Review paper
Pregledni prispevek

DAIRY TECHNOLOGY ON THE TURN OF THE MILLENNIUM*

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Received January 20, 2000, accepted July 10, 2000.
Delo je prispelo 20. januarja 2000, sprejeto 10. julija 2000.

ABSTRACT

In general, the incentive for developing new technologies is determined by a) the need for increased product safety, economy and protection of the environment for existing products; b) the demand of consumers and the market for new dairy products and for foods containing milk ingredients. Membrane technology for separation and concentration of milk offers possibilities in the manufacture of existing consumer products such as cheese, liquid and fermented milk products as well as for the preparation of tailor-made products. One of the emerging technologies is the use of ultra-high-pressure because of its marked influence on milk proteins including enzymes, on lipids and on microorganisms. As this is a very costly technology, its application within the dairy industry may, therefore, be limited to special products. Despite the fact that the manufacturing process for all fermented dairy products includes biological operations, the introduction of new biotechnological methods to transform milk ingredients, the production of specific metabolites and continuous fermentation processes will increasingly gain importance in dairy plants. Energy saving in dairy industry will remain an important task for the technologists of the future. The milk industry is facing increasing product competition. Consequently, the intensive co-operation between industry and basic research is vital.

Key words: dairying / milk / milk products / technology

MLEKARSKA TEHNOLOGIJA NA PRELOMU TISOČLETJA†

IZVLEČEK

Razvoj novih tehnologij spodbujajo potrebe po vse večji varnosti izdelkov, gospodarnost proizvodnje in zaščita okolja na eni strani ter povpraševanje porabnikov in tržišča po novih mlečnih izdelkih in živilih, ki vsebujejo sestavine mleka, na drugi. Membranska tehnologija za ločevanje in koncentracijo sestavin mleka omogoča proizvodnjo že znanih, tradicionalnih mlečnih izdelkov, kot so sir, tekoči in fermentirani mlečni izdelki, poleg tega pa tudi proizvodnjo posebnih, "po meri narejenih" izdelkov. Ena od prihajajočih tehnologij je uporaba ultra visokih pritiskov, ki je zanimiva zaradi značilnega vpliva na beljakovine mleka, vključno z encimi, na lipide in mikroorganizme. Tehnologija je zelo draga, zato bo njena uporaba v mlekarski industriji najverjetneje omejena predvsem na izdelavo izdelkov s posebnimi lastnostmi. Kljub dejstvu, da so v vseh proizvodnih procesih fermentiranih mlečnih izdelkov vključene biološke operacije, pa v mlekarskih obratih vse bolj pridobivajo na pomenu nove biotehnološke metode v predelavi mleka, ki omogočajo neprekinjene fermentacijske postopke in proizvodnjo izdelkov z natančno

* The paper was presented on the 2nd Slovenian congress with international participation Milk and Dairy Products, Portorož, November 14-16, 1999.

† Prispevek je bil podan na 2. slovenskem kongresu z mednarodno udeležbo Mleko in mlečni izdelki, Portorož, 14.-16. november, 1999.

določenimi lastnostmi. Razvoj energetsko varčnih tehnologij bo tudi v prihodnje pomembna naloga tehnologov, zaposlenih v mlekarski industriji. Mlekarska industrija se srečuje z vedno večjo konkurenco, zato je tesno sodelovanje med industrijo in ustanovami, ki se ukvarjajo s temeljnimi raziskavami, nujno potrebno.
Ključne besede: mlekarstvo / mleko / mlečni izdelki / tehnologija

INTRODUCTION

In general, several years are necessary for new technologies to become successful in commercial performance. Most of the technologies that will shape the dairy industry in 10 or 15 years are already known now. The driving force for the development of new technologies is determined

- by the need of increased product safety, economy and the demand for protection of the environment for existing products,
- by the demand of consumers and the market for new dairy products and by incorporating milk ingredients with special functionality in other foods.

Consequently, national and/or regional boundaries become increasingly redundant by this development which is particularly favoured by today's globalisation.

I will now turn to selected developments in dairy technology, technologies which are established in modern dairy industry but offer significant chances for further development to obtain new products for either direct consumption or as functional ingredients.

MEMBRANE TECHNOLOGY

Despite the fact that membrane filtration has been applied in the dairy industry for almost 30 years, developments in the last 10 years offer immense possibilities for new products, either for direct consumption or specific use in many areas of milk processing. I would particularly like to mention the application of microfiltration to remove microorganisms from milk and the use of different membranes in separating milk ingredients from milk and whey. As introductory explanation, I would like to show various possibilities for obtaining milk ingredients with the existing membranes.

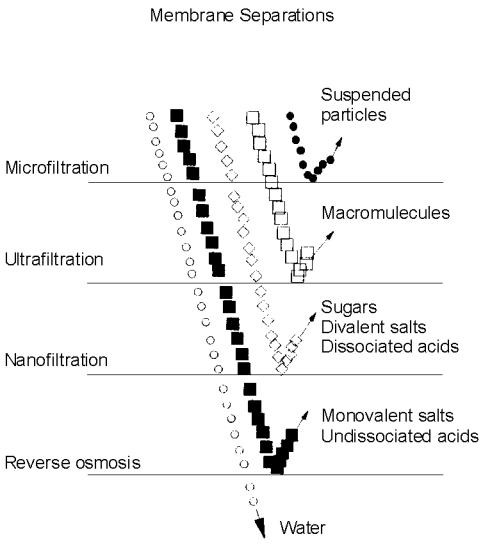

Figure 1. Pressure driven membrane processes and their separation characteristics (Cherian, 1998).

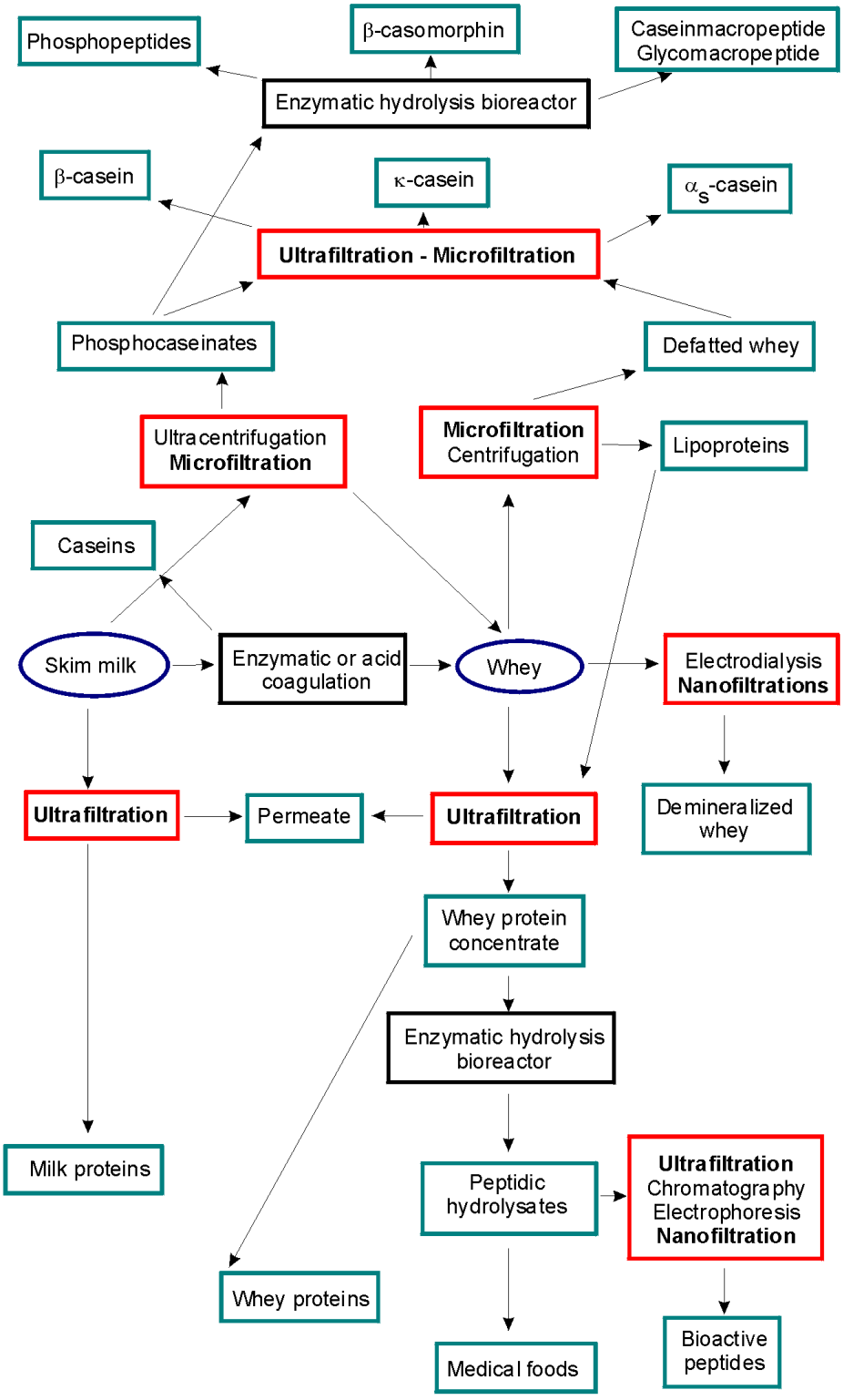

Figure 2. Revised scheme of products obtained by membrane separation of milk and whey (Maubois, 1999, modified).

Maubois, the pioneer of membrane filtration technology and best known scientist in this field, recently published an overview showing the possibilities with different types of membranes,

particularly for separating functional milk proteins and fractions derived therefrom (Maubois, 1999). Many processes are already applied today industrially in the manufacture of consumer products. I will, therefore, only mention applications which have been introduced in the last years and will definitely gain world-wide importance in modern dairy processing.

STANDARDISATION OF MILK IN PROTEIN CONTENT BY UF

The natural variations in the protein content of milk are quite large, i.e. between 28 and 40 g/litre. In many countries, milk payments to producers are increasingly based also on the protein content. Therefore, pressure increases to allow for standardising the protein content of liquid milk, condensed milk and milk powder, so that both producers and processors can obtain the full economic value of the milk. This year the Codex Committee of Milk and Milk Products (CCMMP) passed the Standard for skim milk powder with a minimum protein content of 34%. Consequently, the protein content of the skim milk has to be adjusted prior to drying without, however, influencing the composition of the aqueous phase. The only technology which allows for this is ultrafiltration (UF).

The demand by the industry to also standardise the protein content for liquid e.g. consumption milk is increasing. This practice exists already in some countries, whereby the legal aspect is not clear, but I am convinced that in a few years it will become reality in the major milk producing countries. The process is simple and there are no technological problems (Fig. 3).

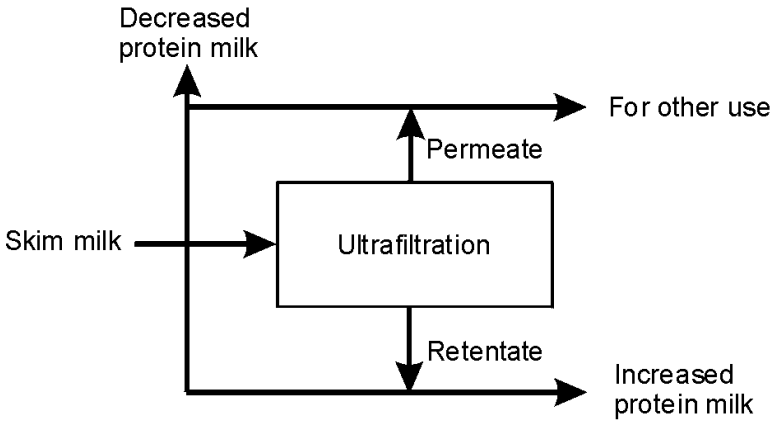

Figure 3. Ultrafiltration for protein standardisation of liquid milk.

MICROFILTRATION FOR SEPARATION OF MICROORGANISMS FROM MILK

Due to the relatively large pore size, the microfiltration (MF) membranes allow the passage of proteins whereas fat globules and microorganisms incl. bacterial spores are rejected and remain in the retentate. Industrial applications of MF for removal of *Clostridium tyrobutyricum* spores from cheese milk in order to prevent "late blowing" during ripening and storage of semi-hard and hard cheeses already started in the late 1980ies. The effectiveness of spore removal is higher than by bactofugation because it is not dependent on the initial count. Since cheese milk with less than 300 spores/litre can be obtained, it is possible to process milk from silage fed cows to the mentioned cheese types without the risk of butyric acid fermentation. One can argue than it is much more economical to inhibit the germination of spores by addition of nitrate or lysozyme, but we have also to consider that consumers are increasingly against the use of additives in dairy products. The process for treatment of cheese milk by MF is described in Fig. 4.

MICROFILTRATION FOR EXTENDED SHELF LIFE MILK

The introduction of "extended shelf-life milk" (ESL) is a more recent development and to my opinion, of great importance for the future. The product is not sterile like UHT milk and, therefore, needs refrigerated storage. Compared to pasteurised milk, the shelf-life is prolonged to between 14 and 45 days depending on the technology applied. According to the claims of the producers, ESL has advantages over UHT milk because a) it tastes similar or even better than pasteurised milk; b) the taste remains constant during the entire shelf-life; and c) savings in production and distribution costs are possible. Several processes are available for drastically reducing the microorganisms in milk, such as bactofugation, MF or steam infusion. However, here again, MF is one of the most suitable method to achieve this reduction with minimal influence on milk ingredients.

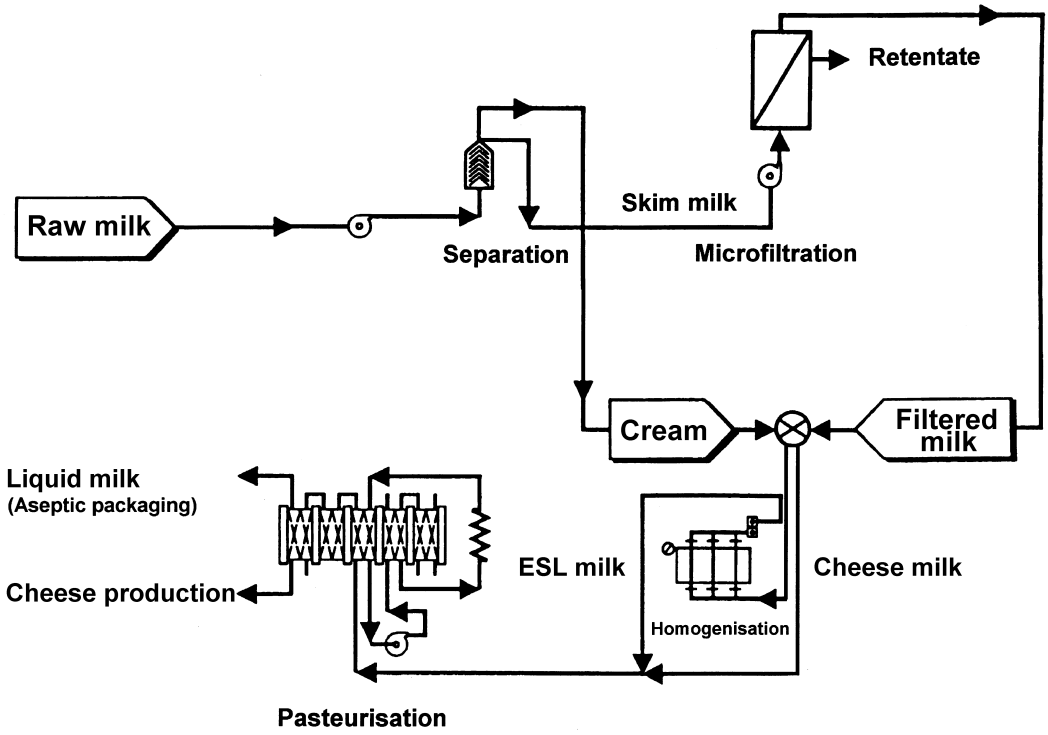

Figure 4. Microfiltration for removal of microorganisms from skim milk.

ULTRA-HIGH-PRESSURE TECHNOLOGY

One of the emerging technologies is the application of ultra-high hydrostatic pressure on food as well as on various bio-systems. The potential of high-pressure treatment of food as an alternative to temperature treatment has already been recognised exactly 100 years ago by Hite (Hinrich *et al.*, 1996) who observed a reduction in the count of microorganisms by the magnitude of 5-6 decimals when subjecting milk to a pressure of 6.8 bar for 10 minutes at ambient temperature. Similar results were some years later obtained when treating meat and fruits.

The presently available equipment only allows for batch-wise treatment of the products, and the pressure applied ranges between 0 and10 kbar at 0-80° C (Fig. 5). The present state of the development of the equipment does not allow treatment of quantities significant for industrial application, not to mention the exorbitant cost for the treatment. Nevertheless, valuable

observations made so far will definitely be of importance for further developing the process. Fig. 6 shows the influence of this treatment on milk products.

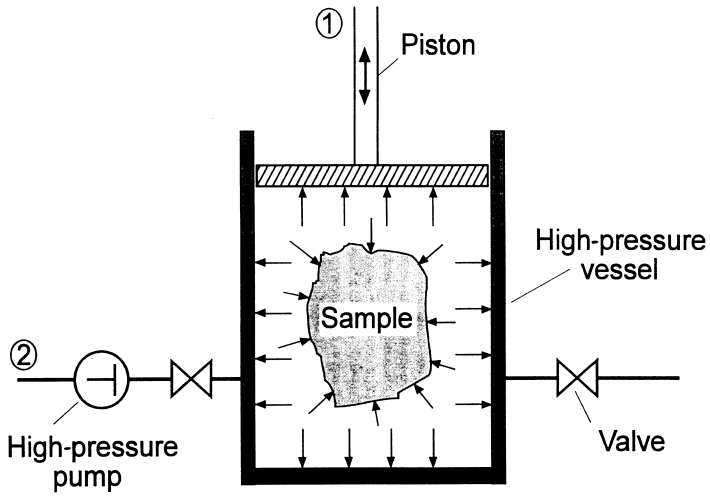

Figure 5. Principle of ultra-high pressure treatment (Hinrich *et al.*, 1996).

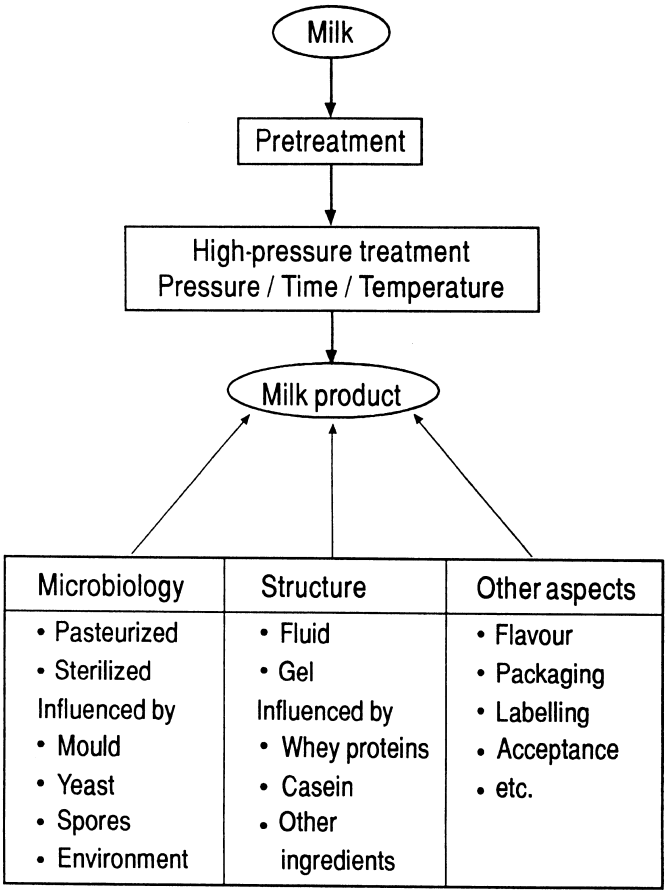

Figure 6. Influence of ultra-high pressure on milk ingredients (Hinrich *et al.*, 1996).

CHANGING NATURE OF FOODS

The growing consumer demand for health and well-being can be met to a great extent by the dairy industry because milk contains a great number of ingredients that are increasingly recognised as health-promoting, even having medical benefits. The potential for foods to provide more than just the basic nutrients for life has been recognised for quite some time now (Marshall, 1999).

Table 1. Functional foods – products of evolution (Nutritio, 1999)

Period	**Function**	**Products**
Since approx. 1990	Added health benefit	Functional foods e.g. with probiotics
Since approx. 1970	Less harmful for health	Dietetic food e.g. low energy, saltless, reduced sugar content
Since approx. 1950	Enjoyment	"Attractive" food e.g. enrichedin sugar, fat and salt
18th century Industrialisation	Save food supply	Processed food e.g. canned food with long self-life
< 4000 BC Settled population	Satisfy hunger	Basic food
< 10000 BC Hunters and gatherers	Satisfy hunger	Everything edible

Table 2. Appreciation of whey as source for functional ingredients (Horton, 1998)

Whey in 1967	Whey today	
Total solids True proteins NPN Lactose Lactic acid Ash (Minerals) Fat	α-Lactalbumin β-Lactoglobulin Bovine serum albumin Immunoglobulins Lactoferrin Lactoperoxidase Proteose peptones/polypeptides Free amino acids Urea Glycomacropeptides Growth factors	Lactose Sialic acid Lactic acid Sodium Potassium Calcium Magnesium Chloride Phosphate Sulfate Citrate Heavy metals Milk fat globule membrane Free fat Lipoproteins

It is informative to follow the function of food in the last several thousands of years, and particularly in our century. The conclusion of Orwel, adapted by Fern (Nutritio, 1999), that "all foods are functional, but some are more functional than others" applies perfectly to dairy products.

In this connection I would like to point to the possibilities for obtaining milk ingredients and their derivatives as shown in Fig. 2. Particularly interesting is the comparison of appreciating whey some 30 years ago and today. A few decades ago it was hardly considered a source for specific ingredients and has mostly been utilised in animal feeding. Today, whey is considered a source of various valuable ingredients.

The market awareness of "functional foods" began by fortifying dairy products with vitamins and minerals and later by using probiotic cultures. Further developments consist in foods for gut regulation (prebiotics + probiotics), for enhanced calcium absorption (with casein phosphopeptides) and functional foods targeted at specific age groups or a-risk segments of the population.

MODERN BIOTECHNOLOGY

Biotechnology is the heart of cheese and fermented milk manufacture. Modern bio-technical methods offer further possibilities for transforming dairy ingredients, influencing the performance of cultures and producing metabolites to increase the shelf-life of foods.

Research in biotechnology during the last 30 years led to a tremendous knowledge increase of metabolic processes in the living cell. For a number of milk processing relevant microorganisms, genes coding for enzymes involved in the metabolic pathways, have been identified and characterised. This information makes it possible to optimise the metabolism for starter organisms used in the manufacture of dairy products.

The effort of metabolic engineering of lactic acid bacteria is among others, directed towards increasing flavour production and flavour stability, which is determinant for the quality of various fermented milk products. Great possibilities have been recognised in genetic engineering for constructing strains with particular properties. Construct strains with altered levels of proteolytic enzymes, increased tendency for lysis and additional phage resistance mechanisms are on trial as cheese starter cultures. For fermented milks with probiotic properties, the colonisation of the intestine is another area of research showing already promising results in animal studies.

Phage resistance of lactic acid bacteria has undergone intensive studies for several decades. Strategies have been developed and applied with variable success. Since the 1970s, techniques of genetic modification have been adapted to lactic acid bacteria and the potential to improve the industrial performance is being intensively exploited.

The techniques for altering the performance and/or properties of microorganisms applied in the dairy industry, however, require the genetic control of characteristics to be sufficiently understood. The acceptability of such genetically modified strains for industrial use, and consequently for the consumer, is under serious consideration. A consensus is likely to be accepted on the basis that

- no antibiotic resistant gene should be present in the modified strain,
- the genetic modification must be well defined, and
- the use of homologous DNA only (originating from cells of the same species) is considered more acceptable than using DNA from different species.

MILK TECHNOLOGY VERSUS ENVIRONMENT

However, enthusiasm for present and future possibilities of utilising milk as starting material for obtaining basic food and of particular ingredients, should not prevent us from making ecological considerations, such as sustainability, etc. The needs of an ever increasing world population, the increasing demand for resources of many kinds, and an increasing output of waste materials must be met by measures to maintain a balanced level in nature.

Therefore, technologies compatible with the environment are required. The saving potential in the dairy industry is remarkable. Experience has shown that energy consumption can be reduced by 10-30% by employing and improving equipment and procedures with optimal energy efficiency and less heat waste with drying air, speed control of pumps, etc.

Energy saving is closely related to waste reduction and treatment. The amount of loss in waste water in the dairy industry is estimated to be around 1-3% of the milk processed. In financial terms, however, this increases by up to 3fold due to expenditure for waste water treatment (Mortensen, 1999).

The increasing difficulty of disposing waste water will force the industry to recycle wastes which can be both of financial and environmental benefit. Recycling of water within the processing plant is of increasing importance world-wide. Advances in membrane and other technologies may provide more cost effective and reliable treatments for reusing water.

CONCLUDING REMARKS

Developments in dairy technology will largely be determined by perception and demands of future consumers. Changing lifestyles will control the requirements for new products and improvements of current products. In order to also ensure a successful production of dairy products in the future, manufacturing companies must continue to invest in dairy research and acquire suitable technologies to produce new products in a cost effective and environmentally sustainable way (Marshall, 1999).

POVZETEK

Razvoj tehnologij spodbudijo potrebe po večji varnosti in gospodarnosti izdelkov ter zahteva po zaščiti okolja ali pa zahteve porabnikov in tržišča po novih mlečnih izdelkih in živilih, ki vsebujejo mlečne sestavine.

Predno nove tehnologije uvedemo, poteče kar nekaj let. Tako večino tehnologij, ki bodo v mlekarski industriji zaživele v naslednjih desetih do petnajstih letih, znanstveniki in tehnologi raziskovalci proučujejo že danes. Prispevek obravnava nekatere od njih, pa tudi možnosti njihove uporabe. Membranske tehnologije za ločevanje in koncentracijo sestavin mleka uporabljamo v proizvodnji mlečnih izdelkov že 20 do 25 let, vendar pa daje razvoj novih membran dodatne možnosti za uporabo v proizvodnji že obstoječih izdelkov, kot so sir, konzumno in fermentirano mleko, pa tudi za pripravo posebnih, »po meri narejenih« izdelkov, ki jih dobimo s frakcioniranjem beljakovin mleka do posameznih beljakovin in peptidov, za katere danes vemo, da imajo posebne fiziološke učinke.

Ena od prihajajočih tehnologij je uporaba ultra visokih pritiskov, ki je zanimiva zaradi izrazitega vpliva na beljakovine mleka, vključno z encimi, na lipide in mikroorganizme. Tehnologija je zelo draga, zato bo najverjetneje njena uporaba v mlekarski industriji omejena predvsem na specialne izdelke, ki se bodo od tradicionalnih razlikovali po večvrednih ali pa posebnih lastnostih.

Področje zahteva še temeljite raziskave. Kljub dejstvu, da so v vseh proizvodnih procesih fermentiranih mlečnih izdelkov vključene biološke operacije, pa v mlekarskih obratih vse bolj pridobivajo na pomenu nove biotehnološke metode za preobrazbo sestavin mleka, proizvodnjo posebnih metabolitov in stalne fermentacijske procese.

Pomembna naloga mlekarskih tehnologov bo tudi vnaprej razvoj energetsko varčnih tehnologij, kar je tesno povezano z zmanjševanjem količine odpadkov in odplak in njihovo obdelavo, saj pomeni zmanjševanje le teh ne samo manjše izgube mleka kot surovine temveč tudi precejšnje zmanjšanje stroškov obdelave odpadnih vod in možnosti ponovne rabe vode znotraj proizvodnega obrata.

Mlekarska industrija se srečuje z vedno večjo konkurenco, zato je tesno sodelovanje med industrijo in ustanovami, ki se ukvarjajo s temeljnimi raziskavami, toliko bolj pomembno.

REFERENCES

Cheryan, M. Ultrafiltration and Microfiltration: Handbook. Lancaster, Technomatic Publ. Co., USA, 1998, 527 p.

Maubois, J.L. Fractionation of milk proteins. Proc. 25th Int. Dairy Congress, Aarhus, Denmark, 1998-09-21/24. Aarhus, 2(1999), 74-86.

Hinrichs, J./ Rademacher, B./ Kessler, H.G. Heat treatments and alternative methods. IDF Special Issue, (1996)9602, 185-201.

Horton, B. Whey. IDF Special Issue, (1998)9804, 12-25.

Marshall, K.R./ Fenwick, R.M. Dairy science and technology. Proc. 25th Int. Dairy Congress, Aarhus, Denmark, 1998-09-21/24. Aarhus, 1999, 41-50.

NN. Funktionelle Lebensmittel. Nutritio, (Nestle Schweiz), (1999)37.

Mortensen, B. State of the art in dairy science. Scandinavian Dairy Information, 4(1998), 14-19.