WHEY PRODUCTS

Whey is the portion of milk left after cheese or casein is made. Whey is about 96% water but contains some valuable protein, much lactose (milk sugar) and various dissolved salts.

Years ago, whey was dumped into streams. These streams became polluted as a result; now, whey is processed into a range of dairy products.

Demineralised whey powder is made by removing dissolved salts and water.

Whey protein concentrate is made by very fine filtration of whey to concentrate the proteins into a small volume which are then dried to a soluble powder.

Whey protein hydrolysates are made by digesting the protein concentrate with enzymes, and then drying the resulting soup to a powder.

Milk mineral products are rich in calcium, which is extracted from the whey and then dried.

All these products are sold as ingredients to food processing companies who use them to make food products such as custards, confectionery, crab-sticks, sports drinks, baked goods and yoghurts.

A glossary of terms is given at the end of this article.

INTRODUCTION

Whey is the by-product of cheese and casein manufacture, being what remains of the milk once the cheese or casein is removed. Generally 100 L of milk produces about 12 kg of cheese or about 3 kg of casein. In either case, about 87 L of whey is made as a by-product.

The annual production of whey in New Zealand is about 4×10^9 L. Its approximate composition is given in **Table 1**.

For decades, most of New Zealand's whey had been used mainly as pig food or run to waste. It has also been irrigated as liquid fertiliser. Since about 1970, the New Zealand dairy industry has increasingly processed its whey into a range of products in an attempt both to extract greater total value from the parent milk and to minimise the environmental impact of whey discharges. Economic processing of whey has been aided by the progressive amalgamation of small dairy factories into larger ones where much whey arises at one site.

MAJOR PRODUCTS MADE FROM WHEY IN NEW ZEALAND

Demineralised Whey Powder

Demineralised Whey Powder is produced using similar equipment to that used to produce milk powder. Whey is first subjected to either electrodialysis and/or ion exchange (described below) to reduce the mineral content by up to 90%. The demineralised whey is then

Table 1. Composition of milk, cheese whey and casein whey

% by weight	Milk	Cheese whey	Casein whey
Fat	4.7	0.05	0.03
Lactose (milk sugar)	4.5	5.0	4.7
Casein protein	2.7	0.10	0.0
Whey protein	0.55	0.65	0.57
Minerals	0.85	0.50	0.80
Minor components	0.20	0.30	0.50
Water	86.5	93.4	93.4
TOTAL	100.00	100.00	100.00

evaporated to about 58% total solids and then rapidly cooled to force as much of the lactose as possible into fine crystal form. The cooled slurry is spray dried. The spray-dried product is about 75% lactose. Spray drying is very fast and gives insufficient time for the lactose to crystallise, so that the lactose dries as a hygroscopic glass. This makes whey powders very sticky under humid conditions. The problem is minimised by first converting as much as possible of the lactose to the α-monohydrate crystal form, which is not hygroscopic. The resulting powder is sold mainly for use in infant formula preparations.

Ion exchange employs tanks full of charged plastic beads called resin. Whey is pumped down through two resin tanks: cation exchange resin in the first tank and an identical tank of anion exchange resin. The cation exchange resins are covered with sulphonate groups which carry a negative charge at all pH values above about pH 2. This resin strips metal ions from the whey and gives up H^+ ions in return. The anion exchange resin is covered in quaternary amine groups which maintain a strong positive charge. This resin picks up chloride, sulphate, phosphate, citrate, nitrate and other anions from the whey in return for OH^- ions. When the cation exchange resin becomes saturated, it is regenerated ready for reuse: a solution of H_2SO_4 is passed through the resin bed so that the H^+ ions present in high concentration displace the Ca^{2+}, Mg^{2+}, Na^+ and K^+ ions extracted from the whey. Similarly, the anion exchange resin is regenerated by NaOH solution.

Electrodialysis (see **Figure 1**) is a process employing a stack of porous plastic membranes sandwiched between two electrodes. Whey is pumped through the envelope made by adjacent sheets of membrane. Water is pumped through the flat spaces between those envelopes. The applied voltage encourages cations to move though the porous membranes from the whey into the water towards the cathode. Similarly anions move from whey to water towards the anode. The passage of ions from water back into whey is impeded by the chemistry of the porous membranes used. Each second membrane carries a net negative charge to make it select for the passage of cations. The alternate membranes are anion selective.

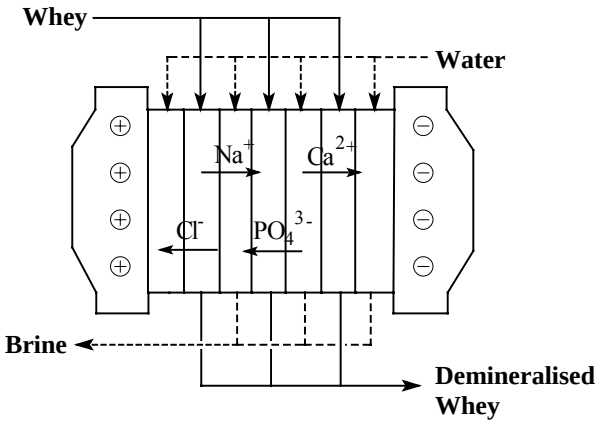

Figure 1 - Electrodialysis

Whey Protein Concentrate (WPC)

Whey Protein Concentrate (WPC) is produced using ultrafiltration. This is also a membrane separation, but it selects on the basis of molecular size and is driven by pressure rather than by applied electric field as in the case of electrodialysis. Ultrafiltration retains (in the liquid product termed "retentate") any insoluble material or solutes larger than about 20 000 Da molecular weight. The rest of the whey stream passes through the membrane, driven by the applied pressure and is called "permeate". The permeate contains most of the lactose, minerals and water from the whey. The retentate, the volume of which is about 1-4% that of the feed whey, is spray dried to a powder containing 35-85% protein as desired. WPCs are made at low to moderate temperatures so that the proteins remain in their native form and the dried product is highly soluble. New Zealand is now the largest manufacturer of WPC in the world, employing many tens of square kilometres of ultrafiltration membrane. WPCs are used as food product ingredients in hams, custards, confectionery, crab-sticks, cakes, infant formulae, sports drinks and formulated stock foods.

Most WPCs contain 5-7% milkfat in the dry powdered product. This fat originated in the milk and is not removed by the cream separators through which the whey passes before ultrafiltration. The most modern WPCs use either microfiltration (like ultrafiltration but using membranes with pores sized at about 200 000 Da molecular weight) or ion exchange of the proteins themselves, prior to ultrafiltration, to make a protein product almost devoid of all fat. These very high value proteins find favour in clear acid sports beverages such as those for body-builders.

Lactalbumin

Lactalbuminin the traditional name for a product made from the same whey proteins as are in WPCs, but in an insoluble form. Lactalbumin is prepared from whey by heat precipitation under acidic conditions. Here, the major whey proteins denature and aggregate into fine flocculant curd particles. These can be separated from the liquid "serum" by centrifugation, and then washed and dried. Lactalbumin is nutritionally very valuable and is used primarily for baking, for speciality foods and to fortify some pizza cheeses. However, as the protein is insoluble, it is not useful in helping a food to gel or foam or bind together.

Whey Protein Hydrolysates

Whey Protein Hydrolysates are manufactured by enzyme digesting, at controlled temperature and pH, either WPC or lactalbumin raw materials, and then filtering and spray drying the resulting solution. Whey protein hydrolysates find uses in high value specialist nutritional

applications such as tube-feeding preparations or special dietary supplements. Appropriately hydrolysed proteins lose the ability to induce allergic reactions in susceptible people, and so can be used in hypoallergenic infant formulae. Proteins are chains of amino acids, in which the amine group of one amino acid is bound to the carboxylic acid group of the neighbouring amino acid by an amide bond. Proteolytic enzymes catalyse the hydrolysis of these bonds (**Figure 2**).

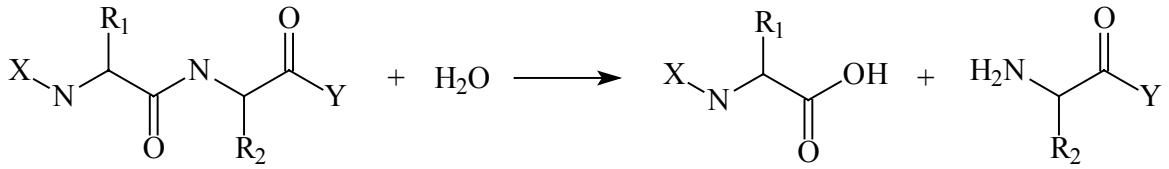

Figure 2 - The hydrolysis of a peptide bond

Small chains of amino acids are called peptides. In a hydrolysate, we might seek to get all the protein into peptides of two to five amino acids, with few free amino acids and no larger peptides. Interestingly, some peptides released from milk proteins can be biologically active. Some can transport calcium from the gut into the blood during digestion, some can inhibit enzymes in the human body involved in excessive blood pressure and some can induce sleepy feelings. However, a problem is that some peptides can be very bitter on the tongue. Choice of the right enzymes and careful control of the hydrolysis process are required to make the desired hydrolysate product.

Milk Mineral Products

Milk mineral products rich in natural milk calcium and phosphate are valuable nutritional supplements in today's osteoporosis-sensitive world. These products are made by precipitation of the calcium phosphates in whey ultrafiltration permeate under suitable conditions of concentration, pH, time and temperature. The crystals that first precipitate quickly undergo solid state transitions depending on the conditions to which they are subjected. It is necessary to grow calcium phosphate particles to sufficient size to recover them in a good yield by centrifugation and filtration. Milk mineral is used as a "natural" calcium supplement in a growing range of food products including milks, yoghurts, canned milk powders, confectionary and health foods.

Demineralised Permeate Powders

Demineralised Permeate Powders are manufactured in a very similar manner to demineralised whey powders, but use ultrafiltration permeate of whey as a raw material. The spray-dried product contains about 95% lactose.

Alcohol

The lactose in whey can be converted by fermentation by a variety of organisms to products ranging from lactic acid to flavouring materials. Three plants in New Zealand use yeast to ferment the whey ultrafiltration permeate or lactalbumin serum to ethanol. The ethanol is recovered by distillation to yield potable or industrial grade alcohol.

GLOSSARY

aggregate	clump together
amine	an organic base compound containing a $-NH_2$ group
amino acid	a compound having both an amine and a carboxylic acid group
anion	a negatively charged ion, attracted to the anode
carboxylic acid	an organic acid compound containing a -COOH group
casein	the major protein in milk, insoluble near pH 4.6
cation	a positively charged ion, attracted to the cathode
centrifugation	separation by sedimentation under an applied centrifugal force
Da	daltons - the basic unit of molecular weight
demineralised	having had soluble mineral salts removed
denature	disrupt the natural shape and structure of a protein
electrodialysis	a demineralisation process involving ions passing through selective membranes under the influence of an applied electric field
flocculant	clumping together to form soft flakes
glass	a non-crystalline, unstructured solid
hydrolysate	a mixture of compounds formed by hydrolysis of a larger compound
hydrolysis	breaking of a bond by water, the water itself also being decomposed
hygroscopic	tending to absorb moisture
hypoallergenic	depleted of compounds able to produce an allergic response
infant formula	formulated baby food
ion exchange	process involving swapping of charged species one for the other
lactose	the major sugar in milk, not sweet but similar in size to sucrose
microfiltration	membrane filtration process retaining particles larger than 100 nm
mineral	metal salt, *e.g.* salt of calcium, sodium, potassium, magnesium, iron
osteoporosis	degenerative disease of the bones
permeate	liquid solution that permeates through a porous membrane
potable	able to be safely drunk
proteolytic	able to hydrolyse proteins
quaternary amine	a compound of the general form NR_4OH
retentate	liquid suspension retained by a membrane
serum	the liquid solution portion of blood or milk
sulphonate	a compound of the general form $-SO_2OH$
ultrafiltration	membrane filtration process retaining particles larger than 5000 Da
whey	the liquid portion of milk left after cheese or casein manufacture
whey protein	a group of minor milk proteins soluble at pH 4.6

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