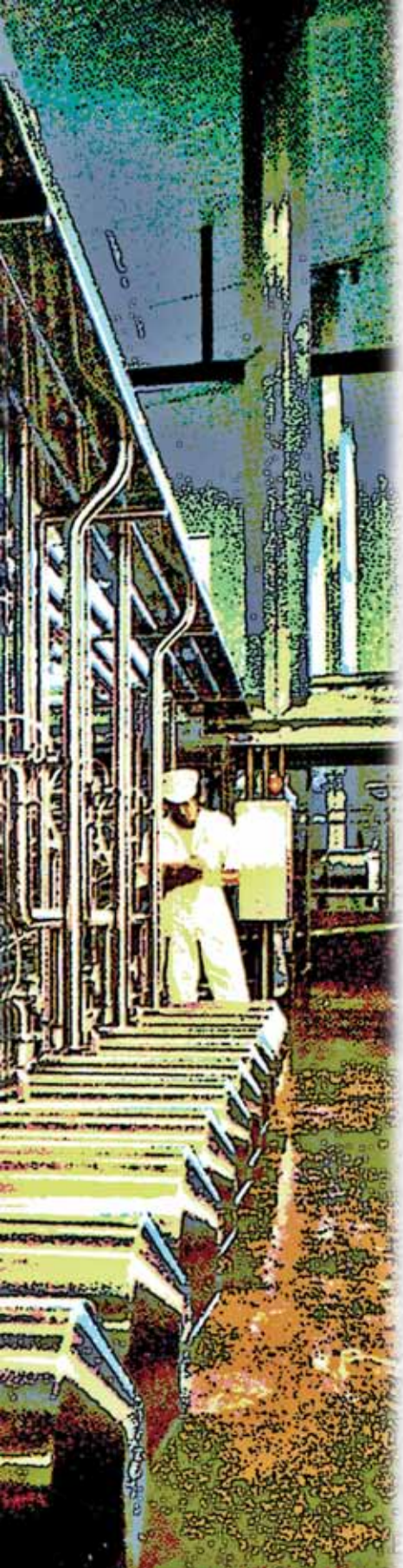

Whey to go

WHEY PROTEIN CONCENTRATE: A NEW ZEALAND SUCCESS STORY

EDITED BY JOHN MACGIBBON

In the early 1970s, Britain was about to join the EEC and New Zealand's dairy industry was desperate for new markets and new products. They were found, partly thanks to a group of talented young technologists, scientists and marketers, a multi-national beverage company and a transformational new technology called ultrafiltration.

At the time, casein products were seen as an important part of the diversification push. But there was a problem: how to deal with the potentially polluting whey by-product from large new casein plants?

One answer came through ultrafiltration, a technique that enabled the production of whey protein concentrates. They could be tailored as specialised food ingredients and were so valuable that processing highly dilute liquid whey became profitable. These concentrates, along with other whey products, are now an established industry and almost no whey is wasted. It is New Zealand's biggest waste to riches story.

Whey to Go is the story of the early decades of development, written by several of the pioneers.

"A fascinating story about how industrial innovation really works in practice. It takes time, it's often not linear, it takes collaboration across disciplines and across organisations, but most of all, it works because of the confidence, imagination, passion and perseverance of individuals. The New Zealand dairy industry has grown to global leadership through a number of technologically based phases of innovation. *Whey to Go* describes one of the most important of them."

Jeremy Hill, chief technology officer,
Fonterra New Zealand

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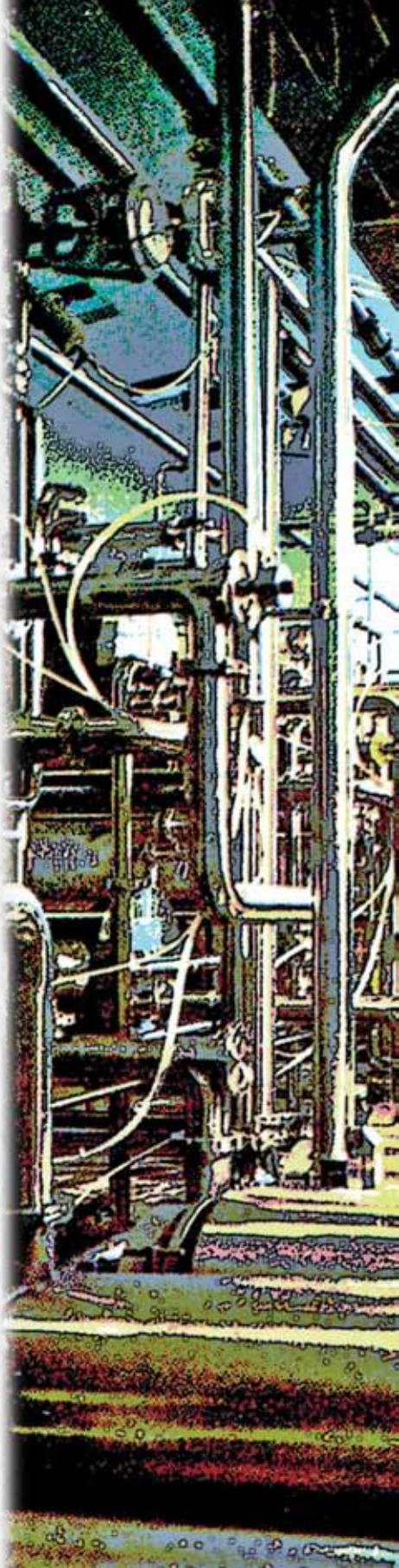

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WHEY PROTEIN CONCENTRATE: A NEW ZEALAND SUCCESS STORY

Edited by John MacGibbon

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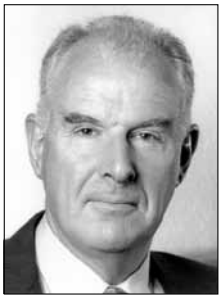
W J Harper.

Dedicated to Ken Kirkpatrick
1940–2010



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PREFACE

In 1995 Ken Kirkpatrick was awarded the J C Andrews Award, the New Zealand Institute of Food Science and Technology's most prestigious award, for a substantial contribution to science and technology and leadership in the food industry. In his acceptance address Kirkpatrick reflected on the future directions for food technology in New Zealand. He expressed pride at having "the great good fortune at the start of my career to be in on the ground floor of the application of a new technology, namely ultrafiltration, and have been given the opportunity to follow it through the various stages of its commercialisation over the succeeding 20 years."

Eleven years later, one of the chapter authors, Kevin Marshall, received the same award.* He devoted his address to innovation in the New Zealand dairy industry, using the story of whey protein concentrate and ultrafiltration development in the 1960s and 70s as his case study.

Whey protein concentrate, or WPC as it is generally known, is a soluble form of whey protein used in a variety of foods and beverages including cakes, protein shakes, sports drinks, infant formula and processed meats.

In preparing his address Marshall sought the help of Kirkpatrick, Dave Woodhams and Jim Harper – all contributors to this book.

At the end of June 2006, Marshall, in an email to Woodhams and Harper, wrote "Ken [Kirkpatrick] and I believe we should try to put together a more comprehensive and fully researched version of the history and we will try to advance that when Jim Harper is here early

*Two other authors of this book were awarded the J C Andrews Award: Arthur Wilson (1997) and Mike Matthews (2008).

in the new year." Kirkpatrick repeated the idea in an e-mail a few days later to Bill Eykamp, an American colleague, adding "to write a more complete history while we still have our marbles and most of the players are still alive."

Later that year a meeting of Don King, Kirkpatrick, Marshall and Woodhams agreed that a book would be attempted. A further meeting with a wider group in March 2007 mapped out the contents of the proposed book. This was refined in February 2009, after which Kirkpatrick wrote an introduction, which appears opposite.

It would take another 18 months to obtain sponsorship for editing and publishing the book. The project has been a labour of love for the authors ever since, with enthusiasm waxing and waning, and now waxing again.

Tragically, Ken Kirkpatrick did not survive to see the book completed. He died of a brain tumour in September 2010.

Whey to Go has been written as a series of chapters by people who were major players in the development of whey protein concentrate products. An exception to this is the editor's chapter on the Whey Corporation, which is based on archival research plus several interviews – particularly with Ken Kirkpatrick, who would otherwise have written the chapter.

The authors hope that the story and insights will be valuable to all involved in process and product development: scientists, technologists, processors, marketers, policy makers and investors.

While the chapters are broadly chronological, there are a few overlaps, both in timing and in information given. We have tried to keep this to a minimum, but some overlaps are inevitable, given the shared knowledge and experiences of the authors and the fact that similar information or activity might illuminate more than one aspect of the WPC story.

In places, numbers appear after 'WPC', e.g. WPC 75. The number refers to the protein content. In this example the content would be at least 75 percent.

ACKNOWLEDGEMENTS

This book was produced by far more than the chapter authors. We consulted widely and received contributions and comments from a host of colleagues. Some remain anonymous while some have their names on sidebar items within chapters. We are indebted to you all:

Tony Baucke, John Begg, John Bell, Rod Bennett, Mal Beniston, Graham Calvert, Gavin Cherrie, Tom Connell, Gerald Crawford, Barry Dixon, Dick and Mary Earle, Bill Eykamp, Bill and Phoebe Falconer, Tony Fayerman, R Fenton-May, Andrew Fletcher, Anne Goldman, Murray Gough, Howard Heap, Conrad Heron, Sheelagh Hewitt, Jeremy Hill, Bernie Horton, Mike Howell, Jeff Jackson, Garry Johns, Don King, Phillip Kirk, Stuart Leiderman, Alex Malaspina, Neville Martin, Wilson McGillivray, Bruce Millar, Graeme Milne, Ken Morison, George Murphy, Birger Nordmark, John North, James Ogden, Dave Packer, Max Parkin, Lindsay Pearce, Peter Robertson, Mike Rockell, Gill Rodley, Ron Russell, Roger Ryan, Wayne Sanderson, Lynne Scanlen, Terry Spencer, Dryden Spring, Terry Thomas, Charlie Towler, Merv Whitehead, John Whitelock, John Wood.

We are also grateful to Fonterra Research Centre, Palmerston North, for providing access to records and photos. While we wrote many of the documents we referred to, access was most helpful in correcting defective memories and filling in gaps in our knowledge of the people and events which contributed to this saga.

INTRODUCTION

KEN KIRKPATRICK

Ken Kirkpatrick *attended Canterbury University, completing a PhD in chemical engineering. He joined NZDRI in 1967 and later headed the whey products section before moving to the New Zealand Dairy Board's Chicago office in a technical marketing role. On his return he headed the Board's protein division, then became founding CE of the Whey Corporation. He later had positions at Massey University, the Foundation for Research Science and Technology and the Department of Prime Minister and Cabinet.*

The dairy industry in New Zealand is now and has been for many decades, a major part of the economy, comprising about 26 percent of total merchandise export revenue and three percent of GDP. It is an industrial enterprise with about 95 percent of production exported, mainly in the form of high quality industrial food and ingredient products with increasing quantities of consumer products, to all corners of the earth. About 35 percent of all milk products traded internationally come from New Zealand, a remote country in the South Pacific Ocean.

The industry has long been driven, largely by competition in the marketplace from subsidised export of surpluses from Northern Hemisphere countries, to be extremely cost-efficient through the whole value chain from farm to customer. This relentless drive for efficiency has led to the development and deployment of new sciences and technologies on farms, in factories and in the distribution system. The New Zealand whey protein story is a part of that continuum.

From very small beginnings in the 1960s and 70s, the whey protein industry grew to be a substantial and highly sophisticated business that over the years, directly and indirectly, has earned many billions of dollars for New Zealand. It continues to deliver income and new market opportunities on a considerable scale. New raw materials using new processing technologies were developed to create completely new products for new food applications in new markets.

Had we had any inkling at the outset of the challenges involved, it is unlikely we would have started down this path. But a combination of necessity, perseverance and sustained investment, to say nothing

of brains, energy and boundless enthusiasm, eventually led on to considerable success. Whey products today are a cornerstone of the sophisticated ingredients business which is a major part of our industry.

This is a story of the first decades of development, told by a group of colleagues and friends, mostly long since retired from direct involvement, who feel keenly the need to tell the story so that others may be encouraged to take the plunge into bold projects, perhaps just a little less blindly than we did. But it is striking to look back and see how many of today's commonplace tactics and strategies of successful innovation and business development we either stumbled upon or worked out and applied for ourselves.

A marriage of necessity and opportunity

One visible consequence of the economic imperative for improving economy has been the continual increase in the scale of farms and factories. The largest average farm size in the world with the lowest milk production costs combined with by far the largest milk processing factories, were and are the foundations of industry success. As a consequence of amalgamations between dairy companies, the larger scale of new factories led to much larger volumes of raw whey, the by-product from cheese and particularly from casein manufacture.

What had been an easy disposal issue from a small factory in the early 1960s became an urgent economic and environmental challenge by the end of the decade as disposal options narrowed or disappeared. This necessity was the mother of our inventions. Developing valued uses for whey was becoming the 'licence to operate' for our casein industry in particular. Without success in meeting that challenge, a major specialised part of the product mix of the industry was at risk.

In this case invention started with the practical application of technology and process engineering, guided by economics and followed eventually by increasingly intensive application of specialised science skills in microbiology, protein chemistry, sensory evaluation and functional property testing, in a relentless and repeated iteration of problem discovery and solution development. There were probably more PhD level engineers and scientists employed in this endeavour than in any other comparable development in New Zealand at that time. The challenges attracted recruits of the highest calibre, many of

whom went on to significant careers and achievements in the global food and dairy industries.

Our whey protein story began with application of the right fundamental engineering principles and economics but quickly encountered unforeseen, and largely unforeseeable, problems requiring application of diligent and highly sophisticated scientific research to unpick and solve in order to advance again down the chosen path. This progress in fits and starts is not at all uncommon in exploration of new fields, combining periods of rapid progress followed by frustratingly slow investigation of an unexpected problem uncovered by venturing blindly into unexplored territory.

Lactic casein whey disposal – our 'necessity'

Our work started with a most unpromising raw material, lactic acid casein whey. We chose this as our starting point for a number of reasons:

- Lactic casein was a very important part of the industry's product mix. In the 1960s its main uses were for industrial products (plastics and paper-coating) rather than for food, so in many countries it was classified as a chemical. Thus it was not subject to the tariffs and import restrictions routinely applied to dairy products. If we could not make whey into a revenue producer rather than having it incur a disposal cost, then this important part of the overall industry strategy, maintaining a diverse product range, would be threatened. Profitable whey utilisation would secure a 'licence to operate'.
- Lactic casein whey was becoming available in increasingly large quantities at single sites as factory throughputs got bigger for efficiency reasons, leading to a bigger problem but also to a bigger opportunity.
- The environmental consequences of land disposal and the cost of doing nothing with increasing quantities of whey were about to bite.
- Earlier work by Don King and others had already shown that it was practical to extract valuable materials from casein whey. One of them, 'traditional lactalbumin', was already part of the dairy industry's product mix, having displaced a similar product manufactured from cheese whey from the market.
- Lactic casein whey was pretty much unique to New Zealand, so anything we developed might be harder for competitors to copy (and so it proved).

Little did we know at the beginning that the proteins in this unwanted and unloved by-product would turn out to have uniquely valuable properties as a gelling protein which took our competitors who started with cheese whey quite some time to reverse-engineer. But it took about six years of sustained effort until about 1977 to find that out, after fighting through all of the challenges of variability of flavour, composition and many other properties of what was a very challenging starting material. Only when the whey tail was able to justify vigorously wagging the milk product dog did we start to get on top of those problems.

Ultrafiltration – our 'opportunity'

Whey is very dilute. To recover anything useful it is necessary to get rid of the water, which can be a costly process, especially if it has to be evaporated. So a membrane separation process such as ultrafiltration, that combines separation out of the valuable component with concentration, was immediately attractive for whey processing. Our quest was recovery of the soluble whey proteins and realisation of their potentially valuable properties as food ingredients. They have high nutritional value, and being soluble in acid solutions, might become fortifying ingredients in acid beverages. Also, like egg-white, they form a firm gel structure when heated under suitable conditions. Egg white already had a large and valuable market just begging for the entry of a cheaper substitute, or so we thought.

All we had to do was to develop a reliable and inexpensive process to recover the whey proteins present at only about 0.7 percent concentration in raw whey. Ultrafiltration was appealing because it operates at temperatures low enough to preserve the solubility of the protein; it does not damage the native properties to any material extent; and it concentrates the protein 30-fold while separating it from much of that water in a low cost pressure driven process. So our engineering and economic instincts led us to explore the then very new process of ultrafiltration for processing our lactic whey.

An alternative ion exchange resin process was being developed right next door at Massey University. We came under a lot of pressure to use this exciting new technology, but we knew it was wrong for us. While the process could achieve the required separation of the valuable protein in undamaged form, it caused further dilution which we knew we could not afford. Some 30 years later, however, ion exchange resins

found their niche in the manufacture of very sophisticated high value protein products.

The starting place

In 1927 the New Zealand Dairy Research Institute (NZDRI) was established to undertake work to improve the quality of butter and cheese, which were then the main products for both the export and the domestic markets. By 1969, which is the start of this story, NZDRI had become one of the leading organisations of its kind in the world, employing some 50 professional and 70 technical staff, including a group of mainly chemical engineers and process technologists who focused on the newer products such as milk powders, casein products and the like.

So we were very well placed to embark on the whey protein odyssey that this book relates. Having this powerful research capability embedded in the industry, with relatively free access for researchers into companies and factories and vice versa for company technologists, was a key reason why we were able to become a global leader in the development and commercialisation of high value whey protein products. The same basis in sophisticated science and technology enabled us to deliver them consistently to customers around the world.

CHAPTER 1

SETTING THE SCENE

DAVE WOODHAMS

I was nine years old when I had my first close encounter with the industry in which I would spend my professional life. It was during a school holiday in 1947 on my uncle's dairy farm in Taranaki, then one of New Zealand's two major dairying provinces. Every night and morning, my uncle machine-milked his small herd of Jersey cows in a walk-through shed. He would cool their milk by trickling it over a bank of water-cooled pipes from where it drained into 20 gallon (90 litre) milk cans.

After the morning milking, the full cans were rolled from the shed's loading dock on to a horse-drawn, two-wheeled dray. For me, a city-bred lad, the exciting part of the day was riding about 1.5 kilometres to the local cheese factory, and occasionally being allowed to drive the dray back. On the factory unloading dock the milk in each can was stirred, assessed for acceptable quality by smell and appearance, sampled for payment purposes and tipped into an open weigh-vat suspended from a large spring balance. The pointer on the huge dial of this weighing device showed how much milk had been supplied.

While the unloading and reception work was going on I would watch, though a gap between the scales and the wall, a pair of paddles in a rectangular cheese vat, slowly stirring a greenish liquid containing a suspension of small yellow cheese curd particles.

Before going home, we would drive around the corner of the factory building and fill our empty cans with green cheddar cheese whey. Then, back at the farm, we fed the whey to pigs before washing the cans for the evening milking.

***Dave Woodhams** trained as a process engineer and joined NZDRI in 1963, working on whey utilisation. He completed a PhD on spray drying, and in 1970 set up the whey ultrafiltration project, later leading the milk powder research team. He has been technical officer for a dairy company and has managed a process equipment supply company. As a dairy process consultant, he managed a number of cutting-edge, multidisciplinary R&D projects.*

Carting cheese whey home from the factory to feed pigs, 1930s. The whey is stored in the tank at upper left.

Little did I know that whey would play an important role in my future and that I would play a small but critical role in helping to develop lucrative new products from a material that was otherwise fed to pigs or dumped.

The cooperative New Zealand dairy industry

Historically, the New Zealand dairy industry developed a structure within which individual cooperatively-owned companies competed strongly at a local level for milk supply, but worked together at a national level to market their export products. Given this background, it was perhaps unsurprising that in 1982 the industry would set up an industry-wide authority over the establishment of whey processing facilities and marketing – the Whey Corporation. This move was critical to the success of sophisticated whey processing and marketing in New Zealand and it was a vital part of the foundations of the industry's domination of the technically demanding end of the whey protein concentrate (WPC) market throughout the 1980s and 1990s.

Also fundamental to the industry's success was the close association between research scientists at NZDRI and the managers and workers in the factories.

Evolution of dairy processing in New Zealand

The first dairy cattle were brought to New Zealand in the early 19th

century to provide the mostly European immigrants with a local supply of milk, butter and cheese. Although the first exports of dairy products occurred before 1850, it was the advent of refrigerated shipping in the early 1880s that allowed the industry to become a major dairy products exporter.

In the second decade of the 21st century, New Zealand is responsible for only 2.3 percent of world milk production, but we export more than 90 percent of that and provide almost a third of all dairy products in international trade. This intense focus on export production is in sharp contrast to almost every other dairy industry internationally, where the industry focus is predominantly on local consumption.

The dominance of production for international trade over local consumption, and the large size of the industry relative to New Zealand's total economy, affect both the nature and the culture of the industry. For example, they affect:


Dave Woodhams

- The calibre of the technical, scientific, farming, marketing and managerial workforce that is attracted to the industry as a career.
- The scale and efficiency of milk production on individual dairy farms. (The average size of a pasture-fed dairy herd in New Zealand in the 2012/13 season was 402 animals, while some individual pasture-fed herds are larger than 2000 cows. They are milked in rotary dairies with up to 100 cows at a time on the milking platform).
- The scale and efficiency of production in individual dairy factories and the size and throughput of individual items of processing equipment. (New Zealand's bigger processing sites have the largest milk throughputs in the world. Last year Fonterra started up the world's largest milk powder dryer, which can produce up to 30 tonnes of wholemilk powder per hour).

Because the New Zealand dairy industry is overwhelmingly export driven, it cannot subsidise exports by increasing prices on the local market. Given its size relative to the national economy, it cannot expect to receive government subsidies. These factors have driven production efficiency both on the farm and in the factory, because of the necessity of competing in international trade with exporters who do benefit from both export subsidies and elevated consumer pricing.

The table on the next page illustrates the rapid development of the New Zealand dairy industry over two 25 year periods, one on either

side of 1969, the starting point of the WPC story in this book. Of particular note are:

- The appearance of products other than butter and cheese between 1944 and 1969 and their significant contribution to export returns by 1994.
- The more than doubling of the average herd size in each 25 year period.
- The rapid decrease in the number of processing plants after 1969.

Development of the New Zealand dairy industry over 50 years

	1944	1969	1994
Total milk processed (million litres/year)	3,500	6,200	8,900
Number of cows being milked (estimate)	1,670,000	2,300,000	2,700,000
Number of suppliers (estimate)	39,800	25,000	14,500
Average herd size	42	92	186
Number of factories	409	229	27
Exports (tonnes):			
Butter	104,000	267,000	264,000
Cheese	86,000	96,000	187,500
Skimmilk powder	Negligible	133,000	136,000
Wholemilk powder	Negligible	7,000	314,000
Casein	Negligible	68,000	77,500
Export earnings (value not adjusted for inflation)	$45m	$200m	$3,500m
Proportion of earnings derived from milk products other than butter and cheese	3%	22.5%	60%

The road to New Zealand's internationally pre-eminent status has not been straightforward. Its foundations are:

- Cooperative, as opposed to proprietary, ownership of the industry.
- The relatively stable financial base for farmers provided by a viable pricing policy for purchase of product for export
- The establishment of a single organisation for the sale of exported dairy products.

Cooperative ownership

Dairy cooperatives have been part of New Zealand's history since 1871 when the first cooperative cheese company, Otago Peninsula Cooperative Cheese Factory Ltd, started operations with eight suppliers.

Milk is perishable. Without refrigeration, it had to be processed daily into products with a longer shelf life – butter or cheese. Without motor vehicles, the factories had to be close enough for daily horse-drawn delivery of milk or cream, because farmers needed a guaranteed outlet for their milk every day of the season. Many farms, ideal for dairy production, were distant from towns, and commercial lenders were reluctant to risk money on geographically isolated factories. Thus ventures that were cooperatively funded by farmer/suppliers proliferated. At the same time, privately owned factories, often closer to towns, also appeared. Pioneered by Chew Chong in Eltham, these companies bought milk from farmers for cash and took the market risk on themselves.

Once refrigerated shipping became available in 1882, a major market beyond Australia came within reach: Britain. However, this market was commercially more sophisticated. While experienced marketers from proprietary companies already had lines of communication to British buyers, this was difficult or impossible for individual cooperatives. The need for professional marketing, together with their perceived need to work together on such matters as hygiene, product quality standards and international transport, led to the cooperatives forming associations that would eventually wield considerable power.

Both cooperative and proprietary dairy companies wanted to take advantage of the new market in Britain and were determined to increase and assure their access to milk. Inevitably the interests of the two groups started to come into conflict.

The proprietary companies were separate commercial entities and they lacked coordination. On the other hand, the cooperatives had shared background and experience and were happy to associate with

EARLY DAIRY FACTORIES
Left: Chew Chong's proprietary factory at Eltham in 1887; right: Maharahara Cooperative Dairy Company's cheese factory near Dannevirke, ca 1910.

each other on issues of mutual benefit and concern. There was a snowballing effect. Over the years, the number of cooperatives increased until they moved far ahead of the proprietaries. Their ability to work together at a district level was soon matched at a national level.

The New Zealand Dairy Board

Cooperative approaches to export marketing received a boost from the onset of war in 1914 during price negotiations for commandeered cheese and butter for the British Government. After the war, in 1923, an empowering act was passed to set up a national Control Board, which, under various names and with varying powers, lasted for over 75 years. In 1934 the Control Board prepared plans for compulsory cooperative marketing of all export dairy produce, plans that were very quickly taken over and given legal substance in 1936 by the newly elected first Labour Government.

At the same time the new government introduced the concept of a guaranteed price for milk, set annually in advance and underwritten by state funding. The intention was to smooth out abrupt movements in market prices with a self-balancing fund. The Government set up a departmental Marketing Division while the Control Board continued to be responsible for commercial functions other than marketing such as shipping, transport and bulk storage.

The Government continued with compulsory acquisition through World War II until 1947, at which stage the Dairy Products Marketing Commission was established. The Commission was no longer a government department but it had a majority of government appointees.

In 1956, with the Dairy Industry Account substantially in credit, the Government yielded its majority position on the Marketing Commission to the industry and, in 1961, merged the Control Board and the Commission to form the NZ Dairy Production and Marketing Board, which had 11 elected industry members and two government appointees. In 1965 it was renamed the New Zealand Dairy Board. Its powers to acquire all product for export remained unchanged.

New Zealand Dairy Research Institute (NZDRI)

It was crucial to later developments in whey processing that the New Zealand Dairy Research Institute, with its strong technological background, was already well-established. NZDRI, established in 1927, was a jointly funded independent research organisation; it was financed

mostly by the cooperative industry and partly by government through the Department of Scientific and Industrial Research. In the late 1950s it was already employing New Zealand-trained chemical engineers. New Zealand-trained graduates in food technology became available for the first time in the mid to late 1960s.

NZDRI embodied important characteristics of the New Zealand dairy industry. There was a deep-seated recognition of the need to invest continuously in research to improve products and processes and a determination not to give up in the face of considerable challenges. So when in the early 1960s the implications of the planned entry of the United Kingdom into the European Economic Community became apparent, progressively taking away from us access to our largest single market, the response of the industry was not to give in to the widespread taunts of 'sunset industry'. Instead the leaders of the industry went out and recruited some of the brightest and best young graduates, sent them overseas to leading universities to work under recognised research leaders and to gain postgraduate degrees in relevant science and engineering disciplines. Then they brought them back, initially to the NZDRI, to challenging and rewarding occupations.

The March 1973 issue of the *New Zealand Dairy Exporter* showed the industry was responding to the call for new products:

> New product development generally starts when the Board's technical division refers a product to the Dairy Research Institute for preliminary investigation and assessment and possibly the production of laboratory-scale samples. If these prove satisfactory pilot production is arranged to allow the client to conduct suitable processing and/or marketing trials.
>
> If the product continues to prove satisfactory, full scale trials are arranged at an appropriate New Zealand dairy company. This requires the close collaboration of the Board's marketing division and overseas subsidiary companies, the Dairy Research Institute for preliminary and ongoing scientific investigation work and the Board's supply division, the Dairy Division of the Ministry of Agriculture and Fisheries and manufacturing dairy companies.

In the early years, small scale experimental and developmental processing was done in a small 1930s-vintage dairy factory on the Massey campus that was shared with Massey University College. However, once the new NZDRI building was established in 1966, the need for a more comprehensive and modern facility was recognised. Designed in-house

and coordinated by the engineering services group, the new Processing Hall, also known for a time as the Dairy Products Development Centre, was built and opened in 1968.

From the start this facility was a registered dairy factory, so sample products could be produced for export. It was provided with pilot-scale milk reception, storage and treatment equipment (around 2000 litres per hour) together with plant of a similar scale to make butter, anhydrous milkfat, cheese, casein and milk powder.

Bill McGillivray, NZDRI Director during the early days of the WPC project in the 1970s.

Operational flexibility and the ability to measure and record process data were built in from the start. The space was sufficiently generous that other pilot scale equipment could be installed and operated on a temporary or semi-permanent basis. Process staff members were employed on a permanent basis under the control of the manager of the processing hall , who was a registered dairy factory manager. While professional staff at NZDRI set the experimental programme, product technologists, who reported both to their NZDRI professional and to the processing hall manager, controlled actual operations. Thus the Institute was essentially the research and development arm of the New Zealand dairy industry.

In 1969, the beginning of the WPC story, NZDRI had three discipline-based departments: chemistry, microbiology and engineering. This was a legacy of its early organisation for the study of cheese and butter manufacture. Investigators would draw on resources from these departments as required, to assemble project-specific cross-disciplinary teams. In mid 1971, however, NZDRI director Bill McGillivray reorganised the staff into product or function-oriented sections within two broad divisions: fundamental research and applied research. The new structure recognised two strands of endeavour – an academic lineage, based firmly in a disinterested scientific tradition, and a commercial applications imperative, directed at innovation and enhancement of New Zealand's dairy product manufacturing and marketing.

Wayne Sanderson, deputy director of NZDRI during the 1970s.

Wayne Sanderson, who, during the 1970s, was deputy director in charge of the applied research division, recalls the importance of McGillivray's role at that time:

> Bill McGillivray had a strong vision of how he thought the NZDRI should develop, trying to increase the interaction with the individual dairy companies but also trying to maintain an arm's length from the Dairy Board (who, of course, provided the Industry funds). He did not like the idea of the Dairy Board dictating R&D direction. He fought

> strongly to maintain as much government funding as possible so that the NZDRI maintained it's 'independence'. On the other hand he was a visionary. While a strong academic and 'pure' scientist himself, he was responsible for the NZDRI's growth into new product and process development. He had the political skills to negotiate with all of the stakeholders and to convince them of his vision. He strongly supported new ideas and I believe that is why New Zealand became one of the world leaders in a number of new technologies. He was prepared to get the funds and to back his staff to develop these new ideas.

The applied research division was expected to respond to both the needs of dairy companies and the demands of the markets. These needs and demands were identified in the never-ending interplay between NZDRI managers and their counterparts at the Dairy Board, and people in the manufacturing companies. NZDRI staff members were required to be well informed about scientific and technical innovations in their field, wherever they might occur, and to identify and assess any new technology of potential value to the industry. This could lead to the purchase or lease of conceptually-new laboratory or pilot scale equipment.

It was at the time of the reorganisation, mid-1971, that my own close association with the whey protein concentrate project ended when I became leader of the milk powder and drying section. Ken Kirkpatrick was appointed head of the whey products group a little before installation began of the first commercial scale WPC plant, at Waitakaruru. When Kirkpatrick moved to Chicago in 1973 as technical manager for the newly formed New Zealand Milk Products, his role was taken up by Kevin Marshall. While the three of us worked together on other projects over the years, launching the whey protein concentrate project was our first alliance and overseeing the writing of this book has been our final collaboration.

CHAPTER 2

WHEY: CHALLENGE AND OPPORTUNITY

DAVE WOODHAMS

Milk is a complex liquid, the end product of aeons of evolution since the first species of mammal developed the capability of feeding its young through a mammary gland. Although the composition of milk varies considerably among species, the various components tend to be very similar and they provide a highly nutritious food for the growing infant mammal. Fats, proteins, sugars (almost entirely lactose) and minerals are all present in milk, in various combinations and concentrations.

In this book we are concerned almost wholly with cows' milk ('bovine milk'), and only peripherally with human milk, although the differences between the two are intimately connected to the whey story.

The nature and composition of milk and whey

In basic terms, milk is an emulsion of small milkfat globules suspended in skimmilk, which is mostly water. If milk is left to stand, the fat globules tend to rise to the top layer as cream. Skimmilk is what remains after the cream has been skimmed off. Skimmilk itself is a suspension of very tiny particles (micelles) of casein (a protein), plus soluble proteins (the whey proteins), lactose and minerals that are dissolved in the water. Butter, made from cream, is about 80 percent fat. Cheese, made from wholemilk, is rich in both protein and fat, (around 30 percent of each) while casein, made from skimmilk, is mainly protein.

The dry solids in whey, the by-product from the manufacture of the cheese and casein product groups, consist mainly of lactose (around 70

percent), with the remainder being protein, minerals and a few minor components.

In the early days of the manufacturing dairy industry, milk was used largely for two products: butter or cheese. Milk for butter was separated into cream and skimmilk in a mechanical cream separator. Farmers supplying butter factories often did their own separation on the farm and sent only cream to the factory. This was particularly necessary when the farm was some distance from the factory over gravel country roads. The skimmilk from farm separation, containing almost all of the protein, lactose and minerals in the original milk, was usually fed to pigs, which were kept on the farm to provide a monetary return from this otherwise wasted by-product of butter production.

Suppliers to cheese factories delivered wholemilk to the factory, as my uncle did in 1947. The supplier might take the whey by-product back to the farm for feeding to pigs. This whey contained lactose, minerals, very little fat and about 20 percent of the proteins in the original milk. Surplus cheese whey not taken for pig feeding was perhaps sprayed on to pasture near the factory but, more likely, was discharged into an adjacent waterway.

This pattern of operations, conditioned as it was by severe limitations on the easy transport of large quantities of wholemilk, was almost universal until the advent of the milk tanker in the 1950s, which permitted fewer and larger butter and cheese factories to develop.

Wholemilk delivery in 2014 at Fonterra's Whareroa manufacturing complex in Hawera.

Proteins in milk

The proteins in milk are divided into two broad classes: casein proteins and whey proteins. The casein class is that which coagulates in the presence of rennet or acid, either separately or together. The whey proteins do not coagulate under these conditions.

The acid conditions necessary for coagulation in the manufacture of casein in the absence of rennet can be brought about either by fermentation of some of the lactose with starter bacteria (a process that was unusual in casein factories outside New Zealand), or by the direct addition of acid. The wheys produced using these processes are called acid wheys because of their relatively higher acid content (pH less than 5.1).

It is the whey proteins that are at the heart of our story.

The composition of wheys

Milk direct from a cow varies in composition depending on the breed and nutritional status of the animal, and on the stage of the season, which in New Zealand is between July and May. The composition and properties of wheys also vary, not only due to the stage of the milking season, but also, and more importantly, because of differences in the product and process from which they are derived. As a consequence it is impossible to be precise with comparative composition data. Typically, however, whey contains 6.5% solids; 4.6% lactose, 0.7% total protein (0.5% true protein)*, 0.6% ash and traces of milkfat, vitamins and minor compounds. Broadly speaking there are four distinct classes of whey:

1. **Rennet casein whey:** a sweet whey derived by the treatment of skimmilk with rennet enzyme. It is distinguished by its almost neutral pH (around 6.6), its low mineral or ash content, its full complement of lactose, and the presence of the peptide fragment glycomacropeptide, produced by the action of rennet on κ(kappa)-casein.
2. **Cheese whey, typically cheddar cheese whey:** a sweet whey derived from the treatment of wholemilk with rennet, assisted by bacterial fermentation. It is distinguished by its slightly acidic pH (around 5.9), its slightly higher mineral content than rennet casein whey, the fact that a small amount of the lactose has been consumed,

*There are two protocols for analysing and reporting protein content in milk and dairy products. They are reported as 'total protein' and 'true protein'. The difference is of more importance for whey than for other products and is discussed in the glossary on page 251, under 'protein analysis'.

THE ACTION OF RENNET

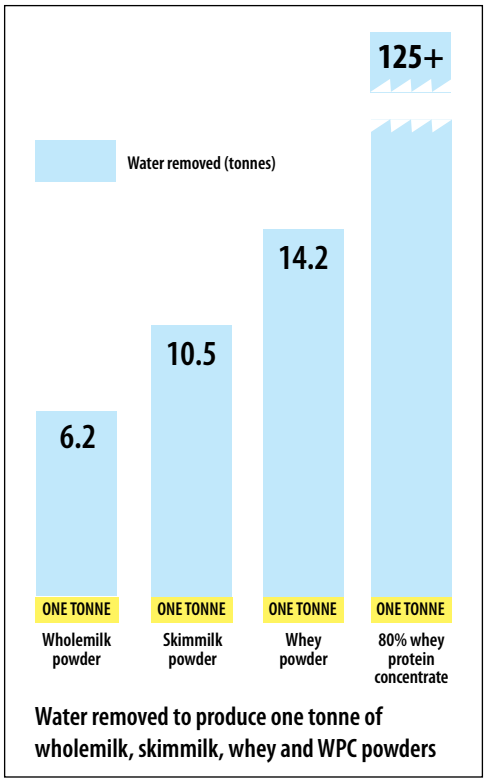
Rennet contains an enzyme which is naturally formed in the abomasum, or fourth stomach, of the young calf. Rennet was commonly used in the past to make junket. The enzyme in rennet used to be called 'rennin', but is now more correctly known as 'chymosin'. Historically, it was extracted from calf vells derived from unwanted young bull calves sent to early slaughter but in recent times an equivalent product has been derived from microbial sources.

At neutral pH, chymosin cleaves a positively charged peptide chain from κ-casein, one of the casein group of proteins. This deprives the casein micelles of their normal protection by the mutual repulsion of the like electrical charges on their surfaces and they become susceptible to coagulation and precipitation in the presence of calcium, which is plentiful in milk. It also results in the release of a soluble protein-like fraction into the serum: the so-called 'glycomacropeptide'.

When cheese is made, the action of rennet is supplemented by fermentation with starter bacteria. These bacteria produce lactic acid from lactose during the initial stages of cheese-making and later go on to play a large part in the development of flavour in the mature cheese. When rennet casein is made from skimmilk, rennet is the sole agent used to provoke coagulation. The wheys produced from these two typical processes using rennet are called 'sweet wheys' because of their relatively low acid content (pH greater than 5.6).

the presence of the glycomacropeptide fragment and the residual presence of fat, or lipid content. Other cheese wheys from gouda, swiss and mozzarella cheese manufacture, will be less acid but otherwise similar in nature.

3. **Lactic casein whey:** an acid whey derived from the manufacture of casein by bacterial fermentation of skimmilk. It is distinguished by its acid pH (around 4.5), its higher mineral content and reduced lactose content when compared with cheese whey.
4. **Mineral acid casein whey:** an acid whey derived from the manufacture of casein by the addition of a mineral acid (in New Zealand typically sulphuric acid) to skimmilk. It is distinguished by its acid pH (around 4.5), its higher mineral content and its full lactose content.



Water removed to produce one tonne of wholemilk, skimmilk, whey and WPC powders

Common properties of wheys: water and pollution potential

A key point about all wheys is that they contain a very large amount of water that has to be removed to produce dry whey solids.

As shown in the graph on this page, making one tonne of a straight whey powder requires the removal of 2.3 times as much water as making a tonne of wholemilk powder and 1.3 times as much water as making a tonne of skimmilk powder. Clearly whey powders are substantially more costly to produce than milk powders. At the same time, the market value of such whey powder is considerably lower than those for the milk powders, so its production is not very rewarding.

Making one tonne of a more sophisticated whey protein concentrate (WPC), that contains 80 percent protein, requires the removal of well over 125 tonnes of water.

The second common point is that, in spite of their very dilute nature when considered as feeds for processing, their potential for pollution (measured as the biochemical oxygen demand, or BOD) if discarded into a waterway is very high. In the worst case, if whey is disposed of into a stream with insufficient water flow, the oxygen needed for the biological decay of the lactose particularly, but also of the proteins, can exceed the capacity of the waterway to provide it. Subsequent decay can then become anaerobic, causing unpleasant odours and the death of water-borne creatures.

Early whey processing

The first product made in commercial quantities from whey in New

Zealand was lactose, also known as milk sugar. It was made by the New Zealand Lactose Company at Edendale, beginning in 1914. This company has continued under a variety of names and ownerships until today, when it produces crystalline lactose for a variety of end uses, from pharmaceutical to industrial. It does this now, under the Fonterra name, at two major sites: Edendale and Kapuni. Before 1969, the main by-product from the lactose crystallisation process from whole whey was 'mother liquor', which found a ready market as a protein-rich feed for stock.

ACID COAGULATION

In the absence of rennet, more acidity (a lower pH) is needed to destabilise the casein micelle. In natural milk the stability of the tiny casein micelles is maintained by electric charges on the micelle surface. In the presence of increasing acid concentrations, the number of negative electrical charges on the micelle surface is reduced until the micelle surfaces reach overall electrical neutrality, at which stage the micelles no longer repel each other. At this so-called 'isoelectric point', in the vicinity of pH 4.6, coagulation occurs.

Historically, the immediate predecessor to WPC was an insoluble whey protein product marketed as 'lactalbumin' and used as a nutritional supplement in cereal products. A brief history of the development of continuous manufacture of this product in the 1950s by Don King and Ted Richards at NZDRI, together with an account of the later uses of the product, can be found in Chapter 9.

Lessons the industry learned from this product were that whey proteins had a value beyond that of stock food and that whey processing imposed a new set of disciplines on the manufacturer. With cheese and butter manufacture, a high value raw material was converted into high value products with relatively low capital-cost equipment. However, in the case of lactalbumin, even though the product could generate an acceptable return on capital expended, whey was a low cost raw material that required a high capital investment to extract value from it. Farmer-directors were starting to get accustomed to the level of investment necessary to process whey profitably.

During the 1960s Roy Leighton at NZCDC Waitoa used ion exchange to produce demineralised cheese whey as an ingredient in

infant formula products made under contract for export customers.

While making lactose, lactalbumin and infant formula was useful and profitable, it was not enough to meet the challenge of the coming decade.

The challenge

By 1969, on the eve of making soluble whey protein concentrates, whey had become a major challenge to the industry for a number of reasons:

- There was too much of it at several major production sites and too few opportunities for doing anything useful with it.
- If not treated or processed it had the potential to be very highly polluting, 100 litres being said to have a BOD equivalent to the domestic waste from about 60 people.
- It was very dilute as a feedstock for processing, being 94 percent water.
- The true protein component, the fraction of most commercial interest, amounted to only about 0.5 percent of the whey volume.
- Other than their nutritional value, our knowledge of the properties of the whey proteins was poor.
- The inability to process whey into anything economically worthwhile threatened the commercial viability of casein manufacture and the product mix of the industry.

It was time for a new direction. The enabler would be ultrafiltration, a new technology that was emerging from research laboratories in America and Europe.

The opportunity: ultrafiltration

I recall reporting to the New Zealand Dairy Research Institute (NZDRI) in 1968, after attending the annual conference of the (US) Institute of Food Technologists, that a new process called 'ultrafiltration' looked interesting for the dairy industry. However, at the time I was totally involved studying spray dryer performance and took no further interest in ultrafiltration until October 1969, when the NZDRI's director, Bill McGillivray, asked me to take part in a secret project that aimed to produce whey proteins in a soluble form from acid whey.

Separation processes exploit differences between the entities to be separated. Traditional lactalbumin was harvested by making the protein insoluble and separating it from the soluble lactose and minerals by

filtration. Ultrafiltration, the method of separation that I recommended for recovery of soluble whey proteins, relies on differences in size between the molecules of lactose, minerals and water on the one hand and the protein molecules on the other. While protein molecules are very small, they are around 40 times larger (and more) than those of the lactose, minerals and water. Ultrafiltration is molecular sieving on a commercial scale.

The actual means of separation is a synthetic membrane that is permeable to the smaller molecules but, because the pores in the membrane are too small, it is impermeable to the protein molecules. Under the influence of pressure, some of the water, together with its share of lactose and minerals, flows through the membrane. This solution is known as 'permeate'. Left behind is a liquid that is rich in soluble proteins, the components that are held back by the membrane. This solution is normally known as the 'retentate', sometimes as the 'concentrate'.

The retentate is what we were interested in, because it contained whey proteins in soluble form.

In the early days – and 1969 *was* 'early days' in membrane technology – the synthetic membrane material was made of cellulose acetate, coated on to the inside of permeable tubes which gave physical support. Cellulose acetate was once the base material for movie film, having replaced its forerunner, the rather unstable cellulose nitrate, in the 1940s. As a membrane material, however, it was rather delicate so normal dairy company cleaning chemicals – hot caustic soda solution and chlorinated sanitisers – could not be used. Later membranes were made of more robust materials but even so, cleaning them has remained an activity calling for special care.

Two membrane properties are commercially important:

The first is *selectivity,* which is the ability of the membrane to distinguish between molecules on the basis of their size. A membrane's ability to retain protein molecules in the retentate and to allow smaller molecules to pass into the permeate is measured as the 'rejection coefficient' of the membrane for each particular species. An ideal membrane would have a rejection coefficient of 1.0 for proteins and coefficients of 0.0 for each of lactose and minerals. The actual rejection depends on the size of the pores in the membrane and the molecular size of the component. Although the pore size in commercial membranes is not uniform, the difference in size between the proteins and the other

components is so great that separation performance is quite close to ideal.

The second important property is *flux*, which is a measure of the rate at which permeate flows through the membrane. It is recorded in litres of permeate per square metre of membrane area per hour (lmh). The actual flux at any specific time depends on a number of external variables such as the pressure difference across the membrane, the protein concentration next to the membrane, the temperature of the solution (which affects its viscosity) and the amount of fouling material that may have built up on the membrane surface. In terms of the membrane itself, the flux, when measured with pure water, depends on the size and number of pores and on the thickness of the membrane. The larger the pore diameter, the greater the flow of permeate under otherwise identical external conditions. However, the thicker the membrane (i.e. the longer the distance within the pore) the lower the flow will be.

These two properties compete with each other. On the one hand, the smaller the pores are, the better is the rejection of protein molecules but the smaller is the flux. On the other hand, a thinner membrane allows a greater flux but its ability to withstand pressure is reduced and pressure is the driving force for permeation. This conflict is resolved in practice by manufacturing the membranes with a very thin skin, with tiny pores, supported by a thicker base with larger pores to facilitate hydraulic flow. This is known as an 'asymmetric membrane'. Its structure is fundamental to all commercial membrane separations.

Membranes are supplied in three basic forms. In the order we saw them used in New Zealand, the first were coated on the inside of porous tubes (tubular design), next were flat sheets stacked up and compressed (plate and frame design), and finally there were flat sheets rolled into spirals, like sponge rolls. (These three formats are examined in greater depth in Appendix I.)

An early process development was the change from batch to continuous operation. In batch mode a volume of whey is pumped through the membrane plant and the slightly concentrated retentate returned to the feed tank. Over time, as permeate is removed, the level of whey in the feed tank (the recirculated retentate) reduces, the protein concentration increases until the desired value is reached and the product is then ready for further processing or drying. A variation of batch processing is semi-batch operation where initially the volume of permeate removed is replaced by the addition of unconcentrated

whey to the feed tank. In the continuous mode, while most of the slightly concentrated retentate is recirculated through the membrane assembly, a portion is fed forward from the first membrane module, or 'stage', into another module that in turn feeds a third module, and so on. This mode is also referred to as 'stages-in-series'.

The natural limit to the protein concentration in the retentate that can be easily handled in a commercial plant is around 10 to 12 percent, at which stage the total solids content is around 20 percent. Thus, in the absence of any other action, the protein content of the dry product is about 50 to 60 percent. It was early recognised however, and indeed mentioned in my first report in November 1969, that higher protein contents could be obtained by adding water to the retentate and removing it as permeate, together with more of the smaller molecules, resulting in dry products with much higher protein contents. The addition and removal of water is known as diafiltration and is a very powerful tool in the manufacture of high-performance WPCs.

The first of our commercial plants, built as described in the following chapter, had tubular membranes and was operated in semi-batch mode. The second, third and fourth plants were of plate and frame construction and were designed for operation as stages-in-series with diafiltration. Later plants were fitted with spiral membranes and were also designed for continuous operation as stages-in-series with diafiltration.

A more detailed description of ultrafiltration and its development for whey protein processing from early days in 1970 to its comparative maturity reached in the mid 1990s is in Appendix I.

New Zealand Dairy Research Institute's new building, opened in 1965.

CHAPTER 3

EXCITEMENT AND SETBACK: THE COCA-COLA YEARS

1969–MID 1970s

KEVIN MARSHALL

Kevin Marshall *graduated in chemical engineering from Canterbury and joined NZDRI in 1963. He completed an MSc at Birmingham University and a PhD at Massey. He eventually headed the NZDRI whey and effluent sections. In 1982 he joined the Dairy Board, later becoming group director of R&D and CE of NZDRI. He spent two years as MD of ViaLactia Biosciences. He had various roles in the International Dairy Federation including president of the coordination committee.*

The New Zealand Dairy Board's annual report for 1968/69 states that "Pilot scale studies of the use of ultrafiltration for the recovery of proteins from whey have been undertaken."

This bland, if factual, statement gives no sense of the exciting roller coaster ride that started in 1969 and would transform the processing of whey in the New Zealand dairy industry.

Beginnings:

The customer

In September 1969, Alex Malaspina, the manager of quality control and development of The Coca-Cola Export Corporation,* sought a meeting with Neville Jones, the Dairy Board's marketing director. Malaspina was impressed by the nature and extent of the New Zealand casein industry, and the research facilities available to help develop products to meet buyers' needs. He revealed to Jones details of a new, soluble whey protein product (later known as whey protein concentrate or WPC) under development by Coca-Cola to provide nutritional enrichment of a new line of beverages. The acid beverage (pH 3) was to be carbonated and have protein added. This information was highly confidential and indeed the New Zealand dairy industry would not mention Coca-Cola by name until many years later.

*Abbreviated henceforth to Coca-Cola.

Malaspina was looking for a reliable and consistent source of this protein from casein whey – perhaps 10,000 tonnes per year. This was an exciting prospect and it is not surprising that Jones was very interested and agreed to remain in touch.

The New Zealand dairy industry did not know how to produce such a product. The only whey protein being made then was a heat-precipitated product known as lactalbumin. This was an insoluble product that was described as 'brown nutritional sand'; it was quite unsuitable for use in a beverage.

Alex Malaspina, Coca-Cola's quality control and development manager, whose approach to Neville Jones in 1969 kicked off the New Zealand cooperative dairy industry's involvement with ultrafiltration and whey protein concentrates.

Selection of ultrafiltration

The Dairy Board wasted no time in following up this enquiry. Within a month of Jones's conversation in New York, Don King (chief engineer at the New Zealand Dairy Research Institute (NZDRI)), asked Dave Woodhams to investigate. Woodhams, an NZDRI chemical engineer, was then completing PhD studies in food science at the University of Wisconsin. He was seconded to the Dairy Board and asked to visit American commercial and university sites to investigate and report on potential methods of producing WPC. Following are excerpts of Woodhams's handwritten report:

> In the past eight days I have worked full time on the problems associated with obtaining soluble whey proteins [WPC] from whey with very low mineral residues and reduced lactose contents.
>
> The requirement is to produce large quantities of soluble whey proteins in 1971, having a protein-ash ratio of greater than 10:1 and a protein-lactose ratio of greater than 1:2.
>
> Thus the minimum specification produced would have a protein content of about 30 percent.
>
> A complication is the requirement of the client company for a minimum quantity of 110lb (50kg) protein per day over an extended period of time for marketing trials, production of this quantity to begin with minimum delay. It is the client's intent to install a small-scale plant in South America at a convenient location for production of this market-test quantity close to the reprocessing location.

Neville Jones, the Dairy Board's marketing director in 1969.

Woodhams and Malaspina visited sites in Mayville (WI), Minneapolis (MN), Boston (MA) and San Diego (CA) during October 1969. They looked at ultrafiltration, reverse osmosis, gel filtration/chromatography, transport depletion, electrodialysis and

advanced lactose crystallisation methods. The report discussed the processes in detail, with flow sheets and mass balances.

Woodhams recommended that the industry proceed with ultrafiltration because he considered the technique was technologically more flexible, that the process was inherently one of concentration rather than dilution, that the protein product specification was comfortably within its capabilities and – incidentally – there was a greater potential to expand the technique to other non-whey uses.

He recommended an Abcor (a Cambridge, MA company, now Koch Membrane Systems) ultrafiltration unit, based on his assessment of the company's potential to develop an efficient and sanitary process. In his view, their technical capabilities were superior to those of Havens, a competing company in San Diego.

Commercial pressure

In the meantime, Malaspina continued to push for material for a market appraisal as soon as possible and was concerned that New Zealand might not be able to provide enough product if the early market development trials were successful. Coca-Cola had few appropriate resources itself and was relying on New Zealand's technical and research facilities and resources. NZDRI director Bill McGillivray assured him that while NZDRI had a group working on modifying casein for a wide range of applications including beverages, another group was working specifically for Coca-Cola on whey protein concentrate.

At the same time Alvin Woolven, general manager of New Zealand Cooperative Dairy Company (NZCDC) and an NZDRI board director, was expressing interest in the process. He was particularly interested in the protein-free permeate which could be a good source of lactose for infant formula manufacture, and for standardising the protein content of skimmilk powder with a consequent improvement in yield.

In light of these commercially driven pressures, McGillivray urged Jones to convince the Dairy Board to fund a pilot ultrafiltration plant at NZDRI.

The Dairy Board accepted this recommendation, and on 3 November 1969 an order was placed for an Abcor ultrafiltration plant (UF-300S). Abcor planned to ship the plant by the end of the year.

New Zealand Dairy Research Institute:

Preliminary experiments: proof of principle

Ken Kirkpatrick did early trials at NZDRI with a laboratory scale Amicon ultrafiltration cell and showed it was possible to recover the protein from whey and produce a soluble whey protein concentrate (WPC). Kirkpatrick was an enthusiastic researcher and attempted to operate this laboratory unit around the clock. I recall his leaving an NZDRI end-of-year function to tend the unit, although his desire to avoid dancing may have been an added incentive.

The New Zealand Dairy Research Institute in 1978. At the rear of the complex, under the 'sawtooth' roof identified by a red dot, is the processing hall where the WPC pilot plant was installed.

Pilot plant

Abcor's plant was installed in the NZDRI processing hall and commissioned in March 1970 – only six months after the first request from Coca-Cola. It was a remarkably short period in which to choose and install a new technology.

At that time we thought* it was the largest (30m^2) ultrafiltration plant processing whey in the world. NZDRI was at the leading edge of the technology and over the next few months, together with Abcor, much was learned about the ultrafiltration of whey, the good and the bad. An Abcor executive would say later that if something was going to go wrong it would go wrong at NZDRI.

*While we believed this at the time, we later became aware that the New Zealand Lactose Company had been operating a commercial-scale WPC plant since March 1970. (See Appendix II.)

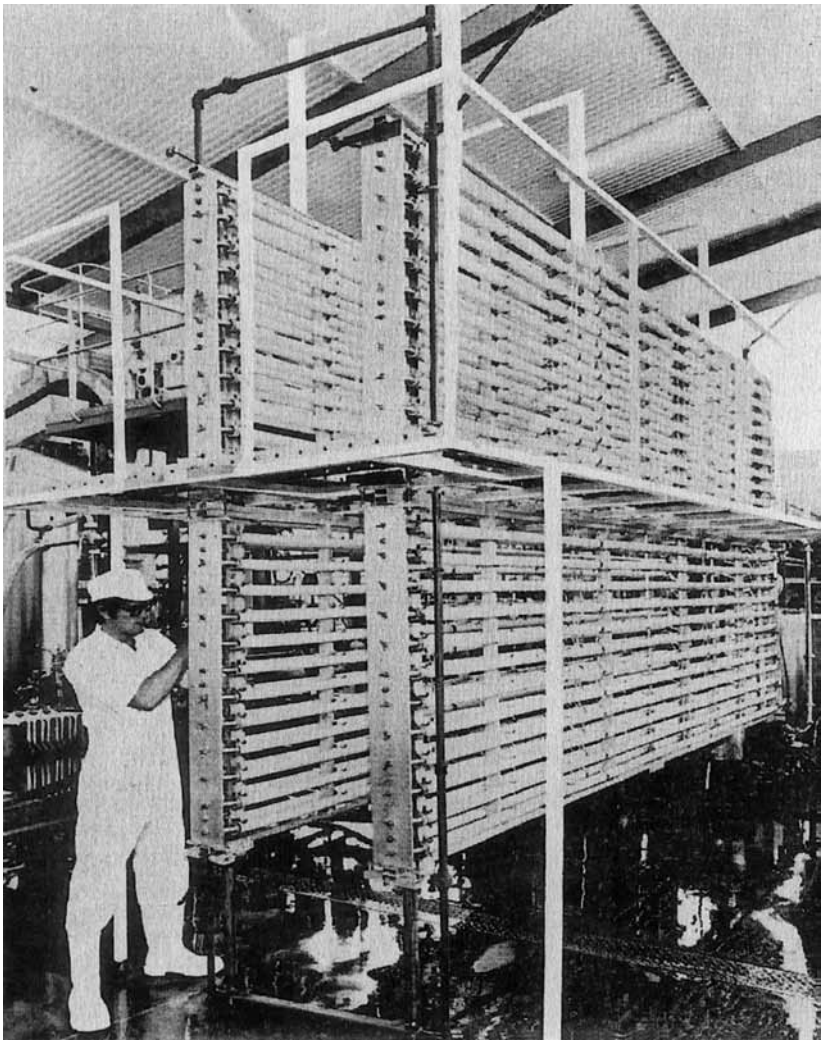
Bill Eykamp (Abcor) remembered the early days of Abcor and this pilot plant:

Bill Eykamp at the source of bovine milk he normally dealt with at a rather more technical level. Eykamp worked for the American Abcor company that supplied the original ultrafiltration plant at NZDRI.

> When I joined Abcor in early 1969, we had a tiny membrane group in a small company founded to exploit gas chromatography on an industrial scale. (We were many decades ahead of our time.) Even though membranes were an afterthought, the unit was staffed by several brilliant, if erratic, PhD chemical engineers who needed rounding up. I was hired as cowboy-in-chief.
>
> One condition of my joining Abcor was that I would do no contract research. "Real world only" was my rule. That is quite confining in a small cash-constrained company, but it seemed to me that pursuing opportunities attractive to customers with cash was the way to build something with value. I was young, and said frequently to my wife, "I can afford to be wrong." We certainly weren't rich, but we both knew how to live low on the hog.
>
> One thing Abcor had in abundance was brainpower. Our overall employee list was 40 percent chemical engineering PhDs, all but one from MIT.
>
> Soon there came a conference, attended by a few of us, when our then vice president, Bob Timmins, met the NZDRI director, Bill McGillivray. Bob saw great potential, and cleared all commitments to be attentive to Bill's needs.
>
> What we had was primitive but promising. Bill became convinced that we might be able to help him, and he hijacked Dave Woodhams from his graduate programme to come check us out. Dave gave us a passing grade, and we began in earnest to learn everything we could about acid whey. Our source of raw material was a distant cottage cheese factory that made regular deliveries in our area. The container was a 20 litre polyethylene bucket known forever after as 'whey buckets'. A few of them can still be found around my home.
>
> Soon, we got an order for a 'pilot plant' to be installed in Palmerston North. It was described as the largest ultrafiltration plant in the world and the fact that it was pilot scale made us salivate.
>
> Ultrafiltration plants have lots of piping and pumps, process stuff which was not, in principle, difficult for us. However, sanitary pumps and pipes were new territory for us, and we asked our share of dumb questions getting the kit together.
>
> Eventually it got constructed and shipped – except for the membrane tubes. During the hardware construction phase, we had one of the not-infrequent total lapses in our ability to cast membranes in the tubes.

"We can always airfreight," we said, and we even convinced NZDRI that it would be preferable, without ever a hint of its necessity. The next few weeks were frantic, but eventually the magic returned and the membrane casting process was restored.

Membranes in the 1960s were primitive. Ours were tubular, which were robust and predictable, something our embryonic competitors lacked. They were also far more scalable than the alternatives, and one could actually imagine a very large plant built from tubes. 'Robust' turned out more potential than factual. Our membranes were made of cellulose acetate, and were cast on porous sintered polyethylene backings (Porex). The backings could only be made about 1400mm long, and were 25mm internal diameter. The sintering process was



Technician Graham Dickson with the pilot plant in the NZDRI processing hall, 1970. The filter press discussed on page 44 was on the right, behind Dickson.

always a work-in-progress, and insufficiently consolidated backings could rupture, spectacularly. The NZDRI plant was built by putting three tubes in series, and then connected through a stainless steel U-bend to the next 4200 mm string. The Porex tubes were surrounded with cellulose acetate butyrate (CAB) clear tubing to collect permeate. All this was held on an open rack with tool clips. I still have a few. The CAB tubing was fitted with a nipple to which Tygon tubing was attached, connected together in series then in parallel, to collect permeate. It certainly looked more like a Kitty Hawk than an F-22.

Finally, the whole thing got shipped and it was time for start-up. I was scheduled to go. About a week before departure, my boss, Bob Timmins said that we really had too much going on for me to be spared, so who should go instead? I looked him straight in the eye and said that no one else could do it. That was only somewhat influenced by the fact that Australia and New Zealand were among the few regions I had missed in my global perambulations.

Betty McGillivray, wife of NZDRI Director Bill McGillivray, who suggested using an enzyme soaker to clean the experimental whey ultrafiltration plant. The soaker was probably a product called *Bio Luvil*, which at the time was being heavily promoted for home laundry use. It did the job, though it was soon supplanted by industrial grade enzyme cleaners.

New Zealand in 1970 was a very different place from what it was 20 years later. New Zealanders were still living in an automotive museum that prosperity was about to change dramatically. For me, it was instant love. I experienced incredible hospitality (courtesy of the Woodhams in the first instance, and the Marshalls soon thereafter), and worked with dedicated, hard-working, highly intelligent collaborators in a supportive environment whose decks had been cleared for our trials. The beer was a plus, when we had time. Hogget was a new and likable experience.

So we got the monster unpacked and installed. The first trials were a shock. The pumps were wrong. I had done detailed calculations on the expected pressure drop, but my colleagues had done detailed experiments, indicating I was wrong by about half. When it turned out that I had been right, our pumps were exposed as being drastically undersized. I called home for advice, and we all agreed that shipping very heavy pumps with rush order premium and airfreight was the only solution. The new pumps worked fine, but any illusions of profitability were now gone.

Finally, we started, first on water, then on whey. The excellent operations staff got more training than anyone wanted on how to fix ruptured tubes. The nipples broke off the CAB shells with stunning regularity – one of very many weak links. In fact, this chain had no strong links.

Then, after the first long whey run, how do we get it clean? I recall Dave (Woodhams) and I at the local grocery acting on a suggestion by Betty McGillivray, the NZDRI director's wife, going through the laundry counter offerings looking for enzyme pre-soaks. It worked like

magic – the fouling layer was dissolved, and the membranes cleaned up nicely for the next trial.

Things had to be figured out as we progressed.

I returned to the States bubbling with enthusiasm for New Zealand and the quality and dedication of those whom I had gotten to know, but burdened by the inadequacy of our product and our inability to truly meet the coming challenges. It was my responsibility to fix it, which was as it should be.

Despite these early problems with the ultrafiltration pilot plant, over the next few months, using casein whey from the Manawatu Cooperative Dairy Company at nearby Longburn, the NZDRI staff were able to produce liquid whey protein concentrate and dry it to a powder without significant denaturation or loss of solubility.

In parallel with this early work at NZDRI, Coca-Cola installed a Havens ultrafiltration pilot plant in Brazil to produce whey protein concentrate from cheese whey for market testing of a protein-fortified beverage. Kirkpatrick was seconded to Coca-Cola to help them with the

Ken Kirkpatrick with the experimental Havens UF plant installed by Coca-Cola in Brazil. This was a single pass unit, rather than batch. The design allowed the Coca-Cola team to easily adapt to the use of diatomaceous earth filtration (regularly used in Coca-Cola bottling plants for water treatment) and cation exchange, also used in some processing for other Coca-Cola beverages. The final resting place of the plant was a dairy in California.

process and learn more of Coca-Cola's requirements. This Brazil plant was at this time producing small quantities of whey protein concentrate solutions for experimental beverage formulation and stability trials. The latter focused particularly on flavour, clarity, and sediment. A particular problem was the formation of a fatty ring (neck ring) around the surface of the beverage in the bottle.

Whey pre-treatment

Kevin Marshall in his early days at NZDRI.

Whey was pre-treated by centrifugation before ultrafiltration because Coca-Cola wanted a product that would leave no sediment in the bottled beverage. The trials in Brazil showed it was also necessary to remove as much lipid material as possible from the whey to preclude the subsequent formation of the fatty ring in the beverage. The milkfat material was not entirely removed by centrifugation and was concentrated during the ultrafiltration process. We also suspected that if the whey was brilliantly clear there would be less fouling of the membranes. It was decided that more stringent pre-treatment of the whey was needed to reduce the amount of insoluble material (casein fines, denatured whey proteins, residual milkfat and bacteria, both dead and alive).

I was undertaking PhD research *(The production of lactic acid from whey by continuous culture as a possible means of waste disposal)* at NZDRI. My PhD was the lowest priority project on the NZDRI list and, when more resources were needed for ultrafiltration and whey protein concentrate, I joined the project with an early task to investigate pre-treating whey to remove suspended material. As a result of such diversions my PhD took eight years to complete.

The NZDRI processing hall already had pilot-scale centrifuges and a plate-and-frame filter-press available. Within 13 days of the decision to improve the pre-treatment of the whey, we were producing crystal clear whey using centrifugation followed by diatomaceous earth filtration.

Upstream process changes

During this time we learned that the ultrafiltration characteristics of the whey and properties of whey protein concentrates were markedly affected by the quality of both the raw milk and the whey – it was no longer acceptable to treat whey as 'a waste

product'; it needed to be treated as a product in its own right with quality controls at least as stringent as those for casein.

In fact the tail started to wag the dog and major changes were made in casein-making procedures, including the development of fundamentally different bacterial starter systems for lowering the pH of the milk. This was a prelude to the use of single-strain starters in commercial casein making.

Silicates in the water and the use of antifoams (e.g. glycerol monostearate) during casein manufacture seriously compromised the ultrafiltration operation. We also learned that it was desirable to leave the membranes, when not in use for more than three days, with a bacteriostatic agent in the water – without such an agent deposits formed on the membranes and were very hard to remove.

Redesign of the pilot plant

The pilot plant, as originally installed, suffered significantly from mechanical breakage of the nipples on the CAB shells, and tube ruptures. The latter resulted in loss of the precious retentate (the concentrated protein solution which does not go through the membrane). Increasingly, problems were also experienced with bacterial growth in the retentate at the temperatures (16-20C) and the long batch times (24 hours) used then.

Theory also indicated that the rate of permeate flow through the membrane (flux) would be increased if higher temperatures were used.

It was decided to operate at up to 55C because this temperature inhibited growth of most microorganisms (in our system, predominately lactobacilli), particularly given the acid pH of the whey.

The CAB shells would not withstand this higher temperature so it was decided to redesign the plant.

The outer CAB tubings were removed and the ultrafiltration (UF) tubes were stacked in a disused cheese-making vat. This change minimised the mess when a tube ruptured and made replacement of the tubes much easier. This so-called 'tub plant' also made collection of permeate simple.

The higher temperature led to a higher flux with consequent halving of batch times and considerable reduction in the potential for microbial growth. There were also advantages in cleaning – the membranes did not foul as quickly. The disadvantage was a decrease in the membrane life. Later experiments showed that the higher

operating temperature had no adverse impact on the nutritional quality of the WPC.

The tub plant became the centre of life for the team of researchers striving to produce product for the Coca-Cola beverage trials.

The Abcor tubular ultrafiltration plant was operated in batch mode. It also had a large internal volume, so in order to achieve the required concentration ratio the starting volume was so large we needed to operate the plant around the clock. This was too much for the small permanent staff of NZDRI, so Massey University students were employed to run the plant overnight (see page 48).

George Murphy was a young technician from Abcor who worked on the ultrafiltration project at NZDRI from January 1970 through April

THE IMPACT OF WHEY PRE-TREATMENT

It was very difficult to achieve and maintain raw material quality and microbiological stability during the entire WPC production process – from milk collection, through casein or cheese making, to the final dried WPC. Particularly critical to producing high quality WPC was removal of residual fine particles of curd, milkfat and bacteria from the whey before ultrafiltration. Whey clarification by centrifugation and filtration became the standard treatment, but for higher specification products, even greater clarity was desirable.

In 1971 Jeremy Atteberry patented a clarifying process in America that included adding a calcium solution to whey, followed by neutralisation and heat treatment to remove lipid material.

In 1972, Peter Hobman investigated the Atteberry process at NZDRI with the objective of adapting and optimising it for acid whey (Atteberry had worked with cheese whey). Because acid whey contained relatively more calcium ions, Hobman thought calcium might not have to be added – that neutralisation, followed by an appropriate heat treatment and clarification, could be effective.

The results achieved in the pilot plant were truly remarkable! First, Hobman found that the resulting insoluble material removed by a self-desludging clarifier was extremely stable. It was later identified as a calcium phospholipoprotein complex.

Second, following clarification, the whey was virtually crystal clear and almost colourless, leading the plant operators to erroneously suggest that the pre-treatment had also removed all the whey protein!

of 1971. A colourful character, he was very helpful in the development work and became a lifelong friend of many of the ultrafiltration team, particularly Kirkpatrick, with whom he undertook a number of business ventures in later years.

Success from the pilot plant

The development activity reached a milestone in September 1970 when batch 2260, the first large (50kg) batch of ultrafiltered whey protein concentrate powder was manufactured, using pre-filtered whey. We had produced a WPC of 65 percent protein that met the requirements of Coca-Cola – even though the specifications for the product had constantly changed, particularly in the requirements

Third, the measured flux during ultrafiltration of the pre-treated whey was very high, and the nominal 80 percent protein retentate was unusually translucent, with a brownish tinge. By this time, plant operators were taking wagers that all of the protein had been removed. However, subsequent analysis confirmed that the final WPC powder did contain 80 percent protein.

But the best was yet to come. Analysis and evaluation of the functional properties of the resulting WPC 80 revealed that it had a very low fat content, was completely bland in flavour and had phenomenal whipping properties. To the delight of all concerned, the low fat WPC was an effective egg white replacer and made excellent pavlova (meringue).

One might wonder why low-fat WPC 80 using the Atteberry process took almost 20 years to become a commercial process. The process was uneconomic until further research identified how to manage the yield losses and the market was ready to pay the extra price required.

But as is often the case, lessons from such failures can be valuable. A decade later, Hobman was able use some of the knowledge gained to develop a process to remove calcium phosphate from acid permeate as a pre-treatment in lactose manufacture. The mineral by-product was the genesis of the Alamin milk calcium product, later used in the highly successful Anlene, a consumer product targeting a reduction in osteoporosis.

for clarity and solubility, as Coca-Cola's understanding of what was required for a protein fortified beverage developed. The product was branded Solac.

During this period, the focus was so consistently on producing the quantities of product that were needed for Coca-Cola's trial marketing

FRIENDS FROM FILTRATION

George Murphy

Projects change lives. Bringing people together to develop a new technology has unforeseen implications, like a new road connecting two communities. This is especially true of a high-intensity project like recovering whey protein concentrate by ultrafiltration. Administrators, engineers, chemists, and microbiologists brought their experience to bear on an endless series of questions and problems. But also, a group of Massey University students was recruited to operate the ultrafiltration pilot plant around the clock in NZDRI's processing hall. Most of those students would remain friends for the rest of their lives.

I came from Cambridge, Massachusetts to NZDRI with the Abcor UF-300S pilot plant, arriving in Palmerston North at the start of 1970. Twenty years old and on my first overseas trip, it was an impressionable time and I was fortunate to befriend this group of Massey students. At about the same time, the Dairy Board and Massey University had begun a postgraduate training programme to recruit and train recent science and engineering graduates at NZDRI. The 1969/70 class started its study at the NZDRI not long after my arrival and trained during my time there. I shared a house with two of them (Bill Stead and Malcolm Parslow) for part of my stay.

The student work at the ultrafiltration plant was part time and scheduled to accommodate university commitments; best of all, it was easy. There was plenty of time between data collection points (and in those days data were collected and recorded manually) for chatting, card playing, study, and even, over one night, painting banners for a Mao parade in Palmerston North the next day. I worked days mostly, but also pitched in during evenings and weekends. A spirit of camaraderie prevailed and friendships grew.

Max Parkin, a microbiology student, quickly established himself as the alpha male who organised the work roster. He went on to senior management positions in the New Zealand dairy industry. Along with

in Brazil that almost no effort could be devoted to really understanding the process – customer demands were overriding the need to understand the science and technology. It was not until later, when Max Parkin and George Murphy began experiments with the test rig, that we really started to understand what was happening.

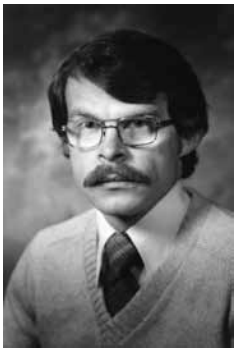
other Massey students Garrick Emms and Doug Wilson, Max could be found playing darts in the public bar at the Majestic Hotel on off hours. John Parks, who was simultaneously working on a genetics thesis, carried on after his shift several nights a week in the nearby bush, finding and tagging hedgehogs by flashlight. Jim Somerville was killed when his car left the road in the Manawatu Gorge, a tragedy for us all.

The feminist movement was gaining steam in those days. Marguerite Tait-Jamieson and Judy MacGibbon were on the roster. John North, a young NZCDC employee seconded to NZDRI, worked the midnight to 8 am shift, with his wife, Tina, at his side. Each morning, they would harvest the previous day's product and clean the plant, getting it ready for the next day's run.

I became lifelong friends with Stuart Loudon, another Massey student. We enjoyed each other's company in Palmerston North, London, Ithaca, New York, Boston and San Francisco. Whenever I returned to New Zealand, I stayed with Stuart and Helen at their Auckland home. Stuart was lost to cancer while this book was in preparation; it is hard to imagine coming to New Zealand and not seeing him.

While my time with the whey project was short compared to many of the contributors to this New Zealand dairy industry success, it was a rich experience. Working around the clock, we were early to the idea of 24/7, now standard operating procedure around the world. My view was from the processing hall floor as a very junior, and not very well-behaved, technician. Startups, shutdowns, replacing blown tubes, sponge balling (a term rich with innuendo) and generally learning stuff that has stood me in good stead to this day.

I am back and forth to New Zealand annually and sometimes more often, for business and pleasure. Almost all my New Zealand friends are connected back to the NZDRI processing hall. And through this book, several old friendships have been reignited, an unexpected and welcome outcome.



George Murphy

Despite this lack of a full understanding of the technology but, confident that all of Coca-Cola's requirements could be met and aware of the continued urgency within Coca-Cola for product, the Dairy Board had earlier decided to build a much larger plant. This was the beginning of even more intense development activity, huge excitement and many frustrations.

Waitakaruru – the first commercial WPC plant

In March 1970 the Dairy Board, in a confidential letter, informed dairy companies that there was growing interest overseas in whey protein concentrate and sought submissions of interest in installing a commercial plant. Support would be available from the Board and NZDRI. The contract was awarded to New Zealand Cooperative Dairy Company (NZCDC).

In September 1970, NZCDC ordered an Abcor tubular batch plant with a design capacity of 200,000 litres per day. The Dairy Board underwrote the plant and total capital outlay in that first year was $590,000. It was installed at the NZCDC's Waitakaruru branch on the Hauraki Plains. The branch had a lactic casein factory that had been converted from a cheese factory.

Other than the fact that it was a lactic casein plant, it is unclear why Waitakaruru was chosen. The ultrafiltration project was considered by the Dairy Board and NZCDC to be highly confidential so it is possible the site was chosen for its remoteness. Also, the staff was made up of relatively young operators who may have been considered more able to cope with a new process. Certainly the manager, Merv Whitehead, was considered to have a flair for training staff. Or it may simply have been the availability of an old storeroom at the plant that could be modified cheaply.

For whatever reason it was chosen, Waitakaruru would become forever engraved on the minds of all involved in the project. It was the cause of a significant amount of travel, trials and tribulations. In many ways it was not an ideal site – hindsight made that clear. There were frequent power cuts. The water pump on the hill often failed and even when it worked, the water supply was inadequate and needed treatment, particularly to remove iron and silicates, which were so damaging to the cellulose acetate membranes. The steam supply was inadequate. The site was remote from a suitable spray dryer. The waste disposal systems were inadequate for the extra

volume of effluent from a large-scale experimental process when breakdowns could be expected.

By December 1970, construction work in the old storeroom was well advanced, and the ultrafiltration equipment was scheduled to arrive in March 1971. Equipment for the quality control laboratory was all on order except for a vacuum oven. There were problems getting an import license for that, because vacuum ovens were being made in New Zealand. We had to go through bureaucratic hoops to prove the locally made ones were unsuitable for our purposes. Those were the days!

Wilson McGillivray, one of the Massey students who had worked earlier on the night shift at NZDRI, was employed as a graduate cadet with NZCDC and appointed as chemist to Waitakaruru. He went to Abcor for three months over the American winter of 1970/71 to see the plant being manufactured and assembled. He worked on the assembly and spent time writing an operating manual.

The design was similar in principle to the pilot plant operating at NZDRI. It was a semi-batch plant comprising 12 modules, operated as two independent units with six modules each. The tubes (2.8m long) were mounted in stainless steel cabinets to collect the permeate that dripped down into a pan.

Eventually the plant arrived and was shoehorned into the refurbished storeroom. A major, unanticipated problem was created by the fall in the floor – normal in dairy plants to permit easy drainage, but not taken into account by the Abcor designers. Despite the best efforts of company and NZDRI staff, the header pipework could not be fitted to the modules. This resulted in a delay of six weeks until pipe welders were available to fix the problem. Welders were generally in short supply and at that time were busy getting other milk plants ready for the start of the new season, with its inexorable milk flow. That was naturally and rationally a greater priority for NZCDC than getting an experimental plant commissioned.

Other problems soon followed. Eykamp, who was back in New Zealand and at Waitakaruru at this time recalls:

> We could not ship the membrane tubes with the cabinets because once again we lost the art of casting the membranes. So we flew the tubes down, but they sat in Singapore for 10 days and grew a really impressive quantity of *Aspergillus niger*. Some was growing right through the membrane. You can imagine the enthusiasm of the customer when I

> opened up those crates! That was only one of many times I was almost deported.
>
> We later found that the water glycerol mixture in which the membranes had been shipped was considerably more dilute than the design specifications and hence lacked the expected bacteriostatic properties.

Based on work at NZDRI, whey pre-treatment comprised a self-cleaning centrifuge down-rated from 50,000 litres per hour to 10,000 litres per hour, followed by two Patterson Candy Ltd Stella candle filters in parallel. In operation, the candles were coated with two grades of diatomaceous earth.

Once the clarifier and filter worked correctly, they produced whey that was brilliantly clear; an ideal feed material for the ultrafiltration plant.

Some months later than scheduled, the plant was commissioned, first with water and later with whey.

During commissioning many tubes failed at the centre joints, with resulting leakage. Other membrane failures occurred as membranes peeled from backings because of another engineering design fault: the inlet/outlet valve opening and closing sequence was wrong, and put the tubes under vacuum.

Major problems also occurred in the casein plant. Following on from experiments at NZDRI, single-strain starter bacteria were being used to produce the acid for casein making because this produced a better quality of whey. These bacteria frequently failed to grow and produce acid and in the morning the casein had not precipitated. These failures were caused by the action of bacteriophage (a virus that infects and replicates within bacteria causing them to die), partially because of the design then typical in casein plants, but also because of a lack of knowledge and experience in the use of these bacteria for large-scale casein making. The casein makers reverted to the normal process of using sulphuric acid to precipitate the casein. These delays in casein making led to a backup of milk, which of course continued to be delivered each day.

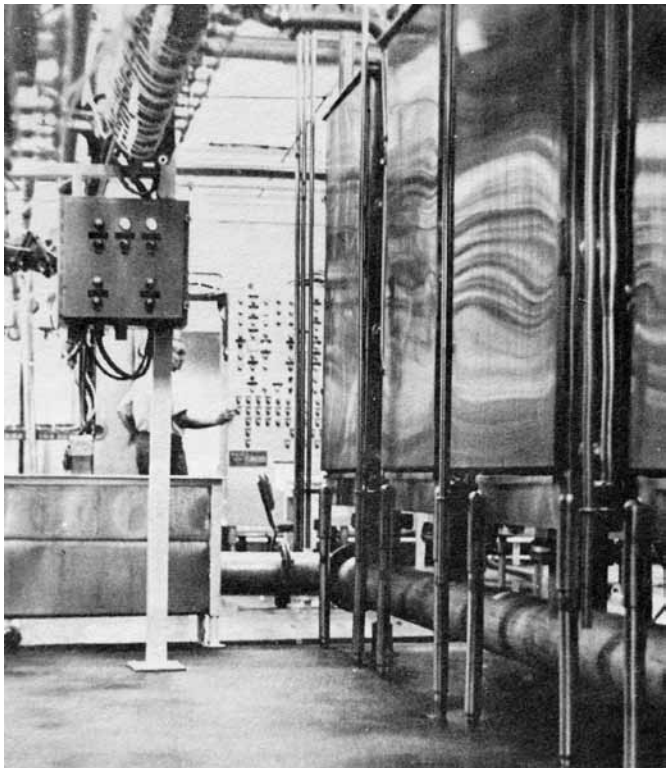
Other aspects of casein making were progressively adapted to produce whey that was better suited to both the ultrafiltration process and the intended end-use for the whey protein concentrate. These changes included more effective removal of milkfat from the incoming milk, pasteurising the milk (a process not usual in the manufacture of lactic casein at that time but considered necessary to improve the whey quality), and modifications to better control the cooking

process and separation of casein from the whey. We had to stop using antifoam to suppress foaming because of the damage antifoam did to the membranes. A downside of this was that we could have large quantities of foam across the floor of the casein making room – not conducive to good working conditions! While all these operations are commonplace today they were innovations at the time.

Poor bacterial control could lead to dire consequences – Eykamp recalls:

> Another problem unique to Waitakaruru, and as far as I know it only happened once anywhere, was the failure of the cleaning process on one day. After a longish run that had seemed too smooth for comfort, we were hanging about in the manager's house waiting for the post-run clean up. Either Ken [Kirkpatrick] or I noticed that we had the correct cleaning pressure drop with only one of two pumps running. I knew what that must mean and reluctantly decided to stop and pop some u-bends to confirm my dread suspicion – half the tubes were totally plugged. It was the only way the symptom could be explained.
>
> We had produced the equivalent, even to the colour, of Beech Nut baby custard, with which as a new father, I was quite familiar. The cleaning pressure had reduced the residue to a gel that would not move. We spent many unhappy hours removing u-bends and pushing out low pH gel, the by-product of a microbial explosion, by pumping balls of sponge rubber through the tubes.

On another occasion Max Parkin and Wilson McGillivray decided in the middle of one night, in a burst of enthusiasm, that the milk pasteuriser was a cause of hygiene difficulties. They took the pasteuriser to pieces to prove the point. Unfortunately they could not put it back together again. They made themselves very scarce the next morning when the



The only known photograph of the highly secret Abcor tubular process UF plant installed at the NZ Cooperative Dairy Company's factory in Waitakaruru. Commissioned in 1971, it was the first commercial UF plant built by the cooperative dairy industry. About half of the plant is visible. The photograph was taken by Bernie Horton from Abcor and published in one of his articles on advances in whey processing. In the background is Roy Leighton, an NZCDC technical manager who provided significant support to the Waitakaruru project.

A VERY PUBLIC WHOOPS

The Waitakaruru project was the most secret project in the New Zealand dairy industry. Even the chairman of the company that owned the plant, Frank Onion, was chased away when he tried to enter. So to have the factory appear on prime time television news was more than a little embarrassing.

The Waitakaruru factory was on the east bank of a canal that was really just a concrete-lined deep ditch that drained the local flats into the Firth of Thames. The primary school was on the west bank. The weather was hot, there had been little rain and flow in the canal was very low. It was tidal and there was insufficient water to flush it out. Anything that went into the canal from the factory tended to remain as a body of contaminated liquid, going backwards and forwards past the school.

There had been a number of mishaps with the ultrafiltration plant. For several days there was too much waste for the spray irrigation disposal plant to cope with and whey was being spilled to the canal. Before long the body of waste outside the school became anaerobic and septic. A Rotorua-type smell of hydrogen sulphide developed and even copious quantities of lime could not quell it.

A resident wrote to the local council about the canal's appalling condition. The Truth weekly paper published the letter.

The last straw was when the lead-based paint on the school buildings went black and started to peel off. Amid much brouhaha, the principal closed the school – the first New Zealand school ever to have been closed because of air pollution. The Health Department began an investigation. It was not long before the plight of the school community was headline news on national TV. It was most embarrassing having to explain to the senior management and board of NZCDC. It must have been even worse for Merv Whitehead (factory manager) and Rex Haggie (chief executive of NZCDC), who had to front up to a meeting of the school committee, the parent teacher association and county council staff to apologise and explain what was being done to alleviate the nuisance.

NOTE: such an incident would not happen today. Many years ago dairy companies, for the most part, ceased discharging whey and untreated effluent from processing plants into waterways. Regional councils strictly regulate any such discharges that do occur.

factory start-up was delayed for some hours while the pasteuriser was reassembled.

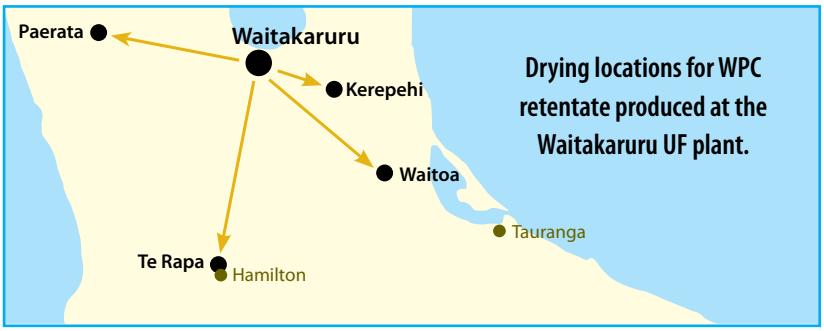
During this time a major equipment problem – splitting of membrane tube backings – started to appear at NZDRI. The tubes failed by splitting longitudinally and this resulted in a loss of precious retentate (concentrated whey protein) into the permeate. If it occurred towards the end of a batch cycle, it was very disheartening to the operators.

Tube failures continued to plague the operations at NZDRI and Waitakaruru for a couple of years. The problem was eventually overcome when Abcor developed a fibreglass reinforced backing.

NZ Cooperative Dairy Company chairman Frank Onion, who was not allowed to enter his own company's secret plant at Waitakaruru.

Arrangements for drying the whey retentate took considerable planning. Some experience at NZDRI, and reports from the Coca-Cola plant in Brazil had shown that by adding small amounts of hydrogen peroxide the retentate could safely be held for up to ten days at a temperature between 2C and 4C. It was important to avoid freezing because this would de-stabilise the protein. It was decided to accumulate retentate for up to four days and dry for a period of twelve hours, rather than run the drying process every day for three hours. It was agreed to cool the retentate at Waitakaruru then transport it to Te Rapa, where it would be refrigerated before drying. In practice the drying site was changed frequently as the needs of NZCDC for milk drying capacity changed. Waitoa and Kerepehi drying plants were also used.

The production issues led quite quickly to a 'them' (casein) and 'us' (whey) situation between the staff on the site. Two of the whey staff, John North and Bill Falconer, recalled that during the first year the ultrafiltration operators were regarded as a 'smart arse group'. Casein operators thought ultrafiltration was a pain because of the extra demands for hygiene, higher whey quality standards, the need to operate a clarifier, the number of starter trials which brought about



manufacturing uncertainty and the increased security imposed on the site.

The ultrafiltration plant finally started commercial production of whey protein concentrate in September 1971. The formal record shows that 70 tonnes, of "generally satisfactory quality" were produced in that 1971/72 season – considerably less than the design amount.

Continued contact with the customer

By the 1972/73 dairying season Waitakaruru was producing Solac that met the specifications now set by Coca-Cola.

Considerable interaction between our customer and the New Zealand dairy industry continued. Coca-Cola staff came to New Zealand and Dairy Board staff visited Coca-Cola's headquarters in Atlanta. The liaison was considerably enhanced by direct contact between Coca-Cola and staff at the New Zealand Milk Products development laboratory and pilot plant in Rosemont, Illinois, established in 1972. Major discussions centred on potential future markets for the original concept of carbonated beverages containing whey protein concentrate. The Dairy Board was anxious for clarity about Coca-Cola's future demand.

In early 1972, Anton Amon, a senior Coca-Cola executive, visited New Zealand and was very enthusiastic about the technical expertise in the local dairy industry. He reported that the samples of Solac performed better in beverages than competing proteins, especially with respect to sediment.

However, Coca-Cola still had not taken delivery of any product because of the on-going development of their marketing plans for the beverage. The Dairy Board was concerned about the mounting and aging inventory at Waitakaruru. Nevertheless, Malaspina continued to express concern that New Zealand might not be able to meet the demand for whey protein concentrate if the proposed beverage marketing was successful.

Not surprisingly, the Dairy Board and Coca-Cola had differing views on pricing for Solac. The Board wanted an acceptable return while Coca-Cola needed to sell beverages to consumers at realistic prices. A major concern to Coca-Cola was that excessive duties on protein imports would erode potential profitability. This was a particular problem in Brazil, a potential first and significant market.

During the first three years of development, Coca-Cola frequently upgraded its specifications for Solac as it gained experience with trial samples from New Zealand and Brazil. The trials highlighted sedimentation, microbial (mainly lactobacilli) and neck ring as specific issues.

Boy in Alegoinhas, Brazil, enjoying a free drink of 'Tai' during Coca-Cola's test marketing of this fruit beverage, which was fortified by WPC from New Zealand.

These changes meant that much (20 tonnes) of the earlier manufactured product was now unsuitable. Coca-Cola preferred the Dairy Board not to sell this product to competing customers and accepted that it was in the long-term interests of both parties to reach a mutually satisfactory arrangement. Coca-Cola pointed out that if the Food & Drug Administration (FDA) could approve the Abcor plant at Waitakaruru, they could find an immediate outlet for the non-specification Solac in a new product developed for the American school breakfast programme.

By September 1972, Coca-Cola was still suggesting that during 1972/73 it would buy 15 tonnes of SP6, the now-agreed specification. Despite this, Bill McGillivray told Coca-Cola that, pending a firm indication of purchase, production of Solac for them would be suspended. He pointed out that capacity at Waitakaruru had increased since installing the new fibreglass-backed tube membrane system and, to more fully use this expensive plant, the Dairy Board wanted to develop whey protein products for other customers.

In response, in January 1973, Coca-Cola asked for production of SP6 to stop despite saying, "Batch EI 10 appears to be a near-perfect product. It is therefore a matter of regret that these technical achievements have not yet been matched by marketing plans."

Coca-Cola and the Dairy Board, together with NZ Milk Products, were by now working together to develop a new specification of whey protein concentrate called SP7 to be incorporated in an instantised

pre-sweetened nutritional beverage that would be sold in powder form.

Even so, within 11 months Coca-Cola informed the Dairy Board that it was exploring a new, less costly, whey protein product called ForeTein (sourced from America) that would be incorporated in a beverage called 'Samson'. Thus the demand for SP7 would be negligible. Coca-Cola wrote:

> We, of course, greatly appreciate your wish to give priority to the whey product requirements of the The Coca-Cola Company. In light of the above situation, however, we must recommend that you pursue the market demand of other applications of whey protein, which have grown from the recent wider awareness of its unique properties. The potential demands of The Coca-Cola Company should not influence your sales to other organisations.

Neville Jones responded in a note to the Dairy Board:

> We could elaborate on the time, effort, and expense incurred by the New Zealand dairy industry and this company on the Coca-Cola exercise, and the disappointment that all concerned must feel at the outcome of their respective efforts. We suggest, however, that little would be gained, and we should now direct our endeavours with even greater determination towards the placement of soluble whey protein, in one form or another, with other interested parties. Success with these people would provide the consolation prize of being able to capitalise on the disappointment of the Coca-Cola decision.

Relationships with Coca-Cola were cordial, although there was some tension in October 1972 when Coca-Cola told the Dairy Board it was applying for a patent covering the whey processing sequence developed in Brazil. Coca-Cola's right to do this was questioned by the Board as the process had been partly developed in New Zealand. Eventually the Board was granted a non-exclusive, royalty-free right to use the process using New Zealand whey.

The Dairy Board remained in contact with Coca-Cola, particularly through Kirkpatrick, who by then was the Board's technical manager at NZ Milk Products in Illinois. More Coca-Cola specifications were trialled but there was no commercial uptake. Meanwhile, stored product that had been made for Coca-Cola continued to deteriorate in flavour. It was purchased by Coca-Cola but remained in New Zealand until eventually being sold as stock food on their behalf by the Dairy Board.

In 1978 Kirkpatrick wrote to R Fenton-May, a senior manager with Coca-Cola:

> I share your satisfaction in seeing the progress being made towards exploitation of the many years of mutual effort that have been spent in developing protein fortified beverages. Perhaps there is a lesson to be drawn from the time scale associated with bringing to fruition this project, which has involved new production technology of new ingredients and new consumer products, all overlaid with the complexities associated with international, political and marketing considerations. If faced with a similar broad and complex project in the future, without loss of optimism and drive to make as rapid progress as possible, I believe a somewhat more realistic assessment of probable timescale would be possible.

An ongoing act of faith

Continued knowledge development

By the time Coca-Cola decided not to proceed with its initial target market, the New Zealand dairy industry team had developed what was undoubtedly the most comprehensive knowledge of whey ultrafiltration in the world.

We had a unique product for a new application using a new technology, but no customer.

Many battles had been won but this phase of the war had been lost. Despite this setback, the New Zealand dairy industry leaders opted to take the risk and continue investing in product development for whey protein concentrates. The persistence in developing products was very much an act of faith by the Dairy Board. Don King, in particular, showed considerable courage in pushing to continue product development and operations at Waitakaruru.

The New Zealand industry – particularly the Dairy Board's overseas technical and marketing staff in Japan and America – worked hard to stay abreast of these international developments. Kirkpatrick in Chicago was particularly assiduous, bombarding Board and NZDRI staff with information and requests for data as well as presenting papers on the uses of WPCs at technical and scientific conferences in America.

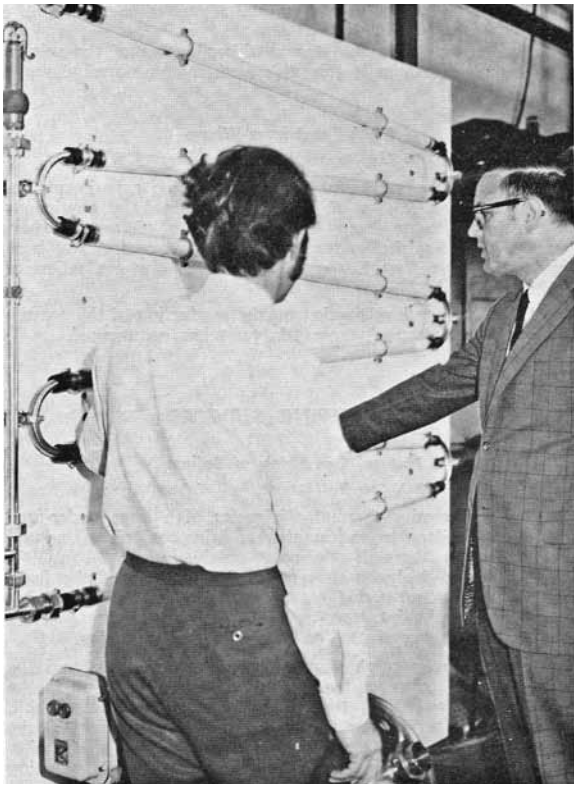
In 1971, I spent 10 weeks in Europe and America, visiting companies manufacturing equipment for ultrafiltration or reverse

osmosis of whey, and dairy companies using these techniques. In 1973 I accompanied a tour of New Zealand dairy factory managers to Europe, particularly the Scandinavian countries. A major focus of the group was whey processing and ultrafiltration. Such international travel is commonplace today but it was unusual in the 1970s.

During the 1971 trip I attended the International Dairy Federation's annual meeting in Dublin. This included the first meeting of a group of experts on "Whey Processing and Utilisation". This would evolve into a continuing international collaboration over many years.

New Zealand Dairy Research Institute

Research and development continued at NZDRI, with much of the work supporting developments at Waitakaruru. However, technical advice was also being offered to other dairy companies interested in ultrafiltration and other means of whey processing. For example Kirkpatrick and I wrote a detailed report, for distribution to all dairy companies, on the principles of ultrafiltration and some possible uses in the dairy industry.



Experimental setup using tubular membranes salvaged from the main NZDRI pilot plant and used for studies of the ultrafiltration process and cleaning regimes. Discussing the equipment are Ken Kirkpatrick (left) and Bob Timmins, CEO of the Abcor company which supplied the equipment.

The very competent NZDRI workshop staff assembled a small ultrafiltration test rig. This comprised ultrafiltration tubes from the undamaged ends of blown tubes from the UF-300S and, later, experimental tubes from Abcor. This plant allowed us to experiment with operating procedures without risking damage to the main Abcor pilot plant. George Murphy and Max Parkin (a microbiologist who had managed the night-shift student team and eventually joined the NZDRI staff) became expert with this test rig and derived significant data on the process of ultrafiltration and cleaning regimes.

A significant outcome of work on the new rig was great improvements in the cleaning of ultrafiltration membranes. The knowledge was later applied to considerable effect in the commercial

plant at Waitakaruru. This research optimised the use of detergents containing proteolytic enzymes. Through experimental work on the rig, detergent consumption was reduced by 90 percent.

In 1973 NZDRI evaluated a variety of UF modules. Here chemical engineer Brian Robinson is working with equipment from De Dankse Sukkerfabrikker (DDS)

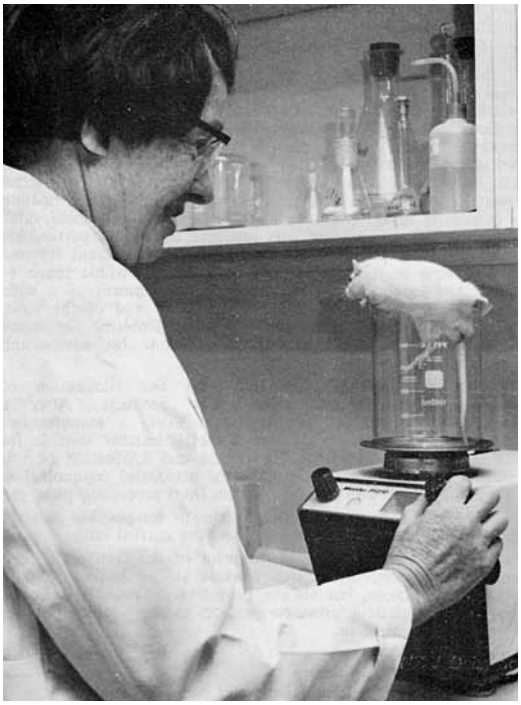
In September 1972, the NZDRI board of directors agreed that research and development was urgently required on the three major membrane-processing techniques of ultrafiltration, reverse osmosis and electrodialysis. Together, these processes provided an opportunity for complete control over the composition and hence processing characteristics of milk and whey, thus eliminating problems associated with seasonal and other variations in the milk. The directors recognised that rapid developments were occurring in these technologies overseas and agreed the New Zealand dairy industry needed to be at the forefront of such developments. They sought and gained a special $55,000 (a considerable sum at that time for a single project) grant from the Dairy Board to cover pilot plant equipment and further research staff.

Max Parkin

The developments that followed included comparison of ultrafiltration modules from suppliers other than Abcor: Dorr-Oliver, De Dankse Sukkerfabrikker (DDS), Patterson Candy (PCI) and Romicon. A major advance in equipment design was the advent of the continuous, stages-in-series ultrafiltration plant. In the continuous plant built at NZDRI, whey would remain in the equipment for between 30 minutes and two hours, compared with ten to twenty hours in a batch process. This significantly reduced the likelihood of microbial growth.

NZDRI installed new pilot plants for reverse osmosis and for demineralising whey using ion exchange and electrodialysis.

Research and development on potential uses for permeate continued at NZDRI and NZCDC. These included production of lactose, milk standardisation, specialty milk powders, and fermentation to



Evelyn Lohrey weighing a rat used in nutrition experiments.

yeast, ethanol, butanol and lactic acid. These technologies and uses (except yeast, butanol and lactic acid) were all later to be commercialised by the New Zealand dairy industry. (See Chapter 9 for more information about work to expand the range of profitable products made from whey and permeate.)

During this time the Pig Farmers Council expressed a real concern that feed sources from the dairy industry traditionally used by pig farmers were disappearing. The pig industry had earlier used skimmilk and whey as significant feed. The NZ pig industry experienced a significant decline as whey found more commercial uses.

Mary Humphries led a very active product development team at NZDRI which incorporated whey proteins into a wide range of foods including baked goods, desserts, beverages and processed meats (work that was continued later by Sheelagh Hewitt). This work also included measuring, in conjunction with the neighbouring Department of Scientific and Industrial Research and the Protein Section of NZDRI, the nutritional value of whey and other dairy products (protein efficiency ratio and amino acid analysis) using a model based on feeding rats. The 'rat house' operated by Evelyn Lohrey was not my favourite place to visit.

Peter Hobman became an expert in formulating and testing carbonated, low pH beverages containing whey protein concentrate, and testing different batches of Solac for compliance with the changing Coca-Cola specifications.

Many NZDRI staff joined taste panels for the various products – not always a pleasant chore as the taste of some of the more

experimental whey protein concentrates was reminiscent of oxidised linseed oil.

Mary Humphries, leader of NZDRI's products development team in the 1970s.

Final years at Waitakaruru

Waitakaruru was operated in an ad-hoc fashion from 1973 until 1978 as part of the effort to develop new products and establish new markets.

Dairy Board technical staff prepared a set of specifications to which product was manufactured at the Waitakaruru plant with no specific customer in mind. So the operation produced a range of whey protein concentrate products, mostly of the 50 to 60 percent protein variety but also some higher protein products of the 70 to 80 percent type for market development work.

NZCDC's interest in the whey protein concentrate project declined. In July 1973, for example, the company would not commit to starting the supply of milk to Waitakaruru because all the milk in the vicinity was being diverted to the new milk drying plant at Kerepehi in an effort to overcome potential start-up problems before the peak of the season. Normal production of milk powder was clearly more profitable and necessary than producing an experimental product with uncertain market demand. This also meant the company would not commit resources to overcome the problems of water, power, hygiene and waste disposal at the Waitakaruru site.

In March 1974 Don King reported that marketing prospects for whey protein concentrate were little changed from the previous year. Some sales were possible in Europe but only as a stopgap until European whey processing plants started up. There was potentially quite a large market in Japan but the price was such that this could only be sustained if a value could be obtained for the permeate by-product from WPC manufacture. It was estimated that the total economic returns from casein manufacture could only be boosted to equate returns to milk powders by successful marketing of whey protein concentrate and realising revenue from products made from the permeate.

Waitakaruru had its best WPC season in 1974/75. There were few membrane failures although there was some concern about spasmodic cleaning problems and the low yield of whey protein concentrate because of leakage through the membranes. The diatomaceous earth

...continued on page 66

LIFE AT

The Waitakaruru branch of the New Zealand Cooperative Dairy Company had been a large (for its time) cheese unit that was converted to a lactic casein plant.

Merv Whitehead, the factory manager, had joined the staff as a young school leaver in 1952 when his father was the manager. Whitehead had the reputation of being dedicated and good at training young staff. He recalls that if any equipment stopped during the night when he was at home in the nearby factory house, he would be one of the first into the factory to see what was wrong – often before other staff were aware there was an issue. One of his irritations was the not infrequent poaching of his better staff by other factory managers in NZCDC. He was obviously a patient man to have coped with the frustrations of a large experimental project with inadequate facilities, not a lot of support from head office and frequent visits from NZDRI and Dairy Board staff. He remembers seemingly endless days of things going wrong, coupled with the paramount need to keep things going because of the inexorable flow of milk through much of the season. However, despite these frustrations he is proud of what was achieved and appreciated the professionalism of many of the visitors.

John North was the assistant manager in charge of whey. In 1970 North was seconded to NZDRI from the Reporoa branch of NZCDC. He and his wife Tina spent 10 weeks at NZDRI being trained in ultrafiltration using the Abcor UF-300S. Later in May 1971, Bill Falconer joined the Waitakaruru staff as first assistant for whey. He, with his wife Phoebe and the Norths, spent a further two weeks at NZDRI operating the Abcor UF-300S and peripheral equipment. When they returned to Waitakaruru they were faced with a half put-together jigsaw of cabinets, pumps, pipes and tubes and took charge of the assembly and commissioning.

North recalls the six staff in the ultrafiltration plant being helped by Ken Kirkpatrick during this commissioning phase. There were huge technical debates long into the night over card games, accompanied by beer and sherry. Kirkpatrick later introduced the group to Cold Duck and SYC wines from Thames. Relaxation was taking his frustrations out on the ultrafiltration team on the squash court.

Phoebe Falconer, who worked in the factory laboratory for a short time, recalls the close-knit community spirit in Waitakaruru township. A lasting memory was children – young factory staff, including Tina North and herself, were starting families at this time.

John North and Bill Falconer recall the dominant role the factory operations played in their early careers:

- Noise when the clarifiers dumped their sludge, or the filters were discharged with a blast of compressed air and, at night, the clanking of a bucket coal conveyer that was missing one bucket.
- Huge changes that the casein and whey staff had to adjust to.
- The sense of humour; one log book entry requested the night staff to "please let the whey tanks go on high tide." A wry entry the next morning from first assistant Alan Scott read: "unfortunately they did not fit under the bridge."
- Huge disappointment when Coca-Cola withdrew from the project.
- Max Parkin from NZDRI running trials to improve the cleaning of the plant with various enzymes. Towards the end of the visits Max's fingers would be red and peeling – that's commitment!

WAITAKARURU

John North became factory manager in 1974 when Merv Whitehead left to take up a lawn-mowing contract – he subsequently became a bus tour operator. Bill Falconer took over as manager in 1976

NZDRI's strong support is illustrated by the factory visitor records: Ken Kirkpatrick, Kevin Marshall, Bill McGillivray, Dave Woodhams, Harry Torrey, Ramsey Southward, Bob Lawrence, Wayne Sanderson, Ray Bysouth, Don King, Terry Thomas, Lindsay Pearce, Jack Roeper and Max Parkin all visited during a single season, some for days at a time.

Dairy Board staff also provided strong support. A frequent visitor was Arthur Hale. He spent long periods of time working in the laboratory, introduced many of the quality control measures and was an astute observer of the physical and chemical changes occurring throughout the process.

Another regular visitor was Roy Leighton, an NZCDC technical services manager. Leighton was a pragmatic chemical engineer who provided sound advice and worked hard to help overcome the technical difficulties experienced in the factory.

At 450 km from Palmerston North and 575 km from Wellington, Waitakaruru was a significant drive through the central North Island for NZDRI and Dairy Board staff. Many of those involved with Waitakaruru at this time recall interesting, even exhilarating trips with Ken Kirkpatrick in his Triumph 2.5 PI, particularly across the Desert Road. John North remembers a sad looking Kirkpatrick arriving at the manager's house one night – he had hit a wandering calf in dense fog on a dark Waikato Road. "A few drams were consumed that night!"

Waitakaruru in 1972. The building housing the WPC plant is marked with a red dot, while the casein plant building has a blue dot. To the right of the factory complex can be seen the tidal canal and beyond that, Waitakaruru School.

filter was no longer in use and a second self-desludging centrifuge had improved the whey pre-treatment process. By now, most of the concentrate was being dried at the company's Paerata plant, near Pukekohe. Some of the liquid retentate was treated by ion exchange to further reduce mineral content and lower the pH.

Total WPC production was 86 tonnes. Only a shortage of milk prevented the planned 200 tonnes being manufactured. Even with the lower than expected production, manufacturing costs per tonne were reduced to 40 percent of those in the previous year.

At the end of the season 58 tonnes of product was on hold for Coca-Cola and 178 tonnes of other specifications were in the store.

In March 1975, it was agreed to mothball the plant and not operate it in 1975/76 unless there was a confirmed need for permeate or sales for Solac. An industry ultrafiltration committee noted that the reason for this decision was not that ultrafiltration had been unsuccessful but rather that marketing of Solac had not kept pace with production. The plant was to be shut down because there were no sales, and care was taken to communicate this message to the staff at Waitakaruru, the New Zealand dairy industry and Abcor. Despite this decision, Waitakaruru did operate during 1976/78, manufacturing product to various specifications set by the Dairy Board in anticipation of sales. In 1977 it was under a lot of pressure to produce WPC 75 for Japan, but much of the product did not meet the gelling requirements. However, some of it was recovered later, as our knowledge of the chemistry of gelling developed. (Work in this area is described in the next chapter.)

The Waitakaruru plant was finally retired in 1978. Some consideration had been given to moving part or all of the membrane components to other factories but by now batch technology was obsolete. New continuous stages-in-series technology had been installed at Te-Aroha Thames Valley Dairy Company and this heralded a new era of whey processing development.

Conclusion

The needs of the Coca-Cola Export Corporation became the catalyst for New Zealand developing a range of new dairy products from whey – a by-product that previously had been mostly fed to pigs or wasted. Developments at NZDRI and Waitakaruru, assisted by the efforts of the Dairy Board, NZCDC and the Board's overseas

development centres, laid the foundations for a future profitable business. These pioneering activities left indelible memories for those involved, many of whom went on to distinguished careers in the dairy industry.

It was a time of considerable excitement and frustration, but it was just the start of the story. Through this work, the New Zealand dairy industry had developed the most comprehensive knowledge of whey ultrafiltration in the world, a platform that was built on extensively over the next two decades. It was able to overcome the setback engendered by Coca-Cola's decision not to continue with launching its beverage product. Decades later such a product was launched, and whey protein concentrates found many other uses including becoming a major component of sports and health drinks.

CHAPTER 4

A NEW DIRECTION: JAPAN 1975–1982

MIKE MATTHEWS

Mike Matthews *graduated in food technology from Massey. His doctoral research in America was in the use of membrane systems for processing milk and whey. At NZDRI he helped develop WPC for the Japanese market. His industry career spanned R&D, technical management, marketing and sales, including six years in Japan, and general management. He was CEO of The Tatua Cooperative Dairy Company for 13 years until 2008. He is now a food industry consultant.*

What an interesting and challenging situation New Zealand's fledgling whey protein business found itself in at the beginning of 1976.

The exciting prospect that had heralded the beginning of the decade of supplying whey protein concentrate (WPC) to Coca-Cola had not come to pass. An excellent business prospect was no more.

Our dairy industry was caught in a dilemma – it had a commercial ultrafiltration plant able to make WPC, it had people who were enthusiastic about the manufacturing technology and it had an inventory of products that could be used to attract and build new business. But where were the orders? Where were the customers? Not surprisingly, people at governance and senior management levels were starting to ask questions. Why were we persisting with these products? The product champions now had the challenge of keeping the technology alive.

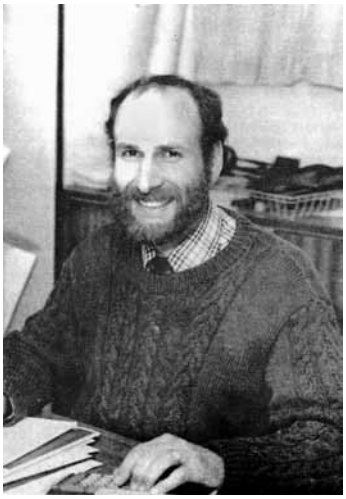
I joined the team that was facing this dilemma.

Background: the apprenticeship

I had only just arrived back in New Zealand from America to take up a job as a research officer in the whey products group at the NZ Dairy Research Institute (NZDRI) in Palmerston North. I had just spent four years living the happy and carefree life of a graduate student in the food science department of the University of Wisconsin, in the eminently agreeable and student-friendly town of Madison. This had been followed

by two years as a very junior academic in the food science department of the University of Illinois. Little was I to know that the experience of those six years in America would prove so important to my future work.

My professor in Madison, Clyde Amundson, had a particularly sharp eye when it came to assessing and appreciating the value of new technologies. He had been quick to recognise potential applications in the dairy industry for the new membrane processes of reverse osmosis (RO) and ultrafiltration (UF).



Mike Matthews in 1979, when he was general manager research & development at Rangitaiki Plans CDC.

Amundson was very effective at getting funds for university research. In association with fellow membrane-processing enthusiast Charlie Hill of the university's chemical engineering department, he had secured funding to install pilot scale RO and UF plants in the food science department.

I was asked if I would like to study membrane processing as the research component of my PhD. By then I had learned of the New Zealand decision in the early 1970s to install a commercial UF plant to make the brand new product, whey protein concentrate (WPC). The decision had been 'top secret', and the detail of it remained so for many years. However, word soon got out that something new and exciting was happening in whey processing in New Zealand. All the while, research interest was growing in America and membrane processing was becoming one of the 'in' things to study. So Clyde's was an offer impossible to refuse.

The University of Wisconsin had its own dairy herds and a commercial processing plant equipped to make consumer dairy products, including various cheeses. We had plenty of milk and whey to work with. It was in this environment that I was involved in several studies using RO, UF and electrodialysis, with skimmilk and cheese whey as raw materials.

I would soon discover just why these technologies were so exciting. That you could concentrate and fractionate a multiple-component fluid system, using what was essentially a molecular sieve, seemed

such a departure from traditional dairy product processing. It was so full of potential for things brave and new that in hindsight it is not surprising that many of us who had the good fortune to be involved became addicted to it.

But not everyone felt that way. Membrane systems of the time comprised an active membrane coating of rather fragile cellulose acetate on a porous plastic support, which needed great care in cleaning and handling. Experienced dairymen of the era were not impressed. If equipment couldn't be boiled out with caustic soda, it was doomed to fail.

I would meet people in both America and New Zealand who felt that way but for us addicts, the critics' concerns were simply something to be dealt with, not surrendered to. We weren't always sure how we would deal with them, but deal with them we would. There was an enduring sense of purpose among membrane enthusiasts everywhere.

After Madison I spent two years at the University of Illinois. This included supervising research projects in membrane processing of skimmilk and soybean extracts. Noteworthy during this experience was meeting the man who would have a major influence on New Zealand's whey research programmes and on me personally. Jim Harper, professor of food science at Ohio State University, spent five weeks with us at Illinois on a special assignment. Very clearly this was a man to be reckoned with. Jim's academic breadth and depth of thinking and his dedication to the teaching of food science were of the highest order. Our paths would cross again, many times.

New Zealand Dairy Research Institute as a place to work in 1976

So with this background, I returned to New Zealand in 1976 to work in the whey products section of NZDRI, which was essentially the R&D arm of the New Zealand dairy industry.

NZDRI was divided into two divisions, one covering fundamental research in areas such as protein chemistry and microbiology and the other applied research. The latter comprised several product sections, each concerned with a particular class of dairy products. One of them was the whey section, managed by Kevin Marshall. Marshall's empathy and never-ending enthusiasm for whey processing threads its way through all of the work outlined in this chapter.

I was asked to look after two closely-linked areas of research:

- The process of ultrafiltration: continuing NZDRI's programme of

studying new membrane systems and enhancing their performance

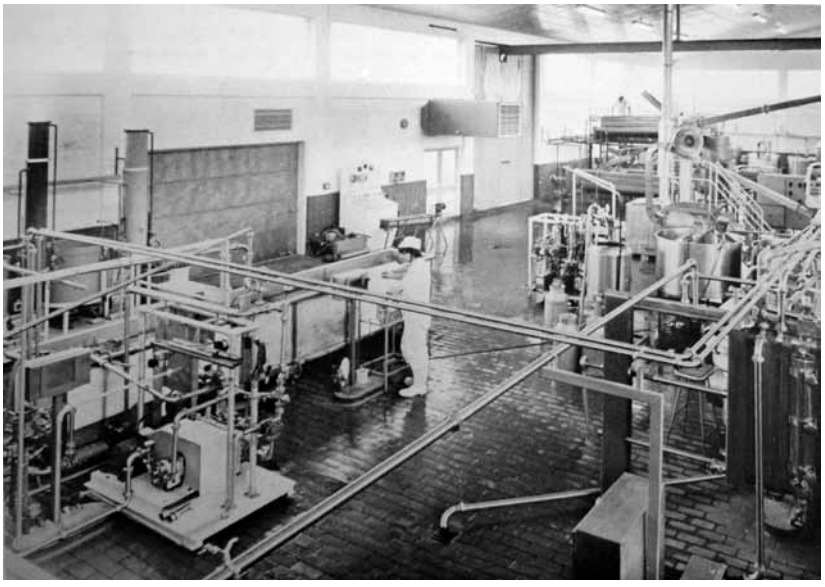
- The products made using ultrafiltration: studying whey protein concentrates with special emphasis on developing new products that would find a ready home in international markets

What a fine place NZDRI was to work at in the 1970s. No other job I have had before or since could rival it in the sense of enthusiasm I had for my work. Later jobs would be satisfying for other reasons but at NZDRI it was like being paid to work on one's hobbies.

By international standards we were not well paid but that did not seem to matter at the time. More important was a pervasive sense of being part of something valuable and of being supported by a dairy industry that really wanted to succeed in whatever it took on. You saw that in the attitudes and spirit of the NZDRI senior managers. It was also reflected in the extent and range of NZDRI's scientific equipment, processing machinery and support services, which were all world class.

Particularly impressive was NZDRI's processing hall. This was a registered manufacturing plant, equipped with pilot scale and in some cases small commercial scale equipment. New manufacturing technologies could be studied and concept samples of new products made. Many product and process innovations were achieved in the centre.

There was no direct project accounting at the time and none of us had to record how we spent our time. By today's standards this might



Part of the NZDRI processing hall in 1975. Some of the whey processing plant is on the left.

seem lacking in discipline but offsetting that, there was every possible encouragement and opportunity for research staff to come up with new ideas and to investigate them. It was an excellent place for a young research person to work, with endless scope to delve and discover, under the guidance of R&D managers who were genuinely supportive and enthusiastic.

None of this is to suggest that all was sweetness and light in the relationships between NZDRI and the masters it had to serve, namely the New Zealand Dairy Board and the many manufacturing cooperatives of the day. Indeed there was tension and conflict but in hindsight, while the debates were robust, they led to strong investment decisions by the industry.

With two-thirds of the Institute's funds coming from industry, NZDRI was expected to be responsive to the needs of dairy companies and markets. The applied research sections derived their work programmes substantially from the needs of the manufacturers and the marketers. These needs were identified in the never-ending interplay between NZDRI managers and their counterparts at the Dairy Board and at the manufacturing companies.

For established products such as milk powders, butter, cheese and casein, much of NZDRI's applied research was directed at enhancements in both products and processes. There were always customers for these products who wanted to see improvements in consistency or better product performance and there were always manufacturers who wanted to know how to make their products more efficiently. Research staff in these sections had to serve a wide constituency. Those of us in the whey section had a far smaller and more limited constituency.

The 'in between' era: after beverages, before gelling

When the Coca-Cola business for soluble WPC ended in 1974, the New Zealand industry had no market for its whey protein concentrate. The whey section continued servicing the commercial manufacture and marketing of the heat-precipitated whey protein known as lactalbumin, but this was produced in small volumes and had only a limited market.

For the Dairy Board in Wellington, charged with finding new markets, and for the NZDRI, the period 1974-1976 was indeed a dark and lonely time for WPC.

It is a great tribute to the leaders of the day that loss of the Coca-Cola business did not lead to closing of the commercial UF plant

at Waitakaruru. Nor did it lead to retrenchment. Indeed the reverse occurred. There were critics but the prevailing view was that we should persist in finding new markets. Three quite powerful factors reinforced this view:

- Discharging whey from casein and cheese factories into New Zealand waterways was becoming increasingly unacceptable. The large polluting power of whey (just two litres of whey equates to the waste generated by one adult human being per day) meant that even a small casein plant that was dumping its whey into a river could generate an untreated pollution load equivalent to that of a human population of hundreds of thousands of people.
- Milk powders were emerging as a strong commercial feature of the industry. If casein and cheese product mixes were to compete for milk, they needed to be more profitable. One way to achieve this was to derive value from whey, to supplement the values derived from casein and cheese.
- WPC, if only we could get it right, could be an important rallying point for the industry's perceived need to diversify its product mix and to add more value to milk.

In essence, the message from the industry's owners was: "Get us off the hook on this environmental problem but do it in a way that makes money."

Manufacturing WPC does not, in fact, greatly reduce the polluting power of whey (typically by just 10 percent). However, it was inevitable that WPC would have the top research priority because it was seen as the fastest path to profit. In due time, to really reduce whey's polluting power it would be necessary to recover its other solids, especially lactose. Some years would elapse before that was accomplished but making profitable protein products from whey would be a strong start. (For details of this, see Chapter 9.)

In 1974 and 1975 the WPC plant at Waitakaruru continued to operate although there was no market for its products. While there were no customer orders, WPC was made to specifications devised by the technical staff of the Dairy Board in the hope of attracting new buyers and building a market. Stocks kept rising.

The primary emphasis at Waitakaruru until 1976 had been on WPC products of intermediate (50-65 percent) protein concentration for

beverage applications, all derived from acid casein whey. Heat stability, pH stability and solubility were key requirements.

As part of the product development activities that supported this work, experimental investigations were also conducted in the use of ion exchange resins that could partially demineralise WPC and improve product stability in beverages. Observations from this work would prove very helpful as we moved on to gelling WPCs.

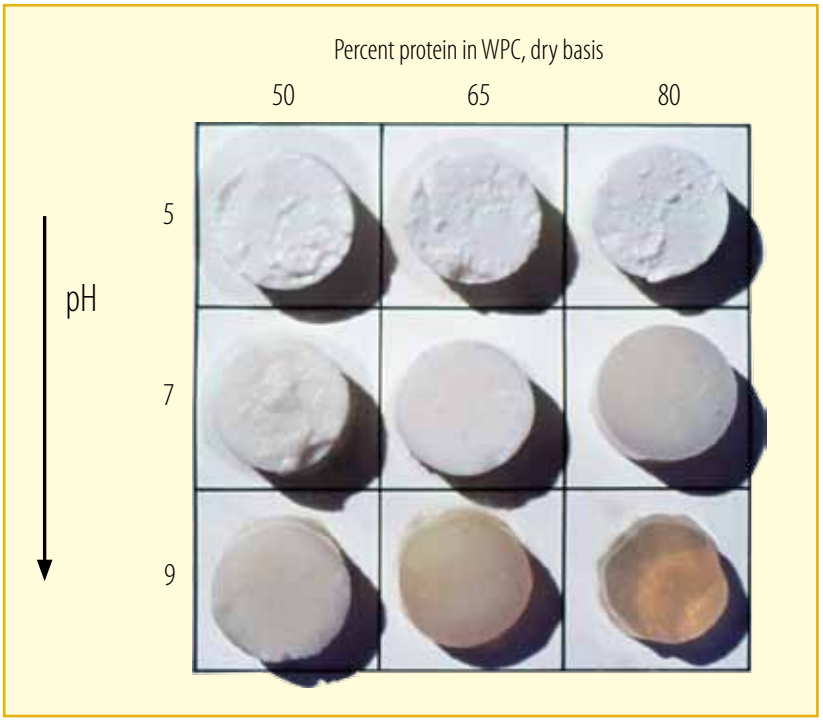
A new dawn: the Japanese prospect

In late 1975, a new and quite different avenue of opportunity opened. The Dairy Board's office in Japan had for many years worked closely with its Japanese distributor for casein products, Nissei Kyoeki (NK). NK was a long-established company that supplied raw materials to Japan's timber and paper industries. The milk protein, casein, is the raw material for an excellent coating for high-grade paper and cardboard that enables exceptional clarity of graphics and text on labels and print media.

New Zealand was a major casein supplier so it was logical that the Dairy Board and NK would form a business relationship. In time, less expensive materials would supplant casein for many paper-coating applications but the relationship formed between the Dairy Board and NK would endure. Indeed it does to this day in the form of Fonterra Japan, a joint venture between the Fonterra Cooperative Group and NK, responsible for importing Fonterra's product range into Japan.

By the late 1950s, Japanese food processing companies were increasingly aware of the food-related applications of casein. Nissei Kyoeki was very well placed to respond to this opportunity. Interest in casein increased substantially, so much so that several major users sought exclusive access to this valuable protein ingredient. However, NK's policy was to supply all prospective buyers. This policy served New Zealand's interests very well, as our industry was able to develop close business relationships with many Japanese protein buyers for both food and industrial applications, without being restricted by exclusivity agreements.

Japanese buyers also became interested in the soluble forms of casein known as caseinates. By the 1970s, New Zealand was one of the world's largest producers of this very valuable and useful form of milk protein. We had become the largest supplier of casein to Japan and the second largest supplier of caseinates behind the Netherlands



Understanding WPC gels: from a 1976 NZDRI study by Mike Matthews of the characteristics of heat-set gels made from acid whey WPCs.

(which had a long-standing position as the supplier of choice to the Japanese processed meat industry).

NK was truly in a commanding position with milk proteins in Japan, ably supported by its own technical department. The company's working familiarity with casein and caseinates would prove a huge asset as New Zealand built its business with milk protein sales to Japanese food product manufacturers.

Expansion of casein and caseinate demand in Japan, plus growth in other markets, also meant that even more whey would be generated in New Zealand. It could only make the whey disposal problem worse. The Dairy Board therefore urged its staff and its partners in various markets to develop new sales for WPC.

The food industry in Japan now became aware of the new class of food proteins that had become available through ultrafiltration of whey. Several Japanese companies were investigating how the special characteristics of whey protein concentrates might be exploited. Nissei Kyoeki was well placed to respond to such interest and also to stimulate it.

There was however an issue relating to import tariffs and product composition. WPCs containing less than 75 percent protein were

Research officer Charlie Towler using the Instron Universal Testing equipment for tensile testing of protein gel at NZDRI in 1974.

subject to import duties. The tariff was zero if the protein concentration in WPC was 75 percent or more but New Zealand had done very little work on such products.

The batch plant at Waitakaruru could make high protein WPCs although it was not ideal for this purpose. Products with protein content above 75 percent were made in 1975 by adding water to batches of partially fractionated whey and continuing the UF process to wash out additional lactose and minerals. The resultant protein-rich retentates (the fluid that had not passed through the UF membrane) were transported to NZCDC's Waitoa site for spray drying.

The Japanese customs problem was initially seen as an impediment but it proved to be an opportunity because it forced us to develop high protein products that had a wider variety of uses in food products.

Understanding your market: what did the Japanese want?

The first significant enquiry from Japan for high protein WPC had come from a company that had been investigating the use of whey proteins as gelling agents for use in processed meats, especially ham. This company had been keen to find a soluble protein of near neutral pH that would replace egg white in the pickling fluids injected into pork during the ham manufacturing process. Egg white had been their protein of choice (over proteins derived from soy and blood).

For reasons of cost, image, labelling and function, the customer was looking for a protein that was priced competitively, had a bland flavour, and above all would retain moisture when hams were cooked. Ideally the hams would have a natural texture (not rubbery). In short they wanted a protein that would gel within the meat during the cooking process (thereby retaining water) while the ham retained as much natural meat texture as possible.

The customer's specifications were sent to New Zealand. Two samples of WPC 75 (whey protein concentrate of 75 percent protein content, made at Waitakaruru) were sent to the customer for evaluation.

The customer also provided a procedure for testing the WPC's gelation ability. This involved preparing solutions from powdered WPC, pouring this solution into test tubes, placing the tubes in 75C and 90C water baths and then measuring the time taken to form a gel.

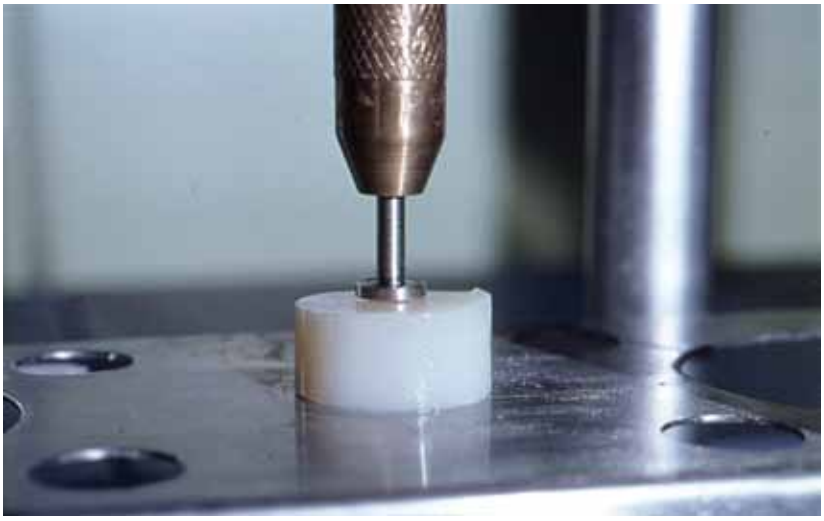
An early observation from the first gel tests was that the so-called gels that formed inside the test tubes were not really gels at all. Rather they were a firm but finely divided curd, like a very fine Ricotta cheese. After a short time this exhibited water leakage (syneresis).

Shortly afterwards a second enquiry came from a customer that would become the largest buyer of New Zealand WPC 75. This company also wanted a gelling whey protein for use in processed meat applications and again it supplied a gelation test: WPC 75 was dissolved in water to provide a 10 percent solution. This was then poured into a flexible plastic film tube and both ends tied to form a cylinder. This was placed in a 90C water bath for 30 minutes. The plastic film was then removed and the tube of gelled WPC was cut into segments. These were then assessed for hardness by measuring the force needed to fracture the gel surface.

Fortune lends a hand

To this day I marvel at the serendipity but one of the samples sent to Japan in late 1975 was reported by a Japanese customer to have exactly the kind of characteristics required. We re-examined a retention sample of this product and saw that its gelation character was quite unlike the other samples of WPC 75 we had assessed. Rather than forming the white, finely divided curd of matt appearance that leaked moisture, so typical of most of the samples we were seeing at that time, this particular WPC formed a true gel. It was shiny, smooth, slightly translucent, light tan in colour and did not exhibit syneresis. I even recall its lot number: FL26, made in January 1975 at Waitakaruru.

Why should this sample have been so different? A check with staff at Waitakaruru revealed that the pH of whey processed that day had been around 4.2, much lower than the normal value of 4.6. This indicated that the production of lactic acid during fermentation might have continued well beyond normal or adventitious lactic acid-producing bacteria had been able to grow in the stored whey, lowering the pH



WPC gel undergoing texture analysis at NZDRI, 1976.

abnormally. Whatever the reason, it had led to a WPC that exhibited the very characteristics wanted by the customer.

This was promising but we had little idea how to make WPC 75 like this all the time. The good gelling properties of lot FL26 did make us speculate on whether the lower pH of the whey during ultrafiltration might have led to greater loss of minerals to the permeate. Analysis did indeed indicate that the mineral concentration in FL26 was lower than normal for WPC 75, by approximately 10 percent.

Opportunity looms, but…

As 1976 progressed, there was a very clear message from Japan that if we could manufacture product like FL26, there was a potential annual market for hundreds of tonnes. This was well beyond the capacity of the Waitakaruru batch plant, which at best could have made no more than 50 tonnes per year. In the face of urgent demands from Japan, Waitakaruru started making WPC 75 retentate every day. The retentate was accumulated and sent every third day to Waitoa for drying.

The limited capacity of the old batch plant at Waitakaruru and the logistical and technical difficulties of transporting precious retentate to another plant for drying worked heavily against us. We concluded that the plant's annual productive capacity was more like 30 tonnes, rather than 50 tonnes – far short of tonnage wanted by the Japanese.

Our challenges were compounded by the fact that we simply could not meet the Japanese gel standard, so much of the 1976 and early 1977 production was not acceptable. We therefore had the painful challenges

Tsutomu ('Tom') Shinya (left), with Kazuyuki Hiraga in 1988. By then Shinya was managing director of the Dairy Board's Tokyo joint venture, Nippon Proteins. Hiraga was the company's laboratory manager.

of how to make a satisfactory product and how to get more capacity out of Waitakaruru (a plant that had not been designed to make this product) while at the same time accumulating product that was not satisfactory. It was indeed a very trying time.

To reinforce the urgency of their requests, NK sent its senior technical manager, Tsutomu Shinya ('Tom' to all his friends) to New Zealand for meetings with Dairy Board and NZDRI staff. Shinya himself spent time in our laboratory, observing the conduct of gel testing and even conducting the test himself to help us understand its nuances. I recall our conversation over dinner that night. Tom insisted this was a major opportunity for New Zealand and we just had to get it right. This was my first meeting with a Japanese business visitor and it was a harbinger of things to come for me – dealing with the extraordinary, sustained insistence that Japanese companies can bring to bear when you have something that they want.

In 1982 Shinya became managing director of Nippon Proteins, the joint venture between the Dairy Board and NK. Then in 1986 I was posted to Japan and worked directly with him. He would be my boss for four of the six years I was in Japan.

Leadership: the Dairy Board at work

Before describing how we were able to achieve a good commercial outcome, it is instructive to recall the role of the Dairy Board in this

saga and to pay tribute to two Board staff who were hugely influential throughout this era.

Don King managed the casein division of the Dairy Board. Whey products and whey initiatives fell very much under King's keen and determined eye. He was a chemical engineer who had worked at NZDRI where he had a major impact on the work programme and on the careers of several staff. He was particularly determined to solve the country's escalating woes with whey disposal, as he knew that unless we did, casein as a product class would be diminished and put at serious commercial risk.

Don King

Assisting King was the hugely energetic and highly personable Arthur Hale. Hale and I worked very closely on this project, in almost daily communication. He had completed the industry's graduate training programme and had worked at the Waitakaruru plant.

King and Hale formed an exceptionally strong focal point for developments in whey processing. Both had good technical and commercial empathy. They were very determined in their dealings with NZDRI, overseas markets and dairy companies. Hale was lost to us in 1986, dying of motor neurone disease to the immense sadness of everyone who knew him. In his time at the Dairy Board he made a major contribution to whey products and later to the cheese section, which he managed.

Arthur Hale

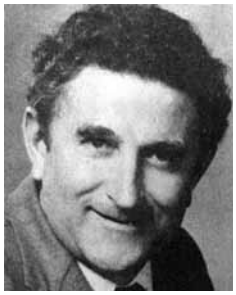
At senior management and governance levels, people of exceptional intellect and vision also served the Dairy Board. Ken Kirkpatrick, who as a young NZDRI chemical engineer had a particularly active role in the Waitakaruru project, had recently returned from five years of working for the Dairy Board in America. Kirkpatrick's knowledge and enthusiasm for whey processing were boundless. Bernie Knowles, the general manager, saw very clearly that whey was both a problem and an opportunity. Together with King he formulated a commercial strategy that in 1982 would see the industry cooperating closely under the umbrella of the Whey Corporation. This is covered in Chapter 8.

At Board level several directors were taking a very keen interest in whey initiatives, especially Graham Calvert who would chair the Whey Corporation for many years and Alan Frampton who would chair the Tatua Cooperative Dairy Company. For all the inter-company rivalries, the consensus reached among dairy companies on whey processing strategies and investments would become a potent enabling force in the WPC industry.

Understanding the product: what happens when gels form?

By late 1976 our situation was becoming quite serious. Anxious but very supportive senior managers at the Dairy Board and NZDRI were starting to worry if we would ever meet Japanese expectations.

During this time a particularly useful and, in hindsight, quite pivotal conversation took place. Arthur and I were speculating on why Lot FL26 should have proved so successful. I had been commenting on the distinction between the curdy, leaky character of so many of the gels we were seeing, versus the smooth, gelatinous character of the gels formed from Lot FL26. Arthur then recalled an observation he'd made at Waitakaruru, when he had been using ion exchange resins to improve the stability of WPCs being made for beverage application. From time to time he had to measure dry matter in whey retentates that had been subjected to cation exchange. He observed that these tests were hard to do because retentates from cation–depleted WPC would form a smooth gel in the drying pan while it was in the oven. The retentate would then retain water, making it harder to dry.



Graham Calvert

We then speculated that the key to whether whey protein might form a smooth gel when heated, as opposed to whether it might form a curd, might depend on finding the right combination of pH, minerals and mineral concentrations. In particular, it seemed that the solution might well relate to how we were able to control the behaviour of calcium, given its ability to promote cross-linking of protein molecules.

Alan Frampton

The next step was to investigate the effects of various calcium-binding agents on the gelling characteristics of acid whey WPC, starting with the classic chemical used for calcium binding studies: ethylenediaminetetraacetic acid (EDTA). We found that small quantities of EDTA had a profound effect, resulting in heat-set gels very similar to those observed when testing lot FL26. With enough EDTA, it was possible to bind calcium so completely that no heat gelation would occur at all.

Bernie Knowles

EDTA is a laboratory chemical and there was no suggestion that we would use it in the manufacturing process. Rather, this simple experiment had proved a principle that led to investigation of the use of food-grade chemical ingredients (phosphates and citrates) that would modify the behaviour of calcium. Relatively quickly, we identified ingredients that let us manipulate the behaviour of WPC 75 so that the strengths of heat-set gels were much closer to the requirements of

two Japanese customers. We still could not do it routinely but at least we were closer.

An immediate practical outcome of this work was that we were able to bring almost all of the accumulated stock of unsold WPC 75 to a saleable state by dry-blending the WPC 75 with calcium modifying agents. This work was conducted quite successfully by NZCDC, much to the relief of staff at both the Dairy Board and NZDRI.

We had not been fully successful at meeting Japanese specifications but they bought what we made and we were sufficiently close to cause them to demand even more strongly that New Zealand increase supply.

Processing: why and how we expanded capacity

Before returning to how we were able to achieve the product specification, it is important to look at a parallel strand to the story: how we chose the commercial membrane systems that would be used to make WPC for the Japanese market.

The first continuous plant: Te Aroha-Thames Valley

In 1977, the Dairy Board, responding to increasing pressure from Japan, decided that it was time for a major expansion in WPC capacity. The Board invited companies that had a supply of acid casein whey to submit proposals for a new WPC plant. Funding of the investment would be available through the dairy industry loans committee, a group within the Board that made loans to dairy companies on commercial terms.

In keeping with the industry's view that the risks of whey processing were too great to be borne by the investing company alone, the project would be underwritten, with defined methods of calculating the amount to be paid to the company for WPC, to make sure that manufacturing costs and capital-related service charges were covered. These principles would later be encapsulated in the workings of the Whey Corporation.

At NZDRI, we prepared process descriptions and product details, linked with the project specifications supplied by the Dairy Board, to assist companies that wished to bid for the new plant. NZDRI was asked to play a major role in deciding the type of UF plant to be installed. The commercial imperative of getting product to market was placing great pressure on the industry to act quickly.

Nevertheless, there really was a sense of: "We know we don't have

The first continuous plant: Te Aroha Thames Valley CDC's DDS plate and frame plant at Paeroa, which started operation in 1978.

all the answers, but this opportunity is just too good to let slip so let's be positive and in due time we will solve those problems." It was a bit scary and disconcerting, but it was all pretty darned exciting as well, especially for us young staff at NZDRI who felt caught up in it all and as keen as could be to be a part of it. In fact I can't recall any naysayers or cynics getting in the way at all.

Choosing the first continuous plant: DDS steps up

Another instance of serendipity awaited. The Danish equipment supply company, Pasilac A/S, wished to bid for supply of the UF plant to the successful dairy company. Their offering was a plate and frame system developed by their subsidiary, the Danish Sugar Company (DDS). They had also developed a non-cellulosic membrane of the polysulphone class of plastics, reputed to be more robust and better able to withstand more

rigorous cleaning regimes. They immediately sent NZDRI a pilot scale batch plant so we could evaluate its performance on both lactic acid and sulphuric acid wheys. Pasilac also provided a procedure for translating batch pilot plant results to a continuously operated commercial plant.

Before arrival of the DDS pilot plant, our work at NZDRI with cellulose acetate membranes had shown that sulphuric acid whey, by then a common form of whey throughout the country, was more difficult to process in the UF plants then available to us. Flux, the measure of the flow rate of permeate through the membranes, was significantly lower than was the case with lactic whey and the membranes needed cleaning more frequently. We did not know the reason but it was yet another cause of anxiety.

To our relief and for reasons never fully understood the DDS pilot plant equipped with polysulphone membranes performed exceptionally well on both lactic and sulphuric acid wheys. In the fastest set of technical and commercial discussions and negotiations I have ever known, the decision was taken to install three DDS ten-stage continuous ultrafiltration lines at the Te Aroha Thames Valley Cooperative Dairy Company (TATV) at Paeroa, to begin operating by August 1978. The raw material would be sulphuric acid casein whey from TATV's caseinate plant. Anticipated annual production of WPC 75 was 500 tonnes.

For me, events were about to take a new turn in that I joined the Rangitaiki Plains Cooperative Dairy Company (RPD) in Edgecumbe in May 1978, while the new UF plant at TATV was being constructed. I maintained contact with TATV and indeed, with the agreement of RPD, spent some days there helping Ross Doughty, my former colleague from NZDRI who had become manager of the TATV whey plant.

It is no secret that TATV's first year of operation fell well short of expectation. The main reason was that DDS had decided, without telling us, to install a different specification of polysulphone membrane than had been used in the pilot plant evaluated at NZDRI. This was revealed in reviews of why the flux performance of the new commercial plant fell so far short of what had been observed at NZDRI. The manufacturer had had good results with a newer membrane in European WPC plants that were processing cheese wheys. They had simply assumed that the new membrane would work well for TATV.

In good faith, DDS accepted responsibility and replaced the membranes. Even when the correct membranes were installed, the plant could still not achieve the target protein concentration of 75

The second DDS plate and frame plant continuous plant, at Rangitaiki Plains CDC's Edgecumbe factory, opened in 1979. Operator Brent Devereaux checks plant settings in one of the two 13-module lines in the ultrafiltration plant.

percent unless the whey feed rate was reduced below design capacity. This placed additional burdens and frustrations on the Dairy Board, which, despite its investment at TATV, was still poorly placed to supply the Japanese market with gelling WPC 75. In fact, projected Japanese demand was now far beyond TATV's capacity, even if it were running at design capacity.

A second continuous plant at Rangitaiki Plains

In what can only be described as a remarkable instance of courage, Don King and Arthur Hale persuaded their Dairy Board masters that there was an immediate need for another large ultrafiltration plant. In late 1978, the Board wrote yet again to the manufacturing companies, seeking proposals for a new plant to make WPC 75 from acid whey, again to be underwritten by the industry. The Board provided the data needed to prepare proposals but there were just four weeks to get these submitted.

Graeme Honeyfield, general manager operations at Rangitaiki Plains CDC.

I had been at RPD for just four months. The company had been through harrowing times financially on account of some failed commercial ventures and was struggling to find its feet. The processing heart of the business was still in good form however, and a new WPC plant might provide just the boost the company needed. In a quiet but

very determined conversation with the general manager operations, Graeme Honeyfield, we agreed that this project was a 'must win' for the company and that we would work on nothing else for four weeks. If we were not successful, it would probably mean that we'd both have to find new jobs. There is nothing like a 'face the brutal facts' session to crystallise thinking.

In as determined a way as we could, we set about preparing a comprehensive proposal for the Dairy Board to consider in November 1978. It was with much relief that our proposal was accepted but there was no time to lose if we were to have the new plant operating by August 1979.

Garry Johns, inaugural WPC plant manager at RPD, later general manager operations at Manawatu CDC.

The day after we were given the go-ahead, we met and appointed the primary building contractor, who set the piling foundation materials aside for us that very afternoon. By Christmas we had chosen and ordered all of the plant items and chosen the installation contractors. Given the strength of RPD's process engineering staff and the internal knowledge of the products to be made, we decided to take full responsibility for overall process design and control strategies. We worked from a basic view that the product was the starting point in process design, not the end.

At the heart of the process was the ultrafiltration plant. As had been the case at TATV, the choice was a continuous, stages-in-series DDS plate and frame system, but configured as two lines of 13 modules, rather than as three lines of ten. There would be extensive diafiltration capability and the right kinds of membranes for RPD's sulphuric acid casein whey.

The relationship between Pasilac and RPD during this project was excellent and illustrated the value of a partnership approach to projects. This was the first Pasilac installation in New Zealand to use a programmable logic controller. A senior Pasilac engineer from Denmark was with us for six weeks.

The plant was commissioned in August 1979 and produced its first in-specification WPC 75 within a week. Today it is commonplace for plants to start-up well but it was not typical back then.

Much of the credit was due to the staff of RPD and in particular the inaugural plant manager, Garry Johns, who was an exceptionally capable manager and an excellent predictor of problems. Johns would become general manager operations for the Manawatu Cooperative Dairy Company two years later, where he again proved his skills.

We were fortunate to have Johns in charge of the plant, with his fine young team of people, many of whom stayed at RPD (or Bay Milk as it became in 1985) for many years. One of the plant operators, Tony Chamberlain, had the distinction of having worked in the whey plants at Waitakaruru, Paeroa and Edgecumbe.

The lessons learned from NZDRI and the earlier whey plants seemed to come together well at Edgecumbe. However, we had not completely solved the problem of how to make WPC 75 so that it achieved the gelling specification each day, every day.

In yet another case of serendipity, and as is so often the case with the fluctuating fortunes of dairy products, we had some unexpected breathing space to sort the problems out. The period of high market demand that had driven the industry to build the new whey plants at Paeroa and Edgecumbe in just two years all but disappeared, in part because of emerging doubt in Japan that we could supply the product. Japanese demand had eased to the point where the Edgecumbe plant was building up WPC inventory. At one point, Don King described RPD as "a galloping horse that has sprinted out of the stable", to convey his sense of alarm and frustration at this latest turn of events.

Fortunately this temporary excess of product proved to be an aberration. For a time the RPD plant was used to make a lower value, non-gelling WPC product but it reverted to gelling products within a year, with new demand from Japan that was stimulated by greater confidence in New Zealand's ability to supply. These products would become the mainstay of the RPD/Bay Milk plant at Edgecumbe and would generate many hundreds of millions of dollars in revenue for New Zealand.

Controlling gel strength: the BIG challenge

The temporary lull in demand for gelling WPC had given us time to resolve the processing problems that had prevented us from consistently achieving Japanese expectations. Working at NZDRI was a young technologist by the name of Julia Johns, who proved to be very conscientious and helpful to us. At RPD we had another young and capable technologist, Vicki Kruse.

We knew there were several key factors that would affect the gelling characteristics of WPC. In particular, we needed better understanding of how to control the behaviour of calcium in WPC during gelation. To do this, we needed to know how to manipulate the combination of mineral

composition, pH and the amount of denatured (heat modified) protein

It was received wisdom that to achieve good heat-induced gelling, there should be no damage (denaturation) to whey protein. However, our work showed that this was not so. Some denaturation was in fact very useful. The combination of mineral composition, pH and preheating, and the sequencing of processing steps, was very important. For example we found that linking the flow rates of certain additives to the product with other process flow parameters could produce much more stable gelling properties in the finished WPC.

Tony Christiansen

In multivariable studies designed with the help of NZDRI, we were able to identify combinations of key significant process variables that would allow us to achieve high gel strengths. By the end of the 1979/80 season, we were well along the path to supplying the Japanese customers with what they wanted. By now new Japanese customers were entering the picture, with new testing regimes and particular wants and needs, but at least we now had a better basis for dealing with their enquiries.

Despite all of the work done and all of the improvements made, we still could not produce WPC 75 with nicely consistent gel strengths, day in day out. We could make products with very high gel strength on one day, well above specification, but as likely as not, gel strength for the next day's product would only just reach the specification. In addition, there was poor agreement between Japanese and New Zealand laboratories testing the same lots of product.

An important visit to Japan: February 1980

In 1980, Don King arranged for one of his technical staff, Tony Christiansen, and me to spend two weeks in Japan. The purpose was to meet with staff of NK and visit the various customers for WPC 75, to discuss the product and its testing in more detail. What an experience that proved to be. It stimulated my own interest in Japan and its people to such an extent that I would spend over six years there from 1986, working on behalf of the New Zealand dairy industry. In 1980, however, I was truly the novice when it came to being in Japan – making more than my share of gaffes, I'm sure.

Central to the visit was two days with the largest user of New Zealand WPC 75. This included being in their laboratory and conducting the same gel test we were having difficulty with in New Zealand. It is not common for Japanese customers to allow suppliers into their laboratories but it was very clear that these people trusted us and wanted

us to get things right. What struck Tony and me was the attention to detail and the precision of their techniques. Whatever the test method said was precisely what they did. Later, when I worked in Japan, I learned that in analytical disputes with New Zealand on any number of products, the Japanese would often prevail because they were so attentive to test methods and techniques.

So we returned to New Zealand, fired up with new enthusiasm for the WPC business and possessing techniques that would form the basis of gel testing for the Japanese market for some years to come.

It has to be said, however, that while this was another step along the path, we still didn't achieve the consistency that we all felt that we should. In time I came to attribute this variability to small day-to-day changes in raw milk itself, with this variability being multiplied many times through the UF process. I also realised later that the Japanese customers were reasonably tolerant of lot-to-lot variability, as long as every lot exceeded their specified minimum. In hindsight we were probably being driven by an innate desire to have everything just right, when in fact it simply was not possible and indeed not necessary from a commercial point of view.

Operator Matthew Taiaroa with the newly opened Manawatu CDC DDS plate and frame plant at Longburn, 1982.

Manawatu joins the party

In 1981, the Manawatu Cooperative Dairy Company at Longburn decided to build a major new milk protein factory. This would be a state of the art plant that produced lactic casein plus WPC 75. It was completed in 1982.

Casein from this plant was of exceptionally fine quality. In time Manawatu became one of just two approved sources of New Zealand casein for food grade applications in Japan. The WPC 75 from




Scenes at Nippon Proteins , the Dairy Board's joint venture in Tokyo with Japanese company Nissei Kyoeki (NK).

this plant was also good, although, being made from lactic casein whey, some of its characteristics differed from the WPC 75 made at Paeroa and Edgecumbe from sulphuric acid whey. This presented new challenges for marketing but it was not long before Manawatu's WPC 75 was also a well-established part of New Zealand's WPC product offering.

The key point was that by 1982, the New Zealand dairy industry had excellent manufacturing plants for making high protein, gelling WPCs from both lactic and sulphuric acid wheys. We were well on the way to establishing a strong business for these products in Japan, with high quality customers who seemed genuinely pleased and grateful for what the New Zealand dairy industry had been able to achieve for them. Further enhancements were to come and new markets were to be developed, but at long last, the business had begun.

Postscript: developments after 1982

The era 1975 to 1982 has been the primary focus of this chapter but as with all good business ventures, the story did not stop there. Following is a summary of some of the changes and developments that occurred

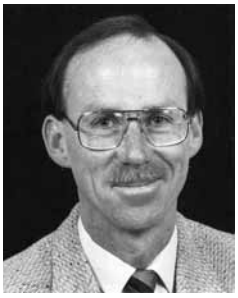
in the manufacture and marketing of WPC for gelling applications in subsequent years and some of the commercial changes that affected the WPC business.

Commercial developments:

Formation of Nippon Proteins

Following years of ever-increasing cooperation between the Dairy Board and NK, the two companies created a 50/50 joint venture in 1982. It was known as Nippon Proteins or NPKK. Its purpose was to import and market New Zealand's range of milk protein products, including casein, caseinates and WPCs, plus various specialised proteins (e.g. lactoferrin) and protein-derived ingredients such as hydrolysates (enzyme treated proteins).

Nippon Proteins was also responsible for importing prepared edible fats (blends of milkfat and vegetable fats). The inaugural chairman was the perceptive and skilful Yukio Fukuoka. For much of its history, the company had a staff of around 26, mostly Japanese but also a succession of seconded New Zealanders.



Peter Hobman

It was my good fortune to be one of those staff for four years. The person who pioneered the role was Peter Hobman (one of the co-authors of this book). Peter was very effective in Japan, establishing particularly close relationships with Japanese companies and with his colleagues. Nippon Proteins would be the focal point of much of the industry's endeavours in developing new whey products for Japanese customers and enhancing its existing range. Nippon Proteins no longer exists – it was subsumed into the Fonterra/Nissei Kyoeki joint venture after the creation of Fonterra itself in 2001 – but it ranks as one of the most successful joint ventures ever formed by the Dairy Board with an overseas partner.

Formation of the Whey Corporation

This is such an important event in the history of whey processing in New Zealand that it has its own chapter in this book (Chapter 8). All of the developments in this chapter pre-date its formation but gelling high protein WPCs for the Japanese market would be the cornerstone generator of revenue and profit for the Whey Corporation. Much of the thinking that led to its formation was forged in the interplay of opinions and tensions among all the various industry players of the day, distilled into the effective and well-run entity that the Whey Corporation proved to be.

RPD was very much in the minority in opposing formation of the Whey Corporation because our own WPC processing was profitable and we regarded newcomers as likely to dilute returns, not expand them. On this we were wrong. In time we all came to see that, for the industry as a whole, the Whey Corporation concept was elegant, fair and a commercially very sound approach to expanding whey processing opportunities across the entire industry. Gelling WPC would flourish as a product under the control of the very supportive and enthusiastic staff of the Dairy Board's whey products section.

Technical developments:

From WPC 75 to WPC 80

Changes in Japanese import regulations and differences of opinion in protein testing methodology led to an increase in the minimum protein concentration required to be able to import these products into Japan. This affected yields (which were reduced) but was good for gel strength, as in general the higher the protein concentration, the stronger the gel.

Cold ultrafiltration

All of the continuous UF plants described in this chapter were operated at 50C because this temperature, at a whey pH of 4.6, prevents the growth of most troublesome microorganisms, in particular lactose-fermenting bacteria of the lactobacillus family. In those years, membrane costs were relatively much higher than they are today, so we were also driven by the need to minimise membrane area. There is no doubt however, that membranes fouled more quickly at higher temperatures, which led to loss of capacity. Typically, membranes were replaced annually.

By the 1990s, the relative cost of membranes had declined and systems became much more compact. The plate and frame systems of the 1970s and 1980s gave way to the much more compact spiral-wound membrane configurations in widespread use today.

Availability of less expensive membranes led to cold ultrafiltration. Processing rates per unit area of membrane were lower than in plant operated at higher temperatures but overall performance was better, with improved yields, better microbiological control, longer membrane lifetimes and better product properties. For example, the Tatua UF plant installed in 1996 to process sulphuric acid whey is operated at 10C. Membrane lifetimes of up to three years have been obtained.

Microbiological control has been excellent. Also of note is that the gel strengths of the WPC 80 made at Tatua are twice what they were for WPCs made at Paeroa and Edgecumbe in the early 1980s.

Cleaning systems

In parallel with all of the efforts to make the right products and have efficient whey processing plants, there was sustained effort by the suppliers of cleaning chemicals to develop much more effective cleaning regimes. It was essential that the membranes could be cleaned every day to restore full performance and that there be no remaining residues that might harbour microorganisms. Today's cleaning regimes, built as they are around enzymes and detergents, are far superior and much more reliable than those of 30 years ago.

Water

An early complication for New Zealand whey processors was that many regions such as Paeroa and Edgecumbe are geothermal and their river and ground waters can contain particularly high concentrations of silicates. These compounds can form complexes on membrane surfaces that are quite greasy and very difficult to remove. Hence they accumulate, gradually slowing permeation rates. The Department of Scientific and Industrial Research provided excellent support to identify causes and resolve this issue. To this day, most New Zealand's plants use demineralised water for diafiltration and for cleaning of membrane systems.

Brine tolerant WPC

A very interesting enhancement of gelling WPC 80 for the Japanese market took place in the late 1980s. One customer in particular had been concerned that whereas solutions of New Zealand's gelling WPC, made by simply dissolving the powder in water and then heating, formed excellent gels, those prepared by dissolving WPC in a salt solution did not. Rather, the 'gel' was more like an aggregated curd, similar to ricotta cheese. There seemed to be a direct analogy to the early days of making WPC 75 for Japan, when gels formed in water were also very curdy.

Pickling fluids injected into pork when making hams contain various salts. Because of this, the customer felt our WPC could do a better job of binding moisture if it were more salt tolerant. The term 'brine

tolerant' came to mean a WPC 80 product that formed a true, heat-set gel (a smooth, elastic gel with minimal syneresis) in the presence of sodium chloride.

The project to develop a brine tolerant WPC product took place while I was working in Japan for Nippon Proteins. The Japanese staff proved to be exceptionally determined and conscientious in their support of this work. They were able to show that extensive diafiltration of an unneutralised, high protein WPC retentate could give WPC solutions that after neutralisation formed very good heat-set gels in the presence of salt. These observations formed the basis of the process now used to make brine tolerant WPC in New Zealand for the Japanese market.

Conclusions

Looking back on the history from today's perspective, it seems to have a cohesion about it that was far from apparent when the work was in progress. Product innovations and their associated technical developments rarely, if ever, follow some pre-ordained path. The time course can be littered with disappointments, setbacks, criticisms, wrong directions, even despair, but if there is one thing that characterised the development of New Zealand's WPC industry between 1975 and 1982, it was believing that one day we *would* succeed. Many people contributed and indeed many people had to contribute. There were so many questions that had to be answered. It was no single profession's domain. Over the seven-year period, there was participation by engineers, chemists, microbiologists, food technologists, product analysts, laboratory technicians, plant managers, operations staff, accountants, marketers, dairy company executives, dairy company directors – just about every profession and function that serves the dairy industry. To them all I dedicate this chapter.

CHAPTER 5

FOOD SCIENCE AND TECHNOLOGY TO THE RESCUE

JIM HARPER

***Jim Harper**, Professor Emeritus, Ohio State University, obtained his PhD from the University of Wisconsin in 1949. He has advised 150 graduate students, taught 18 different food science courses, and published in more than 300 scientific publications. He spent five years at NZDRI between 1981 and 1986 and was a consultant to the New Zealand dairy and food industry between 1986 and 2011. He is an honorary fellow of the New Zealand Royal Society.*

My first direct contact with the New Zealand dairy industry was in October 1975 at the Whey Research Workshop in Columbus, Ohio. I did not foresee that this was the beginning of a close relationship that would last for at least 35 years.

Kevin Marshall, speaking at a symposium in my honour at Massey University in 2009, had this to say:

> That workshop, nearly 35 years ago, was the start of Jim Harper's involvement with the New Zealand whey industry. Jim was a major force behind the organisation of the workshop and he played a prominent part in the proceedings.
>
> I well remember, late one afternoon during that event, a group of us gathered in a motel room socialising with a beer or two. Jim was stretched out on the bed, bottle in hand, expounding on the need for specific research projects and answering questions about milk proteins. It reminded me of an ancient Greek or Roman philosopher in discourse with his academy! I recall thinking it would be great to get Jim to spend some time in New Zealand – little did I (or Jim) know where that thought would eventually lead.

I joined Ohio State University in 1949 and developed research interests in food science and technology, particularly in the properties of proteins and how proteins interacted with other ingredients during food processing, commonly known as functionality. My interest in whey was stimulated when I was contracted in 1969 by the US Environmental Protection Agency (EPA) to investigate dairy factory wastewater and its treatment.

Before the first whey research workshop I had done more than 10 years of research into ultrafiltration techniques to produce whey proteins for use in food processing. I also had a 20-year background in teaching about food additives, model food development and technical problem-solving.


Jim Harper

In the fall of 1980, after a protracted two-hour drive home to Galena, Ohio in a snowstorm, I answered the phone to hear Kevin Marshall ask: "Jim, what would it take to get you to New Zealand for a year." I replied: "Kevin, tonight not much." Then I asked my head of department for a year's leave of absence but was turned down with the comment, "Why do you want to do something as stupid as that." I retired immediately. With 32 years of retirement credit at the Ohio State University, I decided to take the risk and to go to New Zealand.

I joined the Whey Products Section of NZDRI in April of 1981. My task was to support the marketing efforts of the New Zealand dairy industry by leading research into the food science and technology of whey proteins – particularly whey protein concentrates (WPCs).

What Kevin hadn't told me was that much of the WPC produced had been in warehouses for a considerable period. What the New Zealand dairy industry needed was someone to help them develop WPCs with properties someone actually wanted to buy.

I stayed at NZDRI for six years, including a period as the whey products section head. After returning to Ohio I continued my research on WPCs and visited New Zealand between December and February each year until 2011.

The properties of whey protein concentrate

At the beginning of the 1970s, little was known about WPC – its properties and potential uses. But research on whey was increasing throughout the world. Partly this was driven by environmental issues arising from disposing of whey that was a by-product of cheese and casein manufacture. It was also driven by new technologies for producing soluble whey proteins.

Interest in bovine whey proteins has a long history and their nutritional value was recognised by the turn of the 20th century. In 1903 a technique for producing dried whey protein was patented in America. In 1931 a further US patent was filed for a process to make 'lactalbumin' (the name then used for whey proteins), by an acid and

heat process. The patent was assigned to the Borden Company, whose product was marketed as an insoluble but nutritional whey protein.

By 1955, the nutritional value of milk proteins, especially whey proteins, was firmly established. Interest was building in their use in food products, especially candies, soups and bakery.

Very little attention had been given to the functional properties of whey proteins. The most prominent text on dairy products in the 1970s, Webb and Johnson's *Fundamentals of Dairy Chemistry*,[1] had no information on whey protein properties other than a brief reference to its solubility in the acid conditions that would cause the precipitation of the main dairy protein, which was casein.

Between 1930 and 1970, numerous American patents were issued for whey protein manufacturing techniques that included ultrafiltration, reverse osmosis, ion exchange, gel permeation chromatography, electrophoresis, and precipitation by heat, sodium sulfite, soluble iron salts or other chemical additives. Of these, ultrafiltration was given the most attention, notably in America, Australia, New Zealand and parts of Europe.

It was in this context that I became involved, first in two whey workshops, and then with the New Zealand dairy industry and an international collaboration. During the next decade or so I was part of a programme which led to a major increase in knowledge of the properties and uses of whey proteins.

The whey research workshops

During the 1970s, international discussions among scientists and technologists began, encouraged by the global nature of the challenges whey was presenting. Key people who saw the need to share information, problems and solutions included Lawrie Muller of the Commonwealth Scientific and

FUNCTIONALITY

Whey protein 'functionality' refers to the ability of the protein, variously, to be soluble, to form gels, emulsify, foam, form films and be heat-stable. Different foods require different functionalities from whey protein ingredients. For instance, gelation is required for making hams with good slicing characteristics, while infant formulas must be stable in the high heat that makes them sterile. (See the table on page 104.)

Structures of the whey protein to achieve these different functionalities can be quite different. Food scientists and technologists in New Zealand found that changes in the manufacturing process could produce a variety of protein structures. This meant they could tailor proteins to the processing needs of a variety of foods. Such changes included the type of whey used, processing temperatures, removal of fat and addition of salts such as calcium and phosphates.

Industrial Research Organisation (CSIRO) in Australia, Kevin Marshall of NZDRI in New Zealand, John Woychik of the US Department of Agricuture and people in American universities: Walter Dunkley of the University of California at Davis, Charlie Morr of Clemson University and me at Ohio State University.

This contact led to a whey protein workshop, funded by the US National Science Foundation under science agreements with both Australia and New Zealand.

The first workshop was held in Columbus, Ohio, in October 1975. Thirty-one attendees came from America, Canada, Ireland, New Zealand (Ken Kirkpatrick and Kevin Marshall) and Australia. They included people from government, university and industry. Industry people listened, but made few suggestions for future directions. No equipment suppliers attended. On the agenda were reports of research in progress and discussion of the needs for further research. This included a need for better understanding of functional requirements for whey proteins used in the manufacture of food products, more standardised tests to determine how whey proteins will perform in foods, and how to make WPC products better suited to their intended or potential end uses.

A second workshop was held in Palmerston North, New Zealand, in 1979. This workshop identified 38 research priorities and again it identified an urgent need for standard methods for evaluating the functional properties of WPCs. It also highlighted the use of model systems that related closely to end-use applications – an illustration of the philosophy, 'If you want to know how well a protein will function in a finished product you have to bake the cake'. The papers presented at this workshop were published the following year in the *New Zealand Journal of Dairy Science and Technology.*[2]

One of the most important outcomes of these workshops was the establishment of a network of people who would work together over the next 12 years to expand the knowledge of whey proteins and their application as food ingredients. From this evolved a number of collaborations that benefited not only the New Zealand whey products industry, but the whole field of whey protein development.

Whey Protein Collaborative Research Group ('Collab')

After the 1979 workshop, Lawrie Muller (CSIRO in Australia), Mike Matthews (NZDRI) and I discussed forming an international

collaborative group that would try to standardise methods for assessing the properties of whey protein and look at the factors affecting those properties. Mike Mangino, who had joined the Ohio State University in 1976, became a strong supporter.

In 1980 I contacted two other American whey protein researchers, Charlie Morr of Clemson University and Arun Kilara of Pennsylvania State University. They became members of the Collab group, along with Peter Hobman (who by then had taken over from Kevin Marshall as head of the NZDRI Whey Products Section) and Lawrie Muller.

At first this collaboration consisted only of discussions and letters about what to do. However, it was soon recognised that this informal arrangement was not very satisfactory. Communication was occasional and unplanned. After about a year, it was agreed to hold regular conference calls and meetings at one of the institutions to share findings. This developed into a more coordinated programme.

Individual institutions decided on what to investigate and shared their plans with the other members. A quarterly conference call was instituted where all five Collab members could share their results. Several weeks before the call, a summary of the research methods and results would be submitted to the other members. This worked relatively well.

The group agreed to focus initially on standardising measurement of whey protein properties in aqueous systems and evaluating factors that affected those properties. The greatest problem the industry faced was the lack of such standardised measurements – results from one laboratory frequently would not match those from another. Also at that time, most examination of

GELATION

One of the most important properties of whey proteins is gelation. Whey proteins are well known to be sensitive to heat. During heating, the protein structure unfolds and then on cooling re-forms into a different structure that gives different characteristics to the food product in which it is being used. Using different processing conditions, gels can be formed that are either translucent and elastic, or opaque like egg white. An elastic gel is desired for hams, to give good slicing characteristics.

The structure of whey protein gels can be altered during processing in a number of ways:

- Adding or removing calcium, which interacts with denatured whey proteins.
- Heating at different times during processing.
- Changing pH to modify the sulphur bonds in β-lactoglobulin.
- Adding cysteine (an amino acid) This manipulates the structure in different ways to change protein functionality.

whey proteins in aqueous systems was conducted at relatively low concentrations. The Collab group wanted to investigate whey protein properties at real-world concentrations that would actually be used in food processing.

The collaborative programme developed standardised testing methods for the key properties: solubility, gelation, emulsification and foaming. These were developed through inter-laboratory evaluation of protein samples from the same batch of product. The tests were published and used by the different research groups making up the Collab group.

The first meeting took place in July 1982 during the American Dairy Science Association meeting at Penn State University. There were 24 separate presentations by representatives of the various organisations, with emphasis on:

- Whey protein concentrates: industrial status of ultrafiltered protein products (Cornell, CSIRO, NZDRI); commercial separation by ion exchange (Clemson, NZDRI, Penn State); commercial separation by other technologies, e.g. chromatofocusing (CSIRO, OSU), immunoelectrophoresis (OSU), gel chromatography (OSU) and HPLC (CSIRO).
- Functionality: in bread baking (CSIRO, OSU), in salad dressings (NZDRI), in sausages (NZDRI), in protein blends (OSU), in gelled products (CSIRO), in whipped toppings (OSU), in coffee whiteners (OSU), in beverages (CSIRO), and in ice cream (NZDRI, CSIRO).
- Processed-induced changes: β-lactoglobulin structure (NZDRI), β-lactoglobulin denaturation (NZDRI), hydration of calcium caseinate (OSU), sulphydryl changes in whey proteins (CSIRO), demineralisation (NZDRI, CSIRO).
- Methods: standardising testing methods for WPC functionality (Penn State, CSIRO, NZDRI, OSU).

The meeting was declared a success and it was decided to continue the programme.

The meeting agreed to continue testing samples of high (75 percent) protein WPCs. NZDRI produced two samples from cheese whey and two from acid whey for testing. One sample of each whey type was unheated and one was pasteurised.

Sub-samples of each of these 'standardised' WPCs were provided

to each collaborator and others in America, who used their own test procedures to study composition and functional properties. The data were pooled and compared among the participating laboratories, resulting in mutual agreement on standardised test methods thus improving the standard of product quality measurement in all three countries. Four more meetings were held:

- 1983 – Melbourne, Australia
- 1984 – Madison Wisconsin (during a whey protein symposium which included papers by several of the Collab members)
- 1986 – Columbus, Ohio
- 1988 – Melbourne, Australia

Each meeting added important new information. The 1984 meeting proceedings were published in the *NZ Journal of Dairy Science and Technology*. Collaborative efforts continued until 1991.

After 10 years, a large mass of scientific information had been gathered and included, directly or indirectly, in more than 100 publications. Each publication added to our knowledge of the factors that controlled protein conformation and affected how proteins performed in food products. Altogether, the effort of over 20 scientists and 15 technicians and graduate students in this collaboration programme contributed to a better understanding of how whey proteins functioned.

Of course to be of any value, the scientific findings of this work needed to be translated into practice. The New Zealand team excelled in this translation. To understand why, let's go back to the time of my arrival in New Zealand.

Challenges facing the New Zealand whey protein industry in 1981

The late 1970s to early 1980s were times of great challenge for the emerging whey protein industry in New Zealand, in terms of processing, research and marketing. Much progress had been made in understanding how to make 65 percent protein WPC to meet the requirements of Coca-Cola. However, by the late 1970s that interest had waned. To meet the expected growing demand for high protein WPCs, the industry had built manufacturing plants at Te Aroha-Thames Valley CDC (TATV) in Paeroa and at Rangitaiki Plains CDC (RPD) in Edgecumbe. Further plants were planned by Manawatu CDC and NZCDC. Markets for these high protein WPCs had not yet been fully developed, although Japan

was showing a continuing interest in a gelling WPC to replace egg white, especially in hams (see Chapter 6). In the early 1980s there were discussions about setting up a pooling system for whey products manufacturing and marketing to take some of the financial pressure off the individual companies involved in whey protein processing. This would prove a very important development (see Chapter 8). Over the same period researchers in New Zealand had gained considerable understanding of how to use ultrafiltration to make soluble high protein WPC. However many of the more senior personnel had moved on to other positions. Ken Kirkpatrick had joined the NZ Dairy Board, first in Chicago at NZ Milk Products and then in Wellington head office. Kevin Marshall was then heading the whey products group at NZDRI and would become an assistant director of NZDRI in 1979. Mike Matthews, after a short but important stay at NZDRI, had joined RPD to head its technical development of high protein whey products.

All these people, plus other industry leaders, saw a need to be more rational about manufacturing what the market needed. And marketing people in the Dairy Board's whey products group in Wellington and overseas were actively looking for products that 'needed' whey protein concentrates as ingredients.

Considerable competition for the New Zealand industry was developing. Ultrafiltration plants had been installed in Australia, Ireland, Denmark, France, Germany, The Netherlands, South America and North America. Some of this production aimed to reduce the environmental impact of whey by producing a 35 percent protein product that could be used as a skimmilk powder replacement. (However, the lactose content of a permeate would still be a problem.)

The other major production target was a range of WPCs containing more than 75 percent protein. New Zealand was aiming at this target and had an unusual advantage in that it was one of the few dairy industries with major supplies of whey from lactic casein manufacture. Evidence was emerging that WPCs made from lactic casein whey were very different from WPC products made from other types of whey.

By 1981 it was clear that research was needed to move beyond basic 'how to make WPCs', to 'how can we tailor-make WPCs as value-added ingredients in a wide variety of products?'.

It had been observed over the years that WPC properties were influenced by many factors including the whey source (cheese, lactic casein, mineral acid casein, rennet casein), starter type, rate of acid development, pH of casein separation, whey quality, lipid concentration in the whey, changes in upstream processing and seasonality.

The effect of all these variables was both a weakness and an opportunity. Variability made it difficult to meet customer specifications consistently. However, if it could be understood and controlled, then the properties of WPCs could be altered to meet specifications required for new uses. Processing conditions could be changed to give the WPC specific functions and to tailor-make WPCs for particular food applications.

At the same time it was recognised that more than just process engineers were needed. There was a need to understand more than just the process of manufacture. Steps were taken to include people from different disciplines, including process engineers, microbiologists,

NZDRI in 1984. At the rear, under the sawtooth roof, is the processing hall where the whey pilot plant was installed. The whey section's offices, laboratories and model food facilities were on the first floor of the multistory building on the right. In the left foreground is the former Massey University College dairy factory which was used by NZDRI before its own processing centre was built in 1968.

food technologists, food scientists and protein chemists. One of the strengths of the New Zealand dairy industry was that the R&D was all located at the NZDRI, which allowed for small, effective cross-functional teams. These teams were then integrated with the technical and production teams at the dairy factories and the technical officers at the Dairy Board.

'Baking the cake'

At that time the Dairy Board marketing people had already been very active in contacting potential customers, particularly in Japan and America. Many potential food applications had been identified.

Each of these applications required different and sometimes multiple characteristics in the WPC (see the table below).

In food processing, proteins may have more than one function, such as both solubility and emulsification or a combination of water binding and gelation. In some cases a protein may have both positive and negative functions. For example, protein added to a cake recipe can positively or adversely affect surface structure, crumb structure and cake volume. We found that two whey proteins from the same whey source, but processed under different conditions, could function differently in food manufacture. One might give a dry surface and reduce cake volume, while the other might give good volume but produce a sticky surface.

Desired whey protein functions by food group

Food	Required function
Acid beverages	Solubility, acid stability, heat stability, emulsification for some
Restructured meat	Gelation, fat absorption, water binding
Cakes	Emulsification, foaming, gelation, water binding, cohesion
Salad dressing	Water binding, emulsification
Infant formula	Emulsification, heat stability, yield stress rheology
Whipped topping	Emulsification, foaming
Coffee whitener	Emulsification, heat stability (prevent 'feathering')
Puddings	Emulsification, gelation, water binding

Whey protein gels can be made so that when they are set by heat, they can be either translucent and elastic, or white and brittle like egg white. Whey proteins generally require heating over 75C to obtain a

...continued on page 106

THE CHEMISTRY, STRUCTURE AND FUNCTIONALITY OF WHEY PROTEINS

Four major whey proteins (β-lactoglobulin, α-lactalbumin, several forms of immune-globulins and bovine serum albumin), contribute to the functional properties of whey protein concentrates (WPCs) in food systems. These properties include solubility, gelation, emulsification, whipping and heat stability.

Whey proteins comprise from 123 to 316 amino acids. The sequence of amino acids provides the protein's primary structure. Within seconds or less of being secreted from the mammary gland, the protein folds into its final structure.

The secondary structure of the protein dictates much of its characteristics when used in a food product.

Another protein structure, called quaternary, exists when two or more of the same protein combine to form dimers, trimers, or higher polymers. For example the major whey protein (β-lactoglobulin) can form different quaternary structures as pH changes. This affects the characteristics it gives to a food system.

The secondary, tertiary and quaternary structure of the protein can be changed during processing to give different functional properties and interactions in the end-product, by changing pH, temperature, ionic strength, and calcium and/or phosphorous.

Changes in these properties can affect gelation, emulsification solubility, heat stability and whipping characteristics. Often, changing one functional property will change other functional properties and interactions in a food system.

We used ultrafiltration pilot plant studies, in combination with a model food system, to develop different 80 percent WPCs for use in different foods. For example, ultrafiltered acid whey and sweet (cheese) whey products might be used in different foods depending, in part, on their differences in pH. For instance, acid whey could be developed into WPCs that gave good slicing characteristics to ham, whereas a sweet whey could not. In contrast, the opposite was true for heat stable WPC for use in heat treated infant formula, in which acid whey did not work.

More information about proteins, their structure and their analysis, is in the Glossary, pp250-251.

good gel. Acid whey is more suitable for making a gelling protein than sweet wheys.

In contrast, a heat-stable protein, for use in infant formulas, is much easier to make from sweet whey than from acid whey. Acid whey protein concentrates, even when neutralised to pH 7, are not stable when sterilised by heat. In an attempt to understand this, we looked at extensive studies of the individual whey protein components, e.g. β-lactoglobulin, α-lactalbumin, bovine serum albumin (BSA), immunoglobulins, glycomacropeptides and other minor proteins, and investigated how heat and other ingredients interacted with those component proteins. Then we had to manage those proteins throughout the processing so that they were in the correct structural configuration when used by the infant formula manufacturer.

It was clear that whey proteins were subject to changes in conformation both during the manufacture of the whey protein concentrate, and in the manufacture of the food product. Knowledge of these changes would be used to tailor-make whey protein products for use in different types of food.

I set out to organise the vast amount of information that had been accumulated by the NZDRI researchers and which was arising from the Collab studies, and to use my experience of whey protein biochemistry to make sense of the myriad of observations. Several basic principles came into focus. They included:

- Aqueous tests, such as for gelation, foaming or emulsification, did not accurately predict how whey protein would perform in final food processing.
- Each step in the manufacturing process could modify how whey proteins would perform in different food products. Understanding this became a powerful tool when tailor-making whey protein products.
- During manufacture of food products, interactions with other ingredients could change the way whey proteins functioned.

Model food systems

I reasoned that one of the key tools we needed was a 'model food system' for each food product of interest. Such models would help us understand how whey proteins were being modified by different processing steps and other ingredients in a food product. I had experimented with model

WHEN WE GELLED AN ENTIRE ULTRAFILTRATION PLANT

One of our goals was to make whey protein products that would form strong gels at the same temperature that egg white gels at (about 60C rather than the 75C at which the whey proteins gel). This would help us compete against egg white in the food processing industry.

We achieved our goal in the pilot plant and then had a successful commercial run at RPD at the end of the 1982/83 season. When the next season started, we tried another commercial run. Disaster! We managed to clog up the entire ultrafiltration plant with gel. It had to be shut down for several days while the gel was cleaned out.

Later we learned that during the off season a positive displacement pump had been replaced by a centrifugal pump without our knowledge. The increased turbulence disrupted the particulate protein/calcium/lipid complex and prevented its removal. Failure to remove this complex had caused the gelation. That was the last time we tried to do a commercial run of this type of WPC. (We were permitted to make other types of modified whey protein only after we satisfied management we wouldn't shut them down.)

Eventually I was forgiven and presented with a plaque that reads: "Presented to Dr Jim Harper. The rangatira of whey protein development at Rangitaiki Plains Dairy Co, New Zealand, 21/11/1985. The plaque still hangs by my office door today.

food systems at Ohio State University and CSIRO, and the need had been identified at the whey product workshops. Now it was clear we needed to intensify our efforts. We set out to do this, both at NZDRI and in the Collab. This probably was my major contribution to the development of whey protein products as food ingredients.

Subsequently NZDRI became the world leader in model food systems. At the 1982 Collab meeting in Pennsylvania I offered to provide the group with reference models for bread, sponge cakes, chocolate cakes, angel food cakes, meringues, custard pudding, frozen desserts, whipped toppings, infant formula, coffee whitener, meat emulsions and confections.

This work was a major contribution to the standardisation of WPCs to aid marketing. Again a key to the success in this work was the integrated, multidisciplinary approach.

Another key was taking a systematic approach when developing a WPC for a specific food. This included:

- In the pilot plant, determining the effect of each step in the manufacture of the WPC on the functionality (gelling, and/or foaming and/or emulsification) of the WPC.
- Using a model food system to determine the effect of the whey protein product on the characteristics of the target food product.
- Scaling up to commercial scale.
- Investigating markets for the final product.

When developing a model food system, we would begin by reviewing

Most of NZDRI's whey section at scientist Lee Huffman's wedding in 1988. Front row: Mike O'Connell, Tony Mackereth, Allan Marshall, Rex Humphrey, James Conway (partner, not NZDRI), Vaughan Hunt (partner, not NZDRI), Bruce Dukker, John Higgins. Back row: Diana Mackereth, Denise Hughes, Jim Harper, Moyra Roberts, Judith Bartosh, Mary Lojkine, Michael Higgins (John Higgins's son), Graham Devey (partner, not NZDRI), Lee Huffman, Rosemary Cleland, Pam Marks, Gerhard Hoppe, Sharon Wards, Ashley Kells, Lorraine Tremain, Robyn Cotton, David Newstead. Absent whey section staff: Sheelagh Hewitt, Linda Schollum and John Bligh. Judith Bartosh was from the Dairy Board, Robyn Cotton was from Tui Milk Products. Lorraine was head of the NZDRI Knowledge Navigators. Pam Marks and Sharon Wards were from the sensory department and worked with the whey products section. Tony Mackereth and David Newstead were from the milk powders section.

as many formulations as could be found, and selecting ingredients that were common to all the formulations. Next, a small-scale process for making the product would be developed, using processing steps and conditions that were as close as possible to those of the commercial process.

Different foods have varying characteristics, which may include taste, colour and texture. These can be modified by the ingredient formulation and the process. In many instances the protein would influence more than one attribute.

Our technicians became very proficient at gel testing. They also kept track and when Diana Mackareth (pictured) measured her 1000th gel, we baked a whey protein cake to celebrate the milestone. The sausage casings contain gel.

Testing for the effects of the WPC on the interactions with the various ingredients was very complex when more than four or five ingredients were involved. It was often necessary to use sophisticated statistical techniques to design and interpret the results of the experiments based on our model food systems. This helped us more efficiently determine ingredient and processing interactions. It also substantially reduced the number of experiments we needed to do.

Conclusion

Some executives in the Dairy Board had had reservations about bringing me to New Zealand because of my previous association in 1978 with CSIRO in Melbourne. There had also been concern in some quarters that the Collab work would rapidly dissipate New Zealand dairy industry's intellectual property. However, I believe the extra resources bought to bear on the issues, and the ability of the New Zealand multidisciplinary team to implement the outcomes into commercial activities rapidly, more than compensated for any increased risk. (It should be noted that New Zealand was the only Collab group member that had such close integration across research, manufacturing and marketing).

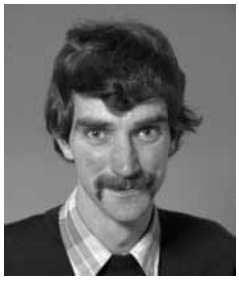
NZDRI had morning and afternoon tea breaks in a central cafeteria, which encouraged interchange of ideas among researchers from different sections – very useful in getting different views from time to time. In

Whey products pilot plant manager Mike O'Connell with a new six-stage, small-scale production plant installed ca 1988. NZDRI and the Whey Corporation (later Whey Products NZ) continually re-invested in pilot plant equipment. This unit was later converted to use spiral-wound membranes.

the whey products section on most Friday afternoons, Diana Mackereth would bake a chocolate cake made with whey proteins in place of egg.

Every Friday morning the whey products section would have a meeting to discuss the previous week's research findings and the next week's programme. This always included testing for gelation and other properties.

Typical of the atmosphere within the section was a 1 April occasion when I found grease on my office door handle, the castors gone from my chair and cut-up rubber bands in my tobacco pouch. I didn't find the latter until I lit my pipe. It didn't take too long to follow the giggles and find the culprits – Diana Mackareth and Coralie Proust.



Allan Marshall

The whey products section grew from eight people in 1981 to 15 people in 1984. The additions included Allan Marshall (chemical engineer) and Lee Huffman (food scientist). Other people were added later.

We were well funded, which made us the envy of other departments. The main reason for our good funding was the influence of Ken Kirkpatrick, who headed up protein marketing at the Dairy Board. I attribute this, in part, to the fact that Ken visited us every week. An avid wine connoisseur, he would drive up to NZDRI for Friday night wine tasting sessions. Then at 10 am the following morning we'd meet in my office. We'd talk about research progress in the whey products section and discuss the latest developments in whey protein marketing. I never had a request for additional funding turned down.

Jim Harper (right), with a greenstone adze presented in 2009 by the Riddet Institute, to honour 28 years of contribution to New Zealand science. With him are NZDRI whey section colleagues Rex Humphrey (protein chemist), Sheelagh Hewitt (applications), Lee Huffman (applications and facilitation of plant trials).

I returned to the 'States' in 1986, but remained active within the New Zealand dairy industry, returning for three months each summer to work on special products. I also helped, for several months a year until 1991, New Zealand Milk Products in California with its work on incorporating WPC into various products. I rejoined the faculty at Ohio State University in 1992 as an endowed chair in dairy foods.

Ken Kirkpatrick and Kevin Marshall also used me to evaluate the technical value of potential New Zealand acquisitions of companies in America, between 1986 and 1992. I continued to serve in a consulting role to the New Zealand food industry until 2011, as a visiting researcher at the Riddet Institute.

ENDNOTES

1 Webb and Johnson, *Fundamentals of Dairy Chemistry*, 2nd ed, Avi Press, New York, 1965.

2 *New Zealand Journal of Dairy Science and Technology,* March 1980.

CHAPTER 6

PRODUCT DEVELOPMEMENT

LEE HUFFMAN

Lee Huffman, *an Ohio State University PhD graduate in food science and nutrition, worked with the NZ dairy industry from 1978-2008. While at OSU, she participated in the international whey proteins 'Collab' group. In 1983 Lee received a Fulbright scholarship to work on whey proteins at NZDRI. In 1990 she moved to New Zealand Milk Products in America as technical services manager. In 2001 she returned to NZDRI, where she specialised in whey protein isolates and new product development.*

During the 1980s, whey protein concentrate (WPC) became a serious business for the New Zealand dairy industry – 26 new and different products were developed and commercialised and most were very profitable.

No single WPC could deliver all of the properties that customers might need, so we tailored our products to specific customers and foods. Some WPCs suited acidic environments such as acid beverages and salad dressings, while others suited neutral pH environments such as infant formula, meats, cakes and whipped toppings. They exhibited one or more of the basic WPC properties of solubility, heat stability, gelation, emulsification, water binding (thin vs thick solutions) and nutrition.

The scene had been set in the 1960s and 1970s, when we had studied the key differences among the different types of whey (rennet, cheese, acid and lactic) and the impacts of upstream processing on WPC chemistry and properties. We had proved it was possible to make WPCs economically with 65-75 percent protein. We reasoned that as we learned more about the needs of our customers, we could exploit the variability we had earlier observed in the WPC products and develop a wider range of products.

The key question we asked ourselves in 1980 was, "how can our next decade of research develop the market and make money?" I joined the team when it was time to start making money.

My introduction to whey processing and New Zealand

My first interaction with New Zealand's whey processing was in 1978 when I was part of the Whey Protein Collaborative Research Group

(Collab), although my work in whey started in 1976. That was when I joined the Ohio State University's department of food science and nutrition. My first job as a graduate student was working on a dairy factory wastewater project under Jim Harper and Rory Delaney. My own masters research was on the β-galactosidase hydrolysis of whey lactose, using Romicon hollow fibre membranes.

My Collab interaction with NZDRI convinced me that New Zealand was the place to be to pursue research in whey proteins. And the Kiwis had made such a positive impression on me, New Zealand was where I wanted to be. So in 1983, when I was about to finish my PhD, I was fortunate enough to receive a Fulbright scholarship to go to NZDRI.

The approach

The approach to that key question of making money was simple: follow the strategy set by the Whey Corporation (see Chapter 8), determine the tangible goals and deadlines, organise small, capable cross-functional teams, and enable them to deliver outcomes in specified time frames. The keys to success were a willingness by the teams to work together for the good of the broader dairy industry, a healthy sense of competition among the dairy companies, long-sighted leadership and talented people with long-term commitment to the challenge.

Over a number of years we adopted the following approach to develop and commercialise WPC products (see table on page 135).

- Identify potential markets and customers, and relevant regulatory requirements.
- Develop the processes and make prototype WPC ingredients at NZDRI, focusing on the whey type and the measurement of the WPC properties in aqueous solutions (based on a 'model food' system and sensory evaluation).
- Develop aqueous functionality specification tests that could predict how WPCs would behave in the model foods.
- Establish cross-functional teams to develop the WPCs commercially. The teams included people from the Whey Corporation, NZDRI, dairy factories and people based in overseas markets.
- Design commercial processes, decide (via the Whey Corporation), where to build factories, and then commission the factory or new ingredient (in an existing factory).
- Drive production consistency and efficiency of the WPC against the

specifications, including aqueous functionality testing and model food evaluation.

- Create technical information to help market the ingredient.
- Modify production protocols in plants as needed to ensure product consistency and supply to the range of customers.

Gaining the confidence of potential customers was frequently a long and difficult process. Early in the relationship, before trust had been established, customers did not wish to share their goals and strategies with us or to divulge critical information that would have helped us develop WPC ingredients specifically for their foods. However, based on our understanding of the potential of our WPCs, we chose to invest in the areas that we thought were most likely to succeed. It was a gradual process. With many customers we built trust to the stage where we jointly developed ingredients and their products. It was an effort, but it was worthwhile.

Ingredients were first developed at the NZDRI pilot plant. Here we could best determine how to make WPCs with the desired functionality in a pilot plant environment where the high risk of fouling or blocking the commercial ultrafiltration plant, evaporator or dryer could be avoided.

The functionality tests were those we had developed in earlier years, adapted for particular customers or food products

We worked on an annual strategy and timetable of developing a new ingredient for each dairy company, targeted to specific customers or potential customers. The dairy companies typically processed only one, or at most two, whey types, so there were natural groupings in the early to mid 1980s: Rangitaiki Plains (RPD) and Manawatu made gelling WPCs from acid whey, Morrinsville-Thames Valley (MTV)* made heat-stable WPCs from cheese and rennet whey, while Kiwi made nutritional WPCs from both acid and cheese wheys.

Once the prototype WPC had been developed at NZDRI, the product had to be transferred to the factory and the project leadership moved to the technical officer of the Whey Corporation and the technical officer at the factory. The NZDRI team would remain key to planning the trials and working alongside the factory production teams. For example, the team that specialised in gelling WPCs included a technical officer from the Whey Corporation aligned to a factory and the factory's technical officer. From NZDRI typically there would be

*Formerly Te Aroha-Thames Valley (TATV).

ALL WORK AND NO PLAY MAKES FOR BORING PEOPLE

One of the traditions after the trials was to have a shout at the end of all the hard work and have some fun. Kiwis really know how to work hard and play hard. So in good tradition, after one of the trial periods at MTV, I offered a shout at the local pub. Two things happened. I was asked who was paying for it, because the factory operators knew that NZDRI scientists weren't paid that well and there were no senior managers with me to pick up the bill. When I said I was paying for it, they asked if I knew how much it would cost, which I didn't. So the operators said they would organise it and all I had to do was show up and they will tell me how much it cost. The shout was a grand time by all and became a regular tradition. I duly 'paid for my shout', but it became very clear that I only paid a fraction of the cost and the guys took care of the rest. It was later explained to me that women did not pay for shouts.

Lee Huffman's 'shout' for MTV plant operators at the end of a WPC trial in 1987.

four team members (chemical engineer or technologist, food scientists and technician) who specialised in a particular whey type and functional ingredient and application and who were also familiar with the factory.

Developing WPCs for the Japanese market was critical to the success of the whey processing industry. High quality and product consistency were crucial. These cross-functional teams were well-exposed to the important Japanese market. They visited Japanese customers under the guidance of Mike Matthews, who at that time managed market research and development at Nippon Proteins, the Dairy Board's joint venture company with Nissei Kyoeki Limited. The

teams visited the customers, listened to their expectations, saw some of their processes, tasted the final products and better appreciated how the WPCs that were being developed fitted into that important Japanese market.

It was also a time to establish commitments to the market, the New Zealand whey protein industry and to each other.

Commercialising new WPCs at the factories

One of the highlights for NZDRI staff was being part of factory trials. It was a time to work hard and travel together, to be with factory staff and see what it was like to work in a factory and learn about 24/7 shift work. The team particularly looked forward to the RPD trials which were challenging and the collaboration strong (and we got to stay at the Awakeri Hot Springs Holiday Park with its welcoming hot pools). There was the challenge of making new products or introducing changes. Careful monitoring ensured we stayed on target or identified potential problems. Then there was time back in the laboratory with the multitude of functional, sensory and stability analysis tests of the WPC ingredients, and making model foods using these new ingredients. Tests, tests and more tests.

Technical visit to Nippon Proteins in Japan in 1989. Rear: Naosuke Furukawa, Phil Kirk (Hautapu WPC factory manager), Brett Ennis (Manawatu technical manager), Steve Morrison (Edgecumbe WPC technical manager), Lee Huffman (NZDRI), Gill Rodley (Whey Products NZ). Front: Ichiro Nakamura, Kazuyuki Hiraga, Mike Matthews (Nippon Proteins), Nobukatsu Fujisaki.

And finally, decisions on the final process and commercialisation work, followed by watching export sales build – sometimes slowly, but other times a quickly sold-out situation. This was the case, for example, for the specialised WPC for infant formula for Japan where we were limited by the capacity of the Paeroa plant until the whey processing plant was transferred and expanded at Hautapu. The sold-out position repeated itself when we introduced the low fat Alacen 865 to America and were not able to supply all the sports customers until we developed whey protein isolates.

Developing specific WPC ingredients

Gelling WPCs

Under the right conditions, whey proteins gel, i.e. they form a solid matrix like cooked egg white, which is important to making cakes, custards and some meat products. In certain markets, WPCs were less expensive or had more stable pricing than egg white. This was an opportunity, particularly in Japan where egg prices were particularly high. The focus was to replace egg white that was used for its gelling and water holding properties in surimi and ham.

We had learned a lot about whey proteins during the development phase of manufacturing WPCs consistently and learning the limitations of manufacture. One of the situations to be avoided during ultrafiltration or evaporation was 'gelling the plant' (see page 107). The intrinsic property of whey proteins to gel could occur quite quickly under the right conditions of temperature, concentration and ionic strength – all key variables during ultrafiltration, diafiltration, evaporation and drying. So while we wanted to make WPCs that could gel like cooked egg white, we wanted that gelling to happen *after* the WPCs were safely bagged.

There are many factors that cause a whey protein to gel, the protein plus the many other ingredients added to foods. The range of possibilities was very complex.

Meats

Our main target in Japan was pumped hams. Whey protein was useful in ham manufacture in that the WPC could be dissolved in water at a high concentration, yet retain a low viscosity. The solution of WPC and other ingredients could be injected into the ham, which would then be cooked to give a juicy tender product. The challenge we faced

was getting the WPC to gel at the correct cooking temperature for the ham. The flagship WPC for this application was Alacen 132.

As the market for ham pumping developed, our Japanese customer asked for a WPC that allowed even more water to be incorporated into the ham with a greater concentration of salt. Building on the foundation of the earlier research on the effect of ions on whey proteins and the subsequent impact of salt in the Alacen 132 work, we changed the manufacturing process to produce a brine-tolerant WPC we called Alacen 162.

The Japanese customer then requested a WPC that gelled at a lower temperature in brine – below the intrinsic gelling level in our WPC design. This was more difficult, especially from a production point of view. While we were able to develop this ingredient (an early prototype of Alacen 152) at the NZDRI pilot plant with little difficulty, when we scaled up to a commercial plant the newly-engineered ability to gel at a lower temperature was far too successful – we blocked the ultrafiltration plant and evaporator more than once! Blocking a plant caused over a day's downtime removing the gel from the membranes and the evaporator.

The lowest gelation temperature WPC we were able to commercialise was Alacen 152. We went through at least three different processes before meeting the specification. Unfortunately, in this case the aqueous functionality specified by the Japanese customers did not predict actual performance in their food manufacturing. Alacen 152 did not perform well and we did not achieve the Japanese sales we had hoped for. However Alacen 152 later found a home in New Zealand and America in restructured meats such as lamb rolls.

The heat-set functionality of WPCs produced smooth gels for custards and puddings.

Custards

Custards were an opportunity for WPC with one of our Japanese customers. We aimed to develop a substitute for whole egg, which is a common ingredient in custard. For this we needed a soft, smooth gel, linked with some emulsification, to make smooth custard that included both fat and water. To meet this customer's needs we created a new

The ability of WPCS to both whip and heat-set was important to making cakes, whipped toppings, meringues, frozen desserts and yoghurts

ingredient by developing a new specification and introducing additional processing steps and a new modified gelation test as well as a custard model food. It wasn't too difficult. By this time it had become easier and quicker to develop and market new ingredients because we and the dairy factories had greater experience and knowledge.

This WPC ingredient for custards, as with many of the ingredients for the Japanese customers, provided consistent sales for years. We found this experience to be typical of the Japanese market; once your ingredient has been approved into a well-established Japanese food, they valued consistency and a long term supply commitment, which benefited both partners.

Yoghurts

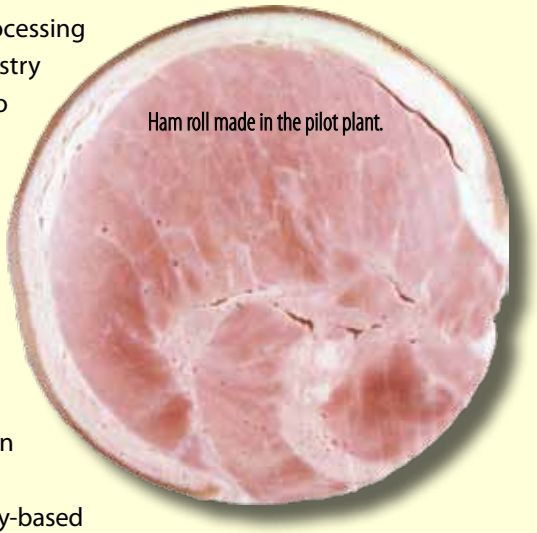
Yoghurts have a tendency to synerese (water separating out on top of the yoghurt). This is not acceptable to most consumers. The problem could be solved by WPCs because of their ability to hold water and acid-heat stability. The same WPC (Alacen 132) that functioned well in pumped hams also worked for yoghurts, improving their texture and water-holding capability.

Whipping WPCs

Under the right conditions, whey proteins whip, i.e. they form a foam like egg white, which is important to making cakes, meringues and mousses. In certain markets, as for the gelling proteins, WPCs were less expensive or had more stable pricing than egg white. This

...continued on page 122

WHEY PROTEIN CONCENTRATE


Ham roll made in the pilot plant.

During most of the 1980s, NZDRI ran a pilot meat processing plant that was the envy of New Zealand meat industry researchers. Initially it supported sales of WPCs to Japanese companies which produced 'pumped ham'.

The Japanese processors might typically turn 10 kilograms of pork into seven kilograms of dry-cured ham. However, by using a gelling product like whey protein concentrate, in conjunction with water and other ingredients, the 10 kilograms of pork could be converted into around 20 kilograms of processed ham similar to what might be called sandwich ham in New Zealand today.

Some of these manufacturers had been using a soy-based gelling ingredient, but it wasn't entirely satisfactory – it tended to produce hams with a yellow-brown tinge and a distinct soy bean flavour. The Whey Corporation saw an opportunity for the New Zealand industry's new Alacen 132 product, which appeared to have the gelling properties required without the soy products' drawbacks.

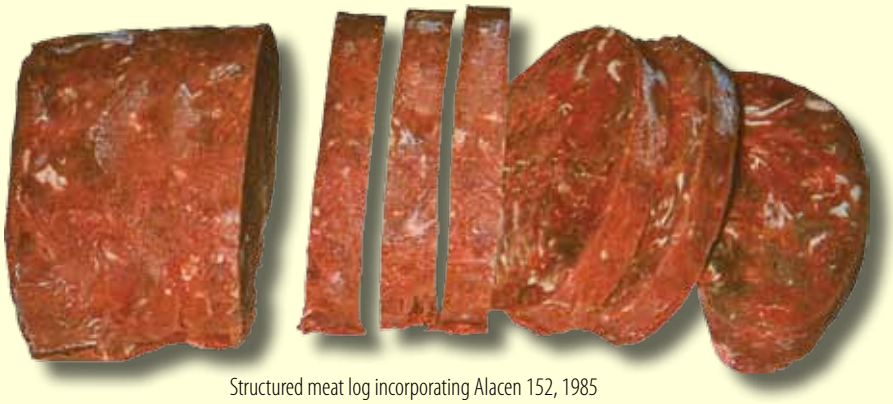

Tony Fayerman operating a bowl chopper in the meat pilot plant at NZDRI.

When the Whey Corporation began to look at this market, very little was known about how WPCs would behave in any form of meat processing, including that being carried out in Japan.

Later, in 1983, NZDRI teamed up with the Meat Industries Research Institute in Hamilton to investigate the use of WPCs as gelling agents in the production of restructured meats. Though the meat industry had little problem selling leg roasts of lamb, there was little demand for shoulder roasts.

A process was developed between the two organisations that trimmed meat out of the shoulders, removed some of the fat and applied a WPC solution in a ham-like process. The main function of the WPC was to glue together the pieces of meat, which were

IN MEAT PROCESSING (JOHN MACGIBBON)



Structured meat log incorporating Alacen 152, 1985

formed into 'logs'. Most of this product was aimed at the local market. One company that commercialised it was Richmond Meats in Hawkes Bay.

By the later 1980s, WPC sales to New Zealand's biggest market – the Japanese ham pumping industry – came under pressure as soy based competitive products improved. New soy protein isolates became about 80 percent as good as WPCs, at half the price. By this stage other food processing areas could soak up all the WPC New Zealand could produce, at better prices. Meat processing had become a relatively low margin, high maintenance market and by the end of the 1980s New Zealand had largely withdrawn from it. However, some New Zealand WPCs are still sold to Japanese meat processors. The NZDRI pilot meat processing plant was closed in 1990.

Formed meat 'steak' cooked in a vertical grill at NZDRI

Tony Fayerman, who headed the NZDRI's work on WPCs in meat during the 1980s, also served as chef and maître d' on special occasions when NZDRI gave VIPs a taste of food enhanced by high-tech dairy products.

was an opportunity, particularly in America where widely fluctuating egg prices made it difficult for companies to manage their costs. So the focus was to replace egg white that was used for its whipping and gelling functionalities.

To get the best whipping properties, fat removal was important. The intrinsic tendency of whey proteins to foam was quite a problem during processing, where it was important to minimise any aeration, such as pumping, that could cause unwanted foam. So while we wanted to make WPCs that could whip like egg white, we wanted that foam formation to happen after the WPCs were in the bag.

Meringues and pavlovas

One of the favourite model foods to make and taste were the meringues, nougat and pavlovas made from the WPCs for those applications. To make a meringue required both the whippability during beating and the gelation during cooking. A whipping WPC, e.g. Alacen 172, was more robust to whipping than egg white, i.e. you could beat it longer without the foam collapsing (whey proteins resist shear denaturation better than egg white proteins). It was harder to make a pavlova with Alacen 172. But that didn't stop the technical staff at NZDRI and RPD from testing these newly developed WPCs in this favourite New Zealand dessert.

Cakes

There are many types of cakes and virtually all require eggs in their recipes. From the beginning of our model foods system, cakes had been used to test our prototype WPCs. Eggs basically provide cakes with aeration (i.e. whippability), structure (gelation during cooking), moisture retention, emulsification properties and flavour. It seemed obvious that WPCs, which had similar functionality to egg, could be sold to cake manufacturers.

The team at NZDRI perfected the chocolate cake with Alacen 132 or Alacen 312. However, 75 percent protein WPCs never really made it into the pre-mix bakery market for a number of reasons. The most likely explanation is that consumers wanted to make their cakes 'home-made' by adding eggs. When the cake mix included WPC, only water needed to be added and the product no longer seemed 'home-made'. Also, consumers didn't typically think of the cost of adding eggs, so the cake mixes with WPC were more expensive. The cake

mix market never developed, not due to poor product, but a lack of really understanding the consumer. The real opportunity was with the food service and in-store bakery cake market that was looking for simplicity and price stability. We felt we could offer greater price stability than egg, but this food service market had very tight margins and processing requirements that the WPCs that we made at the time did not provide, although we were getting very close. There was a specific balance of whippability, emulsification and heat-set gelation that the WPCs did not meet. In an attempt to better understand all aspects of WPCs for the bakery industry, we invested in a bakery unit where qualified bakers did research and development with our WPC ingredients and while we came very close to succeeding in the food service bakery market, the profit margins were too tight for both the bakery industry and the WPC industry.

We were never able to achieve the whipping and heat set properties of egg white needed for angel food cake, which was one of our 'holy grails' for WPC development, as noted in Chapter 5.

THE EDGECUMBE EARTHQUAKE

In March 1987 there was a very shallow earthquake in Edgecumbe that measured 6.3 on the Richter scale. The operation of the RPD factory, including its WPC plant, was completely disrupted.

When difficulty arises the New Zealand dairy industry really shines. RPD needed to take care of itself and the rest of the industry needed to handle the milk and the markets for its specialised products. A 'swat team' was assembled the next day. The gelation team responsible for Alacen 132 from Manawatu joined with the WPC team at Morrinsville-Thames Valley (MTV). We needed to reactivate the acid casein plant at MTV and make acid gelling WPC there. Within days the casein plant at MTV was operating and we were making Alacen product to the Japanese specification. It was very satisfying to have been able to respond so quickly and effectively.

Nutritional WPCs

From the mid-1980s we began to emphasise nutritional benefits of whey proteins as our marketing point-of-difference, especially in the United States. By this time we had good control of the manufacture of WPCs, and were achieving consistency in composition and functionality. We knew the best food applications to target. We also had technical marketing facilities overseas (particularly Japan and America) which could link directly with customers and do the necessary translation between the differences in the overseas nutritional market and New Zealand, which had less emphasis on manufacturing nutritional foods. It was now time to focus on nutritional uses of WPC.

Sports, juice and meal replacer beverages made in the pilot plant at NZMP North America with Alacen 865 WPC.

Beverages – acid, heat-stable WPCs

The intrinsic acid-heat stability of whey protein was a key point-of-difference for WPC from the beginning and has remained so. Other proteins, e.g. caseinates and non-dairy proteins such as soy and pea are typically insoluble in acid. But the key to successful WPC in acid beverages, including fruit juices, was maintaining the solubility of the whey protein throughout the manufacture of the WPC, and throughout the manufacture of the beverage. So to develop WPC for beverages, we also had to become 'beverage manufacturers' and understand the many formulations and processing techniques of beverage companies.

Even after Coca-Cola decided not to proceed with WPC in beverages we continued to test and develop a 65 percent product for acid beverages that would be pasteurised in the bottle. But we still had stability problems – particularly sedimentation and the formation of a 'neck ring' around the top of the liquid in a bottle.

The first simple solution to improving beverage stability occurred when RPD increased the protein content of their WPC from 65 percent to 75 percent by increasing the amount of diafiltration. The altered mineral content changed the interactions between the proteins, minerals and juices, leading to better acid-heat stability.

Challenges remained, particularly in areas of taste and clarity. There was market demand for added nutrition in acid beverages (fruit juices) and we believed this could be supplied by whey proteins. However, consumers and the beverage companies, particularly in Japan and America, wanted the drinks to look and taste like existing juices. Our WPCs added flavour and opacity that was not juice-like – typically they were tart and more opaque.

Another problem with the extra processes was their added cost. Whey

Products New Zealand (WPNZ)*, which controlled pricing with the offshore companies, had specified there be no additional cost, believing the customers would not tolerate it.

WPNZ's insistence, for these beverage ingredients, that the protein flavour be removed without increasing the price to customers, led to some tension between the technical and marketing camps.

We had to take a more holistic approach to the WPC manufacture for beverages and revisit the chemistry of whey before it went through ultrafiltration. This took about two more years of basic research, building on processing work that had been done in the late 1970s and early 1980s, on the 'Atteberry' process.† But now, in our quest to develop a new, better flavoured 85 percent WPC, we had improved analytical and separation technologies, as well as ten more years of research on understanding whey proteins. Our problem had been that taking out the components we believed were causing the flavour problems was likely to reduce yield and increase cost. Now we had developed a process at NZDRI that solved these problems: the LMR process (lipid mineral reduced), which improved both yield and flavour. It was time to scale-up at the factory.

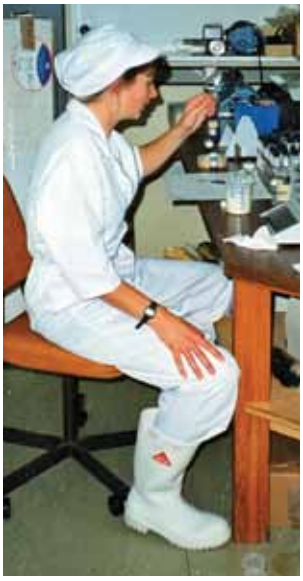
We worked closely with Manawatu and moved from the laboratory bench to commercial, with very few pilot plant trials, to develop this WPC. This high risk approach was chosen because of the experience that Manawatu had running the critical step in the process. The final WPC, called Alacen 865, was a low-fat, 85 percent protein WPC with better flavour which retained all the nutritional value of the whey proteins.

Our model beverage production approach was similar to commercial processing. Using our 'HTST' (high temperature short time) beverage manufacturing processes, Alacen 865 was tested at both NZDRI and the American pilot plant facilities. Using this ingredient, we were able to make beverages that met the desired clarity, flavour and stability standards. Alacen 865 met the aqueous specification tests we had developed as a predictor for the model and commercial beverages.

Until then, almost all of New Zealand's WPC production had been sold in Japan. Sales to America had been very limited, but it was now seen as a growth market. Though American prices were lower, WPNZ decided it was time to invest beyond Japan. And WPC that was low in

*By now the Whey Corporation had become Whey Products New Zealand (WPNZ).

† See sidebar, 'The impact of whey pre-treatment', on page 46.



Denise Hughes, laboratory technician, doing in-process testing during a low-fat WPC 865 trial in the NZDRI pilot plant in 1989.

fat and lactose was seen as the key to the American market.

Three people were seconded to the Dairy Board's American office to support WPC sales. Initially WPNZ sent two technical officers – Simon Harrison and Ken Keyte. Then I joined them in 1990 to transfer functionality and application knowledge and support the launch effort. (I initially went for six months; I stayed 10 years. But that is another story.)

After development work in conjunction with the Research Development Center (RDC) pilot plant facilities within the Dairy Board-owned New Zealand Milk Products (NZMP), in Santa Rosa, California, we now had a predictive model for beverages we were targeting in the juice, sports and nutritional markets.

The market took off. We were able to achieve the profitability required and were quickly in a sold-out position. Interestingly it was a combination of factors that lead to the sales: Alacen 865's improved flavour, good appearance and lack of sediment were 'must-haves'. But it was the inherent nutritional value of the whey protein that ultimately grew our market. These nutritional properties, which had been a major driver in the original development of New Zealand's WPC industry, were finally driving the American market, 20 years later. The sports beverage market had arrived.

In the late 1980s the benefits of whey proteins were being recognised in America in three key markets: sports beverages, weight loss and medical. Medical literature and testimonial advertising were promoting protein-fortified foods, especially beverages and nutritional bars, that included WPCs and WPIs (protein concentrations between 75 and 90 percent). The claimed benefits included muscle building and prevention of muscle wasting caused by some diseases and ageing

Infant formula – neutral, heat-stable WPCs

Developing infant formulas based on cow's (bovine) milk has been a never-ending 'work-in-progress'. As scientific understanding has expanded, manufacturers have sought to bring the composition and

nutritional qualities of their products closer to that of human milk. There has been a long succession of innovations in infant formula developments in various countries. One such innovation that emerged in the 1980s was the inclusion of whey protein concentrate.

There are several important differences between human milk and bovine milk. They have similar concentrations of fat but human milk has a much higher lactose concentration while having much lower concentrations of proteins and minerals. Within the protein fractions, the ratios between caseins and whey proteins are quite different. This ratio is 80/20 in bovine milk and 40/60 in human milk.

For many years, manufacturers had sought to 'humanise' their bovine milk-based infant formula products. Initially, this meant adjusting the gross composition so that the concentrations of fat, protein, lactose and minerals were essentially the same as those in human milk. One approach, for example, was to add demineralised whey solids, which elevated lactose concentration relative to other components while reducing the relative concentrations of proteins and minerals.

The proteins that comprise whey protein in human milk differ in several respects from the whey proteins of bovine milk. For example, the dominant whey protein in bovine milk, β-lactoglobulin, is absent from human milk. The latter, by contrast, has far higher proportions of the whey proteins lactoferrin and α-lactalbumin than occur in bovine milk. There are also significant differences in the casein fractions. In

Morrinsville-Thames Valley's factory at Paeroa made many of the early heat-stable WPCs for the nutritional market.

human milk, β-casein is predominant but in bovine milk, α-casein, absent from human milk, far exceeds β-casein in concentration. While these differences had long been known, there was no commercial process that could alter the relative ratios and the types of whey proteins and caseins to match those present in human milk.

Staff at the Dairy Board and NZDRI were very much aware of the potential use of WPC in infant formula. Well before commercial enquiries began, they believed WPCs could help make such products compositionally closer to human milk.

The New Zealand dairy industry was therefore well placed to respond when commercial enquiries began in the mid-1980s. It had to be well placed, because, unlike the situation with gelling WPCs made from acid whey, New Zealand had no natural advantage with sweet whey. Many other countries had plentiful supplies of good quality cheese whey. New Zealand would have to earn market share for this emerging business through good science and technology and establishing effective relationships with infant formula manufacturers.

Staff at NZDRI had successfully used model food systems to optimise the use of WPCs in various food products, but this approach would not work for infant formulas. The business was very competitive and manufacturers guarded their technical information closely. Product compositions and processing methods to make infant formulas also varied among manufacturers. This made it difficult to create useful and broadly applicable model infant formula systems. We were not confident of developing any reliable models. The key to overcoming this hurdle was the cultivation of very close and constructive relationships with infant formula manufacturers. Had this not happened, we would have been working in isolation, without effective guidance.

The key expectations of the infant formula manufacturers were that any WPCs used in their formulations would be heat stable, soluble, have no adverse effects on flavour and smell, be of excellent nutritional quality, made to a very high standard of hygiene, and, once in the infant formula be tolerated by the infants and liked by parents. Compositional specifications were invariably very strict.

Infant formulas are complex. They contain a wide range of ingredients of both dairy and non-dairy origin, including proteins, carbohydrates, lipids, minerals and vitamins. Potentially unstable ingredients such as vitamins must be present at concentrations no lower than shown in label declarations for the stated shelf life of the products, which can be

up to two years after manufacture. Infant formulas are mostly sold in powdered form for reconstitution in water. However in some markets they are also sold as ready-to-feed products, having previously been processed by retorting or UHT treatment.

These ready-to-feed presentations imposed quite severe additional requirements on the ingredients as the time period available for sedimentation is much longer than with formula that is made up as required from dry powder. Ideally the liquid ready-to-feed product in cans and bottles should be thick (viscous) enough to maintain any fine but insoluble ingredients in suspension during its shelf life. If there is sediment then there is a risk that the infant will not receive the full nutritional value of the product. However, the ideal product, when shaken or stirred, should also become sufficiently fluid for it to be poured easily into a feeding bottle and easily sucked through the teat or nipple by the infant. Similarly, during processing the formula needs to remain fluid and not form a gel in the equipment. This complex fluid behaviour is known as 'shear-thinning'. From our point of view, a WPC used in infant formula might have to perform in all three forms of the finished product.

Two key customers emerged: one in Japan, the other in America. Both were well-recognised market leaders. As was the case with gelling WPCs, success came from developing partnerships between committed suppliers and dependable, competent food companies. Cultivating relationships with both of these infant formula manufacturers proved essential in helping New Zealand to establish a strong commercial position but again, as with gelling WPCs, it was no overnight success. In both markets, it took up to five years to achieve profitable businesses. With targets from the infant formula manufacturers, we were able to develop knowledge that helped us predict the behaviour of WPCs in these products.

In both America and Japan, the customers were required to register their infant formula products with their respective regulators: the US Food & Drug Administration and the Japanese Ministry of Health & Welfare. Such registrations required listings of ingredient suppliers. This was to prove very useful commercially, because once a supplier had been registered (a process that included identification of the factories of origin), it became difficult to change to alternative sources.

It was a tribute to the New Zealand dairy industry that such large and

well regarded manufacturers in America and Japan identified New Zealand as their preferred country of origin for WPCs for use in infant formula.

Heat stability was the greatest challenge in developing WPCs for these customers. We had to find combinations of temperature, holding times, pH and addition rates of neutralising agents that ensured good heat stability while at the same time making sure that the concentrations of all minerals were exactly what customers had specified. Unless steps were taken to prevent it, the high temperatures used in infant formula manufacturing to ensure product safety could cause whey proteins to become insoluble. This would cause sediment in the infant formula, which was clearly unacceptable.

Protein behaviour during processing can have a profound effect on the characteristics of food products. In particular we knew that we had to bring about controlled denaturation of whey proteins during the WPC manufacturing process. This required extensive studies of heat-induced behaviour of each of the primary protein and protein-derived components of cheese whey, namely β-lactoglobulin, α-lactalbumin, bovine serum albumin, immunoglobulins and glycomacropeptide. The aim was to make sure that none of these proteins precipitated when the infant formula manufacturers incorporated WPC into their products, or when the formula was reconstituted in water before feeding to an infant. We made extensive use of analytical techniques such as high performance liquid chromatography and gel electrophoresis during these studies, which enabled us to manipulate processing conditions to make WPCs that worked well in infant formula.

The key sites in New Zealand where these products were commercialised were the Paeroa site of TATV/MTV and, after that plant was closed as part of ongoing milk processing rationalisation, the Hautapu site of NZCDC where Paeroa's whey processing assets were relocated.

The product development process often involved sending prototype WPCs to customers for trialling. Once the prototype was established, further trials were normally required to achieve day-to-day product consistency. Such work often had to be done at commercial scale, at considerable cost, because pilot plant trials were not always reliable predictors of commercial scale results.

Another challenge was that we would not know if our prototypes were successful until we had the results of storage stability trials and infant formula stability and clinical trials by the infant formula manufacturer. These could take 12-18 months to complete – another reason why it

Thankyou cake from a happy customer – celebrating success after five years of developing a new WPC ingredient for an infant formula.

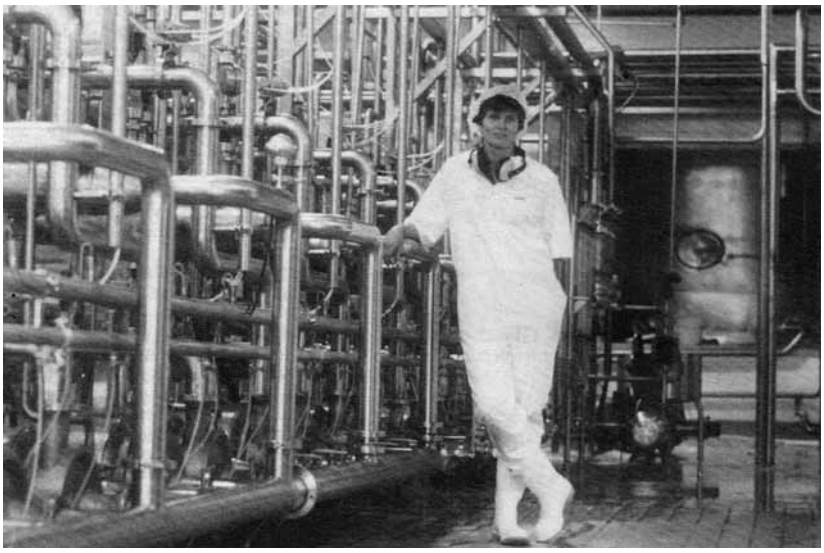
could take up to five years to develop a WPC for an infant formula manufacturer.

A further enhancement to the business was developing WPC products that were modified by the selective use of proteolytic enzymes to make hydrolysate ingredients for infants that were allergic to whey proteins. These hydrolysates became part of the product mix at the Tatua Cooperative Dairy Company, in particular for the Japanese market.

We were fortunate to have so many skilled and helpful people involved in these developments. The results could not have been achieved without the contributions of staff at the Dairy Board, NZDRI, the Dairy Board's offshore marketing companies, especially NZMP and Nippon Proteins. And also the manufacturing staff at Paeroa and Hautapu, who put up with the long and at times very tedious intrusions we made into their production schedule when developing new ingredients for infant formula.

Customer service, the Kiwi way

From time to time our infant formula customers would visit New Zealand as part of the ingredient development programme. They were occasions when everyone put in extra effort to highlight our technical capabilities, but as well as that, we gave the customers a great Kiwi experience. One American project leader was a keen tramper who really wanted to see the country as Kiwis saw it – he didn't want a succession of standard tourist hotels. We booked him into local motels and even a few homestays. Rather than fly, we drove throughout both the North and South Islands. I hiked with him up Mount Ruapehu shortly after



Cathy Bendig in Waikato Valley CDC's new WPC plant at Hautapu, 1989.

it had erupted. On another trip, a Hautapu manager guided him over the Tongariro Crossing through horrible weather, including a white-out. He even freedom-walked Milford Track by himself. This was in addition to his visits to the factory sites, where he gave presentations and explained how their work was making the infant formula project a success. Our integrated teams of Dairy Board, NZDRI and factory staff did the same, presenting our work and factories. After five years of successful development together, this project leader came back to the factories and NZDRI to thank us and celebrate together. We really appreciated that extra effort on his company's part.

Infant formula remains a 'work in progress'. The New Zealand dairy industry has maintained its position as a specialised ingredient supplier to this market sector, not just with WPC but with other whey-derived products. More recent initiatives have included the use of the purified whey protein, lactoferrin, to help the infant formula industry get their protein profile even closer to that of human milk. As science generates more knowledge, more opportunities to supply whey-derived ingredients to this market sector will undoubtedly emerge.

Training a rapidly growing whey processing industry

As our processing and products became more complex and we needed to transfer our knowledge to commercial production, it was important that all participants in the new industry spoke the same technical language. The first industry membrane skills course was held at NZDRI in 1980,

...continued on page 134

WOMEN AND WPC

Whey processing was a new field compared to the more traditional dairy processing of butter, cheese, milk powder and casein, and it opened opportunities for women who wanted a career in the dairy industry. There were more females in senior technical roles compared with the rest of the industry: Judith Bartosh and Gill Rodley at the Whey Corporation, Lynne Scanlen at RPD, Robyn Cotton at Manawatu and Cathy Bendig at MTV. At NZDRI in the 1980s, there were Rosemary Hancock, Sheelagh Hewitt and myself. Offshore were Robyn Laing in Japan and Marsha Swartz in America.

One major achievement was translating the complex ultrafiltration processing variables into operational procedures to achieve WPC characteristics desired by the markets. Cathy Bendig and I worked to simplify those processes and then worked to maximise yields while maintaining quality at MTV.

At Manawatu, Robyn Cotton and I ran an experimental design called 'central composite design' that targeted the operating parameters that affect gel strength and composition. It wasn't easy. Analysing the data was a huge task that took months before it could be put into Massey University's mainframe computer for analysis. And we were up against another deadline: Robyn's date in the maternity ward. I remember her calling me and asking how the data was going. I gave her an update...only to have her tell me, sorry, but I'm in labour and have to go the hospital now – bring me the data. Which I did, and Robyn finished off our part of the analyses in the hospital. In hindsight, I wonder what we were thinking. In the end we succeeded and found the sweet spot of operating conditions where the plant was optimised to meet both of the gelation specification tests.

Then a few years later I had similar experiences when having my own boys, during the development of the new WPC for the American infant formula market. The projects didn't stop just because we were also having and raising children.

While balancing family and career might not be unusual in 2014, in the 1980s and 90s, it was not common. This new product, WPC, offered new career opportunities for women in New Zealand.

Lynne Scanlen, RPD's WPC technologist, led many experimental trials when developing new gelling WPCs.

led by Mike Matthews, who also wrote the training book.

The course was very popular with the operators and managers and was an excellent way to integrate the industry. By the mid-1980s, after Mike had moved to the Japan office, Lynne Scanlen*, from Rangitaiki Plains, drove the course development through the Dairy Industry Training Council. Rosemary Hancock† who had been training most of the new recruits and chemical engineers at NZDRI, continued to update the course content to reflect the increasing complexity of membrane processing.

The skills course, aimed at factory membrane-equipment operators, lasted one to two weeks and has now been running for more than 30 years. The focus was on operating the plant and understanding how the way it was run could impact the functionality of the WPCs and ultimately our success in the market.

This was also a great time to bring the operators from various factories to Palmerston North for a time of fun and cross-fertilisation of ideas. This was the only time most of the operators had a chance to meet each other and also get to know the NZDRI staff in a different setting. Many of the operators went on to become whey protein plant managers or managers for other products.

The rapid growth of whey processing

By 1986, WPC sales were growing so fast that we had to constantly upgrade factories to give higher throughput and yield. Ultrafiltration membranes were being improved and the processing volumes were being increased. With each change, we needed to maintain the composition and characteristics of the products we were selling to customers. This consistency was critical.

It was a time of rapid growth and expansion with new factories being built to process more whey into functional whey protein concentrates for use in a huge range of foods, from infant formula to sports beverages to meats. And it was a time of opportunity to create new careers as these new WPCs were developed and taken to market. It was a time of working hard together and developing trusting relationships that would last for years. The integration of the whey processing factories with the R&D and marketing made this all possible.

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*Lynne Barton at the time of the skills course.

† Rosemary Cleland at the time of the skills course.

I would like to acknowledge the team work and dedication of all of the people who were involved, which is impossible to convey in a chapter.

Whey protein concentrate products developed by the New Zealand dairy industry in the period 1976 – 1990

Note: protein concentration was 75% minimum, as-is basis, unless noted otherwise.

Alacen type	Properties	Application
132	Gelation, and yield and texture improver	Egg white replacer, ham, meat, quiche, cultured products, omelette, pasta
134	Gelation and emulsification	Custard
152	Gelation at reduced temperature, adhesive properties	Re-formed meat, vegetable burgers, fish, poultry
162	Gelation in brine	Ham, surimi
164	Gelation and water holding	Stirred yoghurt
172	High whip, stable foam, heat set foam	Egg white replacer/extender, bakery, frozen desserts, confectionery
193	Gelation, solubility	Cultured foods, salad dressings, desserts
312	Solubility, emulsification, nutritional, heat setting	Acid beverages, infant formula, pasta, yoghurt, bakery glazes, pastry
322	Low sodium	Dietary supplements, nutritional applications, health foods, bars
342	Heat stability, low sodium, emulsification, nutritional	Nutritional beverages, infant formula, protein fortification
343	Low sodium, dispersible	Dry mix beverages, dietary supplements, health foods, breakfast formulations
351 (55% WPC)	Low lactose	Dietary products, health foods, low lactose milk products, geriatric and convalescent diets
352	Low lactose	Health foods, low lactose milk products, geriatric and convalescent diets
392	Solubility, heat stability, emulsification	Bars, infant formula, salad dressings, nutritional applications, bakery
401 (55% WPC)	Heat stable	Infant milks, milk formulations , neutral pH beverages
420 (35% WPC)	Solubility, heat stability, emulsification	Infant formula, dairy desserts, UHT processed foods

Table continued on next page

Alacen type	Properties	Application
421 (55% WPC)	Solubility, heat stability, emulsification	Infant formula, dairy desserts, cultured products, UHT beverages
422	Solubility, heat stability, emulsification	Infant formula, bars, dairy desserts, cultured products
450	Solubility	Dry mix beverages
451	Heat and acid stable	Acid beverages, carbonated beverages, fruit juices
472	Heat stability, emulsification	Infant formula, salad dressings, soups, sauces
372	Heat stability, emulsification, wettable, dispersible	Dry mix beverages, dry mix puddings
865 (85% WPC)	Low fat, low cholesterol, whippability,	Beverages, whipped toppings, egg white replacer, meat, beverages
866 (85% WPC)	Low lactose, heat stability	Low pH beverages, medical enteral products, ham
XB (experimental beverages) (65% WPC)	Acid stability	Low pH beverages
XWG (experimental whipping and gelling)	Whippability and gelation	Egg white replacer

CHAPTER 7

WE NEED CASH FLOW: MARKETING WHEY PROTEINS

ROBIN FENWICK

The fundamental issues of marketing whey protein concentrates (WPC) called for a different approach to market presentation than that used for well-known dairy products.

First: whey, as the raw material, was in surplus – in New Zealand and other countries that made cheese. It had no value – or worse, it was an effluent nuisance that could be given away – perhaps to feed animals. Worse still, if no one was kind enough to take it; whey had to be treated as effluent, at a substantial cost.

Second: whey proteins are only a tiny proportion of liquid whey, so the cost of retrieving them is high. The new technology of membrane separation was evolving and yields were lower than might have been hoped for. Further, the processing plants were costly.

The combined effect of these fundamentals ruled out traditional marketing techniques that had developed to export commodity dairy products made from milk. New approaches were necessary.

In 1980 WPCs were still new to food processing companies and they didn't yet know they needed them. Our selling job would be to demonstrate value. That value would need to be discovered by the potential customers' technical teams in their product development laboratories and pilot plants.

The proteins we initially offered were unlikely to be perfect for whatever purposes food product developers might have in mind. So the R&D process would require a 'to and fro' conversation to allow the technical team in New Zealand to modify WPCs at the point of manufacture. To achieve that, we needed to know what the end product would be, and through what manufacturing processes the WPC as an ingredient would have to survive.

***Robin Fenwick** attended Massey University, completing a degree in dairy technology and eventually a PhD in protein science. He proceeded to a career in international dairy industry development, working in India, Kenya, and Korea. He joined the Dairy Board in 1975, was seconded to a protein products innovation site of NZ Milk Products Inc for two years, then returned to manage the Whey Division in 1982. He later worked as protein development manager, travelling extensively in a market development role.*

Mutual disclosure of precisely what was wanted and how that might be achieved was a fraught process. Both sides of the deal needed to be frank and both sides needed to trust that their secrets would be held confidential. In addition there was room for confusion in translation from unknowable language differences and from mutual cultural incomprehension. So the issues of getting the right product for the right use at the right place, time and price could be overwhelming. Sometimes they were. The Dairy Board needed to move well beyond its comfortable commodity marketing approach. Specialised ingredient marketing would be a new experience.

Robin Fenwick in the laboratory at New Zealand Milk Products' Research & Development Centre in Petaluma, California. New Zealand Milk Products was owned by the Dairy Board.

Part of an improved marketing model already existed. During the 1960s we had created milk powders that were bespoke-designed for particular purposes. Our regular spray dried milk powder needed modification to be suitable for evaporated milk, which required heat stability. Similarly milk powder for sweetened condensed milk needed to resist age thickening. At the time these were the most important products in the Asian recombining trade. The right powders were developed in consultation with technically sound people both in New Zealand and at the Dairy Board's regional offices.

Thus techno-commercial marketing began to evolve. The Board even set up a pilot plant (at Matangi) for recombined evaporated and sweetened condensed milks. The plant's functions included research, development, demonstration and quality control.

The resulting specialised powders were priced at a small premium. The size of that premium was based upon the increased costs of production of the specialised powders – not on their value to the customer. In a short time competitive suppliers latched on to the manufacturing processes. The powders were quickly commoditised and that was that.

The technical marketing approach did, however, survive and was well supported by technically sound people in Wellington and offshore, and by world class research at NZDRI.

New Zealand Milk Products's administration and research centre in Petaluma, when it was opened in 1980.

In America and Japan the qualifications of senior managers of customers' R&D teams were at PhD level. Because of this, we lifted the role of our own technical officers to technical managers, also at PhD level (or of equivalent level of knowledge). Some came from the Dairy Board, but most from NZDRI. In America, Ken Kirkpatrick (later succeeded by Neil Walker and myself), paved the way. We were supported by graduates from a range of disciplines.

For WPCs, might the experience of commoditisation of hard-won new product developments be avoided? By the early 1980s, excellent casein, caseinates, co-precipitates and lactalbumin of food grade quality already existed. They were used to enter markets where milk powder was excluded by trade restraints: Japan and Europe.

There was a provision in international trade law that permitted 'proteins' (powders with more than 75 percent protein) to be treated as 'proteins' rather than dairy products. So imported milk proteins could be used to extend the local supplies of milk at prices that were profitable to both the buyer and the seller. The likelihood was that commoditisation would soon rear its ugly head. That fate was

Flavour panel in the Petaluma meeting room, 1980.

perhaps unavoidable for large volume proteins, but WPCs were small volume and another step up in price level. These would need more marketing sophistication. That transition would be comparable to moving a cumbersome train.

Boarding the train in America

That step-up in marketing sophistication came in a roundabout way. A team of specialists in marketing, supply and product development of caseinates joined the team at New Zealand Milk Products Inc (NZMP). Relevant to the story of whey was their marketing approach. Whereas proteins from New Zealand had always been packed in brown Kraft paper and labelled as 'casein' or 'caseinate', the proteins from NZMP's American plant at Sioux Falls, South Dakota, would be packed in white bags, branded with a prominent company logo. They were thereafter presented as valuable food ingredients that happened to be caseinates, whether made in New Zealand or Sioux Falls.

WPCs, which were necessarily made in New Zealand, were part of the total package on offer. The sales people (all of whom held tertiary food technology qualifications) had a hard job getting the attention

of the R&D managers at the major American food companies. When they were granted a 15 minute time slot they offered a coherent range of proteins selected to be useful to that potential buyer. They needed to quickly and clearly present how the proteins could fit into specific food products.

The WPCs went beyond the available range of caseinates, as food ingredients. They sold themselves as highly nutritive, able to gel when heated, readily soluble, and a foam that could heat set. Unlike caseinates, they could remain soluble in acidic foods.

Eventually the portfolio on offer in America (and subsequently elsewhere) could offer casein, sodium or calcium caseinates, whey protein concentrates, insoluble lactalbumin and an exclusive product named Total Milk Protein. It was a protein range unequalled by any competitor. It was backed by a team of technically sound researchers who were immediately available by phone and spoke with the local accent. In turn, when greater resources were needed, they were backed up by NZDRI.

To make the presentation coherent, a brand, a logo, and a set of attractively printed product bulletins were needed. These were provided through the fertile imagination of Joe Garrell (NZMP's manager of marketing). After a creative evening at home – Joe worked best after dark – he came into the technical centre and told the incredulous team how it was going to be.

The company name was New Zealand Milk Products (NZMP), so the origin of the products would be clear. They would be linked by an umbrella name: 'Ala' (which means 'after the manner of' in French – familiar to most in the form of à la carte or à la mode). The individual proteins would be:

- *Ala-nate* (for caseinates)
- *Ala-tal* (for lactalbumins)
- *Ala-cen* (for WPCs)

Further names were created in time as new forms of protein were devised or sold in other countries.

The product classes were further differentiated by the use of product codes. (See the table on pages 135-136.) This allowed variations of WPC to be identified in the market, with properties designed in consultation with individual customers. Hence Alacen 132 was a WPC with enhanced gelling properties. It found its

greatest outlet in the Japanese market for ham pumping. It was also offered in America for sausages, UHT puddings, custards, and pasta.

Every variant of WPC was differentiated by a different code, so pricing could be de-linked from the cost of manufacture. Each food ingredient was sold according to its value to the customer; not by a cost-plus calculation in New Zealand. Because the individual products were not the same as commodity whey proteins, they could not be replaced by buyers going to the open market. Eventually direct competitors were to reverse engineer many of our products but, by then, our price setting had established a price expectation which our competitors were sometimes willing to respect.

Many incremental changes could be made for individual customers. One Japanese customer requested so many changes to Alacen 132 that we renamed it Alacen 134. It was then offered exclusively to that customer.

The 'NZ/NZ' logo was inspired by the son of NZMP's president. Garrell saw the boy wearing a t-shirt carrying the logo of the Commonwealth Games held in Christchurch in 1974. Garrell just had to have it. Enquiries revealed that it was covered by an act of parliament and the rights were held by the Commonwealth Games authority. The right to re-use it as a company logo and a food ingredient identifier was negotiated back in New Zealand at a surprisingly low cost. That logo gained very high recognition among the customers in America (and later in Japan) but was eventually replaced with a corporate logo (the milk drops). This represented the Dairy Board and its total operation. So was born the WPC market identity.

The logo was also produced in red and blue.

NZMP had still to be recognised by the American food industry. Advertorials appeared in the food magazines and a huge effort went into displays at the annual trade displays of the Institute of Food Technologists. Over 10,000 people turned up to those events. How could an almost unknown company from a faraway country get noticed? An eye-catching display stand was built at considerable cost. A site was applied for annually and a hotel suite for meeting customers was obtained. NZMP had arrived!

Costly as these moves were, some of the most attention-getting items were the simplest. One year, suitably emblazoned ten-cent tin whistles were on offer at the NZMP stand. People felt secure in the

conference facilities but were less sure of themselves on the streets. If they were assailed by frightening people, they could blow the whistle to attract attention. People who had never heard of NZMP (or New Zealand for that matter) sought out the stand to get a whistle. The things could be heard all around the hall.

The concept of branded food ingredients eventually transferred back to New Zealand when I returned to Wellington to establish the whey division under Ken Kirkpatrick.

The outcomes of a very creative five-year period during the early 1980s were:

- WPCs were firmly identified as valuable food ingredients.
- WPCs were designed for purposes that had value to customers.
- The product differentiation permitted by the coding system allowed for price flexibility entirely divorced from cost of production and therefore added to profitability.
- The likelihood of commoditisation over time was minimised (or at least deferred).
- The technical advances made at NZDRI and the manufacturing companies were protected by trade secrecy that was enhanced by the remoteness of New Zealand.
- The intellectual property was eventually protected by a strong brand, identification with New Zealand, trade secrecy about manufacturing know-how, and (when appropriate) patenting. (It would be a further 20 years before we achieved a formal intellectual property strategy.).

Market segmentation:

The train leaves the station: egg white replacement

The most commercially successful WPC was a physically functional whey protein designed to gel under very particular conditions, for use in Japan. For reasons perhaps best left opaque, the poultry industry of Japan was able to command a startlingly high price for spray dried egg white. Imports were not allowed to compete. The whey proteins with gel strength enhancement proved very competitive. That commercial position was enhanced by pricing the Alacen proteins in Japanese currency. It so happened that the New Zealand currency depreciated against

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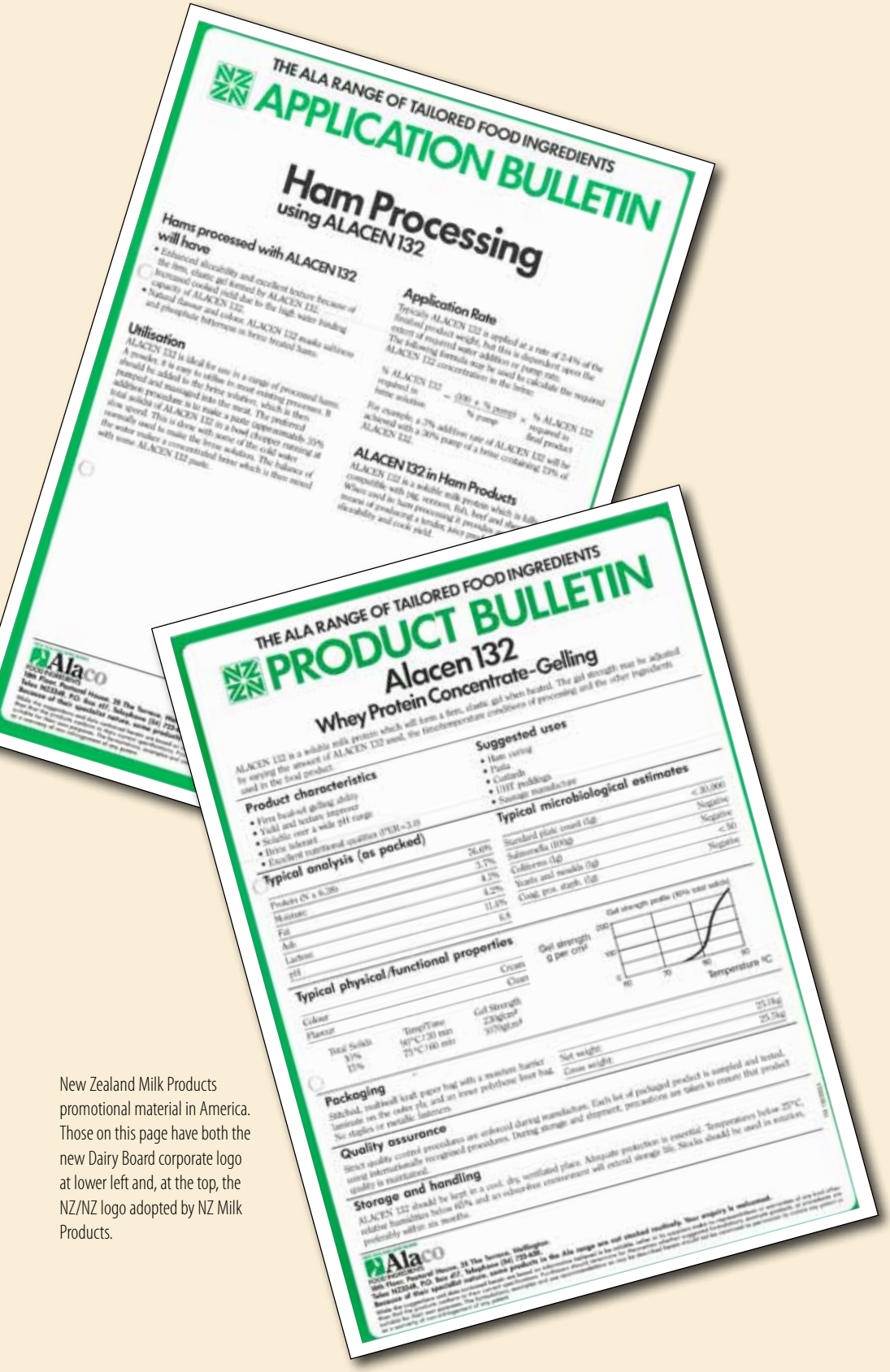

THE ALA RANGE OF TAILORED FOOD INGREDIENTS

APPLICATION BULLETIN

Ham Processing
using ALACEN 132

Hams processed with ALACEN 132 will have

- Enhanced sliceability and excellent texture because of the firm, elastic gel formed by ALACEN 132.
- Increased cooked yield due to the high water binding capacity of ALACEN 132.
- Natural flavour and colour. ALACEN 132 masks saltiness and phosphate bitterness in brine treated hams.

Utilisation

ALACEN 132 is ideal for use in a range of processed hams. A powder, it is easy to utilise in most existing processes. It should be added to the brine whatever, which is then pumped and massaged into the meat. The preferred addition procedure is to make a paste (approximately 35% total solids) of ALACEN 132 in a bowl chopper running at slow speed. This is done with some of the cold water normally used to make the brine solutions. The balance of the water used to make the brine solutions is then mixed with some ALACEN 132 paste.

Application Rate

Typically ALACEN 132 is applied at a rate of 2-4% of the finished product weight, but this is dependent upon the extent of required water addition or pump rate. The following formula may be used to calculate the required ALACEN 132 concentration in the brine:

$$\%\ \text{ALACEN 132 required in brine solution} = \frac{(100 \times \%\ \text{pump required})}{\%\ \text{pump}} = \%\ \text{ALACEN 132 required in final product}$$

For example, a 3% addition rate of ALACEN 132 will be achieved with a 200% pump of a brine containing 33% of ALACEN 132.

ALACEN 132 in Ham Products

ALACEN 132 is a soluble milk protein which is fully compatible with [illegible] veal, fish, beef and also [illegible]. When used in ham processing it provides the [illegible] amount of producing a tender, juicy product with [illegible] sliceability and cook yield.

Alaco

THE ALA RANGE OF TAILORED FOOD INGREDIENTS

PRODUCT BULLETIN

Alacen 132

Whey Protein Concentrate-Gelling

ALACEN 132 is a soluble milk protein which will form a firm, elastic gel when heated. The gel strength may be adjusted by varying the amount of ALACEN 132 used, the time/temperature conditions of processing and the other ingredients used in the final product.

Product characteristics

- Firm heat-set gelling ability
- Yield and texture improver
- Soluble over a wide pH range
- Brine tolerant
- Excellent nutritional qualities (PER = 3.0)

Suggested uses

- Ham curing
- Pasta
- Custards
- UHT puddings
- Sausage manufacture

Typical analysis (as packed)

Protein (N x 6.38)	76.6%
Moisture	3.7%
Fat	4.3%
Ash	4.3%
Lactose	11.4%
pH	6.8

Typical microbiological estimates

Standard plate count (/g)	< 30,000
Salmonella (/25g)	Negative
Coliforms (/g)	Negative
Yeasts and moulds (/g)	< 50
Coag. pos. staph. (/g)	Negative

Typical physical/functional properties

	Cream	Clear
Colour		
Flavour		
Total Solids	Time/Time	Gel Strength
8.5%	60°C/30 min	230g/cm²
15%	75°C/60 min	3070g/cm²

Packaging

Stitched, multiwall kraft paper bag with a moisture barrier laminate on the outer ply, and an inner polythene liner bag. No staples or metallic fasteners.

Net weight	25.0kg
Gross weight	25.5kg

Quality assurance

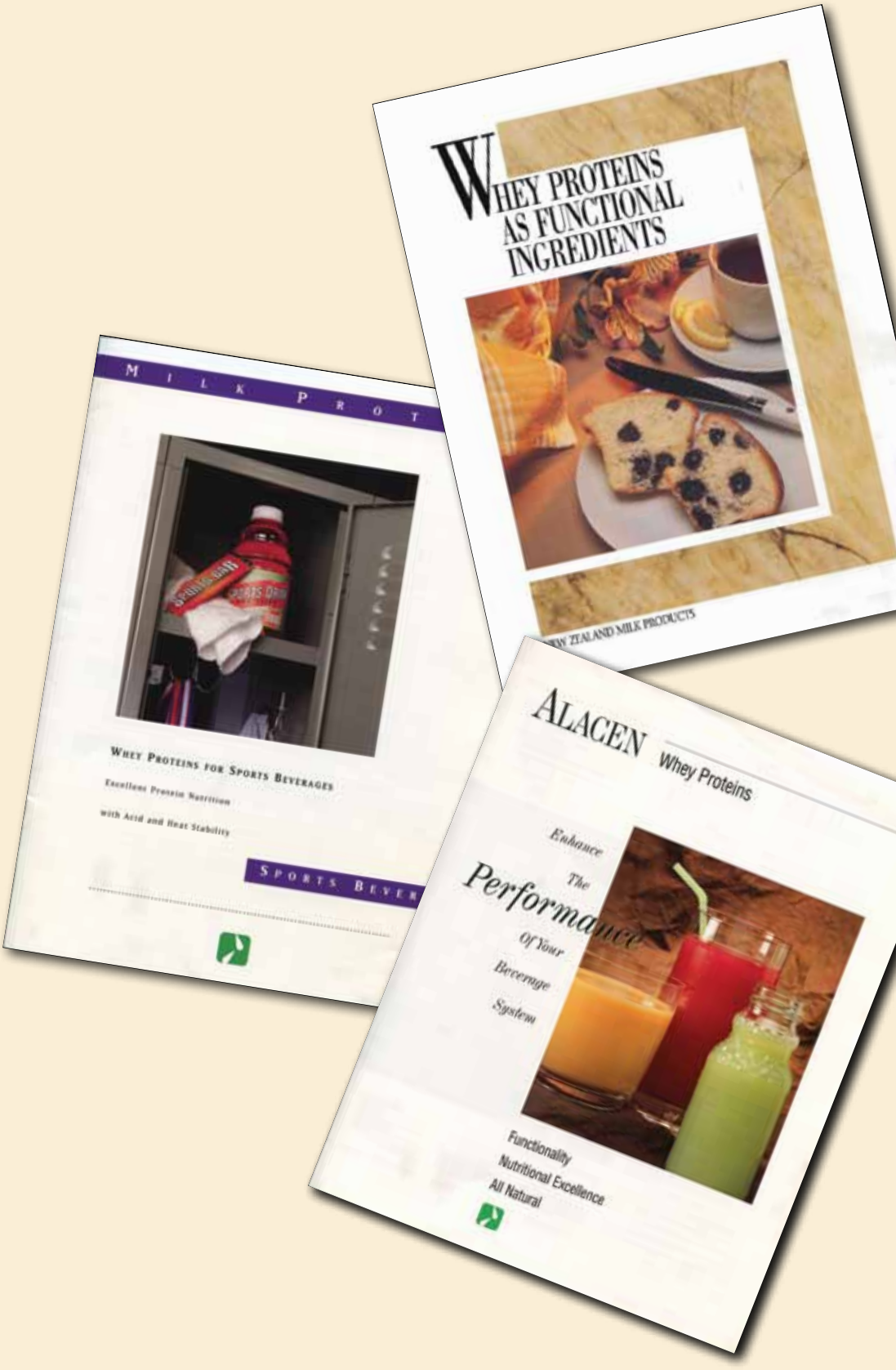
Strict quality control procedures are enforced during manufacture. Each lot of packaged product is sampled and tested using internationally recognised procedures. During storage and shipment, precautions are taken to ensure that product quality is maintained.

Storage and handling

ALACEN 132 should be kept in a cool, dry, ventilated place. Adequate protection is essential. Temperatures below 25°C, relative humidities below 60%, and an odour-free environment will extend storage life. Stocks should be used in rotation, preferably within six months.

Alaco

New Zealand Milk Products promotional material in America. Those on this page have both the new Dairy Board corporate logo at lower left and, at the top, the NZ/NZ logo adopted by NZ Milk Products.


WHEY PROTEINS AS FUNCTIONAL INGREDIENTS
ZEALAND MILK PRODUCTS
MILK PROT
WHEY PROTEINS FOR SPORTS BEVERAGES
Excellent Protein Nutrition
with Acid and Heat Stability
SPORTS BEVER
ALACEN
Whey Proteins
Enhance
The
Performance
Of Your
Beverage
System
Functionality
Nutritional Excellence
All Natural

the Japanese yen so it was possible to hold the price to the buyer steady for some years.

In America, spray dried egg white was a by-product of the egg industry and was sold relatively cheaply as a commodity, so WPC was not price competitive as a replacement. The demand for WPC from Japanese buyers was so lucrative that WPC sales to America were not commercially attractive. Different opportunities had to be found.

The train gathers speed: infant formula

The supply of whey protein to the manufacturers of infant formulas had for many years been satisfied by whole or demineralised whey powders. For Japan, importation was limited by access quotas that were held by only a few dairy companies. Those companies could more efficiently use the quota by importing a more concentrated form of whey protein that could subsequently be blended with other locally available ingredients by the formulators.

One company chose to purchase 35 percent WPC. This opportunity eventually fell to commoditisation when an American competitor, who was pleased to move unwanted whey solids at low prices, gave the buyer an offer we could not meet. This shift in the market led to phasing out the only plant in New Zealand that still made 35 percent WPC.

Other Japanese companies explored the possibility of using 75 percent WPC and this story is told in Chapter 6. In Korea and China the imperative to use quota licenses in this way did not arise. Buyers there used whey powders.

The train reaches full speed

In order to pass the border controls of America, Europe and Japan, our WPCs had to contain at least 80 percent protein. This limited our food ingredient strategy to fairly pure proteins. It occurred to NZMP that once the proteins had entered the country, such restraint would no longer apply. A food ingredient might be designed for the purposes of a customer and be pre-blended from a number of components that were available within the country. So was born the 'Alablen' range.

Large companies, having their own capable R&D teams, did not want assistance formulating blends but some trade with smaller customers in America was developed. It was expensive to service and never became strong business – at least not for WPCs.

The same thought occurred in Europe. Small food manufacturers

abounded, so a strategy of providing a compounded ingredient based upon dairy proteins was devised. So the 'Alaplex' range arose. A formulation facility was installed under the initiative of Richard Laverty at NZMP's Hamburg site. The powders could be priced according to value, so the commodity linkage to cost of production could at last be broken.

The train loses a carriage down a side track

Physiologically functional components of food began to be recognised by the food industry. It was probable that WPCs might have such functions.

Dairy husbandry scientists and farmers had long known that calves were born with low levels of immunity to disease. The first milk – colostrum – of the mother cows provides that immunity. It contains a remarkably high level of antibodies (confusingly called immunoglobulin in dairy fluids). The colostrum is available to the calves for only three days; during which time the mothers' lifetime experiences of disease resistance is passed to the suckling calves. The calves absorb the immunoglobulin through their porous intestinal walls. By the third day the gut walls mature and their ability to absorb such large molecules ceases. If a mother cow is unable to provide colostrum, few if any antibodies will end up in the blood of the calf, which is likely to die.

After the three days of colostrum secretion, milk still contains antibodies that have arisen from the blood of the cows, but at a low level. David Lucas (then working at the University of Arizona) showed that those immunoglobulins of whey retained antimicrobial activity. Indeed the combined immune experience of disease resistance by herds of cows resulted in a very diverse range of anti microbial immunoglobulins. He also showed that, provided the immunoglobulins are not inactivated by heat during cheese making and subsequent whey processing, they are concentrated in WPCs.

Might carefully processed WPC be sold as a colostrum replacer? It worked for neonate calves; perhaps it would also work for lambs and piglets. Might it work for growing calves? While the immunoglobulins could not pass the gut wall once it had matured, they might remain active in the gut and combat infections that lead to diarrhoea.

At this point in his scientific exploration, Lucas joined up with

an investor, Ben Fellows. They set up an entrepreneurial technology exploration company in Minneapolis called Protein Technology Inc. In time, Milk Products Inc (the holding company for Dairy Board marketing in America, headed by Brian Service) became the major shareholder.

A flurry of high intensity animal health research followed, leading to an American patent for Protein Technology Inc. The company entered the animal health market with what it called an 'immunoglobulin concentrate', branded Colostrx and packed in one pound sachets. The WPC business had gone retail.

Technically, Colostrx succeeded. Calves that needed antibodies did survive. Commercially, distributing a small number of retail packs by courier across America to individual farms was not a successful business model. Eventually, Neil Blazey, working at Santa Rosa, California, succeeded in supplying Colostrx to a recognised distributor to the animal health market and a small level of sustainable trade persisted for years.

The real commercial opportunity was to provide active immunoglobulins for growing young calves and pigs. Under the intensive American farming practices for white veal production and hog raising, there was marginal evidence from animal trials that providing immunoglobulins to the mature gut might have prophylactic benefit. Research trials in the open piggery systems of New Zealand and in the small farm systems of Japan showed it clearly did not work.

Protein Technology Inc could not support its overheads, was eventually taken over, and dramatically downsized.

Lessons

During five highly innovative years the concept that whey protein (and indeed all milk proteins) could be presented as branded specialised food ingredients became accepted throughout the marketing ethos of the Dairy Board network. To be credible the products had to be truly 'specialised' and that specialisation had to be maintained as products progressed through their life cycles. The efforts of competitors had to be recognised and forestalled.

The achievement of a strategy that required the New Zealand team to be first to market with new and better protein products was assured by the closest possible collaboration among scientists and

technologists, manufacturing specialists, and marketing specialists. Open dialogue with the technical staff of customer companies who were spread around the world, required a very high level of relationship marketing across cultural and language differences. That commodity marketing was superseded by value added marketing, was perhaps the greatest success of the dairy industry network.

CHAPTER 8

COMING OF AGE: THE WHEY CORPORATION

JOHN MACGIBBON

John MacGibbon *graduated from Massey University with a geography degree, then worked for the New Zealand Dairy Board's economics and technical departments between 1966 and 1974. He later worked in journalism, as a ministerial press secretary, in corporate communications with Databank and the New Zealand Wool Board, wrote several books and established Ngaio Press.*

By the end of the 1970s, whey production had become more than lactose, lactalbumin, demineralised whey powder and more basic spray dried whey powders. Ultrafiltration plants producing whey protein concentrate, or Solac, were operating at Te Aroha Thames Valley (TATV) and Rangitaiki Plains (RPD) cooperative dairy companies. Similar plants were due to open within a year or so at Manawatu and the New Zealand Cooperative Dairy Company (NZCDC) site at Tirau.* Other companies were wondering if they should jump on the bandwagon.

The whey products industry could have continued to develop on a piecemeal basis, company by company, but at high cost and high risk. It still needed high levels of research and development, along with expensive new approaches to production and marketing to the sophisticated food ingredients business.

Staff in the New Zealand Dairy Board's casein and whey products division began to discuss the desirability of a more coordinated industry-wide approach. Chief among the thinkers was Don King, the section's manager. King, a chemical engineer, had long experience with whey that went back to pioneering work on lactalbumin at NZDRI in the 1950s.

While King did most of the original thinking, he was ably supported by the Board's general manager, Bernie Knowles, whose keen legal and accounting mind and ability to think creatively would prove extremely useful. Knowles was hugely respected in the

*The planned Tirau ultrafiltration plant was never built.

industry. He had spent four years as assistant secretary and secretary at the Kaitaia Dairy Company in the 1950s and joined the Dairy Board in 1968. He became the Board's general manager in 1975.

Waiting in the wings was industry political support, notably in the persons of Ken Mehrtens, then deputy chairman of the Dairy Board and Graham Calvert, who was one of the NZCDC's representatives on the Dairy Board's board of directors.


Bernie Knowles

Board directors first discussed a pan-industry approach to whey in November 1979 and again in March 1980, when they asked Board officers to continue investigations and establish a committee that would develop a proposal to establish a whey pool under which financial returns for whey products would be pooled and shared, both as payouts and as underwriting for capital development. The committee was asked to report to the Board's June meeting.

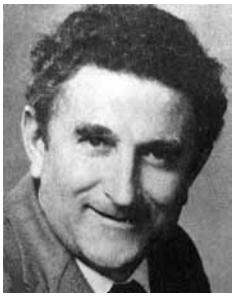
Towards a whey pool

The investigating committee, called the Whey Pool Group, held its first meeting on 2 May 1980. It was a technical, rather than political committee, composed of dairy company and Board executives. They included: Don Fergusson (MD, Mid-Northland), Rex Haggie (GM, NZCDC), Graeme Honeyfield (assistant to the GM, TATV), Brian Kingston (secretary, Taranaki), Malcolm Pettman (CEO, Tui), Don King (Dairy Board) and Tom Connell (Dairy Board), who acted as secretary.


Ken Mehrtens

The committee considered a discussion paper by King, titled *Towards a whey pool: effective whey utilisation.* This was effectively a manifesto for New Zealand's emerging whey industry. King stressed that payment systems for whey products could not be based on the intrinsic value of the raw material, which unlike that of wholemilk, was very low. The reward had to be for the management effort that went in, not for the raw whey.

> New Zealand has no reason to expect a return for whey that will represent anything other than the effort we put into manufacturing it into useable products. If we want maximum returns we will need maximum efforts.
>
> The world market for standard whey products tends always to be over-supplied. This applies, for instance, to whey powders and normally to lactose. Only speciality whey products, for which special markets need to be created and where generally high technology is involved, can command anything but marginal long term returns.


Graham Calvert

King listed New Zealand's advantages as a producer of whey products:

- The main one is that our whey is available in substantial quantity on single sites. Since whey is a dilute material and transport is expensive, this is an increasingly valuable factor. On the other hand, it is a grave disadvantage if whey products are not actually produced, since waste disposal can become very difficult in a limited area.
- While there are ecological pressures in New Zealand, disposal [by spray irrigation on farms as fertiliser] of some proportion of mineral matter and biologically degradable wastes from dairy factories can even be advantageous under New Zealand conditions, so that pressures for complete in-factory utilisation may not be as great as in some countries. This allows us to consider products of low yield which also enjoy the benefit of minimum transport costs.
- New Zealand is an importer of certain goods that can be manufactured from whey – industrial and potable alcohol, certain industrial sugars etc. These are generally fairly bulky and relatively low cost items so their production from whey in New Zealand offers advantages.
- New Zealand has certain uses for whey products within its own dairy industry – infant formula ingredients for instance – which allows us to base some of our technology on a local market, so to speak. This type of local market is not generally available to us. On the other hand, New Zealand's range of supporting industries is small and our expertise in certain areas such as biological transformations (for which whey is an excellent raw material) is limited.
- New Zealand has a good level of dairy technology and an excellent industry organisation and financing system to pursue the development and marketing of dairy products of all sorts, including whey products.

Whey was a national problem, the paper said. New Zealand could not avoid producing whey while continuing to manufacture large quantities of cheese and casein for world markets. To cut back on these products would be "seriously inimical both to the dairy industry and to the economy of New Zealand."

It was no longer possible to establish new cheese or casein factories without considering whey disposal. "It is not an exaggeration to state that no whey-producing dairy factory could be established now without a substantially complete means of utilisation and/or disposal of the resulting whey and that in general spray irrigation could not be considered sufficient in itself."

Existing companies were also under pressure to develop more satisfactory methods of using or disposing of their whey. Some companies were already seriously at risk, King said.

Because of the immediate disposal pressures, the whey industry could not be allowed to grow and develop slowly, as the milk powder industry had been able to do.

The paper warned that there was no single simple way of using all the whey economically. It would be necessary to produce a range of specialised products requiring varying capital investments. Manufacturing costs would vary greatly. "At present, for instance, the range of manufacturing costs for putting whey into saleable form range from nil (company pig farm) through to about $3000 a tonne (for soluble whey protein)." King estimated the net returns per kg of milkfat to range from less than one cent, up to 15 cents.


Don King

Industry-wide capital investment of around $150 million was needed to ensure effective utilisation for reasonable returns, the paper said.

> Many of the projects which will need to be included in a rational programme will involve quite elaborate technology which is expensive both in relation to research and development and in capital and manpower involvement. Most of this research will be of a nature which will require it to be centrally done, with substantial backing resources. We cannot rely on others to pioneer these developments – New Zealand cannot expect to enjoy commercial advantages without being early in the field in at least some areas.
>
> Likewise, it is necessary to develop markets for new products and this in itself is an expensive function, frequently needing substantial promotional and other investment, beyond the resources of individual companies.

Because they were so expensive, it was vital that whey processing plants be operated at maximum throughput and because of this, the industry needed to be organised so that whey raw materials were available as required. Otherwise they could sustain major losses. There was no buffer in whey value, as there was in milk value, to cushion manufacturing losses against becoming actual cash losses.

The paper summarised current systems used by the Board to encourage manufacture of whey products for expected market opportunities. In each case, the products were produced to meet a Non-Standard Purchase Order (NSPO) from the Board.

One existing system provided for manufacture of a product to an agreed specification by a company, which might receive finance

from the Dairy Industry Loans Council. The company would receive full market returns less the Board's marketing costs. King pointed out that, while this was appropriate for fully developed products sold in reasonably stable markets, it was less appropriate for newer products. And as the industry, through its Loans Council, might have invested substantially in research and market development, "one might question whether a full return should go to such a company, even though it is taking a market risk." Another problem was that the Board might not be able to keep the product available should a company decide to curtail production.

Under the second existing system, the Board might underwrite a plant. This was more common for newer and more elaborate high-risk products. Ultrafiltration plants for whey protein concentrate had already been built under this arrangement at Waitakaruru[1], TATV and RPD.

Underwriting schemes took account of the uncertainties and guaranteed a return to a company which, though less than the expected long term market return, was considered equitable in relation to the difficulty of manufacture. The company's return would depend on its performance in terms of yield and quality and was subject to review to ensure equity was maintained over a period. In practice, the maximum net returns to companies for underwritten whey projects had been limited to about five cents per kg milkfat, which included one cent for the whey value and four cents as a manufacturing difficulty allowance.

King concluded that neither existing system was adequate, given pressures on companies to dispose of or use whey more effectively, plus a need to provide immediate facilities for new cheese and casein projects.

> Companies undertaking specific projects are usually those having specific enthusiasm and means, but they are not always well placed to carry on the project in the long run, in comparison with other alternative companies. Further, there have been and still exist, potential problems with non-underwritten companies in relation to the market which our current NSPO system is not able to resolve, particularly when one or only a few, companies produce a given product.
>
> Difficulties between underwritten and non-underwritten companies are minimised when the market is larger than New Zealand's productive capacity. But when the reverse occurs, as will surely happen at some point, an acute difficulty is produced in that the allocation of NSPOs in these circumstances will be almost impossible to do in an equitable manner. The underwritten companies may be producing some revenue

> for the industry at large, which has taken risks along with them and therefore could reasonably be seen as those which should be favoured by continuing production. On the other hand, the non-underwritten plant may equally wish to continue production since not to do so could involved substantial losses to the company. The strains on the NSPO system would at least be very great and in any case the tendency might well be to overproduce and hence depress the overall return.

King concluded that the industry should seriously consider setting up a whey products pool from which returns for whey products, including notional values for unprocessed casein and cheese whey, would be paid and from which companies could receive underwritten payments for their products. He recommended the issues be tackled in two parts. The first part would involve investigation and planning, including product requirements, optimum whey utilisation by individual company and region, R&D requirements and a marketing plan.

The second part was a recommendation that a small committee should gather industry views and prepare proposals for Board consideration on:

1. The establishment of a whey product pool.
2. The principle that the major returns for whey product manufacture should be on the basis of the manufacturing difficulty allowances which should be applicable to each product in a manufacturing series.
3. The establishment of a standard value for underwritten companies for utilised whey.
4. Adjustments to the notional value for unprocessed casein and cheese wheys and whether the figures in current manufacturing costs should be credited to the whey pool.
5. Whether backdated changes should be introduced into current arrangements with non-underwritten companies and the nature of limitations if any to be applied to future arrangements of this kind.
6. Whether companies currently underwritten and non-underwritten should have the opportunity to change their election with the introduction of a pooling scheme or other change in the rules, and if so whether it would be appropriate to have retrospective adjustments to bring them into the same position as they would have been, had they made this election from the inception of their operation.
7. Alternative arrangements that might better meet the industry's needs in coping with the problems outlined above.

Clearly there was plenty of potential for discussion and argument in the years ahead, and so there was. Nevertheless, King had put his finger on the issues and pointed to possible solutions, most of which would be taken up.

The Whey Pool Group's meeting on 2 May 1980 discussed and largely supported the general thrust of King's discussion paper. It was agreed that if a whey pool were to be established, it should not initially cover whey for pig feeding or supply to the NZ Lactose Company. Long-term, it considered that all wheys should be pooled. (Later there were also suggestions that the pool should include whey destined for spray pasture irrigation, and even whey sent directly to waste disposal. In practice, the only whey that was covered by the pool was that which was used directly for whey products manufacture. The issue of whey for the NZ Lactose Company was solved in mid-1983 when the company was bought by the future Whey Corporation.)

A summary of whey projects in operation or soon to come into production was attached to the Whey Pool Group's minutes:

Product	Company	Planned capacity, m^3/day	Commission date
Solac	TATV[1]	500	1978[2]
	RPD	500	Aug '79[3]
	Manawatu	750	81/82
	NZCDC-Tirau[4]	1,200	81/82
Lactalbumin[5]	Taranaki	250	Jan '79
	NZCDC-Reporoa	450	Aug '76
	Opotiki	300	Jun '79
	Mid-Northland	300	Feb '80
	Northern Wairoa	300	81/82
Rennet whey powder	Bay of Islands	N/A	N/A
	NZCDC-various	N/A	N/A
High protein whey powder	Kiwi	N/A	N/A
	NZCDC	N/A	N/A
Demineralised whey powder	NZCDC-Waitoa	4500	Late 80/81
Lactose permeate	TATV	3800	Dec '79

1 Blue shaded projects were underwritten by the Dairy Board.
2 Corrected commission date. The original table said September 1970.
3 Corrected commission date. The original table said September 1980.

4 This plant was never installed or commissioned.
5 This omits an NZCDC lactalbumin plant at Tirau.

Producers of Solac and lactalbumin had been asked what they were doing or planned to do with their permeate by-product, which was a potential pollutant. Most didn't know at that point. TATV had been sending concentrated casein whey and some permeate to the NZ Lactose Company[2] and Manawatu expected to do the same with its forthcoming permeate.

The Whey Pool Group met again in May, released its findings in September, then reconsidered them after an additional meeting held on 9 October at the request of Dairy Board directors. The following day, Don King released a summary that recommended a "suitable form of pooling arrangement", which could operate from the start of the 1981/82 season. The basis for the scheme was that the Board would assume responsibility for, and control of the utilisation and disposal of all whey, in the best interests of the industry as a whole. It would also fund capital works required, in order to maximise overall income. Discussing problems a whey pool could help solve, he noted:

- Utilisation of whey at present is somewhat haphazard and does not ensure the maximum overall return. In products which are currently apparently profitable, there is real risk of wasteful inter-company competition utilising scarce financial and other resources. On the other hand, there are products of good future promise for which it is necessary to establish manufacture in order to develop markets, but where current profitability is low.
- There are also products of widely fluctuating and unpredictable return but which would be expected to provide for a satisfactory long term overall return. No one product stands out as a profitable use for most of the whey. We must provide for a diverse range of products.
- Since the capital involved in whey processing is high, plants once established must be kept operating. They cannot economically be operated intermittently, but to maintain flexibility between milk powders on the one hand and whey-producing casein and cheese operations on the other, it is necessary to provide for some companies to dispose of whey from time to time. Clearly such plants are precluded from participating in potentially profitable whey ventures, but may be seen as subsidising the rest of the industry in permitting whey processing in other places. In equity it is considered such companies should have an appropriate remuneration for their whey.

- There are also a number of difficulties which arise in the allocation of product orders between companies, and in achieving regular supplies for market development, with the current unstructured operating system.
- All of these factors will grow worse as whey processing becomes more widespread.

Industry reaction

Dairy Board directors decided to recommend a whey pool to the industry and circulated a discussion paper to dairy companies. In November, the proposal was considered at an industry meeting in Hamilton. It was opposed by the NZCDC's deputy chairman, Dryden Spring, who said that if central control was acceptable for whey, then it should also be considered for all of the milk. "I believe that would be a great pity – we don't want centralised control. Consultation is no substitute for responsibility."

Ken Mehrtens, a Taranaki Co-op man who by then was chairman of the Dairy Board, championed the pool concept. He emphasised the need for an industry approach to a problem that involved large amounts of capital and high risk, and stressed the industry's traditional cooperative approach to big issues. Tossing the ball back into Dryden Spring's court, he pointed to NZCDC as an example of a company "which grew because many of its functions could not be exercised by a smaller unit."

Stressing a need for full industry consultation, he was confident of company directors' ability to deal with broad industry problems: "There is something unique about our industry. Although we each represent companies and seek to do the best that we can for our suppliers, we also represent the industry."

Dairy company chief executives discussed the matter further in January 1981 and this was followed in March by a Don King discussion paper sent to all dairy companies and discussed at industry ward conferences during that month. It was accompanied by a slightly abridged version of King's original *Towards a Whey Pool* paper, which had stood the test of time.

King concluded that the need for a whey pool arose from a very complex background. While the basic idea of operation was simple, its detailed application was complex, "as indeed is the operation of the industry's rules of acquisition for all products." However, the need for a

whey pool was so great, he said, that a basic scheme should be adopted as an urgent matter, in the knowledge that it could evolve over time.

Industry agreement

Formal industry approval for a whey pool came on 25 July 1981, when a remit was unanimously approved at the annual dairy industry conference in the Michael Fowler Centre, Wellington. The remit was proposed by John Whitelock, chairman of the Manawatu Coop and seconded by the NZCDC's Dryden Spring, who had previously opposed the concept.


Dryden Spring

Explaining his change of tune, Spring says[3] that following the November meeting, he had led several discussions about whey within the NZCDC board. They had decided not to veto an industry approach to whey processing for several reasons. One was an understanding that most companies did not have the financial and technical resources to process whey profitably. There was also a recognition that scale was important to the economics of whey processing, with large quantities of whey needing to be available to any processing site, and year-round operations to optimise capital utilisation. And from a marketing point of view, they felt the Dairy Board needed to be more closely linked to capital expenditure and production decisions – unlike the situation for other dairy products.


John Whitelock

Whey Pool Committee

Following the industry endorsement, a Whey Pool Committee was set up and had its first meeting in December 1981. Chaired by Bernie Knowles, with Tom Connell as secretary, its members included Bob Baldey (GM RPD, for Eastern Ward), Peter Couper (Northland, for Northern Ward) Ralph Dearlove (Sunny Park-Hinuera, for South Auckland Ward), Frank Goldsworthy (secy Kiwi, for Taranaki Ward), Rex Haggie (GM NZCDC for NZCDC Ward), Doug Trotter (CEO Manawatu, for Wellington Ward) and Arthur Wilson (Southland, for South Island Ward). Observers included Stan Florence (Moa-Nui), Ben Hurst (Golden Bay), Malcolm Pettman (Tui), Graeme Honeyfield (TATV), Doug Johnston (Sunny Park-Hinuera), Gordon Spratt (Te Puke), Kevin Mulcahy (Temuka) and Alan Reid (Northern Wairoa)

Board staff who supported the committee included Bernie Knowles, Charles Patrick, Neville Jones, Alan Pollock, Peter Benjes, Jack McFaull, Don King and Robin Fenwick.

Bernie Knowles led a discussion on the supply and disposal of whey

BAKING THE CAKE

Speakers during the whey pools discussion at the 1981 dairy industry conference warmed to a cake-baking theme:

Ken Mehrtens (chairman): "What the Board has done is to get on with the job of baking the cake. It seems to us that most of the concern of those engaged in the whey pool debate is on how to cut it up after it has been baked.

"If it is any consolation, it will probably be another two or three years before it is well-enough baked to have anything available to share out. By that time some of the half-baked ideas which have been raised in opposition will probably have been burnt to a crisp and disappeared."

John Whitelock (Manawatu): "…one would almost be led to believe on this whey subject, that there is a large slice of cake to be carved up…we should dispel then, in the short term, any question of there being a large cake, but should have adequate regard for what we see as the prime responsibility to effectively compensate companies who have taken some commercial risks, and whose innovation in due course should rub off to the benefit of the industry."

Dryden Spring (NZCDC): "You commented, Mr Chairman, that it was important to try to get the cake into the oven and baking as soon as possible. We feel, however, that we are being asked to put the cake in the oven without knowing what the ingredients or the recipe are going to be. It doesn't work very well in my wife's kitchen, and I don't think it will work very well in the industry's kitchen either.

"By law, if you sell formulated foodstuffs you are obliged to put the ingredients on the package, and what the industry is asking in this resolution, is that the ingredients in your cake are clearly stated to the industry, so that we can judge whether we think you are going to bake a good cake or a bad one, Mr Chairman.

John Hedley[4] (Opotiki): "I too, Mr Chairman, would like to refer to your cake analogy. The ingredients and the utensils are around in the kitchen, the oven is warmed up, I don't believe we ought to start baking the cake by tossing in the egg shell and all, or by putting in a couple of kgs of the flour with the wrapper still around it. I believe that we have got to properly mix the cake up and ensure that when it comes out of the oven eventually, it is nutritional for us and the flavour is good. Thank you."

Ken Mehrtens: "Mr Knowles has just pointed out that we hope that foreign matter will be kept out."

Gerald Long (Taranaki): "Probably one of the problems is that the cake was started very many years ago."

solids, which were expected to reach 220,000 tonnes a year by 1990. Also raised was the concept of a controlling body, referred to as a 'corporation' that would not be a legal entity. Such a corporation would acquire whey (but not wash water), negotiate further manufacture of whey products, and/or develop alternative methods for the disposal of whey, and market whey products.

Discussions during the second meeting of the committee in January 1982 included accounting matters, the existing structure of whey processing and disposal, how to integrate existing and planned plants and their operations into a whey pool, estimated returns from processing plants, how to deal with unprocessed whey, acquisition price for whey, capital requirements, how a whey pool would operate, how the 'corporation' would operate and the future of the NZ Lactose Company.

Minutes of the Committee's meeting in January 1982 included the estimated replacement capital value of existing whey processing plant in New Zealand:

Lactabumin	6 plants (3 underwritten, 2 applications for underwriting)	$13 million
Solac	3 plants (2 underwritten, 1 application for underwriting)	$34 million
Lactose	2 plants (1 application for underwriting)	$8-10 million
Whey cheese	1 plant (underwritten)	$1 million
Whey powder	(Number not included)	$35 million
Alcohol	2 plants	$13 million
Waste disposal	46 units	$20-30 million
Total		$124-136 million

Letter 1099

The final report of the Whey Pools Committee was distributed with the Board's Letter 1099 to all dairy companies, on 30 April 1982. This long document, regarded in the industry as a Bernie Knowles 'classic', would have been a synthesis of work by several people, notably Don King. Knowles's particular contributions, apart from general document structure and language calculated to persuade dairy companies, would have been in areas of accounting, costing, valuations and contractual issues. (The full letter is reproduced on page 227.)

The report opened with "background answers to fundamental questions." These were:

- Why does whey present a different 'problem to the industry'?
- Why not stick to powders and leave other countries to cope with whey problems?
- What is the 'cost' of whey disposal?
- Disposal 'costs' may be lower when capital investment in production facilities is made.
- Fluctuation in investment returns.

This section of the report concluded:

1. There is no reasonable prospect of reducing the quantity of whey required to be treated or disposed of by changing product manufacturing plans.
2. Because the whey producing products must, in fact, be manufactured, it should be an industry responsibility for determining the method of treatment or disposal to be adopted by any factory during a particular point of time and, following from that industry decision, the industry should provide the capital necessary for that plant.

A Whey Products Corporation was recommended. It should be "unincorporated", resembling in general concept the Board's Herd Improvement Council.

Companies were invited to discuss the report at Te Rapa, Hamilton, on 30 May. There it was unanimously endorsed by 29 companies that represented 97 percent of milkfat processed in New Zealand in the 1980/81 season.

One company placed a number of concerns on record. This company, RPD, was already producing Solac from casein whey. It had excellent technical staff and was acknowledged to have the most efficient and probably the only profitable ultrafiltration operation in the country. It had less need of a whey products corporation than other companies, and indeed it said the move would adversely affect it in the short term. But it accepted the 'wider industry' argument:

> We recognise that this is a serious industry problem. Within the cooperative spirit of our industry, we are prepared (with some reservations) to endorse the concept of a Whey Processing Corporation in principle, trusting that by responsible interpretation of the document and wise council by the Corporation's Board, the industry as a whole (including our own company) will eventually benefit.[5]

Whey Processing Corporation established

After the Te Rapa endorsement, it was left to the Dairy Board, under the chairmanship of Jim Graham, to formally inaugurate the Whey Products Corporation* on 8 June 1982, in a resolution:

> That as authorised by the industry meeting in Hamilton on 31 May 1982, a Whey Products Corporation be established as a Section 13 Committee of the Board, to advise the Board on all matters relevant to the acquisition of the total volume of whey produced by the New Zealand dairy industry (excluding those wash waters which include inevitably some wheys) and the disposal of the whey so acquired, the acquisition and construction of such processing facilities as may be necessary, and the marketing of whey in its natural form or in the products of its processing, as may be determined and according to circumstance.

The resolution also confirmed Letter 1099 as the guiding document for Whey Corporation operating procedures and responsibilities.

Jim Graham

The initial directors of the Whey Corporation were Peter Couper (Northern Ward), Ralph Dearlove (South Auckland Ward), Rex Haggie (NZCDC), Graham Calvert (NZCDC, chairman), Frank Goldsworthy (Taranaki Ward), Doug Trotter (Wellington Ward), Arthur Wilson (Southern Ward), Dryden Spring (Dairy Board director), Alan Frampton (Dairy Board director) and Bernie Knowles (Dairy Board executive).

The Whey Corporation did none of the day-to-day trading work of ordering, buying and marketing whey products. This was carried out by the whey division of the Dairy Board, headed by Robin Fenwick. The whey division was part of the wider protein and whey products division, which was headed by Ken Kirkpatrick. Kirkpatrick had a dual position – he was also appointed chief executive of the Whey Corporation.

Kirkpatrick had a higher level role that included developing policy and negotiating with the industry. When legwork was needed, he called on the staff of the Board's whey division. When assistance and persuasion was needed at a more political level, he would work with Bernie Knowles and the Whey Corporation board, particularly with its chairman, Graham Calvert.

It was a difficult role. While the public face of the New Zealand dairy industry was one of cooperation and working for the wider industry, this

*From here on, this organisation is referred to as the Whey Corporation, which it was usually called.

was only true to a point. In practice, individual companies competed strongly against one another and were acutely jealous of other companies that might seem to be getting better deals.

The possibility of making appreciable money from whey processing was behind some company interest in whey processing. Figures of five or more cents per kilogram of milkfat had been talked about. Being able to boost your payout by that much could help retain suppliers who were tempted to switch to a neighbouring company. Or it might stave off the day when that neighbour might swallow you up. Or it might help position you to take over that neighbour.


Ken Kirkpatrick

One of the early tasks was to buy all existing whey plants from dairy companies, using a two-year $50 million fund established by the Dairy Board out of current earnings. It was a sizeable chunk out of the money that would otherwise have been paid out to companies – equivalent to about $150 million today. But fortunately, at the time the industry was enjoying good international prices. That combined with skilled lobbying by Knowles, Calvert and Kirkpatrick, meant there was relatively little industry concern about the impact on payouts.

Graham Calvert recently commented that effectively it was dairy companies' money anyway. "We were using our own money to help the Board buy our assets."[6]

As plant was bought, Whey Division staff actually placed ownership labels on equipment in the factories.

Naturally there were considerable arguments about plant valuation. Company A, whose equipment was being purchased, naturally had an interest, but so did other companies, who were determined Company A would get no special favours.

This was new territory for Kirkpatrick and his team, and for the industry as a whole. Looking back in 2010, Kirkpatrick recalled[7] presenting a paper at a dairy industry conference, explaining how the purchasing was being done:

> Amazingly enough the whole thing was accepted. When I think about it now, I think my goodness, what sheer chutzpah. I remember Alan Frampton [Whey Corporation board director] coming up afterwards saying: "Very well done, the only reason that got through was because of the work you've done and the way you explained it, and people accepted it." I was an innocent abroad who had just sort of wandered into the lion's den and did what I had to do.

Buying existing plant (and in some cases, as with unprofitable

GRAHAM CALVERT LOOKS BACK ON THE WHEY CORPORATION

Graham Calvert, chairman of the Whey Corporation, 1982–1996.

Graham Calvert was inaugural chairman of the Whey Corporation, and served in that role for 14 years. Looking back in 2010, he said it had been his most satisfying task in a long industry career, which included being a director of the NZ Cooperative Dairy Company and deputy chairman of the Dairy Board. Commenting on the Whey Corporation, Calvert said the collective will and skills of the industry had prevailed to elevate the smaller companies, some of which might have failed because of their inability to cope with their whey on their own. The Whey Corporation also prevented the larger companies from becoming too selfish and self absorbed.

"Rangitaiki Plains might have been better off without it, but in fact they became a willing and valuable contributor to the workings of the Corporation. There's no doubt that total sales of whey products would have fallen well short of $100m in 1996 if the Whey Corporation had not existed."

Could the Corporation have done better?

"Yes, of course we could have, but at the beginning, we didn't really know what we were going to make, we did not know where the products would be sold, or how, and we did not have a lot of resources to call on. So yes, mistakes were made, but we learned well and, in the end we did what Bernie Knowles foresaw: we turned adversity to advantage."

Calvert said he had admired the work that Knowles and his management team had done to identify and develop good staff at the Board and throughout the industry. The relationship between Knowles and Ken Kirkpatrick had been particularly important. The role of New Zealand Dairy Research Institute in developing whey products had been invaluable, he said, and he took particular pleasure in having been able to help expand the NZDRI's whey processing plant and recruit skilled staff.

Among Calvert's mementoes is a framed chart that tracks revenue growth achieved by the Whey Corporation from 1982 to 1996, signed by fellow directors and managers of the era. It tops out at just over $100 million. "I said I'd retire from the role when we reached that goal, and that is what I did."

lactalbumin plants, closing it) was one activity. Another was deciding what new plants should be built and where they should be located. That was another area for conflict as well as cooperation.

Kirkpatrick: "It was recognised that we had to have a single collective approach to the building of this whey industry and that factories would have to forego their God-given right to build whatever they wanted whenever they wanted, and give the product to the Dairy Board and say 'sell it', which is kind of the way it was for milk products, which were mostly well-established."

Individual company directors, who could also be on the board of the Whey Corporation, might be under pressure to do something with their own whey in their own location. But they now had to accept that it might be better to build the factory somewhere else.

An early decision of the Whey Corporation board, in July 1982, was that companies should be paid for whey on the basis of (1) whey value (one cent per kg milkfat), (2) marginal cost of manufacture, (3) management fee and (4) allowance for use of company-owned plant.

A major part of Kirkpatrick's time in the first few years was working out management incentive systems that would encourage and reward innovation without it looking as though one company was getting an unfair advantage over its neighbours. "We didn't want it to appear that a company was being enabled to give better payouts to its suppliers just because it had the privilege of industry money to build a whey factory, and a Dairy Board executive had made arbitrary decisions about what represented superior effort in terms of product quality and performance."

There was some feeling that as the industry was providing the funding, everyone should get a 'turn'. It couldn't work out that way in practice, because not all companies had the appropriate raw material for particular types of production, or a pattern of supply that would fit likely market demand. Some companies simply didn't have enough expertise. Situations had to be handled sensitively, but the existence of the Whey Corporation made for more rational decisions.

Kirkpatrick said it was a great advantage that facts could be placed in the open where they could be seen by directors, executives and technical people in the relevant dairy companies, technical people from the NZDRI and marketing people. "We could deal in facts to a greater extent than would have been the case in a different form of organisation where it would simply have been the opinion of a board

executive fronting up against the opinion of a dairy company director. You can guess where the facts would go in those circumstances and who would usually win."

When representatives of competing dairy companies shared the board table, they were more likely to take a 'what's good for the industry' approach. Kirkpatrick gave an example: "Graham Calvert was seen as being an NZCDC man through and through, but [in the Whey Corporation] he proved himself to be an industry man to the core and that was a very significant difference."

This was the first and possibly the only time when the Dairy Board made capital investments in New Zealand in its own right. The usual way of going about things was for dairy companies to consider the cost of capital, while the Dairy Board considered the potential for marketing. The Board's Whey Division would write investment proposals for consideration by the Whey Corporation board – and eventually by the Dairy Board – that included both capital cost and sales projections. Robin Fenwick, who managed the whey division from 1982, commented: "So far as I know, the presentation of an investment proposal in the form of a discounted financial analysis with integrated information was a first. I recall Alan Frampton [Dairy Board director] being delighted and quietly asking for sensitivity analysis for the next time that we did it."

Changing roles

Ken Kirkpatrick held the dual chief executive roles at Protein and Whey Products and the Whey Corporation until 1985, when he shoulder-tapped Mal Beniston to take over the Whey Corporation role.

Beniston, then head of the Board's casein division, was cut from different cloth from Kirkpatrick and most of the other executive and professional staff of the Whey Corporation. "It was a little daunting for a strictly commercial bod like me to walk into the hallowed territory of hi-tech science and mix it with all the PhDs like Kirkpatrick, Marshall, Sanderson, Matthews and Harper."

Something Beniston soon discovered was that dairy company executives were less committed to the Whey Corporation concept than their political masters. "Few of them agreed with the concept of the Dairy Board owning assets. I became something of an expert in running into brick walls from all angles until they finally broke."

Sometimes he found himself acting as a commercial foil for Ken

Kirkpatrick, who remained closely involved in Whey Corporation affairs.

Ken never stopped coming up with ideas. This had both pluses and minuses. Projects that seemed simple, suddenly grew hydra heads as

STEPPING INTO KEN KIRKPATRICK'S SHOES: MAL BENISTON RECALLS

I was invited into his office. I sat down, noticing Ken's eye glancing at watch sitting on the desk in front of him.

"He must be in a hurry…again," I thought. Time was always important for Ken.

"I want you to take over the running of the Whey Corp."

"What have I done wrong?" I asked.

Ken, looking perplexed and momentarily annoyed, sighed and looked at his watch; this was going to take longer than he anticipated.

"You've done nothing wrong – in fact this is a promotion. You're doing a good job."

"I need some time to think about it."

"But it's a great opportunity for you – a real step-up."

I did not 'get it' immediately. Here I was, happy in my role as executive manager of the casein division, which was turning over $500 million and had growth potential. I was being asked to run a newly established division that dealt with effluent and turned over around $15 million. This was a promotion?

I could not appreciate that I was about to embark on one of the most satisfying and enjoyable roles in my whole career at the Dairy Board, working for and with a truly inspirational manager with one of the best brains I have ever encountered. Ken saw strengths and potential in me that I did not fully realise, and he helped open my eyes to the possibilities.

There was practical commercial work to be done. The process of buying existing whey processing assets from individual dairy companies was still not complete. Management and lease agreements had to be negotiated with the manufacturing industry. Markets had to be developed, future investments had to be recommended and developed. And above all, we had to make money to fund these investments…a fact which I think sometimes escaped the more technical people.

> Ken warmed up to the many potential opportunities they presented. It was hard to argue, 'keep it simple' with such a powerful intellect and such powers of persuasion. Ken was, however, always willing to listen when I suggested, "for goodness sake let's get it up and running first and add the sexy bits later."

Technical selling at the R&D level remained the Whey Corporation's prime weapon as it developed markets for their very new products.

> Beniston: the "could we make money from it?" question was the most important of all, but by targeting the egg white segment with a functional lower cost alternative, the answer became a resounding yes. It took years of difficult development and it was a credit to the technical ability of the industry that we persevered and won. I remember the day and the excitement when the Whey Corp turned the corner. We had more than doubled the revenue and finally made a commercial profit. It was the beginning of an exciting growth phase.


Mal Beniston

During Beniston's period as CEO, competitors began to emerge in the international whey products market. One way of dealing with this was to form a joint venture with a potentially serious competitor. That competitor was Golden California Cheese in Corona, Los Angeles. The company produced cheese, but also had an integrated, state-of-the-art whey protein concentrate facility which aimed to sell low-priced WPC to Japan.

Golden California Cheese was struggling financially and looking for partners. Graham Calvert and Ken Kirkpatrick had seen a joint venture with them as one means of controlling the marketing channel into Japan.

> Beniston: we were pioneering again, by trying to convince the industry to invest in a manufacturing facility outside of New Zealand. There were financial models to be developed, negotiations on enterprise values, and arguments with New York lawyers. We demonstrated we could make money in off-shore manufacturing investments and, to some extent, control market channels. We may have planted one small seed which helped Fonterra grow into what it is today

Evaluating this project, gaining dairy industry approval and negotiating with Golden Cheese was a long process that extended into the term of Beniston's successor, James Ogden, who became CEO in 1988. Ogden explains the joint venture:

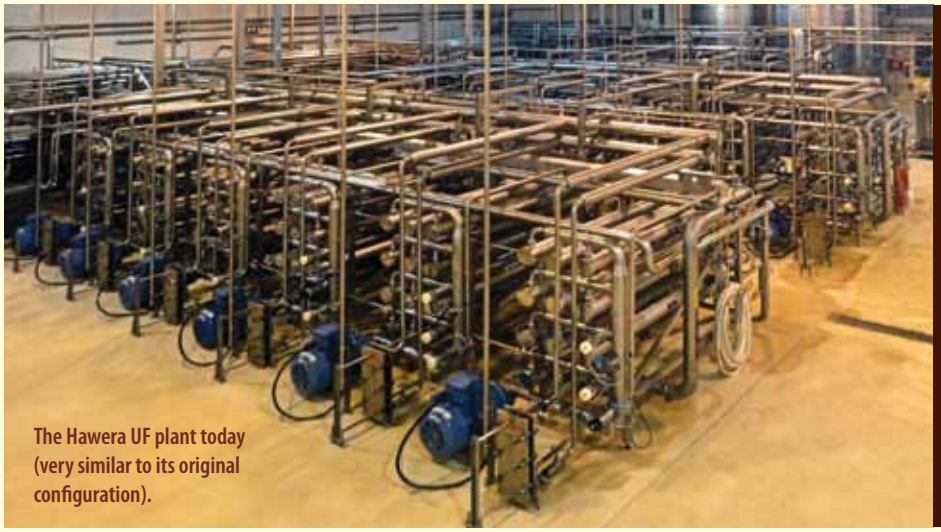
> The way was split, Golden Cheese produced the product with their costs associated with it, and then the Whey Corporation marketed

...continued on page 172

THE WHEY CORPORATION IN ACTION

The Whey Corporation (by this time renamed Whey Products NZ Ltd (WPNZ)), received many proposals from dairy companies to invest in new whey processing. The *modus operandi* in assessing and implementing such applications is illustrated in the following summary of the progression of an actual project at the Whareroa, Hawera, site of one of New Zealand's largest dairy companies.

Applicant:	Kiwi Cooperative Dairy Company Limited.
When:	1992
Proposal:	To build a new WPC plant to process 1.8 million litres per day of whey from Kiwi's dry salt cheese plant (cheddar and related cheeses).
Scope:	Whey thermalisation, separation to remove whey cream, ultrafiltration plus diafiltration, evaporation and spray drying, product packing.
Of note:	First UF plant in New Zealand to operate cold (at 10C).
Completed:	August 1993
Cost:	$25 million.
Expanded:	In 1994, to process two million litres per day of lactic acid casein whey.
Expanded:	In 1997, to process 1.2 million litres per day of mozzarella cheese whey.



The Hawera UF plant today (very similar to its original configuration).

Procedure:

1. Proposal prepared by staff of Kiwi and WPNZ covering technical specification, capital cost, operating costs, revenues and projected return on capital.

2. Proposal endorsed by Kiwi Board for presentation to Board of WPNZ.

3. Presentation and recommendation to WPNZ Board.

4. Acceptance by Board of WPNZ, subject to approval of funding by Dairy Board.

5. Approval of funding by directors of Dairy Board.

6. Project conducted to purchase and install equipment; managed by Kiwi, with WPNZ staff in project team.

7. Kiwi responsible for operating and maintaining the plant.

8. Products acquired and sold by WPNZ.

Result: WPC production capacity more than 30 tonnes per day.

People:

Kiwi:
Chairman: Morris Roberts; site production manager: Graeme Berg; WPC production manager: John Demchy.

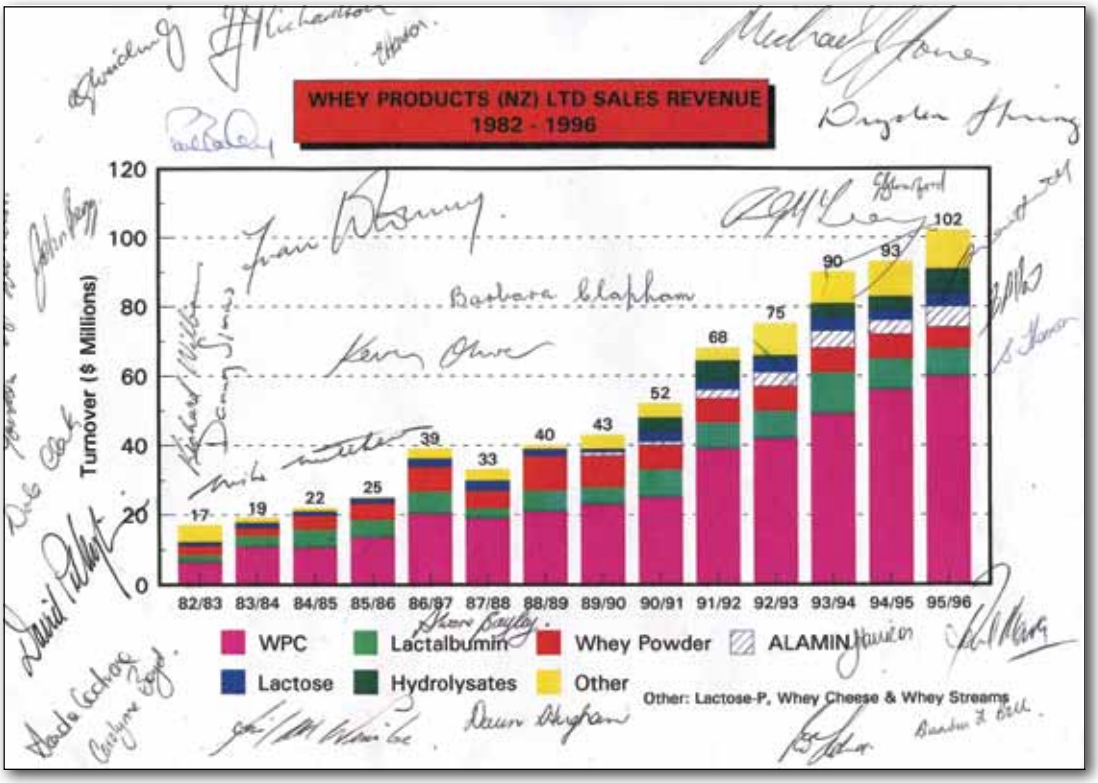
Whey Products NZ Ltd:
Chairman: Graham Calvert; CEO: Jim Hepburn; technical: Craig Bell, Gerald Crawford.

the product along with NZ-produced product. We had a far better international network. Our compelling point was that we could get a higher price for the Americans. We could place their product and get them a higher price because we understood the product and the customers.

Since 1982 the Whey Corporation had been headed by men with broad abilities, each of whom had brought his own emphasis to the job. Kirkpatrick was a technical man; Beniston had a commercial focus. Ogden's strengths were accounting, finance and investment.

One of Ogden's major objectives, emphasised to him by chairman Graham Calvert, was to eliminate or at least reduce a considerable angst that had developed among whey processing companies over the fairness of the complex plant purchase and management agreements that had been made with the Whey Corporation.

I got to know [CEO] Warren Larsen at Bay Milk [previously RPD] very well. Once, we chose neutral ground in Rotorua and had three



Graph presented to Graham Calvert showing revenue growth achieved by the Whey Corporation and Whey Products NZ Ltd between 1982 and 1996, signed by fellow directors and managers. The occasion was a function to celebrate passing the $100 million mark in annual sales.

> days of negotiations with technical experts and accounting people and we said we're not leaving town until we've sorted the issues out. Ferocious negotiations.

Similar negotiations were held at Manawatu, Northland, Northern Wairoa and Edendale.

> These were deeply, deeply, passionately held positions and the more the years went on, the more deeply and passionately they were held. So, like any negotiation, hopefully everybody felt unhappy with the outcome. We felt we over-paid, they probably felt they would continue to be underpaid for the assets they supplied. I can't put my hand on my heart and say every single dispute was settled, but we made a big hole in it.


James Ogden

Ogden remembers Graham Calvert playing a crucial role in the negotiations.

> As my team started to come to – shall we say – arithmetic solutions, Graham did a lot of the behind-the-scenes political work – working with the chairs and the directors of those companies so that when the executives met, the political background was sorted out. Neither party was ever going to get exactly what it wanted. It was always going to be a political compromise.


John Begg

Postscript – after 1990

While this book mainly covers the period from the start of WPC processing up to the early 1990s, the Whey Corporation (and its successor organisation, Whey Products NZ Ltd) lasted until 1999.

James Ogden's time as CEO ended in December 1989, when he was succeeded by Jim Hepburn. Kevin Oliver had the job from 1992-1993, and he was followed by John Begg between 1993 and 1999.

In 1990, the WPNZ setup and operations remained similar to the original 1982 Whey Corporation concept – except that by then the transfer of production assets from dairy companies to WPNZ had been completed.

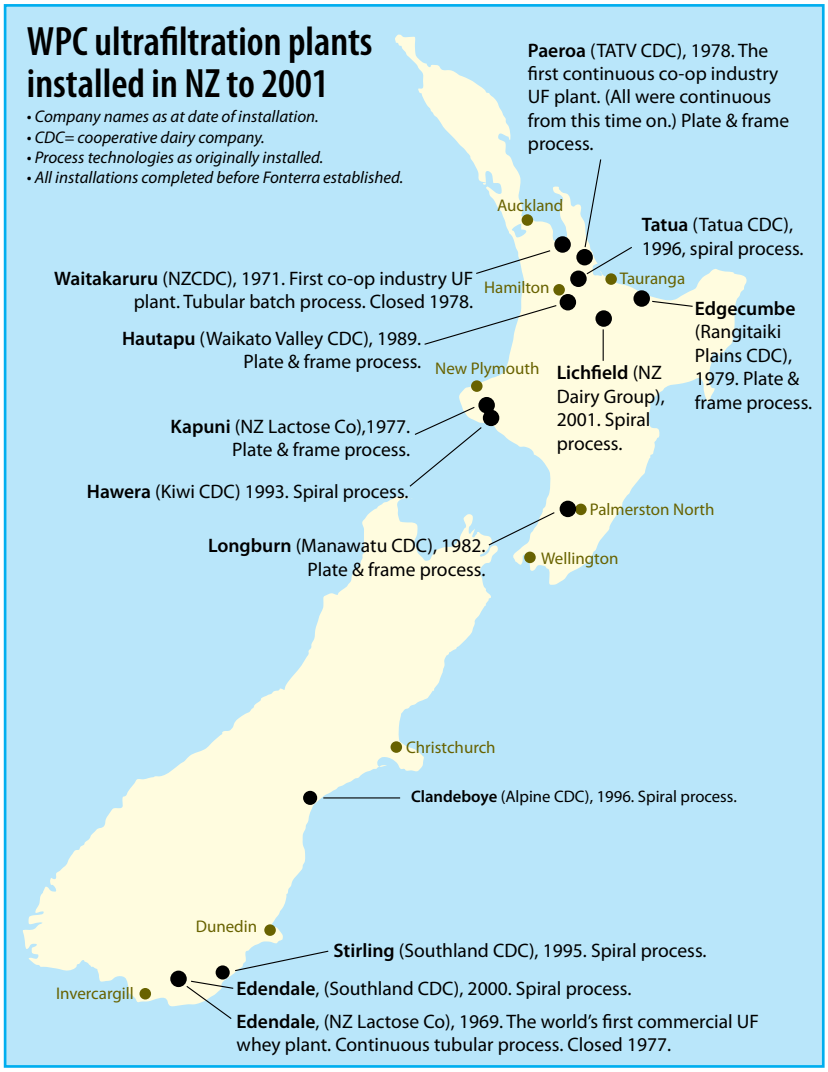
But change was inevitable and it would be drastic. Partly, change would come because whey products manufacture had developed and matured. It was less risky – indeed it became very profitable with increasing economies of scale and introduction of more efficient manufacturing techniques, especially spiral-wound ultrafiltration equipment. Dairy companies saw less justification for whey processing to be underwritten by the industry as a whole.

This coincided with a big step-up in the rate of dairy company

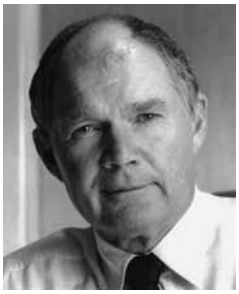
amalgamation, when companies were more than ever looking over their shoulders and hoping to take over rather than be taken over.

As the companies consolidated they became more determined to assert their own rights, to ensure their own survival. There was increasing pressure to take back their lucrative whey processing assets. After an intensive valuation exercise, the industry agreed to a process by which whey processing assets would be sold back to individual dairy companies.

By the late 1990s, the industry had essentially been consolidated into two companies: Kiwi Co-operative Dairies and New Zealand Dairy Group. One whey processor – Tatua Co-operative Dairy Company – remained independent.



Once plants had been sold back to the dairy companies, the remaining activities of Whey Products NZ Ltd (production planning, sales, market and product development) were folded back into the Dairy Board. Then, in 2001, Kiwi, the New Zealand Dairy Group and the Dairy Board amalgamated to form Fonterra, an almost global New Zealand cooperative with only Tatua and Westland Milk Products remaining independent.


Warren Larsen

ENDNOTES

1 Waitakaruru had been decommissioned by this time.

2 "During 1978-79 the equivalent of 6.8 million litres of whey were obtained from this source [TATV]. Later attempts to use spray dried permeate from TATV were less successful. The permeate was derived from sulphuric acid casein whey, from which the protein had been removed by ultrafiltration." (Dryden, John, *Crystal Clear: the story of the Lactose Company of New Zealan*d, The Lactose Company of New Zealand, Hawera, 1992.)

3 Interviewed by Kevin Marshall, 2009.

4 Incorrectly referred to as 'Mr Hayley' in the conference proceedings.

5 In November 1982, Warren Larsen, general manager of RPD, wrote to Graham Calvert, chairman of the Whey Products Corporation, expressing further reservations about the corporation's operations and their potential effect on his company. Nevertheless, the company stayed in the Corporation fold and went on to become a strong supporter. Larsen would later move to the Dairy Board to head its protein division. He then became the Board's chief executive. The objections of RPD should to some extent be seen as lobbying to make sure that they got the best possible deal out of the still-evolving whey pooling/Whey Corporation situation. In the event, RPD was one of the first companies to be funded by the Whey Corporation: $3.1 million in March 1983 for expansion of existing facilities.

6 Interviewed by Mike Matthews, March 2010.

7 Interviewed by John MacGibbon, March 2010.

CHAPTER 9

NON-WPC INITIATIVES

MIKE MATTHEWS

Whey protein concentrates have taken centre stage in this narrative because in the period 1978 to 1990, they were the most profitable of all the whey products known to the industry. As their attractiveness grew, more and more dairy companies wanted to manufacture them. The Whey Corporation was very keen to help, as evidenced by a long succession of investments in WPC capacity.

Though the WPC star was rising, it was also very clear that investment in WPC alone would not deal with the dairy industry's woes from dumping unprocessed whey solids into the environment. At best, removing the protein from whey as WPC 80 reduced the pollution load of whey by just 10 percent. The remaining 90 percent of the polluting power was in permeate, the protein-free fluid that passes through ultrafiltration membranes during the WPC manufacturing process.

Permeate is 95 percent water. The remaining five percent is made up mainly of lactose and minerals. If pumped into waterways, as it often was, it caused massive growth of a slimy microbial mass commonly called sewage fungus. This would coat objects in rivers such as rocks, vegetation and even the insides of water uptake pipes. It would also deplete water oxygen concentrations, with consequent deleterious effects in the normal river or stream life. The impact on waterways and on water users was widely publicised and the industry was extensively criticised. The industry might have been pleased with its success with WPC but it was learning quickly that permeate was just as much of a problem as whey had been.

It was clear that the industry would have to find ways to use the non-protein components of whey, or use whole whey, to reduce the environmental impact. Industry leaders put pressure on staff to come up with initiatives that were technically robust but in addition, they wanted them to be profitable. Nobody wanted to build a waste treatment plant to handle unused whey solids. The cost would have been immense – it would be much better to recover the solids in some economically useful form.

In many locations, wastewaters from dairy plants were spread on farmland, by trucks or by irrigation systems that were fixed or travelling. Such wastewaters commonly included permeate and, in some instances, even whole whey. There was some fertiliser value but as experience soon showed, unless the waste spreading systems and practices were controlled very closely, problems would soon arise. These included soil degradation, compaction, ponding, excessive odours, run-offs to waterways and contamination of ground waters, for example with nitrates.

A succession of investments over a thirty-year period was instrumental in bringing about a major reduction in the industry's environmental impact on waterways, soil quality and groundwater. The WPC story is not complete without a brief outline of what these initiatives were. Most were not as profitable as WPC but without them it would have been much more difficult for the industry to achieve the success that it did. Many of them were made possible because of the removal of protein from the whey.

The first of these is a whey protein product called lactalbumin that is much older than WPC and was an important part of New Zealand's whey processing history. Like WPC, lactalbumin generates a by-product rich in lactose that is the raw material for ethanol, which is also mentioned below. The primary market was America, where the product was best known and where manufacture had been pioneered.

Lactalbumin

Lactalbumin was the first form of concentrated whey protein manufactured by the dairy industry. The basis of manufacture was heat precipitation of proteins from acidified cheese whey, in batch vessels. The insoluble proteins were removed by filtration, then washed and dried to form a tan-coloured powder.

The fluid that remained after the proteins had been removed from the

Lactalbumin production today at Fonterra's Tirau plant. Left: filter press used for recovering heat-precipitated lactalbumin. Right: attrition drier used to dry the lactalbumin.

heated whey was known as serum (see the section below on ethanol).

Lactalbumin is insoluble in water. This limited its use in food products, but it could add protein nutrition to foods such as breakfast cereals.

Starting in the 1950s, Don King and Ted Richards at NZDRI developed a continuous process for making lactalbumin from lactic acid whey. A commercial plant was installed at the Manawatu Cooperative Dairy Company. Market response was encouraging and customers preferred product made by this new processing method.

Lactalbumin plants were installed in casein manufacturing locations as diverse as Manawatu, Te Aroha West, Manawaru, Waitakaruru, Matamata, Northern Wairoa, Toko, Tirau and Reporoa. Today, the product is made in just two plants – Tirau and Reporoa. Both are now part of Fonterra.

The history of this product in New Zealand now spans well over 60 years. The manufacturing principle is unchanged – heating acid whey to near boiling point, then removing, washing and drying the precipitated protein. The equipment has changed somewhat, using, for example, continuous self de-sludging centrifugal clarifiers to recover precipitated protein instead of the former vacuum rotary string filters. Using a filter press to recover lactalbumin before drying improved yield and provided a particle-free serum for further processing – for example into ethanol.

Lactalbumin has had a mixed commercial history, with considerable fluctuation in demand and an ongoing need for technical support in processing methods, product marketing and optimising product applications. One initiative to note was the successful use of proteolytic

enzymes to solubilise the product and to create new demand for its use in nutritional applications, particularly in America.

Lactalbumin has a special place in the history of whey processing in New Zealand. It was the first whey protein product that demonstrated to the dairy industry that the proteins in whey had a value beyond that of stockfeed. Under the guidance of Don King in his work at both NZDRI and the Dairy Board, this product focused attention on potentially valuable whey components. It was a valuable prelude to the much greater concentration of industry resources brought to bear on soluble WPC products starting in the early 1970s.

It was also an early example to the industry of the relatively high capital cost of whey processing assets in relation to product yields. From 250 tonnes of starting whey, just one tonne of lactalbumin could be made. Handling the fluid volume alone required a relatively high capital investment. The seeds of a more collective approach by the industry to the sharing of costs and profits had been sown.

Lactose

The New Zealand dairy industry has had a long history of making lactose, initially entirely from cheese whey and more recently mostly from permeate. For much of this history, the sole manufacturer of lactose in New Zealand was a private company, the NZ Lactose Company with plants at Kapuni and Edendale. In 1983, ownership of the Lactose Company transferred to the Whey Corporation and it is now part of Fonterra.

Opportunities for lactose over the last 20 years have expanded dramatically, driven by expanding worldwide demand for milk powders and infant formulas. Lactose may be added to milk powders, provided the ratio of protein to non-fat milk solids remains not less than 34 percent. It is commonly added to infant formula as the lactose concentration of human milk is about 40 percent higher than it is in cow's milk.

Permeate contains about five percent lactose. It has therefore become a major source. Much of the permeate from New Zealand WPC plants is now processed into lactose. In some instances a partial refining is done at a local site and the resultant intermediate product is sent to Kapuni for finishing. Use of permeate as a source for lactose has done much to remove the pollution challenges once posed by the spectre of increasing volumes of unprocessed permeate as WPC output increased.

Ethanol production at Fonterra's Tirau plant. Left: fermentation vessels. Right: distillation columns.

Ethyl alcohol (ethanol)

Lactose is a sugar, readily fermentable by certain types of yeasts. In the 1970s, most notably in Ireland and in America, new plants had been built to make ethanol from whey. The two primary parts of the process were fermentation using yeasts to convert lactose to ethanol and distillation to boil it off and purify it. The Carberry process from Ireland in particular achieved good results, giving ethanol of high purity. Typically, from two kg of lactose, one litre of ethanol of 96.5 percent purity could be made.

The NZ Cooperative Dairy Company (NZCDC) took a keen interest. At its Reporoa casein plant, it was making lactalbumin. The by-product, called serum, contained most of the lactose initially present in the whey and was therefore a high strength pollutant. It was quite similar to the permeate that arose from WPC manufacture.

In a landmark arrangement for its time, NZCDC contracted Carberry in 1979 to design a plant to make ethanol from serum. This plant was able to process all of Reporoa's serum, producing up to 15,000 litres of ethanol per day. Following this success, NZCDC made a similar investment at its larger Tirau casein factory in 1982, also utilising serum from a lactalbumin plant. The Reporoa and Tirau ethanol plants supplied industrial ethanol to a newly created NZCDC subsidiary called Anchor Ethanol, which by 1984 was selling up to six million litres of ethanol annually. After formation of the Whey Corporation, ownership of the Anchor Ethanol business passed to a 50/50 joint venture formed between the Corporation and NZCDC.

In a third ethanol initiative, in 1982 an agreement was struck between The Rangitaiki Plains Dairy Company (RPD) and the New Zealand

Distillery Company, the sole holder at that time of a potable ethanol licence in New Zealand, to make lactose-derived ethanol at Edgecumbe. Under the agreement the distillery company, owned jointly by several brand-owning liquor companies plus a prominent brewery, relocated their maize-based plant from Auckland and designed it to make both permeate-based and maize based potable ethanol. RPD provided permeate and services in an interesting case of industrial symbiosis.

All three ethanol plants are still operating and are now part of Fonterra. Combined annual output is now about 14 million litres: approximately two-thirds for industrial use and one third for human consumption. Most of the gin and vodka made in New Zealand today is based on lactose-derived ethanol.

Whey powder

Whey powder is a long-established product. It is normally made from sweet (low acid) wheys, such as result from the manufacture of cheese and rennet casein. In Europe and America it was for many years an important by-product for the cheese industry. Its attraction in part was that to make whey powder, all that was needed was to remove water by evaporation and spray drying. All the whey solids were recovered in the whey powder so the pollution load was low.

New Zealand was never a major source of whey powder in comparison with the larger northern hemisphere producers. Nonetheless, whey powder has played a useful role in helping several companies, most notably NZCDC (at Matangi and Kerepehi) and The Northland Cooperative Dairy Company (NDC) at its Maungaturoto site.

An interesting although sobering footnote on New Zealand's history of making whey powder related to the Chernobyl nuclear disaster in 1986. Fallout from that event contaminated areas of northern Europe. Whey powder supply from these regions to Japanese buyers of infant formula ingredients ceased. Some of these buyers turned to New Zealand for help. Whey powder from Maungaturoto proved a very suitable replacement for one major buyer, a business that was to continue for many years, to the relief and satisfaction of a grateful customer.

Demineralised whey powder

A large-scale investment in making demineralised whey powder was made at NDC's Maungaturoto plant in 1983, an early project for

funding consideration by the then recently formed Whey Corporation. This site had a high quality supply of rennet casein whey, the best raw material for making low ash whey powders because of its naturally lower initial mineral content. The new plant would have to be able to make whey powder of three percent ash for a Chinese buyer and also powder of just one percent ash for other buyers. For NDC, a very real need for the future of this site was minimisation of wastewater volume and strength.

Of note was the decision to install an electrodialysis plant to demineralise the whey to three percent percent ash, dry basis, using partially concentrated whey as the feed material. To achieve one percent ash, they installed an ion exchange system. The evaporators chosen were the first of their kind installed in New Zealand, both MVR (mechanical vapour recompression) units supplied by the German company, Wiegand. Also installed were pre crystallisation vessels to ensure that lactose in the concentrated whey was partially crystallised before the product was spray dried. This ensured that the resultant whey powder had little tendency to clump or solidify, retaining its free flowing properties. The plant soon built a reputation for making very good quality whey powders.

Total cost was $13m, a relatively modest sum for such a plant. Of note was that NDC bore a portion of this capital cost, a model for project funding adopted in other instances whereby the Whey Corporation and the dairy company chosen for a project would each provide funding.

Demineralised permeate

An interesting side to the TATV WPC project at Paeroa in 1978 was the decision to install an electrodialysis plant to demineralise permeate. The intention was to remove minerals, then concentrate the permeate using an evaporator for transport to NZ Lactose Company for lactose manufacture. The installation never performed to specification and use of the ED plant ceased. TATV did continue a business evaporating undemineralised permeate for transport to the Lactose Company, although at considerable cleaning cost because of the marked tendency of Paeroa's acidic permeate to cause extensive mineral fouling of the evaporator.

A later demineralisation initiative was to occur in 1989, this time at NZCDC's Hautapu plant. The starting material was permeate from manufacture of lactic acid WPC. The ion exchange process required

was specified by a Japanese customer, who wanted an extensively demineralised spray dried crude (more than 90 percent) lactose product naturally enriched in a minor milk component of interest to infant formula manufacturers. This product proved very difficult to make and was eventually stopped but it was a good illustration of how willing the industry was to invest in new ways of processing whey solids for better profit and reduction of pollution load.

Demineralised whey solids for use in infant formula

Demineralisation of cheese whey by ion exchange was introduced at NZCDC's Waitoa plant in 1968 by Roy Leighton, a very capable South African chemical engineer who designed the equipment required. Demineralisation was necessary to ensure that the infant formulas made under contract for major international brand owners were in specification in mineral concentrations.

Whey cheese

Whey cheese was a condensed whey product, made by evaporating sweet whey to a very high solids concentration, for example 70 percent, using a specially designed evaporator. Immediately after evaporation it was still fluid and therefore could be pumped and packed but it set to a hard, block-like consistency when it cooled. It was sold to Japanese confectioners. It was made at the Edendale site of the NZ Lactose Company. It was never a large tonnage product but manufacture continued for many years.

Whey mineral concentrate

Acid whey has a high concentration of minerals, typically around 12 percent of dry matter. These too add to the polluting load of whey but for quite some years, they provided the basis of a profitable business. The minerals of acid whey are particularly high in calcium phosphate, released from casein micelles during the casein production process. Calcium phosphate is soluble at pH 4.6, the pH at which casein is precipitated from milk. They are insoluble at pH 7. Adding a food grade alkali to acid whey causes calcium phosphate complexes to precipitate. This was the basis for making the commercial whey mineral concentrate, Alamin, a fine, dry mineral powder sold primarily for calcium fortification of foods, including the successful Anlene high-calcium milk powder consumer products.

The Manawatu Cooperative Dairy Company pioneered the process. Further investments in Alamin production were made later at Kiwi Cooperative Dairy Company and RPD.

Use of ultrafiltration to fractionate skimmilk

It is now common to use ultrafiltration to remove permeate from skimmilk prior to casein making. By doing this, the volume of acid whey is reduced, for example by up to 40 percent. The sweet permeate so obtained can be added to skimmilk or wholemilk destined for powder production to adjust the ratio of protein to non-fat milk solids to 34 percent. This improves milk powder yields but it also reduces the volume of acid whey that results from the casein making process. This has therefore helped reduce the pressure of finding new uses for acid permeate. A related development has been the widespread manufacture of milk protein concentrates, made by ultrafiltration of skimmilk. Sweet permeate from this process is also used to adjust the protein to non-fat solids ratio in milk powders to 34 percent.

Conclusion

In summary, much work has been done to deal with the challenge of finding uses for the non-protein solids of whey. Some projects were very successful, others less so, but overall the outcomes have been to improve the economics of making cheese, casein and WPC, to reduce the impact of the industry on the country's waterways and to position New Zealand as a well-regarded, major supplier of whey-derived food ingredients.

CHAPTER 9

IN RETROSPECT: SUCCESS FACTORS

PETER HOBMAN , KEVIN MARSHALL & MIKE MATTHEWS

For many years, New Zealand led the world as the only supplier of technically advanced whey protein concentrates (WPCs). It remains a major source of the most demanding versions of the product. The way WPCs were developed in this country, with the enabling technology of ultrafiltration, is a good case study of how to successfully commercialise a new food ingredient based on new technology.

Identification of the factors behind this development may be useful for others involved in process and product innovation: scientists, technologists, processors, marketers, policy makers and investors.

***Peter Hobman's** dairy industry career began as an engineering technician trainee at NZDRI, where he received a scholarship to complete a B Tech (Biotech) Hons degree at Massey University. He would become head of the whey products section, then assistant director of NZDRI. He was seconded to the Dairy Board in Japan on two separate occasions for a total of four years. Peter held various executive and governance roles with commercial & research companies in NZ and overseas, including NZCDC and Murray Goulburn, Australia.*

Success factors in innovation

Research by the Massachusetts Institute of Technology* and other organisations has led to significant understanding of the process of innovation. Successful commercialisation of innovative ideas, however, is seldom without challenge and can be elusive.

When Gordon Brunner retired in 2000 as chief technology officer of the American company Procter and Gamble, he spoke about his *Tao of Innovation:*[1]

> Innovation is all about making things that people want to buy. It is not about patents or new technical developments – it is about marrying 'what is needed' with 'what is possible'. It is about the products and services you offer, and their acceptance by end-users.

*Later in their careers, four of the authors of this book (Kirkpatrick, Marshall, Matthews and Hobman) attended the Massachusetts Institute of Technology's Sloan School of Management's course, *Management of R&D and technology-based innovation*.)

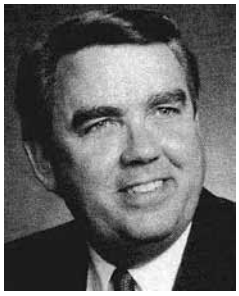
Brunner identified three significant success factors:

1. **Stay close to your customers:**
   - Involve research and development people intimately with customers.
   - Find new uses for your products.
   - Know that customers cannot always articulate their desires.
   - Be persistent and strive for credibility.
2. **Compete with leading edge technology:**
   - Identify superior technology.
   - Apply sound science to understand your product.
   - Use the best talent and intellectual horsepower.
3. **Create a supportive environment for innovation:**
   - Demand that innovation happens.
   - Create an environment in which good ideas flourish.

All of these factors were at work in New Zealand's commercialisation of WPC.

There were also contributing elements specific to the New Zealand dairy industry, including the co-operative structure of the industry, the role of government and the management of intellectual property.

In this chapter we assess the history of New Zealand's development of WPCs against Brunner's criteria and also important New Zealand factors that assisted the dairy industry to achieve success.



Gordon Brunner

BRUNNER'S CRITERIA:

"Stay close to your customers"

Customers are an unmatched source of information. Early in the WPC project, the industry worked closely with The Coca-Cola Export Corporation. This association with a credible customer gave the industry confidence to invest strategically in ultrafiltration technology. Marketing and technical people from both organisations communicated in depth. A technical person from NZDRI was seconded to help Coca-Cola's developments. The New Zealand industry responded promptly to changes in specifications for the product.

Subsequently, linkages with a strong distributor in Japan and with several Japanese commercial companies that wanted to buy gelling WPCs were very important in guiding our product and process

development work. This business was a resounding success and provided a secure foundation for the WPC business to build on.

The Dairy Board established sales and marketing offices in its key markets. The offices in Japan and America focused early on new uses for WPCs. Technical graduates from New Zealand and locally recruited staff supported these offices. Among this book's authors, Ken Kirkpatrick was seconded to the New Zealand Milk Products (NZMP) office in Chicago; Peter Hobman and Mike Matthews worked for Nippon Proteins and the Dairy Board in Japan; Robin Fenwick and Lee Huffman were both at NZMP.

Promoting specialised New Zealand dairy ingredients at the Tokyo Food Fair in 1994. Left to right: Tim Gibson (president, NZ Milk Products Japan), Kevin Marshall (the Dairy Board's global director of R&D and chief executive of NZDRI), Kazuyuki Hiraga (technical manager at Nippon Proteins), Peter Hobman (regional research and development manager, NZ Dairy Board Japan, director, NZ Milk Products Japan and director, Nippon Proteins).

These offices facilitated close contact with potential customers and had their own laboratories and pilot-scale development facilities. Close liaison with research and manufacturing people in New Zealand meant it was possible to create products with a variety of applications for many customers in a timely manner.

These markets provided the critical customer contacts required for success. After initial focus on processed meat applications, further uses were identified in foods such as custards, cakes, salad dressings, meringues and yoghurt. Infant formula manufacturers recognised the potential of WPCs to bring the compositions of their products closer to that of human milk. WPC also found profitable use in sports and nutritional beverages, and bars.

Customers who pioneered the commercial uses of WPCs as food ingredients often assisted with analytical methods that allowed our processes to be developed, manipulated and controlled to meet their specific needs.

Marketing, research and manufacturing staff frequently travelled abroad to spend time with customers and equipment supply companies. This ensured we stayed at the forefront of the developing markets and technologies for whey products.

When he returned from America in 1976, Neville Jones was able to say:

> The initial appreciation of the need to employ the services of highly

> qualified technical personnel with a thorough knowledge of New Zealand conditions had enabled the Board to gain access to the grass roots thinking, intentions and activities of American corporations on their current and future product and trade development. The success of this operation, while inhibited by the quota restrictions on the more conventional forms of dairy produce, has certainly consolidated our position as the number one supplier of sophisticated dairy proteins."

The same could be said for the development centres established by the Dairy Board elsewhere.

"Compete with leading edge technology"

The New Zealand dairy industry has a well-deserved international reputation for developing, manufacturing and marketing an extensive range of milk products. These extend from dairy commodities such as milk powders, butter and cheddar cheese, to specialised ingredients with properties tailored to make them suitable for specific food applications.

The industry is also a world leader in developing large manufacturing facilities to achieve economies of scale. A change specifically relevant to the WPC project was the establishment of a large-scale casein industry and its attendant generation of a large volume of whey.

Also notable is the New Zealand dairy industry's strong link between science and technology, and commercial development. This was a major attraction when Coca-Cola began looking for acid-soluble protein.

Between 1965 and 1975 there was rapid expansion in research and development. The centralised research and development facility, NZDRI, increased in size from 65 staff in 1966 to more than 200 staff a decade later. This reflected the industry's determination to diversify its product mix and expand its markets, driven by the pending loss of much of the British market when the United Kingdom joined the European Economic Union – which it did in 1973.

This period also saw two distinct, separate technical development paths for WPC evolve. Each would deliver good commercial outcomes.

The cooperatives, through their centralised marketing and research organisations, responded to the approach by Coca-Cola. This work had a strong product focus, with the new process of ultrafiltration being a means to making a newly identified product.

Even earlier, the proprietary NZ Lactose Company, aiming to reduce

the cost of lactose manufacture, had invested in an earlier form of commercial membrane processing, reverse osmosis, to lower the cost of removing water from whey. Later, the Lactose Company would also invest in ultrafiltration equipment to make cheese whey WPC.

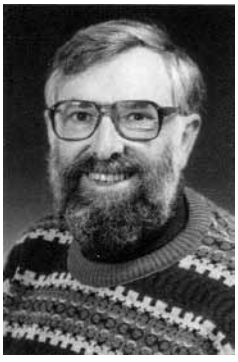
The research team of food technologists and microbiologists was encouraged to interact and cooperate across projects. Such cross-functional cooperation was especially important for developing WPC.

An NZDRI programme of funding staff for university study was successful. Several of the authors of this book and others involved in the early WPC and ultrafiltration projects were part of NZDRI fellowship or industry support programmes. Dave Woodhams completed his PhD in spray drying at the University of Wisconsin on an NZDRI Fellowship; Kevin Marshall completed an MSc in biological engineering at Birmingham University on an NZDRI Fellowship and completed PhD studies on his return to NZDRI; Ken Kirkpatrick completed his PhD at Canterbury with NZDRI funding before joining NZDRI; Peter Hobman completed a B Tech at Massey University with NZDRI funding; and Mike Matthews completed a B Tech at Massey University supported by an NZCDC scholarship, and then independently completed a PhD in food science at the University of Wisconsin, working on membrane processes.


Lindsay Pearce


Terry Thomas

Four other recipients of NZDRI Fellowships for overseas PhD studies subsequently made important contributions to WPC developments. Terry Thomas and Lindsay Pearce studied the use of single strain starters for lactic casein making and contributed much to the knowledge of microbiological control of the ultrafiltration process. Lawrie Creamer provided significant insights into the biochemistry of whey proteins. Neil Walker studied the flavour chemistry of WPC and later was a key member of the staff at NZMP North America.


Lawrie Creamer

The positive profile of the dairy industry in New Zealand and awareness of its innovations led to the recruitment of high calibre people. The industry was able to recruit 'cream of the crop' graduates and retain them. It continues to do so. The Dairy Industry Graduate Training Programme was established in 1969 as a joint venture with Massey University. Many graduates of this programme had or are continuing successful careers in research, manufacturing, technical marketing and business management roles in the industry, including the development of whey processing.

When Coca-Cola first approached the New Zealand dairy industry with a request for an acid-soluble protein to fortify a new line of beverages, no commercial technology was available to produce the protein. Coca-Cola had conducted experimental process development but had not settled on a technology. Dave Woodhams looked at a variety of technologies and recommended ultrafiltration because the process was inherently one of concentration rather than dilution and there was a greater potential to expand the technique to non-whey uses.

Our confidence to tackle the goal of meeting Coca-Cola's vision of 10,000 tonnes per year of a new product by an as-yet unknown technology was, with hindsight, audacious. There would be many technical hurdles but persistence and skill led to success in ways that were not always foreseen.

The recruitment of a world expert (Professor Jim Harper from Ohio State University) to work with a highly competent team at NZDRI gave us in-depth scientific understanding of WPCs and, most importantly, how to optimise their use in food products. The development of model food systems during Harper's time at NZDRI allowed us to simulate customer applications. This enabled the New Zealand dairy industry to refine product prototyping with increased confidence that samples would closely match customer needs. Further enhancement of this model came with the creation of in-market development centres with their ability to perform model system work closer to customers. Model systems and rapid prototyping are critical enablers of product development for the New Zealand dairy industry to this day.

An international collaboration programme ('Collab') initiated in 1975 resulted in major breakthroughs in the development of analytical methods and use of model food systems. Over 100 scientific papers were published. These helped build a strong platform for product development, manufacturing and marketing.

Technical capability meant that the New Zealand dairy industry was able to develop ways of operating the ultrafiltration process and associated pre- and post-treatments to make WPCs for use in different foods as diverse as gelling ingredients for processed meats and soluble, nutritious ingredients for infant formula. This set New Zealand apart from other WPC manufacturers in the 1980s.

NZDRI in Palmerston North was located on a large agricultural research campus. This included Massey University with its expertise in food technology and biotechnology. Also on the campus was the Department of Scientific and Industrial Research (DSIR), where other

specialised and complementary expertise was available. This included a small-animal unit that was used for toxicity and safety testing and protein quality measurements of the new whey protein products (this unit was a prelude to a more dedicated unit later established at NZDRI). Computing, statistical evaluation, amino acid analysis and electron microscopy expertise was also available on the campus.

Along with this broad range of local capability, we cooperated closely with equipment suppliers such as Abcor and DDS who helped resolve many technical difficulties.

Concurrently there were significant advances in methods and materials used for construction of the membranes themselves. By the end of the first decade of this research, plate and frame systems equipped with polysulphone membranes were installed in commercial dairy industry factories, replacing the original cellulose acetate membranes. Developments continued at a fierce pace during the second decade and spiral-wound configurations and non-polymer material such as ceramic membranes were developed. Spiral-wound configurations became the dominant technology for ultrafiltration.

Another success factor was the set of international networks established. Many international experts were consulted. Detailed discussions and meetings were held with Gordon Coton and Ron Dicker of the English Milk Marketing Board. Dicker spent a sabbatical at NZDRI and his knowledge of whey processing and ultrafiltration was freely shared. Paul Jelen from the University of Alberta similarly spent a sabbatical at NZDRI. Rory Delaney of the Irish Dairy Research Institute also visited New Zealand and shared the Irish experiences with WPC and ultrafiltration. Bernie Horton, formerly of Abcor, then for many years an independent America-based dairy industry consultant, took a special interest in New Zealand's WPC endeavours and was a frequent visitor. His advice and suggestions were valuable.

Collaboration with the whey group of the Division of Food Research, part of CSIRO in Australia, was very fruitful. This group was led by Lawrie Muller, a regular delegate to the International Dairy Federation (IDF) and an active participant in international whey research workshops. Staff of CSIRO and NZDRI had frequent meetings to exchange information on whey processing and ultrafiltration.

New Zealanders were active participants in the work of the IDF and much was gained from regular attendance at the meetings of the group of experts on whey processing and utilisation. This group comprised

many of the world's experts on WPC and ultrafiltration and the sharing of information was always insightful and helpful.

"Create a supportive environment for innovation"

The industry had strong leaders who demanded innovation to grow the industry in a profitable manner. In the 1960s and 1970s there were many examples of these leaders making public statements like "the customer is right", "science and technology is the basis of a profitable future" and "it is important for economic survival that the industry innovates both in products and processing."


Stan Murphy

In 1966, Ken Archbold of the Dairy Board's supply and economics division told the annual dairy industry's secretaries' conference, that the dairy industry of tomorrow would attach great importance to new milk protein products and much research into their development was underway to meet new commercial demands.

The Dairy Board's general manager, Stan Murphy, was a major advocate for innovation. In 1970 he said: "we are moving in a perceptible way from a traditional dairy industry to a sophisticated food industry. The concept of dairy production as a so-called 'primary industry' has to go out the window."

Addressing the Auckland branch of the New Zealand Dairy Factory Managers' Association, Murphy gave a comprehensive survey of the new product development projects underway at NZDRI:

> There are 32 product development projects under way at the Institute, and probably more than that number at dairy companies. There is a need for improvement in communications within the industry to make sure that all technical manpower resources are used to the maximum.

In 1972 he described a great future for milk proteins to NZDRI's board of directors. He felt that potential customers were not sure themselves what they wanted and it was therefore necessary for the New Zealand dairy industry to work with customers' technical groups.

Successive chief executives of the Dairy Board (Bernie Knowles, Murray Gough, and Warren Larsen) continued to support and demand innovation.

In 1972, Neville Jones took charge of the recently formed and wholly owned American subsidiary of the Dairy Board, NZ Milk Products. Based in Chicago, NZMP aimed to "provide a direct trading link in the market and facilitate close commercial and technical liaison with the dairy processing industry." Similar offices had already been opened in Tokyo and Singapore. Later others were opened in the United Kingdom, Germany and Mexico.

Dairy Board chairman Jim Graham was able to tell the industry's 1984 ward conference that:

> The marketing of the more elaborate and sophisticated whey protein concentrates is progressing satisfactorily, both for price and demand. Success in this area calls for very close involvement of the marketing activities of the Board and its overseas subsidiaries with individual customers, so that products can meet the precise requirements of each customer. Such a process takes years of development of understanding and trust. Happily this is now bearing fruit.

The director of the NZDRI at the time of the decision to work with Coca-Cola, Bill McGillivray, was persistent and showed significant foresight, first in urging the growth of the Institute's capability to take on new ventures and then encouraging both his own board and the Dairy Board to invest in the Coca-Cola project.


Ken Archbold

Industry leaders were intently involved in research and development and there was close integration of marketing and manufacturing with research and development. Successive deputy chairmen of the Dairy Board were chairmen of the NZDRI board. Similarly chief executives of the Dairy Board were active directors on this board, as were chief executives of the larger dairy companies. Government appointees also played a significant role on the NZDRI board.

After the initial approach by Coca-Cola, the knowledge and confidence of the industry leaders led to a pilot plant being ordered very quickly, based on a rapid but well-focused study of available technologies by Woodhams and small-scale laboratory trials by Kirkpatrick. Evaluation samples had to be made quickly for what promised to be a lucrative market.

The expansion to a commercial plant at Waitakaruru before we had full knowledge of the process of ultrafiltration, while a risk, was again due to the confidence of the industry leaders that the technical resources of the industry would cope with the challenges.

The later work of Matthews and his team in codifying the knowledge of the technology of ultrafiltration assisted the decision making for selection of equipment for the plants subsequent to Waitakaruru. The lessons learned from the problems with water and electricity supply experienced at Waitakaruru, the upstream changes to the casein-making process so that whey was treated as a valuable raw material and the outcomes from ongoing scientific and technological studies (including stages-in-series ultrafiltration with polysulphone

membranes) at NZDRI were part of that codified knowledge.

Work by Harper, Hobman, Huffman and their teams on the science and development of WPCs led to products that greatly expanded market opportunities. It is arguable whether such advances would have been made more quickly, or even at all, if industry leaders had waited until all the science and technological data were available before committing resources to WPC.

Even when Coca-Cola withdrew from the immediate development project, New Zealand dairy industry leaders persisted with the development of WPCs because they recognised that an extensive knowledge of WPC and ultrafiltration had developed, and that such knowledge could be used to find profitable uses for whey and to develop new products using ultrafiltration. Industry leaders thereby demonstrated courage and perseverance and a preparedness to take calculated risks.

It was also a substantial risk to collaborate with a wide range of researchers throughout the world, publishing scientific papers and employing an overseas expert to develop the science capability in New Zealand. There were many who perceived there was a danger that intellectual property and value would be leaked to competitors. However these steps were taken in the expectation that directing a large number of researchers at the same problems would rapidly increase knowledge and that the team in New Zealand would be better placed than others to exploit new information quickly.

CONTRIBUTING NEW ZEALAND FACTORS

A successful cooperative structure

Dairy farmers owned the dairy companies they supplied. This gave a significant sense of ownership and control. Individual dairy companies competed with each other for milk supply at the farm gate and to achieve the highest payout. However they avoided competition in the international market by adopting co-operative supply and marketing through the Dairy Board.

In 1982, the cooperative dairy companies working in concert established the Whey Products Corporation, an entity within the Dairy Board with its own decision-making governance. This brought together whey research, processing and marketing. It allowed orderly investment in new whey processing plants. It also allowed the industry to try things that would have been too risky for individual dairy companies. The Whey Corporation gave a focus and advantage of scale to the rapidly

growing business and proved pivotal in the eventual success of New Zealand whey products. Critical to this success was the freedom with which technical personnel moved among laboratories, processing sites and the market place. This essential interchange of skills and information was facilitated by the Whey Corporation structure.

The Whey Corporation was revolutionary in that it was the first time the Dairy Board and dairy companies working together made capital investment decisions for processing for all of the New Zealand dairy industry. The project proposals that the whey division of the Dairy Board wrote for consideration by the Whey Corporation Board included capital cost and sales projections. Previously these two had been split; the dairy company considered the cost of capital and the Dairy Board the potential for marketing. The individual dairy companies owned all the manufacturing plant, but now for the first time, via the Whey Corporation, the Dairy Board owned plant in its own right. All this can be seen as a prelude to the eventual formation of Fonterra some 18 years later.

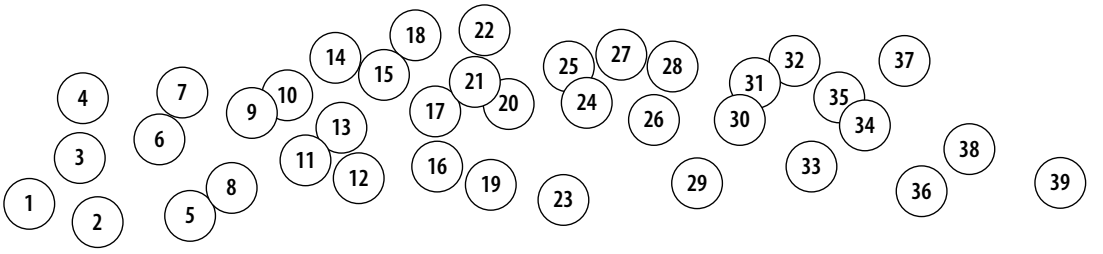
Government support

As well as their normal involvement via public policy and infrastructure, the Government was specifically helpful to this project in a number of other ways.

NZDRI was established in 1926 as part of the government-funded Department of Scientific and Industrial Research. Until 1980, it operated as a partnership with equal funding from industry and government, with a clear mandate for its staff to serve the scientific and technical needs of the New Zealand dairy industry.

The Government contributed financially to the building of NZDRI's processing hall. This included equipment for receiving milk and whey from nearby dairy factories, making cheese and casein, evaporating and drying, and packaging. We were able to install ultrafiltration pilot plant and develop new processes and products quite quickly because the other equipment needed to make these products was already in place, and we had experienced staff. The processing hall was registered as a dairy factory so samples could be exported in compliance with applicable regulations. We were therefore able to produce concept samples in volumes that allowed customers to undertake market evaluations.

Intergovernmental US/Australia and US/New Zealand science agreements provided seed funding for the whey workshops that led to productive collaborations with overseas organisations.



1 Murray Tseng (Canada)
2 H Morris (NZ)
3 Peter Wood (NZ)
4 Bob Zall (USA)
5 Khem Shahani (USA)
6 Mike Matthews (NZ)
7 Graham Latimer (NZ)
8 Mike Ratcliff (Australia)
9 Brian Robinson (NZ)
10 Charlie Morr (USA)
11 Don King (NZ)
12 Roger MacBean (Australia)
13 Bernie Horton (USA)
14 Arie Kuipers (Germany)
15 Gint Behrens (USA)
16 Julia Johns (NZ)
17 Ken Kirkpatrick (NZ)
18 Gordon Coton (UK)
19 Carl Rofe (NZ)
20 David Holmes (USA)
21 Peter Hobman (NZ)
22 Gary Longton (Australia)
23 Rosalie Sutton (NZ)
24 Gary Richardson (USA)
25 Lawrie Muller (Australia)
26 Jim Hourigan (Australia)
27 John Higgins (NZ)
28 John Woychik (USA)
29 Stu Marshall (Australia)
30 Kevin Marshall (NZ)
31 Neill Clarke (NZ)
32 Greg Zadow (Australia)
33 Mike Hanrahan (Australia)
34 Mike Howell (NZ)
35 Norm Snow (Australia)
36 Charlie Towler (NZ)
37 John Dunkerley (Australia)
38 Roy Leighton (NZ)
39 Jim Harper (USA)

Participants and organisers of the Whey Research Workshop II held in Palmerston North, 1979

This and other workshops led to productive collaborations with overseas organisations.

Intellectual property management

The New Zealand dairy industry protected its proprietary intellectual property by secrecy rather than patents.

Patents are expensive to file and maintain. It is also relatively straightforward for processing patents to be circumvented. Process patents would have revealed to competitors how we were manufacturing our products. Competitors could have copied these by means that would not breach the patent or be obvious. By keeping these secrets, our industry was able to dominate this market for almost a decade.

Overseas competitors were eventually able to reverse-engineer the New Zealand products and eventually regain some of their lost ground. Our response was to stay ahead through continual innovation, especially in response to customer requests for product enhancements.

Eventually there was even more competition, particularly from Europe and America, as key people moved around the world and technical information was spread via universities, equipment supply companies and others.

Important success factors

Success factors for the WPC project were:

1. Collaborative relationships were established early with credible customers.
2. The dairy industry had well-resourced offshore offices with close contacts with customers.
3. The industry had effective commercial structures to support development.
4. Many skills were brought to bear such as scientific, engineering, financial, marketing through effective project management structures.
5. A centralised research organisation played a leading role.
6. An extensive knowledge base was created around the science and technology of processing whey and making products that customers wanted to buy.
7. There was strong and consistent support by senior management and directors and recognition that product development frequently takes a long time, punctuated with many setbacks.
8. Valuable international science collaborations were sought and cultivated.

9. Competent and energetic staff were identified, trained and retained.
10. Several people retained ongoing business involvement with WPC over some decades, starting in research and development and moving into technical, marketing and senior managerial roles, providing continuity, education and depth of knowledge. This was enhanced by the coordinating management role of the Whey Corporation.
11. Experts in various fields were employed and consulted.
12. Government support to the dairy industry over many years and in various forms was invaluable.
13. Know-how was protected.

Conclusion

Assessed against Brunner's criteria, New Zealand's history of development and commercialisation of WPCs rates well, particularly in marrying 'what is needed' with 'what is possible'. It is only in hindsight that we can say this. It never occurred to us at the time that we were following a path that history might judge favourably. So many were the challenges and so intractable did some of them seem, that those of us working at the coal face (which includes all the authors of this book in our younger incarnations) could only deal with the technical needs of the day, without thinking that we were part of an integrated network of people responding to a new opportunity that would one day be very valuable to the country.

There is an old saying, "Fortune favours the prepared mind." The 'prepared mind' in this case is a collective term for the industry. It required above all that leaders of the day had the vision, drive, empathy and courage to ensure that the attitudes and resources were in place to respond to the opportunity. Much of this book deals with the technical challenges we faced but an overarching theme of the narrative is leadership and wisdom, from the Dairy Board, NZDRI, the dairy companies, customers and from the many support services and infrastructures provided, including those from government.

In the case of WPC, there was a happy confluence of new technology (ultrafiltration), new products arising from use of the technology (soluble whey protein concentrate) and new market interest stimulated by the valuable properties of these new products. There was also a strong need to resolve pollution issues caused by the whey that was generated by the manufacture of casein and cheese. This in turn drove the need

to derive valuable products from all of the solids in whey, not just the protein. Profitable extraction of protein from whey meant that a range of other products could be manufactured, dramatically reducing the pollution danger. The business is now so profitable that there is no significant unprocessed whey left in New Zealand.

New Zealand has an unusual place among OECD countries in having relatively high reliance on primary industries to generate wealth. That it has done so through commodity products is well known and often criticised. It is ironic then, that some of these very commodity products provide the raw materials for some of the dairy industry's most valuable added margin ingredients. WPC is a prime example of this, building on the stable and profitable commodity base provided by cheese and casein.

WPC and later products such as whey protein isolates, and milk protein concentrates and isolates became a valuable part of our dairy commerce. Net returns from whey protein products have been worth billions of dollars in aggregate since 1980. The technology of ultrafiltration now underlies the manufacture of a variety of products that today return more than a billion dollars per year to the New Zealand dairy industry and economy.

So how will new WPC-type initiatives arise? What other potential value-added gems are waiting to be found among New Zealand's other agricultural products? The paths to identifying and developing them will never be easy. It is very much the collective wish of all of this book's authors that future custodians of the cause of adding value to New Zealand's primary produce find some guidance and inspiration from what was achieved in turning whey from an unwanted waste product into a source of highly valuable food ingredients.

ENDNOTE

[1]Brunner, George F, *The Tao of Innovation, Research*, in *Technology Management*, Jan-Feb 2001.

APPENDIX I

MEMBRANE FILTRATION TECHNOLOGY

DAVE WOODHAMS

This appendix describes membrane filtration and its development from beginnings in the late 1950s to maturity in the 1980s.

Manufacture of dairy products on a large scale is carried out in a series of integrated 'unit operations' which produce chemical, physical or biological transformations and separations. Examples of unit operations are evaporation, drying, crystallisation and filtration. The valuable constituents in whey are proteins and lactose. They become useful products after a series of unit operations have separated them from each other and especially from the mass of water that accompanies them.

As described in chapters two and nine, before membrane filtration was developed whey proteins were harvested as 'lactalbumin', as the product was known commercially. This was done by first making them insoluble by heating them in acid solution, then filtering them out and drying them. The particle size of the insoluble proteins could be made large enough to separate them by filtration from the water and lactose, both of which pass through a woven filter cloth. Although the process preserved the nutritional quality of the whey proteins, it destroyed most of their functional properties (i.e. the physical and chemical properties of the protein that are helpful when they are used as ingredients in food processing).

Figure 1 on the next page illustrates the removal of lactalbumin from whey in a filter press through four stages of the process. There is no recirculation of whey solids and the flow of feed is perpendicular to the filter medium. For the lactalbumin it is a 'dead end' system.

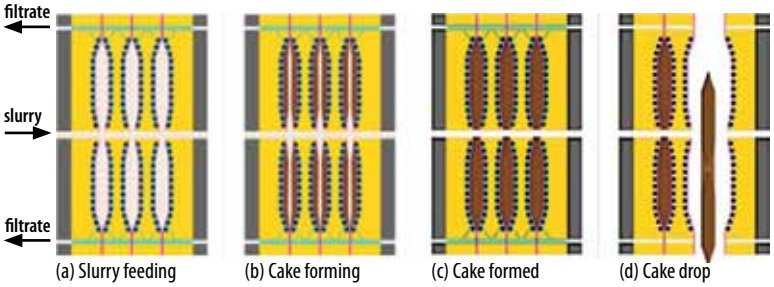


Figure 1

Figure 1 illustrates the removal of lactalbumin from whey in a filter press through four stages of the process. There is no recirculation of whey solids and the flow of feed is perpendicular to the filter medium. It is a 'dead end' system. In contrast, membrane filtration, illustrated in Figure 2, is a cross flow system. The flow of feed is parallel to the filter surface and the retained solids are recirculated.

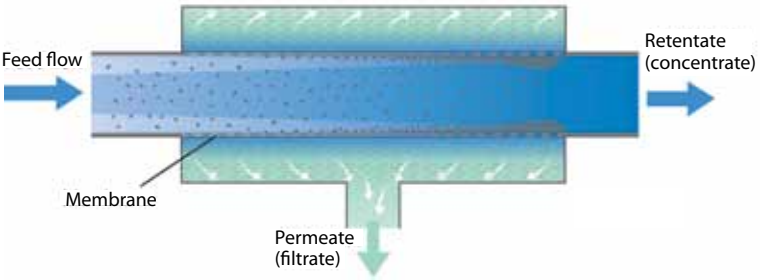


Figure 2

In contrast, membrane filtration, illustrated in Figure 2, is a cross flow system. The flow of feed is parallel to the filter surface and the retained solids are recirculated.

Membrane filtration also differs from ordinary filtration in that it separates the whey proteins from the lactose and water on the basis of their respective molecular sizes, without first turning them into insoluble solids. In doing so it preserves the desirable functional properties of the proteins that are lost during heat denaturation.

Almost all of the equipment and membrane development described in this appendix took place outside New Zealand. Membrane equipment companies in America and Europe played a very substantial and creative role in developing the technology for the dairy industry. However, New Zealand, with its cutting-edge approach to high protein whey products, was a lively and lucrative market for these equipment manufacturers. It was somewhere they could try out new equipment

variations in a commercial environment managed by technically aware, innovative and cooperatively critical people. New Zealand's specific contribution was to apply these equipment and process developments in a commercially demanding situation. Our technologists were able to optimise the performance of whatever equipment they were working with because of their knowledge of protein chemistry and separation technology.

What is a membrane?

Membranes are ubiquitous in the natural world. Every biological cell – animal, plant, bacteriological or fungal – is surrounded by a cellular membrane. This membrane separates and protects the cell from its surrounding environment. The membrane preserves the vitality of the cell by acting as a selective barrier between outside and inside, keeping unwanted material out and permitting or keeping needed material in.

Ultrafiltration is a pressure-driven filtration process in which synthetic porous membranes are used to separate the components of a solution on the basis of their molecular size and shape. Membranes at the heart of whey ultrafiltration, which separate proteins from water and lactose, depend for their selectivity on the relative size of the protein, lactose and water molecules. Typically the pores in ultrafiltration membranes vary in size and have effective diameters in the range of 2 to 10 nanometres (nm). The smallest size entity that can be seen in an optical microscope, using an oil-immersion lens, is around 200 nm.

Membrane materials

The membranes supplied for our first ultrafiltration pilot plant and our first commercial plant at Waitakaruru were made of cellulose acetate. Although it was suitable for the ultrafiltering job, this material had drawbacks. Its limited tolerance to pH (3-7), temperature (<50C) and sanitising chemicals (such as those containing active chlorine) made cleaning and sanitation difficult. Alternative polymeric materials (polyamides, polyvinyl chloride, polyacrylonitrile, polycarbonate, polysulphones and polyethersulfones) have been developed for use as membranes in the years since but in the 1970s New Zealand research workers were not active in such developments except as highly interested users.

Membrane structure

The two main properties of membranes that are used to assess their

usefulness in a commercial process are their selectivity and their flux (the rate of permeation).

Selectivity is measured for individual molecular species and is expressed as a rejection coefficient, R, that ranges from 0 percent to 100 percent. R is a measure of the proportion of the species present in the feed stream that is rejected by (does not pass through) the membrane. Ideally, for separating whey proteins from lactose and water, R_p for the proteins should be 100 percent and R_L for lactose should be 0 percent. The actual rejection depends on the size of the pores in the membrane and the molecular size of the component. In spite of the fact that the pore size in commercial membranes is not uniform, the difference in size between the proteins and the other components is so great that separation performance is quite close to ideal, unless, of course, the membrane is damaged physically or chemically during service. So we expect to see essentially no protein in the solution, known as the 'permeate', that passes through the membrane. We also expect to see lactose on either side of the membrane at the same concentration.

Flux is a measure of the rate at which permeate flows through the membrane and is expressed in litres of permeate per square metre of membrane per hour. The actual flux at any instant depends on a number of external variables such as the pressure difference across the membrane, the protein concentration near the membrane, the temperature of the solution (which affects its viscosity) and the amount of fouling material built up on the membrane surface. In terms of the membrane itself, the flux, when measured with pure water, depends on the size and number of pores and on the thickness of the membrane. The larger the pore diameter, the greater the flow of permeate under otherwise identical external conditions. However, the thicker the membrane (i.e. the longer the distance within the pore) the less the flow will be under identical conditions.

Early experimental work in America was aimed at developing a synthetic membrane that could separate salt from salt water to produce fresh water. The problem was how to make a membrane that would exclude salt while still allowing fresh water to permeate or pass through fast enough for a commercial plant to be economical.

The key discovery that underlies all commercial-scale separations with synthetic membranes was revealed somewhat by chance in late 1959 by Sidney Loeb, working on his master's thesis at the University

of California, Los Angeles (UCLA). He had cast a membrane on a flat glass plate and tested a portion of it for selectivity and flux, finding it close to success in both aspects. However, a second trial using a second piece of the same cast membrane failed dismally. Subsequent tests using material cut from the same casting either failed or were successful on what appeared to be a random basis. It became apparent that the difference lay in the orientation of the membrane. When the membrane surface facing the saline solution was the surface that had been in contact with the glass during casting, it failed. But if the surface next to the solution was the surface that had been exposed to the air during the casting process, both the selectivity and the flux were acceptable. In other words, the membrane was asymmetric, or "anisotropic" as Loeb called it at the time.

On page 206 is an electron-microscope picture of a cross section of an asymmetric membrane. The functional pores, the sizes of which determine the selectivity of the membrane, are located in the very thin skin at the top of the section. This is the surface that was shrunk by contact with the air in Loeb's original membrane. Immediately below this skin, and giving it the strength to withstand the operating pressure differential across the skin, is a much thicker portion of the same membrane material in which the pore size has not been reduced by shrinking, thus offering much less resistance to the flow of the permeating fluid. If the pores were this size throughout the membrane, including the surface, it would have an adequate flux but would not meet selectivity requirements. If the pores were the same size as they are at the surface throughout the membrane, it would meet the selectivity criterion but the flux would be unacceptably low. All membranes used for commercial separations are asymmetric.

Reverse osmosis, ultrafiltration and other membrane separations

There are several types of separations that rely on membranes to exclude molecules or minute particles on the basis of size. Sidney Loeb's original goal was the production of fresh water from salt water or brackish water. The sodium and chloride ions that together make salt in solution are very small when compared with the size of the whey protein molecules. Thus the pore size needed for excluding salt is very small and the pressures needed to achieve an acceptable flux are quite high, 50 or 60 times atmospheric pressure or more. This is only partly because of the small pore size. A large part of the

pressure is needed to overcome the so-called osmotic pressure that results when a solution of small molecules is separated from the pure solvent (water) by a membrane that is permeable to the solvent and impermeable to the solute (salt). Under normal conditions water flows through such a 'semi-permeable' membrane to dilute the adjacent solution, a process known as osmosis. Reversing this flow by pressurising the salt water side, so that water flows from the salt water to the fresh water side of the membrane, thus earns the name 'reverse osmosis'.

The osmotic pressure effect reduces substantially as the molecules in the solution get bigger. Because of this and because the pore sizes needed to exclude protein can be much larger than those needed for salt, much less pressure is needed to drive the water and lactose in whey through the membranes – perhaps two to four times atmospheric pressure, less than a tenth of the pressure needed for reverse osmosis.

This latter process is known as ultrafiltration and the first such membranes were developed in the late 1960s, deriving directly from those made for reverse osmosis. Since then, membranes have been designed and adapted for various functions and a variety of names created to describe them. In order of increasing average pore size we now have: reverse osmosis (sometimes called hyperfiltration), nanofiltration, ultrafiltration, microfiltration and filtration. The chart below shows the nominal ranges covered by these descriptors, revealing a degree of overlap between them.

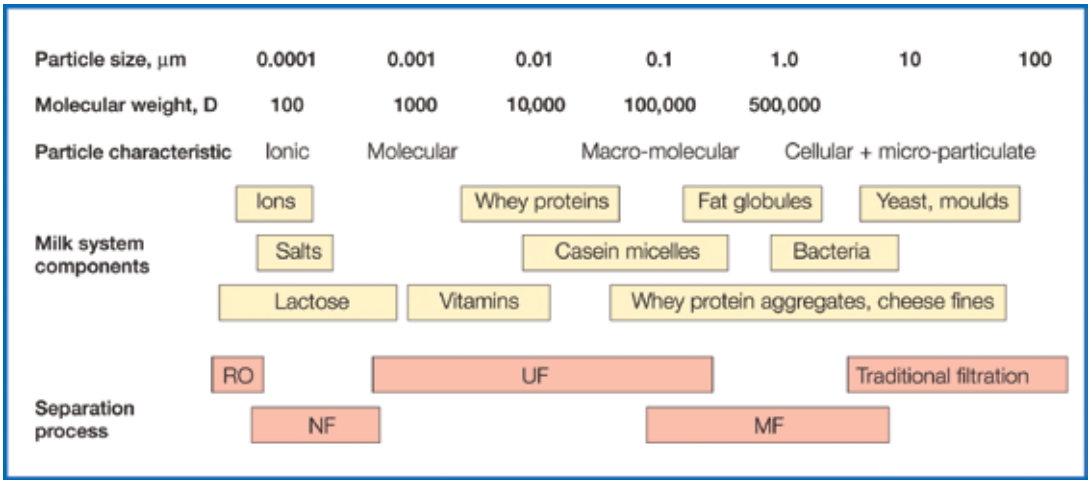


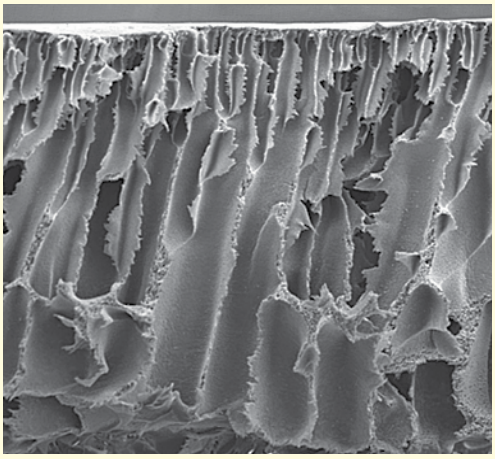
Figure 3: Spectrum of application of membrane separation processes in the dairy industry.

THE ASYMMETRIC MEMBRANE

Major efforts were being made in the 1950s by the United States Department of the Interior through the Office of Saline Water, and by the State of California, to solve the growing problem of shortages of fresh water in dry areas. UCLA was heavily involved in the state supported desalination research. Sidney Loeb recalled* as follows:

"The commercial utility of reverse osmosis depends on combining adequate permeate flux (permeate rate per unit membrane area) with acceptably low permeate salinity (usually less than 500 ppm). These were simultaneously achieved by us in late 1959 by the attainment of a membrane with a very thin (micron or submicron) 'skin' surmounting a relatively thick porous support layer. This anisotropic structure was verified by electronic microscopy at Gulf General Atomics in San Diego. In my opinion, such anisotropy is the seminal feature to the success of RO desalination, and has been a major contributor to the general surge of interest in and applications of membrane separation processes. The attainment of anisotropy could be called serendipitous. However, 'the road to success is paved with failures.'

"The first test with an anisotropic (not known at the moment) membrane was close to being a success by the above two criteria. The second test (from the same membrane sheet) was a dismal failure with subsequent tests being equally good or very bad in random fashion, as if flipping a coin. From this we finally speculated that one side of the membrane was different from the other and that was it. The side facing the air during casting on a glass plate had to be in contact with the saline solution during service. I sometimes wonder if I would have continued testing that membrane sheet if the first test had been a failure. The anisotropic principle is still valid today."



Electron microscope cross- section of an asymmetric membrane

*Quoted by Bob Weintraub in the Bulletin of the Israel Chemical Society, December 2001.

ULTRAFILTRATION

Membrane formats

There are really only two basic ultrafiltration membrane formats: tubular (or cylindrical) and sheet. However there are several ways of applying these two formats in a commercial environment, depending on the demands of the application. Tubular membranes for liquid separations range from hollow fibres 250μm in diameter up to tubular elements 25mm in diameter. The smaller sizes are self-supporting and are generally arranged in bundles that have their ends sealed in a resin plug. Larger tubular elements are cast inside tubular supports, or 'backings', to provide strength against the internal pressure. Sheet membranes may be deployed flat or, more commonly now, in a spiral format like a sponge roll.

Concentration polarisation

In the presence of a feed solution containing proteins the flux is always less than the 'water flux' measured with pure water after cleaning. When water and lactose in whey pass through a selective membrane, leaving the proteins behind, the protein concentration close to the membrane surface increases. This phenomenon is known as 'concentration polarisation'. It imposes an additional resistance to the flow of the permeable materials to the membrane surface. As a consequence, the flow rate of permeate through the membrane (the flux) is markedly affected by the concentration of protein next to the membrane; the higher the protein content is, the greater is the resistance and the lower is the flux. Therefore it is essential, when using membranes in a commercial environment, that the flow of whey across the membrane surface is such that it hydraulically sweeps the protein layer from the surface in order to minimise its resistance to permeate flow. The effect of the higher flow rate is to reduce the thickness of the so-called 'boundary layer' and thus the effect of concentration polarisation. An additional process design consequence of this phenomenon is that, for operational efficiency, permeate should be removed from the whey at the lowest possible bulk protein concentration.

The design of different membrane formats and the development of process and plant architecture can be understood as different ways that designers have devised to counteract concentration polarisation (remove protein effectively from the membrane surface) and, at the same time, to move permeate through the membrane at as low a protein concentration as economically possible.

Tubular designs

The earliest commercially available membrane supports were tubular. Ultrafiltration is a linear descendant of reverse osmosis and the high pressures necessary for reverse osmosis are most easily contained by a circular cross section.

Larger diameter tubular membranes were cast on the inside of support material such as porous fibreglass tubes or, as in the case of our first membranes from Abcor in 1970, porous sintered polyethylene tubes. If whey is pumped through the tubes fast enough, the turbulent flow minimises the thickness of the protein boundary layer, thus minimising concentration polarisation and optimising the flux. An added reason for starting with a tubular system was the US Department of Agriculture's (USDA) insistence that surfaces exposed to food materials must be capable of being visually inspected if a plant was to be certified as acceptable by 3A, an organisation recognised by the USDA as having expertise in the sanitary design of food and dairy equipment.

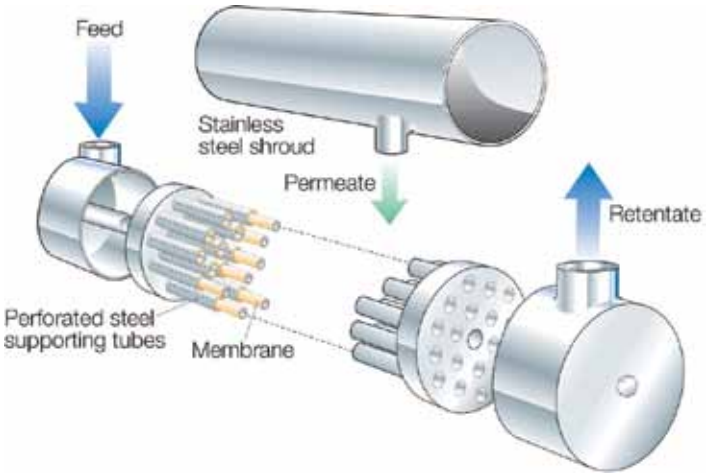


Figure 4: Example of a tubular module in an ultrafiltration system.

In a tubular membrane the thin skin was on the inside of the tube. Permeate flowed through the skin, through the body of the membrane and then through the porous backing to be collected for use or disposal. The retentate, containing essentially all the protein, remained on the inside and was recirculated to achieve the flow rate needed to avoid undue concentration polarisation.

The industry's first commercial whey plant in New Zealand, at

Waitakaruru, used Abcor tubular membranes of the same size as those in the pilot plant, reflecting the ease with which this essentially modular membrane format could be scaled up.

The first NZ Lactose Company commercial plant was a Havens tubular plant and similar modules were available from Patterson and Candy International. Each module contained 18 tubes connected in series, as in Figure 4.

Sheet membranes: plate and frame designs

The first significant challenge to the tubular format was the flat membrane. Dorr Oliver had a 'leaf' system that was in early use (See Appendix II) but the most competitive flat membrane design was developed into a commercial module by DDS, the Danish Sugar Company in Denmark, a country that was free from the dictates of the USDA.

The design of the equipment using flat membranes derived directly from what was known as a plate and frame filter, a well-known piece of industrial equipment for removing solids from liquids. However, in particulate filtration, as shown in Figure 1 above, the solids remain in the space between the filter cloths. The only way out for the liquid filtrate is through the filter cloth. In membrane filtration the retentate, with its dissolved protein, is pumped several times through the membrane compartments, with only a small portion of permeate being removed in the course of each pass. The protein concentration at the membrane surface is reduced by ensuring the space between the membranes is narrow so that the fluid velocity is high.

The flat plate and frame membrane played a very important role in the development of high protein products and held sway commercially for several years in New Zealand until spiral membranes were developed for food use on a commercial scale. New Zealand's second, third and fourth major ultrafiltration plants – the Te Aroha-Thames Valley CDC plant at Paeroa (1978), Rangitaiki Plans CDC (RPD) plant at Edgecumbe (1979), and Manawatu CDC plant at Longburn, (1983) used flat plate and frame membrane technology from DDS. (Figure 5).

In this arrangement, membranes are contained within support plates that are arranged in stacks. The feed solution is pumped through very narrow channels between the plates. A module is usually divided into sections in each of which the flow between the membranes is in parallel

and the sections are then connected in serial flow. Three such sections are illustrated in Figure 5.

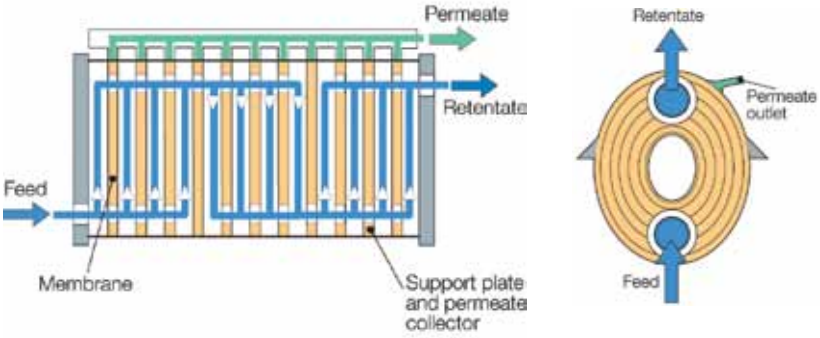


Figure 5: Example of a plate and frame system (DDS) for ultrafiltration

Sheet membranes: spiral-wound designs

Flat sheet membranes may also be made into an inexpensive and compact module by attaching and spirally winding a number of membrane 'leaves' onto a central perforated tube and enclosing the assembly in an outer tube. Each 'leaf' is made up of two membrane sheets enveloping a sheet of thick fabric which is capable of conducting the permeate fluid. The leaf envelopes are sealed with a glue bead around three sides and the fourth side is attached to the perforated central pipe in such a way that the permeate can enter the tube.

To avoid excessive pressure drop along the permeate-conducting fabric, the length of each leaf is limited to about a metre. Before winding the leaves into a spiral, they are interleaved with sheets of 'feed spacer' to define the separation between the working membrane surfaces. The finished round membrane module is enclosed in a net outer wrap and then fitted into a cylindrical outer shell. (See Figure 6 opposite.)

Feed is pumped into one end of the cylinder and flows between the membrane surfaces. The feed spacers control the thickness of the flow channel and also induce some turbulence in the flow to minimise the thickness of the protein boundary layer. Permeate flows through the membrane into the fluid-conductive permeate fabric and makes its way spirally into the perforated central tube and thence to the permeate collection point.

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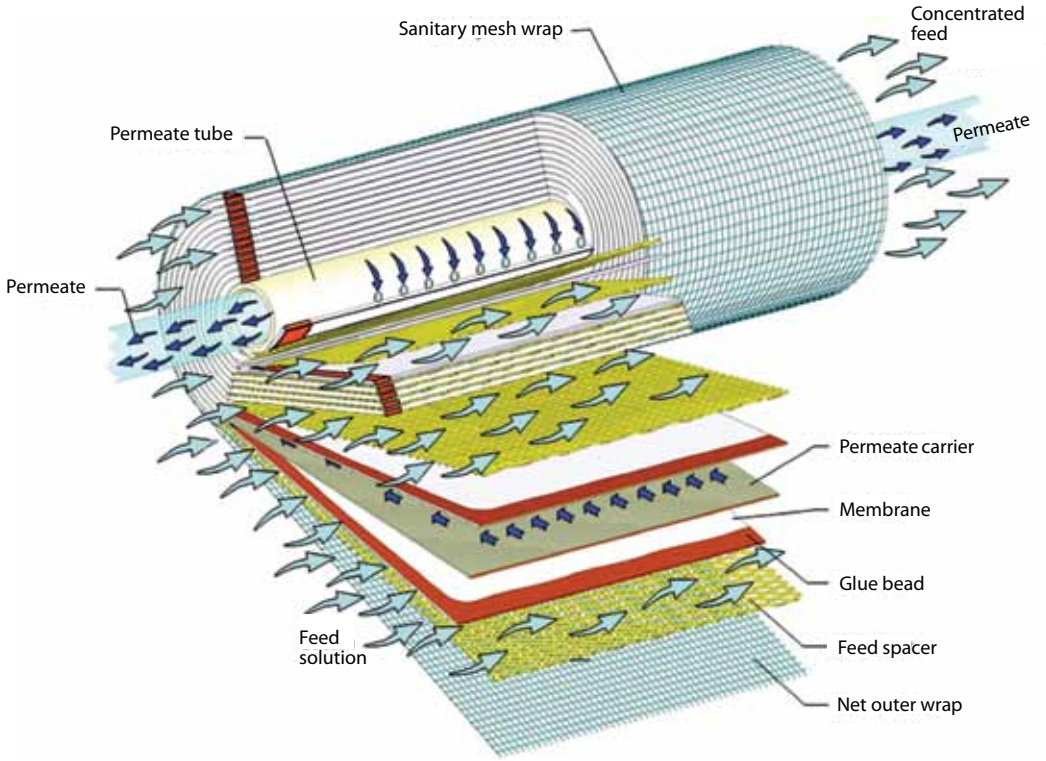

Figure 6: Spiral-wound membrane

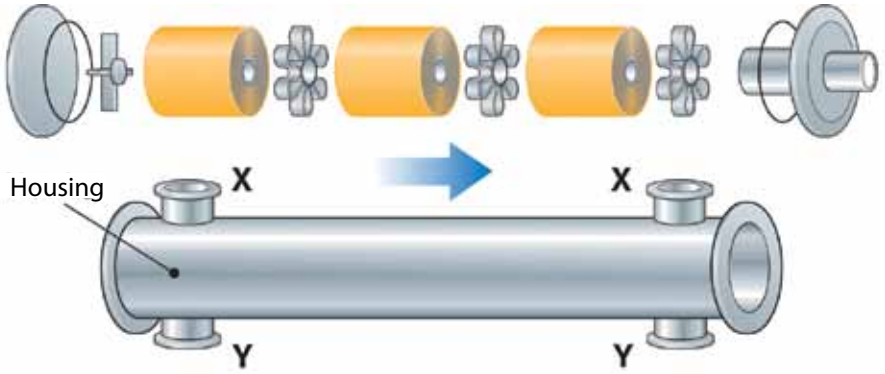

Figure 7: Spiral wound module assembly. Either or both of the pairs of connecting branches (X and Y) can be used for stackable housing, specially used in ultrafiltration concepts.

Today the spiral-wound membrane module is a highly evolved device, made as large as 400mm in diameter and using many leaves. It has slowly increased its market share and is now the design with which other module types are compared for both reverse osmosis and ultrafiltration.

All new ultrafiltration plants installed in New Zealand since the late 1980s have used spiral-wound membrane modules. A spiral module is illustrated in Figure 6. The assembly of three spiral membrane units into a single shell is shown in Figure 7.

PROCESS ARCHITECTURE

Modules

A membrane module is the simplest membrane element that can be used in practice.[1] The spiral module in figures 6 and 7 is an example. It fulfils the requirements of all membrane modules:

- It provides support for the membrane and seals the flow path so that feed solution cannot leak into the permeate stream.
- It provides good contact between the feed stream and the skin of the membrane while allowing turbulent hydraulic sweeping of the surface to avoid undue local build up of protein concentration, thus helping optimise the flux.
- It provides for easy removal of permeate from the system and allows thorough cleaning of all the flow paths.

The module designer's challenge is to meet these requirements with a minimum waste of pump energy during operation and at an economic cost of initial manufacture.

Membrane separation unit

In practice, a number of modules are assembled in banks, together with appropriate recirculation pumps, valves and pipework, to form a membrane separation unit. The modules may be connected either in series or in parallel within the unit. A membrane separation plant is made up of one or more of these units.

Batch ultrafiltration

In its simplest manifestation, an ultrafiltration unit is fed with whey from a large feed tank containing the full batch of whey to be treated. This is illustrated in Figure 8, where no whey is added to the tank during operation. Whey is drawn from this tank and pumped through

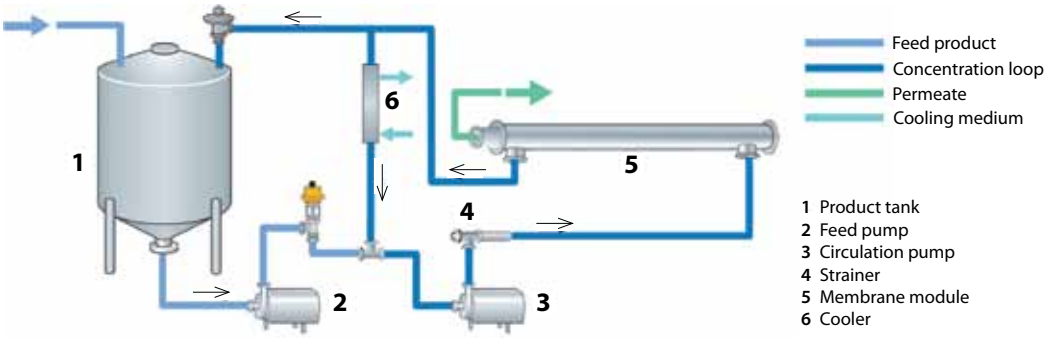

Figure 8: Batch and semi-batch operation of ultrafiltration.

the unit. The slightly concentrated feed solution, less the amount of permeate removed, is returned to the feed tank. Gradually the volume in the feed tank reduces and the protein concentration rises. When the desired protein concentration is reached, the internal contents of the unit are flushed to the feed tank which now contains the product solution (the retentate) for further processing.

A closely related mode of operation is semi-batch, where a smaller feed tank is constantly topped up with fresh whey, replacing permeate that has been removed. Finally the feed valve to the tank is closed and the contents are concentrated to the desired degree.

Full batch operation has the advantage of requiring the least membrane area for a given concentration capacity because all the permeate is removed at the lowest possible protein concentration. Thus, in the early days in New Zealand, the initial pilot plant was operated in full batch mode while the first commercial plant, for scheduling reasons, was operated in semi-batch mode.

A very significant disadvantage of batch operation is that the feed solution has to be maintained at the process temperature throughout the course of the production run, which can last for several hours. In the early days, temperatures were quite warm (50C) in order to improve the flux and to minimise the membrane area needed. Operation at this temperature meant the risks of growth of thermophilic bacteria were quite high. It was several years before membrane costs declined to the stage where it became economic to operate at temperatures as low as 10C, which is microbiologically much more stable. The first low temperature (10C) plant in New Zealand was established at Whareroa by the Kiwi Cooperative Dairy Company in 1993

Multi-stage feed and bleed ultrafiltration

Continuous processing was achieved by connecting a number of individual ultrafiltration stages-in-series (Figure 9). The first stage receives a feed of whey at the original concentration. As permeate is removed through the membrane and a bleed of slightly concentrated retentate is fed forward to the second stage, the volume lost is made up by pumping fresh new feed material into the circuit. The second and succeeding stages operate similarly, each stage receiving a top up feed of the retentate derived from the preceding stage, removing some permeate and bleeding some of the more concentrated retentate forward to the succeeding stage. The process is run so that the concentration of the product of the final stage has the desired composition, in its simplest form controlled by maintaining a set flow ratio between the feed and product flow rates. Recirculation takes place within each stage to ensure adequate velocity over the membrane surface but the common feed line permits the volume of permeate from succeeding stages and product from the final stage to be replaced automatically with fresh feed to the first stage.

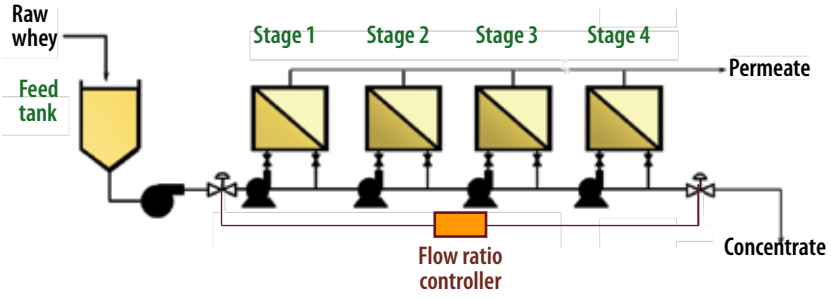

Figure 9: Multistage ultrafiltration

One of the main advantages of continuous operation is that permeate is removed stage by stage at successively higher protein contents, with most of it, because the protein concentration is lower and the flux higher, coming out in the early stages and therefore most economically.

A second major advantage is the very significant reduction in the residence time of the product in the equipment. In a batch plant the protein solution may well be circulated at the process temperature for many hours. The residence time in a continuous plant may be as low as half an hour.

Diafiltration

Diafiltration is the addition of water to the retentate in one or more of

the later stages in an ultrafiltration plant, to aid removal of permeable solutes without having to concentrate the protein excessively. It is analogous to the rinsing of washed clothes to remove the soap and dirt contained in the water that remains in the clothes after the bulk of the wash water has been removed by spinning or wringing. Addition of rinse water and agitation dilutes the dirty water that remains in the clothes and, after a second spin, a good deal of the soap and dirt will have been removed, even though the clothes are just as wet as they were before rinsing. So diafiltration is just another word for water-washing. It permits operation of an ultrafiltration plant to produce a much higher final protein content than would be possible without it.

For example, the practical limit to the degree of concentration of whey by ultrafiltration alone is around 20:1. This means that, ideally, all the protein in the original whey is concentrated into 1/20th of the volume while (again ideally), 19/20ths of the water, lactose and minerals have been removed in the permeate.

Before ultrafiltration, the protein content of whey is about nine percent of the solids in the whey. Ideally, after 20:1 concentration (a volume concentration factor of 20) the protein would be about 63 percent of the dry matter. In practice, of course, membranes are not perfect; they do not retain 100 percent of the protein (more like 98.5 percent) and they are not 100 percent permeable to lactose and minerals (more like 85 percent). So the practical limit to ultrafiltration of whey without water-washing is a dry product with a protein content in the product of around 55 percent.

By 1979 a commercial plant was operating at RPD's Edgecumbe factory. It had nine ultrafiltration stages-in-series, followed by another four stages within each of which diafiltration water was added and removed – like having four successive rinses of the washing. The dry product from this plant had a protein content in the range 78 percent to 84 percent, a very important advantage for some end uses.

Fouling

Once the transient effects of start-up have worked through a multi-stage plant (i.e. the operation has reached 'steady state') the concentration factor in each stage tends to be reasonably constant. However, the flux is not steady and declines as the run proceeds. The rate of decay in flux tends to be greatest in the early stages and is generally attributed to progressive fouling. Freshly arriving whey brings in more of whatever

it is that causes the fouling while the retentate flowing to later stages is depleted in the foulant. RPD operators soon discovered in 1979 that if they stored their whey for at least two hours at 50C before UF processing, fouling was less pronounced. Trying to process very fresh 50C whey just after it arrived from the casein factory would lead to a rapid decline of flux in the early modules. Fouling is less pronounced in plants operated at low temperature. Cleaning processes are designed to remove foulant and to restore membranes to their original flux performance.

The process of fouling is quite distinct from concentration polarisation, the effects of which are generally quite stable through a production run.

Economics

An ultrafiltration plant can be considered to be made up of two broad categories of equipment:

- The membrane modules, including those items directly associated with them such as membrane housings.
- The equipment surrounding and supporting the membrane units, such as pumps, valves, piping and instrumentation.

In the design of an ultrafiltration membrane operation there is a trade-off between the amount of membrane area required for the duty and the amount of supporting equipment needed.

For example, if concentration polarisation is the factor limiting flux, as it is with ultrafiltration of whey, the designer can provide more or larger capacity pumps, supplying more fluid turbulence at the membrane surface. This achieves higher fluxes and uses less membrane area. The result is a lower investment for membranes, a higher investment for pumps and pipes, higher energy operating costs and lower membrane replacement costs.

The trade-off is thus between adding more membrane area and accepting a lower flux on the one hand and, on the other, adding more ancillary equipment to make a smaller installed membrane area more productive. The very high relative cost of membranes in the early years forced the trade-off in the direction of minimising membrane area but, as membrane manufacturers mastered the science, technology and art of their trade and as production volumes increased in later years, membrane costs reduced and the balance swung

back. This allowed designers more freedom in their approach to the process and, in particular, allowed operators to specify much lower operating temperatures than were originally economically practical. This latter development also prolonged the useful life of membranes. In use, membranes progressively acquire a patina of aging that is not removed during cleaning. Eventually, the flux declines to the point that replacement is necessary for economical operation.

The three biggest elements in operating costs are capital charges, membrane replacement costs and energy costs. Thus the design trade-off for optimising operating costs is very similar to that already discussed for capital costs. Chemical costs for cleaning are also important operating costs, together with the opportunity cost of the time taken for cleaning.

Conclusion:

In its maturity, membrane technology has become an important player in the New Zealand dairy industry. As well as being used to produce whey protein concentrates, it is also fundamental to:

- Ultrafiltration of skimmilk prior to casein manufacture. This has the dual advantage of providing 'sweet' permeate that can be used for standardising the protein content of wholemilk and skimmilk powders and simultaneously pre-concentrating the protein content of the by-product whey from casein making for WPC production. The volume of acid whey can be reduced by up to 40 percent, thus substantially reducing the problem of utilising the acid permeate.
- The production of milk protein concentrates made by ultrafiltering skimmilk, again producing sweet permeate for use in standardising.
- The production of milk protein isolates made by ion exchange chromatography of ultrafiltration retentates.
- The standardisation of the composition of milk for cheese manufacture.

ENDNOTE

1 Bill Eykamp, in his article on membrane filtration in Perry's *Chemical Engineer's Handbook* (7th Edition, 2001).

APPENDIX II

SOLUBLE WHEY PROTEIN AT THE NEW ZEALAND LACTOSE COMPANY

ARTHUR WILSON

Arthur Wilson *served as a fitter armourer in the RNZAF during WWII. On return he gained MSc (Hons) in chemistry from Otago University and studied for registration as a chemical engineer by correspondence after joining the NZ Lactose Company as chemist in 1949. He became general manager of the Edendale site in 1954 and, in 1980, general manager of Southland Dairy Cooperative. In 1969/70 he designed and commissioned the first commercial whey ultrafiltration plant in the world.*

Between 1958 and 1964 home-grown improvements to the throughput of the whey evaporator at the NZ Lactose Company's Edendale plant, together with a reduced whey supply, allowed the factory to operate throughout the season on a single shift, even at the peak. However, in 1965 a temporary resurgence in whey supply meant very long hours for staff over the peak period. As a consequence, technical staff took a keen interest in a new process for concentration – reverse osmosis – news of which was appearing in the scientific literature. If some water could be removed by this means, we might avoid double shift manning of the evaporators over the peak.

In 1967, John Wood at the Kapuni factory demonstrated, with an asymmetric membrane he made himself, that reverse osmosis, could remove water from whey. In early 1968 he followed this up by visiting a number of research laboratories and fledgling makers of membrane filtration equipment in America.* Havens Industries was the only one that could supply functioning units.

The company explained that membranes could be made with varying molecular weight cut-off properties, but as Wood's main concern was water removal, he ordered a small (30 module) Havens reverse osmosis unit. It was trialled successfully at Kapuni in late 1968. Following this,

*UCLA Davis, UCLA Berkley, Havens Industries in San Diego, Abcor in Cambridge MA, US Department of Agriculture in Philadelphia and Washington, American Standard in New Jersey. (At the time, USDA was trialling an early spiral design for concentrating maple syrup).

I visited potential suppliers in America, including both Havens and Abcor. At that stage Abcor was still far from having a viable system, leaving Havens again as the only choice.

Glenn Havens was a manufacturer of fibreglass fishing rods who had attended a lecture by Sidney Loeb of UCLA, describing the need for a porous support for cellulose acetate membranes for reverse osmosis equipment. Havens came away from the lecture reflecting that he had had to modify the resin treatment to stop his fishing rods being porous. He could go back to the previous treatment to make porous rods for a membrane support. He got Havens Industries to do just this. The porosity of the membranes could be modified after installation in the support tube by heating the membranes to specific temperatures, the higher the temperature the tighter the membrane.

Loeb's early membranes, which were demonstrated producing drinking water from brackish water at the town of Coalinga, north of Los Angeles, were supported in copper tubes with numerous drilled holes to facilitate the escape of permeate. I visited the demonstration plant in August 1968. A feature of the Coalinga demonstration was that the brackish water supply was split by the reverse osmosis plant into salt-free drinking water and a salty residue. The two streams were reticulated separately through the town, one for drinking and the other for flushing toilets and other non-potable uses.

When I visited in late 1968, Havens offered equipment for both reverse osmosis and for ultrafiltration. Membranes for the latter use retained molecules above a molecular weight of about 18,000 but allowed smaller molecules to pass through. This allowed the salts and the lactose of whey to pass through but held back the whey proteins. Each Havens module consisted of 18 hollow fibreglass tubes, each about 12 mm diameter and 2.5 metres long, housed in a PVC case. Each tube was lined with a cellulose acetate semi-permeable membrane. The whey travelled in series through the 18 tubes in the module.

At that time, the Lactose Company's Kapuni plant, working with local Taranaki whey, was having difficulty matching the lactose yield it had routinely achieved at Edendale. Wood thought one reason might be that the Taranaki whey proteins were different from those in Southland because of the difference between Jersey and Friesian milks that were typical in the respective regions. He believed that Kapuni's Jersey milk might produce concentrated whey with a higher viscosity that slowed and inhibited crystallisation of the lactose. A pilot scale ultrafiltration

plant was obtained for Kapuni to assess its potential for the removal of protein before evaporation.

However, in 1969 the Havens pilot unit trials of both reverse osmosis and ultrafiltration, which had begun at Kapuni, were transferred to Edendale. Kapuni was about to embark on a major expansion in lactose processing.

An alternative design made by Dorr Oliver, first received as a pilot unit in January 1970, used a polyelectrolyte membrane supported on parallel flat plates. Four such units were housed in a plastic module and a Ladish centrifugal pump circulated whey through six modules in series (eight in later versions). Because of pressure limitations, this design was restricted to ultrafiltration.

A kitset Abcor ultrafiltration pilot unit was received in the spring of 1970. From January 1971, after a few weeks' trials running on its own, the Abcor unit joined a broader trial in which it was compared with a similar sized, locally assembled Havens unit and the Dorr Oliver pilot unit.

Reverse osmosis

The pilot Havens reverse osmosis unit relocated from Kapuni was set up at Edendale and used to optimise the flow rate and cleaning procedures on whey. Rod Bennett, on a vacation job from Massey University in the 1968/69 season, ran this investigation. Four parallel banks of modules with four, six, eight and ten modules in series, were operated between the same terminal pressures. A standard inlet pressure of 4100 kPa was provided by a triplex piston pump with a pressure regulator and a surge suppressor. The downstream pressure was set at 2000 kPa. Too high a flow rate in the four-module bank risked dislodgment of the membrane. The low flow rate in the eight or ten row banks permitted the slow buildup of whey protein on the membrane, thus reducing the permeation rate.

The rate of permeate flow and quality was monitored over several weeks. The conventional cellulose acetate ester membranes in the Havens equipment restricted daily cleaning at this time to detergent and mechanical cleaning. The latter involved pumping small rubber balls and later, more effectively, sponge urethane cylinders, through the tubes. Because of the delicate nature of the cellulose acetate membranes, final sanitising was restricted initially to quaternary ammonium compounds. In subsequent years various enzymatic cleaners such as Bioclenz were used.

The use of Havens units on reverse osmosis was not without its moments, such as the excitement of dodging the jet of whey when a tube burst.

For the next three years, sufficient Havens reverse osmosis modules were installed to avoid double-shift staffing on the Edendale evaporators at the peak of the season. The Havens plant involved a unit of six banks of eight or ten modules in series, driven by a 50mm x 2M Moyno progressive cavity pump. The unit was run for most of the season.

Because we saw ultrafiltration separation mainly as a means of removing protein, with the retentate being a waste stream, the reverse osmosis plant was initially arranged in series before the ultrafiltration plant. Before long, however, this was discontinued in an effort to produce Prolac, our name for whey protein concentrate, of a more standard composition. Thereafter the concentrate from the reverse osmosis plant went directly to the evaporators.

Ultrafiltration

In 1969, the main focus of membrane processing at Edendale changed to become production of soluble whey protein. The product, containing 53 to 58 percent protein, was trade-named Prolac, and initially marketed as a replacement for egg white powder, which was selling at that time for about $5000 per tonne.

Once the decision was made, Graham Jamieson, a chemical engineering

New Zealand Lactose Company's ultrafiltration plant for cheese whey at Edendale in April 1970. It consists of 494 Havens ultrafiltration modules. The view shows the permeate manifolds and the isolating tubes for use when there was a membrane failure.

graduate from Canterbury University, was given the job of accelerating fabrication of the large frames for the Havens modules. The company's engineering workshops at Edendale were already well equipped and the frames and special items for this new process were made on site. Havens equipment had a significant capital cost advantage per square metre of membrane area over other designs, partly because the Edendale workshop was able to make the module supports and pipework.

Compared with the experience with reverse osmosis, the average Havens ultrafiltration membrane life was longer because of the lower inlet pressure (340 kPa) used. However the flow rate still had to be moderated to avoid tearing the membranes from their support tubes, although after the ultrafiltration membranes had seen about 18 months service, the failure rate again became a problem. The design of the Havens assembly had to allow for easy isolation and repair of any leaking modules. Once individual leaking tubes were detected in a module, the tubes could be replaced by the plant operators using a homemade module repair kit.

The first five horsepower Puma pump in the flow circuit circulated whey through 13 banks of four modules in series. The remaining eight pumps each supplied two tiers of 13 banks of two modules in series. For the first few years, rotameters mounted side by side, indicated the flow of fresh whey into the assembly and the flow of final retentate respectively. By relating this ratio to the results of regular protein testing of the resulting powder, we used the flow rate ratio to control the protein content of the final product at 55 percent.

Initial plant production, autumn 1969

The cheese whey to be processed was pasteurised, clarified in a Westfalia clarifier and then fed to the ultrafiltration plant, which consisted of 494 Havens modules.

The permeate from individual modules was monitored for protein leakage at least every half hour and if a leak was found, the permeate from the offending module was promptly isolated. The retentate was pasteurised before spray drying in a Bufflovac spray dryer.

Prolac production commenced

By late March 1970, production of Prolac was underway. We were under pressure to produce saleable samples before the Southland whey supply ceased near the end of May. The first shipment went to White Wings

in Sydney for incorporation into instant cake mixes. In August 1970, following this sale, Alex Holmes and I went to England to update the scientists and executives of the parent company, Unigate, on the new process. The presentation included an initial comparison of the three ultrafiltration plant designs.

Bennett, having completed his masters degree at Massey University, returned to Edendale in August 1970 and stayed until 1973. He monitored the production of Prolac from the large Havens installation and organised product testing in the laboratory. In the winter this included baking cakes where Prolac replaced the egg. He recalls visiting Edmonds in Christchurch to suggest they try Prolac in their cake mixes but the response was, "the housewife likes to add the egg herself."

Because of developing doubts about the longevity of the Havens modules, even at the lower pressure used for ultrafiltration, Bennett made a further, more precise comparison of the pilot Havens unit with the Abcor tubular unit and the original Dorr Oliver flat plate unit, all circulating whey from the same feed tank to ensure identical conditions. The cleaning was standardised by a homemade cam controller.

The early days of Prolac production were not without drama. Bennett recalls the night the pH meter was wrongly calibrated during cleaning. Next day the greatly improved flux rate was accompanied by disastrous protein leakage.

Dorr Oliver ultrafiltration plant

The second trial Dorr Oliver unit, received in 1971, had more acceptable stainless steel housings instead of the earlier plastic housings and, by late 1972, Dorr Oliver became our preferred design.

As more Dorr Oliver units were purchased over the next four years, gradually replacing the Havens units, they were operated as stages-in-series, as with the Havens units. As more Dorr Oliver units were commissioned, the earlier stages of the Havens installation were successively decommissioned. Although the Havens units were more prone to failure, at higher protein strengths they gave a better flux than the Dorr Oliver units.

Once all Dorr Oliver units were installed, the strength of the final concentrate was very successfully controlled by a refractive index controller mounted on the final stage.

At Edendale, enzymatic cleaning of modules became the mainstay. Although the date of its introduction is not recorded, it was probably

Dorr Oliver ultrafiltration units at Edendale before their relocation in 1977 to Kapuni. This plant comprised 120 modules with 200 square metres of membrane area. At the time of the transfer the size of the plant was doubled.

after the team at NZDRI introduced it in 1970. The Edendale staff occasionally heard snippets of news about the parallel experiments at the NZDRI and later at Waitakaruru, using Abcor equipment. When we southerners attended the annual Dairy Science conferences in Palmerston North, we had long ears and short tongues.

By the spring of 1976, five Dorr Oliver units containing a total of 120 modules with a membrane area of 200 square metres had replaced all the Havens units. Edendale vegetable gardens were well supplied with fibreglass pea sticks for several years.

Mother liquor, the by-product left after the lactose crystals have been centrifuged from the condensed whey, was relied on by some farmers as supplementary feed for their cows, particularly in winter. However, as the removal of protein for Prolac increased, there was a decreasing amount of protein left in the mother liquor and farmers increasingly complained about its lower nutritional value. It was essential to have a sale for this by-product or lactose production would have a serious waste disposal problem. At the time, there was no prospect of increasing the whey supply so Edendale would be unable to increase its Prolac production. Little did we know then that, 32 years later, Edendale would become the world's largest dairy factory with a daily milk processing capacity of 15 million litres. (*Dairy Exporter*, September 2009.)

The move to Kapuni

The company decided to enlarge the Prolac operation and transfer it

to a purpose-built building at Kapuni. I was given the nine-month job to design, install and commission the enlarged plant at Kapuni, to be in operation by November 1977.

The whey supply at Edendale had been ideal for making soluble whey protein. All the whey came in a pipe from the cheese factory of the Southland Cooperative Dairy Company next door, as soon as it left the whey cream separator. It could not be fresher. Kapuni, on the other hand, had a variety of whey sources, all from separate and different sites. Many supplies, such as casein whey, were quite unsuitable for Prolac, so special arrangements had to be made to isolate fresh cheese whey for ultrafiltration.

Prolac was dried at Kapuni with a modified Stork spray dryer that originally dried mother liquor. Unfortunately this unit was in a separate building and the concentrated permeate had to be pumped across a railway line. The extra distance was less than ideal for transporting expensive concentrate, particularly when it came to the cleaning cycle.

The four stainless steel Dorr Oliver units from Edendale were supplemented by new units to give a total of 400 square metres of membrane surface. The spray dryer operator came on shift late in the afternoon and started by pre-evaporating the retentate to half its volume. The denser spray-dried Prolac particles reduced product losses in the exhaust air.

Two years later, Prolac production capacity at Kapuni was increased by adding Pasilac DDS modules, which almost doubled the existing membrane area. Conrad Heron, who was in charge of the plant about this time, recalls that the plants were run at 50C, but cleaning in place was required both in the middle of the run as well as at the end. After the DDS plant was installed, the Dorr Oliver and DDS plants were operated in series. The concentration ratio in the Dorr Oliver plant was 2:1. Then the DDS plant concentrated the product from the Dorr Oliver plant to produce the final retentate for 55 percent protein WPC.

Work was done to minimise losses and reduce CIP time by trialling different CIP chemicals, including different enzyme cleaners. The water used for cleaning the ultrafiltration plant was demineralised water, being condensate from the lactose evaporators.

Some cheese whey from Brixton that had been concentrated by reverse osmosis for lactose production at Kapuni, was trialled through the ultrafiltration plant to produce 55 percent WPC. This product had a higher mineral content compared with the WPC produced

from standard strength cheese whey. Thus we needed to use more diafiltration water to produce standard 55 percent WPC from this concentrated whey.

The Kapuni plant was upgraded further in 1988, but ceased operations in 1993 when a large new WPC plant was commissioned at the nearby Whareroa site of Kiwi CDC.

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APPENDIX III

THE DAIRY BOARD'S LETTER 1099

Attachment No. 26
8 March, 1982.

WHEY PROCESSING CORPORATION

The Committee set up following the last New Zealand Conference now reports as follows:-

1. BACKGROUND ANSWERS TO FUNDAMENTAL QUESTIONS

Why Does Whey Present a Different "Problem to the Industry"? :

Whey presents what is currently a unique problem to the dairy industry because it is an inevitable by-product of almost all forms of manufacture other than powder manufacture. In most cases the by-product can no longer be discharged to waste without treatment.

At first sight it would appear attractive to suggest that companies with little or no whey disposal problems should manufacture New Zealand's cheese or casein requirements, leaving the remainder to manufacture powder.

Unfortunately, the location of national milk supply is such that over 70% of New Zealand's milk will be processed in areas where there is a significant whey disposal problem. Even more importantly an attempt to rationalise production on the basis of whey disposal opportunities would remove the flexibility of production which is considered essential to New Zealand's marketing requirements. The only alteration would be the provision of additional small scale plants which could operate using available irrigation disposal methods.

The end result would probably entail a higher total capital expenditure across the industry, while still resulting in diminished industry flexibility.

Why Not Stick to Powders and Leave Other Countries to Cope With Whey Problems? :

Unfortunately, powders represent the most volatile of all our products - from a price point of view. There

Attached to the Dairy Board's Letter 1099 to all dairy companies on 30 April 1982, was the final report of the Whey Pools Committee. This detailed the background to, set-up and responsibilities of the proposed Whey Corporation. Regarded in the industry as a Bernie Knowles 'classic', it was a magna carta that was minutely scrutinised by dairy companies who were either making whey products or hoped to make them. The report was endorsed at an industry meeting on 30 May and the Whey Corporation was formally inaugurated on 8 June.

is no doubt that there is still potential for a vast "excess" of skimmilk powder within the world. Much of the present excess skimmilk is being accounted for by feeding stock straight skimmilk. The potential for manufacture of this quantity exceeds by several times New Zealand's total market. Hence, to lay New Zealand open to this form of competition would be to court disaster. The Committee is satisfied that the product flexibility sought and the availability of a product mix manufacturing capacity approximating present 1990 projections is still a valid requirement. On this projection of production, some 20,000 tonnes of whey solids is available for manufacture or must be otherwise disposed of.

What is the "Cost" of Whey Disposal?

There is a tendency to see whey disposal as a 'cost". Since the whey arises from the manufacture of a desired product, any costs of disposal must form part of the manufacturing cost of the desired product. This position is the same overseas!! The whey producing products (cheese and casein in particular) that we make and sell in competition with overseas manufacturers will have incurred whey disposal costs (often of higher unit cost) in their manufacture by others. These costs must be reflected in the manufacturing cost allowances made in the pricing by overseas manufacturers of the same products. Thus, whey disposal costs in New Zealand, if lower than costs overseas, represent a "plus" factor - notwithstanding that they are in fact costs.

Disposal "Costs" May be Lower When Capital Investment in Production Facilities is Made :

It must be remembered that costs of whey disposal are "net" costs. That is "cost" is the amount remaining after recoveries from the sale of any products manufactured from the whey, or after allowing for the value of whey sprayed on pastures. Notwithstanding that these "net" costs may from time to time appear high, they can well be much lower than the costs of a "simple disposal" solution. For example, it may well be that the investment of, say, $8 million in lactalbumin and alcohol facilities at Reporoa cannot be fully serviced from the plant's product income at today's prices and today's interest rates.

Be that as it may, a different perspective is apparent if it is acknowledged that the only alternative to spending $8 million on productive facilities would have been to spend $5 million on what might be described as a superior sewage plant. The net cost of servicing the standing charges of the $8 million investment will, by reason of the revenue (net after paying for materials and labour used) produced from it, be very much lower than the net cost of servicing (incl. labour) the $5 million project which has no associated income.

Fluctuation in Investment Returns :

Clearly, plants which otherwise incur the highest cost of "straight" (i.e. direct disposal to waste) whey disposal will be

those where it is most attractive to introduce whey utilisation activities - even though such utilisation activities may involve substantial capital expenditure and not cover full net costs. Normally, it could be left to market forces to sort out where each utilisation activity should best be pursued - on a marginal income basis. Unfortunately, the marginal income from any one plant or product is very much influenced by the number of participants, while any over-supply of a product which is likely to have only a domestic market (e.g. alcohol or hydrolised lactose) can well reduce sales returns to the level where no party will receive adequate net revenue (even where measured in terms of a minimum negative figure) when product is in excess supply and being sold down to its marginal value. This being so, there needs to be a measure of industry restraint, coupled with a centralised determination of the number and location of plants - based essentially on a market assessment of what the traffic will bear at various levels of production.

Conclusion :

For all the above reasons the Committee concludes that -

1) There is no reasonable prospect of reducing the quantity of whey required to be treated or disposed of by changing product manufacturing plans.

2) Because the whey producing products must, in fact, be manufactured, it should be an industry responsibility for determining the method of treatment or disposal to be adopted by any factory during a particular point of time and, following from that industry decision, the industry should provide the capital necessary for that plant.

2. APPLICATION OF CONCLUSION THAT INDUSTRY SHALL ACCEPT RESPONSIBILITY

Structure :

An industry structure acceptable to all who will be affected by whey processing decisions (which includes powder companies because of the effect of whey processing costs on the SNF [solids-not-fat] pool) should be established. While the Board has, and accepts, an overall responsibility for the planning of objectives for the industry, its direct involvement in manufacture is relatively small. Therefore, it is believed that a wider representation of manufacturing interests should participate in the decisions of the body controlling investment in and operation of whey processing facilities.

Whey Products Corporation :

The Committee, therefore, recommends the establishment of a Whey Products Corporation. This corporation should accept responsibility for planning use of all whey produced (excluding wash waters which include inevitably some wheys). Because it

is envisaged that for many years (perhaps forever) substantial quantities of whey will be either spray-irrigated or piped into waters which can receive them without detrimental effect, there may be some who would have felt that "whey disposal" corporation would have been a more realistic term than "whey products". We have chosen the latter because it should evoke positive thinking - the problem of whey disposal is at the same time a challenge and an opportunity - to manufacture something apparently worthless in itself and likely to have a negative value, into something which returns a positive contribution to the industry.

Hence, the choice of a Whey Products Corporation. Why a "corporation"? The term corporation is used because it best represents a group of institutions working together, employing assets in a continuing operation. The committee does not propose a limited liability "company" incorporation because the tax implications of a body holding separate assets and pursuing a separate and independent function would be adverse to the industry's interest.

Essentially, what is suggested is an unincorporated corporation - resembling in general concept the Herd Improvement Council of the Board, or the Bobby Calf Central Executive. Any funds or assets that either of these bodies have vested in the Board and form part of the industry's total investment, but the Board, notwithstanding its legal right to deal with such assets as it sees fit, holds them in a form akin to a Trusteeship, and administers them in accordance with the advice of the respective committees; always accepting that in the last resort the Board has ultimate responsibility, and could not if it were to receive a recommendation believed to be contrary to the interests of the industry, be expected to accept the recommendation.

The fact of the matter, of course, is that it is very seldom that the Board even alters the form of application of a recommendation - let alone rejects it. All such alterations are, in any case, referred back to the recommending body.

Ownership :

There is also the very real difficulty that the industry will be expected to finance whey products plants (including with them some whey disposal facilities) while not actually owning either the asset itself, or the land on which it is situated. The committee considers that a company's ownership and responsibility for any whey facilities located and operated in conjunction with one of its own plants, should remain with that company, but that there must be an obligation on the part of any company which has had whey treatment facilities financed by the Whey Products Corporation, to continue making those facilities available to the Corporation until such time as the Corporation abandons them as having no further possible use. This obligation for care and maintenance would be made effective through a contra requiring that such plant and equipment be maintained indefinitely (at Corporation cost) for the use of the Corporation, and if sold

or cannibalised towards the end of its useful life (or used for company benefit during its useful life) an appropriate credit would be required from the company to the Corporation.

Structure of Corporation :

As the operating assets would be part of dairy company assets while the benefit of company contractual obligations would accrue to the Board, as the legal institution capable of receiving benefits, the Corporation directorate is, in the first instance, analogous to an advisory committee of the Board. It is envisaged that the Board would receive the Corporation's recommendations at its regular meetings and would, so far as practicable, endorse them for immediate application. The Corporation's "Board" would set policy subject to Dairy Board acceptance and confirmation.

The Committee suggests that the Corporation would have a "Board" of ten persons. There will be one representative of each Ward as at present, plus two appointees who are members of the New Zealand Dairy Board and one ex officio appointment from the executive of the New Zealand Dairy Board. The Committee recognises that an appointment on a Ward basis does not recognise the disparity in milkfat or capital expenditure as between Wards, but accepts that exact correlation is impossible - even as it is impossible in the present structure of the New Zealand Dairy Board. However, there will be issues where the proportionate interest of a Ward should be recognised and the Committee would suggest that this can be met by allowing, at the request of any one member of the "Board", a poll to be taken wherein voting would be exercised on the milkfat strength of each Ward. In such a vote the two appointed Board members would have a "notional milkfat" equalling the average of the other seven members, but the Board executive member would not have a vote.

If any recommendation is made to the Board following a poll it would appear appropriate that the Board should be advised of the result of the poll in full detail in order that appropriate consideration might be given to the nature of the opposition which had continued after the decision on a poll basis.

While it would be the Committee's hope and expectation that polls would be few and far between, it is felt that a mechanism of this nature is essential if a structure which is essentially based on ensuring adequate communication is to become a decision making body.

While a policy making structure of the Corporation is determined as above, the executive structure would be essentially akin to a product division of the Board. Just as the Farm Production Division provides for Herd Improvement Council activities, so a Whey Products Division would be responsible for the marketing and administration of the Whey Products Corporation. All necessary services - e.g. finance, accounting, quality control and the like currently provided by the Board for other product divisions - would continue to be available to the Corporation.

Structure of Manufacture :

A separate schedule of the structure of existing whey products manufacture and treatment facilities is attached.

Responsibility for Wheys :

Essentially, the Corporation would have the responsibility for all wheys from the time of separation from the initial product, and after being gathered into a form of holding facility from which the next treatment or disposal can be commenced. While normally all whey in the holding tank would have the same value, appropriate adjustments would need to be made for any whey which is required to enter the holding tank after special processing, (e.g. pasteurisation), or under other specified conditions (e.g. at a temperature raised or cooled to X° Celsius) or for wheys which require a specific purity or other specification.

While the Corporation would assume control of the whey at the point of entry to the holding tank, and would be responsible for appropriate cost allowances thereafter, the change of ownership would be notional. Any failure to deal with the whey in accordance with agreed procedures would remain a responsibility of the company, and a loss of revenue to the company. The responsibility would be an "absolute" one and not merely a "best endeavours" situation.

For example, in a strike situation, while Wellington might be asked for suggestions as to steps to be followed, the companies would continue to have direct responsibility for the steps which were actually taken and any consequences thereof.

3. COMPENSATION FOR EXISTING FACILITIES

It is considered that the Corporation should accept responsibility to compensate companies for existing facilities.

Reason for Compensation :

Because it is envisaged that the Corporation will make future decisions as to which products will be produced by each company and will approve of all capital expenditure for plants producing whey products, there has to be a starting point at which existing units can be brought in to the Corporation. Without this, there will be plants within and without the Corporation and continuing anomalies.

Therefore, it is proposed that compensation be paid for all whey utilisation and whey disposal assets which have a continuing value to the Corporation. Facilities which will not be required in the foreseeable future (e.g. any disposal facilities at obsolete plants such as Toko, Katikati) will NOT be taken over, but would receive compensation if they were ever required at a later date.

This should not create any anomaly as between whey producing companies and powder companies, because as soon as the compensation is agreed upon, any Asset Use Payment allowances or

Redistributed Interest allowances, previously made for costs of facilities for whey disposal, will cease.

Basis for Compensation :

Without going into great detail, the basis for compensation would be expected to be as follows:-

a) Joint Purpose Plants -

There will be some plants which can be used for whey products, but which are not erected for that primary purpose. An example is a spray drier which can produce both skim powder and whey powder. In normal circumstances, no capital compensation will be made for such a plant. When it is used for whey product manufacturing, the product manufacturing allowance will provide a return of appropriate asset use and redistributed interest allowances, together with operating costs.

(N.B. "Appropriate" does not necessarily mean the same as the allowance made for skim manufacture. Skim manufacture AUP will be appropriate if the plant was used for whey powder throughout a season but would be inappropriate if used only for the off-peak period during which skim was not available to fill the plant.)

Thus, capital compensation is not appropriate for dual purpose facilities, but could be appropriate for a special facility added to allow whey usage (e.g. the added cost of a higher grade of stainless steel) provided that the plant is generally available for whey product manufacture.

b) Manufacturing Facilities Provided for Whey Products Only -

i) Underwritten Plants

Compensation would be based on the unamortised book value of plant in all underwritten plants. That is, companies would receive the amount originally expended on the capital facilities less the capital allowances and provisions made in the underwriting agreement and implemented up to the date of transfer.

ii) Company Plants

In recognising, as the terms of reference required, that the position of companies which had undertaken whey processing facilities at their own risk should be fully considered, the Committee was of the view that the principle that such companies should be no worse off than underwritten companies should be met. Thus, the original capital cost, less amortisation, would be appropriate except that where amortisation had been provided otherwise than out of revenue available for amortisation, after receipt by the company of a net

revenue at least approximating the incentives given for underwritten plants, the amortisation which had in effect been created by the "non-recovery" of costs, would be written back in the valuation of the plant.

For obvious reasons any valuation so derived could not exceed the reasonable replacement value of a plant of the same capacity. In short, the industry would not assume responsibility for obsolete plant if a company had entered the venture on its own account. The Committee was not aware of any plants within this category, but felt it necessary merely to state the principle.

c) Effluent Disposal Facilities -

An attempt has been made to estimate the likely replacement costs and values of various disposal and utilisation systems. Obviously, installed costs for many systems will be less than replacement costs.

In respect of disposal systems there is a major problem to be resolved. This arises because recent work at DRI tends to indicate that if an appropriate "selling" organisation was produced, the industry ought to be able to recover, as fertiliser value, from sale of whey sprayed on to pastures enough to pay the cost of distribution over a ten or fifteen mile radius. This, of course, assumes a need for fertiliser (perhaps missing the Hauraki Plains) and the availability of suitable vehicles (and nurse tankers) to spray out in otherwise unsatisfactory conditions. (It is advised that these vehicles are available in USA.)

If DRI figures could be sustained and an effective selling job done, existing disposal arrangements might well become obsolete, in respect of whey though not for wash water which has a much lower nutrient value.

Clearly the Corporation could hardly start off paying substantial sums for obsolete plant. It may have to make its offers on a basis which recognises that obsolete plant has to be written off and paid for in manufacturing costs, but not necessarily in the exact unamortised sum for each unit.

Clearly, also, even with existing units there has been as between companies a "trade-off" between capital costs and operating costs. Sophisticated spray irrigation units can cost three or four times the cost of "Model 1" units. The annual operating costs, exclusive of capital servicing, will reflect the additional capital input. If the industry is to use any averaging system, either in payment of capital or payment of operating costs, there must be a consistency - i.e. if the middle of the road plant is the basic plant and persons with sophisticated plant are to receive less than their full unamortised capital, they must receive an operating allowance which will show a possible "profit" to

amortise the unreimbursed capital cost. This is a problem that still requires to be wrestled with: It is believed that the industry would be unhappy to be called upon to pay to any company more than the reasonable unamortised value of the plant taken over, but if this is correct, it must allow for some differentials in operating allowances because the Corporation has in effect adopted different plants for different companies, with their concomitant operating costs.

Moving from this philosophical problem, we have estimates as follows:-

i) Pipelines

Disposal of about 1 000 cubic metres (i.e. half a million litres of wholemilk per peak day) over a 24 hour period requires a simple installation costing about $100 000 if the disposal point is within 5 km of the factory. This assumes the simplest of holding capacities (probably plastic lined concrete) and a simple discharge pipe. Costs rise very appreciably if the pipeline is to be taken out to sea and anchored, or if river crossings are necessary.

The annual operating costs of such a plant (excluding all capital servicing) are of the order of $7 000 to $10 000 per year. Costs do not rise directly proportionate to increased volume because clearly pipeline digging etc. is similar, whatever the size of the pipe. It would probably be likely that a 100% increase in capacity would increase costs by 50 to 60%.

ii) Spray Irrigation Systems

These vary very substantially, depending upon the degree of sophistication required. A fully automated minimum-labour cost system for a factory producing whey from about one million litres of wholemilk per day. is estimated to cost in the vicinity of $1 million.

Maintenance and operating costs are higher than straight disposal and would run to $80 000 to $100 000 per year, assuming that there was no land rental charge. The area to be reticulated would be about 270 hectares. In these systems there are relatively little economies of scale because the irrigation area increases directly proportionate to volume and, in fact, requires longer runs to dispose of the additional whey. Thus, pumps become proportionately bigger.

iii) Wash Waters

The systems referred to provide for the handling of wash waters as well as wheys. It is believed that up to one half of the capital cost would remain a company charge as the actual cost of handling wash water even if the Corporation accepts the need for a whey disposal system.

Reported company costs for the past season include figures up to 1.9 cents per kg/fat for spray irrigation from casein manufacture. These figures, of course, include capital servicing charges. The operating costs indicated are of the order of 1 cent per kg/fat. If capital from a $1 million system had to be serviced, costs would immediately rise to above 3 cents.

Holding Capacity for Wheys :

It is apparent that the varying standards of holding tank necessary for product required for further treatment, and product required for disposal would make a company obligation to provide tankage inequitable. Accordingly, it is felt that the Whey Corporation's capital obligations should commence at the holding tank entry point.

The indications are that the following criteria should apply -

a) Cheese

A study of cheese factories indicates that the appropriate point for delivery to the Corporation is immediately following the whey cream separator at a standard temperature of 32C and a standard composition. If the whey were delivered cooler and required so for the downstream processing, this should provide a credit on the whey value. DRI and Board figures indicate that the amounts of whey of standard composition would normally be about 7.5 cubic metres per tonne or about 17 litres per kg/fat for cheddar and cheshire cheeses, about 9 cubic metres per tonne or 18 litres per kilo fat for gouda and edam, and about 7.8 cubic metres per tonne or around 14.2 litres per kilo fat for mozzarella. Similar figures could be found for other types of cheese.

b) Casein

For casein factories it is considered that the point of transfer to the Corporation should be immediately following the plate heat exchanger and downstream of any standard fines recovery system such as rotary screens. While temperatures are more variable in casein factories a standard temperature of 40C appears appropriate with credits and debits for other temperatures perhaps being needed depending on the downstream process operated.

The volumes are also more variable depending upon the dewheying processes used - for instance press and centrifuge dewheying normally would give about 28 cubic metres of whey per tonne of casein for both lactic and rennet while screen dewheying only would give about 24 for lactic and 21 for rennet respectively. It is considered that one could strike an average of, say, 25 for both and at standard yield of .6007, this represents 15 litres per kg/fat - rather similar to cheese figures.

Effect of Compensation :

Once compensation has been paid, the Company has a continuing obligation, as long as agreed maintenance allowances are paid, to maintain the facility in good working order to be used as and when required by the Corporation.

There will be no further capital, AUP or redistributed interest allowances for compensated plant.

If it is agreed with the Corporation that any compensated plant should not continue to be maintained in an operable state, the company owning the same will be given the opportunity of negotiating for the discharge of its continuing operation (in effect buying the plant back) or required to dispose of the plant to best advantage, returning the net proceeds to the Corporation.

Thus, although ownership resides with the company, the use of the plant will be contracted to the Corporation for an indefinite continuing period, so that the equitable interest resides with the Corporation.

Replacement equipment, whether purchased out of the R & M allowance or provided directly by the Corporation (through cash allowances) will be subject to the same continuing contractual obligation of availability to the Corporation.

Once compensation has been effected, all whey producing companies are on the same footing as each other and should, in theory, not be advantaged or disadvantaged by future decisions of the Corporation to allocate particular products to them.

4. NON-CORPORATION PLANTS

i) Present Plants :

Such plants as the Lactose Company and the New Zealand Distillery Co. Ltd. (associated with RPD's whey utilisation) will presumably not be available for purchase and, therefore, do not receive compensation. The companies supplying those plants shall be deemed to acquire the whey supplied to the plant from the Corporation and shall normally account to the Corporation for the whey value received, being credited in turn with the whey value ascribed to whey by the Corporation.

Where a contract for supply exists between a participating company and a non-Corporation user, then the terms of the contract shall be tabled to the Corporation and the Corporation may, at its option, assume the position of the company or such part of that position as the Corporation may choose, returning to the company an ascribed value of whey related to the originating product.

ii) Future Plants :

It will be incumbent on the companies participating in the Corporation to present to the Corporation any proposals

available to them for whey product production. While it would be hoped that individual company initiative would be rewarded with an assignment to manufacture the product, there could at times be compelling reasons why production should be located elsewhere. In such circumstances it is to be hoped that the proposing company could accept the compelling reason and withdraw any opposition to the proposal being developed elsewhere - ideally accompanied by some compensation for any development work carried out.

However, there is always the possibility that the Corporation will not wish to pursue the opportunity. It is not the Board's desire that company initiative should be stifled and if the company feels the Corporation (or the Board) is being negative in its outlook, opportunity must be given to the Company to "go it alone". It is envisaged that this would be done in a contract with the Corporation whereby, in consideration for an agreement to purchase whey from the Corporation for an agreed sum (being not less than the credit given by the Corporation to the company for the same whey), the Corporation would undertake not to enter manufacture of that product for either a specific term of years or until a certain volume had already been sold on the New Zealand market for each of several years.

Obviously, if the Corporation rejects too many opportunities its membership needs to be reviewed. To this end, any rejected proposals should be separately reported to the industry each year to give the industry the information necessary to review the activity of the Corporation.

At the same time this provision maintains for each company "the right to be wrong" - a powerful spur to development of opportunity.

5. FINANCIAL ACCOUNTING

All transactions shall ultimately form part of the SNF account. A whey products section, broken down into the separate whey products themselves, will be prepared and within the limits of competitive confidentiality reported to the industry. The net result will, after including appropriate capital write-offs, be transferred to the SNF account. This is necessary because the alternative costs (of whey disposal) if there had been no whey product manufacture, would have formed part of the costs of manufacture of cheese and casein and would, in any event, have become part of the SNF account.

Because whey product manufacture is capital intensive and some product prices are likely to be volatile (being linked to sugar prices or sometimes to cereal prices) the present Committee (without binding the future Board of the

Corporation or the Board itself) would tend to the view that any early operating surpluses should be used to write down capital investment as quickly as is reasonably possible and politically (to the industry) practicable.

6. PRODUCT MANUFACTURING ALLOWANCES

i) Basic Allowances

Because there will be relatively few units manufacturing the same product and because there will be significant differences in efficiency caused by differing capital expenditure (in part decisions of the Corporation Board, and in part reflecting technological advancements in a rapidly developing technology) the traditional techniques of averaging will be difficult to apply. Indeed, in many instances it is probable that companies would not undertake manufacture if they were to be "averaged" with perhaps only a single company which might have significant fuel or transport advantages.

Hence, although careful not to accept a "cost-plus" philosophy, the Committee accepts that cost allowances will often need to be worked out on a basis which recognises the individual costs of a specific installation. Where industry standards exist for a specific activity these should, of course, be used, but in cases where such standards do not exist they will have to be created as the basis for determining allowances.

All the above must be translated to a product price which recovers manufacturing costs, and whey values, given satisfactory yield recoveries and product quality.

ii) Incentives :

a) Product Risk

Where there is a real risk that, notwithstanding reasonable management intervention, there can be a down-grading of product resulting in failure to recover full manufacturing costs, the incentive needs to be higher than in other cases. What is appropriate is hard to determine without knowledge of all conditions, including the percentage of a company's milkfat which can earn the incentive.

In many ways the sum of incentives can be more important than any individual product incentive.

However, in general terms, and having regard to the fact that some companies may be precluded from earning incentives because the Corporation finds it preferable to allocate manufacturing opportunities to other regional centres, it is unlikely that product incentives exceeding in total (i.e. the sum of incentives where more than one whey product is made) one per cent of the total end-of-season value of milk would be acceptable to the industry.

b) Other advantages accrue principally through the method used for apportioning company overheads against the cost of the whey product. Because the effect of different methods of apportionment can be of much greater monetary significance than incentives, it is important that an agreed basis for apportionment be determined. To make sure that the position is understood, an example is given.

Assume that there is a company with manufacturing facilities, costs and income as set out in A and B and that a third facility C is added to utilise the whey -

	A	B	C
Product	Butter	Casein	Lactalbumin & Alcohol
Quantity	8 000 tonne	4 000 tonne	
Value of Product	$17 million	$10 million	$5 million
Value of Plant	$5 million	$6 million	$9 million

If the cost of insurance of plant rises from $22 000 to $40 000 after the new plant is installed, the marginal cost of insuring "C" plant is $18 000 which is also the cost if the premium is apportioned in conformity with plant value. Hence in this case marginal and average costings produce similar results - no problems.

But if rates on the property were $5 000 before "C" was installed, what share of rates should be borne as cost of manufacturing "C"?

$^{5}/_{32}$ (15%) - proportion of product value?

$^{9}/_{20}$ (45%) - proportion of plant value?

Nothing - because the rates were all being absorbed before product C was manufactured and, therefore, C added no cost?

The latter is a marginal cost approach - the others being forms of absorption costing.

It may be suggested that rates are trivia - but what about milk collection. With whey solids equalling some 40% of total solids it is not hard to see the advantage which would accrue to a company which persuaded the Corporation that 40% of its milk collection costs should be recoverable as a whey product manufacturing cost. Marginal costing would eliminate any charge for milk collection because the milk will have been collected and made available to the factory whether there is any whey product manufacturing or not - it is paid for in the standard product.

However, while this example makes a prima facie case for costing whey manufacture on a marginal cost basis, there can be minor unfairness in such usage. In the case of rates, for example, the fact that they did not rise can only be due to the fact that the company was holding more land than was necessary for A and B only. If it had not been, more land would be needed and rates

would rise, and the rise applied under marginal cost procedures to C manufacture. Thus, there is the denial of an opportunity (i.e. to use the entire land taken for C for another purpose) when marginal costs are strictly applied.

It is, therefore, recommended that while the principle of marginal costing be used for manufacturing allowances for whey products, the Corporation accepts that when a company incurs an "opportunity cost" by manufacturing a whey product, negotiation to include that cost as the manufacturing allowance shall be a normal procedure of the Corporation.

Clearly, marginal costing cannot be applied too vigorously without creating unfairness. The fact that there is still only one general manager after activity "C" is undertaken does not mean "C" is without management cost. Either a more expensive manager will be taken on or his previous responsibilities will be spread in a different manner. The benefit of any doubt in apportionment must accrue to products "A" and "B" so that the company is not penalised. However, conventional apportionment will penalise all companies making standard products by reducing their cost allowances now calculated on the averaging of costs basis.

7. PROPERTY IN WHEY PRODUCTS

a) All product produced by whey product manufacturing plants should pass to the Corporation on the 20th day of the month following manufacture.

   Product reaching acceptable grades should receive the full value -manufacturing allowances, and whey value, plus or minus any grade differentials.

   Other product should receive an advance pending settlement of an appropriate final purchase price. This should be as close to the lower of:-

   i) actual possible realisation in the most favourable utilisation of such product; or

   ii) acquisition price of product meeting grade standards;

   as the Corporation is able to estimate.

b) Whey supplied to an accredited manufacturer (e.g. Lactose Company) shall be deemed a whey product - the property will pass to the manufacturer on delivery - payment to be made on the 20th day of the month following delivery.

c) Notwithstanding that property has passed to the Corporation, the manufacturing allowance shall include a sum to reimburse the company for storing up to 75% of its annual production to the account of the Corporation. Such storage shall be a bailment with all risks, other than insured risks notified by the Corporation to the bailee, to the bailee's account.

8. VALUATION OF WHEY

All whey, including that intended for waste discharge shall, initially, have the same value. It would be intended that the value should be as close as possible to the average residual return from whey (i.e. return after deducting manufacturing costs) in all whey products - but shall never be a negative figure. That value will, of course, be deducted from manufacturing costs of the base product (casein or cheese) from which they whey was derived.

While seasonal compositional differences exist it would appear that these would not be great enough to justify variations in whey value during the season. If significant use opportunities for cheese or casein wheys differ in value, an appropriate variation to whey values is a possibility.

The value of wheys of different composition depends upon their use in each case so this would have to be determined for the particular circumstances surrounding a given combination of operations. However, dilution would almost always be of importance. It would, therefore, be proposed to assess the whey composition against the standard volumes given earlier by means of checking total solids only - although some faster inferential method might well be developed - and it would be necessary from time to time to do overall checks to ensure that the whey remained of normal composition, which averages as follows -

	Rennet	Cheddar	Lactic	Sulphuric
Total solids %	6.6	6.7	6.4	6.3
Ash %	0.5	0.52	0.75	0.79
True protein %	0.62	0.62	0.58	0.58
Lactate	Low	0.2	0.6	Low, but high sulphate

To give more detail, the total solids varies approximately plus or minus 2½% seasonally. Protein also varies about the same amount, but is normally higher when the total solids is lower, thus having a compensatory effect, except perhaps at the very tail of the season. Ash is fairly constant (it is generally an undesirable constituent), lactose varies about plus or minus 2½% also. Lactose content, however, does fall out of this range very late in the season. The lactate which is a measure of acidity can be a problem with some uses. Sulphuric and hydrochloric casein wheys present special problems of their own.

Bearing in mind that the raw value of whey is presently quite low, it would be an unreasonable refinement at this stage to attempt to distinguish between wheys although the possibility can be regularly reviewed.

Payments for Whey :

It would be desirable to pay companies on the basis of kilos of fat handled for whey going to waste disposal only. Such a

system is simple and it is believed equitable, and avoids need for other measurements. However, for whey for processing it would be necessary to pay on volume at standard composition and temperature. Appropriate figures are indicated above - these would need to be extended for other types of whey etc. Any upstream operations which resulted in the whey being more appropriate for the downstream process required, should be reimbursed to the producing company at cost or benefit to the downstream users, whichever is less.

9. COMPANY CONTRACTS

The basis for continuity of Corporation activity lies in the contract between the company and the Corporation. This must be analogous to the present underwriting contract providing for

a) Continuity for so long as the Corporation pays a manufacturing allowance in accord with the contract.

b) Obligation for the company to account for the plant and equipment financed by the Corporation if the product manufacture shall be abandoned.

c) Agreement on any special conditions which are to apply to ensure the manufacture of sufficient of the whey-producing product to provide for economic use of the whey-utilisation plant.

All such costs fall on the Corporation, but equally the company has a continuing liability on itself and its successors to meet its obligations.

10. CAPITAL COSTS

While it may be argued that the early payment of compensation of about $40/50 million to the casein and cheese plants places them at some advantage, the reduction in AUP and redistributed interest which follows that payment should balance the position. As reimbursement is based essentially on book values, there will be no surpluses arising for tax-free distribution, although the company's individual cash flow position should be easier.

At a time when most companies are needing funds for their capital programmes, the eased cash flows can only be to industry advantage.

11. EXISTING CONTRACTS

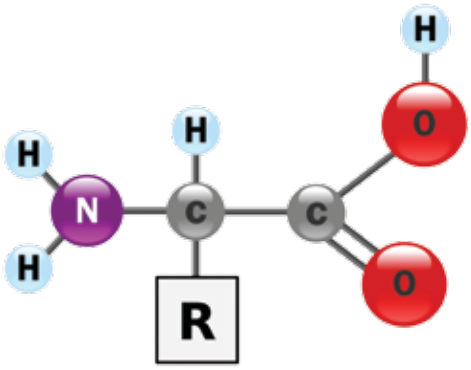
It is appreciated that a number of companies hold underwriting contracts with incentives and allowances which may be more generous than contemplated under the Whey Corporation proposals. It would be hoped that all companies would commit themselves to an industry plan for whey utilisation with similar rulings and accordingly that those companies currently holding underwritten projects would renegotiate their contracts in line with the standard future contracts of the Whey Corporation. It would be essential to have agreement in principle that this should apply before companies could be asked to accept what will be a standard

industry practice. Clearly, if any company is significantly "out of line" by reason of past capital arrangements, an embarrassing (and perhaps even an impossible) situation would arise. It is realised that such companies did undertake a measure of a pioneering role and, provided that other companies which were not underwritten receive appropriate allowances to place them as nearly as possible in the same position as the underwritten companies at the time of transfer, the retention of past benefits would be a proper measure of reward for that initial pioneering co-operation.

[Five pages of tables and diagrams followed.]

GLOSSARY & ACRONYMS

Amino acid: amino acids are the building blocks of protein molecules. Each one consists of a central carbon atom to which is attached an amino group (-NH_2), a carboxylic acid group (-COOH), a hydrogen atom (-H) and a side-chain (-R). The side chain is different for and specific to each amino acid of which there are 20 that are common to most living organisms. The nature of the side chain dictates where the protein molecule folds and bestows hydrophilic or hydrophobic properties to the molecule. (See also 'peptide bond' and 'protein structure'.)



The generic structure of an alpha amino acid in its non-ionised form.

Anion: see Ion.

Asymmetric: describes a condition in which the physical properties of a membrane depend on the direction in which they are measured. See Appendix I, page 203, "The key discovery that underlies all commercial-scale separations..."

Batch mode: in batch mode (no longer used in commercial whey operations), at the start of operations all the feed whey was pumped to the feed tank. From there whey was circulated through the membrane equipment and back to the feed tank. Progressively the protein content of the retentate in the feed tank rose until the required final

composition was reached. See Appendix I, page 212 "batch".

Biochemical Oxygen Demand (BOD): a measure of the amount of dissolved oxygen needed by aerobic biological organisms to break down organic material present in a given water sample at a certain temperature over a specific time period.

Calf vells: dried stomachs of slaughtered young male calves from which natural rennet is extracted.

Casein: the main group of proteins in bovine milk comprising around 80 percent of total milk protein. The caseins are distinguished by the fact that they are precipitated in acid conditions and by the action of rennet. The word casein derives from the Latin word caseus meaning 'cheese'.

Caseinate: casein that has been precipitated by acid can be made soluble again in alkaline conditions and dried. Depending on the alkali used, the product is called sodium caseinate, potassium caseinate, calcium caseinate etc.

Cation: see Ion.

Collab: the international Whey Protein Collaborative Research Group. See page 98, "Collab".

Concentration factor: is the ratio between the concentration of the product solution, or retentate, to that of the feed solution. This may refer to the whole UF plant or it may refer to only part of the plant, such as a single UF stage.

Concentration polarisation: is an accumulation mostly of protein and fat species in a narrow layer of liquid adjacent to the surface of a selective membrane. It is the controlling factor for flux and even influences selectivity. See Appendix I, page 207.

Continuous mode: means that, once started up, there is a continuous feed of whey into the membrane plant at one end and continuous withdrawal of concentrated retentate from the other. Continuous ultrafiltration plants operate as stages-in-series with recirculation of retentate in each stage. At least once a day the plant is shut down for cleaning. See Appendix I, page 214, "multi-stage".

Denaturation: an alteration in the shape or conformation of a protein molecule, caused by a disruption of the cohesive forces that hold a protein in its native state. This disruption may be caused for example by heating,

pH change, pressure, shear, or aeration. The change is typically irreversible but in some cases may be temporary.

Diafiltration: the addition of water to the retentate stream in one or more ultrafiltration stages to aid removal of additional permeable solids without excessive concentration of retained solids. Diafiltration permits the routine production of WPCs with very high protein contents. See Appendix I, page 214, "diafiltration".

Diatomaceous earth: diatomaceous earth filter aids are a processed form of a sedimentary deposit of the skeletal remains of diatoms, a group of single celled marine algae. They are microscopic in size and consist primarily of silica. The structure is filled with pores and channels making them ideal for extremely fine scale filtration. When coated onto a coarse filter they improve the removal of fine particles. They are widely used in swimming pool filters and in filtering beverages.

Divalent: see Ion.

Electrodialysis: this is a membrane-based demineralisation process that relies on the electric charge on ionic species to separate them from neutral species.

Emulsion: an emulsion is a stable, non-separating mixture of two or more liquids that are normally immiscible, like oil and water. In an emulsion, one liquid phase (the dispersed phase) is distributed as very fine droplets throughout the other liquid (the continuous phase). The dispersion of milkfat globules (about 1 to 10μm in size) in milk serum is an example. The word 'emulsion' is derived from the Latin word mulsum, the past participle of mulgere, to milk.

Enzyme: an enzyme is a protein that acts as a catalyst in a metabolic or biochemical reaction by lowering activation energy, the energy barrier between the substrate, or starting molecule, and the product. A metabolic reaction that would not normally take place at physiological temperatures can occur quite rapidly in the presence of a specific enzyme.

Flux: the quantity of permeate that flows through a unit area of membrane in unit time, usually expressed in litres per square metre per hour.

Fouling: involves the adsorption or trapping of unwanted material that is present in the fluid being transported across the membrane. Fouling involves a physical or chemical interaction between the foulant and the membrane, the foulant being more closely bound to the membrane surface

than is the case with concentration polarisation. See Appendix I, page 215.

Functionality: see sidebar on page 97.

Gel filtration chromatography: a process carried out in a column packed with special resin beads that separates molecules according to their size and shape. The stationary phase in the column consists of beads containing pores that span a relatively narrow size range. Smaller molecules in the mobile phase (which could be whey) spend more time inside the beads than larger molecules and are therefore delayed in their passage through the column. As a process for protein recovery, liquid chromatography involves water elution (flushing the material retained in the pores of the beads out with water) with the consequent dilution inherent in this procedure. It is the process of choice for fine separations between protein molecules of different sizes rather than for the coarser separation of proteins from sugars.

Gelation: See sidebar on page 99.

Glycomacropeptide: a large peptide molecule of 60 amino-acid-length and of a molecular weight of about 8000 daltons, cleaved from κ-casein by the action of the enzyme rennin (chymosin) during the manufacture of cheese and rennet casein. (The residual portion of the κ-casein protein chain is 105 amino acids long.)

Hydrolysate: protein hydrolysates are products where the proteins have been broken down into much smaller peptide chains and free amino acids by the action of proteolytic enzymes. A major end use for these products is providing protein nutrition to infants who are allergic to intact (unhydrolysed) milk proteins.

Ion: a single atom or group of bonded atoms in which the total number of electrons and the total number of protons are not equal, giving the atom or group a net positive or net negative electrical charge. A positively charged ion is called a cation. Examples are the sodium ion, Na^{+}, and the calcium ion, Ca^{++}, a divalent cation (meaning it has two positive charges). A negatively charged ion is called an anion. Examples are the chloride ion, Cl^{-}, and the sulphate ion, SO_4^{--}, a divalent anion (i.e. having two negative charges).

Macromolecule: this term is applied to and describes a very large molecule usually produced by the polymerisation of smaller subunits, called monomers. In biochemistry the term is commonly applied to proteins, which are polymers of amino acids, as well as to other biopolymers.

Membrane: a selective barrier that allows the passage of certain constituents in a liquid and not others. Synthetic membranes intended for separation duties are made with a very thin skin that is integral with the body of the membrane. Known as asymmetric membranes, they are fabricated with pores in the skin of a size that is controlled to suit the separation duty intended. See Appendix I, page 202, "What is a membrane?"

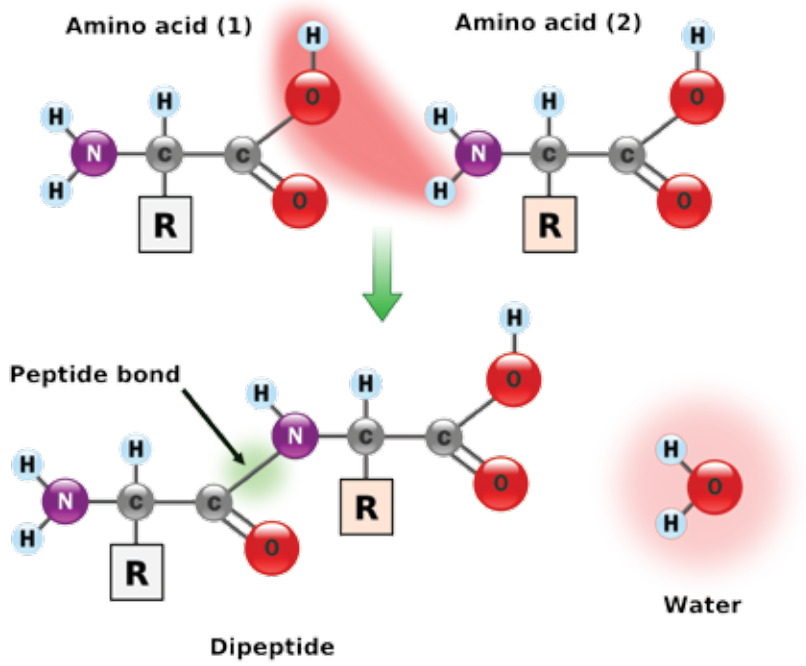
Micelle: an aggregation of molecules dispersed in a liquid. A typical micelle in aqueous solution forms a structure with the hydrophilic (water-attracting) portions of each molecule oriented towards the water and the hydrophobic (water-avoiding) portions oriented to the inside of the aggregate. Casein exists in milk as micelles around 100nm in size.

Molecular weight cut-off: an indirect measure of the pore size of a membrane. It implies that molecules which have molecular weights greater than the cut-off value will not be able to pass through the pores. It is not a precise measure, because molecular weight does not define molecular dimensions with precision; nor are pore sizes precisely uniform.

Osmosis: when pure water is separated from a water solution of a solute (say salt or sugar), by a semipermeable membrane (i.e. it is permeable to water but not to the solute) then water will diffuse spontaneously through the membrane from the pure water side towards the solution, tending to reduce the concentration of solute in the solution. This process is called 'osmosis'. Osmotic pressure is the pressure that needs to be applied to the solution to prevent the diffusion of water through the membrane. As solute concentration increases, osmotic pressure increases. The higher the molecular weight of the solute, the lower is the osmotic pressure. 'Reverse osmosis' is the name given to the process of forcing water to pass through the membrane from the solution into the 'pure' solvent by the application of a pressure to the solution that is greater than the osmotic pressure. (See Appendix I, page 205, "overcome the so-called osmotic pressure".)

Peptides: proteins are chains of amino acids linked by peptide bonds, making them 'polypeptides'. In a peptide bond the amino group, $-NH_2$, of one amino acid combines with the carboxylic acid group, –COOH, of another, with the loss of a molecule of water, H_2O, as illustrated. The word peptide in commercial use refers to a portion of a once-intact protein molecule that has been cleaved off the protein by the action of a proteolytic enzyme.

Permeate: liquid which passes through the membrane is called permeate (because it permeates through the membrane). The permeate which



The condensation of two amino acids to form a *dipeptide* through a *peptide bond*.

results from ultrafiltration of whey includes water, lactose, minerals, vitamins (the permeate is yellowish because of the presence of vitamin B2) and a proportion of the non-protein nitrogen (NPN) content.

pH: a measure of acidity and alkalinity. Acid solutions have a pH of less than 7; the more acid the solution, the lower the pH. Alkaline solutions have a pH greater than 7; the more alkaline the solution, the higher the pH. The pH scale is logarithmic, which means that a change of one pH unit corresponds to a change in acidity or alkalinity of 10 times. A pH of 4 is 10 times as acidic as a pH of 5 and a pH of 3 is 10 times as acidic as a pH of 4.

Protein: proteins are long molecules made of individual amino acids linked together by peptide bonds. For example, α-lactalbumin is a chain of 123 amino acids and β-lactoglobulin is a chain of 162 amino acids. The amino acid sequence in the chain is known as the primary structure of the molecule.

Protein structure: protein molecules are folded into complex structures. Two regular formations are commonly found in portions of numerous protein molecules. These are known as the α-helix and the β-sheet. These two formations are known as the secondary structure of proteins. The shape of the molecule as a whole is dictated by the internal bonding interactions between the side chains of the constituent amino acids. This is known as the tertiary structure of the molecule. Some protein molecules associate with each other further in a quaternary structure. For example, bovine β-lactoglobulin is a relatively small protein with a primary structure of 162 amino acids. As illustrated on the web site referenced below, this chain forms a couple of alpha spirals and several beta strands which then form part of a complex tertiary structure. When secreted this protein is predominantly dimeric (two molecules linked together in a quaternary structure). However, it dissociates into single molecules below about pH 3. For an illustration of the secondary and tertiary structures of β-lactoglobulin see http://en.wikipedia.org/wiki/Beta-lactoglobulin.

Protein analysis: there are two protocols for reporting the protein content of milk, whey and whey products. One records 'total protein' and the other records 'true protein'. Protein is analysed by a method which involves converting all the nitrogen in a sample into ammonia. This is then measured and reported as the 'total nitrogen content' (TN) of the sample. Multiplying this value by 6.38, a standard conversion factor derived from the known nitrogen content of dairy proteins, gives a result that is quoted as the 'total protein' content of the sample. However, not all the nitrogen evolved from milk or whey as ammonia during analysis comes from protein. Some of the nitrogen from milk, perhaps as much as 3%, is naturally present in milk as amino acids and peptides, which are subunits of proteins. Another 3% or so comes from a number of simpler nitrogenous compounds such as urea which are not protein subunits. Such compounds are generically grouped together under the catch-all term, non-protein nitrogen (NPN). In a more complex analysis, the 'real' protein in milk or whey is precipitated from the sample and removed by filtration. Then a second analysis is used to assess the NPN content of the clear filtrate. The 'true protein' content of the sample is then calculated as (TN – NPN) x 6.38. Because much of the original milk protein has been removed as cheese curd or casein, the remaining NPN content of whey can represent as much as 30% of the TN measured. Thus, while the total whey protein content of milk is quoted as 0.7%, the true whey protein content is closer to 0.5%. The true protein content is a measure of the

components that will not pass through an ultrafiltration membrane and is thus important in estimating the potential yield of the process, However, as most NPN components are lost in the permeate from the ultrafiltration process, the difference between the 'total' and 'true' protein contents of whey protein concentrates is much less significant.

Proteolysis: is the breakdown (lysis) of proteins into peptides or amino acids by enzymes called proteinases which hydrolyse the peptide bond.

Rejection coefficient: the selectivity of a membrane is measured for individual molecular species and is expressed as a rejection coefficient, R, that can range from 0 to 1. The rejection coefficient for component X, R_X, is defined as:

$$R_X = 1 - \frac{(\text{concentration of X in the permeate})}{(\text{concentration of X in the retentate})}$$

For a component A that cannot get through the membrane (concentration of A in the permeate = 0), $R_A = 1$; for a component B that is not impeded by the membrane (concentration of B in the permeate = concentration of B in the retentate), $R_B = 0$. An ideal (i.e. perfect) ultrafiltration membrane would reject all protein molecules ($R_{PROTEIN} = 1$) and offer no barrier to lactose ($R_{LACTOSE} = 0$). However, actual membranes are not 'ideal' and, in practice, we observe $R_{PROTEIN} \approx 0.985$ and $R_{LACTOSE} \approx 0.15$.

Rennet enzyme: see side bar 'The action of rennet', page 29.

Retentate: liquid which has not passed through the membrane is called retentate (because it is retained). This will contain the protein molecules and fat particles, plus that fraction of the water and other permeable molecules which have not passed through the membrane.

Reverse osmosis: See osmosis.

Shear thinning: a property of certain gels or fluids that are thick (viscous) under static conditions but will flow (become thin, less viscous) over time when shaken, agitated, or otherwise stressed. A common example is paint which flows easily on to a vertical surface when brushed but stays there when the brushing stops.

Sintered: sintering is a method for creating porous solid objects from powders. In most sintering processes, the powdered material is held in a mould and then heated to a temperature below the melting point. The atoms in the powder particles diffuse across the boundaries of the particles, fusing the particles together and creating one porous solid piece.

Starter: a starter culture is the source of bacteria needed for the fermentation of milk in the production of cheese and lactic casein. Pure cultures of these bacteria are propagated under controlled conditions to become "bulk starter". The bacteria are in a strong growth phase when added to the bulk milk so that they multiply rapidly, using lactose as their substrate and producing lactic acid.

Thermophilic: describes microbiological species that require high temperatures (45C to 60C) for normal development.

Ultrafiltration: Molecular sieving using semipermeable membranes with a molecular weight cut off above about 6,000 Daltons.

Water binding: in food technology, refers to the ability of organic molecules such as starches and proteins to bind water. Significant quantities of water are bound to proteins by hydrogen bonding to the polar hydrophilic groups attached to the amino acids of the protein chain. The capacity of a protein to bind water is dictated by the number of these groups on the protein chain. The water-binding capacity of proteins can be predicted from their amino acid composition. Some non-polar amino acids (alanine, valine) bind only one water molecule. Amino acids with ionic side chains (aspartic and glutamic acids and lysine) may bind four to seven water molecules per molecule of amino acid. The whey proteins are well-endowed with amino acids that are hydrophilic (water-attracting), in contrast to the casein proteins that are predominantly hydrophobic (water-avoiding).

ACRONYMS

CAB: Cellulose acetate butyrate
CDC: Cooperative Dairy Company
CSIRO: Commonwealth Scientific and Industrial Research Organisation (Australia)
DDS: De danske SukkerFabrikker (Danish Sugar Company. A manufacturer of ultrafiltration equipment.)
EEC: European Economic Community
IDF: International Dairy Federation
MTV: Morrinsville Thames Valley Dairy Company
NDC: Northland Cooperative Dairy Company
NK: Nissei Kyoeki
NPKK: Nippon Proteins Company Limited

NSPO: Non-standard purchase order
NZCDC: New Zealand Cooperative Dairy Company
NZDRI: New Zealand Dairy Research Institute
NZMP: New Zealand Milk Products
OSU: Ohio State University
RO: Reverse osmosis
RPD: Rangitaiki Plains Cooperative Dairy Company
TATV: Te Aroha Thames Valley Cooperative Dairy Company
UCLA: University of California
UF: Ultrafiltration
UHT: Ultra high temperature (referring to a sterilising process for liquid foods that can therefore be stored at room temperature)
USDA: US Department of Agriculture
WPC: Whey protein concentrate
WPI: Whey protein isolate

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