Best available techniques (BAT) for the Nordic dairy industry

Eva Korsström
Matti Lampi
# Table of contents

<table>
<thead>
<tr>
<th>Chapter</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>Preface</td>
<td>7</td>
</tr>
<tr>
<td>Summary</td>
<td>9</td>
</tr>
<tr>
<td>Sammanfattning</td>
<td>13</td>
</tr>
<tr>
<td>1. General information on the dairy industry in the Nordic countries</td>
<td>17</td>
</tr>
<tr>
<td>1.1 Statistics</td>
<td>17</td>
</tr>
<tr>
<td>1.2 Denmark</td>
<td>18</td>
</tr>
<tr>
<td>1.3 Sweden</td>
<td>19</td>
</tr>
<tr>
<td>1.4 Finland</td>
<td>21</td>
</tr>
<tr>
<td>1.5 Norway</td>
<td>22</td>
</tr>
<tr>
<td>1.6 Iceland</td>
<td>22</td>
</tr>
<tr>
<td>1.7 The Faroe Islands</td>
<td>23</td>
</tr>
<tr>
<td>2. Applied dairy processes and techniques</td>
<td>25</td>
</tr>
<tr>
<td>2.1 Milk reception and common treatment</td>
<td>25</td>
</tr>
<tr>
<td>2.2 Production of fluid milk and cultured milk products</td>
<td>29</td>
</tr>
<tr>
<td>2.3 Production of butter and butter oil</td>
<td>32</td>
</tr>
<tr>
<td>2.4 Production of cheese</td>
<td>36</td>
</tr>
<tr>
<td>2.5 Whey processing</td>
<td>45</td>
</tr>
<tr>
<td>2.6 Production of milk powder and condensed milk</td>
<td>48</td>
</tr>
<tr>
<td>2.7 Ice cream production</td>
<td>52</td>
</tr>
<tr>
<td>2.8 Packaging and storing</td>
<td>57</td>
</tr>
<tr>
<td>2.9 Cleaning and disinfection</td>
<td>57</td>
</tr>
<tr>
<td>2.10 Utilities</td>
<td>60</td>
</tr>
<tr>
<td>2.11 Treatment of emissions</td>
<td>63</td>
</tr>
<tr>
<td>3. Current emission and consumption levels</td>
<td>69</td>
</tr>
<tr>
<td>3.1 Introduction</td>
<td>69</td>
</tr>
<tr>
<td>3.2 Energy production</td>
<td>69</td>
</tr>
<tr>
<td>3.3 Energy consumption</td>
<td>69</td>
</tr>
<tr>
<td>3.4 Consumption of water</td>
<td>70</td>
</tr>
<tr>
<td>3.5 Consumption of chemicals</td>
<td>71</td>
</tr>
<tr>
<td>3.6 Waste water discharges</td>
<td>72</td>
</tr>
<tr>
<td>3.7 Solid wastes</td>
<td>75</td>
</tr>
<tr>
<td>3.8 Emissions to air</td>
<td>77</td>
</tr>
<tr>
<td>4. Techniques to consider in the determination of “BAT”</td>
<td>79</td>
</tr>
<tr>
<td>4.1 Introduction</td>
<td>79</td>
</tr>
<tr>
<td>4.2 Common techniques</td>
<td>79</td>
</tr>
</tbody>
</table>
4.3 Production of fluid milk and cultured milk products 91
4.4 Butter and butter oil (AMF) 99
4.5 Cheese 100
4.6 Whey 105
4.7 Milk powder and condensed milk 110
4.8 Ice cream production 113
4.9 Packaging and storing 115
4.10 Cleaning and disinfection 116

5. Best Available Techniques 123

5.1 Introduction 123
5.2 Environmental management and training 123
5.3 Reduction of energy consumption 124
5.4 Reduction of water consumption 125
5.5 Reduced consumption of chemicals 126
5.6 Reduction of waste water discharges 126
5.7 Treatment of solid waste 127
5.8 Noise and emissions to air 128
5.9 Reference dairies 128

6. Emerging techniques 133

6.1 Introduction 133
6.2 Membrane techniques 133
6.3 Whey treatment 133

7. Conclusions and recommendations 135

Abbreviations 137
Preface

The aim of this report is to present an overview of the processes, the environmental impact and the consumption of resources in the Nordic dairy industry, and a description of the possibilities for implementation of cleaner technology, as well as current options for best available techniques for prevention or reduction of negative environmental effects.

The report is especially addressed to the dairy industry and the environmental authorities in the Nordic countries.

The presented techniques have been chosen according to the authors’ sector knowledge, based on a survey carried out among 57 major dairies in the Nordic countries. The work was done during the period of January 2000 to February 2001, and the report was prepared by:

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The project was attended by a managing group (the BAT-group), consisting of the following members:

- Magnus Klingspor, Swedish Environmental Protection Agency, (chairman)
- Emelie Enckell, Uusimaa Regional Environment Centre, Finland (contact person)
- Stefán Einarsson, Hollustuvernd Ríkisins, Iceland
- Inger Karin Hansen, The State Pollution Control Authority, Norway
- Ulla Ringbæk, Danish Environmental Protection Agency

The BAT-group is working in the Nordic area to furnish and distribute information on the possibilities of non-polluting production within vital fields. The work of this group is aimed to contribute to furthering the utilisation of the best available techniques (BAT) within selected fields. The object is to reduce the burden on the environment as much as possible.

As a part of the implementation of the EU IPPC directive the Commission has established a technical secretariat – the European IPPC Bureau – that is responsible for promoting the exchange of information and for preparing BAT notes within the fields concerned by the IPPC directive. The aim of this report is to supply a joint Nordic input to the work regarding dairies.

Opinions and attitudes expressed in this publication are not necessarily shared by the Nordic Council of Ministers or by the environmental authorities in the Nordic countries.
Summary

This report deals with environmental issues that are typical of the milk processing industry. It also covers the ice cream industry, although ice cream is not defined as a dairy product. The report does not cover the environmental issues related to the primary production of milk, since this is considered a part of the agricultural sector. Distribution and retail of dairy products are also regarded as out of scope, as are energy production and sewage treatment in general.

The current emission and consumption levels of the Nordic dairy industry were surveyed for the purpose of this study by aid of a questionnaire that was distributed to selected Nordic dairy and ice cream plants, including representatives of all the major dairy groups in each country (except Iceland and Faroe Islands) and covering the whole range of products.

The potential candidates for best available techniques were surveyed by means of a second questionnaire. Based on all results, five production plants were chosen as reference plants due to best overall performance. They are described in more detail at the end of the report. Some other plants are also being referred to in the description of specific techniques in chapter 4.

As for many other food processing industries, the main environmental impacts related to the milk processing industry are the high consumption of water, the discharge of effluent with a high organic load, and the consumption of energy for heating and cooling. Solid waste is also an issue, although most of it is generated in the consumer’s household in the form of discarded packaging material.

Water

Water is mainly consumed for cleaning of equipment and production facilities, but also for cooling operations. The consumption varies considerably case by case, depending on the scale of production, the product portfolio and the type of process (batch/continuous).

Generally, any measures for reduction of water consumption should be preceded by thorough monitoring of the water consumption in the plant, followed by identification of wasteful practices. There are some techniques of interest for the reduction of water consumption:

- reuse of secondary water, such as condensate from the evaporation process and water from reverse osmosis, for cleaning of less critical equipment
- reuse of cooling water for cleaning purposes or use of closed-circuit cooling systems
- use of automated cleaning-in-place systems (CIP) for cleaning of equipment and pipelines, which facilitates monitoring and optimisation of water use

However, the reuse of water is restricted due to hygienic safety and quality reasons, and this type of water must not come in direct contact with the product.
Energy

In dairies large quantities of thermal energy, usually in the form of steam, are used for heating operations and cleaning. The most energy consuming operations are evaporation and drying of milk. Electricity is used for the operation of machinery, for refrigeration, ventilation and lighting as well as for production of compressed air. The refrigeration plays an important role in the quality of dairy products.

Energy-efficient equipment and heat recovery systems are the keys to reduced energy consumption, in combination with good housekeeping practices, such as proper insulation. The use of regenerative heat exchange in the pasteurisation process, and of multiple effect evaporators with mechanical vapour recompression for evaporation, can be mentioned as examples of energy saving techniques.

Waste water

Waste water from dairy processing contains predominantly milk and product residues from the process, as well as caustic and acidic cleaning chemicals and detergents. The dairy effluent is characterised by a high organic load, fluctuations in pH and temperature, and by a high content of nitrogen and phosphorus.

In most cases the effluents from the Nordic dairies are discharged to the municipal sewage treatment plant, but some dairies have their own treatment plants. In order to avoid disturbances in the balance of the sewage plant, it is recommended that the dairy effluent is submitted to pre-treatment, such as fat removal and neutralisation of pH.

The organic load on the effluent should be reduced “at the source” by preventing milk and product residues from entering the effluent stream. This can be achieved in several ways, for example by:

- accurate detection of transition points between product and water phases during production start-ups and final rinsings, in combination with collection of product/water mixtures
- prevention of overfilling of tanks by means of level control and alarms
- thorough draining of pipelines and tanks prior to rinsing/cleaning
- refining of whey into useful products instead of discharging it to the drain
- recovery and utilisation of product condensate from the evaporation process

Optimised cleaning procedures and reuse of cleaning chemicals reduce the quantity of chemicals in the effluent.

Solid wastes

The packaging material is the main form of solid waste deriving from the dairy. It consists of beverage carton, cardboard, plastic materials, metallic barrels and wooden boxes and pallets. Solid waste is generated mainly by filling and packaging, where packaging mistakes are almost unavoidable. Many ingredients are also delivered in packages that have to be disposed of.

Solid waste is segregated in most of the Nordic dairies. Most materials are recycled and the recycling of beverage carton has also been extended to the households. Hazardous
wastes are also treated separately. Today the treatment of nonconforming products is a major problem, as landfill disposal is, or will be, prohibited.

Other environmental issues

Refrigeration systems based on chlorofluorocarbons (CFC) are a considerable environmental risk, and the CFCs should be replaced by less harmful substances, such as ammonia. The freons are being phased out in accordance with EU legislation.

Noise is mainly generated by the substantial traffic load caused by the regular milk deliveries, but also by evaporators, spray dryers and cooling compressors. Problems regarding odour and dust are also occurring, but not to a significant extent.

Best Available Techniques

Due to the diversity of the dairy industry, it is generally difficult to point out any specific technique that can be regarded as a BAT. This report includes examples of techniques and methods that have proven successful in some cases, but they are not necessarily directly applicable to other cases. Each technique should be assessed case by case, taking into consideration the age, the scale and the geographic location of the plant, as well as the product portfolio and the type of process.

The best environmental strategy is to introduce environmental management, which means defining a policy, monitoring the environmental impact of the activity and setting up goals for better environmental performance. Many Nordic dairies have chosen to use the structures of EMAS or ISO 14001 for this purpose, and most of them are already certified.

Other important measures to consider are:

- training of the personnel to raise the environmental awareness
- introduction of benchmarking activities and collaboration in environmental protection and BAT development within the Nordic dairy sector
Sammanfattning


De rådande emissions- och konsumtionsnivåerna inom den nordiska mejeriindustrin kartlades med hjälp av ett frågeformulär, vilket distribuerades till ett urval (57 st) nordiska mejerier och glasstillverkare. Urvalet inkluderade representanter för alla större mejerigrupperingar i varje land (förutom Island och Färöarna) och täckte hela produktortimentet.

De potentiella kandidaterna för ”bästa tillgängliga teknik” (BAT) kartlades därefter med ytterligare ett frågeformulär. På basen av resultaten valdes fem av de ur helhetsynvinkel bästa produktionsanläggningarna till referensanläggningar. De beskrivs mera detaljerat i slutet av rapporten. Rapporten refererar även till andra anläggningar i samband med beskrivningen av enskilda tekniker i kapitel 4.

I likhet med den övriga livsmedelsindustrin präglas mejeriindustrins miljöpåverkan av hög vattenförbrukning, avlopp med högt organiskt innehåll, samt av hög energiförbrukning för upphettning och kylning. Stora mängder fast avfall förknippas i viss mån också med mejeriindustrin, trots att största delen uppstår först i konsumentens hushåll.

Vatten

Vatten förbrukas främst vid rengöring av produktionsutrustning och –utrymmen, men också i stor utsträckning vid nedkylning. Konsumtionsnivån varierar avsevärt från fall till fall, beroende på produktionssskalen, produktortimentet och typen av process (satsvis/kontinuerlig).

Generellt sett borde alla åtgärder för reducering av vattenförbrukningen föregås av noggranna mätningar av förbrukningen i mejeriets olika avdelningar, med därpå följande identifiering av förslösande procedurer. Det finns vissa metoder av intresse för reducering av vattenförbrukningen:

- återanvändning av ”sekundärt” vatten, som t.ex. kondensat från industriprocesser och vatten från omvänd osmos (RO), för diskning av mindre kritisk utrustning,
- återanvändning av kylvatten för diskning, eller användning av slutna kylvattensystem,
- tillämpning av automatiska ”cleaning-in-place”-system (CIP) för diskning av rör och utrustning, vilket underlättar optimeringen och övervakningen av vattenförbrukningen.
Återanvändningen av vatten begränsas emellertid av hygieniska skäl, och återanvänd vatten bör under inga omständigheter komma i direkt kontakt med produkten.

**Energi**


Energisnål utrustning och system för värmeåtervinning utgör nycklarna till minskad energiförbrukenkning, speciellt då de kombineras med energihufläggande driftsrutiner och god isolering. Användningen av av regenerativ värmeväxling vid pastörisering och av mekanisk ångkompression vid indunstning, kan nämnas som exempel på energisparande åtgärder.

**Avloppsvatten**

Avloppsvattnet från mejeriprocesser innehåller företrädesvis rester av mjölk och produkt, samt sura och basiska disklösningar och rengöringsmedel. Processavloppsvattnet kännetecknas av en hög organisk belastning, varierande pH-värde och temperatur, samt av höga kväve- och fosforhalter.

Avloppet från flertalet av de nordiska mejerierna leds till det kommunala reningsverket, men några mejerier har ett eget reningsverk. För att undvika rubbningar i reningsverkets balans bör mejeriets avloppsvatten förbehandlas så, att fettet avskiljs och pH neutraliseras.

Den organiska belastningen av avloppsvattnet kan minimeras ”vid källan” genom att man förebygger produktspill till avloppet, exempelvis med hjälp av följande åtgärder:

- noggrann detektering av övergången mellan produkt och vatten vid uppstartning och slutsköljning, kombinerad med uppsamling av sk. gränsmjölk
- överfyllningsstopp på tankar och kar i form av nivåkontroll och alarm
- noggrann dränering av rör och tankar före sköljning/disk
- förädling av vassle till användbara produkter, i stället för att leda den till avloppet
- uppsamling och återanvändning av produktkondensat från indunstningsprocesser

Optimering av diskprogrammen och återanvändning av disklösningarna minskar mängden kemikalier i avloppsvattnet.

**Fast avfall**

Källsortering av fast avfall förekommer i de flesta nordiska mejerier. De flesta materialen återanvänds och insamlingen av vätskekartong har även utsträckts till hushållet. Farligt avfall hanteras separat. För tillfället utgör restprodukterna det största problemet, eftersom deponering av restprodukter är, eller kommer att bli, förbjudet.

Utsläpp till luft

Kylsystem innehållande freoner (CFC) innebär en stor miljörisk eftersom de inverkar nedbrytande på ozonskiktet. De bör därför ersättas med mindre miljöfarliga ämnen, såsom ammoniak. Freonerna håller på att avyttras i enlighet med EU-lagstiftningen.

Buller orsakas främst av trafiken av mjölkbilar och distributionsbilar till och från mejeriet, men även av indunstare, spraytorkar och kylkompressorer. Olägenheter som lukt och damm förekommer också, dock i en relativt liten utsträckning.

Bästa tillgängliga teknik (BAT)

På grund av mejerindustrins komplexa produktsortiment är det svårt att utpeka någon specifik teknik såsom varande BAT. Denna rapport innehåller exempel på tekniker och metoder som har tillämpats med framgång i många fall, vilket dock inte betyder att de kan appliceras direkt i andra fall. Varje teknik bör utvärderas separat i varje enskilt fall med beaktande av såväl anläggningens storlek, ålder och geografiska läge som produktsortimentet och produktionsprocessen.

Den bästa miljöstrategin är att implementera ett miljöledningssystem, vilket innebär att man definierar en miljöpolicy, följer upp verksamhetens miljöpåverkan samt sätter upp mål för dess förbättring. Många nordiska mejerier har valt att göra detta i enlighet med EMAS eller ISO 14001, och de flesta är redan certifierade.

Andra viktiga åtgärder är att

- skola personalen för att väcka deras miljömedvetenhet
- starta benchmarking- och samarbetsprojekt i miljöfrågor och BAT-utveckling inom den nordiska mejerisektorn.
1. General information on the dairy industry in the Nordic countries

1.1 Statistics

In order to give the reader some background information, this chapter presents some statistic data on the dairy industry in the Nordic countries.

<table>
<thead>
<tr>
<th></th>
<th>Denmark</th>
<th>Sweden</th>
<th>Finland</th>
<th>Norway</th>
<th>Iceland</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dairy cows</td>
<td>681</td>
<td>447</td>
<td>373</td>
<td>324</td>
<td>29</td>
</tr>
<tr>
<td>(1 000 head)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Av. herd size</td>
<td>64</td>
<td>34</td>
<td>15</td>
<td>13</td>
<td>n.a.</td>
</tr>
<tr>
<td>Milk produced</td>
<td>4 656</td>
<td>3 350</td>
<td>2 403</td>
<td>1 797</td>
<td>111</td>
</tr>
<tr>
<td>(1 000 t)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Milk delivered to</td>
<td>4 456</td>
<td>3 299</td>
<td>2 394</td>
<td>1 645</td>
<td>110</td>
</tr>
<tr>
<td>dairies (1 000 t)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Table 1.1 Dairy statistics for the Nordic countries in 1999 /1,2/

<table>
<thead>
<tr>
<th>Production</th>
<th>Denmark</th>
<th>Sweden</th>
<th>Finland</th>
<th>Norway</th>
<th>Iceland</th>
</tr>
</thead>
<tbody>
<tr>
<td>(1000 t)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Liquid milk</td>
<td>544</td>
<td>1 010</td>
<td>719</td>
<td>505</td>
<td>41.0</td>
</tr>
<tr>
<td>(incl. buttermilk, excl. cream)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cream</td>
<td>47.2</td>
<td>94.2</td>
<td>38.1</td>
<td>25.0</td>
<td>2.0</td>
</tr>
<tr>
<td>Fresh dairy products</td>
<td>89.0</td>
<td>268</td>
<td>203</td>
<td>79.5</td>
<td>7.0</td>
</tr>
<tr>
<td>(fermented products)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cheese</td>
<td>293</td>
<td>128</td>
<td>92.4</td>
<td>84.7</td>
<td>5.5</td>
</tr>
<tr>
<td>Butter</td>
<td>47.9</td>
<td>26.1</td>
<td>59.7</td>
<td>22.9</td>
<td>1.5</td>
</tr>
<tr>
<td>Skim milk powder</td>
<td>34.4</td>
<td>33.3</td>
<td>25.9</td>
<td>10.6</td>
<td>0.6</td>
</tr>
<tr>
<td>Ice cream (million litres)</td>
<td>32.4</td>
<td>117</td>
<td>61.7</td>
<td>56.6</td>
<td>3.1</td>
</tr>
</tbody>
</table>

Table 1.2 Dairy production in the Nordic countries in 1999 /1,13,14/.
Table 1.3. Per capita consumption of dairy products in the Nordic countries in 1999 (Iceland 1998) /1,13,14/.

<table>
<thead>
<tr>
<th>Consumption (kg per capita)</th>
<th>Denmark</th>
<th>Sweden</th>
<th>Finland</th>
<th>Norway</th>
<th>Iceland</th>
</tr>
</thead>
<tbody>
<tr>
<td>Liquid milk</td>
<td>96.7</td>
<td>114.1</td>
<td>149.4</td>
<td>109.4</td>
<td>153.6</td>
</tr>
<tr>
<td>Fermented products, milk drinks</td>
<td>29.8</td>
<td>30.2</td>
<td>40.2</td>
<td>19.9</td>
<td>25.3</td>
</tr>
<tr>
<td>Cheese</td>
<td>17.9</td>
<td>17.2</td>
<td>16.6</td>
<td>14.9</td>
<td>18.8</td>
</tr>
<tr>
<td>Butter</td>
<td>1.7</td>
<td>5.6</td>
<td>4.1</td>
<td>3.9</td>
<td>4.4</td>
</tr>
<tr>
<td>Ice cream (litres/capita)</td>
<td>9.2</td>
<td>12.4</td>
<td>13.9</td>
<td>12.4</td>
<td>12.2</td>
</tr>
<tr>
<td>Population (millions)</td>
<td>5.3</td>
<td>8.9</td>
<td>5.2</td>
<td>4.4</td>
<td>0.27</td>
</tr>
</tbody>
</table>

Table 1.4. Number of dairy plants and number of plants with daily milk intake exceeding IPPC-level of 200 tons/day, /9/, /18/, /19/, /20/.

Note, that the exact number of dairies above the IPPC-level in Sweden, Denmark and Norway was not available. There are, however, at least as many as indicated.

1.2 Denmark

1.2.1 Milk production and utilisation

The Danish dairy industry is often held up as a European model of efficiency with a good farm structure, above average sized herds, and milk yields per cow higher on average than anywhere else in Europe (except for Sweden). Consumption levels are among the highest in the world, and good branding and efficient marketing maintain huge volumes of export.

The milk production in Denmark is mainly concentrated in the province of Jutland, where 85% of the farms are located, accounting for almost 90% of the milk deliveries. The output of organic milk is steadily growing and reached 6% of total milk deliveries in 1999. However, the consumption of organic dairy products is now stagnating after several years of considerable growth, but it still remains one of the highest in Europe.
The production of liquid milk absorbs about 12% of the total milk deliveries. The liquid milk market has remained more or less stable, with a decline in the production of whole milk, which is compensated with an increased production of semi-skimmed and skimmed milk. The range of fresh dairy products is very diversified, as in all other Nordic countries, with several popular products that are not produced in the rest of Europe.

Cheese is the main product of the Danish dairy industry and the production absorbs about 40% of the milk fat produced. Feta cheese, produced mostly for export, has been the dominating variety until recently, but the market has been declining. The production of hard and semi-hard varieties, as well as blue-veined cheese, is increasing. Almost 90% of the annual cheese output is exported. /1,2,19/.

1.2.2 Industry structure

The Danish dairy industry is dominated by one large co-operative, Arla Foods, the result of the merger between Danish MD Foods and Swedish Arla in the spring of 2000. MD Foods had earlier merged with the second largest company Kløver Mælk in the beginning of 1999. That merger gave MD Foods control of almost 90% of the total milk deliveries and of 41 of the 89 registered production plants. In 1999 the number of co-operative dairy companies in Denmark was 14, the number of private-owned companies being 31, that is a total of 45 dairy companies comprising 89 production plants. The co-operative sector accounts for about 95% of the total milk deliveries, whereas the private operators are of small average size. The private processors are of significance in the cheese sector of the industry. Within Arla Foods in Denmark there are at least 12 production plants with a daily milk intake of more than 200 tons of milk. /2,19/.

1.2.3 Ice cream production

In 1999 the Danish ice cream producers produced 32.4 million litres of ice cream. There are 6 ice cream plants, of which the biggest producer is Hjem-Is in Esbjerg followed by Polar Is in Thisted. The other four are small-scale producers.

1.3 Sweden

1.3.1 Milk production and utilisation

Sweden has one of the smallest national dairy herds in the EU, followed only by Finland, Greece and Portugal. The cows are, however, the most prolific with an average annual yield some 28% above the EU average. Also the average herd size is above EU average. The milk production is concentrated to the southern half of the country.

About 50% of the total milk deliveries are absorbed by the production of liquid milk and fresh dairy products. This market is diverse, including an important yoghurt sector and a wide variety of fermented, acidified and cultured products. The cream market is growing, which, as in many other developed dairy markets, is contradictory to the increasing popularity of medium or low-fat products. The demand for milk for cheese
making is also slightly growing. The production of organic milk increased by 30% in 1999.

The skim milk powder production is partly for domestic use, mainly as animal feed, but also to balance the overall skim solids market.

Sweden’s entry into EU created wider export opportunities for the dairy industry, and is reflected by a slightly expanded cheese export. The import competition on the local market has become more aggressive for cheese and for yoghurt, particularly by Danish and Finnish products. /2/.

1.3.2 Industry structure

As in most of the Nordic countries, also the Swedish dairy industry is based on a mainly co-operative structure. In 1999 there were 50 production plants in Sweden owned by 16 dairy companies. The four largest co-operatives process about 90% of the total milk supply. The former Arla Group (today Arla Foods) accounts for two thirds of this quantity, covering the south and some of the centre of Sweden. The second largest, Skånemejerier in the south, controls 15 %, followed by Milko (former Milko and NNP) in the central and northern region, and Norrmejerier in the north. /2/.

Arla and the Danish MD Foods merged in the spring of year 2000 into Arla Foods, the largest dairy company in Scandinavia. Arla Foods has 26 production plants in Sweden. In 1999 40 % of the plants had achieved the ISO 14001 certificate, and by the end of year 2001 the rest will be certified. About 11 of the production plants have a daily milk intake exceeding 200 tons.

Skånemejerier has 4 production plants and one central cheese storage. The company is certified according to ISO 14001 and registered according to EMAS since 1997. The daily milk intake in 3 plants exceeds the IPPC-limit of 200 tons/day.

Milko was established in September 2000 through a merger of Milko Mejerier and Nedre Norrlands Producentförening (NNP). Milko Mejerier has 4 dairies, which all are certified according to ISO 14001 and registered according to EMAS since 1999. NNP has 3 production units. Three of these 7 production units receive more than 200 tons of milk per day.

1.3.3 Ice cream production

There are eight ice cream producers in Sweden, of which GB Glace is the largest. GB Glace, which belongs to Unilever, produces over 30 000 tons of ice cream annually, which corresponds to an average daily quantity of more than 100 tons. The other producers, such as Hemglass and Carlshamms Mejeri, produce less than 10 000 tons per year.
1.4 Finland

1.4.1 Milk production and utilisation

The milk production in Finland is characterised by a low average herd size, and many farms are disadvantaged by geographic and climatic conditions. Despite one of the highest average yields per cow, the average output per producer is modest due to the small herd size. Dairy farm numbers have also been dropping steadily since the EU entry in 1995.

Finland has a high consumption of liquid milk, which absorbs over 30% of the total national milk deliveries. The liquid milk market is diversified in the direction of acidified and cultured liquid products. Yoghurt and other similar cultured products, such as the local product “viili”, absorb almost 10% of the milk deliveries. The per capita consumption of liquid milk and fermented products is the second highest in the world. There is also an increasing demand for organic products, and the production of organic milk is growing rapidly.

Production of cheese is the second main milk utilisation in Finland. The domestic consumption is high and exports are significant.

The strength of the Finnish dairy industry is the investment in sophisticated technology and innovation. This has led to development of cultures, fat and protein fractions, nutri-food, infant formulas and other novel products. /2/.

1.4.2 Industry structure

The Finnish dairy industry is dominated by Valio, which is owned by 34 dairy cooperatives with 16 600 producers. In 1999 Valio received 1 585 million litres of milk, which is 68.2% of the total national milk deliveries. The share grew in year 2000, when Kainuun Osuusmeijeri and Maito-Pirkka joined the Valio group. Valio had 16 production plants in 1999, of which 2 produce non-dairy products. The number of plants with a daily milk intake exceeding the IPPC-level of 200 tons/day is 9. Valio achieved the ISO 14001 certificate in 2000.

A second force is Ingman Foods, a private company with 9% of the milk supply. There are also other smaller private and co-op dairies operating on a regional or local basis.

1.4.3 Ice cream production

Valio is the leading ice cream producer in Finland, followed by Ingman Foods. In 1999 Valio’s ice cream plant produced 31.5 million litres of ice cream (approximately 16 000 tons), whereas Ingman produced 12 500 tons.
1.5 Norway

1.5.1 Milk production and utilisation

The average herd sizes in Norway are well below the European level, which reflects the high cost of keeping cows in a northern climate. The Norwegian dairy industry has the unique feature of including about 60 000 goats in its milking herd.

The milk is used mainly for liquid milk/fresh products (almost 40%) and cheese (almost 50%). The most famous cheese is “Gjetost” made from goat’s milk. The production of butter is declining, as the consumption of vegetable fat/butter blends has increased. Norway is not a significant exporter of dairy products and is even less important as an importer, due to the official policy of balancing production with consumption, only with a small safety margin. /2/.

1.5.2 Industry structure

The Norwegian dairy sector has become virtually a single national co-operative. Liquid milk and other dairy products are produced in 70 plants throughout the country under the supervision of 10 co-operative dairy companies. These companies own a single national co-operative named TINE Norske Meierier. TINE is responsible for marketing, export, product development, distribution and production planning, and also for advising and supporting milk producers. The annual turnover of the total dairy sector is around € 1.3 billion.

Of the ten co-operative dairy companies, TINE Midt-Norge is the largest with 15 production plants treating almost 30% of the total milk deliveries (465 million litres). Second largest is TINE Meieriet Sør with 13 production plants treating 340 million litres, followed by Østlandsmeieriet with 14 production plants receiving 260 million litres.

There are at least 5 Norwegian dairies with a daily milk intake of more than 200 tons of milk.

1.5.3 Ice cream production

Norsk Iskrem BA is a Norwegian company owned by 9 Norwegian dairy companies. In 1999 the company produced almost 32 million litres of ice cream and gained a market share of 53.1 %. The company has 3 production plants with an annual output between 4500 and 6500 tons of ice cream.

Henning Olsen-Is is the second largest ice cream producer with a market share of 40%.

1.6 Iceland

In 1998 there were 12 dairies in Iceland. The biggest one is the Southern Iceland Dairy (Mjólkurbú Floamanna) located in Selfoss. The company received about 40 million litres of milk in 1998, which represents almost 38% of the total amount of raw milk
delivered to the Icelandic dairies. The company covers the southern part of Iceland and the milk is delivered by 500 producers.

The second largest dairy is KEA (Kaupfélag Eyfrìringa) in Akureyri. The dairy covers the northern part of Iceland and received about 21 million litres of milk in 1998. MS (Mjólkursamsalan) in Reykjavik received 13 million litres. The rest of the dairies are small units receiving 9.5 to 0.5 million litres per annum.

The 12 dairy companies jointly own the Icelandic Dairy Produce Marketing Association (Osta- og Smjórsalan), which sees to the marketing of the cheese, butter, dairy spreads and skim milk powder produced by the dairies.

There has been a strong decrease in the consumption of liquid milk, whereas the consumption of fermented products, cheese and butter is increasing.

Ice cream is produced in Iceland by Emmessis in Reykjavik. In 1998 approximately 3 million litres of ice cream were produced, of which amount 1 % was exported.

None of the Icelandic dairy production units has a daily production rate exceeding the IPPC level.

1.7 The Faroe Islands

1.7.1 Dairy products

The Faroe Islands Dairy Centre (MBM) is a co-operative that supplies all the inhabitants with fresh milk and other milk products, which are produced in one production plant.

1.7.2 Ice cream

The Faroe Islands have one ice-cream factory, Fóm Ltd., which is situated in Tórshavn and employs 6-12 persons. The company was established in 1981 and has since become the largest domestic supplier. Today 50% of the production is exported. A part of the production has been transferred to the company’s branch in Greenland.
2. Applied dairy processes and techniques

2.1 Milk reception and common treatment

2.1.1 Milk reception

The raw milk arrives at the dairy in insulated road tankers, where it should be kept chilled and free from air. By reception the raw milk is measured either by volume or by weight. As its temperature normally rises to slightly above +4°C during transportation, the milk is usually cooled to a temperature below +4°C before being stored in a silo awaiting processing. Ice water is normally used as cooling media.

The raw milk silos can be equipped with cooling water jackets for circulation of chilled water, but some silos are fitted with insulation only.\(^3\/\)

*Environmental issues*

Ice water is consumed for cooling of the incoming milk. Water is used for rinsing of the reception line and the inside of the tanker. When the hoses are disconnected some milk is spilt on the floor unless they are thoroughly drained.

2.1.2 Heat treatment

Regardless of what the end product will be, the milk must be treated in such a way that all pathogenic microorganisms are killed. This is achieved by pasteurisation, a form of heat treatment that is required by law in most countries. Some types of cheese are, however, made from unpasteurised milk.

The general milk treatment comprises the following steps aiming at modifying the composition of the milk, rendering it more suitable for subsequent processing /3/: 

- clarification to remove foreign particles
- separation to skim the cream from the milk
- standardisation of the fat content by mixing cream and skim milk
- homogenisation to reduce the size of the fat globules
- pasteurisation to kill all pathogenic micro-organisms

In addition to these main operations, the general milk treatment includes other operations, the application of which depends on the final product:

- deaeration to expel gases and malodorous volatile substances
- bactofugation or microfiltration to separate micro-organisms from milk
- standardisation of protein or dry matter content
**Heat treatment**

To ensure total destruction of all pathogenic microorganisms, it is necessary to heat the milk to a given temperature and to keep it there for a given length of time. The most widely used heat treatment is **pasteurisation**, where the milk is heated to 72º-75ºC for at least 15 seconds. The milk is then cooled to about +4ºC. Usually the milk is pasteurised in a plate heat exchanger.

Another type of heat treatment is called **Ultra High Temperature treatment** (abbreviated UHT), where the milk is heated to 135º-140ºC for a few seconds. This kind of treatment is used for products with long shelf life, which can be stored in ambient temperature.

The objective should be to heat treat all incoming milk within 24 hours of arrival. In some cases this is impossible and the milk has to be prepasteurised in order to prevent serious quality deterioration. This process is called **thermisation** and comprises heating to 63º-65ºC for about 15 seconds.

In order to save energy, the pasteurisation process involves regenerative heat exchange, which means that the already pasteurised milk is used as a heating medium for the incoming cold milk. Depending on the equipment, the regenerative efficiency is about 96%. The incoming milk is thus preheated in the regenerative section of the heat exchanger, and is then heated to the final pasteurisation temperature by a hot-water system. The water system is a closed system where the circulating water is heated by steam at a pressure of 6-7 bars.

The pasteurised milk is mainly cooled by means of regenerative heat exchange and the lowest temperature thus obtained is about 8-9ºC. Further cooling to 3-4ºC requires ice water and an even lower final temperature requires use of brine or alcohol solutions. /3/.

**Clarification and cream separation**

Centrifugal separation is a very common process in dairies. In addition to clarification and skimming of milk, it is also used for whey separation, quark separation, Bactofuge treatment and butter-oil purification.

A centrifugal separator consists of a stack of discs in a rotating bowl. The entering milk is accelerated to the same speed of rotation as the bowl and is distributed in the separation channels between the discs. The cream, having a lower density than skim milk, moves inwards towards the axis of rotation, whereas the skim milk moves outwards to the space outside the disc stack. The two fractions are then discharged from the separator through separate outlets.

In most dairies the clarification and the cream separation is carried out by means of self-cleaning separators. The milk is separated into a stream of cream containing 40% fat and a stream of skim milk containing 0.04 - 0.07% fat. The separator also discharges sediment consisting of dirt particles, udder cells, bacteria, leucocytes, etc., which is normally led to the drain. The total amount of sediment in milk is normally about 1 kg/10 000 litres.

The separator is usually connected to the preheating section of the pasteuriser, as the optimum temperature for separation is about 65ºC. /3/.
**Mechanical reduction of bacteria**

The amount of spore-forming bacteria in milk intended for production of milk, cheese and powder must sometimes be reduced by treating the milk in a specially designed centrifugal separator called the Bactofuge. The separation is based on the fact that bacteria have a significantly higher density than milk.

The bactofugation takes place at a temperature of 55 - 60°C either upstream or downstream of the cream separator. The milk entering the Bactofuge is separated by centrifugal force into a bacteria-reduced phase and a bacteria concentrate called the bactofugate. The bactofugate amounts to 0.15 – 3% of the feed, depending on the type of Bactofuge used.

The discharged bactofugate is then separately sterilised at approx 130°C and it can be reincorporated into the product, if permitted by legislation. If reuse is not possible, the bactofugate is either led to the drain or collected for further destruction.

Another possibility to reduce the amount of bacteria is offered by microfiltration of skim milk, using membrane filters with a given pore size. The filtration temperature is 50°C and the filtration equipment is connected to the skim milk line coming from the separator. The retentate (5% of the feed) containing the bacteria is sterilised and reintroduced into the cream used for standardisation. /3/.

**Homogenisation**

The aim of the homogenisation is to prevent gravity separation of the fat in the product. Homogenisation takes place after separation, usually at 70°C. The fat globules of the milk are subjected to mechanical treatment by forcing the milk at high pressure through a narrow gap of about 0.1 mm, which breaks them down into smaller globules.

The homogeniser consists of a high-pressure pump driven by a powerful electric motor, and a backpressure device. The homogenising pressure is between 10 and 25 MPa, depending on the product. /3/.

**Deaeration**

Deaeration of the milk is sometimes necessary to remove excess air in order to improve the syneresis stability of cultured products. The deaeration is normally carried out in a vacuum vessel in connection with the pasteurisation.

**Standardisation of dry matter or protein content**

Standardisation of the dry matter or protein content of the milk is necessary in the production of some cultured products and cheese. The most common ways are:

- evaporation, which takes place in connection with the pasteurisation prior to homogenisation
- addition of skim milk powder by mixing
- ultrafiltration (UF) treatment, where the milk flows under pressure over a membrane which retains the larger molecules in milk
**Environmental issues**

The main environmental issues of the milk treatment described above are related to the high levels of energy consumed in heating and cooling of the milk, and the electricity consumed by the homogeniser, the separator and the pumps.

Water is consumed for rinsing and cleaning of the equipment, which procedure in turn results in waste water containing milk solids and cleaning agents. Water/milk mixtures are also generated at the start-up of the production line, when the water in the pipes is replaced by milk.

The inputs and outputs of the main steps of the pasteurisation process are presented in fig. 2.1.

![Diagram of milk pasteurisation process](image)

*Fig. 2.1. Inputs and outputs of the milk pasteurisation process*
2.2 Production of fluid milk and cultured milk products

2.2.1 Pasteurised milk and long life milk

*Pasteurised market milk and cream*

The market milk undergoes pasteurisation as described in the previous chapter. The fat content of the milk is adjusted to the desired level by mixing cream and skim milk in right proportions. This procedure is called standardisation and is carried out either as pre-standardisation (before pasteurisation), post-standardisation (after pasteurisation) or as direct standardisation (directly after separation).

Pre- and poststandardisation are used in batch processing, but since both methods are labour-intensive and require large tanks, automatic in-line fat standardisation has become more attractive. In this method the fat content is adjusted to the required level by remixing of a calculated proportion of the cream from the separator to the skim milk line.

Cream sold to consumers is also produced with different fat contents. The cream is pasteurised separately at a slightly higher temperature (80º-90ºC) than the milk. Cream with a high fat content intended for whipping must be stored at a low temperature (4-6ºC) for a relatively long time in order to obtain a proper crystallisation of the fat. As heat is released during crystallisation, the cream must be cooled to prevent an increase in temperature.

*Long life milk*

Sterilised milk can be stored for long periods at ambient temperature without spoiling, thus offering many advantages both for the producer, the retailer and the consumer. The production of long life milk involves Ultra High Temperature treatment (135-150ºC for 4-15 seconds) followed by aseptic packaging.

There are two main types of UHT systems:

- direct systems, where the product is heated in direct contact with steam, followed by flash cooling in a vacuum vessel, and
- indirect systems, where the heat is transferred to the product through a partition (plate or tubular) wall

The direct system can be further divided into two categories:

- steam injection systems
- steam infusion systems

Regardless of the type of UHT system, the operating phases are the following:

- pre-sterilisation of the equipment with hot water
- cooling of the equipment
- production
- aseptic intermediate cleaning (AIC) between production runs to remove fouling in the production line
• final cleaning in place (CIP) comprising prerinsing, caustic cleaning, hot water rinsing, acid cleaning and final rinsing

The sterilised, cooled product is finally pumped to an aseptic tank, which provides a buffer between the continuous process line and the aseptic filling machine. The aseptic tank is sterilised with steam and filled with sterile air prior to production. Sterile compressed air is usually used for transferring the product from the tank to the filling machine. /3/

**Environmental issues**

The environmental issues for the production of liquid milk products are the same as those for common milk treatment previously described in chapter 2.1.

For long life milk the environmental impact is greater than that of pasteurised milk, due to the UHT treatment. The UHT-treatment requires more steam and the presterilisation step increases the consumption of water. If the temperature drops during production, the product in the line must be rejected. The rejected product can be reused in other products, provided it is permitted by legislation and does not compromise the quality of the final product, or it can be used as animal feed.

### 2.2.2 Cultured milk products

Culture milk is the collective name for products prepared by lactic acid fermentation or by a combination of this and yeast fermentation. Such products are for example yoghurt, “filmjölk”, kefir, cultured cream and cultured buttermilk.

The production of cultured products involves inoculation of the heat-treated and standardised milk with a starter culture, followed by incubation for a certain time.

**Yoghurt**

Yoghurt is typically divided into the following types:

- **Set type** yoghurt, which is incubated and cooled in the packages
- **Stirred type** yoghurt, which is incubated in tanks and cooled before packing
- **Drinking** yoghurt, which is similar to stirred yoghurt, but the coagulum is broken down to a liquid
- **Frozen** yoghurt, which is incubated in tanks and frozen like ice cream

Regardless of the yoghurt type, the milk used for yoghurt production is heat-treated (90-95°C, 5 minutes), homogenised and standardised to the desired fat content. The content of dry matter is standardised either by addition of skim milk powder, by evaporation of 10-20% of the milk volume or by addition of retentate (=concentrate) from ultrafiltration (UF). Deaeration is usually also a part of the process.

When evaporation is used to increase the dry matter content, some of the evaporated water is used to preheat the incoming milk. This improves the thermal economy of the process line.

After the heat-treatment, the milk is cooled to the desired inoculation temperature (40-45°C).
The bulk starter used for yoghurt production is manufactured under aseptic conditions and the process comprises the same steps as the yoghurt production, that is heat treatment, cooling, inoculation, incubation and final cooling.

After inoculation the stirred type yoghurt is incubated in insulated tanks until the required pH is reached and is subsequently cooled to 15-22°C prior to filling. The set type yoghurts are incubated after filling in an incubation room and cooled afterwards in a cooling tunnel. /3/.

*Other cultured products*

The manufacturing process for other cultured products involves more or less the same steps; only the temperature programs are different. /3/

*Environmental issues*

The production of cultured products involves several heating and cooling steps, which result in high consumption of cooling and heating energy (ice water, cooling water and steam). There is also a high degree of product spill in the form of product/water mixtures generated at production start-ups and end rinsings, and by product changeovers. This spill is usually collected, but as it contains soured product, it can only be used as animal feed.

The inputs and outputs of the process are presented in fig. 2.2.

![Diagram of production process](image)

*Fig. 2.2. Inputs and outputs of production of cultured products.*

**2.2.3 Filling and packing**

The filling of the products into their final packages takes place in adapted filling machines. These machines are cleaned by CIP at given intervals. Usually the machines have their own CIP units with special detergents.
Aseptic filling involves presterilisation of the filling machine, sterilisation of the packaging material and filling with a sterile product in a sterile environment.

The package should preserve the food value of the product by protecting it from bacteriological contamination, mechanical shock, light and oxygen. Liquid milk products are packed in beverage carton, which is mainly paperboard covered by a thin layer of food-grade polyethene on either side. Milk cartons for long life milk have an additional layer of aluminium foil.

Cultured products are packed either in beverage carton, or in plastic beakers with lids of aluminium foil or paper. In some cases the portion beakers are wrapped together in carton as multipacks.

**Environmental issues**

The inputs and outputs of the filling and packaging step are shown in fig. 2.3:

![Figure 2.3: Inputs and outputs for the filling step](image)

The main environmental issues are: product loss from spills and packaging mistakes, wastewater from cleaning operations, and solid waste generated by the package itself.

Most packages end up as household waste. Empty packages and rejected material from the filling machines, as well as packages from nonconforming products, represent a great proportion of the solid waste from the production plant.

There are several ways to lessen the environmental burden caused by the packaging material, ranging from choice of material to recycling and use for energy production. These alternatives will be further discussed in chapters 4 and 5. One must, however, remember that the possibilities for recycling are limited, due to reasons of hygienic safety.

2.3 Production of butter and butter oil

2.3.1 Butter making

Butter is usually divided into two main categories:

- sweet cream butter
- cultured or sour cream butter
Large-scale butter manufacturing processes involve quite a number of stages. Butter can be produced either batchwise in churns or continuously in a butter making machine. Although churns are still used, they are nowadays mostly replaced by continuous machines.

The cream used for butter is pasteurised (even up to 110°C) and, if necessary, subjected to vacuum treatment before being transferred into ripening tanks. In these tanks the cream undergoes a temperature treatment program in order to give the fat the required crystalline structure. The tanks are usually triple-shell tanks with heating and cooling media circulating between the shells.

If sour cream butter is produced, the bacterial souring of the cream takes places in the same tanks. The cream is mixed with a starter culture and is simultaneously acidified during ripening.

From the ripening tanks the cream is continuously fed to the double-cooled churning cylinder of the butter making machine, where the fat globules are disrupted. The formed butter grains and the surrounding liquid (butter milk) are then separated in the separation section of the machine. Here the butter grains undergo a first washing with chilled buttermilk. The remaining buttermilk is removed from the grains in the squeeze-drying section and the grains are subsequently treated in several working sections. The finished butter is continuously extruded from the end nozzle and is transferred to the packaging machine.

In batch processes the ripened cream is agitated in specially designed churns until phase conversion takes place and butter grains are formed. The buttermilk is decanted off and the grains are washed in fresh chilled water. The grains are then worked to produce a homogenous mass with controlled moisture content.

In comparison with the batch process, the continuous process reduces the amount of waste by eliminating the butter grain washing step and by employing a system for continuous recovery of butter fines.

The packaging material used for butter must be greaseproof and impervious to light, flavouring and aromatic substances. It should also be impermeable to moisture to prevent the butter from drying out. Butter is widely wrapped in aluminium foil, whereas dairy blends and spreads are packed in plastic tubs with an inner lid of aluminium foil.

Butter, dairy blends and spreads should be stored cold at +5°C. Butter can also be frozen for long term storage, which requires temperatures below −15°C. Sufficient air circulation must be provided in order to allow even chilling. /3/.

Environmental issues

The impact of the pasteurisation step is associated with the consumption of heating energy as well as with the high organic load of the rinsing and cleaning water. As frequent cleaning is required, the loss of milk solids is also high.

The churning step produces buttermilk, which represents a potential environmental loading, unless collected. The buttermilk usually amounts to approximately 50% of the
original cream volume, and it can be used as an ingredient in other products. Sour buttermilk is more difficult to use for other purposes than animal feed.

When a continuous butter production line is closed down, the residual fat remaining in the equipment has to be rinsed out before the equipment is cleaned, which results in high organic loads in the generated waste water.

The inputs and outputs of the butter making process are described in fig. 2.4.

![Butter production process diagram]

**Fig 2.4 Inputs and outputs of the butter production process.**

### 2.3.2 Production of anhydrous milk fat (AMF)

Anhydrous milk fat products are divided into three categories:

- Anhydrous Milk Fat
- Anhydrous Butter oil
- Butter oil

This description will cover the manufacture of AMF in general.

*Production*

AMF can be produced either directly from cream or via butter. When cream is used the incoming cream is heated or pasteurised before it is submitted to centrifugal pre-concentration in order to increase the fat content to 75%. The cream concentrate undergoes phase inversion in a homogeniser, after which it is further concentrated in a
separator to butter oil of 99.5% fat. These steps are carried out at a temperature of 60ºC. The butter oil is then preheated to 95-98ºC and the moisture content is reduced to 0.1% in a vacuum chamber, followed by cooling to packaging temperature (35-40ºC).

The centrifugal concentration steps produce a by-product also called buttermilk, which still contains some fat. This fat can be separated and reused in butter production.

AMF is often produced from butter. This method involves melting and heating of the butter to 60ºC, followed by final concentration, preheating, vacuum treatment and cooling, as described above. /3/.

**Refining methods**

The obtained AMF can be further refined by the following methods /3/:

- **Polishing**, that is washing of the oil with water after the final concentration in order to obtain a clear product. 20-30% water is added and after a short hold it is separated out again, thus removing mainly protein.

- **Neutralisation** in order to reduce the level of free fatty acids. The procedure involves addition of 8-10% NaOH and water followed by separation of the saponified free fatty acids.

- **Fractionation** of the oil into high-melting and low-melting fats by melting and slow cooling, whereupon the different fats crystallize and are filtered out. The fractionation is usually preceded by polishing.

- **Decholesterisation** for removal of cholesterol from the oil. This is done by mixing the oil with modified starch.

**Packaging**

The AMF is usually filled in containers. Nitrogen is used in order to remove air from the container, thus preventing oxidation of the oil. /3/.

**Environmental issues**

Energy is consumed in the heating steps and for melting of butter, and cooling water is required for cooling. The phase inversion performed by the homogeniser requires electricity. The refining processes require water and the generated waste water, which contains water-soluble substances, is led to the drain. The process also produces a by-product in the form of buttermilk, which contains less than 1% fat.

The inputs and outputs of the production of AMF from cream are described in fig. 2.5.
2.4 Production of cheese

Cheese is generally defined as a milk concentrate obtained by coagulation and consisting mainly of casein and fat. The residual liquid is called whey. The different cheese types can be categorised according to the following attributes:

- **Consistency**, depending on the moisture content (extra hard <41%, hard, semi-hard, semi-soft, soft >67%)
- **Fat content** (high fat >60%, full fat, medium fat, low fat, skim <10%)
- **Curing characteristics** (ripened, mould ripened, unripened)
In addition to the official classification of cheese, other national classifications are often used. In Denmark, for instance, the designation ‘yellow cheese’ covers semihard, ripened cheese made of cow’s milk. Subdivision of hard and semihard cheese according to texture (closed, granular, round-eyed) is also common.

Cheese production comprises numerous steps, of which several are common to most types of cheese. However, there are also many procedures that are type-specific. The following description is intended to give a general view of the most important procedures.

2.4.1 Curd production

The milk used for most types of cheese is preferably pasteurised before being pumped into the cheese vat. This treatment also usually involves bactofugation (see chapter 2.1.2), which mechanically reduces the amount of spore-forming bacteria in order to prevent the cheeses from “blowing” during ripening.

Another possibility to reduce the amount of bacteria is microfiltration. Due to its high bacteria-reducing efficiency, microfiltration allows production of hard cheese without addition of chemical additives like NaNO₃, to inhibit growth of spores.

The fat content of the cheese milk is standardised either by direct in-line standardisation after separation, or by pre-standardisation prior to pasteurisation.

When the milk is entering the cheese vat (usually at a temperature of 30ºC), starter culture is added in-line. The quantity varies, depending on starter activity. The starter addition is followed by addition of other necessary components, such as calcium chloride and salpetre.

Rennet is added when the acidity of the cheese milk has reached the desired level. The rennet acts to coagulate the milk solids into curd. The coagulation time is usually about 30 minutes and when the curd is firm enough the coagulum is cut. The cheese vat is equipped with cutting knives that gently break the coagulum into small cubes.

When the curd is cut, the suspension is gently stirred in order to expel whey from the grains. At this stage some of the whey can be drained off, depending on the type of cheese that is produced. This reduces the energy consumption of the subsequent heating step.

The suspension is heated in order to limit the acidification of the curd and to promote syneresis (whey expulsion from the curd). There are several ways to heat, depending on the type of cheese:

- Indirect heating by steam in the vat jacket
- A combination of steam in the jacket and addition of hot water directly into the vat
- Direct heating by addition of hot water
The temperature varies from 40ºC up to 56ºC depending on the cheese type. The heating phase is followed by final stirring until the desired acidity and firmness of the curd has been obtained.  

**Environmental issues**

The main environmental impact of curd production is related to the energy consumption required for the heating of the curd. Depending on the type of cheese produced, 85-90% of the original milk volume is drained off as whey, which requires further treatment. Rinsing of the cheese vats generates waste water containing cheese fines and traces of fat. Electricity is required for the cutting and stirring tools.

The inputs and outputs of traditional curd production are described in fig. 2.6.

![Diagram of curd production process]

*Fig 2.6 Inputs and outputs of traditional curd production.*

### 2.4.2 Curd handling, whey separation

The down-stream handling of the curd varies depending on the type of cheese to be manufactured. The main differences are outlined in fig 2.7. The cheese types B, C and D represent hard/semihard cheeses.
Pressing

After cooking and final stirring the whey is separated from the curd. When producing cheeses with a granular texture, the whey is removed before the curd is distributed into moulds for final pressing. This is usually done by means of a vibrating or rotating strainer.

The curd intended for round-eyed cheeses must not be exposed to air before pressing, which means that most of the whey is removed in the prepressing step. This is usually done in a separate prepressing vat. The curd is pumped into the vat and distributed evenly on the woven plastic bottom. Pressure is applied by means of a pressing lid and the whey is discharged through the perforated plates covering the inner walls of the vat.
The prepressed cheese block is conveyed out of the vat and simultaneously cut into smaller blocks for moulding. The cut blocks are placed in plastic moulds either manually or by means of a mechanical moulding device.

Prepressing, cutting and moulding into moulds can also be done continuously using a system called Casomatic.

The curd in the moulds is subjected to final pressing in order to:

- remove the last whey
- provide texture
- shape the cheese
- provide a rind on cheeses with long ripening time

In large-scale production the alternatives for final pressing are:

- trolley table pressing
- auto feed tunnel pressing
- conveyor pressing

The auto feed tunnel and the conveyor presses are highly mechanised, and they are normally equipped with CIP systems for cleaning.

Semi-soft and soft cheeses, like the blue-veined cheeses and Brie, are allowed to settle by self-pressing, during which procedure the cheeses are turned several times.

After the final pressing the cheese is unmoulded and the moulds are washed before refilling. /3/.

**Cheddaring**

Cheese types with a closed texture, such as Cheddar, are manufactured using a specific process called cheddaring. All the whey is drained off and the curd is left for continued acidification. The curd is formed into blocks, which are stacked and turned. The blocks are milled into chips, which are salted and moulded ("hooped"). The subsequent treatment is equal to that of other hard cheeses.

The cheddaring process can be done in a mechanised cheddaring machine, which is a continuous system for dewhaying, cheddaring, milling and salting, consisting of several conveyors that convey the curd through the different treatment sections. /3/

**Cooking and stretching of Pasta Filata types**

“Elastic” cheese, like Mozzarella and Provolone, are obtained by cooking and stretching of cheddared curd. The milled chips are cooked with hot water at 82-85°C in a continuous cooking and stretching machine with counter-rotating augers. The cheese is worked until it is smooth and elastic, and is subsequently moulded. The moulded cheese is cooled in a hardening tunnel prior to demoulding and brining.

The cooking water is usually saved and the fat is separated. /3/.
Environmental issues

The pressing of cheese produces more whey. Curd grains are often spilt on the floor during moulding and are usually flushed into the sewer by water at the end of the day.

The operation of the presses requires electricity and compressed air. Electricity is also consumed by the conveying systems.

The Pasta Filata process requires both heating and cooling energy.

Water and cleaning chemicals are used for cleaning of the cheese moulds and the pressing equipment.

The inputs and outputs of cheese pressing are described in fig. 2.8.

![Diagram](image)

Fig. 2.8. Inputs and outputs of cheese pressing.

2.4.3 Salting

Salt is added to cheese as a condiment, but it also serves as a retarding agent for starter and other bacteriological activity. The salt content of cheese is usually 0.5-2%. The method used for salting depends on the cheese type, the alternatives being:

- **Dry salting**, where dry salt is applied either manually or mechanically to the curd (e.g. Cheddar, Mozzarella),
- **Brine salting**, where the cheese is placed in a container with brine (e.g. Emmental, Tilsit).

**Brine salting**

In large-scale production of brine-salted cheese the most common brining systems are shallow brining, deep brining or rack brining. Regardless of the system used, the idea is to keep each cheese immersed in brine for a given time, which depend on the type and the size of the cheese. The salt concentration of the brine is usually 18-23%, the temperature being 10-14°C.

The salt concentration of the brine needs to be readjusted as moisture is expelled from the cheese in exchange of sodium chloride. The microbiological activity in the brine must also be kept under control in order to prevent quality defects in the cheese. For this purpose the brine can be pasteurised, but this method upsets the salt balance and requires expensive equipment, as brine is highly corrosive. Other alternatives are
microfiltration, kieselguhr filtration, UV-treatment and addition of chemicals. The chemicals used are mainly sodium hypochlorite, sodium or potassium sorbate, or delvocide (= pimaricine). /3/.

Environmental issues

Mostly the brine is never changed. However, small surplus volumes are discharged to the drain, thus causing a significant load on the waste water due to the high concentration of salt.

The inputs and outputs of cheese brining are described in fig. 2.9.

Fig. 2.9. Inputs and outputs of cheese brining.

2.4.4 Ripening

Ripening of cheese induces a series of microbiological, biochemical and physical changes in the cheese. The ripening takes place in storage under controlled conditions and involves several ripening stages with specific combinations of temperature and humidity. A complete air conditioning system is required to maintain the ripening conditions. /3/.

Environmental issues

The cheeses are covered to prevent drying and to protect the cheeses from dirt. Cheese with rinds can be covered with paraffin or wax, whereas rindless cheese is wrapped in plastic film or shrinkable plastic bags. These bags are removed after ripening and discarded as waste.

The ripening temperatures in the ripening rooms are strictly maintained, which requires large quantities of energy. Cooled storages consume refrigerants, some of which might accidentally leak into the air.

The inputs and outputs of the ripening of cheese are described in fig. 2.10.
2.4.5 Ultrafiltration

Ultrafiltration (UF) is a membrane technology used for concentration of large and macromolecules. In cheese manufacturing it can be used for concentration of milk protein in order to standardise the protein to fat relation.

Depending on the degree of concentration, it can be combined with traditional cheese making equipment or used for completely new types of cheese.

The milk is pasteurised before entering the UF equipment. Filtration is carried out at approximately 50°C. The retentate (concentrate) is cooled to renneting temperature and is further processed to cheese. The warm permeate, containing only lactose, some minerals and non-protein components, is used to heat the incoming milk in the regenerative section of the pasteuriser. /3/.

*Production of Feta-cheese by ultrafiltration*

Ultrafiltration is widely used in the production of Feta-cheese. The retentate from the UF process is mixed with culture, rennet and salt, and the mixture is allowed to coagulate in a coagulator consisting of insulated, spiral-wound coagulation pipes. The curd is cut into cubes at the exit of the pipes in a cutting unit. The curd is allowed to acidify and is subsequently filled in tins together with brine.

*Environmental issues*

UF limits the losses of protein and fat. However, the cleaning of the membranes requires large quantities of water, heat and cleaning chemicals.

2.4.6 Processed cheese

Processed cheese is made from finished cheesed by further processing into cheese spreads with soft consistency or firm cheese blocks. The process comprises washing and grinding of the cheese, followed by heating under vacuum in steam-jacketed cookers and blending with emulsifiers and stabilisers.

The cheese used as raw material for this process can be either high quality cheese or cheese with defects. Several types are usually blended together. /3/. 
2.4.7 Quark

Quark is a product defined as an unripened curd cheese made of sour skim milk. It is often mixed with cream and fruit.

The skim milk is pasteurised at high temperature (85-95°C, 5 – 15 min), followed by cooling to 25-28°C. A coagulum is formed by addition of starter and a small amount of rennet, followed by incubation. The obtained coagulum undergoes thermisation and is then separated in a centrifugal quark separator. The separated quark is cooled before being packed. The whey from the separator outlet is collected for further treatment. /3/.

There are several national specialities whose manufacturing process follows the same principles as quark manufacturing. One example is the Icelandic Skyr, which is a fermented, concentrated milk product containing 20.9% dry matter. The product is concentrated either by separation or by ultrafiltration (see chapter 2.4.5).

2.4.8 Packing

Processed cheese spreads are usually packed in plastic tubs with an inner lid of aluminium foil. Soft cheeses like cottage cheese are packed in small plastic containers, whereas others, like Camembert are wrapped in aluminium foil or paper. Aluminium foil is also used for blue veined cheeses.

Hard cheeses can be packed as such in cardboard boxes, or cut into smaller blocks that are packed in plastic bags. Before the cheeses are cut, the rind is cut off and collected together with nonconforming pieces for further processing into grated or processed cheese.

Many cheese types are brushed or washed after ripening before being packed in retail packages. /3/.

Environmental issues

The major wastes from the packing of cheese are solid wastes in the form of discarded cuts and small pieces of cheese, as well as spent ripening bags and wax residues.

In addition, there are liquid discharges from cleaning of surfaces, packaging machines and conveyors.

The inputs and outputs are described in fig. 2.11.

![Diagram](image)

Fig.2.11. Inputs and outputs of packing of cheese /7/.

44
2.5 Whey processing

When cheese is produced, 10-15% of the milk is converted to cheese and the remaining 85-90% is whey. Whey from cheese manufacture is known as sweet whey and it still contains about 50% of the nutrients from the original milk. The valuable nutrients of whey can be recovered by means of several different processes. The predominating products today are whey powder, demineralised whey powder, lactose and delactosed whey powder.

Whey concentrate or powder is used both as animal feed and for human consumption. Lactose can be used for human consumption and in industrial products. /3/.

2.5.1 Separation

Regardless of the treatment of whey, the first step is always separation of cheese fines and cream, because these components interfere with the subsequent treatment.

The cheese fines (casein) are removed first, either by means of cyclones, centrifugal separators or rotating filters. The can be pressed as cheese and used in processed cheese.

The fat is recovered in centrifugal separators and can be used for standardisation of the cheese milk.

Whey is an excellent growth media for bacteria and must therefore be processed as soon as possible after collection. If this is not possible, the whey has to be chilled or pasteurised as soon as the fat has been removed. /3/.

2.5.2 Concentration

RO (reverse osmosis) is often used to preconcentrate the whey. It is based on a membrane technology, which retains both high and low-molecular substances. The permeate consists of water, which can be used internally in the dairy for cleaning purposes.

The preconcentrated whey is then evaporated to its final concentration (45-65% dry matter) under vacuum in multi-stage falling film evaporators. Most of these evaporators are equipped with mechanical and/or thermal vapour compression in order to save energy /3/.

The evaporation process is further described in chapter 2.6.1

The concentrated whey can be further dried to powder in the same way as milk in drum or spray dryers as described in chapter 2.6.

Environmental issues

The application of membrane processes requires special cleaning chemicals (mainly acids and lye), thus generating waste water containing chemicals.

The environmental impact of the evaporation process is described in chapter 2.6.1.
2.5.3 Fractionation

The block diagram in fig 2.12 shows the various processes used in fractionation of whey solids, some of which processes will be described in this chapter.

![Fractionation Diagram]

**Fig 2.12 Fractionation of total whey solids /3/**

**Protein recovery**

Whey proteins are mainly isolated by membrane separation and by chromatographic processes. The native whey proteins thus obtained have good functional properties as to solubility, foaming and gelling.

The liquid whey is first concentrated 20-30 fold by ultrafiltration (UF) and the obtained concentrate is then further processed by diafiltration. The process also involves microfiltration (MF), if a defatted product is desired.

The final retentate contains up to 80-85% protein (of the dry matter) and is dried to powder by spray drying. The rest of the whey (95%) is collected as permeate, which can be further processed for recovery of lactose.

Whey proteins can also be separated from the whey by a combination of denaturation with heat (90-95°C) and precipitation with acid. The obtained denatured whey proteins are used in the manufacture of soft and semi-hard cheeses to improve structure and yield. /3/. 

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46
Lactose recovery

Lactose (milk sugar) is the main constituent of whey and it is mainly recovered by crystallisation of concentrated whey, followed by centrifugal separation and subsequent drying in a fluidised-bed dryer. The remaining mother liquid can be dried and used as animal feed. /3/.

Demineralisation

The high content of salt in whey is limiting its use for human consumption. By removing the salt, either partially or highly, the range of applications can be broadened. The so-called demineralisation can be achieved by the use of nanofiltration NF (partial demineralisation), or by electrodialysis or ion exchange (high degree demineralisation).

The nanofiltration process uses a specially designed RO membrane that reduces the salt content of the whey by 25-30%.

Electrodialysis is based on the transport of ions through membranes under the force of a direct electric current. A unit consists of a stack of compartments separated by membranes with electrodes at each end of the stack. The whey feed and acidified brine pass through alternate compartments in the stack, and the application of direct current over the stack causes the ions to migrate from the brine.

In the ion exchange process resin beads packed in columns are used to adsorb minerals from the whey by exchanging them by other ions. The process is suitable for demineralisation levels up to 90%. /3/.

Environmental issues

The electrodialysis process consumes high levels of electric power, steam and chemicals, mainly hydrochloric acid. There is also a risk of bacteriological growth in the product, which requires addition of hydrogen peroxide, when allowed. The waste water stream contains high levels of lactose and phosphate. Electrodialysis is merely suitable for a demineralisation level of 70%. /3/.

As the salt content of whey is high, the ion exchange resin has to be regenerated with chemicals (dilute hydrochloric acid and sodium hydroxide) at short intervals. The main environmental drawback of this process is the high consumption of said chemicals and rinsing water, as well as the high salt load on the waste water. /3/

The inputs and outputs of the demineralisation processes are described in fig. 2.13 and 2.14.
2.5.4 Lactose conversion

The lactose in whey or in whey permeate deriving from UF or other membrane processes can be converted to glucose and galactose by hydrolysis. This increases the solubility and sweetness of the lactose, making the final product, whey syrup, a suitable replacer for sugar in many products. Hydrolysis can be achieved by the use of either enzymes or acid, of which alternatives the former is less troublesome.

The enzyme hydrolysis process uses immobilised galactosidase enzyme bound to a carrier (an adsorption resin). The achieved degree of hydrolysis is up to 95%. After hydrolysis the whey is generally evaporated to a dry matter content of 60%./3/.

Environmental issues

The process converts whey to a more useful ingredient thus eliminating the environmental burden caused by whey itself. The negative impacts are the same as for any whey treatment process involving demineralisation or evaporation.

2.6 Production of milk powder and condensed milk

Earlier milk was preserved either by adding sugar to evaporated milk (sweetened condensed milk) or by sterilising evaporated milk in sealed cans (unsweetened condensed milk). The manufacturing has declined over the years and the main markets in South America and South-east Asia are mainly supplied by companies that reconstitute skim milk powder. Therefore this chapter will focus on the production of milk powder, where evaporation is used as a first step to reduce the moisture content, followed by drying. The reason for this is that the drying process requires up to twenty times more energy per kilogram of evaporated water than the evaporation process.
Today the need for energy efficiency has resulted in the use of multiple-effect evaporators and double-stage dryers. /3/.

### 2.6.1 Evaporation

In the dairy industry evaporation is used for pre-concentration of skim milk, milk and whey before drying and for production of condensed milk. In the case of pre-concentration of milk, the solids content to be obtained lies in the range of 45-50%. For condensed milk, a solids content of 25-33% is required. The initial solids content of milk is 9-13%.

**Falling film evaporators** are the most commonly used evaporators. They usually have a tubular structure made of stainless steel, but also plate-type evaporators are applied. The pasteurised milk is introduced at the top of the evaporator and is distributed as a thin film that flows down over the heating surface, which is surrounded by steam. The milk is preheated to the evaporation temperature before entering the evaporator. The milk becomes slightly superheated in the evaporator and part of the water is vaporised immediately.

By connecting several evaporators in series multiple effect evaporation is achieved, which improves the energy efficiency, as the vapour from the first effect can be used as the heating medium in the following effect.

The thermal efficiency can be further improved by the use of thermal vapour recompression (TVR), which means that the vapour is mixed with high-pressure steam to compress the mixture to a higher pressure. The use of TVR in a two-effect evaporator system reduces the specific steam consumption from 0.60 to 0.25 kg steam/kg water evaporated. In a seven-effect evaporator with TVR the specific steam consumption is 0.08. /3/.

Some installations employ a mechanical vapour recompression (MVR) system, which improves the degree of heat recovery even further. This system recompresses all the vapour by mechanical energy that drives the compressor. The steam is circulated in the plant and there is no excess steam that has to be condensed. As the MVR systems are driven by electricity, the operating costs are considerably lower. The power consumption is 10 W per kg evaporated water /3/.

**Reverse osmosis (RO)** is also applicable for preconcentration prior to drying, but it allows only a two-fold concentration of the dry matter.

*Environmental issues*

The in- and outputs of the evaporation process are shown in fig. 2.15.
The most significant impact of the evaporation process is the high level of energy consumed. The TVR evaporators also generate noise.

The condensate from the evaporators is usually regarded as clean enough to allow direct disposal, but it is often collected and used for cleaning purposes instead of hot water. Improper adjustments of the equipment can, however, cause pollution of the condensate by milk solids and the reuse of condensate for cleaning is therefore a controversial subject. Another solution commonly applied is to use condensate as feed water to the steam boiler.

2.6.2 Drum drying

In drum or roller drying the milk is distributed on rotating, steam-heated drums, where the water evaporates. The layer of milk on the drum dries, and is continuously scarped off by knives. The dried milk falls into a screw conveyor and is ground into flakes.

The intense heat treatment increases the water-binding properties of the powder, which makes it useful for specialised products. In most cases, however, drum drying has been replaced by spray drying /3/.

Environmental issues

Drum driers involve severe environmental problems, as they generate fine milk flakes in the exhaust vapours. This has called for external vapour cleaners.

2.6.3 Spray drying

In spray drying an atomiser disperses the preconcentrated milk as fine droplets into a conical base chamber, where it is mixed with hot air of 150-250°C. The water in the milk is evaporated and the milk settles as a powder at the bottom of the spray tower. The powder is pneumatically conveyed to the packing section by cooling air.

As the last traces of moisture are the most difficult to remove, spray drying is often carried out as two-stage drying, where the pneumatic conveying system is replaced by a fluid-bed dryer. In the fluid-bed dryer excess moisture is removed and the powder is cooled down. The fluid bed is connected to the bottom of the drying chamber and consists of a casing with a perforated bottom. The powder is conveyed through the dryer by vibration. The incoming powder passes through drying sections, where air at a
gradually decreasing temperature passes through the bed. Finally the powder is separated from the air in a system of cyclones.

The two-stage solution provides better process economy, as the energy consumption is lower. The total energy consumption when drying skim milk with an initial dry matter content of 48% is 6 678 kJ/kg powder (1 595 kcal/kg) in one-stage drying and 5 652 kJ/kg powder (1 350 kcal/kg) in two-stage drying /3/.

Even greater savings can be achieved by three-stage drying, which is an extension of the two-stage drying.

**Environmental issues**

The inputs and the outputs of the spray drying process are shown in fig 2.16.

![Fig. 2.16. Inputs and outputs of the spray drying process /7/.

The fine milk powder residues in the exhaust air from the drying system are a possible source of pollution, as they cause acidic deposits on the surrounding areas. This can be prevented by the use of filters or scrubbers.

The presence of hot air and fine dust creates a fire and explosion hazard. All modern dryers are equipped with explosion release mechanisms and fire prevention systems.

Cleaning of the spray tower is normally a dry operation, as moisture can induce bacterial growth.

A large amount of heat is lost in the drying process. Some of it can be recovered from the exhaust air in specially designed heat exchangers. It is also possible to use the heat of the condensate from the evaporation process in the drying process, which can save some 5-8% of the drying costs /3/.

**2.6.4 Packing**

The powder is usually packed in multi-layer paper bags with an inner bag of polyethylene, which is welded. The bag sizes are usually 15 and 25 kg, but also big bags are common. Containers and barrels are also used. The bags are stored on pallets and shrink-wrapped for protection. /3/
Milk powder for households is packed in laminated bags, which, in turn are packed in cartons.

**Environmental issues**

Milk powder dust from leaking sacs and from the filling operation can cause corrosion of the equipment, if it comes in contact with water. It is therefore important to keep the packing and storing areas dry. The dust also forms corrosive acidic deposits on the surrounding roofs, if it is let out in the exhaust air.

The inputs and outputs of milk powder packing are described in fig. 2.17.

![Fig. 2.17 Inputs and outputs of powder packing /7/](image)

**2.7 Ice cream production**

**2.7.1 The ice cream process**

There are four main categories of ice cream:

- ice cream made exclusively of milk products
- vegetable fat ice cream
- sherbets made of fruit juice with addition of milk based ingredients
- water ice made of water, sugar and fruit concentrate,

of which only the manufacturing of milk based ice cream will be discussed in this chapter.

The ice cream manufacturing process comprises the basic steps shown in fig. 2.18.
Fig 2.18. The basic steps of the ice cream manufacturing process /3/

2.7.2 Production of ice cream mix

The ice cream manufacturing involves handling of both dry and liquid raw materials. They are stored in silos, tanks, containers or bags. Milk products are chilled before storage, whereas high viscosity products like glucose, vegetable fat and anhydrous milk
fat must be stored at higher temperatures (30-50°C). When butter is used as an ingredient, it is melted and stored in tanks, usually under protection of an inert gas (N₂). The dry ingredients must be stored and handled in a dry area. Dry bulk materials, such as crystalline sugar and milk powder, can be stored in silos.

The ingredients are weighed or metered by volume into a mixing tank equipped with an efficient agitator. The mixture is heated indirectly and blended to a homogenous mass.

The ice cream mix is preheated to 73-75°C in a plate heat exchanger before being homogenised. Then the mix is pasteurised at 83-85°C for about 15 seconds and cooled to 5°C.

The mix is then aged in an ageing tank for at least 4 hours at a 2-5°C while being gently agitated. During the ageing the fat crystallises and the stabiliser takes effect. /3/.

Environmental issues

The heating and pasteurisation steps require energy in the form of hot water and steam. Ice water is required for cooling. Rinsing of the equipment generates waste water containing milk residues and fat.

The inputs and outputs of the ice cream mix preparation are described in fig. 2.19.

![Fig. 2.19. Inputs and outputs of ice cream mix preparation](image)

2.7.3 Freezing, whipping and filling

After ageing the ice cream mix is pumped into a continuous freezer, which consists of a cylinder with a cooling jacket containing ammonia, and a rotating scraper that continuously scrapes off the frozen mix from the inner wall of the cylinder. The freezer has a dual function:

- to freeze the water in the mix
- to whip air into the mix

The mix is frozen to a temperature between −3° and −6°C while 80–100% air is being incorporated. The texture of the frozen mix is soft, which makes it suitable for pumping and subsequent processing, that is either packing, extrusion or moulding. /3/.
**Packing**

The ice cream is filled in cups, cones or containers in a filling machine and the packages are passed through a hardening tunnel, where the ice cream is frozen to –20°C.

**Extrusion**

The ice cream can also be extruded on trays or into moulds in a tray tunnel extruder. The trays pass through a hardening tunnel for final freezing to –20°C. After hardening the products are removed from the trays, wrapped and packed in cartons.

**Moulding**

Moulding of ice cream bars with sticks takes place in specially designed freezers. The ice cream is filled directly from the continuous freezer into moulds, which are conveyed through a brine bath of –40°C. The frozen bars are removed from the moulds by passing them through a warm brine solution, which melts the surface of the bars. The bars are automatically extracted and can be dipped in chocolate before wrapping./3/.

**Environmental issues**

Freezing of ice cream mix requires electricity for whipping and refrigerant (ammonia) for freezing.

Filling mistakes cause mainly solid wastes consisting of product and discarded packaging material.

Handling of nonconforming products is usually regarded as problematic where ice cream lollies and cones are concerned. The ice cream is usually separated from the stick and the wrapping by hand. If the product is already hardened, it has to be melted first. Bulk packages melt slowly at ambient temperature, and the melting must therefore be quickened by aid of hot water.

The ice cream mix from nonconforming products and from mixer start-ups can be reworked into new products, provided that it is of good quality. Ice cream mix, which is not suitable for reworking, can be sold as animal feed.

The inputs and outputs of the process are described in fig. 2.20.
2.7.4 Hardening and storing

Products packed in cups, cones and containers require final hardening in a hardening tunnel at –20°C.

The individually packed products are packed in cartons and stored in a cold storage on shelves or pallet rackets at –25°C. /3/.

Environmental issues

Storing of frozen products requires considerable amounts of refrigerants and electricity for the cooling compressors. The maintenance of the cooling equipment is of great importance in order to avoid accidental leakage of refrigerants.

The inputs and outputs of the process are described in fig. 2.21.

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**Fig. 2.20. Inputs and outputs of ice cream freezing, filling and packing.**

**Fig. 2.21. Inputs and outputs of ice cream hardening.**
2.8 Packaging and storing

Liquid dairy products are mainly packed in beverage carton packages of various sizes. Yoghurts and related products are packed in plastic cups with lids of aluminium foil or plastic-coated paper. Carton and cardboard boxes are used as secondary packaging material. These packages are, in turn, wrapped together in plastic film and stored on wooden pallets.

Other products, such as butter and cheese, are wrapped in aluminium foil, plastic film or filled in small plastic containers.

For fresh dairy products packed in beakers it is common to use cardboard or plastic trays as secondary package. The trays are used both for transportation and for displaying the products in the stores. They prevent damages to the beakers and protect the content from external shock. The plastic trays are returned to the dairy and are reused after being washed.

Roller cages of metal are used for transportation and displaying of liquid products in beverage cartons. The cages are also returned to the dairy, where they are washed before being reused.

The equipment used for packaging consists of filling machines, conveyors, mechanical tray formers, wrapping machines and palletizers. The packages are transported to the storages by means of fork lifts and electrical trucks.

Most dairy products require storing in cool storages with a temperature below +6°C. The production is usually planned in such a way that the storing time for fresh products is kept to a minimum. Season products like ice cream are usually produced in advance and stored for longer periods.

Environmental issues

The consumption of packaging materials and the solid wastes deriving from damaged or otherwise nonconforming packages are the main environmental issues related to the packaging operations. The use of recycled material in primary packages is not possible due to hygienic safety reasons.

Refrigerated or deep freeze storages require large amounts of cooling energy and refrigerants, depending on the size and temperature of the storages.

2.9 Cleaning and disinfection

The cleaning represents an essential part of the operations in a dairy plant. The specific hygiene standards and cleaning requirements are normally defined by the authorities.

The objective of cleaning dairy processing equipment is to achieve chemical and bacteriological cleanliness, which means that the equipment is first thoroughly cleaned with chemical detergents followed by disinfection with a disinfecting agent.
2.9.1 Cleaning in place (CIP)

The design of modern dairy equipment allows cleaning and disinfecting to take place without dismantling of the equipment, i.e. cleaning-in-place (CIP). Rinsing water and cleaning solutions are pumped through all the components that are in contact with product and some equipment has built-in cleaning nozzles to improve the distribution of the cleaning solution.

The cleaning solutions are generally distributed to the CIP circuits from a central CIP station consisting of several tanks for storing of the cleaning solutions. The solutions are heated by steam and their concentration is constantly monitored and adjusted.

The cleaning program differs according to the equipment to be cleaned, but the main steps are /3/:

- Pre-rinsing with water
- Cleaning by circulation of detergent
- Final rinsing with water
- Disinfection
- Cooling with water

Pre-rinsing

The equipment is rinsed with warm water to remove any product residues for 3 – 10 minutes. The rinsing water is usually collected separately for further treatment in order to minimize pollution.

Cleaning

The equipment is cleaned by circulation of an alkaline solution (usually sodium hydroxide of 0.5 – 1.5 %) at 75°C for about 10 minutes. Equipment like pasteurisers, with hot surfaces requires longer circulation times and stronger solutions.

The returning cleaning solution is directed back to the detergent tank for reuse. For this purpose, the return pipes are equipped with conductivity transmitters, which detect the content of the pipe.

If required, alkaline cleaning is followed by cleaning with acid. In this case an intermediate rinsing with warm water must be carried out between the cleaning steps in order to rinse out the alkaline solution. The acid solution (nitric acid of 0.3 – 0.7%) is circulated for about 5 minutes at 65°C. “Hot” equipment requires a circulation time of 30 minutes.

Final rinsing

Any remaining cleaning solution is rinsed out with warm or cold water. Chemical-free water from the final rinsing is usually collected and reused for pre-rinsing.
**Disinfecting**

The disinfection step is normally carried out immediately before the production line is to be used again. This can be done either chemically by use of a disinfecting agent (e.g. hydrogen peroxide, peracetic acid, sodium hypochlorite), or by circulating hot water of 90-95°C for about 10 minutes.

**Cooling**

If the equipment has to be cooled down or if the disinfecting agent must be flushed out, the equipment is rinsed with cold water.

**Exceptions**

Special equipment, like UF-plants or other membrane appliances, has its own special detergents and internal cleaning circuits in order to prevent damage to the membranes. The chemicals used are mainly phosphoric, sulphuric and hydrochloric acid as well as potassium hydroxide.

Butter making machines are cleaned separately from the ordinary CIP plant due to the large amount of residual fat in the machines.

**Environmental issues**

The use of central CIP units reduces the amount of cleaning solutions needed, thus saving both detergents and water. Cleaning is still one of the most water-consuming operations in the dairy, accounting for 24-40% of the total water consumption. /7/.

The pollution load on the waste water is high due to residual milk fat and proteins as well as cleaning chemicals. The organic load caused by the cleaning chemicals is minor; the main problem is the fluctuation of the pH of the waste water, which disturbs the balance of the waste water treatment plant. The storage of concentrated chemicals also represents a risk, both for the environment and the occupational safety. /7/.

The cleaning solutions can be replaced by commercially available CIP-detergent mixtures, in which the cleaning properties of alkaline and acid detergents are combined. However, some of these mixtures contain phosphates and tensides, which increase the load on the waste water.

The inputs and outputs of cleaning are described in fig 2.22.

![Diagram of cleaning process](image)

*Fig. 2.22 Inputs and outputs of cleaning /7/*.
2.9.2 Manual cleaning

Manual cleaning is required whenever cleaning-in-place is not possible. The floors of the production facilities are manually cleaned and any product spills on the floor or on the outside of the equipment have to be manually flushed. Special detergents and foams are used in combination with low-pressure cleaners and brushes. /3/.

Environmental issues

Manual cleaning consumes a great deal of water. Leaking hoses and taps increase the water consumption even further. The water containing detergents and product residues usually flows directly to the drain.

2.9.3 Cleaning of milk tankers

The road tankers are cleaned every day at the end of each collection round. The cleaning takes place in the reception area or in a special cleaning station by connecting the tanker to a cleaning system. The outside of the tanker is also cleaned daily. /3/.

Environmental issues

The cleaning of the milk tankers has the same environmental impact as the other cleaning operations mentioned above. In addition, the cleaning of the outside of the tanker produces waste water containing sand particles, heavy metals, road salt and lubricants.

2.10 Utilities

2.10.1 Steam

Steam of 140-150°C is the most frequently used heating medium in dairy processing. It is produced in a steam boiler and distributed to the processing area by insulated pipes. The condensate is returned to a condensate tank and is recirculated as boiler feed water. The boiler is normally fuelled with oil, coal or gas, but also electricity can be used. Depending on the efficiency of the boiler and the heat losses in the distribution pipes, about 65-77% of the total thermal energy can be utilised in production /3/.

Environmental issues

When fossil fuels are used for steam production, the boiler plant emits carbon dioxide (CO₂), sulphur dioxide (SO₂), nitrogen oxides (NOₓ) and polyaromatic hydrocarbons. Inadequate adjustment of the combustion process increases the emission of flue gases even further.

The storage of fuel oil is an environmental risk, as leakage can cause serious pollution of soil and water.

The inputs and outputs of steam production are described in fig. 2.23.
2.10.2 Electricity

Electricity is used for the operation of machinery, for refrigeration, ventilation, and lighting and for the production of compressed air. Dairies normally purchase their electric power from local distributors. The electrical system in a dairy comprises:

- high voltage switchgear
- power transformers
- low voltage switchgear
- generating set
- motor control centres

The environmental impact of the production of electricity depends on the primary source of electric power, and is therefore regarded as being out of scope of this report.

2.10.3 Compressed air

Pneumatically controlled automation systems are frequently used in dairies. Compressed air is also used for powering actuators in some equipment, such as filling machines and valves, for emptying product from pipes and for agitation. The compressed air is classified according to the quality demands of the application.

The compressed air is produced in an air compressor and is directed to a dehumidifier, where the water vapour is removed by cooling and precipitation. High quality air is further dried in adsorption filters and sterilised in sterile filters /3/.

Drying of compressed air by cooling results in a dew point of +2°C, which normally is sufficient for the compressed air used in the production area. Drying by adsorption is required for air that will be used in areas where the temperature is below 0°C. /8/.

Environmental issues

Air compressors are driven by electricity and the consumption is quite high. Leaks in the pipelines increase the consumption.

The compressors require cooling, which is usually done by water or air. The cooling water is often recirculated via a cooling tower in order to reduce the water consumption. It can also be used for cleaning purposes.
CFC-based refrigerants were formerly used in drying of compressed air, but they are replaced by less hazardous hydrogenated chlorofluorocarbons (HCFCs). In the near future also the HCFCs should be replaced by other refrigerants. /7/.

The inputs and outputs of production of compressed air are described in fig. 2.24.

![Diagram of air compressor inputs and outputs](image)

**Fig. 2.24. Inputs and outputs air compressor /7/.

2.10.4 Refrigeration

A refrigeration system is a closed system where the refrigerant cycles between gaseous and liquid form by undergoing alternate pressure reduction (expansion) and pressure increase (compression). When the refrigerant expands it vaporises and absorbs heat from the surrounding liquid, the secondary coolant, which in turn is cooled. The absorbed heat is removed from the refrigerant in a condenser by air or water.

Ammonia is the most commonly used refrigerant, as the use of freon is restricted due to its negative effects on the ozone layer. The secondary coolant is usually ice water, brine or glycol. /3/.

Most dairies have ice water basins or silos, where the ice water is stored and cooled. These systems are usually accumulating, which means that ice is produced at night, when the electricity is cheaper. The benefits of an accumulating system are, however, reduced today, as the production often runs in three shifts requiring continuous ice water production.

*Environmental issues*

The consumption of electricity is high. Water is also consumed in large quantities, especially for cooling of compressors and of the refrigerant. The water is recirculated to some extent, or used as secondary water for cleaning purposes.

In older installations the heat released from the refrigerant in the condenser is very often lost, whereas modern plants are equipped with heat recovery systems.

Refrigerant leaks are an important environmental issue, especially when freons are used. Today most of the harmful CFCs are replaced by HCFCs, which in turn will be replaced in the near future. Ammonia and glycol leaks are also a problem, both for the health and safety of the personnel and for the environment.
Modern screw compressors are cooled by oil and the used compressor oil is classified as hazardous waste.

The inputs and outputs of the process are described in fig. 2.25

![Diagram showing inputs and outputs of cooling system]

Fig. 2.25 Inputs and outputs of cooling system /7/.

2.10.5 Water supply

Dairy processing characteristically requires large quantities of fresh water. Water is used primarily for rinsing and cleaning of process equipment. The incoming water must be treated in such a way, that it meets with the quality requirements of the application.

The dairy water is often supplied from the municipal waterworks, which supply potable water. Many dairies have their own wells, which means that some pre-treatment of the water might be necessary.

Water used in dairy products must be of higher quality than drinking water. The pre-treatment often includes softening and dechlorination by filtration. /3/.

Environmental issues

Water is a valuable resource and excess use of it should be avoided whenever possible. Leaking water pipes increase the consumption considerably.

Pumping of water requires electricity, and the consumption is directly related to the water consumption. /7/.

2.11 Treatment of emissions

2.11.1 Solid waste

The packaging material is the main form of solid waste deriving from the dairy. It consists of beverage carton, cardboard, plastic materials, metallic barrels and wooden boxes and pallets. Solid waste is generated mainly by filling and packaging, where packaging mistakes are almost unavoidable. Many ingredients are delivered in packages that have to be disposed of.
Nonconforming products are also a source of solid waste. Usually the content is removed from the package and treated separately as animal feed, but sometimes the whole lot is discarded. Emptying of the nonconforming packages is rather difficult, especially for viscous products and ice cream. In many cases the packages have to be emptied manually for best result. Mechanical emptying can be done by means of specially designed machines that press the product out of the package.

Hazardous waste consists of lubricant oil from gearboxes and oil traps, laboratory chemicals, cooling agents, batteries etc. and is collected separately by the waste companies.

Legislation is becoming increasingly restrictive and today most Nordic dairies segregate their solid waste as follows:

- beverage carton => recycling or incineration
- corrugated paperboard => recycling
- plastic materials => recycling or incineration
- paper => recycling or incineration
- metallic waste => recycling
- wood => incineration
- hazardous waste => special treatment
- other solid waste => landfill or incineration

Organic waste is often segregated for composting, although it is not yet common praxis. Sludge is either disposed of as landfill, used for production of biogas or spread on cultivated land.

The solid waste is compressed, whenever possible, in order to reduce transportation costs.

2.11.2 Waste water

Dairy waste water can be divided into the following three categories:

- cooling water
- sanitary waste water
- industrial waste water

The cooling water is normally free from pollutants and can be discharged directly into the storm water piping system. The sanitary waste water is either led directly to the sewage treatment plant or mixed with the industrial waste water /3/.

The dominant environmental problem related to dairy processing is the large amount of industrial waste water with the following typical properties /7/:

- high organic load due to presence of milk residues
- fluctuations in pH due to presence of alkaline and acid detergents and other cleaning chemicals
- high content of nitrogen and phosphorus
- fluctuations in temperature
The effluents from the dairies are often discharged to the municipal sewage treatment plant. In many cases the effluents from the local dairy represent a significant load on the sewage treatment plant. In most dairies the effluents are pre-treated to some extent in order to decrease the load. The most commonly applied pre-treatment operations are:

- neutralisation/adjustment of the pH
- fat separation

In cases where the waste water is treated further on-site, the treatment usually includes biological treatment and nutrient removal. As these treatments can be regarded as part of general sewage treatment, they will only be briefly described in this context.

**Neutralisation**

The pH of untreated dairy effluents varies between 2 and 12 due to the use of alkaline and acid cleaning solutions. Waste water with a pH below 6.0 or over 10 must not be discharged to the sewage system, as it corrodes the pipes and interferes with the activity of the micro-organisms in the biological treatment plant.

The pH of the effluents from the cleaning units and from the production are usually collected in a balancing tank or basin. The pH of the effluent is monitored and adjusted to the required level before the tank is emptied to the sewage system. Sometimes the blending of the liquids in the tank has the effect of producing a neutral pH, but if big variations occur, the pH must be adjusted by addition of chemicals. The most common chemicals used for this purpose are sulphuric or nitric acid, sodium hydroxide, carbon dioxide or lime.

The consumption of chemicals for pH adjustment is affected by the size of the balancing tank. Small tanks with a short retention time require more neutralising chemicals. According to studies the average retention time is 9.5 hours. /22/.

The balancing tanks are usually equipped with an alarm system to prevent accidental bursts.

**Fat separation**

Fat in the effluent presents a problem, as it tends to stick to the walls of the sewage system and thus may inhibit the operation of the subsequent biological treatment. Dairies manufacturing butter usually separate the fat from the fatty rinsing water already in the process and reprocess the recovered fat.

Fat residues in the waste water can be partly removed in special gravity fat traps or by passing the effluent stream through a flotation plant.

The fat traps consist of a concrete tank divided into cells, where the fat floats on the surface. The fat is generally removed by manual or mechanical skimming. These traps require frequent cleaning and maintenance.

In a flotation plant the waste water is aerated with finely dispersed air, which carries the fat to the surface, from where it is automatically strained off. The fatty sludge can be further treated by anaerobic digestion. There are several flotation systems with different
working principles available: dissolved air flotation (DAF), the so-called “Hydrofloat system, electro-flotation and the “Zeda System”. The Zeda system is a pre-purification process, which is widely used in Denmark and Norway, and which produces a sludge that can be used as animal feed. /22/.

**Biological treatment**

The alternatives for biological treatment are either anaerobic digestion, aerobic treatment or a combination of both.

Aerobic activated sludge systems, with a variety of modifications, are the most common treatment techniques applied to dairy waste water. The organic impurities of the waste water are broken down by bacteria in an aeration basin, where air is supplied in order to provide the bacteria with oxygen. The bacteria form an active sludge, which is separated from the effluent by settling in a post-sedimentation basin and subsequently returned to the aeration basin. Excess sludge is eventually converted to biogas by anaerobic digestion or irrigated on cultivated land.

The biological filter is an alternative to the aeration basin. The filter consists of a filter bed filled with pieces of stone, plastic, bark or other suitable material, which act as a carrier for the bacteria. The effluent is allowed to trickle down through the filter bed and the organic impurities are broken down. /3, 22/.

**Nutrient removal**

Nutrient removal from dairy waste water is usually achieved by a combination of a biological nutrient removal system with some other treatment, such as chemical precipitation. Usually the biological system significantly reduces the nutrient levels of the effluent, and the role of the chemical treatment is to ensure that the nutrient limits are consistently met. /22/.

**2.11.3 Odour**

Generally, odour problems are rare and relate to accidental emissions. Bad smells mainly derive from the waste water, especially if the dairy has its own waste water treatment plant. They are caused by putrefaction processes in the sedimentation basin and can be avoided by aeration. /3/.

**2.11.4 Noise**

Cooling compressors and condensers generate noise, which is reduced by proper isolation.

Another significant source of noise, which is more or less unavoidable, is the heavy traffic due to the regular delivery of milk and packaging materials etc., as well as regular shipment of products. Milk deliveries arrive to the dairy on a 24-hour basis, which is a problem for dairies located in residential areas. Other deliveries can be scheduled to daytime.
The traffic arrangements are an important issue when choosing the location for a new dairy.

2.11.5 Dust

The exhaust air from spray drying equipment is a potential source for dust. Milk powder residues can be deposited on the surrounding roofs and, as they become acidic in contact with water, might cause corrosion.

Spray drying equipment usually includes cyclones for the separation of powder fines from the drying and cooling air. In most cases the exhaust air is further treated by filtering or wet scrubbing in order to remove the last traces of dust.
3. Current emission and consumption levels

3.1 Introduction

The current emission and consumption levels of the Nordic dairy industry were surveyed for the purpose of this study by aid of a questionnaire (see appendix 1) that was distributed to selected Nordic dairy plants, including ice cream producers. The data in this chapter is based on the responses received from 57 production plants, including representatives of all the major dairy groups in each country (except Iceland and Faroe Islands) and covering the whole range of products. 36 of the participating production plants have a daily production exceeding the IPPC-level of 200 tons/day.

The emission and consumption levels are based on data from 1999, unless otherwise stated. They are expressed in relation to the amount of processed milk, in order to make them comparable. Comparing the different production plants is, however, very difficult, as the emission and consumption levels vary considerably depending on the product portfolio and complexity, the scale of the plant and on the age and type of the equipment. Most dairies have mixed production, that is, they are not producing products exclusively from one product group (liquid products / cheese / butter / powder), which makes a comparison even more complicated. Thus, the division according to product portfolio in the following tables must be regarded as indicative.

3.2 Energy production

Most dairies have steam boiler plants on-site, but in many cases, e.g. in Finland, the operation of the boiler plant is outsourced to a separate company.

In Sweden and Norway the boiler plants are mainly fuelled with light fuel oil, but some dairies also report use of electricity for the production of thermal energy. Natural gas is also used to some extent. In Denmark the main fuel is natural gas. The Finnish dairies use heavy fuel oil, peat or natural gas in their boiler plants. The price level and the availability of the fuel in each country affect the choice of energy source. Iceland is in a special position in this respect, as the resources for thermal energy are almost unlimited.

The energy production of the dairy industry does not differ from that of any other industry, and is therefore regarded as being out of scope of this study.

3.3 Energy consumption

In dairies large quantities of thermal energy, usually in the form of steam, are used for heating operations and cleaning. The most energy consuming operations are evaporation and drying of milk.
Electricity is mainly used for refrigeration, production of compressed air and for running the machinery, although some dairies also use electricity for production of steam.

The table below shows the total energy consumption (including electricity) reported by some Nordic dairies. The number in brackets indicates the number of dairy plants included in the range.

<table>
<thead>
<tr>
<th>Product range*</th>
<th>Sweden</th>
<th>Denmark</th>
<th>Finland</th>
<th>Norway</th>
</tr>
</thead>
<tbody>
<tr>
<td>Market milk + cultured products</td>
<td>0.11 – 0.34 (8)</td>
<td>0.07 – 0.09 (3)</td>
<td>0.16 – 0.28 (8)</td>
<td>0.45 (1)</td>
</tr>
<tr>
<td>Cheese, whey</td>
<td>0.15 – 0.34 (4)</td>
<td>0.12 – 0.18 (4)</td>
<td>0.27 – 0.82 (3)</td>
<td>0.21 (1)</td>
</tr>
<tr>
<td>Powder, cheese and/or liquid products</td>
<td>0.18 – 0.65 (7)</td>
<td>0.30 – 0.71 (3)</td>
<td>0.28 – 0.92 (2)</td>
<td>0.29 – 0.34 (2)</td>
</tr>
</tbody>
</table>

* The first group comprises dairies that produce mainly market milk and cultured products, the second group comprises dairies with cheese production (exclusively) and the third group includes dairies with production of powder in combination with other products.

Table 3.1. Indicative data on total consumption of energy (kWh/litre of processed milk) from some Nordic dairies.

The corresponding figures from the ice cream industry vary between 0.75 – 1.6 kWh/kg of produced ice cream (4 plants).

The variation in the above figures can be partly explained by the varying proportions of energy consuming products (e.g. powder) within the product range. Plants with powder production generally have higher energy consumption than the others. Within the group of market milk producers, the production of butter slightly raises the energy consumption.

The data presented in the above table indicate that the energy consumption generally is higher in Finland, whereas the Danish dairies report the lowest consumption. The limited sampling might, however, affect the results. The size of the production plant and the production volumes of each product also affect the consumption figures. Some of the participants also reported their consumption data directly, while others reported only the fuel consumption, which then had to be converted.

### 3.4 Consumption of water

The cleaning of equipment accounts for a large proportion of the total quantity of water consumed in a dairy. The water consumption (per litre of milk) reported by the participating dairies is summarized in table 3.2. The figures include municipal water and process water from own wells, not cooling water from nearby lakes or rivers.
### Table 3.2. Indicative data on consumption of water (liters/liter of processed milk) from some Nordic dairies.

The variation is mainly due to different product portfolios, batch sizes and daily number of cleanings. The water consumption level also reflects the availability and price of water, as can be seen in the Norwegian figures. In Finland some dairies have their own well. The lowest water consumption was reported by the Danish dairies.

The corresponding levels reported for the ice cream industry vary between 3.6 and 10.3 litres/kg of produced ice cream (7 plants). The big variation can be partly explained by the product portfolio, as some products have a high content of water (e.g. water ice products).

### 3.5 Consumption of chemicals

Most of the chemicals are used for cleaning and disinfection of process machinery and pipelines. Fresh product dairies use mainly lye (sodium hydroxide) and nitric acid and some disinfectants, such as hydrogen peroxide, peracetic acid and sodium hypochlorite.

Production of special whey powders, involving electrodialysis, ion exchange, ultra and nanofiltration, requires additionally large amounts of phosphoric, sulphuric and hydrochloric acid as well as potassium hydroxide and sodium hypochlorite. The consumption of chemicals used for cleaning of spray towers and evaporators is rather high.

Table 3.3 shows the consumption of some cleaning chemicals (sodium hydroxide and nitric acid) expressed as kilograms of 100 % chemical per 1000 litres of processed milk (or 1000 kg of ice cream produced).

<table>
<thead>
<tr>
<th>Product range</th>
<th>Sweden</th>
<th>Denmark</th>
<th>Finland</th>
<th>Norway</th>
</tr>
</thead>
<tbody>
<tr>
<td>Market milk + cultured products</td>
<td>0.96 – 2.8</td>
<td>0.60 – 0.97</td>
<td>1.2 – 2.9</td>
<td>4.1</td>
</tr>
<tr>
<td></td>
<td>(8)</td>
<td>(3)</td>
<td>(8)</td>
<td>(1)</td>
</tr>
<tr>
<td>Cheese, whey</td>
<td>2.0 – 2.5</td>
<td>1.2 – 1.7</td>
<td>2.0 – 3.1</td>
<td>2.5 – 3.8</td>
</tr>
<tr>
<td></td>
<td>(4)</td>
<td>(5)</td>
<td>(2)</td>
<td>(2)</td>
</tr>
<tr>
<td>Powder, cheese and/or liquid products</td>
<td>1.7 – 4.0</td>
<td>0.69 – 1.9</td>
<td>1.4 – 4.6</td>
<td>4.6 – 6.3</td>
</tr>
<tr>
<td></td>
<td>(7)</td>
<td>(3)</td>
<td>(2)</td>
<td>(2)</td>
</tr>
</tbody>
</table>
### Table 3.3. Indicative data on consumption of cleaning chemicals (kg/1000 litres of processed milk or kg/1000 kg of ice cream) from some Nordic dairies.

The consumption of disinfecting agents is small, varying from 0.01 to 0.2 kg/1000 litres of processed milk.

One dairy group reports that 55% of the total chemical consumption is sodium hydroxide, 30% is nitric acid, and the remaining 15% consists of other chemicals, mainly hydrochloric acid, potassium hydroxide and sulphuric acid, as well as disinfecting agents and laboratory chemicals.

#### 3.6 Waste water discharges

The main environmental impact of the dairy industry is caused by the waste water, but efforts are constantly made to reduce the load. The concentration and the composition of waste water from dairies depend on the product portfolio, the operating methods and the design of the process. The table below shows the biological (BOD) and the chemical oxygen demand (COD) of some milk products.

<table>
<thead>
<tr>
<th>Product</th>
<th>BOD₅ (mg/l)</th>
<th>BOD₇ (mg/l)</th>
<th>COD (mg/l)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cream, 40% fat</td>
<td>400 000</td>
<td>450 000</td>
<td></td>
</tr>
<tr>
<td>Whole milk, 4% fat</td>
<td>120 000</td>
<td>135 000</td>
<td>220 000</td>
</tr>
<tr>
<td>Skim milk, 0,05% fat</td>
<td>70 000</td>
<td>80 000</td>
<td>100 000</td>
</tr>
<tr>
<td>Whey, 0,05% fat</td>
<td>40 000</td>
<td>45 000</td>
<td>70 000</td>
</tr>
<tr>
<td>Whey concentrate, 60% DM</td>
<td>400 000</td>
<td>450 000</td>
<td></td>
</tr>
</tbody>
</table>

*Table 3.4. Biological and chemical oxygen demand for some milk products /3/, /6/*

Table 3.5 contains a summary of the waste water discharge based on the survey. The generated amount of waste water is expressed in relation to the amount of processed milk as litres / litres of milk.
<table>
<thead>
<tr>
<th>Product range</th>
<th>Sweden</th>
<th>Denmark</th>
<th>Finland</th>
<th>Norway</th>
</tr>
</thead>
<tbody>
<tr>
<td>Market milk + cultured products</td>
<td>0.86 – 2.5</td>
<td>0.83 – 0.94</td>
<td>1.2 – 2.4</td>
<td>2.6</td>
</tr>
<tr>
<td></td>
<td>(7)</td>
<td>(3)</td>
<td>(8)</td>
<td>(1)</td>
</tr>
<tr>
<td>Cheese, whey</td>
<td>1.4 – 2.0</td>
<td>0.77 – 1.4</td>
<td>1.5 – 3.2</td>
<td>3.2</td>
</tr>
<tr>
<td></td>
<td>(4)</td>
<td>(5)</td>
<td>(2)</td>
<td>(1)</td>
</tr>
<tr>
<td>Powder, cheese and/or liquid products</td>
<td>1.2 – 4.3</td>
<td>0.75 – 1.5</td>
<td>1.9 – 3.9</td>
<td>2.0 – 3.3</td>
</tr>
<tr>
<td></td>
<td>(7)</td>
<td>(3)</td>
<td>(2)</td>
<td>(2)</td>
</tr>
<tr>
<td>Ice cream</td>
<td>2.7 – 4.4</td>
<td>-</td>
<td>5.6</td>
<td>3.0 – 7.8</td>
</tr>
<tr>
<td></td>
<td>(3)</td>
<td></td>
<td>(1)</td>
<td>(3)</td>
</tr>
</tbody>
</table>

*Table 3.5. Indicative data on emission of waste water (litres/litre of processed milk or litres/kg of ice cream) from some Nordic dairies.*

The table shows that the variation is big, mainly because of differences in the product variety and batch sizes, which, in turn, define the number of daily cleanings. Still, this summary gives some indication of the level of each country. The Danish dairies report the lowest waste water emission, which is explained by the fact that they reported quantities deriving from the process only, and that many Danish dairies treat their own waste water on site.

The quantity of waste water is generally smaller compared to the consumption of water, see table 3.2. This is partly due to the fact, that many dairies also measure the intake of cooling water (often from own wells), but the unpolluted, spent cooling water is then discharged unmeasured to the surroundings.

The pH of the waste water varies within the range of 4.5 – 11 before neutralisation, the median being 6.6 – 7.5.

Table 3.6 shows the BOD₅ and the COD₇ values in relation to the amount of processed milk. Note that Finland reports BOD₇. For municipal sewage it is usually assumed that BOD₇=1.15 x BOD₅.
Table 3.6. Indicative data on BOD$_5$ (BOD$_7$) and COD loads on the waste water (kg/1000 litres of processed milk or kg/1000 kg of ice cream) from some Nordic dairies.

Table 3.7 shows BOD and COD values in relation to the quantity of waste water.

Table 3.7. Indicative data on BOD$_5$ (BOD$_7$) and COD loads on the waste water (mg/litre of waste water) from some Nordic dairies.

The COD/BOD ratio was < 2 in all reported cases, indicating easily degradable substances.

Some dairies from Denmark, Sweden and Finland also reported the quantity of phosphorus and nitrogen in the effluent stream:
Table 3.8. Indicative data on the quantity of nitrogen and phosphorus in the waste water (mg/litre of waste water) from some Nordic dairies.

The difference between the three countries is not significant, with the exception that the quantity of phosphorus is slightly lower for the Swedish market milk dairies (4-15 mg/l).

### 3.7 Solid wastes

Nordic dairies usually report their solid wastes according to the following division:

- **Recyclable waste:**
  - paper
  - beverage carton
  - paperboard, craft paper
  - plastic materials
  - aluminium
  - other metals

- **Waste for incineration:**
  - wooden pallets
  - big bags
  - plastic films
  - dirty paperboard

- **Waste to landfill:**
  - sludge
  - nonconforming products
  - ash
  - other solid waste

- **Hazardous waste:**
  - lubricants
  - batteries
  - paint
  - fluorescent lamps
  - laboratory chemicals etc.

Additionally, some dairies also segregate and report the following types of solid waste:

- **Compostable waste:**
- organic waste

- Reusable waste:
  - metallic barrels
  - plastic containers

Nonconforming products are often disposed of as animal feed, in which case they are reported separately. Landfill disposal of nonconforming products will be prohibited in the near future and is already a very costly solution, thus being an area calling for development of other alternatives.

Three dairies report that sludge from fat traps and flotation plants is utilised in production of biogas. In Denmark 2/3 of the sludge from dairies is irrigated on cultivated land and the rest is utilised in biogas production.

Table 3.9 shows the reported total amount of solid waste in relation to the amount of processed milk and the corresponding division of the waste. Due to some insufficiency of the received information, the figures must be regarded as indicative. The figures do not include waste that is intended for animal feed, but nonconforming products discharged as landfill are included.

<table>
<thead>
<tr>
<th>Product range</th>
<th>Total solid waste kg/1000 l</th>
<th>Of which</th>
<th>For incineration %</th>
<th>Composted %</th>
<th>Landfill disposal %</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Market milk + cultured products</strong></td>
<td>1.7 – 14 (13)</td>
<td>5 – 41</td>
<td>0 – 48</td>
<td>0 – 14</td>
<td>14 – 95</td>
</tr>
<tr>
<td><strong>Cheese, whey, powder</strong></td>
<td>0.5 – 10 (17)</td>
<td>1 – 91</td>
<td>0 – 80</td>
<td>0 – 2</td>
<td>9 – 88</td>
</tr>
<tr>
<td><strong>Ice cream</strong></td>
<td>35 – 58 (4)</td>
<td>4 – 33</td>
<td>0 – 6</td>
<td>0</td>
<td>67 – 95</td>
</tr>
</tbody>
</table>

Table 3.9. Indicative data on total solid wastes (kg/ 1000 litres of processed milk or kg/1000 kg of ice cream) from some Nordic dairies.

The national differences are not significant, except for the fact, that the Danish dairies produce a smaller proportion of landfill waste. This is due to the general political effort to minimize landfill disposal by raising charges and by encouraging incineration. The same applies in Norway.

The big variations indicate that this is an area where improvements can be made.
3.8 Emissions to air

3.8.1 Emissions from energy production

The emissions of carbon dioxide, sulphur dioxide and nitrogen oxides from the dairies will not be included in this report, as they derive from the energy production in the boiler plants.

3.8.2 Freons

Many dairies still use freons in their cooling systems. They are mostly HCFCs, but small amounts of CFC still exist, although mainly in laboratory refrigerators and in farm tanks.

According to EU regulations (2037/2000 of June 29, 2000) the replenishment of CFC in cooling equipment shall be phased out by the end of year 2001. The manufacturing of HCFC-based cooling equipment shall phase out between 2002 and 2004, and replenishment of virgin and recycled HCFC will by prohibited from 2010 and 2015, respectively.

Sweden prescribes a faster phase out than scheduled by the EU regulations. The use of CFC is prohibited by law from year 2000 and a total phase out of HCFC refrigerants is due on January 1, 2002. All dairies are replacing the remaining freons by less harmful refrigerants.

In Norway the import and installation of cooling equipment using CFC has been prohibited for 10 years, but old installations are still replenished. The use of CFC in the dairy industry is approx 4% of the total consumption and the dairies aim at replacing the CFC equipment by year 2003. Import and installation of HCFC for equipment of 150 kW and over, as well as in cold stores and ware houses, is prohibited since the beginning of 2001 Replenishment of virgin HCFC shall cease by 2010 and of recycled HCFC by 2015. Norway intends to fulfil EU-regulations on ozone depleting substances.

Denmark has banned HCFC refrigerants in new plants and prescribes a total phase out of virgin HCFC by the very beginning of 2002. Recycled HCFC will still be allowed after this, as will the operation of existing HCFC cooling systems. A proposal for exclusion of HFC refrigerants has also been launched. /21/.

In Finnish dairies the hazardous freons are already replaced by ammonia and less harmful freons. The manufacturing and installation of equipment that uses HCFCs ceased at the end of year 2000 and the replenishment will cease by 2010.

In Iceland installation and import of CFC and HCFC based cooling equipment is prohibited, but replenishment of HCFC in equipment installed before 1996, is still allowed.
3.8.3 Odour

A few Nordic dairies report odour complaints. These are usually related to effluent treatment operations, such as sedimentation tanks and flotation basins, but also to accidental bursts of ammonia.

3.8.4 Noise

The dairies that are situated in urban areas usually receive complaints regarding noise. Mostly they concern noise caused by the traffic of milk tankers and distribution lorries. Also evaporators, spray towers and cooling condensers generate noise. No exact noise levels were reported.

In Finland the noise abatement regulations define the maximum noise level in residential areas as 55 dB(A) during daytime and 50 dB(A) at night. Generally, the limit is not exceeded, with exception for the evaporators, which occasionally generate higher noise levels. At night the noise level is exceeded by the warning signals from backing vehicles.

The Swedish regulations define the maximum noise levels for existing plants as 55 (daytime), 50 (evenings) and 45 dB(A) (at night), while the corresponding levels for new industry are 5 dB lower.

In Norway the maximum levels for new plants are the same as in Sweden, that is, 50, 45 and 40 dB(A). Also existing plants should aim at the same levels.

In Denmark the maximum levels are set based on individual assessment. The general maximum levels are 45, 40 and 35 dB(A).

In Iceland the maximum levels in residential areas with small scale industry are 55, 50 and 40 dB(A).
4. Techniques to consider in the determination of “BAT”

4.1 Introduction

The techniques for reduction of environmental impact presented in this chapter are mainly based on a survey among several of the participating dairies and ice cream producers. The survey was done by aid of a questionnaire (see appendix 2), which was distributed to 20 participants. Due to the limited coverage the reference plants mentioned in the context do not necessarily reflect best performance.

This chapter deals only with commercially available techniques that are applied in an industrial scale. Emerging novel techniques are separately discussed in chapter 6. Common techniques, which are applicable to the processing of any type of dairy products, are presented in chapter 4.2 “Common techniques”, whereas the more product-specific techniques are presented in chapter 4.3 – 4.10.

4.2 Common techniques

4.2.1 Reduction of energy consumption

The techniques for reduction of energy consumption can be divided as follows:

- techniques for reduced consumption of electrical power
- techniques for heat recovery
- other measures for reduction of energy consumption

Techniques for reduced consumption of electrical power

Frequency converters

- Description:

  It is often necessary to control the flow in a pipeline in order to adapt the product flow to the capacity of some equipment, e.g. a filling machine. The traditional way to control the output of a pump in a production line is to throttle the pump outlet by means of a valve or orifice plates. The method is flexible but uneconomical, as the pump still runs at the same speed and consumes the same amount of electricity even when there is virtually no flow in the pipeline. Throttling of positive displacement pumps by this method is not advisable, as it will dramatically increase the pressure in the line and cause damage to the product by excess mechanical treatment.

  The most flexible and energy saving method for flow control is to control the speed of the pump by a frequency converter. The speed of the impeller is then exactly
adapted to the required output of the pump, and so are the power consumption and the treatment of the liquid.

- **Applicability:**
  A frequency converter can be used together with standard three-phase motors. They are available for both manual and automatic speed control and can be applied both in existing and new plants for process pumps, as well as for ventilation equipment and conveying systems.

- **Environmental impact and benefits:**
  The reduction of the power consumption depends on the capacity and number of the pumps and motors that are equipped with frequency converters. Generally, a 10% reduction in the output of a pump corresponds to a 28% reduction in the power consumption of said pump/15/.

- **Cross-media effects:**
  There are no cross-media effects involved in this technique.

- **Driving force for implementation:**
  The reduced consumption of electrical power in combination with a gentler treatment of the product acts as the driving force for implementation of this technique.

- **Economics:**
  As an example, the price of a 5.5 kW frequency converter is approximately € 600. In the Taulov dairy 203 motors with a total power of 1 216 kW were equipped with frequency converters. The estimated annual saving is € 90 000 (1 325 MWh), the investment costs being estimated to € 311 000. /15/

- **Reference plant:**
  The new Taulov dairy of Arla Foods, Denmark.

**Precooling of ice water with ammonia**

- **Description:**
  The amount of energy consumed for production of ice water can be reduced by installation of a plate heat exchanger for precooling of returning ice water with ammonia prior to final cooling in an accumulating ice water tank with a coil evaporator. This is based on the fact that the evaporation temperature of ammonia is higher in a plate cooler than in evaporator coils (−1.5°C vs. −11.5°C). /17/.

- **Applicability:**
  The capacity of an existing ice water system can be increased without increasing the compressor capacity, by installation of a plate cooler for precooling of the returning ice water.
Environmental impact and benefits:
In one illustrative case this precooling system saved almost 20% of electricity, when installed in an existing ice water system. /17/.

Cross-media effects:
The use of ammonia involves an occupational health and safety risk. Leakage must be prevented by proper maintenance.

Driving force for implementation:
Reduced energy costs and/or increased cooling capacity without investment in a new ice water tank.

Economics:
The price of a precooling system depends on the existing ice water system and the required capacity. In the illustrative case the investment costs were estimated to approximately € 50 000, including a plate cooler, a pump, valves, regulators, piping and installation. /17/.

Reference plant:
Today this type of cooling system is commonly applied in new installations.

Precooling of ice water by river/lake water

Description:
Cold water from a river or a lake can be utilised for precooling of ice water. In an illustrative case cold river water is pumped into a cooling tower, where the warm water of a closed ice water system is cooled prior to final cooling in an ice water basin. The river water is then led back to the river.

Applicability:
This solution is applicable only in cases where the dairy is located near a river with cold water.

Environmental impact and benefits:
The consumption of electrical power required for cooling of the ice water can be reduced to some extent, depending on the temperature of the river water. Electrical power is still required for pumping of the river water to the tower.

The illustrative system saves cooling energy corresponding to a temperature decrease of 7 – 10°C.

Cross-media effects:
The cross-media effects are small, as the river water returns unpolluted, only with a slightly increased temperature.
Driving force for implementation:
Reduced energy costs.

Economics:
The system requires pipelines from the river and back, as well as an efficient pumping system, and a storage tank. One plant reports investment costs for such a system of roughly € 230,000, the annual savings being approximately € 23,000.

Reference plant:
Milko Grådö dairy, Sweden.

Techniques for heat recovery
In order to save heating and cooling energy heat should be recovered whenever possible and heat losses should be prevented by proper insulation.

Improved insulation of piping and equipment

Description:
Dairy pipes and equipment containing hot or cold product are traditionally insulated to some extent, but in many cases insufficient insulation of utility pipes leads to excessive heating of the surrounding process areas.

The insulation of the piping and the storage tanks should be optimised in order to minimize the loss of heat or cold. In the new dairy in Taulov, Denmark, all pipes with a temperature difference of more than 10°C in relation to the surrounding area were equipped with 30 mm insulation. The process tanks were equipped with 50 mm insulation.

Pre-insulated pipes were used for the distribution of heating and cooling media instead of utility pipes with traditional insulation, i.e. metal sheet covered mineral wool. When pre-insulated pipes are used, the pipe supports are mounted on the outside of the insulation coating, whereas they traditionally are mounted directly on the utility pipes, thus increasing the heat loss. /15/.

Applicability:
Improved insulation of pipelines can be applied both in old and new installations. Pre-insulated utility pipes are applicable when new lines are installed.

Environmental impact and benefits:
Insulation of tanks and pipes reduces the heat/cold loss by 82-86%. Additionally 25-30% heat can be saved by using pre-insulated utility pipes instead of traditionally insulated ones. /15/.

The insulation of hot pipes also involves an occupational safety aspect that should not be underestimated.
- Cross-media effects:
  None.

- Driving force for implementation:
  Reduced energy costs.

- Economics:
  The saving potential and the investment costs for improved insulation has been estimated for the new Taulov dairy in Denmark. The estimate included more than 9 km of piping and 53 tanks. The calculated savings were:

  - heating energy: 6 361 MWh/a
  - cold: 2 397 MWh/a (equivalent to 479 MWh/a of electricity)

  with a supplementary investment of about € 1 408 000 and a payback of 7.6 years /15/.

- Reference plant:
  The new Taulov dairy of Arla Foods, Denmark.

**Heat recovery from cooling systems**

- Description:
  Heat can be recovered from cooling equipment and compressors. The system comprises several heat exchangers and storage tanks for warm water. Depending on the cooling equipment, warm water of approximately 50 - 60°C can be obtained.

- Applicability:
  In new dairies a system for recovery of heat from cooling compressors is almost always installed, but in old dairies the installation of such a system is usually limited by lack of space.

- Environmental impact and benefits:
  The recovered heat can be utilised for:
  - heating of tap water
  - heating of ventilation air
  - defrosting of deep freeze storages
  - preheating of cleaning liquids
  - preheating of product
  thus saving heating energy.

  As an example, the installation of a heat recovery system in a cooling plant comprising both screw and piston compressors with a cooling capacity of 3 200 kW resulted in energy savings of about 1 200 MWh/a.
Driving force for implementation:
Reduced energy costs.

Economics:
The heat recovery from cooling equipment is economically feasible mainly in production plants with deep freeze storages, as normal cold storages do not produce sufficient quantities of heat during wintertime.

The investment costs for a heat recovery system in the cooling plant for frozen products mentioned above were about € 160 000, payback 6.3 years /8/.

Regenerative heat exchange – enhanced regenerative efficiency

Description:
The concept of regenerative heat exchange is well known and widely used. Almost all pasteurisers are today equipped with regenerative counter-current flow heating sections, where the incoming milk is preheated with the hot milk flowing from the pasteurisation section. The regenerative energy-saving effect of a modern milk pasteuriser is typically between 90 – 96%.

Applicability:
Regenerative heat exchange is usually applied both in new and old installations. In older dairies heating and cooling energy is saved when old plate heat exchangers are replaced with more energy-efficient ones.

Environmental impact and benefits:
Regenerative heat exchange saves heating and cooling energy. As an example, the increase of the regenerative efficiency of a milk pasteuriser (capacity 38 000 kg/h) from 85% to 91% results in 880 MWh/a of saved heating energy /15/.

Cross-media effects:
None.

Driving force for implementation:
Reduced energy costs.

Economics:
The saving potential and the investment costs for heat exchangers with higher regenerative efficiency than the traditionally used have been calculated for the new Taulov dairy in Denmark. The calculation involved 9 plate heat exchangers with increased regenerative efficiency from either 85% to 91% or 91% to 95%. The calculated savings were:

- heating energy: 2 712 MWh/a
- electricity: 542 MWh/a

with an investment cost of about € 370 000 and a payback of 3.6 years /15/.
Reference plant:
The new Taulov dairy of Arla Foods, Denmark.

Heat pumps

Description:
The working principle of a heat pump is based on heat transfer from a lower temperature to a higher temperature by aid of electrical power.

Applicability:
The application of heat pumps requires a good heat source in combination with a simultaneous need for heat near the source.

Environmental impact and benefits:
In the dairy industry heat pumps are used for several purposes, one of which is heat recovery from warm cooling water. The cooling water is cooled and the heat can be used for heating of hot water.

Cross-media effects:
Heat pumps require electricity.

Driving force for implementation:
Reduced energy costs.

Economics:
The economical feasibility depends on the price of fuel in relation to that of electrical power.

Other methods for reduction of energy consumption

An internal system for monitoring the energy consumption is a good basis for energy saving measures. The fast feedback of such a system also facilitates the detection of malfunctions and leaks in the energy distribution system, thus preventing accidental bursts. There are several monitoring systems on the market, some of which are supplied by the energy producing companies. For instance, the Umeå dairy in Sweden has installed such a system, the price of which was roughly € 40 000.

There are also several minor measures aiming at reducing the energy consumption /7/:

- implementation of automatic switch-off programs for lights and equipment
- installation of sensors for controlling the lights in areas that are less frequently used
- elimination of steam leaks
- training of the personnel to increase their awareness in combination with follow-up on energy saving efforts
4.2.2 Reduction of water consumption

Generally, any measures for reduction of water consumption should be preceded by thorough monitoring of the water consumption in the plant and followed by identification of wasteful practices. For example, excessive use of water for manual cleaning can be prevented by automatic control, such as timers and restrictors. Other means to control excessive use are:

- to install trigger nozzles on hoses to reduce flow rate
- to use compressed air instead of water where appropriate
- to install meters on equipment to monitor consumption
- to pre-soak equipment and surfaces prior to final cleaning
- to fix leaks immediately

Once the wasteful practices have been identified, the water use for essential operations can be optimised by means of detailed investigations and trials. When the essential process functions have been optimised, water reuse can be considered.

The reuse of so-called secondary water, which mainly consists of product condensate from the evaporation process or water from reverse osmosis (RO), reduces the water consumption. This will be further discussed in chapter 4.7.2 and 4.10.1.

Cooling water from cooling compressors can be reused as seal water in vacuum pumps instead of fresh water, or as secondary water for other purposes.

Utilisation of closed-circuit cooling systems reduces the water consumption but increases the energy consumption, as recooling of the cooling water requires electrical power. A hygienic risk is also involved.

Some other opportunities for water reuse are described later in this report.

In all cases, where water is reused, one must remember that the reuse must not compromise product quality and hygiene!

4.2.3 Reduction of waste water discharge at the source

Waste water reducing efforts involve measures both for reducing the pollutant load on the effluent and for reducing the volume of the effluent. Generally, measures for reduction of water consumption result in a reduced volume of waste water. The pollutant load can be reduced by avoiding loss of raw material and product into the waste water stream.

Prevention of accidental emissions

Mix-proof valves

- Description

A mix-proof valve is usually double-seated, which means that it is used in the connection between two adjacent pipes. It has two independent seals separating the two liquids and a drainage chamber between the seals. The drainage chamber is open to the air and any leakage in the seals can be easily detected. The leaking liquid flows
into the chamber and does not come in contact with the other liquid. The chamber is cleaned during CIP. /3/.

When a mix-proof valve is installed between to pipelines, one of them can safely be cleaned even if the other one is still filled with product.

- **Applicability**
  Mix-proof valves can be installed in new pipelines or when old valve manifolds are modified.

- **Environmental impact and benefits:**
  The use of mix-proof valves prevents product loss caused by accidental mixing of two separate liquids in case of a leak in the valve seals.

- **Cross-media effects:**
  None.

- **Driving force for implementation:**
  Mix-proof valves offer improved product safety by preventing accidental mixing of cleaning solutions into the product, and consequently improved flexibility of production/cleaning schedules.

- **Economics:**
  Mix-proof valves are more expensive than ordinary seat valves (2 – 2.5 times more expensive, depending on size and type), but valve manifolds consisting of mix-proof valves are less complicated and involve less piping. The investment cost depends entirely on the amount of valves installed and on the degree of automation.

**Monitoring of drain pipes by optical sensors**

By continuous monitoring of the content of the drain pipes by means of a system of optical sensors connected to an alarm, any accidental spillage of product into the drain can be immediately detected.

**Overfill prevention**

All tanks and vats should be equipped with level controls in combination with an alarm and an automatic shut-off system to prevent overfilling.

In order to prevent accidental emissions, a proactive maintenance programme should be implemented, including intensified inspection routines of critical points.

Additionally, all plants should also have an action plan in case of accidental emission of milk, cream, whey, brine or chemicals into the sewer or the storm water system.

**Other methods for reducing the load on the waste water:**

- pipelines should be installed with a slight slope to make them self-draining
• complete draining of tanks and pipes should be ensured prior to cleaning/flushing
• all milk spilt by the disconnection of hoses and pipes should be collected
• spill of solid material should be swept up instead of flushed to the drain
• drains should be equipped with screens to prevent solid material from entering
• drip pans or trays should be installed to collect drips and spills

4.2.4 Waste water reduction at “end-of-pipe”

The question whether each dairy should have its own waste water treatment plant is irrelevant to this report, as it is merely a question of geographic location and treatment costs. The overall environmental impact remains more or less the same. Some measures should, however, be taken in order not to disturb the balance of the final waste water treatment plant, irrespective of whether it is a municipal one or owned by the dairy.

Regular monitoring

Regular, preferably continuous monitoring of the wastewater stream is important. The system should be combined with an alarm and an automatic shut-off system in order to prevent accidental emissions. Optical sensors can be used for continuous monitoring.

Fat trap/flotation

The fat should be separated from the wastewater, as it tends to stick to the walls of the sewer system. It also causes problems in the neutralisation tank and in the sedimentation basin.

The fat can be separated in a simple fat trap well or in a flotation plant.

Flotation

o Description:

In the flotation process a flocculant is mixed into the wastewater in order to facilitate the separation of the fat. The floating fat flocks are then collected from the surface of the flotation basin as sludge.

o Applicability:

The flotation process is applicable in old or new plants provided that the required space is available.

o Environmental impact and benefits:

In a flotation plant up to 90% of the fat can be separated. The sludge is suitable for production of biogas. By converting the sludge to biogas, the amount of waste for landfill disposal or incineration is significantly reduced.

o Cross-media effects:

The process requires addition of chemicals, mainly nitric acid, lye and flocculant. Also odour problems might be involved.
Driving force for implementation:
A flotation plant is in some cases required due to local waste water restrictions, in order to facilitate subsequent treatment in the waste water treatment plant.

Economics:
No information available.

Reference plant:
GB Glace, Flen, Sweden:
capacity of flotation plant: wastewater 35 000 m³/h
degree of fat separation: 90-95%
degree of BOD reduction: approximately 40%
supplier: PURAC, Lund, Sweden
sludge disposal: 1000 tons/a for biogas production, equalling 118 m³ diesel oil.
consumption of chemicals: nitric acid (53%) 52 m³/a, lye (35%) 55 m³/a, flocculant 14 m³/a
The transportation of the sludge to the biogas plant consumes 5 m³ diesel oil.

Neutralisation
The pH of the waste water should be as neutral as possible in order to avoid corrosion of the sewer pipes and disturbances in the biological treatment. As the pH of the dairy effluent varies greatly due to the use of acid and alkaline detergents, the wastewater should be collected in a tank for neutralisation. The tank must be big enough to balance the pH variations during the day. The pH in the tank can be regulated by addition of chemicals, but if the capacity of the neutralisation tank is high enough, a neutral pH can be achieved without any additional chemicals. Many dairies use two alternating neutralisation tanks; one is filled while the other is emptied.

Regular, complete emptying of the neutralisation/equalising tank is imperative, as sludge deposits cause odour problems.

4.2.5 Reduction of solid wastes

Segregation of solid waste

Description:
The amount of solid waste disposed as landfill can be significantly reduced by thorough segregation of the generated waste into reusable waste, recyclable waste, compostable waste, waste for incineration/energy production and hazardous waste.

The segregation should be carried out close to the source, and it can be facilitated by use of containers of different colours.

Applicability:
Segregation of solid waste is applicable in all plants. However, successful segregation requires proper training of the personnel.
Environmental impact and benefits:
Reduction of solid waste disposed as landfill.

Driving force for implementation:
Segregation is subject to local regulations and is applied by force of high charges for landfill disposal.

Economics:
Reduced amounts of solid waste also mean reduced costs for industrial waste. If some of the waste can be used for energy production on-site, the fuel costs will also be reduced.

Reference plants:
Segregation of solid waste is common praxis in the Nordic dairy industry.

Other methods
Other methods for reduction of solid waste are further presented in chapter 4.3.3 and 4.9.

4.2.6 Reduction of other emissions (refrigerants, noise, odour, dust)

Replacement of refrigerants
The environmentally harmful freons should be replaced by less harmful refrigerants, such as ammonia or glycol. However, leaking ammonia or glycol can cause health and safety problems locally, and leaks must therefore be prevented. Preventive measures are:

- Intensified inspections and maintenance routines
- Protection of the refrigerant pipes against external damages by e.g. railings

Noise
Cooling condensers generate noise and should be properly isolated by acoustic panels. Slow start-up of burners and high-power motors reduces the level of noise emitted to the surrounding areas.

The traffic of milk tankers cannot be avoided during the night. Therefore, the traffic arrangements should be planned in such a way, that heavy traffic through residential areas is avoided, or at least kept to a minimum, at night. The noise can also be reduced by baffle walls.

Dust
Dust reducing measures are described in chapter 4.7.
Odour

Odours deriving from the waste water can be avoided by regular emptying and cleaning of the neutralisation tank and by introducing aeration.

4.2.7 Training and motivation

In addition to the technical solutions, the human factor plays an important role in the efforts to reduce the environmental impact. It is important to ensure that the employees are aware of the environmental aspects of the company’s operation and of their personal responsibilities. **Training, motivation and commitment** are the key issues, when aiming at raising the environmental awareness of the personnel.

The motivation can be increased by involving the persons working with the daily operations on the factory floor in:

- assessment, development and improvement of daily working routines
- monitoring of environmental performance
- follow-up and evaluation of results

Significant improvements and cost savings can be gained by simple modification of housekeeping procedures and maintenance programs. Prevention and collection of spill, production planning and cleaning operations are examples of areas, where much can be gained only by motivating the personnel.

The following list contains some general measures for improved housekeeping /23/:

- to keep working areas tidy in order to avoid accidents
- to maintain good inventory control to avoid waste of raw materials
- to train the personnel in good cleaning practices
- to schedule regular maintenance activities to avoid breakdowns and interruptions in the production
- to optimise and standardise equipment settings
- to identify and mark all valves and equipment settings to reduce the risk for incorrect settings
- to improve and optimise start-up and shut-down procedures.

4.3 Production of fluid milk and cultured milk products

4.3.1 Reduction of energy consumption

*Partial homogenisation*

- Description:
  
  In addition to the energy saving techniques mentioned in the previous chapter, partial homogenisation can be applied in order to reduce the consumption of electrical power.
In partial homogenisation only the cream is homogenised together with a small proportion of skim milk (the optimum fat content of the mixture is 12%). The rest of the skim milk flows directly from the separator to the pasteurisation section of the pasteuriser. The homogenised cream is remixed into the skim milk stream before it enters the final heating section.

- **Applicability:**
  Partial homogenisation is applicable in the production of pasteurised market milk and is widely used in modern dairies.

- **Environmental impact and benefits:**
  By applying partial homogenisation the hourly capacity of the homogeniser can be substantially reduced because of the smaller volume passing through. For example the partial homogenisation flow of a pasteurisation line with a nominal flow of 25000 l/h is only about 8 500 l/h. By installing a smaller homogeniser (55 kW) the total power consumption can be reduced by approximately 65%.

- **Cross-media effects:**
  None.

- **Driving force for implementation:**
  Lower investment and energy costs.

- **Economics:**
  The investment costs for a pasteurisation line are reduced if a smaller homogeniser can be used. In the example above, the price of the smaller homogeniser is roughly 55% of that of the bigger one.

**The Scania method**

- **Description:**
  In the Scania method the cream is separated at 62 – 64°C and is fed at this temperature into a holding tank prior to pasteurisation, instead of being submitted to intermediate cooling to about 8°C. There is no agitation in the holding tank and most of the air content is naturally removed together with volatile off-flavours, which reduces the risk of fouling in the pasteuriser. The holding temperature inactivates the lipase enzymes and stops the hydrolysis of free fat.

  The volume of the holding tank and the capacity of the cream pasteurisation line should be optimised in such a way that the holding time in the tank does not exceed four hours. /3/.

- **Applicability:**
  The method is applicable in any type of plant.
Environmental impact and benefits:
The method saves energy, as one intermediate cooling-heating step is left out. However, the savings are not that significant, as the advantage of regenerative heat exchange is partly lost in the cream pasteuriser, where a larger cooling section will be required.

Cross-media effects:
None.

Driving force for implementation:
The favorable effect on the quality of the cream is the only reason for applying this method.

Economics:
Not available.

Reference plant:
The method has been developed in Sweden, where it is used mainly in the production of whipped cream.

Minimizing of product recirculation in pasteurisation lines

Description:
Normally a production line should be designed in such a way, that the capacities of the individual components are optimised with respect to the others, in order to prevent product build-up or shortage in some part of the line. Later changes in the production line or in the filling schedule might, however, disturb the balance causing interruptions in the continuous operation.

For instance, if the capacity of the packaging tanks is too small compared to the output of the pasteuriser in a pasteurisation line, the milk has to be recirculated in the pasteuriser several times during the day. This consumes energy and harms the quality of the product. Longer interruptions require cleaning of the pasteuriser, which increases the frequency of cleaning.

Interruptions in the line can be avoided by adapting the size/number of packaging tanks to the output of the pasteuriser and by optimising the product changeovers.

Applicability:
Attention should be paid to the packaging tank capacity and the running of the pasteurisation lines, especially in older plants. Lack of space might unfortunately limit the possibilities to increase the number of packaging tanks.

Environmental impact and benefits:
If recirculation in the pasteuriser can be avoided or minimised, energy is saved mainly in the form of reduced ice water consumption. The total consumption of electrical power, required for the running of pumps, homogeniser and separator, also
decreases, as the total processing time becomes shorter. The negative effect of excess heat treatment on the quality of the product is also reduced. The cleaning frequency is also reduced, which saves water and chemicals.

In one case, the addition of packaging tanks to a pasteurisation line, in combination with automation of the product changeovers, resulted in a 30% reduction of the processing time and the following annual savings:

- electrical power: 250 MWh/a
- heating energy: 230 MWh/a

- Cross-media effects:
  
  An increased number of tanks means more objects to clean, which increases the consumption of water and detergents.

- Driving force for implementation:
  
  The solution offers improved flexibility in combination with better quality and lower operation costs.

- Economics:
  
  The investment costs depend on the size and number of tanks, the number of packaging lines, valves and on the degree of automation etc. In the case mentioned above, the payback on the investment was estimated to 4.5 years.

### 4.3.2 Reduction of waste water discharge at the source

Product loss and the corresponding load of the waste water discharge can be reduced by the following means:

- Accurate detection of transition points between product and water phases during production start-ups and final rinsings
- Collection of product/water mixtures for further treatment
- Collection and reuse of product/product mixtures from product changeover
- “Component-filling”

#### Detection of product/water transition points

When production starts, the pipelines are usually filled with water that has to be pushed out by product. The water is drained through a drain valve situated at the end of the line. The pure water is followed by a “mixing zone” consisting of water and product, which can be collected. Finally, when the line is filled with pure product, the drain valve is closed and production begins.

Traditionally the moment when to close the drain valve has been determined visually or by counting the time needed for filling the line with product. As most production lines are fully automated today, there are more accurate on-line methods available:
- Measurement of volume by flow transmitters or density transmitters
- Conductivity measurement by conductivity transmitters
- Optical on-line sensors

**Description**

The production lines are usually equipped with a device for measuring the produced quantity: *electromagnetic flow transmitters* or *density transmitters*. These transmitters are also widely used for determination of transition points. As they are sensitive to air bubbles and variations in viscosity, they have to be combined with a time factor for security.

*Conductivity transmitters* measure the conductivity of the liquid flowing through the pipes. They are mostly used in CIP centres for detection of transition points between water and detergent solutions, but they can also be used in product pipes. When installed in drain pipes, they also function as safeguards preventing accidental emissions to the sewage system. Their proper function must be maintained by regular calibration.

The *optical on-line sensors* are quite new, but commercially available and in full-scale use. The technique is based on measuring light scattered from the milk that flows in the line. These sensors can also be used for standardisation of the fat content of milk and for accurate detection of product/product transition points during changeovers. The main benefits compared to other methods are reliability, accuracy and short response time.

**Applicability:**

The transmitters or sensors can be installed in new or in existing pipelines. Minor modifications in the process control system is required.

**Environmental impact and benefits:**

A more accurate determination of the transition point reduces product loss, thus reducing the BOD of the waste water.

In one case the collection of product/water mixtures by aid of *conductivity transmitters* has decreased the BOD of the waste water discharge by 30%.

According to users of *optical sensors*, the amount of milk-containing rinsing water going to the drain is reduced to a couple of litres per start-up. Tests show that the product loss and the corresponding environmental impact can be reduced by 50% when optical sensors are used. In filling lines for liquid milk products the use of these sensors has reduced the amount of changeover mixtures by 30-40% /4/.

**Cross-media effects:**

None.

**Driving force for implementation:**

The product loss is reduced and the costs for waste water treatment become lower.
- Economics:
  The price of an optical sensor is about €2 700.

- Reference plant:
  Turku dairy, Valio, Finland, has installed 20 optical on-line sensors in the process lines for detection of transition points.

  Generally, conductivity transmitters and flow transmitters are commonly used, whereas the application of optical on-line sensors is relatively new.

**Collection of product/water mixtures**

The use of the aforementioned equipment simplifies the collection of water/product mixtures deriving from production start-ups, rinsing of equipment etc. Mixtures containing only milk and/or cream can be dried to powder. Mixtures containing sour product should be collected separately and are usually sold directly to the farmers as animal feed. The mixtures can be concentrated by ultrafiltration.

**Collection and reuse of product/product mixtures**

When producing and filling liquid milk products of various fat content or cultured products with different flavours, there are always several product changeovers. During these changeovers intermediate rinsing with water should be avoided, whenever possible, in order to save water and to reduce the amount of waste water. The changes should also be planned in advance in such a way, that the “mixing zones” can be incorporated in either product. For example, when filling yoghurt, the filling is started with unflavoured yoghurt and continues with successively “darker” yoghurts.

If the “mixing zones” have to be collected separately, they can be packed in marked packages and sold to the personnel at reduced price as so called “changeover products”.

**“Component-filling”**

For several reasons a need has occurred for developing the production in such a way that products are diversified as late as possible, preferably immediately prior to filling. This production technique would make it possible to fill short product series and it would also significantly eliminate the drawbacks related to product changeover.

- Description:
  As a step in this direction, a filling machine concept called component-filling has been developed. The fat content of the liquid milk is standardised to the desired level in the filling machine from two incoming pipelines – one with skim milk and the other with cream – directly into the package.

- Applicability:
  This type of filling machines is applicable in new dairies or as a replacement for old filling machines. The installation of a component-filler in an existing production line requires modifications of the piping and of the automation system.
Environmental impact and benefits:
The two components (cream and skim milk) are continuously fed to the filling machine regardless of the end product, which eliminates the loss of product and packaging material caused by product changeover. By traditional filling, the product loss easily amounts to 75 - 100 litres per changeover, depending on the diameter and the length of the pipe.

Component filling also reduces the need for intermediate storage tanks and corresponding cleanings. /12/.

Cross-media effects:
None.

Driving force for implementation:
This filling concept improves the flexibility of the production, allowing a more customer-driven approach. A faster movement of the product through the supply chain reduces the need for cold storage space.

Economics:
The price of a new component-filling machine with a filling capacity of 12 000 – 12 500 packs/h is approximately € 1 million, exclusive of any necessary process modifications /16/.

In many cases one component-filling machine can replace several ordinary fillers.

Reference plant:
Valio Kouvolan dairy, Kouvolan, Finland.

There are altogether 3 filling machines of this type in the Nordic countries.

4.3.3 Reduction of solid wastes

Replacement of aluminium lids

Description:
The aluminium lids of the portion packages for cultured products are being replaced by paper lids with a thin film of plastic.

Applicability:
The sealing of paper lids can be problematic in older filling machines due to the poor thermal conductivity of paper.

Environmental impact and benefits:
This solution improves the possibilities for recovery of the material for energy production/incineration, mainly in the consumer’s household, as separate collection of aluminium lids is not arranged in the communities.
Cross-media effects:
None.

Economics:
Not available.

Reference plants:
Valio Kouvolan dairy, Kouvolan, Finland, among others

**Beverage carton**

Most Nordic dairies segregate their solid waste. Beverage carton is mostly recovered for incineration (energy production) off-site. However, beverage carton is not always suitable for incineration without prior removal of the aluminium layer.

In Finland beverage cartons are collected both from the dairies and from the consumers for the manufacturing of paper roll cores for the paper industry. In this case beverage carton containing aluminium is also accepted. In 1999 12% of the beverage carton was collected (3,600 tons). From this amount 60% was converted to paper roll cores. The plastic fraction (21%) was used for production of energy, yielding 9.2 MWh/ton plastic. The total amount of energy thus produced is sufficient to cover the energy consumption of the core manufacturing process /5/.

The Norwegians consume 900 million beverage cartons per year, which corresponds to an amount of 19,500 tons of recyclable material. In 1998 45% of the beverage cartons was collected and recycled to envelopes and egg cartons /9/.

In Iceland 1,191 tons of beverage carton were sold in or imported to Iceland in 1999. 80 tons (7% of the total amount) were recollected and shipped to Sweden for recycling /10/.

Collection and recycling of beverage carton can, however, not be regarded as an on-site technique for reduction of solid waste.

**Nonconforming products**

Most dairies are facing the problem caused by nonconforming products. These products are either products with expired selling date returned from the retailer, or damaged, contaminated or underfilled packages. Until recently most of these packages have been transported to the tip as solid waste. Today the authorities are regulating this kind of activity, thus forcing the manufacturers to find other ways to dispose of the waste.

The content of the package can be reused as animal feed after it has been extracted from the packaging material. This can be done manually, but there are several types of “screws” on the market, which press the product out of the package and then compress the packaging material, which reduces the cost of further transportation. Once all traces of product are removed, the packaging material is suitable for recycling or incineration.

The aforementioned treatment of nonconforming products can be regarded as an “end of pipe”-solution. Additionally the quantity of nonconforming products should be reduced.
It has been shown, that by a thorough system of traceability by coding and follow-up on these products, the amount can be significantly reduced.

4.4 Butter and butter oil (AMF)

4.4.1 Reduction of waste water discharge

Removal of residual fat

As the COD of fat is high, it is important to prevent residual fat from the butter production from entering the waste water stream. This can be accomplished by:

- removing the residual butter and cream from the equipment by aid of steam or hot water
- flushing the cream from the pipelines with skim milk
- sweeping butter residues from the floor instead of flushing them to the drain

The residual fat should then be separated and used for reworking or as animal feed.

Fat trap/flotation plant

The fatty rinsing water from the production of butter oil cannot be led to the drain, as the fat clogs the sewer system. The fat is usually separated and reprocessed several times, but due to its consistency most of it finally ends up in the waste water.

The installation of a fat trap or a flotation plant (see chapter 4.2.4) offers the opportunity to use the residual fat directly for production of biogas, instead of reprocessing it, which is energy consuming and causes hygienic problems.

Other methods

Special attention should be paid to the melting of nonconforming packed products intended for rework. Direct melting with hot water should be avoided, as it generates fatty waste water. Indirect heating methods are to be preferred.

4.4.2 Reduction of solid wastes

Aluminium-free wrapping material

- Description:

In Finland many dairies have replaced the traditional aluminium foil used for wrapping of butter by an almost aluminium-free material (contains 0.1% aluminium). The new material has the same protecting properties as the old one and it consists of two layers of fat-resistant paper with a layer of PET (polyethylene terephthalate) in between.
Environmental impact and benefits:
The new wrapping material allows recovery of the material for energy production/incineration, mainly in the consumer’s household, as separate collection of the wrapping is not yet arranged.

Cross-media effects:
None.

Driving force for implementation:
The replacement of the wrapping material is a part of the general aim to replace aluminium as packaging material.

4.5 Cheese

4.5.1 Reduction of energy consumption

Protein standardisation of cheese milk by ultrafiltration

Description
Ultrafiltration is a membrane filtration technique using membranes with a pore size of $10^{-2}$ - $10^{-3}$ µm. Ultrafiltration can be used for protein standardisation of cheese milk as the membranes withhold protein molecules thus increasing the protein content of the retentate (=concentrate).

The ultrafiltration unit in the new Taulov dairy in Denmark consists of 10 spiral-wound modules with polymer membranes, four pumps and the necessary flow transmitters and regulating valves. The product flow through the unit is 65 000 l/h and the protein content of the cheese milk is standardised to 3.7 - 3.8 % by controlling the ratio between feed and permeate. /15/.

The permeate from the UF unit is further treated by reverse osmosis (RO) (see chapter 4.6.2) and the obtained, so-called RO-water is utilized for cleaning purposes (see chapter 4.10.1).

Applicability:
Ultrafiltration units can also be installed in existing production plants.

Environmental impact and benefits:
The immediate effect of protein standardisation by UF is an increased cheese yield per processed milk unit. This means that the required amounts of energy and water, as well as the generated quantity of whey and waste water, are smaller compared to traditional standardisation.

In the case of Taulov dairy, the savings potential has been calculated based on a 12% reduction in cheese milk volume compared to traditional standardisation procedures. The estimated savings when producing 25 000 tons/a of yellow cheese, were /15/:
electricity: 473 MWh/a <=> 19 kWh/ton cheese
heat: 1 235 MWh/a <=> 49 kWh/ton cheese
water: 7 500 m³/a <=> 300 l/ton cheese

o Cross-media effects:

The ultrafiltration process requires additional electrical power, heating energy and water compared to traditional standardisation. In large-scale production the increase in cheese yield compensates for the increased consumption of energy and water.

The membranes require specific cleaning chemicals and the cleaning procedure is rather water consuming, as each filtration loop has to be thoroughly flushed with water prior to and after cleaning.

o Driving force for implementation

This technique yields cheese of homogenous quality due to constant protein content and it offers flexibility in terms of different cheese types.

o Economics:

Generally, the method is economically feasible only in large scale production due to high investment costs.

The investment costs for the UF process of Taulov dairy were estimated to € 430000, and the payback to 5.9 years /15/.

o Reference plant:

Taulov dairy, Arla Foods, Denmark.

**Preheating of cheese milk with whey**

The energy consumption related to the preheating of the cheese milk is reduced if the incoming milk can be heated with warm whey, which is simultaneously strained off from another vat.

This technique is applied in the new Taulov dairy and is described as a part of whey treatment in chapter 4.6.1.

**4.5.2 Reduction of water consumption**

Cleaning of cheese moulds, racks and frames is a water and energy consuming operation, thus being an area for potential savings.

**Continuous cleaning of cheese moulds**

o Description:

Traditionally cheese moulds are cleaned batchwise in open, uninsulated tanks containing solutions of acid and lye, followed by rinsing with water. The spent cleaning and rinsing water is discharged to drain.
By cleaning the cheese moulds in a continuous process, where their flow rate and holding times are automatically controlled, the cleaning can be optimised in terms of energy and water consumption. The process includes a prerinsing step, which facilitates the subsequent cleaning. The water from the final rinsing step is reused for prerinsing. The basins containing warm cleaning solutions are insulated. /15/.

- **Applicability:**
  The continuous cleaning process is applicable both in old and new cheese plants.

- **Environmental impact and benefits:**
  According to calculations for Taulov dairy, the savings for the continuous system compared to the traditional batch cleaning are /15/:
  
<table>
<thead>
<tr>
<th>Energy Source</th>
<th>Savings</th>
</tr>
</thead>
<tbody>
<tr>
<td>Electricity</td>
<td>39 %</td>
</tr>
<tr>
<td>Heat</td>
<td>64 %</td>
</tr>
<tr>
<td>Water</td>
<td>39 %</td>
</tr>
</tbody>
</table>

  the capacity of the continuous cleaning system being 100 moulds/h equalling 484000 moulds/a. The water consumption of the system is 2,7 m³/h. /15/.

- **Cross-media effects:**
  None.

- **Driving force for implementation:**
  Reduced operating costs.

- **Economics:**
  The additional investment costs required for the automatic continuous cleaning system were estimated to € 80,000, with a payback of 3.6 years. /15/.

- **Reference plant:**
  Taulov dairy, Arla Foods, Denmark.

**Automatic cleaning of racks and frames**

- **Description:**
  Energy and water can be saved by implementation of a fully automated washing machine for cleaning of cheese frames and racks, instead of a manual or partly automated cleaning system.

  The washing machine in Taulov dairy is adapted for cleaning of both frames and racks. The washing machine consists of two insulated washing sections, where the cleaning solutions are heated to 80°C, and a rinsing section, where the frames/racks are rinsed with pure water, which is circulated. The frames/racks are loaded and unloaded by means of a robot. /15/.

- **Applicability:**
  The washing machine is applicable in both old and new cheese plants.
o Environmental impact and benefits:
In the Taulov case (25 000 ton cheese/a), the saved quantities of heat, electricity and water are estimated based on previous experiences of similar systems /15/:

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>electricity</td>
<td>80 MWh/a</td>
</tr>
<tr>
<td>heat</td>
<td>71 MWh/a</td>
</tr>
<tr>
<td>water</td>
<td>8 500 m³/a</td>
</tr>
</tbody>
</table>

o Cross-media effects:
None.

o Driving force for implementation:
Lower consumption of electricity, water and heat, which equals lower operational costs.

o Economics:
The investment costs for a fully automated washing machine for cheese racks and frames are about € 67 000, the payback 3.2 years (25 000 t cheese/a). /15/.

o Reference plant:
Taulov dairy, Arla Foods, Denmark.

4.5.3 Reduction of solid wastes
The plastic (usually PVDC) ripening bags used for ripening of rindless cheese, are traditionally discarded as solid waste after use. In many cases the cheeses can be cut after prepressing into consumer-size pieces, which allows ripening in the final consumer package, which, in turn, considerably reduces the quantity of solid waste.

Cheese of second-class quality should, if possible, be used for other products, such as processed cheese, or as animal feed. Pieces of cheese can be used for grated cheese.

4.5.4 Reduction of waste water discharge

Unchanged brine
The brine used for salting of cheese can be kept unchanged, provided that measures are taken in order to keep the microbiological status under control. The alternatives are:

- microfiltration (MF)
- kieselguhr filtration or separation, combined with subsequent pasteurisation, UV-treatment or addition of nicine.

Microfiltration

o Description:
The membranes of a microfiltration (MF) unit have a pore size of 1-10 µm and they retain larger molecules like bacteria and some proteins.
The microfiltration unit of Taulov dairy comprises 22 spiral-wound modules with a total filtration area of 616 m², 3 circulation pumps and a heat exchanger for cooling with ice water. The capacity of the unit is 15 000 l/h. /15/

- **Environmental impact and benefits:**
  The lifetime of the brine is considerably extended when the bacteria are removed. This means that practically no brine is discarded to the drain.

  In comparison with kieselguhr filtration and subsequent treatment, the MF treatment removes both bacteria and other solid particles, which saves energy. Pasteurisation also tends to disturb the microbiological balance of the brine.

- **Cross-media effects:**
  The membranes require specific cleaning chemicals and the cleaning procedure is rather water consuming, as each filtration loop has to be thoroughly flushed with water prior to and after cleaning.

- **Driving force for implementation:**
  A microbiologically stable brine solution improves the quality of the cheese and reduces the risk of contamination.

- **Economics**
  Not available

- **Reference plants:**
  Taulov dairy, Arla Foods, Denmark.

**Other methods**

Reverse osmosis (RO) (see chapter 4.6.2) can be used for purification of spent cooling water deriving from direct cooling of cheese. The purified water is then reused for cleaning purposes (chapter 4.10.1), instead of being discharged directly to the drain. One dairy reported an estimated 50-70% reduction in the quantity of polluted cooling water discharged to the sewer system. The cooling water should at least be filtered or purified by separation before being discharged.

In addition, the load on the waste water discharge can be reduced as follows /7/:

- overfilling of cheese vats should be prevented
- whey and cheese curd residues should be completely removed from the vats before rinsing
- cheese fines should be separated from the drained whey and from other liquid streams, e.g. cooling water
- curd spilt by moulding and pressing should be swept up instead of being flushed to the drain
- all of the generated whey should be collected, not even small quantities should be discharged to the drain
• if surplus brine is discharged to the sewer, whey and other impurities have to be removed first
• rinsing water from UF-equipment used in Feta production should be collected.

4.6 Whey

4.6.1 Energy consumption

Concentration of whey by nanofiltration

o Description:

Traditionally, the whey deriving from the cheese manufacturing process is evaporated prior to further refining procedures in order to remove excess water. This energy consuming evaporation process can be replaced by nanofiltration (NF). The highly selective membrane used in nanofiltration completely withholds lactose, which is the main constituent of the dry matter in whey. The permeate contains only water and salts. The membrane filtration processes use pressure as the driving force, which in turn is obtained by the use of special pumps. Nanofiltration allows concentration of whey to a dry matter content of 25% by removing 80% of the water.

The removed water can be utilized for cleaning purposes if it is further treated by reverse osmosis (RO), which removes the salt (see chapter 4.6.2). The membranes used in RO are even more selective than the ones used in NF, which means that only water can pass.

o Applicability:

Nanofiltration is applicable both in old and new processes.

o Environmental impact and benefits:

The energy consumption is far lower than that of traditional evaporation. The concentration of all the whey (about 160 million litres) produced in one illustrative production plant to a dry matter content of 25% would require 23 500 MWh/a of steam if evaporated, but by using a combination of NF and RO, the energy consumption is reduced by almost 80%.

As the water removed by membrane filtration is of better quality than evaporated water, this secondary water can be reused, thus reducing the overall water consumption.

o Cross-media effects:

The cleaning of the membranes is rather water consuming and requires specially adapted detergents, depending on the membrane material and the supplier’s requirements. The detergents used are mainly alkaline solutions containing enzymes (lipases and/or proteases).
Driving force for implementation:
The nanofiltration process produces partially desalinated whey of a more uniform quality at lower energy costs. The water consumption is indirectly reduced, as the water from the filtration process can be used for cleaning.

Economics:
The investment cost for a combined NF and RO unit with an input capacity of 40 m³/h is about € 700 000.

The method is economically feasible only in large-scale production.

Reference plants:
Valio’s plants in Joensuu, Haapavesi and Lapinlahti, Finland

Today approximately 90% of the whey produced in Finland is concentrated by nanofiltration.

**Heat recovery**

Heat recovery from whey

Description:
In the Taulov dairy the heat from the pasteurisation of whey is transferred to the cheese milk entering the cheese vats.

The cheese milk is heated from 12°C to 32°C with heat from a closed system with circulating water of 34.5°C. The temperature of the water decreases to 13°C and the water is subsequently reheated in the cooling section of the whey pasteuriser, where the whey is cooled from 36°C to 14.5°C.

The system comprises, in addition to the required plate heat exchangers, two buffer tanks of 150 m³ for the circulating water./15/.

Applicability:
This type of heat recovery system is also applicable in old cheese plants, unless limited by lack of space.

Environmental impact and benefits:
The heat of the whey is recovered, which saves heating energy for the heating of cheese milk, as well as ice water for the cooling of whey.

The estimated saving potential calculated for Taulov, based on approximately 250 million kg/a of whey, is /15/:

<table>
<thead>
<tr>
<th>Category</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>electricity</td>
<td>1 200 MWh/a</td>
</tr>
<tr>
<td>heat</td>
<td>6 065 MWh/a</td>
</tr>
<tr>
<td>water</td>
<td>4 200 m³/a</td>
</tr>
</tbody>
</table>
Cross-media effects:
None.

Driving force for implementation:
Reduced energy costs.

Economics:
The investment costs for the heat recovery from whey are included in the costs for the whey treatment processes of Taulov dairy described in chapter 4.6.2.

Reference plant:
Taulov dairy, Arla Foods, Denmark

Heat recovery from evaporation of whey

Methods for heat recovery from evaporation of whey are further described in chapter 4.7.1 as a part of the evaporation of milk.

4.6.2 Reduction of waste water discharge at the source

Whey, like municipal sewage, responds to biological treatment, but its waste strength is about 300 times more concentrated. Therefore whey should not be discharged to the sewer as such. Today most of the whey produced in the Nordic dairies is processed into useful products (see chapter 2.5), either on-site or in separate whey refining plants.

Recovery of water from whey permeate

Reverse osmosis

Description:
The permeate deriving from ultrafiltration of whey for recovery of protein, can be treated by reverse osmosis in order to obtain so-called RO-water, which can be utilized for cleaning purposes. The membranes used for reverse osmosis have a pore size of $10^{-4} - 10^{-3}$ µm, which retains also the smallest molecules, such as lactose and minerals.

In the new dairy in Taulov, permeate from the ultrafiltration units used for the production of whey protein concentrate and for protein standardisation of cheese milk is treated by reverse osmosis (RO). The RO-unit consists of 18 spiral-wound modules and the filtration area is 666 m². The capacity of the unit is 45 000 l/h and the treated permeate is concentrated to 7% dry matter. /15/.

Applicability:
RO is also applicable for the recovery of water from other types of UF permeate, such as milk permeate.
Environmental impact and benefits:
The RO-unit in Taulov is planned to treat approximately 700 tons of permeate per day, thus yielding approximately 260 m³ RO-water per day, which can be used for cleaning instead of tap water (see chapter 4.10.1). The amount of recovered water is estimated to 125 000 m³/a.

Cross-media effects:
The cleaning of the membranes is rather water consuming and requires specially adapted detergents.

The RO-water can not be used as a replacement for potable water in products without prior sterilisation.

Driving force for implementation:
RO offers a means to concentrate permeate, simultaneously providing useful water.

Economics:
The investment costs for the whole whey treatment process, including filtration units and equipment for heat treatment and recovery amounts to approximately € 1.6 millions with a payback of 3.8 years. /15/.

Reference plant:
Taulov dairy, Arla Foods, Denmark.

Special whey processes
Several new whey processes have been developed in order to improve the utilisation of whey. The processes both improve the yield of existing whey products and offer new products, thus lessening the environmental load caused by wasted whey. They can mainly be regarded as techniques for waste water reduction “at the source”.

The application of the special processes is shown in fig 4.1. The whey hydrolysis process is used in industrial scale, whereas the chromatographic process is being further developed into a continuous one.
**Whey hydrolysis process**

**Description:**

The whey hydrolysis processes are used for conversion of lactose into glucose and galactose. The raw material is either whey or whey permeate from ultrafiltration, and the product is accordingly either whey syrup or permeate syrup. The product, which is rich in taste, can be used as a sugar replacer in ice cream products, confectionery and bakery products.

The hydrolysis is carried out either batchwise by blending the raw material and the enzyme in a tank, or by a continuous process using an immobilised enzyme bound to a carrier (an adsorption resin) and placed in a column. As the hydrolysis lowers the viscosity of whey, the syrup can be concentrated in an ordinary falling film evaporator.

**Applicability:**

When the continuous process is installed in an existing whey plant, the additional investment cost is very reasonable. The space requirement for the continuous process is also much smaller than that for the batch process.

**Environmental impact and benefits:**

The process offers new applications for products derived from whey, thus improving its utilisation.

**Cross-media effects:**

None.
Driving force for implementation:
Further refining of whey yields more valuable products, which, in turn, leads to increased attention to the treatment of whey in general.

Economics:
The operating costs of the continuous process are 10 – 25% of the corresponding costs for a batch method, mainly due to substantially lower enzyme costs. In many cases the payback period is below 2 years. /11/.

Reference plants:
Valio Äänekoski plant, Finland

Other methods for reduction of waste water discharge
The salty waste water deriving from demineralisation of whey can be further treated by nanofiltration (NF), which removes the salt from the waste water. The retentate (=concentrate) containing approximately 3% dry matter can be concentrated and sold as “licking stones” for calves.

In one case the RO-water generated by dehydration of whey using reverse osmosis (RO) is used for watering a nearby golf course during the summer. As the quality of the water is good, it can also be discharged to a lake or river.

The collection and reuse of evaporated water deriving from evaporation of whey is further described in chapter 4.7.2.

4.7 Milk powder and condensed milk

4.7.1 Reduction of energy consumption
Heat recovery from condensate

The heat of the product condensate leaving the evaporation plant can be recovered either in a heat exchanger or by a heat pump. There are several examples of applications where the heat can be utilized:

- preheating of drying air for spray dryer
- preheating of incoming air for air conditioning systems
- preheating of cheese milk

Mechanical vapour recompression

Description:
A mechanical vapour recompression (MVR) system draws all the vapour out of the evaporator and compresses it by aid of mechanical energy before returning it to the evaporator. No thermal energy is supplied, except for the steam required at start-up, only electricity is required for the operation of the evaporator. /3/.
Applicability:

Today most new evaporation systems are equipped with MVR.

Environmental impact and benefits:

Mechanical vapour recompression offers an even better degree of heat recovery than the thermal vapour recompression system (TVR) (see chapter 2.6.1). MVR makes it possible to evaporate 100 – 125 kg water with 1 kW. The evaporation temperature is lower, which means less burnt-on product. This, in turn, allows longer production cycles and fewer cleanings.

Cross-media effects:

The MVR generates noise and has to be properly isolated.

Driving force for implementation:

Reduced energy costs.

Economics

The operating costs of a three-effect evaporator with MVR are approximately 50% of the costs of a conventional seven-effect evaporator with TVR. However, the investment costs are higher /3/.

Reference plants:

Valio Lapinlahti plant, Finland, among others.

Other methods

The evaporation process can in some cases be replaced by nanofiltration, as described in chapter 4.6.1.

4.7.2 Reduction of waste water discharge

Collection and reuse of evaporated water

Evaporation is used as a preliminary step to drying. When the product (whey or milk) is concentrated, water is boiled off and is collected as so-called product condensate. The condensate can be reused, even though the quality of the water is a limiting factor.

Description:

In an illustrative case the product condensate is collected and classified in terms of quality. The condensate from the first effect of an evaporator with thermal recompression is usually clean enough to be used as feed water for the steam boilers in the boiler plant. The pipeline is equipped with a conductivity transmitter that monitors the quality of the condensate. If the condensate is unsuitable for steam production, it is diverted to a tank for secondary water.

The condensate from the other effects is also collected as secondary water. A conductivity transmitter monitors the quality, and condensate of poor quality is
diverted to the drain. Cooling water from the air compressors is also collected in the same tank.

The heat of the secondary water is recovered in a heat exchanger for preheating of the drying air for the spray dryers.

The secondary water is distributed from the collection tanks to the CIP centres of the dairy, where it is used for prerinsing and intermediate rinsing, as well as for cleaning of the spray towers and the outside of the milk tankers. /8/.

Generally, secondary water can be used for the following purposes, provided measures are taken to ensure the hygienic safety:

- boiler feed water
- prerinsing and intermediate rinsing of equipment
- preparation of cleaning solutions (acid and lye)
- cleaning of the outside of milk tankers

The secondary water can be purified by reverse osmosis (RO), which makes it suitable also for cleaning purposes (chapter 4.10.1).

- Applicability:
  A collection system can also be installed in old plants, unless limited by lack of space.

- Environmental impact and benefits:
  The reuse of evaporated water (product condensate) reduces the consumption of water. Also the load on the waste water stream is reduced, although some of the product condensate is eventually lead to the drain. (For instance, the BOD of whey condensate is about 50 mg/l and the COD is above 100 mg/l.)

  In the above case, 230 million litres of secondary water are collected yearly, of which 190 million litres are reused.

- Cross-media effects:
  None.

- Driving force for implementation:
  Reduced costs for water and waste water.

- Economics.
  No investment costs are available, as the system has been built bit-by-bit over several years.
4.7.3 Reduction of emissions to air

**Dust**

The milk powder residues in the exhaust air from the drying process are recovered in cyclones. The last traces of dust are then removed either by textile filters or wet scrubbing. It is important that the filters are inspected and changed regularly and often.

**Noise**

The noise level of the drying process can be reduced by the following means:

- noise reducer on the air outlet of the dryer
- soundproofing of the filtration unit for inlet air
- soundproofing of cyclones

The dairy in Falkenberg, Sweden, reports a reduction of the noise level by 8 dBA after installation of a noise reducer on the spray tower.

4.8 Ice cream production

4.8.1 Reduction of energy consumption

**Heat recovery**

- Description:

  Heat can be recovered from the ice cream pasteurisation process. The ice cream mix enters the pasteuriser at a temperature of 60°C and is heated to 85°C followed by cooling to 4°C prior to ageing. The cooling phase consists of several steps. In the first step the ice cream is cooled to 70°C by regenerative heat exchange and in the second step cooling water is used for further cooling to approximately 20°C. The final temperature of 4°C is achieved by cooling with ice water.

  The heat released from the ice cream mix in the second cooling step can be used for preheating of water for various purposes, mainly for cleaning operations (see also chapter 4.10.1). This requires a number of storage tanks for the hot water.

- Applicability

  The system is also applicable in old production plants, provided that there is space available for the necessary water storage tanks.

- Environmental impact and benefits:

  In an ice cream plant, the heat from the second cooling step is used for preheating of approximately 25% of the total amount of water used in the plant. The heat recovery yields hot water of approximately 70°C. The average inlet temperature of the cooling water being 10°C, the corresponding quantity of heat recovered is 7600 GJ/a, which represents approximately 14% of the energy consumption of the plant. The hot water is used for CIP and the quantity of water saved is approximately 1000 litres / ton ice cream mix produced.
Cross-media effects:
The hygienic quality of the water has to be checked, as leaks in the plates of the heat exchanger result in contamination of the water with product.

Driving force for implementation:
Reduced costs for energy and water.

Economics:
No information on the economic aspect is available, but the savings can be estimated based on the above information.

Reference plant:
GB Glace, Flen, Sweden

Improved efficiency of deep freeze storage

Automatic defrosting

Description:
The layer of frost that is formed on the surface of the evaporators acts as isolation, thus reducing the cooling capacity of the evaporator. The frost can be removed by automatic defrosting, which is an effective means of preventing icing of the evaporator, thus ensuring minimum loss of energy. Usually warm gas from the compressors is used for this purpose. /17/.

Applicability:
Automatic defrosting is usually included in modern cooling systems and can also be installed in older systems.

Environmental impact and benefits:
The consumption of electricity is reduced. The saved quantity depends on the number of evaporators and the operating time with frosted evaporators. In an illustrative system with 5 evaporators running 3 000 hours per year with an ice layer of 0,87 mm, the saving potential is approximately 100 000 kWh/a. /17/.

Cross-media effects:
None.

Driving force for implementation:
Reduced energy costs due to improved efficiency.

Economics:
In this particular case the investment costs for an automatic defrosting system were estimated to approximately € 15 000, with a payback of 2.2 years. /17/.
4.8.2 Reduction of waste water discharges and solid wastes

In an ice cream factory the quantity of solid wastes, as well as the load on the effluent, is highly dependent on the amount of rework (= ice cream remnants, surplus and spill) that is generated and on the possibilities to utilise the rework in other products instead of downgrading it to animal feed or, in the worst case, to landfill.

Firstly, the amount of rework should be kept to a minimum, as reprocessing of the rework also consumes energy, and secondly, a suitable product should be developed, in which the rework can be incorporated. Unfortunately, the tendency towards complex products considerably limits the possibilities for reincorporation of rework.

4.9 Packaging and storing

4.9.1 Reduction of energy consumption

The energy consumed for the cooling of storages can be reduced by the following means:

- proper insulation of the cold storages
- regular defrosting and maintenance of refrigeration systems
- fast-closing doors or air sluices between cold storages and process rooms with different temperatures
- insulated loading docks

Additionally the lighting of storages should be controlled by movement sensors or timer switch-off systems in order to prevent unnecessary consumption of electricity.

4.9.2 Solid wastes

Circulating transportation packages

- Description:

Many products are packed in cardboard and/or wrapped in plastic film for transportation. These tertiary packages are discarded after being used and are therefore regarded as solid waste. Many dairies have replaced these transportation packages by circulating transportation units, which also can be used for displaying the product in the store. When empty, they are returned to the dairy for refilling. Examples of this type of transportation packages are:

- plastic trays, for beakers etc.
- plastic crates for liquid products etc.
- metallic roller cages for liquid products

- Applicability:

In order to be feasible, the returnable transportation units should be applied within the whole dairy company, preferably even more widely. The dimensions of the transportation units should be of a given standard to facilitate handling.
Environmental impact and benefits:
The amount of solid waste, mainly carton and plastic film, is reduced.

Cross-media effects:
The returnable transportation units have to be cleaned, which increases the consumption of energy, water and detergents.

Driving force for implementation:
The transportation packaging and the transportation itself are facilitated and the products are well protected against damages.

Economics:
Not available

References:
In Finland about 80 % of the dairy products are transported in returnable transportation packages. The system is also in use in Sweden.

4.10 Cleaning and disinfection

4.10.1 Reduction of water consumption

Reuse of water from final rinse

Description:
The aim of the final rinse is to remove the last traces of cleaning solutions from the cleaned equipment. Clean water is used and the rinsing water, which returns to the central CIP unit, still is clean enough to be reused for prerinsing or intermediate rinsing, instead of being discharged to the drain.

The recovery of the final rinsing water requires a connection from the CIP return pipe to the prerinsing tank. The returning final rinsing water is diverted to the prerinsing tank by aid of a conductivity transmitter.

The final rinsing water can also be utilised for the preparation of cleaning solutions.

Applicability:
The technique can also be implemented in existing CIP units. The implementation requires modification of the control system. Today the reuse of final rinsing water is becoming common praxis.

Environmental impact and benefits:
Reuse of the final rinsing water reduces the water consumption as well as the quantity of waste water.
Use of secondary water for cleaning purposes

Secondary water, that is product condensate from the evaporation process, permeate from RO-treatment or spent cooling water, is suitable for cleaning, but due to the hygienic risks involved, it should be used for less sensitive areas, such as the outside of milk tankers, for preparation of cleaning solutions (acid or lye), or for prerinsing of equipment.

Treatment by reverse osmosis (RO) can be implemented in order to improve the hygienic quality of secondary water, thus rendering it suitable for cleaning of walls and floors, as well as for crate washers.

The secondary water must in all cases be distributed through a separate system with clearly marked pipes and taps, in such a way that it cannot be confused with potable water. The secondary water must never come in direct contact with the product, unless it has been sterilised.

A scrupulous hygienic control of the secondary water is a precondition for further reuse.

Reuse of warm cooling water for cleaning

Description:
Many dairy operations involve cooling with cold water in heat exchangers, which results in warm cooling water. Warm cooling water with a temperature above 50°C can be reused as such, or at least should the heat be recovered before the water is led to the drain.

Usually the warm cooling water from the process is reused for cleaning purposes, mainly for cleaning of milk tankers, but also for manual cleaning and CIP of equipment.

Applicability:
The technique is applicable both in new and old installations. In old dairies the space required by the necessary storage tanks can be a limiting factor.

Environmental impact and benefits:
The gained reduction in water consumption depends on the amount of reusable warm cooling water. A reduction of about 2% in daily water consumption has been reported.

Cross-media effects:
The reuse of warm cooling water also reduces the energy consumption.

When used for cleaning of surfaces, which are in contact with product, the hygienic quality of the warm cooling water is of great importance. Basically the quality is good, provided that the water does not contain any traces of product deriving from leaks in the equipment. Usually the warm water has to be stored in an insulated buffer tank for some time awaiting further use. This involves a risk for
bacteriological growth, especially if the storage time is long. One way of minimising this risk is to treat the water with **UV-light**.

- **Driving force for implementation:**
  - **Reduction of costs for water.**

- **Economics:**
  - The equipment required for such a system consists of a storage tank and piping for collection and distribution of the water.

- **Reference plants:**
  - Arla Foods, Kallhäll dairy, Stockholm, Sweden
  - Valio Ltd, Turku dairy, Finland

**Low-pressure foam cleaning**

- **Description**
  - Traditionally walls, floors and equipment surfaces are manually cleaned with water hoses, brushes and manually dosed detergents. This technique can be replaced by low-pressure foam cleaning, either using separate units or a decentralised foam cleaning system.

  The new dairy in Taulov (25000 tons of cheese/a) has a decentralised system consisting of about 50 satellite units, located in the different process areas. The satellites are supplied with preblended detergents and high-pressure water from a central unit and during cleaning they automatically shift between foam spreading and rinsing. /15/.

- **Applicability:**
  - The foam cleaning system is applicable in old and new plants.

- **Environmental impact and benefits:**
  - The foam cleaning system saves both water and energy compared to traditional manual cleaning.

  The water consumption of the decentralised foam cleaning system in Taulov is calculated to 40% of the corresponding consumption for traditional manual cleaning. The foam cleaning system uses cold water of 10°C, whereas manual cleaning with water hoses requires water of at least 40°C /15/.

  According to calculations, the savings in this particular case are /15/:
  
  - **water:** 19 800 m³/a
  - **heat:** 1 160 MWh/a

- **Driving force for implementation:**
  - The cleaning result is better and the problems connected with high-pressure cleaning, e.g. spreading of aerosols containing dirt particles and bacteria, are eliminated.
o Economics:
   The investment costs of the foam cleaning system in Taulov were about € 188 000, with a pay-back of 3,2 years /15/.

o Reference plant:
   Taulov dairy, Arla Foods, Denmark.

Other methods

Optimum operational settings should be determined and maintained in order to reduce the consumption of water and chemicals. This can be achieved by:

- efficient control and monitoring of water flow and pressure by means of strategically positioned sensors
- regular sampling and analysis of cleaning results
- individually adapted cleaning programs for each piece of equipment
- automatic control and regular fine tuning of cleaning sequences in order to minimize the required cleaning and rinsing times
- regular maintenance of spray nozzles

4.10.2 Consumption of chemicals

Techniques for reduced consumption of chemicals

Cleaning-in-place (CIP)

Automated CIP of process equipment with readily prepared detergent solutions dosed from a central CIP station can, as such, be regarded as a means to reduce the consumption of chemicals.

Recirculation of detergent solutions

o Description:

   Normally, the detergent solutions (acid and lye) used for CIP can usually be reused several times before being discharged to the drain. The returning cleaning pipes should be equipped with connecting valves to the detergent tanks in the central CIP station, allowing circulation of the detergent solutions. The different phases (rinsing water – detergent solution) are then automatically diverted to the corresponding tanks by means of conductivity transmitters, which detect the content of the return pipe.

   The detergent tanks should also be equipped with conductivity transmitters for continuous monitoring and control of the concentration. The concentration of the detergent solution should be maintained at the defined level by automatic dosage of chemicals and water, which eliminates fluctuations in the concentration and excess addition of chemicals.

   The detergent solution must be changed as soon as its hygienic quality becomes poor. The spent solutions can be used for cleaning of evaporators before being discarded.
Nanofiltration of the detergent solutions offers a possibility to extend their useful life by removing product residues and other impurities. One dairy reports that this application has reduced the consumption of lye by 3.5 tons per week and it has also had a favourable effect on the water consumption.

**Self-neutralisation**

- **Description:**

  As described in chapter 4.2.4, the waste water from the dairy should be neutralised before being forwarded to the waste water treatment plant. Therefore it should be collected in an equalising/mixing tank, the size of which should be adapted to the average daily output of waste water.

  In many cases addition of chemicals is required in order to obtain a neutral pH. If the pH of the untreated waste water is constantly above 7, the addition of inorganic acid can be replaced by use of carbon dioxide for neutralisation.

  In some cases the size of the equalising tank, in combination with favourable variations of the pH, result in self-neutralisation of the waste water, which means that no addition of chemicals is required.

**Selection of chemicals with reduced environmental impact**

The environmental aspects are an important factor in the choice of cleaning and disinfecting chemicals. The Nordic dairies claim to use environmentally approved cleaning chemicals.

In Sweden the dairy industry has founded a council for the assessment of chemicals used within the industry ("Branschgemensamt kemikalieråd"). The council consists of one representative from each major dairy company in Sweden (5). The objective is to develop standards for cleaning chemicals and to test different alternatives in cooperation with the manufacturers, emphasising on environmental and safety aspects, as well as on bacteriological efficiency. Dairy companies that are not represented in the council can also benefit from its achievements.

**Prevention of accidental emissions**

Rigorous safety measures must be taken in handling and storage of chemicals, in order to ensure occupational health and safety, and to prevent accidental emissions to the environment.

Accidental chemical emissions can be prevented by:

- a bunded area under the chemical storage tanks
- sealed sewers in the chemical storage
- double-walled chemical tanks
- protection against over-filling by means of level switches
- covered rainwater sewers during unloading of chemicals
- intensified inspection routines of critical points
- proactive maintenance
All plants should also have an action plan in case of accidental emission of milk, cream, whey, brine or chemicals into the sewer or the storm water system.
5. Best Available Techniques

5.1 Introduction

Due to the diversity of the dairy industry, it is difficult to define any specific techniques as BAT. This chapter lists the techniques and measures described in chapter 4, which are in line with BAT according to the principles of the IPPC Directive (96/61/EC). Most of these techniques are generally recognized. However, it should be noted, that although the techniques have proven successful in many cases, they are not always directly applicable to other cases.

The candidate techniques not mentioned in this chapter are either too plant-specific, or they involve cross-media effects or other aspects, which make them questionable as BATs at this stage. Although they are not yet classified as BATs, their status as environmentally beneficial techniques remains.

5.2 Environmental management and training

Generally, the Nordic dairy industry is a technically well and homogenously developed sector, where the technical solutions are known and available to all. The competitiveness of the dairy companies is usually based on other virtues. This also applies for environmental issues, where the decisive factor is in the human resources. Important, environmentally beneficial improvements can be achieved simply by changes on “the human level”, in operator practises and work procedures.

The best environmental strategy is to introduce environmental management, which means defining a policy, monitoring the environmental impact of the activity and setting up goals for better environmental performance. The structures of EMAS or ISO 14001 can be recommended for this purpose, as they may eventually lead to certification.

Regular monitoring and follow-up of emissions and utility consumption are essential preconditions for a successful implementation and use of any type of technique. Continuous monitoring reveals the peaks and identifies the most consuming operations. Attention must be paid to the peaks, even if the average values are below the set limits.

Training and motivation of the personnel, including personal involvement and responsibility, are also important issues when aiming at improving the environmental performance. Collection of spill, for instance, should be a natural part of the daily routines (chapter 4.2.7). Training, motivation and involvement are measures that can be regarded as low-cost, leading to significant improvements.
5.3 Reduction of energy consumption

Overall energy savings usually are the result of small savings in a number of areas. Reductions up to 25% are possible through improved housekeeping and fine-tuning of processes, whereas an additional 20% can be gained by more energy-efficient equipment and systems for heat recovery. Improved housekeeping is a low-cost solution, but improved equipment and heat recovery usually involve high capital investment. /7/.

The techniques for reduction of energy consumption can be divided into 1) techniques for direct reduction of energy consumption and 2) techniques for heat recovery and reuse.

5.3.1 Direct reduction of energy consumption

The energy consumption is directly reduced by techniques that save either electrical power or thermal energy. Electrical power can be saved by:

- frequency converters on motors (chapter 4.2.1). Significant reductions can be expected only in big production plants,
- precooling of ice water, either with ammonia, which is commonly applied in new installations, or, if possible, by using cold water from a nearby river or lake (chapter 4.2.1),
- minimizing product recirculation in pasteurisers by optimising the tank capacity before and after pasteurisation (chapter 4.3.1),
- partial homogenisation of market milk (chapter 4.3.1),
- using ultrafiltration for protein standardisation of cheese milk, which also saves water (chapter 4.5.1),
- isolation of cold storages to prevent the cold from “escaping” (chapter 4.9.1),
- automatic defrosting of cooling evaporators in deep freeze storages (chapter 4.8.1),
- implementation of automatic switch-off programs for lights and equipment (chapter 4.2.1),

The best means to save thermal energy are:

- to use mechanical vapour recompression (MVR) in multiple-effect evaporators. New evaporators are usually of this type (chapter 4.7.1),
- to ensure proper insulation of pipes and equipment, (chapter 4.2.1),
- to include elimination of steam leaks as a part of the maintenance program (chapter 4.2.1).
5.3.2 Heat recovery and reuse

Recovery of heat is recommended in every phase of the production process, if feasible. There are several areas where simultaneous heating and cooling takes place, which offer excellent opportunities for heat recovery and reuse. Among the techniques for heat recovery, the following have proven successful:

- **regenerative heat exchange** in the pasteurisation process. Today this is commonly applied, but the regenerative efficiency of old pasteurisers can still be improved (chapter 4.2.1),
- utilisation of heat from whey for preheating of cheese milk (chapter 4.5.1),
- heat recovery from cooling systems (chapter 4.2.1),
- heat recovery from product condensate deriving from evaporation of milk or whey (chapter 4.7.1),
- heat recovery from cooling, e.g. of ice cream mix, (chapter 4.8.1),
- heat pumps for heat recovery from various sources (chapter 4.2.1).

The recovered heat can be utilised for heating of product and/or cleaning solutions. Heat can also be stored as hot water in a buffer tank for a short time, provided that the hygienic quality is not affected.

5.4 Reduction of water consumption

A reduction of the water consumption requires identification of the wasteful practices by monitoring of the water consumption at each stage of the production process. Excessive use should be prevented and the water consumption of the essential operations should be optimised (chapter 4.2.2).

As cleaning is the most water consuming operation in a dairy, the water saving measures should focus on this area. Automated cleaning-in-place (CIP) is to be preferred to manual cleaning, whenever possible. Other proven means to save water are:

- reuse of final rinsing water for prerinsing (chapter 4.10.1),
- optimisation of CIP sequences, that is cleaning and rinsing times, (chapter 4.10.1),
- automatic and continuous cleaning of cheese moulds, racks and frames (chapter 4.5.2),
- reuse of secondary water, such as RO-water and product condensate, for cleaning of less sensitive areas, or for preparation of cleaning solutions, (chapter 4.10.1),
- reuse of warm cooling water for cleaning, (chapter 4.10.1).
- low-pressure foam cleaning in manual cleaning (chapter 4.10.1).
When using secondary water or warm cooling water, the hygienic aspects must be taken into consideration!

5.5 Reduced consumption of chemicals

Automated CIP also reduces the consumption of chemicals compared to manual cleaning. The consumption is further reduced if the CIP includes:

- recirculation of cleaning chemicals (chapter 4.10.2),
- automatic dosage of chemicals and monitoring of concentrations by means of conductivity transmitters (chapter 4.10.2),
- optimised cleaning sequences, (chapter 4.10.2),
- self-neutralisation in the neutralisation tank (4.10.2).

5.6 Reduction of waste water discharges

The efforts to reduce waste water discharges should focus on reducing the pollutant load of the waste water. The volume is also an important issue, but as it is closely related to the consumption of water, any measures to reduce water consumption will eventually reduce the quantity of effluent.

5.6.1 Reduction “at the source”

It is recommended that measures for reducing the quantity and load of waste water discharges are taken at the source, instead of applying only “end-of-pipe”-solutions. Techniques for prevention or reduction of product spill and for collection of water/product rinsings are of high priority.

Preventive measures:

- installation of level control, alarms and shut-off systems to prevent overfilling of tanks (chapter 4.2.3),
- monitoring of drain pipes to prevent accidental emissions (chapter 4.2.3),
- complete draining of tanks and pipes (chapter 4.2.3),

Spill-reducing measures:

- accurate detection of transition between product and water during flushing and start-up (chapter 4.3.2),
- optimisation of equipment capacities to avoid intermediate rinsings related to unnecessary production breaks,
- separation of cheese fines from whey (chapter 4.5.4),
- a “component-filler” could be considered, when old filling machines are replaced or new filling lines are planned (chapter 4.3.2.)
• purification of spent cooling water from direct cooling of cheese, either by reverse osmosis, filtration or separation (chapter 4.5.4)

Collection:
• collection of rinsing water containing product residues, combined with further treatment, such as concentration, separation or drying, and utilisation as feed, or in other products (chapter 4.3.2),
• collection of solid spill, either by sweeping or screening (chapter 4.2.3),

Other important measures for reducing load and quantity of waste water discharges are:
• collection and reuse of secondary water, such as product condensate (chapter 4.7.2),
• unchanged brine in cheese production (chapter 4.5.4),
• further refining of whey
• optimisation of cleaning (CIP) sequences (chapter 4.10.2),
• utilisation of final rinsing water from cleaning for prerinsing (chapter 4.10.2),
• recirculation of cleaning chemicals (chapter 4.10.2).

5.6.2 “End-of pipe”- techniques

The end-of-pipe-solutions depend on the capacity and type of the final waste water treatment, but generally the following measures are recommended:
• continuous monitoring of waste water stream in combination with an alarm system to prevent accidental emissions (see also chapter 5.2)
• separation of fat, either in a fat trap or by flotation (chapter 4.2.4),
• neutralisation, preferably self-neutralisation (chapters 4.2.4 and 4.10.2).

5.7 Treatment of solid waste

The solid waste mainly consists of discarded packaging material and nonconforming products.

For the packaging material, it is recommended to:
• segregate the solid waste in order to minimise landfill disposal (chapter 4.2.5),
• use more “environment-friendly” materials in order to facilitate segregation and recycling (chapter 4.3.3),
• use circulating transport packages (chapter 4.9.2).

and the best way to treat nonconforming products is to:
• reduce the quantity by a system of traceability, including coding and follow-up,
• separate them from the package and utilise them as animal feed or for reworking into other products (chapter 4.3.3).

5.8 Noise and emissions to air

Any emission of ozone depleting freons to the air should be prevented by:

• replacing the harmful freons with less harmful refrigerants, such as ammonia or glycol (chapter 4.2.6),
• implementing intensified inspection and maintenance routines on the refrigeration equipment.

Emissions of noise, odour and dust are merely a local inconvenience and can be prevented by:

• soundproofing equipment that generate noise, such as spray dryers and cooling condensers (chapter 4.7.3),
• making proper traffic arrangements and by scheduling deliveries
• separating dust from the exhaust air from spray dryers by means of cyclones in combination with textile filters or wet scrubbing (chapter 4.7.3),
• regular emptying and cleaning of neutralisation tanks (chapter 4.2.6).

5.9 Reference dairies

Based on the results of the questionnaires, 5 plants were chosen as reference dairies. These plants were chosen among the participants according to the criteria that each plant produces almost exclusively one main type of product, and that they represent best overall performance within each product group. Another criteria was a production exceeding 200 tons/day (the IPPC criteria).

The chosen plants were:

• Arla Foods Stockholm dairy, Sweden, market milk producer
• Skånemejerier Malmö dairy, Sweden, market milk producer
• Arla Foods AKAFA plant, Denmark, powder producer
• Arla Foods Taulov dairy, Denmark, cheese producer
• GB Glace AB, Sweden, ice cream producer

Originally, the Taulov dairy was not involved in this study, as the plant was commissioned in 2000. However, the plant was chosen reference dairy as a representative of the latest state of the art.
It should also be noted, that these dairies have the best emission and consumption levels, but they do not necessarily apply all of the best available techniques that are mentioned in the previous chapters.

The reference dairies are described in more detail in Appendix 1.

5.9.1 Energy consumption

The total energy consumption (electricity and heating energy) of the reference dairies, expressed as a key performance indicator in kWh per litre of received milk or kg of produced ice cream, is indicated in table 5.1.

<table>
<thead>
<tr>
<th>Reference dairy</th>
<th>Product portfolio</th>
<th>Milk reception tons/a</th>
<th>Energy consumption kWh/l milk or kWh/kg ice cream</th>
</tr>
</thead>
<tbody>
<tr>
<td>Stockholm</td>
<td>market milk</td>
<td>246 400</td>
<td>0.11</td>
</tr>
<tr>
<td>Malmö</td>
<td>market milk</td>
<td>167 000</td>
<td>0.12</td>
</tr>
<tr>
<td>AKAFa</td>
<td>powders</td>
<td>445 970</td>
<td>0.42</td>
</tr>
<tr>
<td>Taulov</td>
<td>cheese</td>
<td>121 000²</td>
<td>0.15</td>
</tr>
<tr>
<td>GB Glace</td>
<td>ice cream</td>
<td>31 500 ¹</td>
<td>0.75</td>
</tr>
</tbody>
</table>

¹) Annual production of ice cream
²) Quantity received during 5.5 months in 2000/2001

Table 5.1. Key performance indicators on the energy consumption in the reference dairies, 1999.

As indicated in table 3.1, the energy consumption of the participating dairies ranged from 0.07 to 0.92 kWh/litre received milk, and from 0.75 to 1.6 kWh/kg product for the ice cream factories.

The reference dairies have the benefit of large scale production in combination with a limited product range as opposed to mixed production. The level of automation is high and the production equipment mostly modern and energy-efficient. Generally, the energy-efficiency of the dairies is improving through enhanced heat recovery and bigger production units.

5.9.2 Water consumption

The consumption of water in the reference dairies, expressed as a key performance indicator in litres per litre of received milk or kg of produced ice cream, is indicated in table 5.2.
### Table 5.2. Key performance indicators on the water consumption in the reference dairies, 1999.

As indicated in table 3.2, the water consumption of the participating dairies ranged from 0.60 to 6.3 litres/litre received milk, and from 3.6 to 10.3 litres/kg product for the ice cream factories. According to other studies, the water consumption at dairy processing plants is within the range of 1.3 – 2.5 l/kg of milk intake /25/. Even 0.8 – 1.0 l/kg milk intake can be achieved with advanced equipment in combination with a very good housekeeping and resource awareness among the employees /3/.

Generally, the housekeeping is improving with the enhanced resource awareness, which is brought forward by various environmental programs. However, this tendency does not, for obvious reasons, seem to apply in the areas where water is available in abundance.

#### 5.9.3 Waste water discharges

The volume of waste water discharged from the reference dairies, expressed as a key performance indicator in litres per litre of received milk or kg of produced ice cream, is indicated in table 5.3, together with the corresponding load levels.
Table 5.3. Key performance indicators on waste water discharged from the reference dairies, 1999.

The waste water discharges of the participating dairies ranged from 0.75 to 4.3 litres/litre received milk, and from 2.7 to 7.8 litres/kg product for the ice cream factories (table 3.5).

The scale of operation and the type of process (batch/continuous) have a major influence on the waste water discharges. The tendency towards large production plants is favourable in terms of effluent load per unit of production, but on the other hand, the large product variety with short production series and order-driven production, has the adverse effect through an increased need for cleaning. There is still a potential for improvement in waste water reduction “at the source”, mainly in the form of enhanced product recovery.

5.9.4 Solid wastes

The total quantity of solid waste, including its “destination”, from the reference dairies, expressed as a key performance indicator in kg per ton of received milk or produced ice cream, is indicated in table 5.4.
<table>
<thead>
<tr>
<th>Reference dairy</th>
<th>Product portfolio</th>
<th>Total solid waste (kg/ton)</th>
<th>Recycled (kg/ton)</th>
<th>Energy/ incineration (kg/ton)</th>
<th>Composted (kg/ton)</th>
<th>Landfill disposal (kg/ton)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Stockholm</td>
<td>market milk</td>
<td>4.6</td>
<td>1.0</td>
<td>2.1</td>
<td>0.1</td>
<td>1.4</td>
</tr>
<tr>
<td>Malmö</td>
<td>market milk</td>
<td>3.0</td>
<td>0.8</td>
<td>1.4</td>
<td>0.4</td>
<td>0.4</td>
</tr>
<tr>
<td>AKAF</td>
<td>powders</td>
<td>1.6</td>
<td>0.5</td>
<td>0.7</td>
<td>-</td>
<td>0.4</td>
</tr>
<tr>
<td>Taulov</td>
<td>cheese</td>
<td>0.6</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>0.2</td>
</tr>
<tr>
<td>GB Glace</td>
<td>ice cream</td>
<td>58</td>
<td>12</td>
<td>-</td>
<td>-</td>
<td>46</td>
</tr>
</tbody>
</table>

Table 5.4. Key performance indicators on the quantity of solid wastes from the reference dairies, 1999.

The amount of solid wastes from the participating dairies varies from 0.5 to 14 kg/ton of received milk, and for the ice cream factories the amount is within 35 – 58 kg/ton ice cream (table 3.9). The landfill disposal of GB Glace is nowadays significantly lower, as 1000 tons of sludge from the flotation process is utilised for biogas production.

The amount of solid wastes discarded as landfill is slowly decreasing through increased segregation and recycling of packaging materials. The main area for improvements is in the treatment of nonconforming products, where innovations are needed.
6. Emerging techniques

6.1 Introduction

This chapter contains information on novel pollution prevention techniques, which are under development or in pilot-scale use. Generally, the environmental awareness of the Nordic dairy industry is at a high level, and efforts are constantly made to improve the environmental performance. However, the strict requirements on the hygienic safety of the dairy products limit the possibilities to introduce completely new, “revolutionary”, techniques that are economically feasible.

6.2 Membrane techniques

The membrane techniques are already in full-scale commercial use in many areas. Ultrafiltration, for example, has been successfully used in the production of Feta-cheese for many years. Another successful application is the use of UF for standardisation of the protein content of milk. Also the other membrane techniques (RO, NF and MF) are being introduced, and industrial trials are made in order to optimise their application for removal of bacteria, in demineralisation processes and for isolation of different milk components.

There are also other areas where the membrane techniques are of great potential, such as in purification of secondary water and rinsing water, as well as in concentration of product spills and cleaning solutions, where the negative environmental impact is reduced, as the purified components can be reused.

However, the application is still limited by the high costs involved in the investment and operation of the equipment. The operation of the equipment must be simpler and more reliable, and the filtering efficiency must be stabilised.

The cleaning of the membranes is still time and resource consuming, but efforts are made to develop membrane materials that are resistant to cleaning chemicals. The development of ceramic membrane materials that can be cleaned with traditional detergents is regarded as a step in the right direction. /15/.

6.3 Whey treatment

As previously mentioned, whey contains valuable components that can be recovered by several methods. A continuous chromatographic process has been developed for selective separation of lactose. The process is applicable for both whey permeate and skim milk and offers a better yield than traditional crystallisation /11/.

Also another process under development for the total utilisation of whey can be mentioned in this context as an emerging technique. The process involves
chromatographic separation and hydrolysis, in combination with membrane processes (UF and NF) and evaporation. The process converts the whey completely into the following useful products: whey protein, whey permeate syrup and so-called whey molasses, a product used as animal feed.
7. Conclusions and recommendations

The dairy industry has a relatively low environmental impact compared to many other sectors. The consumption of water and energy, as well as the discharge of waste water are the main concerns. The environmental pollution caused by dairy processing is mainly due to cleaning operations and accidental product spills, whereas process waste water, in the proper sense of the word, does not exist.

The Nordic dairy industry is taking steps to further improve its environmental performance, which involves on-going projects to improve products and processes, as well as to implement environmental management systems, such as EMAS and/or ISO 14001. This study shows that environmental progress has been made, but that there still are areas, where further improvements are required.

The mission of the dairy industry is to provide the consumer with safe dairy products of high quality. The requirements on hygienic safety limit the number of applicable techniques for reduced environmental impact, and the safety aspect must be thoroughly considered in every step towards improved environmental performance.

The Nordic dairy industry is a technically well and homogenously developed sector, where the technical solutions are known and available to all. The competitiveness of the dairy companies is usually based on other virtues. This also applies for environmental issues, where the decisive factor is in the human resources. Important, environmentally beneficial improvements can be achieved simply by changes on “the human level”, in operator practises and work procedures.

This report is based on a survey among 57 Nordic dairy plants and does not exclude the existence of other environmentally beneficial techniques within the field. According to the survey, the consumption and emission levels representing BAT were found to be within the following ranges:
<table>
<thead>
<tr>
<th>Product portfolio</th>
<th>Energy consumption kWh/litre of received milk</th>
<th>Water consumption litres/litre of received milk</th>
<th>Waste water discharge litres/litre of received milk</th>
</tr>
</thead>
<tbody>
<tr>
<td>market milk</td>
<td>0.1 – 0.2</td>
<td>1.0 – 1.5</td>
<td>0.9 – 1.4</td>
</tr>
<tr>
<td>cheese</td>
<td>0.2 – 0.3</td>
<td>1.4 – 2.0</td>
<td>1.2 – 1.8</td>
</tr>
<tr>
<td>powders</td>
<td>0.3 – 0.4</td>
<td>0.8 – 1.7</td>
<td>0.8 – 1.5</td>
</tr>
<tr>
<td>ice cream ¹)</td>
<td>0.8 – 1.2</td>
<td>4.0 – 5.0</td>
<td>2.7 – 4.0</td>
</tr>
</tbody>
</table>

¹) level expressed as per kg of produced ice cream

Table 7.1 Consumption and emission levels representing BAT.

The report can be used as a basis for further benchmarking activities and cooperation in BAT development and environmental protection within the dairy sector. The collaboration and exchange of information on environmental issues should be extended to involve also retailers, consumers and suppliers.
Abbreviations

CIP  Cleaning In Place
UHT  Ultra High Temperature
RO   Reverse Osmosis
UF   Ultrafiltration
NF   Nanofiltration
AMF  Anhydrous Milk Fat
COD  Chemical Oxygen Demand
BOD  Biological Oxygen Demand
EMAS Eco Management and Audit Scheme
PET  Polyethylene terephtalate
PE   Polyethylene
PVDC Polyvinylidene chloride
CFC  Chlorofluorocarbon, commonly known as freon
HCFC Hydrogenated chlorofluorocarbon, commonly known as freon
MVR  Mechanical Vapour Recompression
TVR  Thermal Vapour Recompression
Appendices

Appendix 1  Reference plants
Appendix 2  First questionnaire
Appendix 3  Second questionnaire
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