Paper 07: Technology of Milk and Milk Products
Module 26: Technology of processed cheese and processed cheese-based products

Introduction

Process cheese is a cheese product that is not made directly from milk, unlike natural cheese. The main ingredient of process cheese is natural cheese. Process cheese is produced by blending natural cheese of different ages and degrees of maturity in the presence of emulsifying salts and other dairy and non-dairy ingredients, followed by heating and continuous mixing to form a homogeneous product with an extended shelf life. The origin of process cheese dates back to the early 20th century. The initial idea of process cheese was to increase the shelf life of natural cheese and find alternative uses for natural cheese that was difficult to sell.

Process cheese was invented in 1911, in Switzerland, by Walter Gerber and Fritz Stettler of Gerber and Co. who melted Swiss cheese using sodium citrate as the emulsifying salt. A few years later, in the United States, the development of process cheese was brought about by J. L. Kraft in 1916, when he preserved natural cheese in cans by heating and mixing it to extend its shelf life. The development of process cheese with the use of phosphate-based emulsifying salts in the United States was attributed to J. L. Kraft and the workers from Phenix Cheese Co. who was awarded numerous patents for their work on process cheese between 1916 and 1938.

Definition of Processed cheese and related products as per FSSAI

***Processed cheese*:** It is the product obtained by grinding, mixing, melting and emulsifying one or more varieties of cheeses with the aid of heat and emulsifying agents. It may contain cream, butter, butter oil and other milk products subject to maximum 5.0 % lactose content in the final product and edible common salt, vinegar/acetic acid, spices and other vegetable seasoning and foods other than sugars properly cooked or prepared for flavouring and characterization of the product provided these additions do not exceed $1/6^{th}$ of the weight of the total solids of the final product on dry matter basis and cultures of harmless bacteria and enzymes. It shall have a pleasant taste and smell free from off-flavour and rancidity.

The specifications for both processed cheese and cheese spread are furnished in Table 1. Processed cheese chiplets (packed sliced cheese), when sold in a package other than tin, shall contain a maximum of 50.0 % moisture.

Processed cheese spread (PCS): It is the product obtained by grinding, mixing, melting and emulsifying one or more varieties of cheese with emulsifying agents with the aid of heat. It may contain cream, butter oil and other dairy products, subject to a maximum limit of 5.0 % lactose in the final product, salt, vinegar, spices, condiments and seasonings, natural carbohydrate sweetening agents namely sucrose, dextrose, corn syrup, corn syrup solids, honey, maltose, malt

syrup and hydrolyzed lactose and food properly cooked or otherwise prepared for flavouring and characterization of the product, provided these additions do not exceed $1/6^{th}$ of the weight of total solids of the final product on dry weight basis and cultures of harmless bacteria and enzymes. It shall have a pleasant taste and flavour free from off-flavour and rancidity.

Table 1. Special requirements for processed cheese and cheese spreads as per FSSAI

Parameters	Processed cheese	Processed cheese spread
Moisture (%), Max.	47.0	60.0
Milk fat (dry basis, %), Min.	40.0	40.0

Table 2. Microbial specifications for processed cheese and cheese spreads as per FSSAI

Type of count	Specified limit
Total plate count per g (Max.)	50,000
Coliform	Absent in 0.1 g
E. coli	Absent in 1 g
Yeast and Mold count	Absent in 1 g
Anaerobic spore count	Absent in 1 g
Salmonella	Absent in 25 g
Shigella	Absent in 25 g
Listeria monocytogenes	Absent in 25 g

FSSAI – Food Safety and Standards Authority of India

Processed cheese food: There is yet another category of processed cheese called 'Processed cheese food' in countries abroad. Pasteurized process cheese food must contain at least 51% cheese, not more than 44% moisture, and ≥ 23% fat. Acids may be used to adjust the pH to 5.0. In addition to the optional ingredients permitted for process cheese, cheese foods may also contain other dairy products such as milk, whey, and high-moisture cheeses such as skim milk cheese.

Cold pack/Club cheese: A blend made from different batches of cheese of some variety; or two or more varieties of mild and sharp natural cheese that have been ground (comminuted). Unlike processed cheese, cold pack is not heat treated nor cooked at the time of packaging.

Food additives used in processed cheese or cheese spread formulation

Natural cheese of varying maturity level is the major ingredient for preparation of processed cheese or cheese spreads. Emulsifier levels are limited to 3 % (w/w) phosphate- or citrate-based salts; optional ingredients include cream, anhydrous milk fat or dehydrated cream, acidifying agents, water, salt, artificial colors, mold inhibitors, enzyme-modified cheese, and lecithin as an anti-sticking agent. In addition to the optional ingredients permitted for processed cheese foods (PCF) may also contain other dairy products such as milk, whey, and high-moisture cheeses such as skim milk cheese.

Natural cheese: Natural cheese has a marked influence on total calcium, intact casein, and pH and hence, the final functional properties of process cheese. Various types of natural cheeses such as Cheddar, Swiss, Gouda, and so on, are used to manufacture process cheese. Depending on the type of process cheese being made, the amount of natural cheese in a process cheese formula varies from 51% to >80% of the final process cheese. Appropriate selection of natural cheese is critical to achieve a process cheese with the desired chemical and functional characteristics. The natural cheese used in a process cheese formulation is generally selected on the basis of type, flavor, maturity, consistency, texture and pH. Process cheese manufacturers select the appropriate blend of young and aged natural cheese in order to achieve process cheese with desired flavor and textural properties. As the age of natural cheese used in process cheese manufacture increases, the unmelted firmness of the process cheese decreases while the meltability of the process cheese increases.

The level of unhydrolyzed casein in relation to total nitrogen in raw cheese is termed as 'Relative Casein Content' (RCC). The extent to which the casein is degraded in cheese for processing will influence the melting characteristics and the structure and properties of final product. Block processed cheese (BCC) which has good slicing properties, generally requires a raw material which has a long structure and a RCC of > 70% i.e. predominantly young cheese. To produce BCC with good grating and toasting properties, the RCC should be 80-85%. In order to prepare spreadable type processed cheese, the blend should be composed of medium-ripe raw material, a small proportion of young cheese to increase stability and some ripe cheese to impart a strong flavor.

Emulsifying salts (ES): These are ionic compounds made up of monovalent cations and polyvalent anions which have a major influence in processed cheese manufacture. The two primary functions of ES in process cheese are 'calcium sequestering' (to disrupt the calcium–phosphate-linked protein network present in natural cheese) and 'pH adjustment'. Both these functions help in hydrating the caseins present in natural cheese so as to easily interact with the water and fat phases, thereby producing a homogeneous process cheese emulsion.

Examples of ES used in processed cheese industry include mono-, di-, and trisodium phosphates, dipotassium phosphate, sodium hexametaphosphate (SHMP), sodium acid pyrophosphate, tetrasodium pyrophosphate, sodium aluminum phosphate, sodium citrate, potassium citrate, calcium citrate, sodium tartrate, and sodium potassium tartrate. The most common ES used are trisodium citrate (TSC) and disodium phosphate (DSP); sodium aluminium phosphate is gaining popularity. TSC is the preferred emulsifying salt for slice-on-slice process cheese varieties, whereas DSP (or appropriate combinations of di- and trisodium phosphates) is used in loaf-type process cheese and process cheese spreads. Sometimes, low levels of SHMP are used along with these emulsifying salts.

Phosphate emulsifying salts have a bacteriostatic effect on process cheese products, which provides protection against the growth of *Clostridium botulinum.*

Rework cheese: 'Rework' is a term used to describe process cheese produced in a manufacturing facility that cannot be sold for a variety of reasons. The type of rework ranges from process cheese lost during production line changeovers; shavings and edge trimmings removed during slice line operations; residual process cheese that is removed from the cookers, lines, hoppers, and packaging machines, also referred to as 'hot melt'; and process cheese that has been rejected by quality control due to improper weight, packaging, or based on quality defect. In general, the addition of rework tends to decrease the meltability and produce a firmer process cheese. It is recommended not to use rework cheese exceeding 4% of total cheese blend to avoid any undesirable effect on cheese properties. The phenomenon where excessive cooking of process cheese can increase the interactions among the caseins to such an extent that they attain a thick pudding-like consistency is referred to as 'overcreaming', which maybe caused through excessive usage rate of rework cheese.

However, in Europe, fresh rework cheese which has a weakly dispersed (hydrated) protein structure (i.e. long structure), can be effectively used to stabilize a process cheese that might show a tendency to overcream under normal cooking conditions. Normal rework with optimum protein dispersion and emulsification can be used from 2-30% in process cheeses, where the creaming action is desired.

Nonfat dried milk/dried whey/whey protein concentrate: The levels of dairy-based ingredients other than natural cheese used in processed cheese are specifically defined by the regulations. Ingredients such as Non-fat dried milk (NFDM) and whey-based dairy ingredients such as liquid whey, whey powder, and whey protein concentrate (WPC) can be used in processed cheese food (PCF) and PCS. Since the addition of these ingredients to process cheese formulation helps to reduce the cost of the product, manufacturers often try to maximize the addition of NFDM and whey based dairy ingredients in their products. Since commercial NFDM and dried sweet whey have lactose content of about 50% and 75%, respectively, and commercial NFDM and WPC have a significant amount of whey proteins, two important formulation factors viz., (i) level of lactose and (ii) level of whey protein provided by such ingredients in the final product need to be taken into account. Excess of lactose may lead to 'sandiness' problem, while excess of whey proteins may hinder 'meltability' of processed cheese.

Food gums/Hydrocolloids: The Code of Federal Regulations (CFR) of Food and Drug Administration (FDA) allows gums or hydrocolloids to be used in PCS at maximum level of 0.8% of the finished product. These include carob bean gum, gum karaya, gum tragacanth, guar gum, gelatin, sodium carboxy methylcellulose, carrageenan, oat gum, sodium/propylene glycol alginate, or xanthan gum singly or in combination. Since PCS has a high moisture content (up to 60%), the major function of gums is to bind water and to provide appropriate

viscosity/thickening to the product and improve its mouth feel. Therefore, gums in a PCS formula have an effect on melted textural properties. The selection of any gum depends on the ease of dispersibility, solubility, hydration behavior, moisture holding ability, cook viscosity, compatibility with milk proteins and other compounds present in process cheese, and optimum working pH range. Another important area where the use of gums is gaining popularity is in 'low-fat' and 'reduced-fat' process cheeses. Typical usage levels for gums in these applications are 0.1% to 0.5%.

Sodium alginate forms a non-thermoreversible gel in the presence of calcium, and gives a glossy look to process cheese spreads. Pectins can be added to a low-pH product, such as a spread flavored with salsa, to prevent the dehydration of casein during heat treatment and the subsequent development of a gritty texture.

Acidifiers/pH controlling agents: Citric acid, phosphoric acid, acetic acid, lactic acid, sodium hydrogen carbonate and/or calcium carbonate have been used to control the pH of resultant processed cheese.

Colours: Annatto, β-carotene, chlorophyll including copper chlorophyll, riboflavin, oleoresin of paprika, and curcumin have been used as colouring matter.

Enzyme modified cheese (EMC) flavouring: For creating a process cheese with a nice, characteristic cheese flavor, EMCs are the primary ingredient of choice. However, process cheese products can only be flavored with an EMC made from the cheese variety for which it is used as a flavoring agent.

Preservatives: Either sorbic acid and its sodium and potassium salts, propionic acid and its sodium and calcium salts or nisin have been used for extending the shelf life of cheese products. Nisin is a compound produced by certain strains of *Lactococcus lactis,* which exerts activity against certain Gram-positive bacteria. The United States FDA affirmed GRAS status for nisin in 1988 and approved its use in process cheese spreads at a usage rate of maximum 250 ppm nisin preparation. Use of 100 to 250 ppm nisin preparation (4000 to 10,000 IU nisin/g) was required to prevent botulinal growth and toxin production in cheese spreads. Sorbic acid is a short chain unsaturated fatty acid with a water solubility of 0.16%. It is about three-fold more soluble in fat. Potassium sorbate is more soluble in water. The antimicrobial activity of sorbate is pH dependent and increases as the pH approaches its dissociation constant. Sorbic acid may be added to process cheese at levels below 0.2% (w/w).

Optional ingredients in processed cheese food

- Cream, butter and butteroil and other dairy products
- Salt (sodium chloride)
- Vinegar
- Spices and other vegetable seasonings in sufficient quantity to characterize the product
- For flavouring the product, foods properly cooked or otherwise prepared, may be added in sufficient quantity to characterize the product provided these additions, calculated on the basis of dry matter, do not exceed one sixth of the weight of the total solids of the final product.
- Sugars (any carbohydrate sweetening matter)
- Cultures of harmless bacteria and enzymes

Manufacture of processed cheeses

The major steps in process cheese manufacture can be divided into two stages:

I. Ingredient selection and formulation

- Selection and grinding of natural cheese (on the basis of age, pH, flavor, and intact casein content)
- Selection of an appropriate emulsifying salt
- Formulation and computation of other ingredients (to meet legal standards)

II. Process cheese processing and storage

- Cooking (heat and mixing)
- Packaging, cooling, and storage

***Ingredient selection and formulation*:** The first stage of process cheese manufacture involves selection of ingredients and preparation of a formulation. In addition to natural cheese and emulsifying salts, there are various other dairy and nondairy (colors, flavors, spices, food gums, mold inhibitors, etc.) ingredients that are used in process cheese manufacture.

Different ingredients affect the physico-chemical properties, flavor, and the functional properties of process cheese in different ways. Moreover, the appropriate selection of natural cheese and emulsifying salt is very important in order to produce process cheese with desired final properties.

Process cheese processing and storage: In large factories, the shredded cheese is melted continuously and in smaller plants it is transferred to cookers. Firstly, water, salt and emulsifying salt are mixed into the cheese. The mixture is heated to 70-95^{o}C, or even higher (depending on the type of processed cheese) in steam-jacketed cookers and by direct steam injection to speed up the cooking time, 4-5 min for block cheese and 10-15 min for spreads. It is kept constantly agitated during heating, to avoid scorching. The process usually takes place under vacuum. It removes undesirable odors and flavours and makes it easier to regulate the moisture content. The capacity of batch cooker is about 75 kg.

Although, the minimum cook temperature and time specified by CFR for process cheese is 65.5°C for 30 s (FDA 2006), process cheese manufacturers use various types of cookers with different designs and operating conditions to manufacture process cheese. The cookers used may be of batch or continuous type; the type of mixing and agitating systems involved, and the type and mechanism of heating (indirect heating or direct steam injection) may vary. Two common types of batch cookers use single/twin-screw augers (Blentech Cooker, Blentech Corp., Calif., USA) or high speed cutting blades (Stephan Cooker, Sympak Inc., USA). The single/twin-screw auger cookers operate at low mixing speeds (i.e. 50 to 150 rpm) with product temperatures ranging from 70 to 90°C with manufacturing times of 3 to 7 min. The high-speed cutting blade-type cookers operate at 1500 to 3000 rpm at 95 to > 100°C for 2 to 5 min. A recently introduced cooker is the Rota Therm continuous cooker (Gold Peg Intl. Pty Ltd., Victoria, Australia). This cooker operates at a high mixing speed (i.e. 600 to 1000 rpm) with temperatures above 90°C and a residence time of approximately 30 to 40 s. A recent process cheese manufacture involves sterilizing the premixes to 130 to 145°C for 2 to 3 s. The primary method of heating utilized in most of the cookers is direct steam injection.

The processed cheese is then discharged from the cooker into a stainless steel container which is transported to the packaging station and emptied into the feed hoppers of the packaging machines. The packaging machines are fully automatic and can produce packaged of different weights and shapes. Normally, the cheese is hot packed at the cooking temperature.

The spreadable type of processed cheese should be cooled as rapidly as possible and therefore should pass through a cooling tunnel after packaging. Rapid cooling improves the spreading properties. On the other hand, the cheese block should be slowly cooled. After molding, the cheese is left at ambient temperature.

Processing conditions such as cook time, temperature of cooking, extent of agitation (mixing) during cooking, and the rate at which the cooked process cheese is cooled dictates the functional properties of resultant process cheese.

Distinguishing features of processed cheese from natural cheese

In contrast to natural cheese, process cheese can be described as a stable oil-in-water emulsion. The use of ES such as DSP and TSC in process cheese manufactures aids in improving the emulsification properties of caseins by displacing the calcium-phosphate complexes in the insoluble calcium–paracaseinate (Ca-paracaseinate) phosphate network present in natural cheese. This displacement of calcium-phosphate complex disrupts the molecular force that cross-links the various monomers of casein in the network. Such disruption of complex in conjunction with heating and mixing leads to hydration and partial dispersion of the Ca–paracaseinate phosphate network. In addition, the partially dispersed Ca–paracaseinate complex interacts with fat via hydrophobic interactions. After manufacture and during the cooling stage, the partially dispersed

caseinate matrix forms ‘flocs’ and such flocs interact to form a uniform, closely knit gel network. This phenomenon gives rise to fat emulsified by a uniform closely knit protein gel network. Thus, process cheese structure essentially consists of a fat phase evenly dispersed (in the form of fat globules, approximately < 1 to ~ 5 μm in diameter) in a partially dispersed casein gel network.

pH of processed cheese

The final pH of a process cheese has a significant effect on the quality and the type of protein interactions in the resulting process cheese emulsion. The type and level of emulsifying salts and the type and age of natural cheese used during process cheese manufacture have a marked influence on the final pH of the resulting process cheese. The pH range of a good-quality process cheese should be between 5.4 and 5.8. The pH of product should be 5.6-5.9 for spreads, and 5.4-5.6 for types to be sliced. At higher cheese pH (6.1), the process cheese had an open structure and a weaker emulsion.

The final pH of process cheese is an important factor controlling the final structure and thus the functional properties of process cheese. The final pH of the process cheese had influence on the firmness of cheese too; raising the pH of cheese from 5.0 to 6.2, led to an intial increase in the firmness up to about pH 5.8; however, with further increase in pH (5.8 to 6.2), the firmness tended to decrease.

Functional properties of processed cheese

The functional properties expected from block processed cheese are slicing, shredding/grating and meltability. Toasting quality is sometimes anticipated in block cheese. Processed cheese spread should exhibit spreadability at refrigeration temperature.

The meltability of the process cheeses manufactured using TSC and DSP were not significantly different; however, process cheese manufactured using sodium hexametaphosphate had a significantly lower meltability. The firmness of process cheese manufactured using TSC was significantly lower than the process cheeses manufactured using DSP and SHMP.

As the concentration TSC, DSP and SHMP in process cheese (39% moisture, 33% fat) increased, its firmness increased but its meltability decreased. At 2.75% emulsifying salt concentration, PC made using SHMP was the most firm and the least meltable, followed by PC made using DSP and TSC. The pH of the process cheese made using SHMP (@ 2.5% level) was significantly lower (pH 5.3) than the other process cheeses made utilizing DSP, TSC and tetrasodium pyrophosphate (pH 5.9 to 6.0). The meltability and flowability of process cheeses made using TSC and DSP were similar.

Functional properties of processed cheese spread

For PCS, the lower pH limit is 4.0, but in practice the pH is usually 5.4 or higher. To maintain product functionality, flavor, and safety, optional ingredients may also include stabilizers, sweetening agents, and nisin.

Even when the final pH of PCS was adjusted to 5.4 to 5.5, the PCS batches made using Cheddar cheese with higher pH were harder and less meltable, when compared to those made using Cheddar cheese with normal pH.

Packaging material for processed cheese

A typical aluminium foil (11–15 μm) for processed cheese is coated with a protective polymer and a polyvinyl co-polymer with a sealing temperature of 65–75^{o}C. This coating protects the aluminium from corrosion due to salts and acids present in the matrix and also prevents the undesirable migration of aluminium into the cheese body.

End-use applications of processed cheeses

Process cheese is one of the leading cheese varieties in the world that is used as an ingredient in various food preparations (processed foods and food service). In several countries, process cheese is produced and sold in various forms such as loaves, slices, shreds, and spreads and is used as an ingredient in numerous products.

Depending on its end-use application, the functional properties of process cheese can be grouped into two major categories: (i) unmelted texture and (ii) melted texture properties. In addition to the individual functional properties, certain process cheese applications require interaction between the melted and the unmelted textural properties. For example, the process cheese slice for a toasted sandwich should not only have firmness, cohesiveness, and limited adhesiveness so that it has appropriate machineability during manufacture, but it should also have normal melt during toasting.

Shelf life and safety of processed cheese

Premium grade processed cheese should be given a shelf-life guarantee not exceeding 3–4 months, especially when the product is packaged in plastic foils. Products stored in metal cans or tubes may have longer shelf-lives. Processed cheese products usually retain their good quality for up to 6–12 months at room temperature. At room temperature, the product keeps well for about 8 weeks for slices, 20 weeks for small portions, more than 1 year for products packed in tubes or cans. However, even bacteriologically stable products in good packaging usually maintain their quality only for 6–12 months at room temperature. The changes with the age of processed cheese are influenced by four main factors: product composition, processing, packaging and storage conditions (temperature and duration).

Microbiological hazards during processed cheese production can be eliminated by UHT processing: even temperature-resistant spores such as *Clostridium butyricum*, *Clostridium tyrobutyricum*, *Clostridium sporogenes* can be destroyed. Post-sterilization infection could be prevented by hot filling (85-95±1ºC) into the packing.

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