Introduction
This paper addresses the use of lactose in a range of foodstuffs. The structure, chemical and physical properties of lactose are discussed and compared with other saccharides. The utilisation of lactose in a range of foods, including infant foods, confectionery, meat, packed goods and biological media, are outlined. Some nutritional aspects are also considered. It is concluded that increased utilisation of lactose will probably be the result of developments in infant food and confectionery, together with its application as a feedstock for the production of lactose hydrolysed products and fermented products.

General Considerations
The utilisation of the lactose in by-product streams from cheese and casein manufacture remains one of the dairy industry's most difficult problems. Until recently, the major source of lactose has been whey from the manufacture of casein and cheese. However, the development of ultrafiltration (UF) technology for the processing of milk and whey is resulting in a rapid increase in the production of UF permeate high in lactose content. This trend is certain to continue as UF technology continues to be more widely applied to cheese making and to the production of whey protein concentrates (WPC). The increased volume of permeate so produced will have important implications regarding the utilisation of lactose.

In the past, the processing of wheys has generally aimed at utilisation of the protein fraction, as this attracts the highest economic return. Thus, WPC manufacture is aimed at maximising utilisation of the protein in whey. To date, the utilisation of the protein-free permeate from the UF of milk or whey has to a large extent been ignored. However, with the increased use of UF in cheese making resulting in the production of larger volumes of permeate rather than whey, increased emphasis is likely to be given to permeate utilisation. Because permeate is virtually protein free, potential returns for the product are significantly lower than for whey and applications within the food industry are more restricted.

The increasing role of UF in the production of permeate has been outlined by Teixeira et al. (1983a). These authors reported that whilst the potential market for whey protein concentrates in the USA is about ten times the 15 thousand tonnes used in 1981, by 1986 the demand for lactose would have risen by only about 25% over the 1981 production. They strongly suggested therefore that new applications be developed for the utilisation of lactose permeate from UF.

World cheese whey solids production is currently at least 9,000,000 tonnes per annum. These solids contain about 4,000,000 tonnes of lactose. Currently, commercial utilisation of lactose is about 200,000 tonnes per year. Much
of the residual lactose is utilised directly in the form of whey - as animal food, in spray dried whey or disposed of on the land or by sewage treatment.

There is little information available regarding the utilisation of lactose by individual countries, or on a world basis. However, it is likely that major users include the manufacturers of infant foods and the pharmaceutical industry, where the ability of lactose to be moulded into tablets and pills is beneficial.

World demand for lactose is considered to be inelastic and thus any significant increase in production would likely result in a sharp reduction in price. For this reason, there has been some tendency for the dairy industry to utilise lactose as a raw material for the manufacture of other more valuable products. However, this approach often requires the injection of considerable capital, as well as the assessment of alternative technologies and the development of new markets.

However, there are still many useful applications for lactose within the food industry and these continue to be developed. Some of these applications are outlined in review articles by Teixeira et al. (1983b); Coton et al. (1982) and Mann (1984).

Many of the uses of lactose by the food industry rely on its particular characteristics in comparison with other sugars. For example, lactose is a useful carrier for flavour and colours and this has led to its utilisation in products such as sachet wafers, seasonings and baked goods. The confectionery industry uses lactose to obtain desired end products properties, relying on lactose to alter the crystallisation characteristics of other sugars. The reducing nature of lactose, coupled with the fact that it is not fermented by bakers' yeast means that it offers unique properties to the baking industry. The addition of lactose will increase the browning of the crust and, since lactose is not fermented during bread making, any other functional properties conferred by the lactose will not be lost during manufacture. In beer, lactose may be also used as a means for improving organoleptic quality, as it is not fermented by beer yeasts.

Lactose may also be used as a substrate in the production of penicillin, as seed material in the manufacture of concentrated and condensed milks and as a raw material for the production of specialty chemicals and in some fermentations.

Properties of Lactose

Structure

Essentially, the sole source of lactose is the milk of mammals (other sources are rare, but it is also found as a component in the polysaccharides of some flora). It is a di-saccharide that, on hydrolysis, yields D-glucose and D-galactose. The two mono-saccharides are linked through the aldehyde group of d-galactose; thus the aldehydic portion of lactose is attached to the glucose moiety. The structure of lactose is shown in Figure 1.

Lactose exists in two isomeric forms (anomers), alpha and beta, which differ only in the configuration of the substituents on the number one carbon atom of the glucose residue (Figure 2). The solubility of these two forms is significantly different - the solubility of the alpha form is about 7g/100g at 15°C, whereas that of the beta form is about
50g/100g. On dissolution of lactose, mutarotation occurs, yielding a solution containing about 63% beta-lactose. On concentration, some alpha-lactose will precipitate and further mutarotation will occur, with conversion of soluble beta-lactose to alpha-lactose. As crystallisation proceeds, this process continues, yielding a product mainly composed of alpha-lactose monohydrate. The composition of the product so obtained will therefore depend on the rate of two competing equilibria, the rate of conversion of soluble beta-lactose to soluble alpha-lactose and the conversion of soluble alpha-lactose to alpha-lactose mono-hydrate crystals.

Alpha-lactose crystallises as a hydrate; however, beta-lactose contains no water of crystallisation. When lactose solutions are dried rapidly, there may be insufficient time for crystallisation of the alpha-lactose to alpha-lactose hydrate to occur. The dry lactose is then in a form similar to that present in the liquid. A number of studies have confirmed that lactose in rapidly dried dairy products is in the form of a mixture of beta-lactose, alpha-lactose mono-hydrate and amorphous alpha-lactose. Neither beta-lactose nor alpha-lactose mono-hydrate are hygroscopic. However, anhydrous alpha-lactose is highly hygroscopic and absorbs water from the air, forming the hydrate that occupies more volume than the anhydrous form. This is the cause of the caking and lumping observed in many dried dairy products.

These characteristics need to be taken into account during manufacturing processes if difficulties are to be avoided. Normal procedures for the manufacture of 'non-hygroscopic' dairy products generally involve the conversion of much of the lactose into a crystalline form prior to drying. This can be achieved by holding the concentrate under fixed conditions to allow for the formation of alpha-lactose hydrate crystals. As an alternative, techniques similar to 'instantising' can be employed, where the surface of the product is humidified or the particles dried partially to permit crystallisation of the lactose before final drying.

**Sweetness and solubility**

Lactose is much less soluble and much less sweet than sucrose. These properties substantially restrict its range of applications in the food industry as an alternative sweetener. The relative sweetness and solubility characteristics of lactose, glucose, galactose and sucrose are shown in Table 1 (Pazur, 1970; Shah and Nickerson, 1978). However, relative sweetness varies with concentration and thus the values shown in Table 1 should be taken only as a guide. The sweetness of lactose increases with concentration more rapidly than does the sweetness of sucrose, although there appears to be little difference in the effect of concentration on the sweetness of lactose, glucose or galactose. It is generally accepted that beta-lactose is sweeter than alpha-lactose, but at low concentrations, it is not significantly sweeter than the equilibrium mixture.

The development of lactose crystallisation in frozen foods may lead to undesirable calcium-protein interactions and instability (Muir, 1985). A number of options to improve freeze-thaw stability of lactose containing frozen products are open to the food formulator, including lactose hydrolysis.
Manufacture of Lactose

It is not my intention to discuss the manufacture of lactose in detail. The principles for the manufacture of lactose were outlined as long ago as 1895 by Zirm (1895) and then by Aufsberg (1910). The principles described by these authors for the manufacture of lactose remain relevant today. Today, the technology for production of lactose can be purchased from a number of experienced equipment supply companies. In general, production of lactose involves protein removal (for example by liming, heat treatment and filtration), concentration of the mother liquor, refiltration, further concentration, induction of crystallisation and removal of crystals by centrifugation. Continuous systems have not been successfully developed to commercial application as yet.

In the batch crystallisation procedures, about 50% recovery of the lactose is achieved and the mother liquor may be sold as delactosed whey powder. It should be noted that permeate from the UF of milk or whey is an ideal raw material for this process, as it does not require removal of protein.

Lactose Utilisation

Infant foods

The only source of carbohydrate in mammalian milk is lactose and lactose is also a major contributor to energy requirements during infancy. Lactose is hydrolysed only slowly in the intestines, resulting in a steady energy supply and a comparatively constant blood glucose level between feedings. The replacement of lactose by glucose (for example) in infant diets would require a greater response from the insulin system, with risks of over secretion of insulin and consequently low blood sugar levels. It is also believed that lactose assists in the development of a favourable environment in the intestine, resulting in development of lactic acid flora, which may inhibit the growth of pathogenic flora and also has a useful effect of calcium absorption.

Some of the differences between human and cow milk are outlined in Table 2 (Visser et al. 1986). It is common practice to fortify infant foods based on cow milk with lactose because of the difference in lactose content between human and cow milk.

There is extensive literature available on the formulation of infant foods, including useful reviews by Mann (1977), Mathur and Shahani (1979) and Ulrich (1976). The preparation of a food for premature infants based on whey protein concentrate, lactose, maltodextrin, vegetable oils, glycerol mono-stearate, lecithin and oil vitamin concentrate has been outlined by Lucas and Barr (1985). The process involves clarification, pasteurisation, homogenisation and heating. The food contains more

### Table 1

<table>
<thead>
<tr>
<th>Sweetness and solubility of lactose</th>
</tr>
</thead>
<tbody>
<tr>
<td>Relative Sweetness*</td>
</tr>
<tr>
<td>----------------------</td>
</tr>
<tr>
<td>At 10°C</td>
</tr>
<tr>
<td>----------------------</td>
</tr>
<tr>
<td>Sucrose</td>
</tr>
<tr>
<td>Lactose</td>
</tr>
<tr>
<td>D-Galactose</td>
</tr>
<tr>
<td>D-Glucose</td>
</tr>
<tr>
<td>D-Fructose</td>
</tr>
</tbody>
</table>


### Table 2

<table>
<thead>
<tr>
<th>Some attributes of human and cow milk</th>
</tr>
</thead>
<tbody>
<tr>
<td>Solids (%)</td>
</tr>
<tr>
<td>Total</td>
</tr>
<tr>
<td>Lactose</td>
</tr>
<tr>
<td>Calorific Value (kJ/100mL)</td>
</tr>
<tr>
<td>Total</td>
</tr>
<tr>
<td>Lactose</td>
</tr>
<tr>
<td>Osmotic Pressure (mOsm/L)</td>
</tr>
<tr>
<td>Total</td>
</tr>
<tr>
<td>Lactose</td>
</tr>
</tbody>
</table>

Adapted from Visser, Van den Bos and Ferguson (1986).
than 160 microg/100μ ribo-

than

flavin and may be beneficial to

infants undergoing photo ther-

apy.

Confectionery

The confectionery industry is a

major user of lactose (Spurge-

on 1976; Riedel and Hansen,

1979; Mann, 1982; Estelmann,

1984). Recent reports have

outlined the use of lactose

in fondant fillings were

studied by these workers. Manu-

facture of a lactose con-

taining fondant was achieved

by bringing the lactose and

sucrose into solution and

crystallising them together. Alter-

natively, microfine lactose,

could be introduced to prepar-

ed fondant with further mixing.

Inclusion of lactose in fond-

ants resulted in control and

reduction of sweetness, intensi-

ification of whiteness in fond-

ant and economies in oper-

ation. Meggle Milchindustrie

(Anon, 1985) have also repor-

ted a lactose containing a spe-

cial ingredient for toffee and

fudge.

Boesig and Pritzwald-

Stegmann (1981) have de-

scribed the use of a mixture of

sucrose and lactose for sugar

coating of cores (e.g. chocolate

buttons or hazelnuts). The ratio

of sucrose to lactose examined

covered the range 90:10 to

50:50. Lactose suppressed

sucrose crystallisation allow-

ing the coating to be effected at

lower temperatures and reduc-

ing the sweetness of the coat-

ing.

Baked goods

The applications of lactose

within the baking industry are
determined to a large extent

by the reducing nature of lact-

ose, coupled with the fact that

it is not fermented by bakers

yeast. The addition of lactose,

for example, will increase the

browning of the crust, which is

often highly desirable. Lukasas

(1984) has reviewed the appli-
cations of lactose-based prod-

ucts in the baking industry. 

Harper et al. (1984) examined

the use of whey-based prod-

ucts in breadmaking and con-

cluded that lactose concentra-
tion was not related to the

loaf depression associated with

use of some whey-based prod-

ucts.

Meat

Although the application of

lactose in meat products would

appear to have considerable

potential, there is comparative-

ly little information concern-

ing such uses in the litera-

ture. Finel (1981) has consid-
ered various possibilities in a re-

view article. Lauck and Mela-

chouris (1983) have outlined

the manufacture of a deprotein-

ised whey-based product con-

taining 40 to 50% lactose which

is particularly suitable for

addition to comminuted meat

products as a flavour enhan-
cing and binding agent. 

Scharner et al. (1981) have de-

scribed a lactose-containing

product which may be added to

raw sausage formulations as a

carbohydrate source for the

starter culture.

Cultures and

biological materials

Lactose fractions derived from

whey UF permeate have been

recommended as an ingredient

for a wide range of culture

media for bacteria or fungi

(Keggins et al., 1984).

The use of milk-based

powders for the drying of start-
er bacteria has been studied by

Harju et al. (1983). Dried milk

products were used to absorb

the water and this technique

was compared with freeze

drying and spray drying. Prop-

ionibacterium freudenreichii

and Lactobacillus helveticus

drewed successfully by the sorp-

tion method, with survi-

val rates of more than 50%.

Freeze drying was more suc-

cessful for Streptococcus lactus.

Spray drying was unsuitable

for all three organisms.

Miscellaneous

Lactose has been recently sugges-
ted for as an ingredient in

coffee creamers (Moran and

Halstead, 1981), dietetic agents

(Kowalsky and Scheer, 1981),

delible gel products, (Le Grand

and Paul, 1981), food release

agents (Noborio and Maeda,

1981), ketchups and sauces

(Dordevic et al., 1981), a water

miscible starch based product

(Gasser and Badertscher,


The firming of vege-

tables by addition of lactose was

studied by Jelen and Chan,

1981). Blanched carrots, green

beans and peas were retorted

at 121°C in 2% sodium chloride

brine containing 0-15% lact-

ose. After 37 and 68 days, hard-

ness of the vegetables was eval-

uated. Increasing lactose

content correlated significant-

ly with average hardness of

peas and beans and, to a lesser

extent, carrots. All samples

from brines containing more

then 8% lactose showed higher

average hardness than those

containing less or no lactose.
The increase was noticeable to an untrained panel.

Eisenstadt (1981) has suggested the use of lactose in di-peptide sweetener formulations to give a product approaching the natural sweetness of glucose and requiring the minimum addition of di-peptide sweetener.

Nutrition

Lactose malabsorption

Lactose malabsorption and its implications for the development of lactose hydrolysed products has been recently reviewed by Hourigan (1984), amongst others.

Calcium absorption

There is much evidence that dietary lactose assists the absorption of calcium (Allen, 1982; Schaafsma, 1983). The enhancement of calcium absorption by lactose is due to increased passive diffusion (Allen, 1982), but beyond that, the mechanism is uncertain. The effect is thought to be due to the metabolic by-product of lactose, lactic acid (rather than lactose itself), as consumption of sour milk also improves calcium absorption. The mechanism may involve a decrease in pH in the intestinal tract as a result of fermentation resulting in increased solubility of calcium increasing transport. Part of the effect may be due to the formation of soluble complexes between calcium and lactose (Renner, 1983). Other work has not supported these suggestions however. Experiments with rats showed that the effect was not due to a lowering of pH by fermentation or to stimulation of intestinal metabolism by lactose (Wasserman and Lengemann, 1960). Further, the suggestion that lactose forms a complex with calcium increasing absorption (Charley and Saltman, 1963) is not supported by the lack of the necessary detailed structure in lactose (Angyal, 1974). It is does remain clear however that milk is the most concentrated and available form of dietary calcium.

Intestinal flora

During digestion, lactose is virtually unhydrolysed in the stomach and little is absorbed in the upper section of the large intestine. However, in the next portion of the intestine it is cleaved by the enzyme lactase and the resulting mono-saccharides provide a useful substrate for the body's flora. The lactic acid so produced results in development of acid conditions believed to be desirable to inhibit the growth of many putrefying bacteria, allowing their replacement with acidophilic flora.

Conclusions

Increasing markets for the utilisation of lactose as such will remain difficult. Its applications are limited by its low sweetness and low solubility and, as such, lactose has little

<table>
<thead>
<tr>
<th>Table 3</th>
<th>Some options for lactose utilisation</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Product</strong></td>
<td><strong>Applications</strong></td>
</tr>
<tr>
<td>Acetic acid</td>
<td>Foods</td>
</tr>
<tr>
<td>Acetone</td>
<td>Various</td>
</tr>
<tr>
<td>Alcohol</td>
<td>Foods, energy</td>
</tr>
<tr>
<td>Amino acids</td>
<td>Various</td>
</tr>
<tr>
<td>Antibiotics</td>
<td>Medical</td>
</tr>
<tr>
<td>Butanol</td>
<td>Various</td>
</tr>
<tr>
<td>Citric acid</td>
<td>Foods</td>
</tr>
<tr>
<td>Food oils</td>
<td>Animal foods</td>
</tr>
<tr>
<td>Fuel gas</td>
<td>Energy</td>
</tr>
<tr>
<td>Gelatonic acid</td>
<td>Various</td>
</tr>
<tr>
<td>Gelatonic acid</td>
<td>Various</td>
</tr>
<tr>
<td>Glucaric acid</td>
<td>Plant hormones</td>
</tr>
<tr>
<td>Gluconic acid</td>
<td>Various</td>
</tr>
<tr>
<td>Gluconic acid</td>
<td>Various</td>
</tr>
<tr>
<td>Hydrolysed lactose</td>
<td>Sweetener, lactose malabsorbers</td>
</tr>
<tr>
<td>Iaconic acid</td>
<td>Various</td>
</tr>
<tr>
<td>Lactase</td>
<td>Enzyme applications</td>
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<tr>
<td>Lactic acid</td>
<td>Foods</td>
</tr>
<tr>
<td>Lactic polymers</td>
<td>Biodegradable plastics, prosthetics</td>
</tr>
<tr>
<td>Lactitol</td>
<td>Non-nutritional sweetener</td>
</tr>
<tr>
<td>Lactobionic acid</td>
<td>Chelating</td>
</tr>
<tr>
<td>Lactose crystals</td>
<td>Food, tablet binder</td>
</tr>
<tr>
<td>Lactose foams</td>
<td>Insulation</td>
</tr>
<tr>
<td>Lactose polymers</td>
<td>Surfactants</td>
</tr>
<tr>
<td>Lactosyl urea</td>
<td>Ruminant feeding</td>
</tr>
<tr>
<td>Lactulose</td>
<td>Infant nutrition</td>
</tr>
<tr>
<td>Malic acid</td>
<td>Various</td>
</tr>
<tr>
<td>Oligosaccharides</td>
<td>Medical</td>
</tr>
<tr>
<td>Polysaccharides</td>
<td>Food gums</td>
</tr>
<tr>
<td>Single cell protein</td>
<td>Various</td>
</tr>
<tr>
<td>Vitamins</td>
<td>Food fortification</td>
</tr>
</tbody>
</table>

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in the way of specific advantages to offer to the food manufacturer.

Increased utilisation of lactose is more likely to come about through a development of further applications in the fields of infant foods, confectionery and meats. Other applications are unlikely to be of major significance on a world scale. However, it is more likely that increased utilisation of lactose will be through its application as a raw material for further processing, such as the feedstock for a range of chemical products.

There is extensive literature on the manufacture and utilisation of lactose derivatives. Reviews of particular value include those of Thelwall (1985), Andrews (1986) and Pritzwald-Stegmann (1986). Many of the options available to the lactose processor for conversion of lactose are shown in Table 3. Whilst virtually all of these options are technically feasible, it is probable that many would be uneconomic in practice (Hobman, 1984).

References


Uses for Lactose-Hydrolysed Dairy Products

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Introduction
Of the solids in cows' milk, lactose, comprising approximately 39%, is the most abundant. Dairy by-products such as wheys and permeates contain even greater proportions of lactose. To enhance the sale of dairy products the lactose can be converted into its constituent monosaccharides, glucose and galactose. To assist manufacturers in establishing product prices it is useful to know that the likely hydrolysis costs in Australian currency for milk and whey are 1-20c/L for an unconcentrated product (Gadow 1986; Mitchell, Muller and Weinert, unpublished report).

Advantages of Lactose Hydrolysis
The advantages of LH products over the non-hydrolysed products are many. After lactose hydrolysis (LH) wheys and permeates are able to be used as food ingredients due to the properties of the monosaccharides. In the food industry lactose is hydrolysed using the enzyme beta-galactosidase or lactase. Typically, lactase-catalysed lactose hydrolysis shows a nonlinear relationship for lactose conversion versus time, characteristically a rectangular hyperbola. Often a greatly diminishing rate of hydrolysis occurs after 70% conversion is achieved. This translates to greatly increased costs in achieving levels of hydrolysis greater than this level. The kinetics of the enzyme-catalysed lactose hydrolysis reaction will usually depend on the type of feed and the source of the enzyme together with temperature and pH conditions.

Costs
This article aims to show a wide range of market opportunities from the many uses for LH products. The price set by the LH product manufacturers will heavily affect market demand. To assist manufacturers in establishing product prices it is useful to know that the likely hydrolysis costs in Australian currency for milk and whey are 1-20c/L for an unconcentrated product (Gadow 1986; Mitchell, Muller and Weinert, unpublished report).

Processing & Storage of LH Products
One of the more economical methods used to manufacture LH products is based on the use of immobilised lactase. CSIRO has assisted in the development of such a process — which is also capable of hydrolysing a wide range of dairy products, including milks, wheys and permeates.

LH milks can be spray dried in conventional dairy driers. However, the greater concentration of monosaccharides in the solids of LH wheys and permeates makes this difficult. For prolonged storage of hydrolysed wheys and permeates, concentration to a syrup of around 70% total solids is more suitable. Hydrol-
Analysis of such syrups to 85% conversion would maximise the saccharide solubilities (Bourne et al., 1983).

**Uses for Hydrolysed Products**

LH products have been manufactured in Australia and uses of these products have included a reduced lactose milk and as a combined humectant and sweetener used by the pet food industry. More detailed uses are now described:

**Hydrolysed milks**

Hydrolysed milks can alleviate the discomfort associated with lactose malabsorption in the lactase deficient person. Hydrolysis levels of 60-70% are necessary for milk to be well tolerated by such people (Hourigan, 1984). An example of a situation where a LH milk would be beneficial is in food aid programs where many of the recipients have a reduced ability to digest lactose and could be subject to deterioration in health if fed normal milk.

Milk can be frozen to increase the shelf life. On thawing, a coagulum can form, giving the milk an unpalatable appearance. Hydrolysed milks show more stable freeze-thaw characteristics which may offer some marketing advantage (Tumerman et al., 1954; Woychik and Holsinger, 1977; Free and Hayes, unpublished data).

Milk is often flavoured and sweetened to increase its appeal. Hydrolysed milks require less added sweetener than normal milks and this can also be used as a marketing advantage.

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**Table 1**

A comparison of sweetness and solubility measurements of different sugars.

<table>
<thead>
<tr>
<th></th>
<th>Sweetness (comparative)</th>
<th>Solubility (g/100g solution at 30°C)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sucrose</td>
<td>100</td>
<td>69</td>
</tr>
<tr>
<td>D-Fructose</td>
<td>173</td>
<td>82</td>
</tr>
<tr>
<td>D-Glucose</td>
<td>74</td>
<td>54</td>
</tr>
<tr>
<td>D-Galactose</td>
<td>32</td>
<td>36</td>
</tr>
<tr>
<td>Lactose</td>
<td>16</td>
<td>20</td>
</tr>
</tbody>
</table>

(a) Pazur (1970)

(b) Shah and Nickerson (1978)

Note the low sweetness and solubility of lactose compared to glucose and galactose.

---

*Figure 1.*

Structural formulae of lactose, glucose & galactose.
Hydrolysed wheys and permeates

LH wheys and permeates can be used as sweeteners. However, the minerals contained in wheys and permeates tend to impart a salty flavour which becomes particularly unpleasant after concentration. Demineralisation is therefore an important adjunct to hydrolysis of wheys and permeates. Concentrated wheys which have been demineralised by 50% have been reported to be without noticeable salty flavours (Salmon, 1981). The use of hydrolysed wheys as fermentation feedstock may also benefit from demineralisation.

Food companies often require a continuous supply of product. Production of hydrolysed whey and whey permeates in Australia would be variable, following the seasonal production of cheese. Storage to even out supply may however be economically unviable.

Ice-cream

When lactose hydrolysis technology is used in ice-cream manufacture the increased sweetness and solubility of glucose and galactose and the reduction in lactose may reduce the body defect referred to as 'sandiness' as well as reducing the amount of added sweetener. The resultant ice-cream is softer which should also appeal to consumers.

It appears possible to manufacture an acceptable ice-cream using LH whey to replace up to 50% of the non-fat milk solids and sucrose. Typically the level of hydrolysis should be 70%. Table 2 is a summary of the effects of lactose hydrolysis on ice-cream

<table>
<thead>
<tr>
<th>Replacements</th>
<th>Additions</th>
<th>Flavour</th>
<th>Body/texture</th>
<th>Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td>MSNF</td>
<td>Hyd syrup WPC</td>
<td>+ +</td>
<td>+</td>
<td>Huse et al. (1984)</td>
</tr>
<tr>
<td></td>
<td>Hyd-whey</td>
<td>0</td>
<td>+</td>
<td>Patel &amp; Mathur (1982)</td>
</tr>
<tr>
<td>MSNF</td>
<td>Hyd/dem. whey</td>
<td>0</td>
<td></td>
<td>Trzecieksi (1982)</td>
</tr>
<tr>
<td></td>
<td>lactase</td>
<td>0</td>
<td>0</td>
<td>Miller (1977)</td>
</tr>
<tr>
<td></td>
<td>Hyd-whey</td>
<td>+</td>
<td>+</td>
<td>Bray (1987)</td>
</tr>
<tr>
<td>Sucrose</td>
<td>+</td>
<td></td>
<td></td>
<td>Newshaw et al. (1988)</td>
</tr>
<tr>
<td>Sucrose</td>
<td>+ +</td>
<td></td>
<td></td>
<td>Coton (1979)</td>
</tr>
<tr>
<td></td>
<td>Hyd-whey</td>
<td>+/-</td>
<td>0</td>
<td>Guy (1980)</td>
</tr>
<tr>
<td></td>
<td>Hyd-whey and dem.</td>
<td>0</td>
<td></td>
<td>Martinez and Speckman (1988)</td>
</tr>
<tr>
<td></td>
<td>Hyd-whey</td>
<td>+ +</td>
<td></td>
<td>Gregory (1982)</td>
</tr>
<tr>
<td>MSNF/fat</td>
<td>Hyd-demin. whey</td>
<td>+</td>
<td></td>
<td>Reissmann (1982)</td>
</tr>
<tr>
<td>MSNF</td>
<td>Hyd-whey</td>
<td>0</td>
<td>0</td>
<td>Leewenstein et al. (1976)</td>
</tr>
<tr>
<td>MSNF</td>
<td>Hyd-whey</td>
<td>0</td>
<td>0</td>
<td>Bhursi et al. (1976)</td>
</tr>
<tr>
<td></td>
<td>Hyd-whey</td>
<td>+</td>
<td></td>
<td>Guy et al. (1974)</td>
</tr>
</tbody>
</table>

Legend:

Hyd = Hydrolysed
MSNF = Milk Solids-Not-Fat
WPC = Whey Protein Concentrate (The following comments refer to a comparison with the normal product):
0 = No significant differences reported
+ (+) = Hydrolysed product (much) preferred
- = Product less preferred
+/- = Variable results

Table 2
Summary of the effects of lactose hydrolysis on ice-cream manufacture

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manufacture (adapted from Mitchell, 1990).

**Yoghurt**

The benefits of lactose hydrolysis of the base to be used in yoghurt manufacture are:

- Less sour flavour
- Reduced level of added sweetener required for flavoured yoghurts
- Increased rate of acid production, and
- Wider choice of starters.

The optimum level of hydrolysis is approximately 70%, as at this level the acid production and costs of hydrolysis are optimised. Table 3 is a summary of the effects of lactose hydrolysis in yoghurt manufacture (adapted from Mitchell, 1990).

**Other uses**

Table 4 summarises some of the other uses for LH products.

**Markets**

Many dairy companies have the opportunity to utilise LH products ‘in-house’. The LH product could be used to replace bought-in sweetener or increase the market appeal of existing products. ‘In-house’ uses such as replacement of bought-in ingredients would be most economical.

However, it may not be possible to utilise all LH products ‘in-house’. Many dairy products are sold as ingredients to general food manufacturers. The marketing of such products may be facilitated by the increased sweetness and reduction in the likelihood of sugar crystallisation conferred by lactose hydrolysis.

---

### Table 3.

**Summary of the effects of lactose hydrolysis in yoghurt manufacture**

<table>
<thead>
<tr>
<th>Replacement</th>
<th>Additions</th>
<th>Flavour</th>
<th>Body/texture</th>
<th>Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sucrose</td>
<td>Hyd</td>
<td>+</td>
<td>0</td>
<td>Whalen et al. (1988)</td>
</tr>
<tr>
<td>Asp/Hyd</td>
<td></td>
<td>0</td>
<td>0</td>
<td>Botha et al. (1987)</td>
</tr>
<tr>
<td>Hyd</td>
<td>0</td>
<td>0</td>
<td></td>
<td>Kreuder (1987)</td>
</tr>
<tr>
<td>Hyd</td>
<td>+</td>
<td></td>
<td></td>
<td>Hilgendorf (1981)</td>
</tr>
<tr>
<td>Hyd</td>
<td>0</td>
<td>0</td>
<td></td>
<td>Engel (1973)</td>
</tr>
<tr>
<td>Lactase</td>
<td>+</td>
<td>+</td>
<td></td>
<td>Dariana et al. (1982)</td>
</tr>
<tr>
<td>Hyd</td>
<td>+</td>
<td></td>
<td></td>
<td>Antila et al. (1978)</td>
</tr>
</tbody>
</table>

**Legend:**

Hyd = Hydrolysed (The following comments refer to a comparison with the normal product):

0 = No significant differences reported
+ = Hydrolysed product better
Asp. = Aspartame

### Table 4

**Examples of uses for hydrolysed wheys and permeates**

<table>
<thead>
<tr>
<th>Use/Product</th>
<th>References</th>
</tr>
</thead>
<tbody>
<tr>
<td>Humectants</td>
<td>Anon, 1982</td>
</tr>
<tr>
<td>Breads, cakes and biscuits</td>
<td></td>
</tr>
<tr>
<td>Confectioneries, sweeteners</td>
<td></td>
</tr>
<tr>
<td>Fermentation feedstock, beer production and animal feeds</td>
<td>Brulé 1981; Heyneman and Hoyrigan 1981; Rydar 1988; Cetan 1980</td>
</tr>
<tr>
<td>Cheese</td>
<td>(Thompson and Brower 1976; Thakar et al. 1987; Gyorics and Thompson 1976; Anon 1977)</td>
</tr>
</tbody>
</table>
Market advantage may also be gained if the LH product is part of a blended product (Morris, 1985).

Other opportunities may include reduction in taxes or tariffs paid on ingredients. There have been cases where it has been advantageous to replace sucrose in flavoured milks with a dairy-based sweetener. Such opportunities need to be carefully investigated together with the regulatory restrictions that might apply to the use of LH products.

Conclusion
Of the many possible uses for LH products most relate to the increased sweetness. In America and the United Kingdom corn starch syrups are commonly used as sweeteners, but in Australia LH products would be competing with sucrose from cane sugar. The likelihood of successful competition depends on many factors, of which price has major importance. However if LH products confer cost as well as functional and nutritional advantages then profitable returns for LH manufacturers appear possible.

References


Food Research Quarterly Volume 51 Nos. 1 & 2, 1981
solids and cane sugar in ice cream with lactose hydrolysed sweet whey solids. *Journal of Food Science, 45*; 129-33.


New Cheese Products As Food Ingredients

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Highett, Victoria, 3190

Introduction
Cheese may almost be described as the boom product of the dairy scene, enjoying great popularity. It has an excellent image, being perceived as healthy, natural and nutritious.

Increasingly cheese is being appreciated by consumers for the great interest and variety it adds to the eating experience. Textures range from smooth and creamy to hard and crumbly; flavours from subtle to robust and tastes from mild to piquant.

Cheese consumption is still rising in Australia after two decades of steady growth. In the last year, domestic sales of both Australian and imported cheese varieties rose by 6%, the increase coming principally in the non-cheddar and lowfat categories (Australian Dairy Corporation, 1989).

How is cheese being consumed?
Of the 126,600 tonnes of cheese sold in 1989 on the domestic market, 88,200 tonnes went to the retail sector, mostly in portion packs for table use or for food preparation in the home. Approximately 30% of this amount was processed cheese, mainly in the form of individually wrapped or stacked slices. The remaining 38,400 tonnes went to the industry and food service sectors which are growing in importance as outlets for cheese, reflecting greater consumption of pre-prepared meals and convenience foods, and a trend towards more meals being eaten away from home (Australian Dairy Corporation, 1990).

Cheese is thus an important dairy ingredient which has the potential to add sales appeal to many food categories. These include:
- Processed cheeses
- Cheese dips and spreads
- Bakery goods
- Snack foods
- Canned foods

What does cheese offer the industrial user?
Firstly, cheese may be used simply as a source of dairy fat and protein. However, good quality cheese is a fairly expensive way to buy fat and protein. In past years there have, at times, been significant quantities of downgraded cheese, but the amount of low-priced cheese available to reprocessors and other industrial users is presently quite limited, and it will probably become very small in future as modern methods of total quality management take effect.

Secondly, cheese may be the ingredient of choice in order to provide the structural matrix of the prepared food. This is an important function which is brought to all the processed cheese products, as well as to dips, spreads, cheesecakes and other foods containing cheese. For some of these products it may be desirable for the cheese protein to be substantially intact, whereas in others, a significant degree of proteolysis may be required. Some product formulations dictate that the fat and protein of the cheese are present in proportions quite different from those normally found in cows’ milk. Satisfying these special requirements can add significantly to the cost of cheese as an ingredient.

Thirdly, cheese offers the food processor a source of flav-
our and taste sensations which can withstand the rigours of processing treatments and give much consumer appeal to the finished product.

Cheese therefore is a convenient and readily marketed food ingredient. However, cheese is an expensive ingredient; it is not shelf-stable; and it may be a somewhat variable ingredient.

Therefore I wish to discuss two relatively new 'cheese' products which may be used in the food processing sector and the cheese processing industry to provide the desirable attributes of cheese with fewer of the drawbacks.

**Enzyme Modified Cheese (EMC)**

One of the factors which adds to the cost of cheese as an ingredient is the time required for the cheese to develop typical flavour. For some varieties this may be greater than one year. Cheese maturation also carries an element of risk that undesirable flavours may develop. Furthermore, for some cheese types, a large quantity of cheese is needed to impart sufficient of a cheese note to the finished food product. The use of enzyme treatment technology to produce controlled, intense cheese flavour concentrates is a comparatively modern innovation which overcomes some of the problems of cheese as a food ingredient.

The impetus for the development may have come partly from the pioneering work of Kristoffersen, Mikolajiec and Gould (1967). They suggested that cheese-curd slurries, incubated under conditions which favoured rapid proteolysis and lipolysis, may provide the flavour component for processed cheese manufacture in a cheaper and more reliable way than afforded by the use of matured natural cheese. Sutherland (1975) extended the work to produce a range of rapidly ripened slurries and demonstrated the potential for positive control over the course of flavour production. These slurries were made from unpresseed salted cheddar cheese curd which was macerated with added water and salt to give a finely ground slurry with 40% total solids and 3.2% salt. The slurries were incubated at 25°C as prepared or after addition of rennet, glutathione, a lipolytic enzyme or provision of additional headspace oxygen. Flavour development proceeded differently in each of the slurry preparations, yielding rather intense flavours, some of which were like blue cheese, Italian cheese or unbalanced cheddar. The ripened slurries were used for manufacture of processed cheddar cheese and were found to give most acceptable products when used in combinations of three types at a total addition rate of 10-20% of the processed cheese blend.

Later work by Jameson and Shanley (unpublished) showed that this slurry technique was not sufficiently reliable to be applied directly in industrial practice. However, this basic idea has been taken up by commercial suppliers of enzymes to the dairy industry who have developed proprietary processes for rapid, controlled development of highly flavoured slurries through controlled enzyme curing.

Developments in EMC technology have recently been reviewed by Moskowitz and Noelck (1987) and a considerable amount of utilisation information is available from the present suppliers of enzyme preparations to the dairy/food industry.

EMCs are available with flavours claimed to provide the essential notes of Cheddar (mild to mature), romano, provolone, parmesan, Swiss, gouda/edam, blue cheese and others. The EMCs may be supplied in a cheese-like form or as heavy pastes which are stable under refrigeration for at least six months. Some EMCs are available in powder form which makes them well suited to the bakery and snack food industry. EMCs are more intensely flavoured than the cheese which they replace and so the level of incorporation is correspondingly lower. For example, liquid types of Dariteen cheddar cheese flavours (Miles Laboratories Inc., Elkhart, IN, USA) are claimed to have from five times to twenty-five times the cheese flavour of quality cheddar cheese and spray-dried types are claimed to have an eight-fold concentration.

A wide range of cheese-like flavours for food formulation are available from dairy supply companies and food flavour suppliers, some of which are synthetic mixtures but some are 'natural' products, being the result of enzyme treatment of natural substrates such as lipids (of animal or vegetable origin), protein-lipid or protein-lipid-carbohydrate mixtures. These products are considered outside the scope of this review but readers are referred to the review of Kilara (1985).
Over the last ten years or so there has been much research carried out on the use of enzymes to reduce the ripening time of natural cheeses. This work does not seem to have led to any 'new' cheese products at this stage, being more concerned with maintaining trueness-to-type of the cheese variety under study. For reviews of this field see Law (1978) and the reports of the International Dairy Federation Expert Group (IDF, 1983, 1987, 1990).

Utilisation of EMCS

Commercial enzyme modified cheese have a flavour profile which may be quite different from a table cheese and yet, on dilution with a suitable bland or nearly bland base, do provide the cheesey note which is desired in the end product.

The principal usage of EMC is understood to be in the processed cheese industry as a substitute for some or all of the expensive matured cheese component of the blends. As early as 1974 in the USA, EMC became a legally approved optional ingredient for manufacture of processed cheese (40% moisture max., 50% FDM [fat in dry matter] min.), processed cheese food (45% moisture, 45% FDM) and processed cheese spreads. EMC is also used as the flavour source in manufacture of imitation cheese products, a product range with a small but significant niche in the US market.

Other typical applications of EMCS include cheese sauces, spaghetti sauces, soups and dips which require a stronger cheese flavour. As a flavour booster, the inclusion of 1-5% of EMC can increase the total cheese flavour of a formulated food without adding greatly to the cost. A typical recipe for cheese sauce using EMC as 50% replacer for cheddar cheese is shown in Table 1.

### Cheesebase

Cheesebase is the generic name for a comparatively new range of cheese products developed specifically as food ingredients and coming from the research activities of the CSIRO Dairy Research Laboratory. The early phase of the research was conducted in collaboration with Professor Tony Ernstrom of Utah State University (Ernstrom, Sutherland and Jameson, 1980) and further development to pilot and commercial scale took place in collaboration with Schreiber Foods Inc. (SFI) of the USA. The process is protected by patents in all major cheese processing countries.

The cheesebase process has been in operation on a large commercial scale (22,000 tonnes per year) at Tempe, Arizona for just over five years and a substantial body of experience now exists with respect to both manufacture and utilisation. The process is now available for licensing to local manufacturers.

While the EMC was developed as a low-cost replacer for the mature cheese component of processed cheese foods, the cheesebase range was developed as a replacer for the mild or young cheese component. The young cheese in

<table>
<thead>
<tr>
<th>Ingredients</th>
<th>Control %</th>
<th>Plus EMC %</th>
</tr>
</thead>
<tbody>
<tr>
<td>Milk</td>
<td>52.30</td>
<td>60.30</td>
</tr>
<tr>
<td>Mild Cheddar Cheese</td>
<td>28.00</td>
<td>14.20</td>
</tr>
<tr>
<td>Water</td>
<td>6.90</td>
<td>9.90</td>
</tr>
<tr>
<td>Margarine</td>
<td>7.20</td>
<td>7.20</td>
</tr>
<tr>
<td>Flour</td>
<td>3.00</td>
<td>5.00</td>
</tr>
<tr>
<td>EMC*</td>
<td>-</td>
<td>2.80</td>
</tr>
<tr>
<td>Salt</td>
<td>0.50</td>
<td>0.50</td>
</tr>
<tr>
<td>Mustard</td>
<td>0.05</td>
<td>0.05</td>
</tr>
<tr>
<td>Cayenne Pepper</td>
<td>0.05</td>
<td>0.05</td>
</tr>
<tr>
<td><strong>100.00%</strong></td>
<td></td>
<td><strong>100.00%</strong></td>
</tr>
</tbody>
</table>

* Derived from Miles Technical Bulletin L-406-4

* Miles Daniteen NCF 130 - 60% of the mild Cheddar has been replaced by EMC on a ratio of one part EMC to five parts cheese.
processed cheese blends is needed to provide the structural matrix and much of the nutritional value of the finished products.

**Manufacture of Cheesebase**

Cheesebase products are manufactured using a combination of membrane filtration, fermentation and high-viscosity evaporation. A typical flow sheet for a cheddar cheese replacer is shown in Figure 1.

The raw material for cheesebase is standardised milk, with the fat/protein ratio adjusted to give any desired FDM content in the finished product. The milk is pasteurised on the way to a continuous ultrafiltration plant where it is concentrated from 4.5- to 6-fold (total solids in the range 30-45%). As the concentration proceeds, the lactose/protein ratio of the concentrate is continuously regulated by controlled addition of water to selected stages of the ultrafiltration plant. In this way the pH of the concentrate after fermentation of the lactose can be accurately controlled.

Starter cultures are added to the milk concentrate (retentate) and fermentation proceeds to complete utilisation of the lactose in 12-16 hours. Normally such retentates would undergo an acid coagulation at pH values below about 5.3 but this is prevented by adjustment of the ionic strength, preferably using common salt.

The moisture content of the fermented retentate is then reduced to any desired level (but commonly in the range 35-40%) in a specially engineered swept-surface vacuum evaporator.

---

**Table 2.**

Comparative Retention of Milk Solids - Cheddar Cheese and Cheesebase

<table>
<thead>
<tr>
<th>Component of Milk</th>
<th>Cheddar Cheese</th>
<th>Cheesebase</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fat</td>
<td>89</td>
<td>100</td>
</tr>
<tr>
<td>Protein</td>
<td>77</td>
<td>98-99</td>
</tr>
<tr>
<td>Total Solids</td>
<td>51</td>
<td>60</td>
</tr>
</tbody>
</table>
ator. The high viscosity product is pumped from the evaporator to a packing station where it may be formed into blocks or filled into drums for long-term storage. Alternatively, the cheesebase may be pumped directly to a processed cheese manufacture line for immediate use. On cooling, the cheesebase becomes practically solid and can be stored and handled in the same manner as conventional cheese.

A feature of the process is the ability to vary the functional properties of the cheesebase products by a controlled heat treatment following fermentation and before evaporation. For example, it is possible to produce cheesebases which will yield processed cheese with high or low remelting properties, a significant factor in acceptability of cheese supplied to major fast-food outlets.

The cheesebase process is one of the highest yielding cheesemaking methods in terms of fat and protein recovery (Table 2). Lactose is the only major milk component which is lost during the process, and the yield advantage over conventional cheddar manufacture is in the range 16-18%.

Composition of cheesebase

By varying the fat/protein ratio of the milk and the production parameters it is theoretically possible to manufacture cheesebase with the composition of practically any known, or imaginable, cheese type. Experience has been gained at commercial scale with a modest range of compositions, e.g. total solids from 32% to 45% and FDM from 45% to 58%. At pilot scale, considerable work has been done to expand the proven range of compositions with FDM levels as low as 5%, total solids in the range 27% to 55% and pH values in the range 4.4 to 5.4. Reduced mineral content cheesebase has also been produced by acidification of the milk prior to ultrafiltration. US research (Anis and Enstrom, 1984) suggests that the reduction of calcium content may yield a cheesebase with improved functionality for the production of processed cheese with a high re-melt capacity.

Cheesebase variants

Cheesebase may be produced with an increased content of undenatured whey proteins by incorporation of a liquid whey-protein concentrate. This yields a cheese with the capacity to undergo heat gelation.

Cheesebase, in standard form, is a storage stable product since the enzymes normally responsible for cheese maturation are inactivated by the heat treatment which follows fermentation. However by reducing the severity of heating during evaporation, or by re-inoculation after evaporation, it is possible to have a cheesebase variant with potential for protein and lipid breakdown and associated flavour formation.

Properties of cheesebase

Cheesebase, in its standard form, lacks the body and texture of conventional cheese. Although it appears solid at temperatures below 15°C it is actually a very high viscosity paste which can be readily redispersed in water to a consistency similar to milk. It has a mild lactic flavour and a pleasant smooth creamy mouthfeel.

Cheesebase is a stable form of young cheese solids with the same functional properties in cheese processing as young cheese. Stability in storage of high pre-heat cheesebase has been demonstrated, with the product still acting as young cheese after more than 12 months storage at refrigerator temperatures. This attribute may prove most useful as a means of overcoming the problem of lack of young cheese during the Australian seasonal periods of little or no cheese production.

With its low flavour, lack of a yield point under compression and its tendency to 'dissolve' in the mouth, cheesebase is unlikely to be a consumer product in its own right. Nevertheless, because of the relative simplicity of the process, the excellent composition control and the favourable economics offered by cheesebase manufacture, there is a considerable incentive to work towards a new family of dairy-based cheese products by such technology. Since the casein in cheesebase is still intact it should be possible to induce structure formation by mechanisms known to generate a protein matrix in other products, e.g. by the rennet reaction. Preliminary research is underway in this area.

Conclusion

In an address to a meeting at the Australian Society of Dairy Technology as long ago as 1976 (Sutherland, 1976), it was proposed that processed cheese products of the future might be made by a combination of a
high-yield base material and cheese flavour concentrates. The technology to manufacture these new ingredients is now available for the enterprising food processor to use in creating profitable new foods.

References


Fermented Dairy Products as Food Ingredients

by Allan Main
New Zealand Dairy Board, Wellington, New Zealand

Introduction
The scope of this topic is too extensive to enable an in-depth review of the total subject. I propose to focus on the market and application aspects of the topic. In particular, this paper will attempt to use the historical context to project a scenario for future development of cultured milk products as food ingredients.

It is proposed that there have been four stages to the adoption of fermented milk products as ingredients in food production. These are presented in Table 1. The four phases represent an evolution of technology reacting to market needs. Each will be dealt with in turn.

Traditional Fermented Dairy Products in Foods
Fermentation of milk to produce different foods, pre-dates history. Traditional fermented dairy products, such as yoghurt, cheese, sour cream and innumerable local variants, were the product of harnessing the coincidental fermentation that occurred on storing milk.

With time and experience, the art was mastered and progressively became science, though old hand cheese makers may like to dispute the level of science.

These traditional fermented dairy foods were naturally used as ingredients in home cooking in regions where they were endemic. As food manufacture moved to cottage industry, and ultimately full industrial status, the use of traditional fermented milk products in food processing was a natural consequence of their domestic use.

Today a wide range of food products taken home from the supermarket feature traditional fermented dairy foods in their ingredients lists. Some examples of these are given in Table 2.

The role of these ingredients in the formulation relates principally to flavour and texture, although secondary functionalities (e.g. microbial control) are occasionally important. Nevertheless such uses of fermented dairy products are mere extensions of the domestic use of these ingredients.

Form-Modified Fermented Dairy Ingredients
The dairy industry, responding to needs of the broader food processing industry, has developed more convenient forms of traditional fermented milk products, enabling wider use of these as ingredients. Foremost among these are spray-dried powders. Products like cheese powders, yoghurt powder and sour cream powder have entered the ingredient trade as a consequence. A point recognised by the industry, but frequently not by intending users of these ingredients, is that they do not re-hydrate with any of the physical or textural properties typical of their feedstock. Their practical contribution is primarily flavour.

The introduction of these ingredients had two consequences for food manufacturers. Firstly, they have simplified the manufacturing process for some food products based on traditional fermented dairy ingredients. This is a consequence of replacing unstable, biologically active ingredients with dry powders, stable for many months. This has obvi-
**Table 1.**

**Historical phases in fermented dairy products as food ingredients**

<table>
<thead>
<tr>
<th>PHASE</th>
<th>DESCRIPTION</th>
<th>TYPIFIED BY</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>TRADITIONAL FERMENTED DAIRY PRODUCTS</td>
<td>USE OF TRADITIONAL FERMENTED DAIRY FOODS (EG CHEESE, YOGHURT) IN FOOD MANUFACTURE.</td>
</tr>
<tr>
<td>2</td>
<td>FORM-MODIFIED FERMENTED DAIRY INGREDIENTS</td>
<td>TRADITIONAL FERMENTED DAIRY INGREDIENTS IN MORE STABLE/CONVENIENT FORM (EG SPRAY DRIED)</td>
</tr>
<tr>
<td>3</td>
<td>FLAVOUR-MODIFIED FERMENTED DAIRY INGREDIENTS</td>
<td>FLAVOUR INCREASED TO ENABLE LOWER USE RATE, USUALLY THROUGH BIOTECHNOLOGY (EG ENZYME MODIFIED CHEESE)</td>
</tr>
<tr>
<td>4</td>
<td>FUNCTIONALLY ENGINEERED FERMENTED INGREDIENTS</td>
<td>TOTALLY NEW PERFORMANCE ATTRIBUTES THROUGH FERMENTING DAIRY SUBSTRATE WITH NON-TRADITIONAL ORGANISMS</td>
</tr>
</tbody>
</table>

**Table 2.**

**Traditional fermented milk products as ingredients in processed foods.**

<table>
<thead>
<tr>
<th>INGREDIENTS</th>
<th>FOODS USED IN</th>
</tr>
</thead>
<tbody>
<tr>
<td>HARD CHEESES</td>
<td>PIZZAS, CHEESE SAUCES, BREAD TOPPING, SAUSAGES, PASTA DISHES, MICROWAVE MEALS</td>
</tr>
<tr>
<td>SOFT CHEESES</td>
<td>CHEESECAKES, FLANS, CHILLED DESSERTS.</td>
</tr>
<tr>
<td>YOGHURT</td>
<td>SALAD DRESSINGS, FROZEN YOGHURT, ETHNIC FOODS (ESPECIALLY INDIAN), CHILLED DESSERTS.</td>
</tr>
<tr>
<td>SOUR CREAM</td>
<td>DIPS, BAKERY PRODUCTS, CHILLED DESSERTS.</td>
</tr>
</tbody>
</table>

Significant as these gains are, they are over-shadowed by the second consequence of the development of powdered, fermented dairy ingredients. This is the development of totally new consumer products which could not exist without the dried form of the fermented milk products. Examples are cheese-flavoured extruded snacks, powdered sour cream dip mix and yoghurt-coated confectionery.
The manufacture of dried, fermented dairy products is amply detailed in the literature (Société Laitière, 1969; Avleson et al., 1979; Noznick et al., 1974.) and little purpose would be achieved in outlining these here. It is notable however that manufacturers are increasingly taking account of the functional demands of such ingredients in specific food systems and optimising these in ingredients tailored to the final application. This approach is enabled by the greater understanding of how manufacturing conditions impact on functional properties of the resulting powder and accelerated by customers who appreciate the value of reliable performance within their process. As a consequence, today's reputable suppliers are likely to offer a range of (say) cheese powders formulated to tight performance specifications rather than using the food ingredient market as the means to dispose of fermented dairy products that failed to meet standards required for direct sale.

Table 3 provides an example of how desirable properties for yoghurt powder differ between two major applications and indeed cannot be optimised for both applications in one product. The fact that one system has a continuous fat phase in which particles are suspended and the other is primarily an aqueous product, determines the essential performance needs.

### Flavour Modified Fermented Dairy Ingredients

Recognising that the critical determinant in using a fermented dairy ingredient is its flavour contribution led to the development of flavour-modified dairy ingredients. The primary application of this is enzyme modified cheese (EMC) manufacture. By exposing the cheese to carefully selected enzymes under well controlled conditions, the flavour contribution can be increased dramatically. Claims as high as 50 times the flavour of cheese have been made, but levels between 5 times and 25 times are more reasonable (Moskowitz et al., 1987).

The manufacture of enzyme modified cheese is achieved by enzyme addition at almost any point in the cheese manufacturing process. The resultant product may have a texture similar to that of the cheese it is derived from, or if extensive hydrolysis is encouraged, it may be in paste form. Selection of the extent of flavour development is determined by balancing the contrary aspects of flavour strength (and type) against the loss of texture. The flavour profiles developed in enzyme modified

<table>
<thead>
<tr>
<th>APPLICATION</th>
<th>IMPORTANT ATTRIBUTE</th>
<th>UNIMPORTANT ATTRIBUTE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Confectionery Coatings</td>
<td>Low Lipase Activity</td>
<td>Solubility</td>
</tr>
<tr>
<td></td>
<td>Even Particle Size</td>
<td>Dispersibility</td>
</tr>
<tr>
<td></td>
<td>Flavour</td>
<td>Viable Culture</td>
</tr>
<tr>
<td></td>
<td>Small Particle Size</td>
<td></td>
</tr>
<tr>
<td>Soft Serve</td>
<td>Solubility</td>
<td>Lipase Activity</td>
</tr>
<tr>
<td></td>
<td>Viable Culture</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Dispersibility</td>
<td></td>
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<tr>
<td></td>
<td>Flavour</td>
<td></td>
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</tbody>
</table>

*Table 3.
Desirable attributes for yoghurt powders in two applications.*

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cheese are not totally representative of the flavour complexity of traditional cheese but show heightened flavour notes of some aspects of the cheese flavour. For this reason they are generally used as extenders or enhancers for natural or powdered cheese in processed food products such as sauces or snack sprinkles.

The primary benefit of EMC products is economy. The process used allows the production of a product with typically ten times the flavour of the equivalent natural cheese, but in considerably less time than it takes to produce a fully matured cheese. Thus the production economics favour EMC, yielding substantial savings to the users where the application enables its use. Typical usage rates of EMC are in the range of 0.1% to 2.0% of finished food.

Similar flavour effects are to be had by enzyme treating butter fat. Whilst not strictly a fermented dairy product (unless of course lactic butter is the substrate!) enzyme modified milkfat is so closely allied to enzyme modified cheese in its biotechnology and marketing that it ought to be dealt with at the same time.

In both cases the intent is to mimic the biochemistry of flavour development that occurs more slowly in a microbial fermentation and to drive the reaction beyond where it would normally stop. In so doing greater concentrations of the flavour compounds are produced.

By exposing butteroil emulsions to lipase from microbial, fungal or animal sources increased ‘buttery’ or ‘creamy’ notes are observed. The flavour concentrate made in this way is heat deactivated and used either in the oil form or in a spray dried powder. Commercial products of this type are used in chocolate, sugar confectionery, popcorn, cooking oils and baked goods to give enhanced dairy notes (Dziezak, 1986).

Functionally Engineered Fermented Daily Products

Whey, the by-product of cheese or casein manufacture, has long been used as the substrate for fermentations for producing food and non-food chemicals. Ethanol and lactic acid have been extensively commercialised, but more exotic materials such as carotene (Friend et al., 1988) and microbial oil have been suggested. However these technologies do not, of necessity, require dairy substrates. Nor does the dairy content carry through to the finished product due to purification steps designed to isolate the desired chemical in its purest form.

A more creative approach has been patented, yielding ingredients which (at least in the USA) can be declared as ‘cultured whey’ or ‘cultured non-fat milk solids’ yet contain functional chemicals as a consequence of a microbial fermentation. Two examples can be taken here, both recently commercially marketed in the USA and elsewhere.

In the first case an antimycotic agent, propionate, is produced by fermenting sweet whey to lactic acid and in turn to propionic acid using appropriate bacteria (Ahern et al., 1987). The resultant broth is dried as is (i.e. without extraction or purification of the propionate) allowing the description ‘cultured whey’. When used in baked goods at 0.5% to 3.5% of the flour weight to replace milk solids, shelf life is extended by the anti-mycotic effect.

In the second example, whey is fermented with a specified strain of Xanthomonas campestris in order to produce a thickening polymer, xanthan (Schwartz et al., 1984). Again, the total product is dried without purification and the resultant powder used as a food ingredient. Functions of texture improvement and creamy mouthfeel are the major claims for the product, which is recommended for cupcakes, puddings, mousses, soups, sauces and gravies (National Starch, 1989).

An allied product based on the same fermentation, but using skimmilk as the substrate is recommended for ice cream where emulsification and stabilisation are the objectives (Stauffer, 1986).

In each of these cases the raison d’être for the fermented dairy ingredient is pursuit of a ‘clean’, that is additive-free, label through providing the functional performance of propionate or xanthan while only labelling ‘cultured milk solids’ or a similarly friendly declaration. Time alone will determine if this approach is seen as serving the consumer interest, but should it continue to be condoned, further functional additives might be expected to be developed by similar technologies.
Prospects for Fermented Dairy Ingredients in Foods

The current mood of the consumer market is favouring the use of fermented dairy products as food ingredients. As these products, and most notably yoghurt, have moved into the mainstream of western food habits, and are seen as 'healthy' rather than 'health' food there is a proliferation of new food products which capitalise on this consumer demand for variants based on these healthy ingredients. A recent issue of a new product monitoring service in the United States recorded 19 new product releases in August 1990, which obviously used a fermented dairy food as an ingredient (Friedman, 1990).

Frozen yoghurt has been the success story of 1990 in the United States. While the product sold now bears little relationship to the early, fully cultured versions which had limited success, the proliferation of frozen yoghurt launches in 1990 confirms the mainstream acceptance of cultured milk-based new food concepts.

The market conditions which have lead to the situation can only continue and are summarised in Table 4. It is fair to say that these market forces are consistent through all developed regions of the world in markets as diverse as Japan, Europe and America. This situation will ensure the growth in opportunities for the first three groups of fermented milk ingredients outlined in this paper. Indeed, there will probably be new opportunities for niche ingredients such as acidophilus milk or kefir-based ingredients as the consumer continues to pursue new interests.

What is less clear though, is what direction the fourth group, the functionally engineered fermented dairy products will take in the future. At this point they appear to exploit a regulation loophole which could be closed at a stroke of a pen. This will not be determined in any way by the technology, but by political and moral judgement. Should these products' continued existence be supported by the regulators then products of this type will proliferate. In that environment it is likely that fermentation yielding products of every functionality of food interest will appear. Colours, antioxidants and emulsifiers will appear by this route and the current limited range of stabilisers and preservatives will be added to. There are indications from the scientific literature that this is already an active area of research.

Conclusions

In this paper the historical use of fermented dairy products as food ingredients has been reviewed. Use of fermented dairy products in this way is showing increasing momentum and it is expected that this trend will continue. The future can only be bright for food ingredients manufactured by the fermentation of dairy substrates.

Table 4.

<table>
<thead>
<tr>
<th>Market Force</th>
<th>Examples</th>
</tr>
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<tbody>
<tr>
<td>Broadening interest in 'Healthy foods'</td>
<td>Biologically active foods</td>
</tr>
<tr>
<td></td>
<td>Reduced fats will flavour</td>
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<tr>
<td></td>
<td>Yoghurt</td>
</tr>
<tr>
<td>Increasing internationalisation of food tastes</td>
<td>Ethnic foods</td>
</tr>
<tr>
<td></td>
<td>Exotic 'new' flavours</td>
</tr>
<tr>
<td>Continuing interest in 'Clean' ingredient labels</td>
<td>Minimum number of additives</td>
</tr>
<tr>
<td></td>
<td>Positive image ingredients</td>
</tr>
<tr>
<td></td>
<td>Favoured</td>
</tr>
</tbody>
</table>

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The technology of hydrolysis of milk proteins is gaining in importance with the recognition that technological modification to proteins can assist the human digestive process. The reasons why a consumer might prefer a hydrolysed protein are various. One group of potential customers consists of those who are concerned with rapid and efficient nutrition, such as sports minded people, and those who are concerned with healthy foods. A more challenging group of consumers are those whose ability to utilise proteins is in some way compromised. In recent years foods which are ‘hypo-allergenic’, particularly those targeted for infants, and foods which are designed for recovery of patients after hospitalisation have been developed and are now being commercialised. These product developments coincide with, and are dependent upon, an understanding of the technology and science of enzymology, the commercial availability of adequately pure enzymes and an understanding of the nutritive impact of protein hydrolysates.

The technology of manufacture of hydrolysed milk proteins appears at first sight to be simple. An enzyme is added to a protein suspension, acts for a while, then is inactivated. The idea is simple but the control of the hydrolysis process in order to obtain repeatedly a precisely defined product can require very sophisticated scientific support. The issues that must be resolved in designing a process include the following:

a) The selection of a raw material
Firstly, the amino acid profile of the final product may be important in a dietary food ingredient. If so, milk proteins are commonly very satisfactory when compared with vegetable proteins.

However, this comparative advantage may not be significant in practice because a manufacturer of hydrolysed protein can add selected amino acids to the ‘soup’ of peptides which, in its final form, can no longer be distinguished as having the properties of any particular native protein.

Secondly, and perhaps more importantly, the original protein will create characteristic flavours after hydrolysis. Some proteins give rise to flavours described as ‘yeasty’, ‘brothy’, ‘astringent’, and, very significantly for milk proteins, ‘bitter’. Casein creates a specially difficult flavour profile because the end peptide of beta-casein, which is quickly released, is intensely bitter. For example, the peptide Arg-Gly-Pro-Pro-Phe-Ile-Val is 20 times more bitter than caffeine. In some foods, bitterness is acceptable, but this is seldom true in foods where hydrolysates are used as ingredients. Technological means to reduce bitterness are available, but are of limited utility (Roy, 1990). Whey proteins tend to be the dairy raw material of choice as a consequence.

b) The Nature Of The Final Product
Those products that will be used for general nutritive purposes can be designed to have a broad range of peptides with a variety of molecular weights. They are comparatively easy to manufacture.
Other products that are designed for convalescent patients usually contain a high proportion of di-peptides and tri-peptides. This requires a thorough hydrolysis which may require a high level of enzyme addition and a long period of reaction. Both of those factors will push up the cost.

Perhaps the most challenging end use is the preparation of a product which will avoid allergic response. This is particularly important in foods designed for infants.

Allergic response is triggered in a number of ways. The mechanism of protein allergy is a response to protein fragments, known as epitopes, which are recognised as 'foreign', so that the immunological system of the body mounts a defence against them. Enzyme hydrolysis which will break up those epitopes will avoid the process of recognition. An extensively hydrolysed protein, with fragments less than six amino acids in length, will likely be safe. Longer peptides may, or may not, cause an allergic response, depending on the sensitivity of the individual. In either situation, hydrolysates need to be checked for clinical response and cannot simply be assumed to be non-allergenic.

At a truly critical level, a response from the intestine in which Immunoglobulin E(IgE) is involved may result in the bodily release of histamines and other reactive compounds initiating shock, which can be life threatening. Fortunately that response is rare, but the manufacturer of products that are labelled 'hypo-allergenic' must ensure that those products will not trigger the IgE response. Very carefully hydrolysed proteins have been defined for this market sector (Knights, 1985). Nutramigen and Pregestimil in the USA and Morinaga's MA1 in Japan are designed to meet these threats to health.

At a less critical level, the body may respond in a generalised way with symptoms developing slowly. It is more likely that the response of the body is Immunoglobulin G(IgG) mediated. These allergies are much more difficult to diagnose (Institute of Food Technology, 1985; Butkus and Mahan, 1986). Consequently, the estimates of incidence of allergy vary widely from 0.3% to 20% of adults. Less completely hydrolysed proteins may be adequately digestible to avoid, or ameliorate, such responses. Nestle's 'Beba HA' in Europe and Carnation's 'Good Start' in USA, are designed to meet the needs of infants with this level of problem.

Other products for sensitive individuals utilising hydrolysed protein are beginning to reach the market and can be expected to provide variable levels of effectiveness depending on the thoroughness of the hydrolysis and the sensitivity of the individual consumer. An alternative for the consumer is to not use milk protein at all. Soy-based formulae are widely available and do help some infants, but soy protein is more foreign to the human infant than cow's milk protein and allergic response to soy frequently occurs. Breast milk is preferable but it too can (though less frequently) carry allergens.

Not all sensitivities are protein related, so while protein hydrolysis will assist many infants, informed supervision of any dietary experimentation is desirable and the use of a protein hydrolysed infant food is not a sure method of avoiding a reaction.

Enzyme modification has also been used to alter the physical properties of a variety of proteins so that the functionality of those proteins in food or technical uses will be enhanced. (Kilara 1988). Modification of solubility, heat stability, pH stability, emulsifying properties, and foaming has been achieved.

c) Enzyme Selection & Process

A wide variety of enzymes, of varying levels of purity, are available. Some have broad specificity and are useful for initial hydrolysis of the total protein molecule. Others specifically hydrolyse individual bonds in the molecule and are useful for precisely controlling the length of the peptides produced. (Loffler, 1986; MAFF, 1982). Peptidases which hydrolyse only the end groups of peptides are offered by many suppliers. Both amino peptidases and carboxy peptidases are available and are claimed to reduce or to eliminate bitterness.

Details of the preparation of trypsin-hydrolysed whey proteins to produce an infant formula ingredient has been published (Pahud, et al., 1985) and the process patented (Jost, et al., 1988).

d) Measurement

The measurement of extent of hydrolysis of proteins can be readily achieved by chemical procedures, such as non-prot-
tein nitrogen, amino nitrogen and degree of hydrolysis. These measurements provide only a gross measure of the progress of hydrolysis and are more useful to control the process than to characterise the product. For hypo-allergenic applications it is necessary to ensure that no lengthy peptide remains which could precipitate an allergic response. Chemical test methods can not provide that level of assurance. Consequently, HPLC methods of determining the molecular weight profile have been developed. While these are helpful in characterising a hydrolysed protein product, they do not guarantee that an allergic reaction will not occur. Confirmation of the success of a hydrolysis requires either animal tests or clinical tests on humans.

Conclusion

If it is to be successfully used, the apparently simple technology of protein hydrolysis requires an intensive level of scientific support. The process conditions, once they have been selected, must be precisely observed in the manufacturing plant and characterisation of the end product must be precise. As an ingredient, a protein hydrolysate is not easily designed and a satisfactory product requires the closest of co-operation between the supplier and the customer.

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Microbiological Considerations in the Production of Dairy Ingredients

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Introduction

The commercial success of new processes developed for manufacture of food ingredients or to improve the efficiency of manufacture of existing products is dependent upon many factors. One factor that is often underestimated is the problem of proliferation of undesirable microbes in the new process. Each food process provides a unique set of circumstances that determines the type and number of microbes capable of proliferation. Proliferation of pathogens renders the food product unsafe for consumption, while proliferation of other non-pathogenic microbes may adversely affect product quality. Control of unwanted microbes in a new process may require:

- The application of new criteria in selecting raw materials.
- The development of new cleaning and sanitation programs to reduce initial contamination of equipment used in the process.
- Modification of the process in order to control proliferation of undesirable microbes during manufacture of each batch.

Since the effects of undesirable microbes may not become apparent in a new process until after commercial production has commenced, research and development in this area is often carried out under crisis conditions. This paper discusses two examples of the problem of proliferation of undesirable microbes in new dairy food processes. The first is in protein-rich whey powders and the second in a new cheddar cheese making process.

Protein-Rich Powders

In addition to the importance of proteins as structural components in many foods, proteins are also used as food ingredients because of their physico-chemical properties and nutritional value (Kinsella, 1976, 1982; Morr 1984). In the USA, 168,000 tonnes of whey powders are used annually as functional ingredients in foods, making whey proteins the major functional ingredient protein in human foods (Table 1).

The potential market for functional ingredient protein is expected to increase worldwide as the food industry increases the trend to formulation of new foods from basic ingredients. In order to satisfy this demand food processors require protein-rich ingredients with consistent functional properties that act in food systems in a reproducible manner.

Unrefined whey powders are used mostly as inexpensive filler ingredients, for example to increase the level of essential amino acids, whereas refined whey powders enriched in protein are marketed for their specific functional properties such as gelling, foaming and emulsifying activities. However, commercial protein-rich whey powders display a highly variable range of functional properties which has been attributed to differences in composition (Morr, 1979; Marshall, 1982; Melachouris, 1984; and Mathews, 1984), variation in the basic composition of the raw milk as influenced by stage of lactation (Morr, 1982), and the quality...
of the raw milk as influenced by mastitis and the growth of psychrotrophic bacteria (Schmidt et al., 1984).

Research in our laboratory has found high levels of thermophilic bacteria in some common preparations of protein-rich whey powders. The bacteria were shown to be predominantly species of *Bacillus* and *Enterococcus* (Dimopoulos, 1990; Solomon, 1990). The presence of thermophilic bacteria might be expected since the membrane processing to enrich for whey proteins is carried out at temperatures of 50°C or greater. Further research was therefore initiated to determine the significance of contaminating microbes in the variation in functional properties of commercial protein-rich whey powders.

The gel strength and foam stability of commercial protein-rich whey powders obtained from one manufacturer, containing 570 to 200,000 cfu of thermophiles per gram, were measured in simple model food systems. A log-log plot of the data showed an inverse straight-line relationship between both functional properties, gel strength and foam stability, and the concentration of thermophiles (Solomon, 1990). The observed relationship between lost functionality and the number of thermophiles suggests that the bacteria were capable of changing the structure of the whey proteins, which caused a degenerative effect on functionality. This conclusion highlights the importance of controlling these bacteria if protein-rich whey powders are to be used successfully by the food industry for their functional properties. Consistent functional properties can only be achieved if the number of thermophilic bacteria are kept at a consistently low level in the protein-rich whey powders.

The same species of thermophilic bacteria isolated from protein-rich whey powders have also been isolated from raw milk and from residues present on cleaned whey processing equipment (Dimopoulos and Hull, unpublished). This result indicates that the source of thermophilic bacteria in protein-rich whey powders originate from raw milk supplies and/or in-process contamination. Kinsella and Whitehead (1989) have pointed out the need for rapid reliable methods to monitor these organisms in the raw milk supply and in the manufacturing process.

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### Table 1.

<table>
<thead>
<tr>
<th>Ingredient Source</th>
<th>Estimated Market* (tonnes)</th>
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<tbody>
<tr>
<td>Milk</td>
<td>136,000</td>
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<tr>
<td>Whey</td>
<td>165,000</td>
</tr>
<tr>
<td>Egg</td>
<td>6,800</td>
</tr>
<tr>
<td>Meat</td>
<td>?</td>
</tr>
<tr>
<td>Fish</td>
<td>14,000</td>
</tr>
<tr>
<td>Cereals</td>
<td>145,000</td>
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<tr>
<td>Oilseeds</td>
<td>1,400</td>
</tr>
</tbody>
</table>

*Adapted from Kinsella and Whitehead, 1989.

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New Cheesemaking Processes

The introduction of new cheesemaking technologies has led to the continuous operation of cheese/milk pasteurisers and ultrafiltration (UF) plants for periods of up to 22 hours. Continuous operation of dairy food processing equipment allows microbes to multiply to high numbers with possible adverse effects on product quality. For example, Hup et al., (1979) reported off-flavours and excess openness in Gouda cheese caused by heat resistant streptococci originating from a pasteuriser that had been operated for an extended period of time without cleaning. A build-up of bacteria in pasteurised milk has been reported after 7-12 hours of continuous operation (Hup et al., 1979; Driessen and Bouman, 1979; Bouman et al., 1982).

Research in our laboratory in collaboration with a cheese manufacturer has shown that the total bacterial count of pasteurised cheese/milk can increase rapidly after 8-15 hours of continuous operation of a commercial cheese/milk pasteuriser. The increase is not observed in pasteurised milk sampled after the holding tube section, but is seen in pasteurised milk sampled after the regenerative section of the pasteuriser (Lehmann, 1990; Lehmann et al., 1990).

A miniwash of the pasteuriser after approximately 10 hours of operation, using a 15 minute cold water rinse, a 20 minute 1% caustic solution (70°C) wash and a 10 minute hot water rinse was found to prevent or delay the increase in total bacteria in pasteurised cheesemilk (Lehmann et al., 1990, Figure 3).

In UF cheesemaking pasteurised milk is fed to a UF plant to concentrate the milk prior to cheesemaking. The UF plant is usually operated at 50-55°C, conditions suited to the multiplication of thermophilic bacteria. The species of thermophilic bacteria most commonly isolated from pasteurised milk and UF concentrated cheesemilk were Bacillus species (Solomon and Lehmann, 1990). The source of these organisms was shown to be raw milk supplies (Russell and Lehmann, 1990) and that the two main sites for bacterial multiplication in cheese processing plant are the cheese/milk pasteuriser and the ultrafiltration plant (Lehmann, 1990).

Preliminary results of cheesemaking trials, in which thermophilic bacteria isolated from UF concentrated milk were added to UF concentrated cheesemilk, indicate that some can produce flavour defects in UF Cheddar cheese (Lehmann, Mayes and Hull, unpublished). In addition, UF concentrated milk containing high levels of thermoduric bacteria is unsuitable for the production of lactic starter culture. The spores of these organisms require very high temperatures to inactivate them and survivors have been shown to be capable of multiplication in lactic starter cultures. The finding that thermophilic and thermoduric bacteria can have adverse effects on new cheesemaking processes again points to an urgent need for rapid reliable methods to monitor these organisms in raw milk supplies and in the manufacturing process.

Acknowledgement

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