mother Dairy etc. Amul is the top brand for the production of paneer in India. Paneer is available in three pack sizes viz. 100 g, 200 g and 1 kg in tamperproof heat sealed poly-pouches to ensure the quality as claimed by manufacturer. Amul fresh paneer can be stored in the refrigerator for 15 days. It can remain good in the deep freeze for 6 months. Recently they have launched block paneer in 100 g, 200 g, 500 g and 1 kg packs in Aluminum foil and paper carton over it. Amul *malai* paneer consists of 55.0% moisture (max) and 50.0% fat (min) on dry matter basis. Paneer from Mother Dairy, packed in vacuum packing, is available in 100 g, 250 g and 1 kg pack sizes. It is available in vacuum package. It has 25, 25 and 50% respectively fat, protein and moisture. Britannia also produces paneer under the brand name "Britannia Milkman". It is available in 200 g packs. It is claimed to be hygienically vacuum-packed in an attractive pouch, giving it a shelf life of five days at refrigerated temperature.

The label of branded paneer should mention the information like price, calorie contribution per 100 g, best before date or date of expiry, ingredients used, preservatives, composition (fat, protein and carbohydrates) and the presence of any special health promoting ingredients like probiotics, vitamins etc.

Conclusion

Paneer is analogous to fresh, unripe soft cheese made by heat and acid coagulation of milk. It is very popular in South Asia and is used for preparation of various culinary dishes and acts as an ingredient for vegetable dishes and snacks. There is a wide variation in the chemical composition and yield of paneer due to the use of varied techniques by paneer manufacturers. Hence there is a need to adopt standard procedure for paneer manufacture. Irrespective of the type, milk should be standardized to a fat and SNF ratio of 1:1.65 so that the final product conforms to PFA requirements. Good quality paneer is obtained by heating milk to about 90 °C, acidifying the hot milk by adding citric acid solution (1–2% strength) followed by removal of whey and pressing of the curd in chilled water in order to enhance the yield of paneer. The use of mechanized and semi-mechanized systems which involves membrane processes and in-package texturization etc. needs to be undertaken at larger scale as the products from these systems have uniform quality, better yield and longer shelf life. Incorporation of functional ingredients like fibers (soy fiber, inulin etc.), proteins (groundnut protein isolate etc.), hydrocolloids, herbs, vegetable oils and other such ingredients will help to increase yield and decrease carorific value of paneer thus making it attractive to health conscious people. It also results in formation of new varieties which further will increase its marketability. A need for change in PFA definition seems inevitable. Channa usually has more moisture than paneer as it is not pressed, but still PFA has given same standard for moisture levels (not more than 70%) for both paneer and channa. It seems to be too high for paneer which hardly crosses 60% moisture. In light of these observations PFA standards for moisture level needs to be revised and separated from channa. In India, stringent measures should be enforced to ensure strict adherence of hygienic practices during paneer manufacture at small scale, unorganised sector to ensure public health safety and adequate shelf life of product.

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