Processed Cheese and Analogues
The Society of Dairy Technology (SDT) has joined with Wiley-Blackwell to produce a series of technical dairy-related handbooks providing an invaluable resource for all those involved in the dairy industry, from practitioners to technologists, working in both traditional and modern large-scale dairy operations. For information regarding the SDT, please contact Maurice Walton, Executive Director, Society of Dairy Technology, PO Box 12, Appleby in Westmorland, CA16 6YJ, UK. email: execdirector@sdt.org

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Preface to the Technical Series

For more than 60 years, the Society of Dairy Technology (SDT) has sought to provide education and training in the dairy field, disseminating knowledge and fostering personal development through symposia, conferences, residential courses, publications, and its journal, the *International Journal of Dairy Technology* (previously published as the *Journal of the Society of Dairy Technology*).

In recent years, there have been significant advances in our understanding of milk systems, probably the most complex natural food available to humans. At the same time, improvements in process technology have been accompanied by massive changes in the scale of many milk processing operations, and the manufacture a wide range of dairy and other related products.

The Society has embarked on a project with Wiley-Blackwell to produce a Technical Series of dairy-related books to provide an invaluable source of information for practising dairy scientists and technologists, covering the range from small enterprises to modern large-scale operations. This tenth volume in this series, on *Processed Cheese and Analogues*, provides a timely and comprehensive update of the principles and practices involved in the production of these products, from raw materials and processing technology to assurance of the quality of the final product. Processed cheese and its analogues have found many uses in both domestic consumption and in the catering and fast food sectors, providing functional properties beyond those that can normally be achieved with traditional cheeses.

Andrew Wilbey
Chairman of the Publications Committee, SDT
Preface

There is a wide range of processed cheese products, i.e. natural products made from blending different cheeses to form a range of solid and spreadable products, and cheese analogues (made not from cheese, but from dairy and non-dairy ingredients) available to the food market worldwide. Some of these products are extensively used in the fast food/catering chains (e.g. as ‘shredded’ cheeses), and are of increasing economic value in the industrialised and developing countries.

The purpose of this book, which is written by a team of international scientists, is to review the latest scientific developments in this field. The authors, who are all specialists in these products, have been chosen from around the world. The scientific aspects reviewed in this publication include (a) the functionality of ingredients, including the natural cheeses, emulsifying salts, stabilisers, flavourings and colourings, (b) the interactions between natural cheese and processing conditions in developing the rheology and final texture of the product, (c) current processing equipment and manufacturing practices, (d) the current statutory regulations (national and international) of these products because an appreciable percentage of the internationally traded ‘natural’ cheese includes processed cheese varieties and (e) quality assurance of processed cheese (in terms of chemical, physical and microbiological properties and sensory profiling) to ensure the safety of the product for the consumer.

Some key scientific aspects of processed cheese manufacture can be manipulated to control and maintain the consistency and quality of the final product, and coverage of this topic has produced some overlap with those sections dealing with, for example, the interaction of emulsifying salts with natural cheese components. I have felt justified in allowing this overlap because it emphasises the prime importance of the ingredients used during the preparation of the cheese blend including the effects of processing on the quality and consistency of processed cheese for the end-user.

There is no doubt that the book will have an international recognition by dairy technologists, students, researchers and processors, and will become an important component of the Technical Series promoted by the Society of Dairy Technology.

A.Y. Tamime
Contributors

Editor

Dr A.Y. Tamime
24 Queens Terrace
Ayr KA7 1DX
UK
Tel. +44 (0)1292 265498
Fax +44 (0)1292 265498
Mobile +44 (0)7980 278950
E-mail: adnan@tamime.fsnet.co.uk

Contributors

Dr M.A.E. Auty
Teagasc Food Research Centre
Moorepark
Fermoy
Co. Cork
Ireland
Tel. +353 25 42442
Fax +353 25 42340
E-mail: mark.auty@teagasc.ie

Professor E.M. Buys
Department of Food Science
University of Pretoria
Lynnwood Road
Pretoria 0002
South Africa
Tel. +27 12 420 3209
Fax +27 12 420 2839
E-mail: elna.buys@up.ac.za

Mr S. Dixon
215 Moss Bank Road
St Helens
Merseyside WA11 7NS
UK
Tel. +1 507 775 7070
Fax +1 507 775 7878
Mobile +1 507 254 2338
E-mail: stevedixon51@yahoo.co.uk and
steved@meadowingredients.com

Dr J. Domagala
University of Agriculture
Animal Products Technology Department
30–149 Krakow
Balicka 122
Poland
Tel. +48 12 662 4803
Fax +48 12 662 4810
E-mail: rtdomaga@cyf-kr.edu.pl

Dr K.J. Domig
Department of Food Science
and Technology
BOKU – University of Natural Resources
and Life Sciences
Muthgasse 18
A-1190 Vienna
Austria
Tel. +43 (0)1 47654 6750
Fax +43 (0)1 47654 6751
E-mail: konrad.domig@boku.ac.at

Dr E. Duggan
Food and Health Institute
UCD Agriculture and Food Science
Centre
University College Dublin
Belfield
Dublin 4
Ireland
Tel. +353 1 7167675
Fax +353 1 7161147
E-mail: elaine.duggan@ucd.ie

Dr K. Dürrschmid
Department of Food Science and Technology
BOKU – University of Natural Resources and Life Sciences
Muthgasse 18
A-1190 Vienna
Austria
Tel. +43 (0)1 36006 6295
Fax +43 (0)1 36006 6293
E-mail: klaus.duerrschmid@boku.ac.at

Dr T.P. Guinee
Dairy Products Research Centre
Teagasc
Moorepark
Fermoy
Co. Cork
Ireland
Tel. +353 25 42204
Fax +35325 42340
E-mail: Tim.Guinee@teagasc.ie

Dr M. Hickey
Derryreigh
Creggane
Charleville
Co. Cork
Ireland
Tel. +353 (0)63 89392
E-mail: mfhickey@oceanfree.net

Dr A. Hill
University of Guelph
Department of Food Science
Guelph
Ontario N1G 2W1
Canada
Tel. +1 (0)519 824 4120 extension 53875
Fax +1 (0)519 824 6631
E-mail: arhill@uoguelph.ca

Mr S. Kaliappan
Frito-Lay R&D
7701 Legacy Drive
Plano, TX 75024-4099
USA
Tel. +1 (0)972-334-4951
Fax +1 (0)972-334-2329
E-mail: siva.kaliappan@pepsico.com

Professor W. Kneifel
Department of Food Science and Technology
BOKU – University of Natural Resources and Life Sciences
Muthgasse 18
A-1190 Vienna
Austria
Tel. +43 (0)1 36006 6290
Fax +43 (0)1 36006 6266
E-mail: wolfgang.kneifel@boku.ac.at

Professor J.A. Lucey
University of Wisconsin-Madison
Department of Food Science
1605 Linden Drive
Madison, WI 53706-1565
USA
Tel. +1 (608) 265 1195
Fax +1 (608) 262 6872
E-mail: jalucey@facstaff.wisc.edu

Dr A. Maurer-Rothmann
Management Business Line Dairy
Business Unit Food
BK Giulini
Ladenburg
Germany
Tel. +49 (0)6203 77 148
Fax +49 (0)6203 77 185
E-mail: andrea.maurer@bk-giulini.com

Dr L. Metzger
Alfred Chair in Dairy Education
Dairy Science Department
South Dakota State University
Box 2104 Dairy-Microbiology Building
Brookings, SD 57007
USA
Tel. +1 (0)605-688-5477
Fax +1 (0)605-688-6276
E-mail: Lloyd.Metzger@sdstate.edu

**Dr J.F. Mostert**
Food Safety and Human Nutrition
ARC-Animal Production Institute
Private Bag X2
Irene 0062
South Africa
Tel. +27-12-672-9296
Fax +27-12-665-1551
E-mail: ferdie.mostert@telkomsa.net

**Professor D.D. Muir**
DD Muir Consultants
26 Pennyvenie Way
Girdle Toll
Irvine KA11 1QQ
UK
Tel. +44 (0)1294 213137
E-mail: Donald@ddmuir.com

**Professor M. Nogueira de Oliveira**
Universidade de São Paulo
Departamento de Tecnologia Bioquimico-Farmacêutica
Avenue Prof. Lineu Prestes 580, Bloco 16
Sao Paulo 05508-900
Brazil
Tel. +55 (0)11 3091 3690
Fax +55 (0)11 3815 6386
E-mail: monolive@usp.br

**Dr N. Noronha**
Food and Health Institute
UCD Agriculture and Food Science Centre
University College Dublin
Belfield
Dublin 4
Ireland
Tel. +353 1 7167675
Fax +353 1 7161147
E-mail: nessa.noronha@ucd.ie

**Professor E.D. O’Riordan**
UCD Agriculture and Food Science Centre
University College Dublin
Belfield
Dublin 4
Ireland
Tel. +353 1 7167016
Fax +353 1 7161147
E-mail: dolores.oriordan@ucd.ie

**Professor G. Osthoff**
Department of Microbial Biochemical and Food Biotechnology
University of the Free State
PO Box 339
Bloemfontein 9300
South Africa
Tel: +27 (0)51 4012216
Fax +27 (0)51 4019335
E-mail: OsthoffG.SCI@ufs.ac.za

**Mr M. O’Sullivan**
Food and Health Institute
UCD Agriculture and Food Science Centre
University College Dublin
Belfield
Dublin 4
Ireland
Tel. +353 1 7167158
Fax +353 1 7161147
E-mail: michael.osullivan@ucd.ie

**Mr E. Slabber**
Dairybelle
PO Box 744
Bloemfontein 9300
South Africa
Tel. +27 (0)51 4114426
Mobile +27 (0)825619092
Fax +27 (0)51 4301450
E-mail: Ernest.Slabber@Dairybelle.co.za
Contributors

Dr A. Smith
University of Guelph
Analytical Microscopy
Department of Food Science
Guelph
Ontario N1G 2W1
Canada
Tel. +1 (0) 519 824-4120 ext. 52112
Fax +1 (0) 519 824-6631
E-mail: smitha@uoguelph.ca

Professor Z. Ustunol
Michigan State University
Department of Food Science and Human Nutrition
2105 S. Anthony Hall
East Lansing, MI 48824
USA
Tel +1 517 355 7713 extension 184
Fax +1 517 353 1676
E-mail: ustunol@anr.msu.edu

Dr M. Wszolek
University of Agriculture
Animal Products Technology Department
30–149 Krakow
Balicka 122
Poland
Tel. +48 12 662 4788
Fax +48 12 662 4810
E-mail: monika@cyberia.pl
1 Processed Cheese and Analogues: An Overview

A.Y. Tamime

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.
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 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 & Richards, 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* between 1995 and 2004.

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

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

**Source:** After IDF (2005).

*NA, not available.
Processed Cheese and Analogues: An Overview

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 (Caric & Kalab, 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.

<table>
<thead>
<tr>
<th>Type of processed cheese products</th>
<th>Natural cheese</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mild</td>
</tr>
<tr>
<td>Block</td>
<td>70–75</td>
</tr>
<tr>
<td>Slices</td>
<td>30–40</td>
</tr>
<tr>
<td>Slices</td>
<td>55</td>
</tr>
<tr>
<td>Spread</td>
<td>30</td>
</tr>
</tbody>
</table>

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 $\sim 10–12\ g\ 100\ g^{-1}$. 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 & Kalab, 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 & Kalab (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 $\alpha_s$- and $\beta$-caseins region, but only $\gamma$-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.

<table>
<thead>
<tr>
<th>Additive</th>
<th>Comment</th>
<th>References</th>
</tr>
</thead>
<tbody>
<tr>
<td>Goat’s milk cheese or casein</td>
<td>Addition of such component(s) had no effect on flavour, but improved the consistency of the product</td>
<td>Fredriksen &amp; Steinsholt (1978)</td>
</tr>
<tr>
<td>Chocolate</td>
<td>Blending processed cheese and chocolate for the manufacture of a nutritious product</td>
<td>Vajda et al. (1983)</td>
</tr>
<tr>
<td>Hydrolysate of processed cheese</td>
<td>Processed cheese waste was hydrolysed with hydrochloric acid and added to the blend at a rate of 5–25 g 100 g⁻¹</td>
<td>Kunizhev et al. (1984)</td>
</tr>
<tr>
<td>Mashed potato</td>
<td>The blend consisted of Gouda cheese, emulsifying salts, mashed potato, curry powder and sweet corn</td>
<td>Shinozaki &amp; Imagawa (1985) (see also Awad, 2003)</td>
</tr>
<tr>
<td>Decolorised blood protein</td>
<td>The protein was added to the milk before making a fresh cheese by acidification and centrifugation</td>
<td>Vareltziz &amp; Buck (1985)</td>
</tr>
<tr>
<td>Prawns, salami, bacon and paprika</td>
<td>These additives enhanced the niche market of processed cheese</td>
<td>Anonymous (1987) and Abeid et al. (2001)</td>
</tr>
<tr>
<td>Different types of margarine, fats and oils</td>
<td>The manufactured product was acceptable and more economical</td>
<td>Radovets et al. (1987) (see also Bodenstein et al., 1990; Greim et al., 1990; Türkoglu et al., 2002)</td>
</tr>
<tr>
<td>Calcium salts and phosphatidic acid</td>
<td>These additives were used to produce a dietetic product, and clinical tests gave positive results</td>
<td>Doležálek &amp; Neždařílk (1987) (see also Samodurov et al., 1990)</td>
</tr>
<tr>
<td>Vegetable protein</td>
<td>Soya and chickpea flour enhanced the consistency of the product</td>
<td>El-Neshawy et al. (1988) (see also Čarić et al., 1990; Ahmed et al., 1995; DingMei et al., 2008)</td>
</tr>
<tr>
<td>Nuts and dried fruit</td>
<td>Prepare the cheese paste and, while still hot, pour into the packaging container in which these additives are placed</td>
<td>Schoegel &amp; Daurelles (1991) (see also Maslov et al., 1992)</td>
</tr>
<tr>
<td>Iron fortification</td>
<td>No effect on quality</td>
<td>Zhang &amp; Mahoney (1991) and El-Sayed et al. (1997)</td>
</tr>
<tr>
<td>Egg protein</td>
<td>Affected the texture and formation of clumps</td>
<td>Hong (1992)</td>
</tr>
<tr>
<td>Smoke condensate</td>
<td>The recipe and the manufacturing processes have to be modified</td>
<td>Solo’eva et al. (1994) and McIlveen &amp; valley (1996) (see also Niketić &amp; Krsjev, 1990)</td>
</tr>
<tr>
<td>Extract of concentrated fruit juices and/or fruit pulp</td>
<td>Improved organoleptic properties and enhanced the mineral content of the product</td>
<td>Lapshina et al. (1994), El-Shabrawy et al. (2002) and Awad et al. (2003a)</td>
</tr>
<tr>
<td>Mustard oil</td>
<td>Suitable as partial substitution of milk fat</td>
<td>Grigorov et al. (1995)</td>
</tr>
</tbody>
</table>
Table 1.3 (Continued)

<table>
<thead>
<tr>
<th>Additive</th>
<th>Comment</th>
<th>References</th>
</tr>
</thead>
<tbody>
<tr>
<td>Buffalo’s milk cheese</td>
<td>The age of the matured cheese used in the recipe influenced the quality of the processed cheese</td>
<td>Joshi &amp; Thakar (1996) (see also Singh et al., 1993; Tiwari et al., 1996; Joshi &amp; Thakar, 1996)</td>
</tr>
<tr>
<td>Plant protein isolates</td>
<td>Reduced the flavour acceptability as the level is increased to 15 g 100 g$^{-1}$.</td>
<td>El-Sayed (1997)</td>
</tr>
<tr>
<td>Blue cheese taste</td>
<td>Blending Blue cheese with Emmental and casein to produce a good flavour processed cheese product</td>
<td>Lubbers et al. (1997)</td>
</tr>
<tr>
<td>Wheat fibre</td>
<td>Improved quality of the product without affecting the sensory properties</td>
<td>Noli (1998)</td>
</tr>
<tr>
<td>Okara</td>
<td>Acceptable product made with up to 15 g 100 g$^{-1}$. Okara plus skimmed milk powder and starch</td>
<td>Real del Sol et al. (2002)</td>
</tr>
<tr>
<td>Casein hydrolysate or supernatant</td>
<td>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</td>
<td>Kwak et al. (2002)</td>
</tr>
<tr>
<td>Transglutaminase (Tg-ase)</td>
<td>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</td>
<td>De Sa &amp; Bordingnon-Luiz (2010)</td>
</tr>
</tbody>
</table>

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.

<table>
<thead>
<tr>
<th>Ingredients/product type</th>
<th>References</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Processed cheese spreads</strong></td>
<td></td>
</tr>
<tr>
<td>Palm oil was used for the preparation of processed cheese spread, but affected its sensory characteristics</td>
<td>Salam (1988a,b) (see also Azzam, 2007; Calvo et al., 2007)</td>
</tr>
<tr>
<td>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</td>
<td>Kulč &amp; Carić (1990)</td>
</tr>
<tr>
<td>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</td>
<td>Quiblier et al. (1991), Kokane et al. (1996) and Gokhale et al. (1999)</td>
</tr>
<tr>
<td>Addition of glycerol (5 g 100 g⁻¹) improved the spreadability of the processed cheese product</td>
<td>Kombile-Moundouga &amp; Lacroix (1991)</td>
</tr>
<tr>
<td>Incorporation of butter residue into the cheese blend improved the sensory properties of high-fat spreadable cheese</td>
<td>Abou-Zeid (1993)</td>
</tr>
<tr>
<td>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</td>
<td>Aly et al. (1995)</td>
</tr>
<tr>
<td>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</td>
<td>Dholu et al. (1990, 1994), McGregor et al. (1995), Hanna &amp; Nader (1996), Tukan et al. (1998), Hanna (1999), Abdel-Hamid et al. (2000), Modler &amp; Emmons (2001), Awad et al. (2003b), El-Shibiny et al. (2007) and Awad &amp; Salama (2010)</td>
</tr>
<tr>
<td>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</td>
<td>Abd El-Salam et al. (1996, 1997) and El-Khamy et al. (1997) (see also Kebary et al., 2001; Hu et al., 2006; Pinto et al., 2007; Shazly et al., 2008)</td>
</tr>
<tr>
<td>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</td>
<td>Abd El-Salam et al. (1998)</td>
</tr>
<tr>
<td>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</td>
<td>Kebary et al. (1998) (see also Lee &amp; Brummel, 1990; Anonymous, 1992; Swenson et al., 2000)</td>
</tr>
<tr>
<td>The use of denatured whey protein, which was modified with succinic anhydride, improved the spreadability of processed cheese</td>
<td>Fayed &amp; Metwally (1999)</td>
</tr>
<tr>
<td>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</td>
<td>Saleem et al. (2003)</td>
</tr>
</tbody>
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