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Extension of Shelf Life of Paneer-An Indian Variety of Soft Cheese: A Review

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ABSTRACT

Conventional dairy products constitute a vital role in the human diet in India. Paneer, an indigenous soft cheese, is a versatile nutrient-dense food used as a pedestal substance in various culinary preparations. It contains a good amount of high-quality animal protein, fat and minerals. However, relatively short shelf life of paneer, up to 5-6 days, creates a significant obstacle for commercial manufacturers. Conventional techniques like drying, freezing or chilling are not considered proficient in extending paneer's keeping quality. This review summarizes different techniques used for the shelf life extension of paneer. The main focus was apprehended on research that contributes to increasing nutritional content and keeping the quality of paneer. Based on the perceptions of various researchers available in the shape of literature, it was concluded that edible coating incorporated with active compounds could be a pioneer preservation technique for Paneer. Moreover, some novel food techniques (Non-thermal techniques, hurdle technology, smart packaging) have also shown considerable potential to enhance keeping quality of paneer without jeopardizing flavour and texture. However, these technologies are at their nascent stage and require extensive research.

Key words: Casein, Edible film, Packaging, Paneer (Indian cottage cheese).

The "Operation Flood program" triumph in the 1970s was one of the most extensive collective dairy programs, making India the leading milk producer in the world (Khan and Pal 2011). Besides, the continuous increase in the number of cattle and improved quality of feed and fodder are significant factors responsible for the astronomical milk production of the country (Dairy and dairy products-OECD-FAO agricultural outlook 2019-2028). An estimated 55% of the milk produced in India is used for product manufacturing and residuum is used as liquid milk (Rao, 2020).

Paneer is an indigenous dairy product produced by coagulating milk at elevated temperature using organic acids (citric acid, lactic acid and tartaric acid) (Khan and Pal 2011; Raveendran *et al.* 2018). It is used as a pedestal substance in various culinary dishes, especially (Matar paneer, palak paneer, kadhai paneer) and other food products (pakoras). Food Safety and Standard Authority of India (FSSAI) defines "Paneer as the food product obtained from any variant of milk, with or without added milk solids, by precipitation with permitted acidulants and heating" having not more than 60% moisture and not less than 50 % fat. Fresh and good quality Paneer has a pleasant, sweetish, nutty flavour, has a compact, smooth, closely knitted texture and must be tender enough to maintain its shape at the time of cutting and is easily chewable. In addition, the type of milk also affects the organoleptic characteristics of paneer, ranging from greenish to yellow ting in paneer prepared using buffalo and cow milk, respectively (Khan and Pal 2011; Kumar *et al*. 2014).

Paneer belongs to the soft cheese category and is believed to have been developed by the South Asia region nomads (Raveendran *et al*. 2018; Kumar *et al*. 2014). Several different types of fresh cheese (Wara, Anari, Feta, Queso Fresco *etc*.) are manufactured worldwide with similar characteristics as Paneer. These cheeses are either rennet set or acid set and have a short shelf life of up to two weeks (Khan and Pal 2011; Aspri *et al*. 2017; Lourenço *et al*. 2017; Hamdy *et al*. 2021).

The relatively short shelf stability of paneer limits the industrialist from adopting a commercial manufacturing process. This review aims to examine existing studies that may help in extending the shelf life of Paneer without much jeopardizing its flavor and texture. Moreover, this study also focuses on enhancing the nutritive value of paneer by incorporating various bio-active compounds in the form of edible coating.

Structure of paneer

Paneer is a network of casein micelles entangling the other milk components like whey protein, fat globules, lactose and minerals), which are also responsible for its flavor and texture. The type of milk and its constituents, mainly (water

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and fat content), will affect the structural properties of the Paneer. The presence of high moisture content will form a loose and soft body texture (Ahmed and Bajwa 2019).

The microstructure of paneer observed under scanning electron microscope (SEM) showed that fat globules are coated with the membrane and casein micelles are fused to the fat globule membrane. The protein network comprises the varying size of aggregated protein particles and fat globules are uniformly entangled within the network. The microstructure of paneer made from cow milk has smaller and uniformly distributed protein molecules, whereas Paneer produced from buffalo milk contains densely packed fused protein particles. The fat globules and protein network defines Paneer's microstructure and consequently affect tactile properties like mouthfeel, firmness and elasticity (Hui, 2007).

The formation of the paneer structure starts with the acidification process of milk when there is a dynamic change observed in the physicochemical properties of milk, as illustrated in (Fig 1). The casein micelles present in milk dissociate from the Colloidal Calcium Phosphate (CCP) complex and release into the serum phase. This phenomenon occurs due to the decrease in net charge on casein micelles. When the pH of milk falls from 6.6 to 5.5, the collective charge on casein micelles is lost continuously, resulting in the collapse of the micelle's surface's hairy structure onto the surface. The stabilizing membrane of casein micelles collapse below pH 5.5. The collapse causes the electrostatic forces between the casein micelles to become weaker and bring them close to form the cluster. At pH-4.6, the cluster of casein micelles becomes denser and more compact and eventually forms into a gel (Jacob *et al.* 2011; Sinaga *et al.* 2017; Li and Zhao 2019). The other milk constituent separates in whey from the curd (Cottage) or gel structure of paneer (Lucey, 2011).

Value-added paneer

Growing consumer awareness about the functional foods incorporated with antioxidants, dietary fibre, phytosterols, phenolics, *etc.*, forced the food scientist to transform traditional foods into value-added food products. Paneer is seemed to be a promising matrix to incorporate bioactive compounds as it is appreciated by the consumer for its suitable organoleptic property and high nutritive value. It is devoid of iron, dietary fibre and (Vitamin-C) thus, most studies focus (Table 1) on incorporating these nutrients in the Paneer to make it a complete food (Díaz-Castro *et al.* 2012; Caleja *et al.* 2015). In addition to nutrients, adding bioactive compounds like (phenols, antioxidants and natural color pigments) helps increase its shelf life and enhance the organoleptic and textural properties of paneer.

Methods to extend the shelf of paneer

Paneer has a minimal shelf life of a day at ambient temperature and about 5-6 days at refrigeration temperature. Although the heat treatment given to milk destroys all the pathogenic and spoilage micro-organisms, washing and handling the curd can reintroduce spoilage organisms like *Psychrotrophs*, *Coliforms*, yeasts and molds (Raju and Sasikala 2016). The quality of Paneer deteriorates due to the growth of this spoilage micro-organism on the surface during storage.

Nevertheless, low-temperature storage is an effective and economical method to control pathogenic decay. It has been reported that microbial load on paneer is significantly increased during storage, even under refrigerated conditions (Lamdande *et al.* 2012). Although the refrigerated storage of Paneer maintains its keeping quality for up to 6 days, colour and appearance are affected after three days. Thus, chilling also limits the storage period (Rani *et al.* 2014). Several attempts, as mentioned in (Table 2), have been made to enhance the shelf life of Paneer, which include the addition of preservatives, packaging in modified conditions (vacuum packaging, modified atmosphere packaging, dehydration and heat sterilization) (Goyal and Goyal 2016). However, these methods were not fully effective in extending the keeping quality and also rendered alteration in texture and flavour of the product. In recent years, the focus has

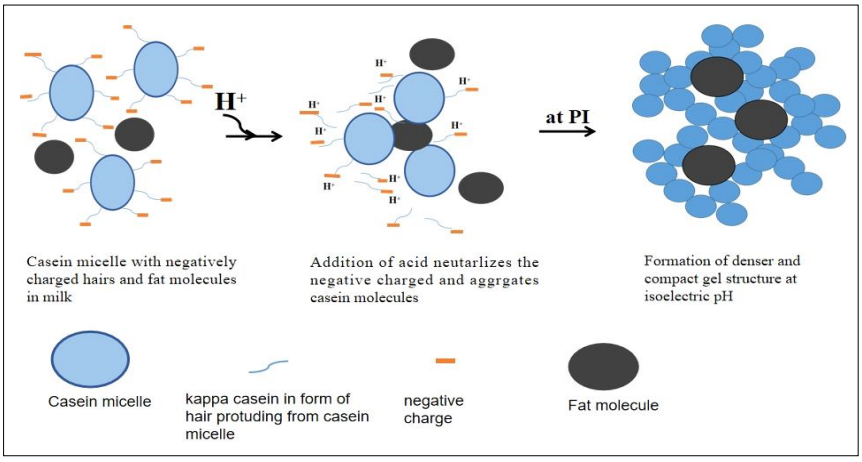

Fig1: Gel structure formation of paneer.

Table 1: Different types of value-added Paneer/Cottage cheese.

Type of milk	Active substance incorporated in paneer	Level	Remarks	Reference
Buffalo milk	Carrot juice	20%	Paneer containing carrot juice shows superior organoleptic and nutritional properties. In addition, carrot juice containing paneer has high protein content as compared to control.	Raveendran *et al.* 2018
Buffalo milk	Cardamom, Black pepper	0.50%, 0.25%	Paneer prepared by using herbs shows better organoleptic properties with slightly elevated antioxidant properties as compared to control. However, herbs have no or least effect on the proximate and physiochemical properties of paneer.	Badola *et al.* 2018
Cow milk	Carrot extract	20%	Sensory analysis suggests that paneer prepared by using carrot juice had high acceptability. Carrot juice also increased phosphorus, calcium, lipid, protein and ? carotene content in paneer.	Nivedha *et al.* 2017
Buffalo milk	Lemon grass leaves	2, 4, 6, w/v	Adding lemongrass into milk, which is further used to form paneer, shows slightly altered textural and physiochemical properties.	Joseph and Rao 2019
Cow milk, Buffalo milk	De-bittered lemon rind	8 g/kg of milk	The addition of lemon rind is observed to have increase nutritional value of Paneer.	Yashvantha *et al.* 2020
Milk	Pomegranate peel extract, lemon peel extract, Orange peel extract	2%	Paneer prepared by pomegranate peel extract shows the highest antioxidant activity to prevent peroxide generation.	Singh and Immanuel 2014
Buffalo milk	Garlic paste	4%	The incorporation of 4% garlic paste in Paneer shows maximum acceptability in terms of taste, flavor and texture.	Singh *et al.* 2018
Standard milk	Coconut powder	1.5%, 2%	Fibre enriched paneer was prepared using coconut powder. Fiber enriched paneer was found to have increased protein, ash and fiber content compared to standard milk Paneer.	Chauhan and Chandra 2016
Buffalo Milk	Curry leaves, cumin powder	Both 0.2%	Curry leaves and cumin powder were incorporated in milk to produce spicy paneer. This value-added product has medicinal and nutritional properties with better taste as compared to control	Kale *et al.* 2020
Cow Milk	Coconut milk, soy milk coconut milk,	1:2 of cow's milk, coconut milk, soy milk and millet	Cottage cheese prepared using this innovative blend of milk has shown good acceptability in all the dishes	Banu and Aswini 2016
Buffalo milk	Raw turmeric extract	10%	The raw turmeric extract was found to be enhancing the nutritional, organoleptic and physicochemical properties of paneer.	Khobragade *et al.* 2020
Sheep milk	Fennel powder and fennel decoction	0.5% of fennel decoction and 2.1% of fennel powder	Cottage cheese containing fennel decoction shows better antioxidant activity after 14 days of storage and no signs of deterioration as compared to the control sample	Caleja *et al.* 2015
Ewe (Sheep) milk	Microencapsulated rosemary extract	0.9 g of microspheres of cheese	Microencapsulation of rosemary extract increase the antioxidant potential of cottage cheese during storage without affecting its nutritional composition.	Ribeiro *et al.* 2016
Buffalo milk	Water soluble date extract	20%	Incorporation of water-soluble date extract into Paneer was observed to have better sensory qualities and antioxidant activity than the control sample of paneer.	Qureshi *et al.* 2019

been shifting to new technologies as elicited in (Fig 2) which perverse the quality of paneer and parallelly promote environmental sustainability.

Hurdle technology

Hurdle technology (HT) is an innovative concept that utilizes different hurdles like water activity (aw), redox potential (Eh) and pH to work synergistically by either killing the microorganism or preventing their multiplication without affecting the product quality. Keeping quality of paneer could be increased up to 12 days at 30±1°C and 20 days at 7± 1°C by adopting the hurdle concept, which comprises reducing aw and pH of paneer. Further effect in preventing spoilage of paneer was imparted by packaging under modified conditions (Carbon dioxide: Nitrogen gas = 50:50) (Thippeswamy *et al.* 2011). Similarly incorporating antioxidants (Eugenol, gallic acid, quercetin, piperine and methanol) and subsequent storage at low-temperature storage has been proven effective in extending Paneer's shelf life (Sharma *et al.* 2019). Applying heat treatment to

Table 2: Preservation methods of paneer.

Method of preservation of Paneer	Remarks	References
Pickling	Paneer stored in 20% brine solution and 14% spice vinegar solution shows shelf stability up to 2 months.	Rani *et al.* 2014
Incorporation of Nisin and potassium sorbate	Keeping quality of Paneer has been enhanced by adding 0.1% Potassium Sorbate and nisin acts synergistically to inhibit the growth of micro-organisms.	Thakral *et al.* 1990
Bacteriocins	Bacteriocin isolated from *Enterococcus faecium* BS 13 successfully increased the storage time of paneer at refrigeration conditions.	Bali *et al.* 2013
	Lactobacillus paracasei ND11 bacteriocin was observed to reduce total plate counts, yeast and mold count significantly at 25°C when incorporated with paneer.	Solanki *et al.* 2016
Antibacterial peptide	The partially purified antibacterial peptide obtained from *Bacillus licheniformis* Me1 shows an antilisteral effect in paneer.	Nithya *et al.* 2018
Lactobacillus plantarum	Incorporating *Lactobacillus plantarum* into paneer inhibits spoilage and pathogen bacteria (*Bacillus cereus* and *Eschericia coli*) until 7 days at room temperature and 9 days at cold storage.	
Hydrogen peroxide and delvocid	Dipping of paneer cubes in the solution of H_2O_2 and delvocid had extended the keeping quality paneer for 35 days at 8°C	Singh and Kanawajia 1990
Tertiary Butyl hydroxy Qunione and butyrate hydroxy toluene	Both the artificial antioxidant alone or individually were able to extend storage time of the paneer by 20 days at 5°C as compare to the control sample.	Kumar and Bector 1991
Lysozyme and Lactoperoxidase System (LP)	Lysozyme and lactoperoxidase treated paneer shows a life expectancy of about 28 days.	Agrawal 2001

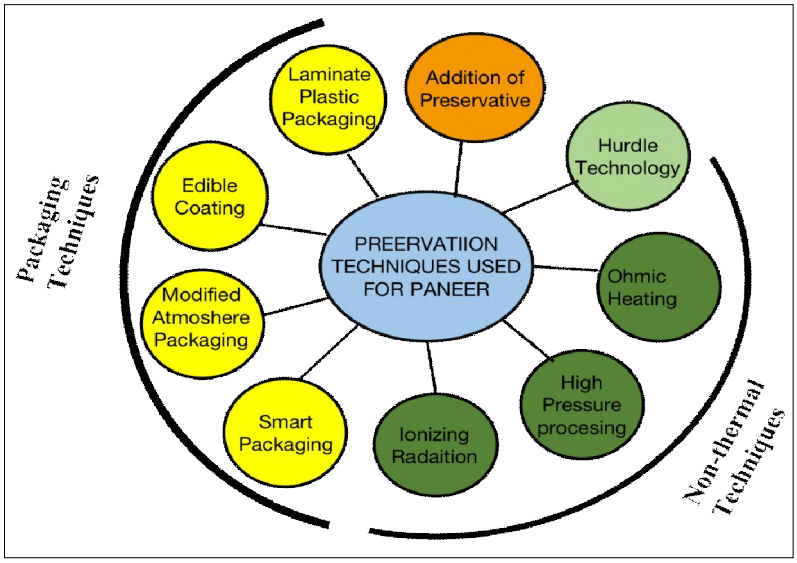

Fig 2: Preservation techniques for Paneer.

pickled paneer works synergistically, thus helping in increasing shelf life for 30 days under refrigerated conditions (Narayanan *et al.* 2016). The hurdle concept also successfully preserves Paneer products like canned paneer and ready-to-eat canned Paneer curry (Rao and Patil, 2009).

Non-thermal technologies

Non-conventional Technology has the potential to provide a better substitute over thermal treatment to maintain sensory and nutritional characteristics as they employ low temperature and short processing time. Dairy products such as Paneer are rich in many essential nutrients and provide suitable conditions for the growth of food pathogens, especially *Listeria monocytogenes*. Non thermal techniques impaired the cellular or genetic material of pathogenic strains and inhibit the growth of pathogenic microorganisms (Pereira *et al.* 2020; Nuñez *et al.* 2020).

Ionizing radiation, ohmic heating, high-pressure processing (HPP) and supercritical carbon dioxide application are some non-thermal techniques to preserve paneer (Lacivita *et al.* 2019; Kapoor *et al.* 2021, Kapoor *et al.* 2021). These techniques improve the shelf life by reducing microbial load without much affecting the textural properties of the paneer. Irradiation and Supercritical Carbon dioxide techniques were reported to increase the shelf life of paneer up to 30 days (Singh *et al.* 1991; Kapoor *et al.* 2021). Paneer manufacture by milk undergoing ohmic heat treatment showed a significant reduction in microbial load and a less brittle texture as compared to conventional processes (Kumar and Hausain, 2014). High-pressure processing of cheese reduces the moisture content of cheese and may produce a new texture, lose more whey with high nitrogen content compared to untreated cheese, inactivates pathogenic microorganisms (*Listeria monocytogene*) and accelerates cheese ripening in ripened cheese (Capellas *et al.* 2001; Tomasula *et al. 2014*). Application of the high-pressure processing technique shows a positive effect on the shelf life and texture profile of paneer (Kapoor *et al.* 2021).

Packaging of paneer

Continuously occurring dynamic microbiological and chemical changes makes the paneer a perishable commodity. Its high moisture content makes it susceptible to microbial attack and thus limits its storage period to 5-6 days under refrigerated conditions. The formation of whitish or yellowish, thick, gelatinous, slimy film around the surface of the Paneer is the primary defect occurring during low-temperature storage. This is followed by discoloration of Paneer and occurrence of off-flavor (fruity, rancid, or bitter) (Ho *et al.* 2016). The growth of gram-negative psychotropic bacteria (*Aeromonas, Alcaligenes, Pseudomonas, Proteus*) is believed to be responsible for the degradation of Paneer (Chen and Hotchkiss 1993). To limit microorganisms from proliferation and thereby extend the shelf life of Paneer, packaging could be considered one of the excellent preservation methods.

Packaging requirement of paneer:

1. Packaging of paneer must extend its shelf life and protect it from physical and chemical microbiological damage.
2. It must ensure the conservation of flavor, texture and taste of paneer during storage and transportation.
3. Only food-grade packet/ wrapper should be used for the packaging of paneer.
4. The packaging material used for the packaging of paneer must be structurally strong to withstand harsh conditions and should be aesthetically appealing to the consumer (Spreafico and Russo 2021).

According to the survey conducted by FSSAI in India, most commercial brands' paneer is wrapped in printed polyvinyl chloride (PVC) material (poly pack) and blister transparent packet. On the other hand, the loose Paneer sold in the local market was found to be packaged in recyclable paper covered with biodegradable PVC film. Commonly used plastic materials for packaging Paneer are coextruded plastic laminates and sachets made up of Polyethylene, shrink films, parchment paper coated with edible wax and polypropylene (PP) films. On the other hand, polyethylene bags, ethylene vinyl acetate (EVA) / Poly Vinyl di-Chloride (PVdC)/EVA, or cryovac laminates are preferred for vacuum packaging (Paneer: Eat It with Caution, FSSAI).

Modified atmosphere packaging of paneer

Modified atmosphere packaging (MAP) is a new area in food packaging that maintains the product's initial fresh-like characteristics for a much more extended time (Maniar *et al.* 1994). The atmospheric conditions around the food product inside the food package are altered to minimize food deterioration. Rai *et al.* (2008) observed that modifying the gaseous atmosphere surrounding the paneer can effectively increase its shelf life and minimize the chemical changes that affect its quality. Paneer packed under a modified atmosphere containing 100% CO_2 shows satisfactory sensory characteristics up to 28 days of storage. CO_2 dissolves within the Paneer and provides additional protection besides inhibiting spoilage microflora without altering the sensory characteristic (Maniar *et al.* 1994).

Smart packaging

The smart packaging industry has the potential to outpace other traditional packaging systems in the coming years. In that field, the evolution of novel packaging techniques (active, intelligent packaging and bioactive packaging) requires protecting the food component and giving real-time information about food conditions. Thus it reduces the risk of foodborne illness and early food recalls as consumer/ retailer is aware of the food condition inside the food package (Biji *et al.* 2015).

Paneer wrapped in LDPE film immobilized with Betanin (antimicrobial compound), a type of active packaging system, showed a three times reduction in the growth of *Staphylococcus aureus* (Manohar *et al.* 2017). Studies are also centered on developing intelligent systems for

Table 3: Different edible coatings applied on Paneer.

Composition of edible film for paneer	Remarks	References
Sodium Alginate calcium complex + 2.5% cinnamon essential oil	The keeping quality of paneer is increased up to 13 days from 4-5 days at refrigerated temperature	Raju and Sasikala 2016
Whey protein + ferrous sulfate heptahydrate salt	The iron content of the coated film is increased about 3 times as compared to control samples. As a result, a maximum of 93.5 ppm of iron concentration can be achieved in paneer coated with iron salt and whey protein edible coating.	Jotarkar *et al.* 2018
Carboxy methyl cellulose + 0.5% Oregano/Clove essential oil.	Keeping quality of paneer is extended up to 12 days. Paneer wrapped in oregano essential oil film has better sensory, physicochemical and microbiological properties than paneer enwrapped in clove essential oil edible film.	Karunamay *et al.* 2020
Sodium caseinate + 0.25% Oregano/ Clove bud/ Parsely essential oil.	Paneer sample coated with 0.25% clove bud oil did not show many differences in sensory characteristics compared to the control sample.	Archana *et al.* 2020
Whey protein concentrate	Paneer coated with edible film and packed in LDPE laminate was observed to have a low total viable count (1.6×10^3) on the 40^{th} day of storage compared to the control sample.	Lamdande *et al.* 2012
VitC (125 mM concentration)	Vitamin C coating on paneer cubes helps to regulate the growth of biofilm-forming multidrug resistance (MDR) *E.coli*	Shivaprasad *et al.* 2021
Partially purified antibacterial peptide (ppAP)	Cellulose film incorporated with ppAP produced by *Bacillus licheniformis* Me1 was successful in limiting the growth of pathogenic micro-organisms in Paneer	Nithya *et al.* 2013

packaging paneer, which carry out advanced functions like tracking, sensing, detecting and recording the food product throughout the supply chain Kant and his colleagues develop an radio frequency identification device (RFID) tag to provide real-time information about the quality of paneer during its storage period. They observed that spoiled and fresh paneer behave differently when the frequency is applied (Kant *et al.* 2018).

Edible coating

Edible coating focuses on regulating the moisture loss transfer of gases and flavours and provides a suitable matrix for incorporating additives and bioactive compounds. An edible coating is a thin layer of structural substance (protein, carbohydrate, lipid, or multi-component mixture) formed as a coating on the food product. Immersion in structural matrix or spaying of matrix onto the food is the standard method of applying an edible coating onto the food product (Falguera *et al.* 2011; Quirós-Sauceda *et al.* 2014).

Application of the edible coating helps in the amplification of safety and quality characteristics of Paneer (Table 3). Edible coated paneer sample has a shelf life of up to 40 days with 1.6×10^3 colony-forming unit/gram of total viable count (Lamdande *et al.* 2012). Furthermore, the environment-friendly nature of edible coatings helps reduce packaging waste, thus being an excellent alternative to traditional packaging systems.

CONCLUSION

Paneer is a highly nutritious, soft unripened cheese prone to microbiological and chemical deterioration during storage. Commercially, the extension of shelf life of paneer is mainly attributed to packaging in laminates under modified conditions and further stored at refrigerated temperature. However, an edible coating is a promising investment as an alternative to plastic packaging due to its role in controlling respiratory loss and inhibiting pathogenic bacteria. It thus can be an important and sustainable alternative for paneer preservation. Other innovative techniques (Ionizing radiation, hurdle technology, Intelligent packaging system) used for the preservation of Paneer are at their nascent stage of research which requires more optimization before being applied at the commercial level.

Conflict of interest: None.

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