1 Processed Cheese and Analogues: An Overview

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1.1 Historical background

The production of processed cheese started in Europe, and could date to the mid-1890s. Natural cheeses have limited shelf-life and, depending on many factors (i.e. level of moisture content, sanitary conditions during the manufacturing stages and storage conditions of the product), this can range from a few weeks to a couple of years. It is possible to suggest that the idea of processed cheese originated from a desire to extend the shelf-life of natural cheese or to develop a new type of cheese which was milder in taste or more stable. Around the same period, commercial developments were made in Germany for the export of short shelf-life soft cheese, e.g. Camembert, Brie and Limburger, which was achieved by heating the cheeses in metal cans. Similar processing methods were also developed for Dutch cheeses, but the process was most successful in Switzerland by using sodium citrate (Berger *et al*., 1989).

Essential steps in the manufacture of processed cheese is melting and heating blends of natural cheeses (e.g. different types, varying degree of maturity, i.e. fresh/young or matured, and cheese 're-work'), the addition of emulsifying salts, agitation to produce a homogeneous mixture, followed by packaging and cooling or vice versa. The application of heat (i.e. indirect or direct steam injection) inactivates the starter culture organisms and other bacteria, including the enzymes present in natural cheeses, and produces a product with extended shelf-life. Although the casein in natural cheeses possesses certain emulsifying characteristics, the stability of processed cheese could not be achieved without the use of emulsifying salts, such as citrates and phosphates.

Commercial production of processed cheese started in earnest in Europe and the USA between 1910 and 1920. The production techniques were based on Cheddar and other cheese varieties, and used citrates or phosphates as the emulsifying salts. These early attempts to produce good-quality processed cheese were of limited success, but the process became widespread by the 1930s when the emulsifying salts (e.g. polyphosphates and other types) appeared on the market (Berger *et al*., 1989). In addition, other dairy and non-dairy ingredients could be added to the blend before processing, and the use of these ingredients is normally governed by statutory regulation within each country of manufacture.

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Over the past few decades, many aspects of the manufacture of processed cheese have been reviewed by many authors (Jackson & Wearmouth, 1959; Price & Bush, 1974a,b; Shimp, 1985; Sachdeva *et al*., 1988; Marchesseau *et al*., 1997; Schar & Bosset, 2002; Abd El-Salam *et al*., 2005; Dimitreli & Thomareis, 2007; Kapoor & Metzger, 2008), and the same subject has been reviewed in different textbooks (Meyer, 1973; Thomas 1977; Guinee, 1987; Berger *et al*., 1989; Carić, 1991; Merkenich *et al*., 1992a,b, 1994; Carić & Kaláb, 1993; Kaláb, 1995; Carić & Milanović, 1997; Kosikowski & Mistry, 1997; Zehren & Nusbaum, 2000; Guinee *et al*., 2004; Schrader & Hoffman, 2008; Adhikari *et al*., 2009; Bunka *et al*., 2009; Johnson *et al*., 2009). In addition, Mann (1969, 1970, 1974, 1975, 1978a,b, 1981, 1983a,b, 1986, 1987, 1990, 1993, 1995, 1997, 1999, 2003) has compiled several successively up-to-date international digests on processed cheese. Contrary to the current belief, processed cheese is made from good-quality natural cheeses (blends of fresh/young and matured) rather than degraded stock; however, these latter types of cheeses are only used in very small proportions, including re-work processed cheese. In addition, the processing equipment used during the manufacture of processed cheese is known as cooker or kettle (e.g. vertical or horizontal; see Chapter 6), and continuous or batch processes are also available on the market. Although the latter method of processing is more popular as it provides greater control of product quality and is more suitable for large-scale operations, the batch process may be still be favourable in small- and medium-sized production units or, alternatively, because the batch process was developed first – 'old habits die hard'.

In contrast, 'imitation' processed cheese is made from mixtures of dairy and/or non-dairy proteins and fat/oils. Hence, it was suggested by Shaw (1984) that in response to increasing manufacturing costs of processed cheese, imitation products have been developed to meet demand in fast food outlets (e.g. pizza), by the catering trade, ready cooked foods, in formulated foods and in school lunch programmes (see also IDF, 1989; McCarthy, 1990; Mortensen, 1991; Engel, 1992; Lee *et al*., 1992; Song *et al*., 1992; Bachmann, 2001; Hoyer & Kirkeby, 2007).

It is evident that there are many similarities between the manufacture of processed cheese and analogues, and this chapter provides a general background to these products, their properties and the patterns of their consumption in some selected countries.

1.2 Diversity of products

1.2.1 *Terminology and/or nomenclature*

The products of the preservative treatment of natural cheeses by the application of heat came to be known as processed cheese or processed cheese food; in some instances the word 'process' is used instead of 'processed'. This product is manufactured in many countries, and numerous variants of this type of product have appeared on the market over the years with alternative names, such as 'pasteurised', 'emulsified', pasteurised blended, 'American', 'cooked' or 'sterilised' cheese (Carić & Kaláb, 1993; Guinee *et al*., 2004; see also Chapter 2).

Developed products, known as 'imitation' processed cheese, are widely produced, and are made from mixtures of dairy and/or non-dairy proteins and dairy fat or vegetable oil. These products are variously labelled as 'analogues', 'analogs' imitation', 'substitute', 'artificial', 'extruded', 'synthetic', 'Tofu' and/or 'filled' cheese (Shaw, 1984; IDF, 1989;

McCarthy, 1990). The following references are recommended for further reading on different aspects on processed cheese analogues (Santos *et al*., 1989; Ahmed *et al*., 1995; El-Nour *et al*., 1996, 1998, 2001a,b; Hetzner & Richarts, 1996; Ennis & Mulvihill, 1997; Abou El-Nour *et al*., 1998, 2001; Muir *et al*., 1999; Tamime *et al*., 1999; Kaminarides & Stachtiaris, 2000; Mleko & Foegeding, 2000, 2001; Bachmann, 2001; Lobato-Calleros *et al*., 2001; Pereira *et al*., 2001; Abou El-Nour & Buchheim, 2002; Pereira *et al*., 2002; El-Nour, 2003; Gustaw Mleko, 2007). These types of product are reviewed in Chapter 9.

1.2.2 *Classification*

At present, there are many types of processed cheese made worldwide. Smith (1990) reported the classification of these products based on the FAO/WHO Food Standards Programme of the Codex Alimentarius Commission, and they are grouped into two different categories based on the physical characteristics of the product: processed cheese and spreadable processed cheese (for further details, refer to Chapter 2). The standard also details the following aspects.

- Permitted dairy and food additives/ingredients.
- Minimum processing temperature at 70°C for 30 s.
- The named variety of natural cheese to be used to describe the processed cheese type, and the blend being required to contain at least 70 g 100 g^{-1} of the cheese mentioned.
- The chemical composition of the product is expressed as dry matter content and percentage of fat-in-dry matter (FDM).
- Labelling information.

The main difference between processed cheese and processed cheese spread products proposed by Smith (1990) is the level of moisture content in the product, which affects its rheological properties, the spreadable type being softer. However, the commercial manufacture of processed cheese may also include the 'block' and 'slices' types, which merit separate subgrouping in the proposed FAO/WHO standards (Smith, 1990). Last but not least, there is no existing standard for processed cheese 'sauce' (i.e. natural and/or analogue), which is used sometimes in hamburger outlets. An example of the processing method of cheese sauce was reported by Hine (1995) (see also Duval *et al*., 1994a,b). Natural cheeses used as an ingredient during the manufacture of processed cheese products may range from a minimum of 51 g 100 g^{-1} in the spreadable type to 95 g 100 g^{-1} in other products (Anonymous, 1986). The standards/legislations for these products in different countries are reviewed in detail in Chapter 2.

1.3 Patterns of production

In the mid-1980s, the production figure for processed cheese in the European Union (EU), USA, Norway, Finland, Austria, Switzerland and Australia was ~1.4 million tonnes (IDF, 1995; Anonymous, 1999), increasing to 1.53 million tonnes in 2004 (IDF, 2005). Detailed production figures for the 30 member countries of the International Dairy Federation (IDF) are shown in Table 1.1. It is possible that the world production of processed cheese will increase in the future, mirrored by the expected growth in the world production of natural

Table 1.1 Production trends (×1000 tonnes) of processed cheese for 30 International Dairy Federation (IDF) member countries[a] between 1995 and 2004.

	Year		
Country	1995	2000	2004
Argentina	7	10	7
Australia	58	60	47
Belgium	52	55	44
Canada	76	67	71
Denmark	17	NA[b]	19
Estonia	NA	NA	1
Finland	13	16	17
France	128	138	129
Germany	159	171	175
Hungary	11	10	11
Iceland	0.3	0.3	0.4
Ireland	12	11	12
Israel	2	1	1
Italy	NA	4	4
Japan	94	111	112
Lithuania	NA	1	3
Netherlands	31	19	16
New Zealand	11	24	25
Norway	3	3	3
Poland	30	48	60
Russian Federation	68	78	141
South Africa	5	5	5
Spain	39	36	NA
Switzerland	14	13	11
UK	24	33	37
USA	668	630	543
Total	**1522**	**1557**	**1527**

Source: After IDF (2005).

[a]Production figures for processed cheese in Austria, Greece, Italy, Sweden and Cyprus are included with natural cheeses, not specified or not reported.

[b]NA, not available.

cheeses, i.e. an annual growth rate of 1.8% from 2004 to 2014 (IDF, 2005). Nevertheless, annual production data (×1000 tonnes) for processed cheese in some selected countries are as follows: 30–40 (Egypt in 2007; M. Abd El-Salam, personal communication), 8.7 (Syria in 2007; A.-H. Klandar, personal communication) and 113.4 (Brazil in 2007; Associação Brasileira das Indústrias de Queijo or ABIQ, 2008).

It is safe to suggest that the demand for processed cheese in countries of the Far East is expected to rise due to an increase in annual income and the westernisation of consumer taste for pizza and hamburgers. Consequently, similar growth may also occur in the urban populations of China, India, South America, the Middle East and possibly Africa.

There are no data available for world production figures of processed cheese analogues.

1.4 Principles of manufacturing stages

The complexity of the manufacture of processed cheese and its analogues is well known, and is primarily influenced by the chemical interactions between the dairy constituents and the emulsifying salts, and these aspects will be reviewed in detail in different chapters. In addition, the rate of these interactions is governed by the application of heat, the duration of heating and processing, and the rate of shear applied during production, all of which will affect the quality of the final product. Nevertheless, the different stages of manufacture of processed cheese products including analogues are similar (Fig. 1.1) and the diversity of these technologies are briefly discussed in subsequent sections.

1.4.1 *Natural cheeses*

The successful production of processed cheese is dependent on the proper quality and selection of natural cheeses. It is possible to use one or more varieties of cheese or blends of cheeses of different degrees of maturation (Carić & Kalàb, 1993; Guinee *et al*., 2004; Kapoor *et al*., 2007). In general, the formulation for using Cheddar cheese (i.e. mild, medium or mature flavour) may consist of different ratios (Table 1.2) and such typical blends provide the desirable elasticity character in the final product. The criteria for selection of natural cheese include flavour, texture, consistency and level of acidity. Degraded cheese (off-flavour or microbial defects) should not be used in processed cheesemaking as the quality of the final product will be reduced or unacceptable.

When the cheeses have been selected, the products are removed from the wrapper, de-rinded, cleaned and ground before processing. This physical treatment of natural cheese facilitates an easier melt, ensures proper blending of the added ingredients, and enhances better contact between the emulsifying salts and cheese components.

1.4.2 *Formulation of a balanced mix*

The main components of natural cheeses are fat, solids-not-fat (SNF) (mainly protein, minerals and sodium chloride) and moisture. Hence, formulation of a balanced mix is based on the proximate composition of the natural cheeses used, including ingredients added for the fortification of the SNF and/or fat contents (e.g. dairy powders, ‘cheese base’ – CB)

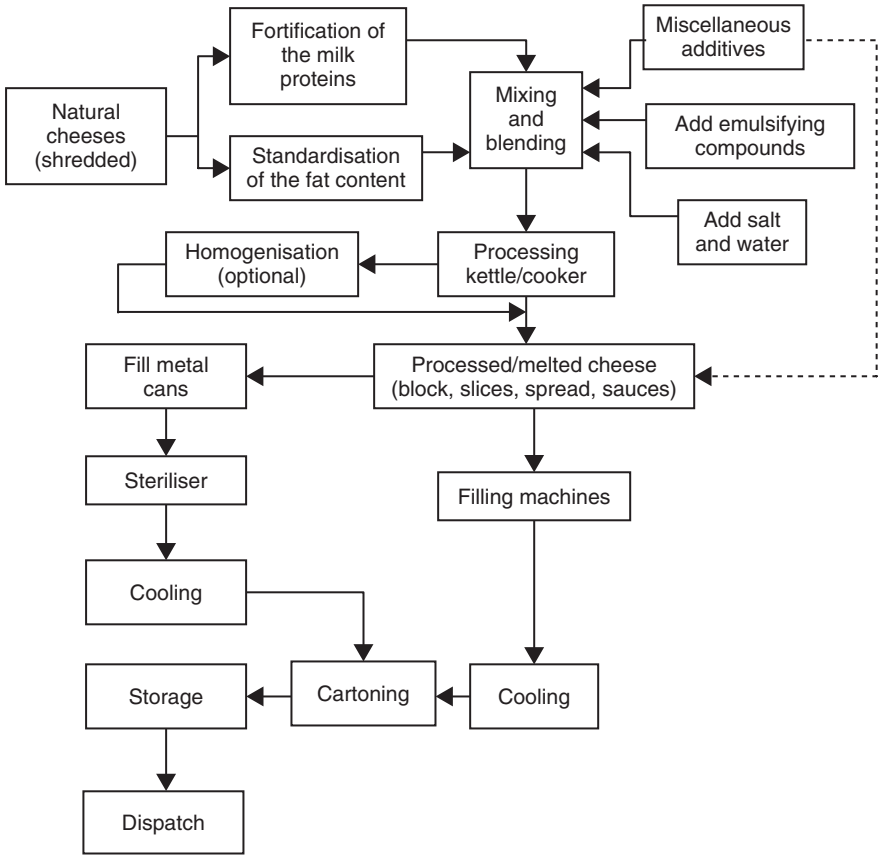

Fig. 1.1 Schematic illustration showing the manufacturing stages of processed cheese products. Note that dotted line represents an alternative route; for cheese analogue use different ingredients, and some of the processing stages may not be applicable, e.g. use of metal cans.

Table 1.2 Some typical ratios of recommended blends of Cheddar cheese for the manufacture of processed cheese products.

	Natural cheese		
Type of processed cheese products	Mild	Medium	Mature
Block	70–75	← 25–30 →	
Slices	30–40	50–60	10
Slices	55	35	10
Spread	30	50	20

and processed cheese re-work, standardisation of the fat level (e.g. cream, anhydrous milk fat or AMF, or butter), and added water or condensate from direct steam injection during the heating stage. However, some adjustments of the balanced mix should be taken into account when using food ingredients such as meat, fish or liquid additives (e.g. colouring matter – flavouring agents).

Skimmed milk powder (SMP) tends to improve the quality and stability of processed cheese, and the recommended level of fortification is ~10–12 g 100 g^{-1}. Caseinates and whey protein concentrates (WPC) are added at a rate of 5–7 g 100 g^{-1} to the blend; higher rates of fortifications will affect the stability, flavour and structure of the product (Carić & Kalàb, 1993; Guinee *et al*., 2004). The maximum permitted amount of caseinates in processed cheesemaking in the EU is 5 g 100 g^{-1} (Citro *et al*., 1998). However, CB produced from whole milk can be used to replace up to 80 g 100 g^{-1} of natural cheeses. The proximate chemical composition of Cheddar type CB is similar to natural cheese, and its use in processed cheesemaking has been reported by Rubin & Bjerre (1984), Tamime *et al*. (1990, 1991), Ganguli (1991), Park *et al*. (1993), Jang *et al*. (1993), Abdel-Hamid *et al*. (2002), Awad (2003) and Kycia *et al*. (2006).

1.4.3 *Emulsifying salts*

In general, emulsifying salts consist of monovalent cation (sodium-Na) and a polyvalent anion (phosphate); for more details refer to Chapter 4. These salts are normally added at a rate of up to 3 g 100 g^{-1} and, for pH adjustment, food grade citric acid is used; in addition, sodium chloride (NaCl) may be added to the cheese blend for adjusting the level of salt in the final product.

Emulsifying salts are not amphiphilic and hence are not emulsifiers *per se* (Dalgleish, 1989). However, emulsifying salts promote, with the aid of heat and shear, a series of concerted physicochemical changes in the cheese blend which, as a consequence, result in rehydration of the aggregated *para*-casein and its conversion into an active emulsifying agent. Although the primary functions and/or effects of emulsifying salts during the manufacture of processed cheese will be detailed elsewhere, Carić & Kalàb (1993) and Guinee *et al*. (2004) reported that these salts supplement the functional properties of milk protein. In brief, they:

- remove calcium (Ca^{2+}) ions from the micelle;
- peptise and solubilise the protein;
- hydrate and swell the protein;
- emulsify the fat and stabilise the emulsion;
- control and stabilise the pH level; and
- form an appropriate structure of processed cheese after cooling.

Although the use of emulsifying salts is important during the manufacture of processed cheese, overdose of specific emulsifying agents (i.e. high in phosphorus content) can lead to bitterness in processed cheese slices (Mayer, 2001). The same author reported that bitter slices showed very weak or even no α_{s1}- and β-caseins region, but only γ-casein and low-molecular-weight peptides, and contained high concentrations of hydrophilic and hydrophobic peptides.

1.4.4 *Addition of miscellaneous additives*

The primary objective of flavouring processed cheese products is to provide the consumer with a wider choice, which may lead to increased consumption. A wide range of flavouring materials has been used in processed cheese products (see Chapter 5) and a selective list for possible novel products is shown in Table 1.3.

Table 1.3 Food products and flavouring agents currently used in processed cheese production.

Additive	Comment	References
Goat's milk cheese or casein	Addition of such component(s) had no effect on flavour, but improved the consistency of the product	Fredriksen & Steinsholt (1978)
Chocolate	Blending processed cheese and chocolate for the manufacture of a nutritious product	Vajda *et al*. (1983)
Hydrolysate of processed cheese	Processed cheese waste was hydrolysed with hydrochloric acid and added to the blend at a rate of 5–25 g 100 g^{-1}	Kunizhev *et al*. (1984)
Mashed potato	The blend consisted of Gouda cheese, emulsifying salts, mashed potato, curry powder and sweet corn	Shinozaki & Imagawa (1985) (see also Awad, 2003)
Decolorised blood protein	The protein was added to the milk before making a fresh cheese by acidification and centrifugation	Vareltziz & Buck (1985)
Prawns, salami, bacon and paprika	These additives enhanced the niche market of processed cheese	Anonymous (1987) and Abeid *et al*. (2001)
Different types of margarine, fats and oils	The manufactured product was acceptable and more economical	Radovets *et al*. (1987) (see also Bodenstein *et al*., 1990; Greim *et al*., 1990; Türkoğlu *et al*., 2002)
Calcium salts and phosphatidic acid	These additives were used to produce a dietetic product, and clinical tests gave positive results	Doležálek & Nezdařilīk (1987) (see also Samodurov *et al*., 1990)
Vegetable protein	Soya and chickpea flour enhanced the consistency of the product	El-Neshawy *et al*. (1988) (see also Carić *et al*., 1990; Ahmed *et al*., 1995; DingMei *et al*., 2008)
Nuts and dried fruit	Prepare the cheese paste and, while still hot, pour into the packaging container in which these additives are placed	Schoegel & Daurelles (1991) (see also Maslov *et al*., 1992)
Iron fortification	No effect on quality	Zhang & Mahoney (1991) and El-Sayed *et al*. (1997)
Egg protein	Affected the texture and formation of clumps	Hong (1992)
Smoke condensate	The recipe and the manufacturing processes have to be modified	Solo'eva *et al*. (1994) and McIlveen & Vallely (1996) (see also Niketić & Kršev, 1990)
Extract of concentrated fruit juices and/or fruit pulp	Improved organoleptic properties and enhanced the mineral content of the product	Lapshina *et al*. (1994), El-Shabrawy *et al*. (2002) and Awad *et al*. (2003a)
Meat emulsion	Development of a novel cheese-meat burger	Guinee & Corcoran (1994)
Mustard oil	Suitable as partial substitution of milk fat	Grigorov *et al*. (1995)

Table 1.3 (*Continued*)

Additive	Comment	References
Buffalo's milk cheese	The age of the matured cheese used in the recipe influenced the quality of the processed cheese	Joshi & Thakar (1996) (see also Singh *et al*., 1993; Tiwari *et al*., 1996; Joshi & Thakar, 1996)
Plant protein isolates	Reduced the flavour acceptability as the level is increased to 15 g 100 g^{-1}	El-Sayed (1997)
Blue cheese taste	Blending Blue cheese with Emmental and casein to produce a good flavour processed cheese product	Lubbers *et al*. (1997)
Wheat fibre	Improved quality of the product without affecting the sensory properties	Noli (1998)
Okara	Acceptable product made with up to 15 g 100 g^{-1} Okara plus skimmed milk powder and starch	Real del Sol *et al*. (2002)
Casein hydrolysate or supernatant	The hydrolysed product (i.e. after 4 h, improved the emulsifying activity of the casein) was used at a ratio of 3:1 with ordinary emulsifier to produce a good-quality processed cheese with no effect on the flavour of the product	Kwak *et al*. (2002)
Transglutaminase (Tg-ase)	Milk gels (i.e. rennet coagulation) treated with Tg-ase and later used during the manufacture of processed cheese improved the physical properties (i.e. reduced syneresis index and increased consistency index) of the product, possibly due to the occurrence of enzymatic cross-linking of the protein matrix	De Sa & Bordingnon-Luiz (2010)

Another additive widely used as a preservative in processed cheese products are generally known as bacteriocins. These are polypeptide compounds produced by many lactic acid bacteria and can inhibit the growth of pathogenic and undesirable microorganisms in dairy and food products (Tamime *et al*., 2006). An example of such a bacteriocin, which has been commercialised, is nisin, and is produced by certain strains of *Lactococcus lactis* subsp. *lactis*. Nisin has been shown to possess antibacterial activity against Gram-positive bacteria, such as heat resistant spore-formers (e.g. *Clostridium* spp. and *Bacillus* spp.) and pathogenic microorganisms belonging to the genera *Staphylococcus, Listeria* and *Salmonella*. For more information regarding the use of nisin and other preservatives (e.g. potassium sorbate) in processed cheesemaking, the reader is referred to some comprehensive reviews and research reports (Delves-Broughton, 1987, 1998a,b; Hurst & Hoover, 1991; Plockova *et al*., 1997; Delves-Broughton & Friis, 1998; JungHoon & Floros, 1998; Turtell & Delves-Broughton, 1998).

Some suggested dairy ingredients employed during the manufacture of processed cheese products are listed in Table 1.4.

Table 1.4 Some suggested dairy ingredients employed during the manufacture of processed cheese products.

Ingredients/product type	References
Processed cheese spreads	
Palm oil was used for the preparation of processed cheese spread, but affected its sensory characteristics	Salam (1988a,b) (see also Azzam, 2007; Calvo *et al*., 2007)
Natural cheese flavours (i.e. obtained from Cheddar and Parmesan cheeses) were added to fresh cheese and used successfully to produce processed cheese spread; this approach of flavouring was useful in replacing mature cheeses by up to 15 g 100 g^{-1} in the blend	Kulić & Carić (1990)
Incorporating starch solution (1–25 g 100 g^{-1} in water, milk, buttermilk or ultrafiltered permeate) into the cheese curd maintains the creaminess of low- or fat-free cheese spreads; the addition of hydrocolloids in the cheese blend improves the texture of the product	Quiblier *et al*. (1991), Kokane *et al*. (1996) and Gokhale *et al*. (1999)
Addition of glycerol (5 g 100 g^{-1}) improved the spreadability of the processed cheese product	Kombile-Moundouga & Lacroix (1991)
Incorporation of butter residue into the cheese blend improved the sensory properties of high-fat spreadable cheese	Abou-Zeid (1993)
Replacement of mature Ras cheese (an Egyptian variety) by up to 80 g 100 g^{-1} with enzyme-treated retentate improved the flavour, colour and consistency of the product	Aly *et al*. (1995)
Chakka (an Indian fermented milk), cheeses (pickled or brined cheeses, Queso Blanco, Ras, Ricotta or low-fat Mozzarella), Labneh (Middle Eastern concentrated yoghurt) and fermented barley (i.e. a Labneh-like product) were used successfully in the preparation of processed cheese spread	Dholu *et al*. (1990, 1994), McGregor *et al*. (1995), Hanna & Nader (1996), Tukan *et al*. (1998), Hanna (1999), Abdel-Hamid *et al*. (2000), Modler & Emmons (2001), Awad *et al*. (2003b), El-Shibiny *et al*. (2007) and Awad & Salama (2010)
Addition of whey protein concentrate (WPC) (20–25 g 100 g^{-1} total solids) to the cheese blend improved the texture and body of the product	Abd El-Salam *et al*. (1996, 1997) and El-Khamy *et al*. (1997) (see also Kebary *et al*., 2001; Hui *et al*., 2006; Pinto *et al*., 2007; Shazly *et al*., 2008)
The whiteness of processed cheese spreads was improved by increasing the content of WPC and emulsifying salts in the blend, but the product tended to become darker during storage, possibly due to the Maillard browning reaction	Abd El-Salam *et al*. (1998)
Replacement of dairy fat with fat-substitutes up to 40 g 100 g^{-1} with Dairy-Lo™ improved the sensory score of the product, whilst Maltrin® and Crestar® increased the rate of oiling off and meltability of low-fat processed cheese spreads	Kebary *et al*. (1998) (see also Lee & Brummel, 1990; Anonymous, 1992; Swenson *et al*., 2000)
The use of denatured whey protein, which was modified with succinic anhydride, improved the spreadability of processed cheese	Fayed & Metwally (1999)
Taiz cheese (a Yemeni smoked variety) used at a rate of 30 g 100 g^{-1} in the cheese blend had the highest organoleptic score of processed cheese spread when compared with the control	Saleem *et al*. (2003)

Table 1.4 (*Continued*)

Ingredients/product type	References
Cheddar cheese (low fat and full fat) was made from a mixture of buffaloes' and cows' milk, and the cheeses (i.e. fresh and mature) were used in the blend with different stabilisers to produce good-quality spreads	Rabo *et al*. (2004)
The addition of ι-carrageenan (0.25 g 100 g^{-1}) to the cheese blend improved the firmness of processed cheese and spreads, and was more effective than κ-carrageenan	Cernikova *et al*. (2007, 2008)
Cholesterol-reduced processed cheese spread was made by cross-linking β-cyclodextrin (91.5 g 100 g^{-1} was removed), and had significantly higher scores for gumminess, brittleness, yellowness, bitterness and elasticity, and significantly lower scores for processed cheese flavour and slimy texture compared with the control product	Kim *et al*. (2009) and SooYun *et al*. (2009)
Low-sodium processed cheese spread was made from ultrafiltered Edam cheese (i.e. the brine was prepared from a mixture of NaCl and KCl at a ratio of 1:1). The meltability was low and oil separation was high of the product compared with the control, and sensory scores of low-sodium processed cheese were high	Amer *et al*. (2010)
Processed cheese (blocks and slices)	
Formulation for the manufacture of foamed processed cheese was made from Cheddar cheese (young and mature), cream, yoghurt, emulsifying salts, starch and other dried dairy powders and, after melting the blend, it was homogenised and whipped	Bode *et al*. (1986)
Enzyme-modified Cheddar cheese (lipase-treated) was suitable as a flavour enhancer for processed cheese	Lee & Ahn (1986)
The addition of WPC (~26 g 100 g^{-1} total solids), trisodium citrates and calcium to replace 20–25 g 100 g^{-1} of the natural cheese in the blend improved the firmness of the product, but reduced the meltability of the cheese	Gupta & Reuter (1990, 1992, 1993) and Thapa & Gupta (1992a,b, 1996) (see also Gupta *et al*., 1984; Metwally *et al*., 1984; Prajapati *et al*., 1991, 1992; French *et al*., 2002; Mleko & Lucey, 2003; Kapoor & Metzger, 2004; Gustaw & Mleko, 2007)
The size of protein aggregates, firmness and elasticity of the product were influenced by the type of low-molecular-weight emulsifier added and the pH level of the rennet casein used	Lee *et al*. (1996)
Factors influencing the pink discoloration of annatto (emulsion or solution) used in processed cheese included the following: cooking temperature, continuous heating, type and blend of emulsifying salt, amount of coloured cheese in the blend and amount of whey powder added	Shumaker & Wendorff (1998)
Good-quality processed cheese was made on an industrial scale containing increased levels of potassium salt (i.e. 75–80 g 100 g^{-1}) of that of the sodium content of the final product	Reps *et al*. (1998; 2009) and Iwanczak *et al*. (2001)
Processing the cheese blend containing WPC under atmospheric conditions, hydrogen donors and iron increased the content of conjugated linoleic acid (CLA) in processed cheese; in addition, the processing temperature (75 vs. 90°C) increased the content of CLA in the product and spread	Shantha *et al*. (1992), Shantha & Decker (1993), Garcia-Lopez *et al*. (1994) Luna *et al*. (2005), Calvo *et al*. (2007), Zhang *et al*. (2007) and JunHo *et al*. (2009)

(continued)

Table 1.4 (*Continued*)

Ingredients/product type	References
Low-fat processed cheese was produced using carrageenan and microcrystalline cellulose and ultrafiltered sweet buttermilk	Bullens *et al*. (1995) and Raval & Mistry (1999) (see also Trivedi *et al*., 2008a,b)
Reduced-fat cheese containing lecithin was acceptable, but was less elastic in processed cheese	Drake *et al*. (1999)
Addition of ultra-high pressure-treated whey protein to the cheese blend improved the texture and body of the product	Lee *et al*. (2006)
The application of concentrated milk (i.e. vacuum evaporation and ultrafiltration) for Cheddar cheesemaking influenced the overall functionality and structure of processed cheese	Mistry *et al*. (2006)
The addition of 1-monoglycerides affected the sensory properties of processed cheese due to the off-flavour	Bunka *et al*. (2007)
Sudanese white cheese (presumably a fresh and brined product) was used to produce Sudanese processed cheese	El-Diam & Intisam (2007) (see also Kaminarides *et al*., 2006)

1.4.5 *Heat treatment*

The level of heating applied during the manufacture of processed cheese products ranges between 72 and 145°C; in brief, these products are categorised as 'pasteurised' or 'sterilised' (for more details refer to Chapter 7). In general, products that are sterilised are higher in water activity, which requires the additional security of high temperature processing conditions to eliminate the main threat of clostridial spores that can germinate and grow during the shelf-life if the product is not refrigerated. Sterilised products are not generally aseptically produced due to the complexity of the packaging, e.g. triangular foil portions. However, the pasteurised products are those heated to 72–95°C by means of direct steam injection under vacuum. This heating usually takes place in a batch cooker, and can be in concert with high or low mechanical/shear action. The important point is to have a minimum filling temperature of 72°C to ensure adequate pasteurisation of the packaging.

Sterilised processed cheese products are normally heated to a temperature of 140°C for 10 s (corresponding to an Fo 8 value). The time/temperatures combinations that are widely used range between 128 and 145°C. It is obvious that the higher the temperature, the shorter the hold time. The widespread introduction of refrigeration of these processed cheese products has generally meant that these products have two barriers (i.e. high processing temperature and cold storage of the product) that prevent product spoilage.

1.4.6 *Homogenisation*

The equipment (i.e. pilot and large-scale) employed for the manufacture of processed cheese products does not require homogenisation of the melted cheese blend because it is designed to provide an excellent shear effect to produce an emulsion of the fat droplets in a continuous hydrated phase. High-shear cookers basically simulate the homogenisation effect

by producing extremely fine fat droplets, and modern continuous cookers with tangential steam injectors produce the same effect, the speed of the mixing device of the cooker controlling the 'creaming' effect in the product. However, if the homogenisation stage is required, it would be installed downstream of the cooker.

1.4.7 *Filling machines and packaging materials*

Different types of packaging materials, such as glass jars, metal tin cans, laminated aluminium foils, collapsible metal or plastic tubes, laminated plastics, 'squeezy' plastic bottles and heat-shrink or heat-melt sheets or pouches, are widely used to package processed cheese products, including analogues (refer to Chapter 8 for further details including types of filling machines). Some patented and developed packaging materials for processed cheese products are summarised in Table 1.5, and some examples of packaging materials and systems are shown in Fig. 1.2. In general, processed cheese slices are packaged individually in laminated plastic material, and a set of slices (e.g. 6 or 12) is stacked and overwrapped in similar material(s). Alternatively (i.e. an older method), unwrapped slices are packed in laminated plastic material and, to inhibit the slices from sticking to each other, parchment paper is inserted between the slices of processed cheese.

Processed cheese packed in metal tin cans (see Pillonel *et al*., 2002) exhibited the least chemical changes and microbiological quality during the storage period (at 30°C and 60% relative humidity (RH) and at ~7°C and 80% RH) compared with parallel products packed in polystyrene or low-density polyethylene tubs (Goyak & Babu, 1991a,b). While the keeping quality of processed cheese spread packaged in glass jars for 3 months at 25–30°C or 5–8°C was superior to the same product packaged in different types of Egyptian-made polymeric laminated materials or imported polyamide sheets, there was a slight change in the microbiological quality and sensory scores, but the temperature of storage had a greater effect on the quality of the product. In addition, packages made from different polymers leached out substances that absorbed in the UV spectrum in solution simulating the aqueous phase of the product, and glass jars were recommended for packaging processed cheese due to their inertness (Metwally *et al*., 1996; see also El-Shibiny *et al*., 1996; Alves *et al*., 2007).

Table 1.5 Examples of some patented packaging materials for processed cheese products.

Type of package	References
Multilayer of oriented films from propylene copolymers and unplasticised Saran (i.e. heat shrinkable), suitable for block-type processed cheese	Schirmer (1986)
Cylindrical pack with a lid (shipping container) that is suitable for gas flushing with N_2 and CO_2 to protect the individual wrapped portions of processed cheese	Daime (1987)
Coated aluminium foil for wrapping processed cheese (i.e. standard specifications)	BSI (1987)
Packaging system for single portions of processed cheese	Rabier & Bonnin (1992)
A package for packing triangular portions of processed cheese	Bernard *et al*. (1992) and Weber *et al*. (1993)

Fig. 1.2 Some illustrations of packaging materials used for processed cheese and analogues sold in the UK market. (See Plate 1.1 for colour figure.)

1.5 Conclusions

In summary, the technology of processed cheesemaking, including analogues, has evolved dramatically over the past century. It was to some extent an art, where manufacturers tended to blend different cheeses and select emulsifying salts (types and amounts) based largely on experience. Developments in emulsifying salt blends over the past few decades to suit processed cheese and analogues producers have been achieved, but there is a lack of knowledge about the exact mechanisms involved and they are still not clear since there are multiple reactions simultaneously occurring. There is no doubt that increased consumption of processed cheese products worldwide is mainly due to consumer changes in food habits (i.e. popularity and acceptability of fast food and pizza), and the product is more widely accepted by the younger consumer because it has a milder flavour than natural cheeses. Variations in existing definitions and standards for processed cheese products are evident in many countries, and international standards appear to be difficult to harmonise because of possible conflicts with national standards. Future developments in technology will encompass further reliance on automation and product safety. The following chapters reflect these aspects.

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