EFFECT OF FAT CONTENT AND HEATING TEMPERATURE OF MILK IN THE SENSORY QUALITY AND YIELD OF PANEER

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A dissertation submitted to the Department of Food Technology, Central Campus of Technology, Tribhuvan University, in partial fulfillment of the requirements for the degree of B. Tech. in Food Technology

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Approval Letter

This *dissertation* entitled *Effect of Fat Content and Heating Temperature of Milk in the Sensory Quality and Yield of Paneer* presented by Chandra Kanta Dhamala has been accepted as the partial fulfillment of the requirements for the B.Tech. degree in Food Technology.

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Abstract

The study is focused to prepare the product (paneer) using buffalo milk, taking fat (%) and heating temperature (ºC) as variable parameters. A Central Composite Rotatable Design (CCRD) for two variables at three levels was designed for experimental combinations. Fat percentage was varied in the range of 3-5% and pasteurization temperature in the range of 80-90ºC according to the sample formulation prepared using Response Surface Methodology (RSM). Five different formulations were prepared.

The maximum yield of product was found to be 14.15%. The composition of the product were determined where the moisture content, protein content, fat content, lactose content and ash content were 54.6%, 18.8%, 22.5%, 2.0% and 2.1% respectively. The best result according to the findings of GenStat and considering the yield (%) came out to be sample-E i.e. formulation of 5% fat content and heated at 90ºC. The fat and heating temperature had not significant effect in the color and appearance of the product but had significant effect in the flavor, taste, texture and overall acceptance of the product. As the fat content in raw milk was decreased, quality of product declined. As the heating temperature was increased, considerable increase in the yield of product was observed. Oil uptake had a direct relation with the initial fat content and moisture content of the product. More moisture and less fat showed greater oil uptake and vice-versa. The oil uptake by the paneer samples was found in between 26-32% (dry basis). The cost of paneer was calculated to be Rs.632.86 per kg.

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List of Abbreviations

Abbreviation	Full form
ANOVA	Analysis of variance
CCP	Colloidal calcium phosphate
CCRD	Central composite rotatable design
CIP	Cleaning in place
DM	Dry matter
DOA	Department of agriculture
FAO	Food and agricultural organization
GDL	Glucono-δ-lactone
kGy	kiloGray
LDPE	Low density polyethylene
LSD	Least significant differences
NPN	Non-protein nitrogen
PFA	Prevention of food adulteration
PV	Peroxide value
RSM	Response surface methodology
SNF	Solids-not fat
TA	Titratable acidity
TS	Total solids
Y&M	Yeast and mold

Part I

Introduction

1.1 General introduction

Dairy cattle are believed to have been first domesticated some 6000-10000 years ago, and are recorded in early documents and artefacts in India, Babylonia, Egypt and Old Testament Palestine Robinson (1996). The consumption of animal milk is a by-product of animal domestication, which occurred about 10,000 years ago. Milk and dairy foods are nutrient-dense foods supplying energy and significant amounts of protein and micronutrients. The inclusion of dairy products adds diversity to plant-based diets. The primary role of milk is to nourish the infants of a species. The biological value of milk proteins is very high and when supplemented with cereals, the biological value gets enhanced. This enhancement of the biological value is known as the "supplementary value" of milk proteins. Milk lipids exist in milk as fat in water emulsion in the shape of globules which are stabilized by a membrane primarily of lipoprotein complex. Milk lipids provide the necessary calories for the maintenance and growth of mammalian off-springs. (Muehlhoff *et al.*, 2013). Milk was known as a food of high value-but was also recognised as being highly perishable. Therefore its transformation into products of somewhat greater keeping quality, such as cheese, butter and curds has been known and practised for many centuries (Robinson, 1996).

According to Prevention of Food Adulteration (PFA) rules (1983), paneer means a product obtained from cow's or buffalo's milk or a combination thereof by precipitation with sour milk, lactic acid, or citric acid. It shall not contain more than 70% moisture and the fat content shall not be less than 50% of the dry matter. Good quality paneer is characterized by a typical acidic flavor with slightly sweet taste , a firm cohesive and spongy body , and a closely-knit , smooth texture (Sachdeva and Singh, 1995).

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 favorite for making snacks, pakoras or fried paneer chunks. Paneer is a rich source of animal protein available at a comparatively lower cost and forms an important source of animal protein for vegetarians. Overs and above its high protein content and digestibility, the biological value of protein in paneer is in the range of 80 to 86 (Khan and Pal, 2011).

1.2 Statement of the problem with justification

Paneer is a high nutrient diet containing a good amount of fat and protein. Because of high protein and fat content and easy availability of the raw material i.e. milk; paneer production can be done as an alternative to the meat protein. It is also becoming a great animal protein supplement for vegetarians. This study aims to highlight the nutritional richness and the convenience in making such nutritionally rich food.

Paneer can be made in a diverse way with different modifications. It can be made with different coagulating agents, at a suitable heating temperature range. The fat content and heating temperature employed in the preparation of the product directly affects the product quality. On one hand, low fat milk may not meet the required standard and on the other, the heating temperature has a direct role in the textural property of the product. The variation in fat content and heating temperature affects the color and appearance, flavor, and body and texture of the final product.

As the traditional method of paneer preparation technology has been commercialized these days, there is the need of product modification. This can be achieved by monitoring the influencing factors that may affect the final quality of product; such as by making control over the temperature during heating, fat content of milk used, type and concentration of coagulating agent etc. This study was a part of an effort on the improvement of the existing traditional methodology which use none of the aforementioned subjects to get a perfect product. The main problem related to this study is to get the optimized parameters regarding fat content and heating temperature. Similarly, it is to compare the yield of paneer with respect to the heating temperature and milk fat varied.

1.3 Objectives

1.3.1 General objectives

The general objective of this work is to study the effect of fat content and heating temperature of milk in the sensory quality and yield of paneer.

1.3.2 Specific objectives

a) To carry out physico-chemical analysis of milk.

b) To prepare paneer by employing different heating temperatures and with different fat content and compare the yield.

c) To study the effect of fat and heating temperature in the sensory quality of paneer.

d) To carry out the physicochemical analysis of the final product.

e) To study the oil uptake by paneer during deep oil frying.

f) To estimate the cost of the product.

1.4 Significance of the study

Nepal and the countrymen have a long history with milk and milk products which have become integral part of daily intake. It was always a matter of concern to food technologists to develop a product which could be an alternative to meat protein so that a large vegetarian population could make a reach to it on one hand and, also it could be a cheap source of protein to every class of customers on the other. Due to the 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. The ability of paneer to be deep fried is one feature that has led to its wider acceptance and a favourite for making different types of culinary dishes and as an ingredient in snacks.

In the traditional and household practice, paneer is prepared by adding lemon juice to boiling milk to coagulate it which results inferior product quality. The control over the process is not done which yields variation in the quality of product. This study and its results will directly help the people to understand the effect of fat content of raw milk and the heating temperature employed in making of the product. Also, the standardization and optimization of their existing process in preparation of the product can be achieved.

1.5 Limitations of the study

i. Microbiological analysis of milk and product was not done.

ii. Shelf life of the product was not studied.

Part II

Literature review

2.1 History of dairy development

Organized dairy development activities in Nepal began in 1952 with the establishment of a Yak cheese factory in Langtang of Rasuwa district under Food and Agriculture Organization (FAO) assistance in 1953. In 1954, a Dairy Development Section was established under the Department of Agriculture (DoA) and also a small-scale milk processing plant was started in Tusal, a village of Kavre district. In 1955, a Dairy Development Commission was formed.

The First Five Year Plan (1956-61) stressed on the need to develop a modern dairy industry. Accordingly, in 1956, a Central Dairy Plant, with an average milk processing capacity of 500 L/h was established in Lainchaur, with the financial assistance from New Zealand and technical assistance from FAO. Around the same time, a second mini milk processing plant was established at Kharipati, in Bhaktapur district. The plant started processing of milk and marketing activities from 1958. History of dairy cooperatives dates back to the First Five Year Plan (1956-61) when the dairy cooperatives were formed in Tusal Village of Kavre district.

In earlier days when there were no organized dairies, demand for milk was fulfilled by raising cows/buffaloes by the people themselves or through the direct supply from the professional milk producers. These producers used to go house by house and deliver the required quantity of milk to the households (FAO, 2010).

2.2 Socio-economic impacts

Dairy farming is an integral part of rural livelihood which shows the concept of cooperative approach for gaining common goal of farmers. Dairy cooperatives have made the farmers to unite in a group, which has made them more social. Dairy cooperative is a common venue where farmers meet in the morning and evening daily during milk delivery. So regular meeting have provided them opportunity for mutual harmony and sharing their socio-economic impact. Dairy cooperative makes society organized, harmonized and helpful. Dairy cooperative helps to create awareness in health, sanitation, and education to the farmers The income from the milk and livestock farming has made them culturally changed such as with good housing, hygienic toilet, bio-plant, television and education. Livestock farming specially dairying is backbone of income for the villagers. Animal and animal by-products keep economic value such as animal sale, milk cash, fertilizer, draught, and biogas and broadly speaking, it has socio-economic importance (Chaudhary and Upadhyaya, 2013).

2.3 Milk

The primary role of milk is to nourish the infants of a species. The consumption of animal milk is a by-product of animal domestication, which occurred about 10,000 years ago. Milk and dairy foods are nutrient-dense foods supplying energy and significant amounts of protein and micronutrients. The inclusion of dairy products adds diversity to plant-based diets (Weaver *et al.*, 2013). Milk contains many different components like water, fat, protein, lactose and ash. The most important component is butterfat, which gives milk its special creamy taste and color. Milk can be regarded as a complete food, containing protein, fat, lactose, vitamins and minerals, together with natural enzymes and those derived from microorganisms within the milk. It has a high nutritional value, but is an excellent medium for microbial growth. Milk is extremely variable in its composition. There are variations between individual cows in a breed, between breeds and between seasons. Variations between species are also very considerable (Lewis, 1994).

2.3.1 Physicochemical aspect of milk

The principal constituents of milk are water, fat, proteins, lactose (milk sugar) and minerals (salts). Milk also contains trace amounts of other substances such as pigments, enzymes, vitamins, phospholipids (substances with fatlike properties), and gases. The residue left when water and gases are removed is called the dry matter (DM) or total solids content of the milk (Bylund, 1995a).

The composition of milk of different species is tabulated in the Table 2.1.

Table 2.1 Proximate composition of milk of different species

Animal	Moisture %	Protein %	Fat %	Lactose %	Ash %
Human	87.4-88.5	1.2-1.3	2.1-4.0	6.8-7.0	0.2
Cow	86.6-87.5	3-4	3.3-6.4	4.4-5.6	0.7-0.8
Buffalo	82.9-84.2	2.7-4.7	5.3-15	3.2-4.9	0.7-0.9
Goat	85.5-86.5	3-5.2	3-7.2	3.2-4.7	0.7-0.9
Sheep	82.7	5.5-5.8	6.4-7.9	4.5-4.7	0.8-0.92
Horse	87.6	2.2	1.7	6.2	0.5
Camel	87.7	3.5	3.4	4.7	0.71

source: Robinson (1996)

According to (Gantner *et al.*, 2015), the fat content, protein content, lactose content and ash content of buffalo milk was found to be 5.3-15%, 2.7-4.7%, 3.2-4.9% and 0.8-0.9%.

2.3.2 Pasteurization of milk

Pasteurized beverage milk must be safe for the consumer and have a shelf life of a week or longer when kept refrigerated. Flavor, nutritive value, and other properties should deviate only slightly from those of fresh raw milk. Milk is heated for a variety of reasons. The main reasons are: to remove pathogenic organisms; to increase shelf-life up to a period of six months; to help subsequent processing, e.g. fore-warming before separation and homogenization; or as an essential treatment before cheese making, yoghurt manufacture and the production of evaporated and dried milk. When milk is heated, many changes take place; these changes that may lead to protein coagulation are as follows;

- decrease in pH
- precipitation of calcium phosphate
- denaturation of whey proteins and interaction with casein
- Maillard browning

- modification of casein: dephosphorylation, hydrolysis of K-casein and general hydrolysis
- changes in micellar structure: zeta potential, hydration changes; association-dissociation.

The casein fraction of milk is very heat stable, whereas the whey protein fraction is heat labile and almost completely denatured at 100ºC. The denatured whey protein complexes with the casein and does not usually precipitate. But when cheese whey is heated, the proteins start to denature, coagulate and precipitate between 75 and 80ºC. This illustrates the protective effect of casein towards coagulation (Lewis, 1994).

Pasteurization means heating every particle of the milk or milk product to a specific temperature for a specified period of time (63°C for 30 min). This destroys bacteria and other micro-organisms that may affect consumers' health. It makes the milk safe and healthy, and also improves the keeping quality, so that milk and milk products can be stored for longer periods without being spoilt. Pasteurization ensures the safety and greatly enhances the shelf life of the product. A mild heat treatment, e.g., 15 s at 72°C, kills all pathogens that may be present (especially *Mycobacterium tuberculosis*, *Salmonella* spp., enteropathogenic *E. coli*, *Campylobacter jejuni*, and *Listeria monocytogenes*) to such an extent that no health hazard is left. Some cells of some strains of *Staphylococcus aureus* can survive the heat treatment, but they do not grow to the extent as to form hazardous amounts of toxins. Such pasteurization inactivates alkaline phosphatase to the extent as to be no longer detectable (the enzyme may, however, regenerate slightly after keeping the product for some days, but this is especially true of pasteurized cream). Most of the spoilage microorganisms in raw milk, such as coliforms, mesophilic lactic acid bacteria, and psychrotrophs, are also killed by low pasteurization. Among those not killed are heat-resistant micrococci (*Microbacterium* spp.), some thermophilic streptococci, and bacterial spores. But these microorganisms do not grow too quickly in milk, except *Bacillus cereus*. The latter organism is pathogenic if present in large numbers. Among the undesirable enzymic decompositions, lipolysis (as caused by the natural milk lipoprotein lipase) is of special importance. Homogenized milk is highly susceptible to lipolysis because of its readily accessible substrate; therefore, it should be rather intensely heated (e.g., 20 s at 75°C) to reduce its lipase activity to 10^{-3} or 10^{-4}. Plasmin is not inactivated by pasteurization but the keeping time of pasteurized beverage milk generally is too short to cause problems (Walstra *et al.*, 2006b).

2.4 Composition and types of milk protein

Proteins are giant molecules built up of smaller units called amino acids. A protein molecule consists of one or more interlinked chains of amino acids, where the amino acids are arranged in a specific order. About 95% of the nitrogen in milk is in the form of proteins. Casein is the main milk protein being ¾ th of the total, remainder of which are the serum proteins and other minor protein in traces. Carbon, Hydrogen, Nitrogen, Oxygen, Sulphur, and phosphorus are the elements present in protein (Walstra *et al.*, 2006b).

2.4.1 Casein

Casein is defined as the protein precipitating from milk near pH 4.6. It thus is not soluble at its isoelectric pH. Casein is not a globular protein; it associates extensively and is present in milk in large aggregates, the casein micelles, which also contain the colloidal calcium phosphate (CCP). On acidification, the CCP dissolves. Casein does not show denaturation. However, heating at temperatures above approximately 120°C causes the casein to slowly become insoluble due to chemical changes. Caseins are hydrophobic; they have a fairly high charge, many prolines, and few cysteine residues. Casein molecules cannot or can hardly be denatured, because they have little secondary and tertiary structure. Several different caseins occur in milk, but their separation is not easy. Reactions that cause their precipitation from milk (acidification, renneting, and centrifugation after adding calcium) all yield a more or less complete mixture of caseins. Casein is a dominant protein found in milk. The casein easily forms polymers containing several identical or different fractions of molecules. The different fractions are differing in composition, solubility, and rennet coagulation. Casein is the macromolecule in the form of micelles and each micelle composed of about 1000 casein micelle. Casein exists in colloidal form comprising αs-, β-, k- caseins along with a divalent ion to form a stable micelle (Waugh, 1961). With the discovery of k- casein as the stabilizing agent, reaction steps involved in the rennet action on casein resulting in clotting of milk has now been understood clearly (Walstra *et al.*, 2006b).

2.4.2 Serum proteins

Serum proteins are present in a dissolved form, in the serum. They are often called whey proteins, although they are not precisely identical to the proteins of rennet whey, which also contains the peptides split off from κ-casein. The immunoglobulins in milk vary widely in concentration and composition (colostrum has a high immunoglobulin content). Most serum proteins (except proteose peptone) are globular proteins; they have relatively high hydrophobicity and compactly folded peptide chains. (Walstra *et al.*, 2006b).

2.4.3 Minor proteins

Amongst the minor proteins present in milk, milk enzymes play a vital role in assessing milk quality and shelf life. Milk being a repository of several enzymes, it is a popular starting material for the isolation and purification of certain enzymes. Alkaline phosphatase, xanthin oxidase, lipase, lysozyme, robinuclease, acid phosphatase, protease, catalase, peroxidase,and lactosesynthetase are some enzymes present in milk. The membrane of the fat globule contains several of these, including various glycoproteins. Most of the many enzyme proteins present in milk are also located in the fat globule membrane. All membrane proteins also occur in the plasma, although in very small concentrations (Walstra *et al.*, 2006b).

2.5 Precipitation of casein

Generally, casein is precipitated by the following methods.

2.5.1 Acid coagulation of casein

The pH value of normal milk often ranges from 6.6 to 6.7. When acid is added, the pH is reduced and at pH 4.6, i.e. isoelectric point will be obtained in which casein will be precipitated. At acid coagulation of milk, casein micelle properties are altered by a lowered milk pH. This causes CCP to dissociate from the micelles and the negative charges in the casein micelles are neutralized, with aggregation occuring as the isoelectric point of the casein micelle (pH 4.6) is approached. A porous network of loosely linked aggregates is formed. The acidification method of milk can be done by using bacterial cultures, which ferment lactose to lactic acid, direct addition of acids, such as HCl, or the utilization of glucono-δ-lactone (GDL), which is hydrolyzed to gluconic acid, resulting in a reduction in pH. At normal milk pH, most proteins have a net negative charge value causing long-range electrostatic repulsion and short-range hydration repulsion between protein molecules, which stabilizes casein micelles. At low pH, the net negative charge on the casein micelles is lowered because of the decrease in pH. The acidification from pH 5 to 4.6 induces the disassociation of the calcium complexes by the phosphoserines, whereas the previous pH region (pH 6.6 to 5) induces mainly the solubilization of the calcium phosphate (Phadungath, 2005).

2.5.2 Enzymatic precipitation of casein

The dynamic stability of micelle is due to κ-casein but it is most susceptible to enzymes. It responses positive to enzymes. When enzyme like renin and pepsin are added in milk, precipitation of casein takes place with the formation of p-casein. The reaction is as follows.

$$\kappa\text{-casein of micelle} \xrightarrow{\text{rennet}} \underset{\substack{\text{Hydrophobic} \\ \text{(insoluble in water)}}}{\text{para-}\kappa\text{-caseinate}} + \underset{\substack{\text{Hydrophilic} \\ \text{(soluble in water)}}}{\text{Glycomacropeptide}}$$

In the above reaction, para-κ-caseinate remains in micelle with αs and β casein. Being insoluble, it causes precipitation of casein which is known as enzymatic precipitation of casein. The soluble glycomacropeptide part which is soluble is drawn with whey during the precipitation especially on cheese manufacturing (Acharya, 2006).

2.5.3 Heat precipitation of casein

Pure casein is not precipitated by heat, but in fresh milk prolonged heating at high temperatures 100ºC for 12 or more hrs or 120ºC under pressure will cause the precipitation of casein. On boiling fresh milk, a thin layer of finely precipitated casein, together with other milk constituents including fat, forms a thin layer over the surface of the milk. The application of heat to milk that is slightly acidic will cause the precipitation of casein. When milk is heated at 130ºC for several hours hydrogen bond ruptures and β- dimensional structure of casein disruption causes ultimately the protein denaturation and finally precipitation occurs. The cooked curd casein is less soluble and contain more ash than the other caseins (Acharya, 2006).

2.5.4 Alcoholic precipitation of casein

When the fresh milk is acted upon by microorganisms and the pH value is lowered than 6.6, due to the formation of lactic acid, at this condition, if we add alcohol the precipitation will take place. It is called alcoholic precipitation of casein.

The principle of alcoholic precipitation is the dehydration of adsorbed layer of micelle and exposure of κ-casein and ultimately action of developed acidity due to microbial contamination upon the milk. Hence alcoholic precipitation of milk will be only possible if the milk is contaminated by microbes and acidity is developed. This method is used to quick check the freshness of milk. If the milk is immediately precipitated out on adding alcohol, it is not fresh and vice versa (Acharya, 2006).

2.6 Factors influencing coagulation of milk

Coagulation of milk is a complex process, influenced by many different factors. The most obvious are pH, calcium content and temperature. Decreasing the pH and increasing the temperature will decrease the coagulation time. Regarding calcium, the coagulation reaction is favored both by increased levels of bound colloidal calcium phosphate (CCP) and free calcium ions. Adding calcium to the milk will increase these levels in addition to lowering pH. Many factors are intertwined and the milk protein fraction, which has 19 different effects on the coagulation properties. Milk from cows with mastitis is associated with a high pH and low levels of casein (Hallén, 2008).

2.7 Whey

Whey, the liquid residue of cheese and casein production, is one of the biggest reservoirs of food protein still remaining largely outside human consumption channels. Whey comprises 80–90% of the total volume of milk entering the process and contains about 50% of the nutrients in the original milk: soluble protein, lactose, vitamins and minerals. Whey as a by-product from the manufacture of hard, semi-hard or soft cheese and rennet casein is known as sweet whey and has a pH of 5.9 – 6.6. Manufacture of mineral-acid precipitated casein yields acid whey with a pH of 4.3 – 4.6. Liquid whey consists approximately 93% of water and contains almost 50% of total solids present in milk of which lactose is the main constituent while protein represents less than 1% of total solids. Whey must be processed as soon as possible after collection, as its temperature and composition promote the growth of bacteria. Otherwise the whey should be quickly cooled down to about 5°C to temporarily stop the bacterial growth (Bylund, 1995b).

2.8 Some milk based products prepared by coagulation in the Indian subcontinent

2.8.1 Chhanna

This acid-coagulated curd is used for sweet-making in Nepal. Chhanna from cow milk has higher moisture, protein and ash contents and lower total solids i.e. fat and lactose than chhanna made from buffalo milk. The main feature of the large-scale process is the use of acid whey from previous batches of chhanna to bring about the coagulation (Nembang and Aneja, 1990).

2.8.2 Bandel

Bandel cheese is an indigenous unripened, salted soft variety of cheese made in perforated pots. It is similar to surti paneer but made from cow's milk. It is available in and around Bandel, a Portugese colony in eastern India, and seems to have derived its name from it. The cheese is formed into a flattened circular shape and is ready for immediate sale (Nembang and Aneja, 1990).

2.8.3 Dacca

This cheese is available in the eastern region. It is similar to *bandel* but differs from it in that the finished flat round cheeses are smoked in a fire (Nembang and Aneja, 1990).

2.8.4 Chhanna and channa-based sweets

The acid precipitation of milk solids leads to paneer and to chhanna and several chhanna-based products including sweets. It consists of acid coagulated milk solids used for the preparation of many milk based sweets. It differs from Paneer in that no pressure is applied to remove the whey. Chhanna is widely used in the eastern parts of India and Bangladesh. Cow milk is preferred since it yields a soft bodied and smooth textured product. Both these characteristics are suitable for the production of high grade chhanna sweets. Buffalo milk produces a chhanna with a slightly hard body, a greasy and coarse texture, and does not produce good quality chhanna sweets (Nembang and Aneja, 1990).

2.8.4.1 Rasogolla

It is prepared using fresh and soft-chhanna in the form of a typical spongy body and smooth texture. It is stored and served in sugar syrup. Freshly-made chhanna is squeezed by hand in a muslin cloth to remove as much whey as possible. 1-4% of the wheat flour/semolina is mixed with the chhanna in a container and kneaded thoroughly by hand to make dough. The dough is portioned and rolled into balls of about 15 mm diameter having a smooth surface with no cracks - 1 kg of chhanna yields 90-100 rasogollas. The dough balls are cooked in a especially prepared whey based medium for about 15 min. For chhanna made from cow milk, cooking medium with sugar is preferred, and for all other types of chhanna, cooking medium without sugar is preferred. After the cooking is complete, the balls are transferred to a container with water at 30–35°C for texture stabilisation and colour improvement of the balls. After 5-10 min of texture stabilisation in water, the texture stabilised balls are transferred to sugar syrup. The desired sugar syrup concentration in the final product is 45-50%. This is achieved by dipping the texture-stabilised balls first in 35-40% sugar syrup for 1-2 h, followed by a second dipping in 58-60% sugar syrup. The product finally acquires the desired sugar concentration after equilibration between the sugar syrup inside and outside the balls is achieved (Nembang and Aneja, 1990).

2.8.4.2 Lalmohan

It is a product similar to *gulabjamun* but is made from chhanna and is lighter in colour. Chhanna is mixed with 2–3% wheat flour and kneaded into a uniform dough. The dough is rolled into small balls and deep fried in ghee until light brown in colour. The balls are transferred to a 60% sugar syrup and allowed to soak for a few hours before being served (Nembang and Aneja, 1990).

2.8.4.3 Other

Other chhanna based sweets includes Khirmohan, Rasmala, etc (Nembang and Aneja, 1990).

2.9 Historical background of paneer

Paneer is the Hindu name of the seeds of Whitania Coagulans, a vegetable rennet that produces a bitter curd. In past times, ancient Indians already produced curdled milk products obtained by admixture of pieces of creeper called Putika or pieces of bark of Palasa tree or Kuyala (Jujuke) to the milk. However, the curdled milk product, Paneer, appears to have been introduced in the subcontinent from the Middle East. One of the unique Iranian nomadic cheeses is called paneer khiki. It was originally developed by the well-known Bakhtiari tribe that used to stay in Isfahan (in summer) and in Shiraz (in winter). When salted, this cheese is known as paneer-e-shour. The word paneer means container and khiki means skin. Rennet from goat or sheep was used for its production. It may be assumed that paneer was introduced in India by Persian and Afghan invaders. It is perhaps for this reason that Paneer making practice is confined to the North-west frontier regions of the sub-continent (Nembang and Aneja, 1990).

It is believed that the nomads of south west Asia were the first to develop several distinctive heat and acid coagulated varieties of cheese. 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. Paneer Khiki is one of the unique Iranian nomadic cheese developed by Bakhtiari tribe of Iran; 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 the Persian word for cheese. 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 (Khan and Pal, 2011).

Traditionally, buffalo milk is boiled in a suitable iron vessel and a small portion of this is then transferred to a smaller vessel. The coagulant (usually sour whey) is added to the hot milk and stirred with a ladle till coagulation is completed. The contents of the vessels are emptied over a piece of coarse cloth (to drain off whey) held over another bigger vessel (to collect whey). The whole process is repeated several times till all the milk is converted into paneer (Rao *et al*., 1991) .

2.10 Heat treatment of milk

During the heat treatment, milk behaves as a complex reaction system where many physical, chemical and biochemical reactions take place. The heat induced reactions in bulk of milk can be subdivided into five categories; destruction of microorganisms, inactivation of enzymes, denaturation of proteins, loss of nutrients and formation of new components (Britz, 2008).

2.10.1 Heat stability of milk

Heat treatment is applied in many dairy processes either to enhance desirable properties of the products, such as texture and taste, or to ensure its safety and shelf-life. Heat-treated milk proteins have interesting functional properties that are widely applied in food, cosmetics or pharmacy. The formation of complexes between whey proteins and κ-casein during heat treatment of milk dramatically affects the protein organization in both the colloidal casein and the serum phases of milk and consequently, its technological applications (Donato and Guyomarc, 2009).

The problems of regulating heat stability (that is the relative resistance of milk to coagulation upon sterilization) appeared over a century ago in the manufacture of evaporated (condensed) milk. The heat stability of milk refers to the ability of milk to withstand high processing temperatures without visible coagulation or gelation. The ability of milk to withstand high-temperature treatments without loss of its stability is fairly unique and makes the production possible of many sterilized milk products with a long shelf life. These products include UHT milks and creams, in-can sterilized milks, evaporated milk, sweetened condensed milk and milk powders, especially those intended for reconstitution and recombination into sterilized products (heat-stable powders). Concentrated milks are considerably less heat stable than non-concentrated milks.

The optimum heat stability is dependent on a certain balanced ratio of calcium plus magnesium ions to phosphate plus citrate ions. Any disturbance in the salt balance, due to the excess or deficiency of either group accelerates the heat coagulation. Practical solutions to the heat stability problems include the following:

• manipulation of preheat treatments

• matching the natural pH of milk to that of the heat stability maximum

• addition of different levels of phosphate

• addition of buttermilk and phospholipids at appropriate levels

• combination of the above treatments (Singh, H. 2004).

2.10.2 Factors affecting heat stability of milk

The higher the acidity and low pH means lower the heat stability and vice versa. Addition of acid to milk, either by bacterial action or chemical means, results in an increase of ionic calcium, which in turn disturbs the salt balance and lowers the heat stability. The higher the total solids, the lower will be the heat stability and vice versa. The temperature-time and method of pre-heating/fore-warming milk affects the heat stability of milk. Homogenization of milk tends to slightly lower the heat stability which is affected by the pressure used; the greater the homogenization pressure, the greater will be the reduction in heat stability. The increase in the concentration of ratio of calcium plus magnesium ions to phosphate plus citrate ions disturbs the salt balance resulting in lowering of heat stability. Table 2.2 shows the changes in milk during heating and its impact on heat stability.

Table 2.2 Changes in milk during heating and their possible impact on heat stability

Changes that promote instability	Changes that enhance stability
• Decrease in pH	• Reduction in calcium ion activity
• Deposition of calcium phosphate onto micelles	• Association of whey proteins with casein micelles
• Association of whey proteins with casein micelles	• Reduced sensitivity of casein to calcium ions

• Dephosphorylation of casein • Dissociation and hydrolysis of caseins, in particular κ-casein • Reduction in zeta potential and hydration • Covalent bond formation	• Thermal degradation products of lactose

Source: Singh (2004)

2.11 Factors affecting the quality of paneer

2.11.1 Type of milk

Acidic milk having titrable acidity of 0.20 to 0.23% yields a product with inferior quality. Homogenization of cow milk is recommended to bring about improvement in the yield and organoleptic score of paneer. For making good quality paneer, buffalo milk is considered more suitable than cow milk (Sachdeva *et al.*, 1985).

Animal udder infection (mastitis) results in higher pH values for fresh milk whereas lower values show bacterial action. The bacterial action disturbs salt balance i.e., causes progressive removal of calcium and phosphates from caseinate phosphate micelle due to which coagulation is faster simply on heating or on addition of small amount of coagulant which directly affects the quality of the final product (Acharya and Katwal, 2002).

2.11.2 Acidity of milk

Milk having acidity within the range of 0.14-0.16% should be accepted for paneer manufacture. As a result of bacterial action on milk lactose there is increase in acidity in milk (Acharya and Katwal, 2002).

2.11.3 pH of milk

Variation in the pH of coagulation has a significant effect on the body and texture, flavour, quality and yield of paneer. According to (Sachdeva and Singh, 1988a), with the fall in pH (5.5-5.0), the moisture retention and yield of paneer decreased. 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.

2.11.4 Coagulant

Among citric acid, ascorbic acid, tartaric acid and lactic acid for the preparation of paneer using buffalo milk, ascorbic acid is the best coagulant for providing best texture properties as well as chemical and organolaptic test (Karadbhajne and Bhoyarkar, 2010).

2.11.5 Concentration of coagulant

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 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 (Khan and Pal, 2011). The total solid loss in whey increases as there is an increase in concentration of coagulants. (Sachdeva and Singh, 1988b) reported that loss of total solid in whey was 5.8%, 6.4% and 6.8% on coagulating milk with 1,2 and 3% citric acid respectively.

The sensory score were maximum for paneer made with each coagulant of 1% solution and decreased with increase in concentration; stronger solutions resulted in paneer with slightly acidic taste and harder body. Solutions lower than 1% concentration would increase the bulk of the contents posing problems in handling (Sachdeva and Singh, 1988b). The yield of paneer obtained from 1% citric acid was highest (14.2%) than other coagulant concentrations. The sensory evaluation results indicated that the product prepared from citric, tartaric and lactic acids at 1% each could be considered the best product(Karadbhajne and Bhoyarkar, 2010). The percent yield obtained from 1% citric acid was 14.2%, which is higher than 2% and 3% solution whereas in case of tartaric acid and lactic acid, 2% solution was optimized (Acharya and Katwal, 2002).

2.11.6 Coagulation temperature

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 60ºC to 90°C decreased the moisture content of paneer from 59% to 49%. 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, 1988a).

A coagulation temperature of 70°C has been recommended for paneer making from buffalo milk (Bhattacharya *et al.*, 1971a). Temperatures higher than this resulted in dry and hard paneer while lower temperature yielded product having very moist surface (Sachdeva and Singh, 1988a).

2.12 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. Since the milk solids in paneer constitutes mainly fat, protein, lactose and minerals, it is desired that the maximum recovery of individual components would maximize the yield and recovery of total milk solids in paneer (Sachdeva and Singh, 1988a).

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%). They recommended 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 (Singh, S. and Kanawjia, 1988) . The yield of paneer from buffalo milk decreased with an increase in coagulation temperature while for cow milk it increased. Homogenization increased the yield of paneer significantly (Sachdeva and Singh, 1988a).

2.12.1 Role of heating and fat content in the yield

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. More amount of fat in milk allows the higher retention of total solids in the curd after coagulation which ultimately improves the yield of the product. 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% (Khan and Pal, 2011).

Heating causes denaturation of whey proteins which is an irreversible process and the whey proteins get associated with casein micelles. Whey proteins are the heat sensitive, globular, water soluble proteins and enzymes. The degree of denatured whey proteins depends on the time-temperature combination during the heating and is mainly determined by the maximum temperature to which milk is heated. During the process of heat-acid coagulation, calcium and phosphate are transferred from the solution to the colloidal state. These reactions are irreversible. The mineral balance also changes on heating. Calcium and phosphate become more insoluble and bind to the casein-micellar structure. The constituents of fat globule membrane particularly phospholipids influence the recovery of fat (Akkerman, 2014). Low recovery of milk solids and fat is due to the less number of fat globules in milk which could not trap the sufficient amount of milk protein through their association with the fat-globule membrane. Also, during cooling, the rate of cooling had the most prominent effect on the recovery of total milk solids in paneer than the rate of heating. Faster the rate of cooling, the overall recovery of milk solids was higher as compared to heating. In case of lactose recovery only, faster heating rate was found to be better. By decreasing the combined effect of heating and cooling rates, increased in the recovery of total milk solids (fat, protein, lactose and minerals) was observed (Sahu and Das, 2010).

2.13 Preservation of paneer

2.13.1 Low temperature storage

A report suggested that the storage of paneer at subzero temperature, i.e., -13ºC and -32ºC for 120 days did not affect its flavor and appearance, and the product was acceptable even up to 120 days after frying. Further, the paneer made from 4, 5, and 6% fat milk could be stored for not more than six days at 10ºC, and for 120 days at -13ºC and -32ºC. A decrease in moisture content and increase in non-protein nitrogen (NPN) was observed, but the decrease in moisture content was more for the samples stored at -13ºC, while the increase in NPN was observed to be more for the product stored at -32ºC. Storage at 10ºC for 6 days revealed no appreciable physico-chemical changes up to 6 days, but putrid flavor developed on the 7^{th} day (Arora and Gupta, 1980).

Frozen paneer had a shelf life of up to 8 days but surface drying was observed. However, the sensory qualities of frozen paneer at -9ºC or -15ºC were found to be almost comparable (Vishweshwaraiah, 1987).

2.13.2 Dehydration and deep freezing

Vishweshwaraiah (1987) studied the effect of dehydration or freezing on the shelf life of paneer. Fresh paneer had an average composition of 55% moisture and 45% total solids (TS). It was (i) cut into cubes and hot air-dried at 75ºC for up to 4 h; (ii) extruded to increase surface area, then dried for up to 2 h; or (iii) frozen at -9ºC or -15ºC. After 4 hr drying, it (i) had a moisture content of 15–18%; (ii) extruded paneer retained less moisture (5–9%) and drying was comparatively faster (≤2 h). Although extruded paneer had a shelf life of up to 2 months versus three days for fresh product, the rehydration characteristics were poor and lacked cohesive properties.

2.13.3 Heat Sterilization

Thermal sterilization of paneer at 15 psi for 15 min in tin cans kept the product well over a period of 50 days at room temperature but slight browning and cooked flavor affected the organoleptic quality significantly. Paneer cubes fried prior to sterilization, however, got spoiled earlier due to the development of pronounced oxidized flavor after 40 days of storage (Sachdeva, 1983). Rao *et al.* (1984) developed a method that extended the shelf life of paneer for up to three months at 35ºC. The process involved concentration of standardized milk (2% fat, 9.2% Milk Solids-not-Fat (SNF)) to 27% total solids by ultrafiltration, followed by texturization at 118ºC for 5 min, which also inactivated the microbial spores and yielded a long shelf life of product. The resultant product had a greater proportion of whey protein bound to the casein network than in traditional paneer.

‘’Total solids recovery was 95%, and overall acceptability score (on the 9-point Hedonic scale) was 8.5.

2.13.4 Use of preservatives

2.13.4.1 Brine

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

Paneer dipped in 5% brine solution lasts for nearly 20 days as against control that is spoiled after 6 days of storage at 8-10°C (Narayanan *et al.*, 2016).

2.13.4.2 Sorbic acid, irradiation, and benzoic acid

The experiments revealed that the shelf life of paneer could be extended up to 36 days at room temperature by adding sorbic acid to milk (0.15%) and subsequent wrapping of paneer in sorbic acid-coated butter paper. However, similar shelf life (36 days) of paneer was achieved at 5ºC when the product was prepared by adding 0.05% sorbic acid to milk. The sorbic acid content in paneer varied from 0.15 to 0.3%. It was observed that treatment of paneer with sorbic acid and/or gamma radiation reduced the microbial load. Combination treatment of 0.10% sorbic acid in milk and irradiation of the product at 2.5 kilo Gray (kGy) preserved paneer samples for 30 days at ambient temperature (25–35ºC). The use of benzoic acid (1200 ppm =0.12%) for the enhancement of shelf life of paneer to 40 days at refrigerated temperature, and to 20 days at 37ºC was studied (Singh *et al.*, 1989) .

2.13.4.3 Potassium sorbate and nisin

Incorporation of 0.1% potassium sorbate enhanced the shelf life of paneer from 6 days to 18 days when stored at 5ºC. The keeping quality of paneer containing was extended by addition of 0.1% potassium sorbate by 13 days, 3–4 days, and 1 day at 7, 22, and 37ºC, respectively. However, the keeping quality was further improved by adding nisin together with the potassium sorbate (Rao *et al.*,1991) .

2.14 Packaging of paneer

Packaging means safely and cost-effectively delivering product to the consumers in accordance with the marketing strategy of the organization. The primary role of packaging is to protect the nutritional and sensory properties of milk and milk products from processing stage to the final consumption. Good packaging lowers product costs, reduces product wastage, helps consumers make purchase decisions, and protects against tampering and spoilage. Paneer is highly susceptible to chemical and microbial changes, and its packaging should protect against these changes, maintain quality and effective sales appeal, and add to consumer convenience. Above all, good packaging is essential to protect human health, and provide safety and comfort. It is observed that the technology for production of paneer is well known for over a long time, but its proper packaging needs attention. Various materials have been used for the packaging of paneer, they are; PE sachets, Butter paper, Parchment paper, Wax coated paper, Saran coated films, LLD/BA*/Nylon-6/BA*/LDPE (* polybinding agent), coextruded laminates, heat-induced shrink films (Goyal and Goyal, 2016).

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, 1990b). Vacuum packaging of paneer in laminated pouches can help to increase its shelf life to about 30 days at 6 ± 1°C (Narayanan *et al.*, 2016).

2.15 Storage of paneer

2.15.1 Physico-chemical changes in paneer during storage

2.15.1.1 Moisture

The effect of storage at 10ºC, -13ºC, and -32ºC on the moisture content of paneer was studied by (Arora and Gupta, 1980). The observations made in their experiments indicated that the initial moisture content of 53.20% in fresh paneer increased to 54.36 and 54.61% on the third and sixth day respectively when stored at 10ºC, while at -13ºC storage, the moisture content was observed to be 54.89, 52.22, 50.25, and 57.22% on the 30th, 60th, 90th, and 120th day of storage respectively, but when the product was stored at -32ºC, the moisture content decreased to 52.78, 52.10, 51.91, and 49.07 on the 30th, 60th, 90th, and 120th day of storage respectively. Rao *et al.* (1984) observed reduction in moisture content of paneer when stored for six days at 5ºC. Pal (1998) observed that moisture content in fresh paneer prepared from standardized buffalo milk (3.5% fat) was 55.78%, which decreased to 54.85% on the 5th day, 53.74% on the 10th day, and 52.36% on the 15th day of storage.

2.15.1.2 pH value

The pH of paneer (prepared from standardized buffalo milk with 5% fat) decreased from 6.60 to 5.80 on the sixth day of storage at 10ºC (Bhattacharya *et al.*, 1971b). Arora and Gupta (1980) reported that there was an increase in the pH value of paneer (6% fat) from 6.0 to 6.02 and 6.03 on the third and sixth day of storage at 10ºC, while at -13ºC, pH was found to be 6.04, 5.99, 6.02, and 5.88 on the 30th, 60th, 90th, and 120th day of storage respectively, and at -32ºC storage the pH was 5.94, 6.00, 5.73, and 5.90 on the 30th, 60th, 90th, and 120th day of storage respectively. The work of Pal (1998) indicated that the pH value of fresh paneer, i.e. 6.21, decreased during storage at 8 ± 2ºC to 6.04, 5.78, and 5.73 on the 5th, 10th, and 15th day respectively.

2.15.1.3 Titratable acidity (TA)

Bhattacharya *et al.* (1971b) reported that the initial TA in terms of percentage of lactic acid (%LA) 0.15% in fresh paneer increased to 0.49% on the sixth day when stored at 10ºC. Pal and Garg (1989) reported an increase from 0.192 to 0.328 in TA of paneer samples stored at 7±1ºC for 11 days.

2.15.1.4 Peroxide value (PV)

Sindhu *et al.* (2000) reported that peroxides were absent in fresh paneer but appeared after 30 days of storage at <10ºC in buffalo milk paneer (0.4 meq/kg of fat) and cow milk paneer (0.34 meq/kg of fat).

2.15.2 Sensory property of paneer

The data collected by Bhattacharya *et al.* (1971b) on the changes in organoleptic quality of paneer prepared from milk containing 5% fat and stored at 10ºC revealed that the rating of the flavor and texture score decreased from "very good" to "good" and "fair" respectively after three and 6 days of storage. However, slimy appearance at the top of paneer samples were observed after 6 days of storage.

The textural profile analysis showed that all textural properties of refrigerated paneer (stored at 6 to 8ºC), such as hardness, cohesiveness, springiness, gumminess, and chewiness, initially increased up to 15 days, and thereafter decreased appreciably 45 days of storage. Conversely, all textural properties of frozen samples (-28 to -30ºC) decreased consistently throughout the storage period of 60 days. This may be due to the injury caused by the formation of ice-crystals and solidification of fat, which upon thawing disturb the casein matrix. Similar trends were observed in the case of gumminess and chewiness of paneer (Kanawjia and singh, 1996) .

Sachdeva and Singh (1990a) observed gradual deterioration in the flavor score during the storage of paneer dipped in plain water for 2 hrs packed in PE pouches. The product was rated unacceptable after 10 days due to the development of putrid odor, and an acidic and bitter taste. Slight decrease in the body and texture score was also noted due to the loss of moisture, but when paneer was dipped in H_2O_2 solution (0.2%), a moldy flavor developed after 22 days of storage at 10ºC, and the product was evaluated as unacceptable.

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

2.15.3 Microbiological changes in paneer during storage

Sachdeva (1983) noted increase in the total counts as well as yeast and mold (Y&M) counts during storage of paneer up to 10 days at 5ºC. The total counts of mesophilic bacteria, Y&M, and coliform increased during 15 days of storage of paneer at 8 ±2ºC (Pal, 1998). Singh *et al*. (1989) reported reduction in mesophilic count initially at 5ºC in stored paneer but rapid increase was noted after four days in unwrapped samples, and after six days in wrapped sorbic acid-coated paneer.

2.16 Shelf life

The shelf life of paneer was reported to be only six days at refrigeration temperature 10ºC without much deterioration in quality, but the freshness of the product was lost after 3 days; while at room temperature paneer did not keep well for more than 1 day. Spoilage of paneer at surface decreases the shelf life (Bhattacharya *et al.*, 1971b). Arora and Gupta (1980) reported that the paneer prepared from milk having 4, 5 and 6% fat could be stored for not more than 6 days at 10ºC, and for at least 120 days at -13ºC and -32ºC without much decrease in sensory quality. Sachdeva (1983) observed 16 days shelf life for paneer samples tightly wrapped in heat shrink film and stored under refrigeration conditions. The researcher reported that paneer could be stored well for over a period of 50 days at room temperature by sterilization. Rao *et al*. (1984) observed relatively less moisture loss in paneer packed in PE bags compared with parchment paper when the product was stored for six days under refrigeration conditions. Sachdeva and Singh (1990a) found that dipping of paneer samples in brine, acidified brine, or H_2O_2 extended the shelf life to 22, 20, 22, and 32 days, respectively. Ranawat *et al.* (1991) dipped paneer in sorbic acid solution (1000 ppm) and found that the paneer could be stored at 0 to 4ºC up to 6 weeks. Pal and Garg (1989) reported that the shelf life of paneer was 7 days at 7ºC when made from sweet cream buttermilk, then the flavor, texture, and appearance scores gradually declined but still the paneer was acceptable for up to 9 days with lower sensory scores. Kanawjia and Khurana (2006) reported that the limited keeping quality of paneer at refrigeration temperature can be enhanced by using antimicrobial substances and vacuum packaging. In order to determine the shelf life of MAP paneer, Shrivastava (2007) subjected the samples to five types of atmospheres (air, vacuum, 100% CO_2, 100% N_2, and 50% CO_2/50% N_2) and stored at 3±1ºC. The shelf life of paneer increased significantly up to 30 days for the product packaged under 100% CO_2, 100% N_2, and 50% CO_2/50% N_2. Under vacuum, shelf life of 20 days was achieved. Pal (1998) observed that the shelf life of low-fat paneer coated with paraffin wax was more than 10 days at refrigeration temperature.

The shelf-life of paneer is only 1 day at room temperature (30±1°C) and the spoilage is mainly attributed to the growth of surface tainting and off-flavour producing microbes. Shelf-life of paneer could be significantly enhanced by adopting MAP with a gas mixture (CO_2:N_2=50:50) prepared by adopting HT comprising of 3% NaCl, 1% CA and 0.1% potassium sorbate. Keeping quality of paneer was extended from 1 to 12 days at room (30±1°C) and 6 to 20 days at refrigeration (7±1°C) temperature without much affecting the sensory and physico-chemical characteristics of paneer. In order to enhance the shelf life of paneer several attempts have been made in the past, which included addition of preservatives, vacuum packaging, low temperature storage, dehydration and heat sterilization, treatment with brine, chlorinated water, H_2O_2, delvocid, sorbic acid, potassium sorbate and antioxidants (Thippeswamy *et al.*, 2011).

2.17 Proximate composition of paneer

The proximate composition of paneer shows total solids of 49.93%, fat content 28.86%, protein 16.07%, lactose 2.33% and ash 2.67% (Masud *et al.*, 1992). Similarly, the moisture content of market paneer was found to be 52.90%, fat content 16-28% and protein content 18.06% (Desale *et al.*, 2009). In another finding, the moisture content of paneer was found to be 52.75%, fat content 25.64%, protein content 15.62%, lactose content 2.68% and ash content of 2.14% (Kumar *et al.*, 2014).

2.18 Deep oil frying

Frying is considered to be one of the oldest methods of food preparation due to high cooking rates and desirable product characteristics. It is a unit operation which is mainly used to alter the eating quality of a food. Deep-fat frying involves immersion of food in hot edible oil at a temperature above the boiling point of water for a given period of time. Vegetable oil is must suitable for deep frying since it contains health friendly unsaturated fat and have a higher value of smoke point (Farkas *et al.*, 1956; Simmons, 2017). The process involves both mass transfer, mainly represented by water loss and oil uptake, and heat transfer. Deep-fried foods are now popular for their distinct flavor and texture, as evidenced by the multi-billion dollar market products. The attainment to a high and constant quality of fried products with appropriate oil content is of considerable interest to food industry and consumers (Ziaiifar, 2008).

The moisture removal from food material must be sufficient to ensure the optimum fat uptake (Farkas *et al.*, 1956; Ziaiifar, 2008). During frying, water escapes from the food while oil migrates into the food providing nutrients and flavors. Frying oils thus have the original property of being both a heat transfer medium and an ingredient of the final product representing up to 40% of the total mass in products like chips. During deep-oil frying, water in the crust will evaporate and move out of the food. In order for the flow of vapor to continue, sufficient water has to be able to migrate from the core of the food to the crust and the crust has to remain permeable. The fact that the vapor leaves void for the oil to enter later is the reason why oil uptake is largely determined by the moisture content of the food. Similarly, sections of the food with more moisture loss also show more oil-uptake (Mehta and Swinburn, 2001).

Oil uptake is considered the major nutritional critical point of deep-fat frying because of the obesity and the negative effects of excess oil consumption on human health. This point has caught the attention of researchers. In recent years, there has been a strong encouragement to reduce oil content of fried foods, prompting many researches on the development of food products that have reduced fat and cholesterol levels. The quality of frying oils as well as fatty acids composition and degree of degradation of fat, frying medium, oil content and frying temperature affects the oil uptake and texture of fried food products (Mirzaei *et al.*, 2015). The capillary effect (primary) and the vacuum effect (secondary) are the main mechanisms in oil absorption. The product porosity can be the place of oil absorption so it determines the capacity of oil absorption. During the frying period, the absorbed oil content is not enough to fill the pores, which are continuously forming. While during cooling period, the pores are mostly filled by oil (Ziaiifar, 2008).

Choe and Min (2007) observed the oil uptake in different food products. They found the oil uptake in potato chips, corn chips, tortilla chips, dough nuts, French fries and fried noodles to be in between 33 -38%, 30-38%, 23-30%, 20-25%, 10-15% and 14% (Choe *et al.*, 1993) respectively. Similarly according to a study by Mirzaei *et al.* (2015) the oil uptake of potato French fries was 23% to 28% at 160ºC and180ºC respectively. It was observed that the oil uptake was higher at around 180ºC than 160ºC (Mirzaei *et al.*, 2015).

2.19 Functional properties of milk protein and paneer

A functional property of a material is its ability to produce a specified property in the product in which the material is applied. Proteins can produce nutritional value and a number of physico-chemical properties. An important functional property of milk proteins is that they can be used to make gels. A gel can also be made in order to immobilize the liquid in the gel. Milk proteins are often used to help making oil-in-water emulsions and to stabilize these against physical changes Proteins are the foaming agents of choice. If the protein is well soluble, its concentration is high, and the beating is vigorous, the overrun obtained can be considerable, up to 1000% or even more. Protein-stabilized foams are, however, quite sensitive to fast coalescence if the system contains even small quantities of lipids (Walstra *et al.*, 2006a).

Paneer does not melt and so can be used to introduce interesting textures in hot dishes. Paneer will undergo browning when cooked, including Maillard browning due to its relatively high lactose concentration. This brown colour can add visual appeal to certain dishes. Paneer itself has a rather bland flavour but it can act as a flavor carrier. Therefore it is excellent marinated or used in a curry or sauce. The mild flavour of the paneer also lends itself to use in sweets where the flavour of sweetened paneer compliments other flavours such as pineapple or coconut (Anon., 2011).

2.20 Uses of paneer

Paneer is the important nutritious and wholesome indigenous, dairy product, which occupy a prominent place among traditional milk products and carry a lot of market potential. These products are of high quality proteins, fat, minerals and vitamins. Paneer is used as a base material for the preparation of a large number of culinary dishes and it is a popular food product at the household level as well as its use is increasing in organized food chains. It is an excellent match of non-vegetarian food (Karadbhajne and Bhoyarkar, 2010). Paneer is commonly used in sweets, snacks or with vegetables. Paneer can be included in curries, particularly with tomatoes, potatoes or peas. Cubes of paneer can be added to soup which provides texture. Paneer can absorb other flavours, for instance it can be marinated and grilled. Different traditional Indian dishes can be prepared by cooking Paneer with spinach, peas or mustard leaves. Fresh paneer can be boiled in sugar syrup and served as a sweet. Another sweet can be made by mixing paneer with flour and other ingredients and then frying the mixture and serving it in sugar syrup. A snack can be made by frying rolls made from grated paneer mixed with water soaked bread and spices. A snack can be made by deep frying crumb coated balls of mashed potato and paneer. Paneer can be blended with other ingredients and used as a sandwich filling (Anon., 2011).

2.21 Sensory quality of paneer and evaluation

Sensory quality is a combination of different senses of perception coming into play in choosing and eating food. Appearance, which can be judged by the eye, eg: color, size, shape, uniformity, absence of defects etc is of first importance in food selection. Flavor embraces the senses of taste, smell and feeling. Odor, a vastly complex sensation is the most important factor in flavor. Kinesthetics, principally concerns about texture and consistency (Ranganna, 2012).

2.21.1 Evaluation of sensory quality

From early times, judging has been the preserve of experts, who had trained themselves to remember and distinguish small differences in odour and taste of specific products like tea, coffee, wine etc. With the development of sensory evaluation techniques on scientific lines, the experts are being replaced by the panels whose sensitivity and consistency have been established by training and repeated tests. The panel members analyze food products through properly planned experiments and their judgments are quantified by appropriate statistical analysis for determining the significance of variation of average scores and the contribution of individual quality characteristics to overall quality. The trained panel is generally constituted of a small number of people who in a rigorously controlled set-up in the laboratory look after quality control of in-line and final product, process development and to a limited extent preliminary acceptance testing (Ranganna, 2012).

2.21.2 Hedonic rating test

Hedonic rating relates to pleasurable or unpleasurable experiences. The hedonic rating test is used to measure the consumer acceptability of food products. The panelist is asked to rate the acceptability of product on a scale usually of nine points ranging from ‘like extremely’ to ‘dislike extremely’. The results are analyzed for preference with data from large untrained panels. Semi trained panels in smaller number are used to screen a number of products for selecting a few for consumer preference studies. The test is more useful in determining the preferences than in determining the differences. To analyze the results, numerical values are assigned to each point on the scale, one point usually being given for ‘like extremely’ and nine points for ‘dislike extremely’ or vice versa. The scale may be reduced to seven or five (Ranganna, 2012).

Part III

Materials and methods

3.1 Materials

3.1.1 Collection of milk

Raw buffalo milk for paneer preparation and analysis was collected from the Himali Krishi Farm, Dharan-12, Chatara line. It was brought in LDPE plastic bags and refrigerated until use. Butter ghee obtained after the cream separation of milk was used as the fat for deep frying of paneer.

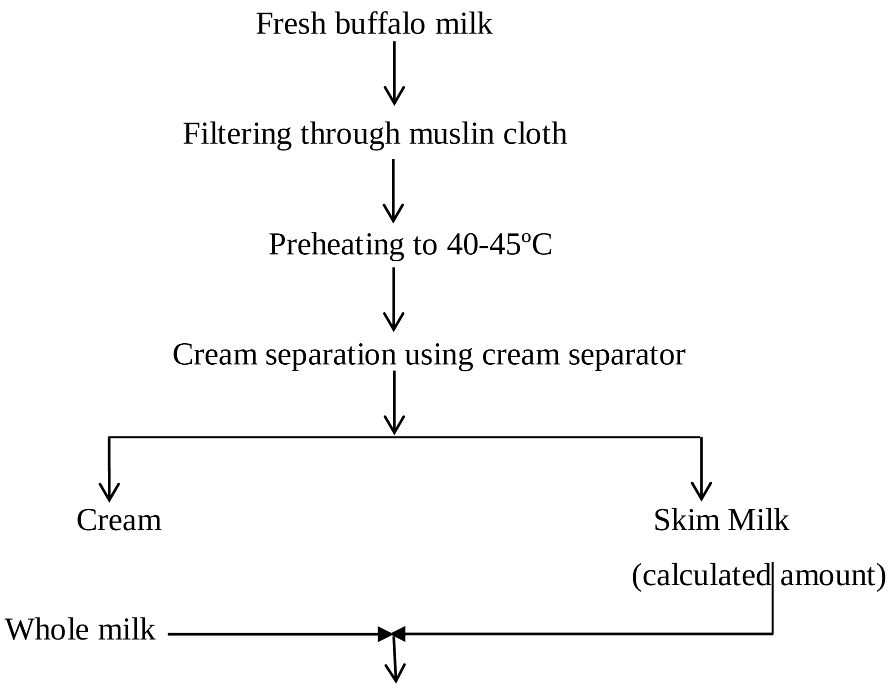
3.2 Materials used

The materials required were used from the labs of Central Campus of Technology. The glasswares, chemicals and instruments used in the research purpose are listed in Appendix B.

3.3 Methodology

3.3.1 Preparation of paneer

Fig. 3.1 shows the procedural flowchart for the paneer preparation.



Standardization (making desired fat content)

↓

Heating to required temperature (80-90ºC)

↓

Cooling to 70ºC

↓

Coagulation of milk by 1% citric acid solution

↓

Stirring till greenish whey separates out from curd

↓

Allowing to stand for 5 min for complete curd-whey separation and curd settlement

↓

Filtration through muslin cloth

↓ → Whey

Pressing the curd in the wooden mould (4"×4"×4") with 2 kg/cm^2 pressure for 25 min

↓

Weighing to get yield

↓

Immersing in clean, chilled water at 4-5ºC for 1-2 h

↓

Cutting the product into rectangular pieces of uniform dimensions having desirable weight

↓

Vacuum packaging in LDPE plastics

↓

Refrigeration for storage and further analysis

Fig. 3.1 Flow chart for the preparation of paneer

Source: Bhattacharya *et al*. (1971a) and Sachdeva and Singh (1988a)

3.3.1.1 Standardization of milk fat

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 the standards requirements for paneer. Buffalo milk was employed for the preparation of paneer. The milk was first sent for the cream separation. Whole milk was used along with skim milk to adjust the required fat content. Standardization was done on weight basis. The standardized milk with respect to fat content was then used for product preparation.

3.3.1.2 Heating of milk

The standardized milk was heated to different temperatures ranging 80ºC to 90ºC for pasteurization at a constant medium flame with continuous stirring. In order to maximize the total solids recovery, it is desirable to heat the buffalo milk to 90°C without holding (Sachdeva and Singh, 1988a).

3.3.1.3 Cooling and coagulation

The heated milk was allowed to cool to 70ºC for coagulation. Smitha *et al.* (2014) suggested the coagulation temperature of 70ºC since the yield was much influenced by fat at this temperature.

1% citric acid solution was used for coagulation. 1% citric acid solution was prepared with fresh water. Acid solution was poured slowly with constant light stirring till greenish whey separated out. It was allowed to stand as such for five minutes for curd settlement and complete curd-whey separation.

3.3.1.4 Whey drainage

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

3.3.1.5 Filtration

The curd-whey mass was then filtered through muslin cloth to separate curd from whey. Filtrate was discarded. Curd was then wrapped properly in the same muslin cloth used and pressed for final shape.

3.3.1.6 Pressing

Pressing was done in a wooden mould of dimension 4"×4"×4" with a pressure of 2kg as per De *et al*. (1971) and Vishweshwaraiah (1986). It was done for 25 min. Pressing was done for complete whey expulsion and to get the final desired shape of the product. After pressing, the pressed curd was weighed for the yield of paneer cut into desired dimensions and then dipped in previously prepared clean chilled water at 3-4ºC for 1-2 h to arrest the growth of microorganisms. Then, it was vacuum packed in LDPE plastic and refrigerated.

3.3.2 Experimental design

Response Surface Method (RSM) of Design Expert 7.1.5 was employed for the systematic sampling and recipe formulation. Response surface methodology (RSM) was adopted in the experimental design as it emphasizes the modeling and analysis of the problem in which response of interest is influenced by several variables and the objective is to optimize this response. A three-level, two-factor Central Composite Rotatable Design (CCRD) was employed. The independent variables selected for the experiments were: fat content and heating temperature. The response variable was yield. The three levels of the process variables were coded as −1, 0 and 1.

The range of fat adjusted was from 3% to 5% and temperature was set in the range of 80ºC to 90ºC. Table 3.1 shows the experimental combinations in coded and uncoded levels for the fat content and heating temperature.

Table 3.1 Experimental combinations in Coded and Uncoded levels for fat content and heating temperature.

S.N.	Sample code	Coded variables		Uncoded variables	
		A	B	Fat content (%)	Heating temperature (°C)
1	A	0	0	4	85
2	B	-1	-1	3	80
3	C	1	-1	5	80
4	D	-1	1	3	90
5	E	1	1	5	90

3.3.3 Sensory evaluation

The prepared and refrigerated samples were cut into pieces of uniform dimensions and kept for sensory analysis. Sensory analysis was performed with thirteen semi-trained panelists evaluating color and appearance, flavor, taste, body and texture and overall acceptability of prepared paneer. The samples were organoleptically evaluated on 9 point hedonic scale rating based upon the degree of their like and dislike (9 = like extremely, 1 = dislike extremely) by panelists comprising of teachers and students of Central Campus of Technology, Dharan. Each panelist was provided with coded samples and a sheet of sensory evaluation card. They were asked to evaluate the sample according to quality attributes like color, flavor, taste, texture and overall acceptability. They were also provided potable water to rinse mouth between the tests. The specimen of score card is given in Appendix A. The results of the sensory evaluation were statistically studied using the software GenStat Release 12.1.

3.3.4 Physicochemical analysis

The physicochemical analysis of the product was done by adopting the methods as follows

3.3.4.1 Moisture content

The moisture content was determined by the oven drying method according to Ranganna (2012).

3.3.4.2 Titratable acidity

The titratable acidity was obtained by titration method as described in Ranganna (2012).

3.3.4.3 Protein content

The protein content of milk was determined by formal titration and of product by the micro kjeldahl method and the nitrogen to protein conversion factor used was 6.25 as explained in Ranganna (2012).

3.3.4.4 Fat content

The fat content of the milk was done using milk fat butyrometer and of product was determined using ether extractives (petroleum ether) in soxhlet apparatus according to Ranganna (2012).

3.3.4.5 Ash content

The ash content was determined according to the total ash method as explained in Ranganna (2012).

3.3.4.6 Lactose content

The lactose content was determined by the Lane and Eynon method according to Ranganna (2012).

3.3.5 Oil uptake

Vegetable oil was used for frying. Deep oil frying was done by immersing the paneer cubes in oil at 160ºC. Oil uptake by the product was calculated using mass balance concept as Kodavali (2012).

$$\text{Oil uptake} = \frac{\text{final fat content} \times \text{mass after frying-intial fat content} \times \text{mass before frying}}{\text{dry mass}}$$

(in dry basis)

3.3.6 Statistical analysis

All the data obtained in this work were analyzed by the statistical program known as GenStat program which was developed by Lawes Agricultural Trust (1955). The results of the sensory evaluation were statistically studied using software GenStat Release version 12.1. The results of sensory analysis were subjected to two-way ANOVA and LSD tests at 5% level of significance among formulations were made. Actually, the judgements of panelists were on the basis of their likes and dislikes but not on the basis of the fat content or treated temperature of the product. The samples were coded as A, B, C, D and E. The ANOVA results of the sensory analysis of all five paneer samples are given in Appendix C.

Part IV

Results and discussions

The present study was carried out to optimize the preparation of paneer. The fresh whole milk was analyzed for proximate composition. It was then preheated to make slightly warm to around 40˚C to make sure every fat globule has melted and skimming would be easier. The product preparation was then started. All samples were prepared and stored accordingly. The prepared paneer were cut into cubes of dimension 2cm×2cm×2cm (±0.5cm) and subjected to sensory evaluation. The best sample was selected from the sensory evaluation and statistical analysis of the data. Physico-chemical analysis of the product was done accordingly.

4.1 Milk composition

Table 4.1 shows the proximate composition of milk.

Table 4.1 Composition of milk used for paneer preparation.

Constituents	Percentage (%,wb)
Moisture	84.7(0.4)
Fat	5.3(0.1)
SNF	9.75(0.02)
Protein	4.52(0.2)
Lactose	4.42(0.2)
Ash	0.8(0.1)

The values in the table are the means of the triplicate samples and the figures in the parenthesis are the standard deviations.

The results of the milk composition from the above data are in accordance with the findings of Gantner *et al*. (2015) and Robinson (1996).

4.2 Standardization of milk

Cream separation of whole milk was done using cream separator. The whole milk was mixed uniformly with the skimmed milk to get the desired fat content. The skimmed milk fat content used in the standardization of sample A, B, C, D and E was 0.1%. Fat standardization was done using the Pearson Square method on weight basis. Table 4.2 shows the results of standardization of milk.

Table 4.2 Results of standardization of milk

Sample	Whole milk used (kg)	Skimmed milk used (kg)	Standardized milk fat (%)
A	2	1.18	4
B	2.2	1.74	3
C	3	0.18	5
D	2.3	1.82	3
E	3	0.18	5

4.3 Effect of fat content and heating temperature on the sensory quality of paneer

4.3.1 Color and appearance

Among five samples, samples A, D and E had the maximum mean sensory score for color and appearance with 7.231 while samples B and C had the minimum score with 7.154. Statistical analysis of the collected data showed that there is no significant effect ($p<0.05$) of fat content and heating temperature on color and appearance at 5% level of significance. All samples were similar in respect to appearance of the product and were not significantly different between each other. The value in vertical axis shows the mean scores given by 13 panelists.

The formulation of all sample were found to be similar in terms of color of the product. The results are in accordance to the findings of (Bhattacharya *et al.*, 1971a). Bhattacharya *et al.* (1971a) studied the effect of different fat levels viz; 6, 3.5 and 1.5% in milk in the sensory characteristics of paneer. They found that the color and appearance was not affected to a remarkable extent but lower fat milk yielded paneer with less acceptability. It is thus concluded that the variation in the fat content and heating temperature does not significantly affect the color and appearance of the product. Fig. 4.1 shows the mean sensory scores for color of paneer.

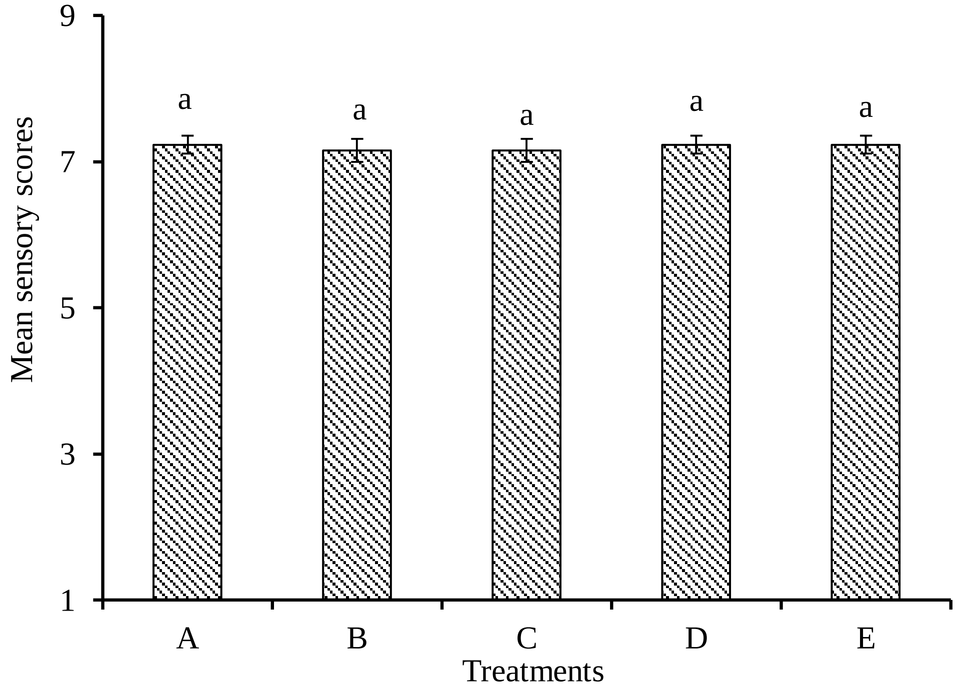


Fig. 4.1 Mean sensory scores for color of paneer

*Values with same letters for any sensory parameter are not significantly different at $p<0.05$.

4.3.2 Flavor

The flavor of paneer has a direct relationship with fat content of milk. Paneer made from milk with fat content up to 3% is fairly acceptable, but reduction in fat percent from this level, the paneer is unacceptable (Chawla *et al.*, 1987). Among five samples sample E got the maximum mean sensory score for flavor with 7.385. Statistical analysis showed that there is significant effect ($p<0.05$) of fat content and heating temperature on the flavor of paneer at 5% level of significance. The mean sensory score of sample E was more than other samples and was significantly different than other samples. Sample E had the proportion of fat and heating temperature of 5% and 90˚C respectively. Similarly samples B and D were less preferred by the panelists and hence got least sensory scores. Statistical analysis showed that they were significantly different than other but were not different among themselves. Fig. 4.2 shows the mean sensory scores for flavor of paneer.

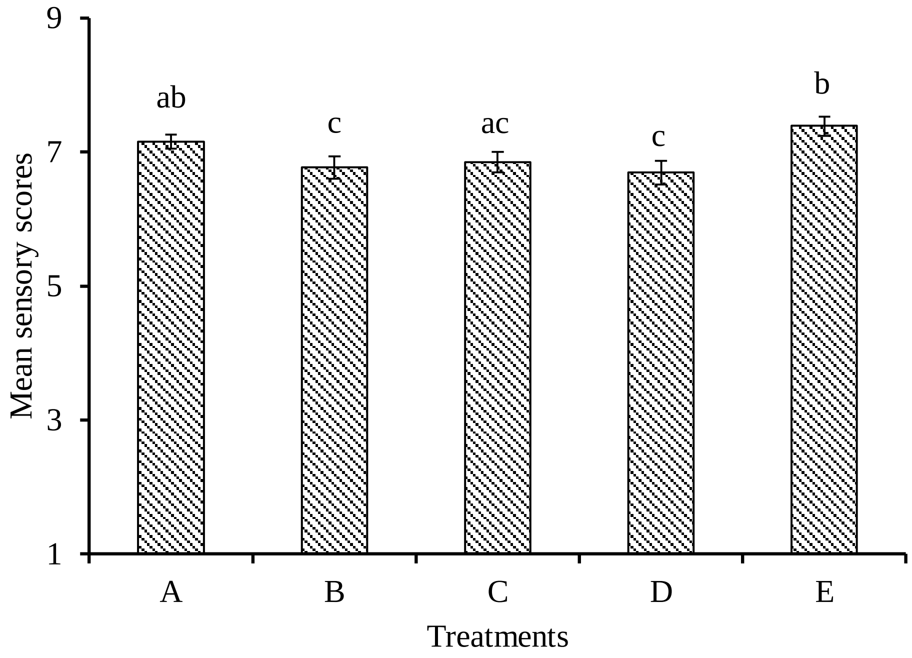


Fig. 4.2 Mean sensory scores for flavor of paneer

*Values with same letters for any sensory parameter are not significantly different at $p<0.05$.

4.3.3 Taste

Among the five samples, sample A and E are found to have the maximum mean sensory score having 6.846 each for taste. Statistical analysis showed that there is significant effect ($p<0.05$) of fat content and heating temperature on the taste of paneer at 5% level of significance. Samples A and E were significantly different in terms of taste than other samples but were not significantly different among themselves. The mean sensory score of sample B and D were less than other samples hence least accepted by the panelists. Fig. 4.3 shows the mean sensory scores for taste of paneer.

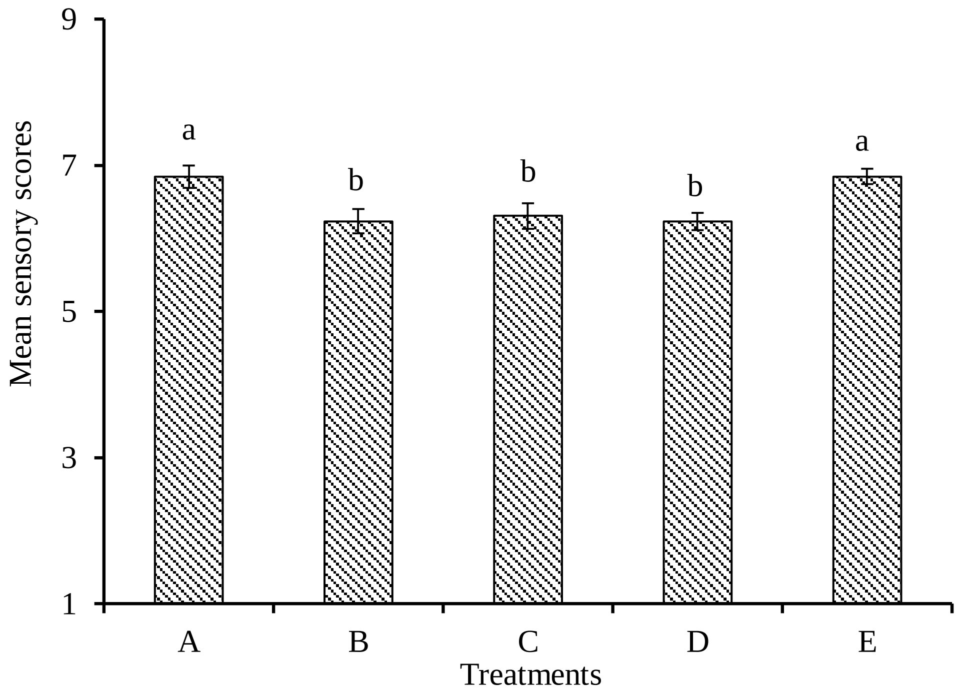


Fig. 4.3 Mean sensory scores for taste of paneer

*Values with same letters for any sensory parameter are not significantly different at $p<0.05$.

4.3.4 Texture

The maximum mean sensory score for texture among five samples A, B, C, D and E was found to be 7.385 and it was of sample E. Statistical analysis showed that there is significant effect ($p<0.05$) of fat content and heating temperature on the texture of paneer at 5% level of significance. The mean sensory score of sample B was least than other samples.

Here among the prepared paneer samples with different formulations of fat percentage and heating temperature, sample E was found to be superior to all followed by sample A. Various researchers suggested use of buffalo milk standardized to 5–6% fat to get product complying with the PFA standards. Bhattacharya *et al*. (1971b) found that buffalo milk contains higher amount of milk solids (fat, proteins, lactose and minerals) than cow's milk. The spongy characteristics of paneer is associated with buffalo's milk, which is the reason for the superior quality of paneer from this milk. Sample B and D were lacking good texture. It is due to the less fat retention in the product. Fig. 4.4 shows the mean sensory scores for texture of paneer.

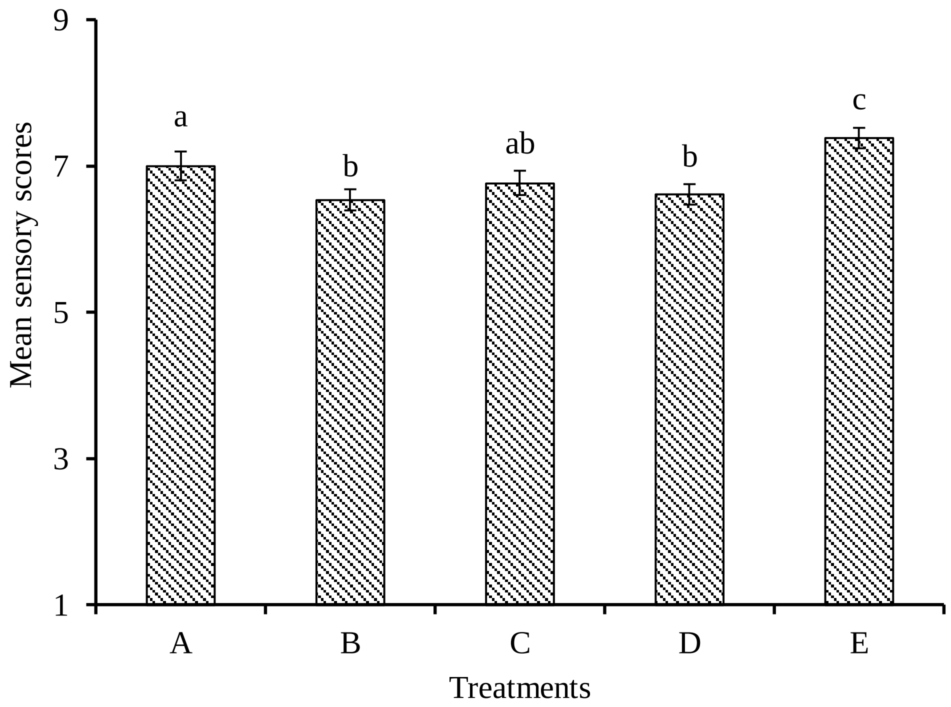


Fig. 4.4 Mean sensory scores for texture of paneer

*Values with same letters for any sensory parameter are not significantly different at $p<0.05$.

4.3.5 Overall acceptance

Heat treatment is one of the technological requirements of the process, which affects the sensory and microbiological quality of paneer. Similarly the fat content of milk affects the yield and sensory attributes. According to the panelists, sample E get the highest mean sensory score for overall acceptance among five samples A, B, C, D and E and was found to be 7.385. Similarly, sample D got the least mean sensory score with a total score of 6.538 respectively. Statistical analysis showed that there is significant effect ($p<0.05$) of fat content and heating temperature on the overall acceptance of paneer at 5% level of significance. The mean sensory score of sample E was more than other samples. Fig. 4.5 shows the mean sensory scores for overall acceptance of paneer.

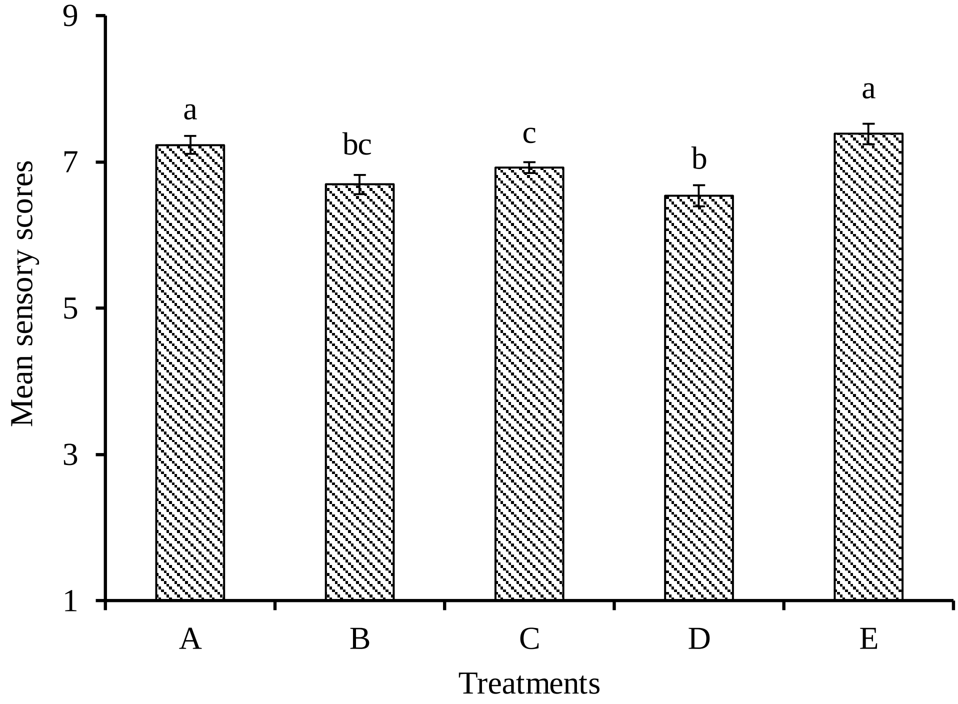


Fig. 4.5 Mean sensory scores for overall acceptance of paneer

*Values with same letters for any sensory parameter are not significantly different at $p<0.05$.

4.4 Yield of paneer samples

The yield of paneer samples A, B, C, D and E were found to be 13.2%, 10.78%, 13.65%, 12.5% and 14.15% respectively. These values were slightly less than the findings of (Smitha *et al.*, 2014). Fig. 4.6 shows the yield of prepared paneer samples.

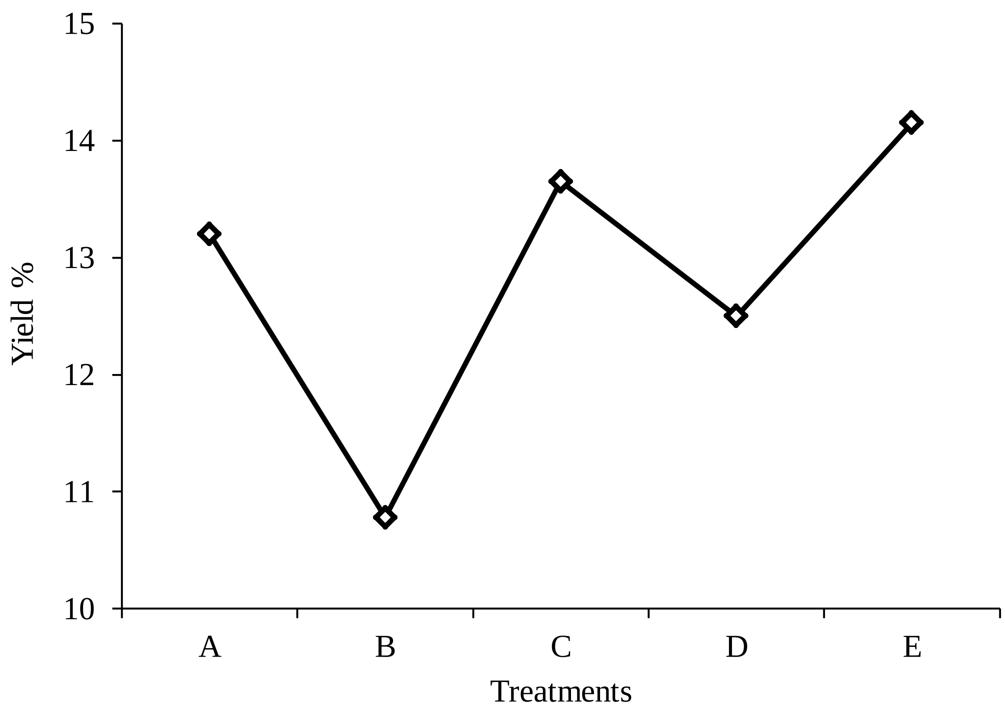


Fig. 4.6 Yield of the prepared paneer samples

The yield and TS recovery increased with increase in heating temperature while solids in whey decreased. This is due to complex formation between whey proteins and casein. At higher temperature, casein acts as scavenger for serum proteins, which are otherwise lost in whey. Sachdeva and Singh (1988a) recommended a final heating temperature of 90ºC (without holding) to be the most suitable for the manufacture of paneer. A lower final heating temperature (<80ºC) resulted in a product with poor consistency. In order to maximize the total solids recovery, it is desirable to heat the buffalo milk to 90°C without holding. Milk heated at 90ºC without any holding, results in paneer with a total solids recovery of about 66%. The recovery does not increase appreciably on holding the milk at 90ºC and is, therefore, not required (Sachdeva and Singh, 1988a).

Higher fat in milk also results in lower moisture retention in paneer and, therefore, a loss in terms of yield. Paneer of good quality can never hold moisture beyond 60% and thus the value of 70% as the maximum limit for moisture in paneer as stipulated in PFA standards appears to be too high. The yield of paneer mainly depends on the fat and SNF of milk as well as on the moisture, fat and protein retained in the paneer (Bhattacharya *et al.*, 1971a); (Sachdeva and Singh, 1988a). The yield and TS recovery increased with increase in heating temperature while solids in whey decreased. This is due to complex formation between whey proteins and casein. At higher temperature, casein acts as scavenger for serum proteins, which are otherwise lost in whey. Sachdeva and Singh (1988a) recommended a final heating temperature of 90ºC (without holding) to be the most suitable for the manufacture of paneer. In order to maximize the total solids recovery, it is desirable to heat the buffalo milk to 90°C without holding. Milk heated at 90ºC without any holding, results paneer with a total solids recovery of about 66% (Sachdeva and Singh, 1988a).

The sample formulation with 5% fat content and heated at 90ºC had the highest yield. It is due to the significantly higher retention of milk fat and SNF into the curd. Smitha *et al.* (2014) concluded that the highest yield of paneer was obtained at coagulation temperature of 70ºC with optimum moisture percentage. They also observed that when milk was coagulated at 70ºC, the yield was more influenced by fat. The milk used in the sample E preparation had fat and SNF content of 5.3% and 10.22% respectively. The yield in percentage of all paneer samples is shown in the figure above. The yield of prepared paneer were found to be slightly less than that found by Smitha *et al.* (2014).

4.5 Proximate Composition of Paneer

The proximate composition of the best product (formulation-E) was determined. The moisture content, protein, content, fat content lactose content and ash content of paneer were found to be 54.6%, 18.8%, 22.5%, 2.0% and 2.1% respectively. The pH and titratable acidity were found to be 5.83±0.057 and 0.225±0.0011 respectively. These values were similar to the findings of Masud *et al.* (1992), Desale *et al.* (2009) and Kumar *et al.* (2014). Table 4.3 shows the results of the composition of paneer.

Table 4.3 Results of the composition of the paneer

Constituents	Percentage (%,wb)*
Moisture	54.6(0.2)
Protein	18.8(0.3)
Fat	22.5(0.2)
Lactose	2.0(0.01)
Ash	2.1(0.06)

*The values in the table are the mean of the triplicates and values in the parenthesis are the standard deviation and are in wet basis.

According to a study by Masud *et al.* (1992), the total solids, fat, protein, lactose and ash content of paneer made from buffalo milk was 49.93%, 28.86%, 16.07%, 2.33% and 2.67% respectively which closely matches with my findings. Similarly, another study by Desale *et al.* (2009) found the average moisture content of paneer to be 52.90%, fat content in the range of 16-28% and average protein content of 18% from wide variety of samples. The results of my study are comparable to the findings of Desale *et al.* (2009). The results of table 4.4 are also in accordance to the findings of Kumar *et al.* (2014) where moisture content of 56.77%, fat content of 22.30% and protein content of 16.62% of paneer was observed.

4.6 Oil uptake by paneer

Vegetable (sunflower) oil was used for deep frying of paneer. Vegetable oil was used since it contains health friendly unsaturated fat and have higher value of smoke point (Farkas *et al.*, 1956; Simmons, 2017). The frying temperature was set to 160ºC because Mirzaei *et al.* (2015) recommended it since frying at 160ºC gave the product with best texture and suitable crust thickness but higher temperature than this offered very thick crust. Fig. 4.7 shows the results of the oil uptake by paneer samples.

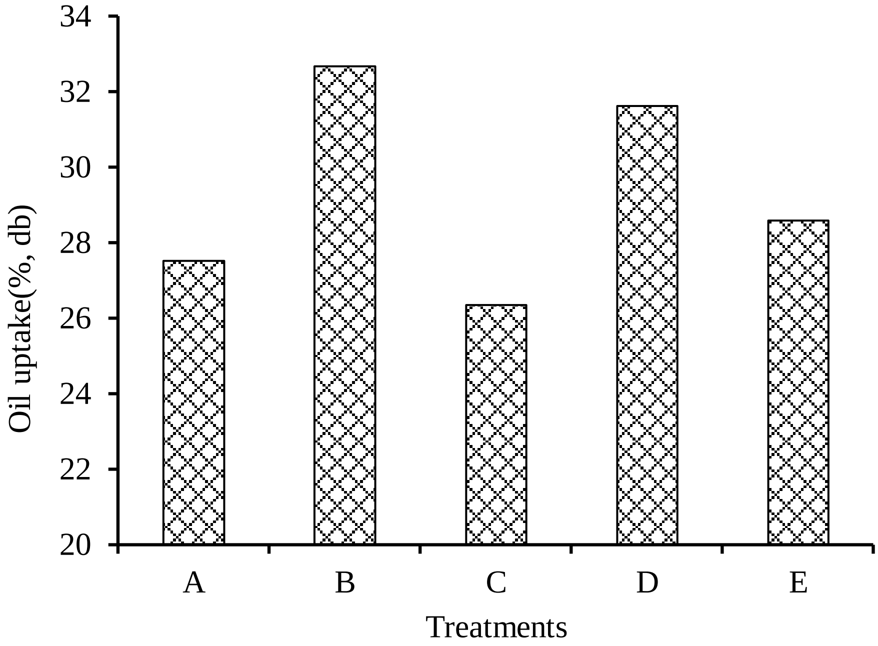


Fig. 4.7 Results of oil uptake by the paneer samples

The samples were diced into cubes of approximately 2cm × 2cm × 2cm (±0.5cm). Deep oil frying was done at a temperature of 160ºC for 2 min. The oil uptake by paneer samples after deep oil frying was calculated in dry basis. 10 g deep oil fried sample was taken for the oil uptake determination. Sample E yielded the maximum 2.3 g oil than all other samples. During frying, water escapes from the food while oil migrates into the food providing nutrients and flavors. Deep oil frying process involves both mass transfer, mainly represented by water loss and oil uptake, and heat transfer. The moisture removal from food material must be sufficient to ensure the optimum fat uptake (Farkas *et al.*, 1956; Ziaiifar, 2008). The results of oil uptake supported the review done by Ziaiifar (2008).

The paneer samples B and D were found to have higher values for oil uptake i.e. 32.67% and 31.62% respectively. The samples A, B, C, D, and E had the oil uptake 27.51%, 32.67%, 26.35%, 31.62% and 28.59% respectively. Oil uptake is dependent in the initial fat and moisture content of the product. Higher value of fat means lower will be the moisture content. During frying, oil fills the voids created in the product by rapid loss of water vapor. The less moisture content means less oil uptake since the amount of moisture leaving the frying material becomes minimum allowing less space for oil to penetrate and fill the void spaces and vice-versa. The samples B and D had less initial fat content and higher values for moisture content than other which resulted greater value of oil uptake. During frying, porosity increases due to forceful water evaporation and pore formation which makes way for oil penetration to the interior of food being fried. During cooling, surface oil temperature tends to decrease while adhered oil interfacial tension and viscosity increases resulting in more oil absorption. The quality of frying oils as well as fatty acids composition and degree of degradation of fat, frying medium, oil content and frying temperature affects the oil uptake and texture of fried food products (Mirzaei *et al.*, 2015). Choe and Min (2007) observed the oil uptake in different food products. They found the oil uptake in potato chips, corn chips, tortilla chips, dough nuts, French fries and fried noodles to be in between 33 -38%, 30-38%, 23-30%, 20-25%, 10-15% and 14% (Choe *et al.*, 1993) respectively. Similarly according to a study by Mirzaei *et al.* (2015) the oil uptake of potato French fries was 23% to 28% at 160ºC and180ºC respectively. It was observed that the oil uptake was higher at around 180ºC than 160ºC (Mirzaei *et al.*, 2015).

4.7 Cost calculation

The cost of the product was calculated by considering the cost of raw materials, transportation cost and processing cost used in paneer with 10% overhead cost of the final product. The cost of paneer was calculated to be NRs. 632.86/kg. The cost calculations are given in Appendix D.

Part V

Conclusion and recommendation

5.1 Conclusion

This study was carried to understand the role of fat content of milk and heating temperature in the yield and physicochemical properties of the product. Semi trained panelists of the Central campus of technology were employed in the sensory evaluation. The conclusions of the study are summarized into the following points

I. The highest value of yield of paneer was observed to be 14.15% for the formulation with 5% fat and heated at 90ºC.

II. Fat content and heating temperature had not significant effect in the color and appearance of the products but had significant effect in the flavor, taste, texture and overall acceptance of paneer.

III. From sensory analysis, sample formulation of 5% milk fat heated at 90ºC was found best.

IV. The oil uptake by the product (best sample) was calculated to be 28.59% in dry basis.

V. The cost of paneer was calculated to be Rs. 632.86/kg.

5.2 Recommendations

Based on this study, following recommendations have been made

I. For commercial scale production, calcium phosphate incorporation can be done to increase the yield of paneer.

II. Effect of coagulating agents other than citric acid can be studied.

III. The findings of thesis can be used by the manufacturers (domestic or industrial scale) to make much acceptable product according to sensory attributes.

Part VI

Summary

Paneer is a high protein food prepared after coagulating the milk. Paneer is a high nutrient diet containing a good amount of fat and protein. Because of high protein and fat content and easy availability of milk; paneer production can be done as an alternative to the meat protein. It is also becoming a great animal protein supplement for vegetarians. It is hugely popular in the eastern Asia and mostly in the Indian subcontinent.

For this study, milk was brought from the local dairy of Dharan. Cream separation was done to adjust the fat content accordingly. The product was prepared after heating milk at suitable required temperature followed by coagulation with 1% citric acid solution and pressing in a wooden mould of 4"×4"×4" dimension. The sample formulation for the study was adjusted according to the fat content and heating temperature of milk. Altogether five different formulations were prepared. A Central composite Rotatable Design (CCRD) for two variables at three levels was designed for experimental combinations. Sensory analysis by thirteen semi-trained panelists based upon nine point hedonic rating scale was done and the sensory scores obtained were statistically analyzed using two way ANOVA (no blocking) at 5% level of significance.

The formulation of 5% fat content in milk heated at 90ºC gave the best outcome in terms of sensory score, they were preferred by the sensory panelists over other samples. The percentage yield was highest for the product with same formulation. Further physico-chemical analysis of the best sample was done.

From the study it is concluded that fat content and heating temperature had not significant effect in the color and appearance of the products but had significant effect in the flavor, taste, texture and overall acceptance of paneer. Appreciable paneer can be prepared using buffalo milk with fat content of 3-5%, heating at 80-90ºC. The oil uptake was found to be in the range of 26-32% (db) and cost of the product was calculated to be Rs.632.86 per kg.

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Appendices

Appendix A

Specimen card for sensory evaluation

Sensory Evaluation of Paneer

Name of panelist:…………………

Date:………………………

Name of the product:……………………..

Please test these given samples and check how much you like or dislike each one i.e. by your perception of individual parameters. Please give points for your like or dislike as given below, for each parameters.

Parameters	Samples				
	A	B	C	D	E
Color and appearance					
Flavor					
Taste					
Body and Texture					
Overall acceptance					

Give points as follows

Like extremely:9

Like very much:8

Like moderately:7

Like slightly:6

Neither like nor dislike:5

Dislike slightly:4

Dislike moderately:3

Dislike very much:2

Dislike extremely:1

Comments:

……………………………………………………………………………………………………

……………………………………………………………………………………………………

____

Signature

Appendix B

Table C.1 Materials used in product preparation

S.N.	Materials used
01.	Centrifuge
02.	Cream separator
03.	Wooden mould (for pressing)
04.	Van Gulik butyrometer
05.	Refrigerator
06.	Vacuum sealer
07.	Heating vessels
08..	Heating system
09.	Thermometer
10.	Muslin cloth
11.	Packaging plastics LDPE
12.	Titration set
13.	Kjeldahl protein determination set
14.	Digital electronic balance
15.	Hot air oven
16.	Muffle furnace
17.	pH meter
18.	Beakers
19.	Volumetric flasks
20.	Amyl alcohol
21.	Gerber acid (90 % sulfuric acid)
22.	Citric acid

Appendix C

(Data of GENSTAT release of paneer)

Two way ANOVA (no blocking) for sensory analysis of paneer samples

Table C.1 Mean sensory scores for different treatments

Samples	Treatment				
	Color	Flavor	Taste	Texture	Overall acceptability
A	7.231^{a}	7.154^{bc}	6.846^{b}	7^{b}	7.231^{c}
B	7.154^{a}	6.769^{a}	6.231^{a}	6.538^{a}	6.692^{ab}
C	7.154^{a}	7.154^{bc}	6.308^{a}	6.769^{ab}	6.923^{b}
D	7.231^{a}	6.692^{a}	6.231^{a}	6.615^{a}	6.538a
E	7.231^{a}	7.385^{c}	6.846^{b}	7.385^{c}	7.385^{c}
Grand mean	7.2	6.969	6.492	6.862	6.954

The values are the mean of sensory scores given by thirteen panelists. The samples having same superscript in each column did not vary significantly at 5% significance level.

F-ratio ≤ 0.05 indicates significant difference at 5% level of significance.

Two way ANOVA results for sensory analysis of paneer

Table C.2 Two way ANOVA (No blocking) for color

Source of variation	d.f	s.s	m.s.	v.r.	F pr.
Panelist	12	6.4	0.5333	3.24	0.002
Sample	4	0.0923	0.0231	0.14	0.966
Residual	48	7.9077	0.1647		
Total	64	14.4			

Since F pr>0.05, there is no significant difference between the samples so, LSD testing is not necessary.

Table C.3 Two way ANOVA (No blocking) for flavor

Source of variation	d.f	s.s	m.s.	v.r.	F pr.
Panelist	12	9.9385	0.8282	5.23	<.001
Sample	4	4.4	1.1	6.95	<.001
Residual	48	7.6	0.1583		
Total	64	21.9385			

Since, F pr <0.05, there is significantly different between the sample so, LSD testing is necessary.

Table C.4 LSD for flavor LSD at 0.05=0.3138

Sample code	Mean score	Mean difference	
A	7.154	A-B>LSD*	B-D<LSD
B	6.769	A-C<LSD	B-E>LSD*
C	6.846	A-D>LSD*	C-D<LSD
D	6.692	A-E<LSD	C-E>LSD*
E	7.385	B-C<LSD	D-E>LSD*

*=significantly different

Table C.5 Two way ANOVA (No blocking) for taste

Source of variation	d.f	s.s	m.s.	v.r.	F pr.
Panelist	12	7.8462	0.6538	3.52	<.001
Sample	4	5.4769	1.3692	7.37	<.001
Residual	48	8.9231	0.1859		
Total	64	22.2462			

Since, F pr <0.05, there is significantly different between the sample so, LSD testing is necessary.

Table C.6 LSD for taste LSD at 0.05=0.34

Sample code	Mean score	Mean difference	
A	6.846	A-B>LSD*	B-D<LSD
B	6.231	A-C>LSD*	B-E>LSD*
C	6.308	A-D>LSD*	C-D<LSD
D	6.231	A-E<LSD	C-E>LSD*
E	6.846	B-C<LSD	D-E>LSD*

*=significantly different

Table C.7 Two way ANOVA (No blocking) for texture

Source of variation	d.f	s.s	m.s.	v.r.	F pr.
Panelist	12	8.5538	0.7128	3.07	0.003
Sample	4	6.0615	1.5154	6.53	<.001
Residual	48	11.1385	0.2321		
Total	64	25.7538			

Since, F pr <0.05, there is significantly different between the sample so, LSD testing is necessary.

Table C.8 LSD for texture LSD at 0.05=0.3799

Sample code	Mean score	Mean difference	
A	7.0	A-B>LSD*	B-D<LSD
B	6.538	A-C<LSD	B-E>LSD*
C	6.769	A-D>LSD*	C-D<LSD
D	6.615	A-E>LSD*	C-E>LSD*
E	7.385	B-C<LSD	D-E>LSD*

*=significantly different

Table C.9 Two way ANOVA (No blocking) for overall

Source of variation	d.f	s.s	m.s.	v.r.	F pr.
Panelist	12	6.0615	0.5051	3.88	<.001
Sample	4	6.5538	1.6385	12.59	<.001
Residual	48	6.2462	0.1301		
Total	64	18.8615			

Since, F pr <0.05, there is significantly different between the sample so, LSD testing is necessary.

Table C.10 LSD for overall LSD at 0.05=0.2845

Sample code	Mean score	Mean difference	
A	7.231	A-B>LSD*	B-D<LSD
B	6.692	A-C>LSD*	B-E>LSD*
C	6.923	A-D>LSD*	C-D>LSD*
D	6.538	A-E<LSD	C-E>LSD*
E	7.385	B-C<LSD	D-E>LSD*

*=significantly different

Appendix D

Cost calculation for paneer

Table D.1 Cost calculation for paneer

Ingredients	Rate	Quantity	Cost
Milk	80/ltr	3.18 L	254.4
Citric acid	900/kg	5 g	4.5
Total cost			258.9
Final cost with 10% overhead			284.79
Product prepared			450 g
Cost/kg			632.86

Photo Gallery

Plate 1. Wooden mould (4"×4"×4")

Plate 2. Prepared paneer samples

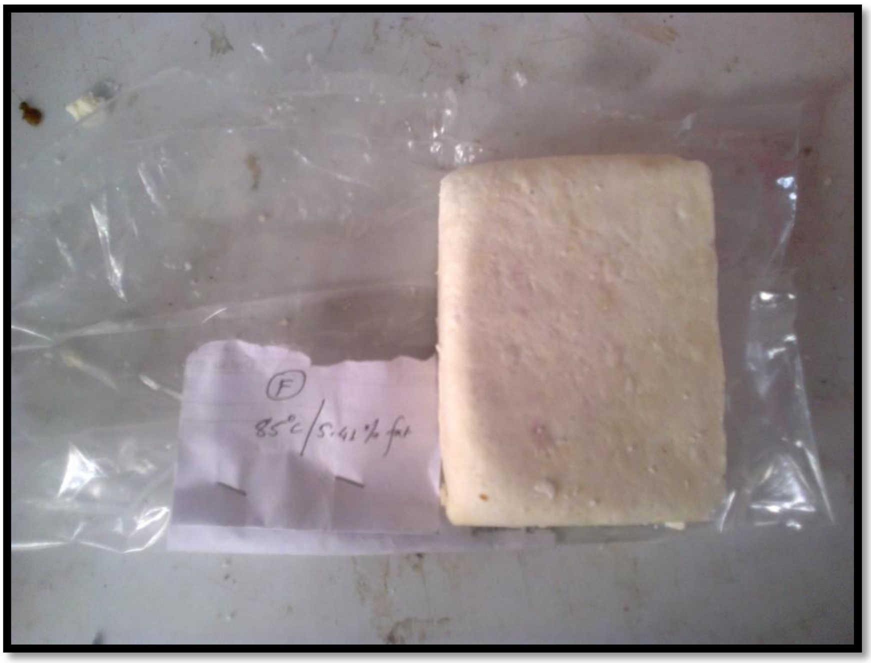

Plate 3. Best sample

Plate 4. Oil fried paneer cubes