

# Overcoming heat stability issues with Whey

A new way of designing high protein products with microparticulated whey proteins.

By Esra Cakir-Fuller and Aaron Fanning



# Introduction

Whey protein is a valuable nutrient that is of interest to numerous consumer segments including infant formula, healthy ageing, weight management, sports performance and recovery, and the medical nutrition market.

## HIGH QUALITY PROTEIN FOR ALL LIFE STAGES

Whey is the highly nutritious liquid by-product that results from the coagulation of milk and is generally produced from the manufacture of cheese or casein. Whey protein is a high quality dairy protein – with an excellent protein digestibility corrected amino acid score (PDCAAS) – and is not only naturally high in essential amino acids and the branched chain amino acids but also uniquely high in the amino acid leucine, the amino acid that is thought to be critical to the stimulation of muscle protein synthesis. This high level of leucine, as well as a unique fast digestion profile, enables whey protein to stimulate muscle protein synthesis to a greater extent than casein and soy protein in young<sup>(1)</sup> or older adults<sup>(2,3)</sup>. Through all these unique nutritional properties, whey proteins deliver a broad range of health and application benefits to different consumer targets, across life stages.

### Whey protein:

- Is often used to increase the whey protein content of infant formula to closer to the high whey protein content that is found in human breast milk.
- Promotes healthy weight management by promoting satiety following consumption and by supporting muscle maintenance.
- Provides high quality amino acids to promote recovery from sports activity and to stimulate muscle protein synthesis. It is a particularly sought-after nutritional ingredient for the sports nutrition market because of its unique nutritional benefits, not only for elite athletes and professional body builders but also for people who are seeking an active lifestyle.
- Supports healthy ageing by promoting more muscle protein synthesis to help to maintain muscle as we age.
- Is a protein that is of interest for medical nutrition as it is an abundant supply of essential amino acids, is easily digestible and promotes muscle protein synthesis, helping to maintain muscle mass for hospitalised and convalescing patients.

## Protein has a key role to play across the lifestyles



"Whey proteins deliver a broad range of health and application benefits to different consumer targets, across life stages"





## LARGE OPPORTUNITIES, PLENTY OF COMPLICATIONS

The increasing health and wellness trend among consumers drives many food and beverage manufacturers to seek opportunities to boost the whey protein content in their products. Although whey proteins have significant potential for use in beverage formulations at high concentrations, their use is limited because of their susceptibility to heat-induced destabilisation.

Nutritional beverages, like many other liquid food products, are subjected to high heat treatments during processing [i.e. retorting or ultra-high temperature (UHT)] to ensure product safety and extended shelf life. However, the thermal treatments applied to liquid formulations to provide microbial control cause whey proteins to denature irreversibly and to polymerise into aggregates or gels. As a consequence, the products exhibit unwanted sensorial attributes such as chalkiness, sandiness, lumpiness and high viscosity, and limited shelf life because of sedimentation or gelation soon after production. These problems are more prevalent in formulations with high whey protein content, leading to products with unwanted aggregates and a risk of extensive fouling and blocking of the production plant, such as UHT heating equipment.

## ADVANCED TECHNOLOGIES PROVIDE A SOLUTION

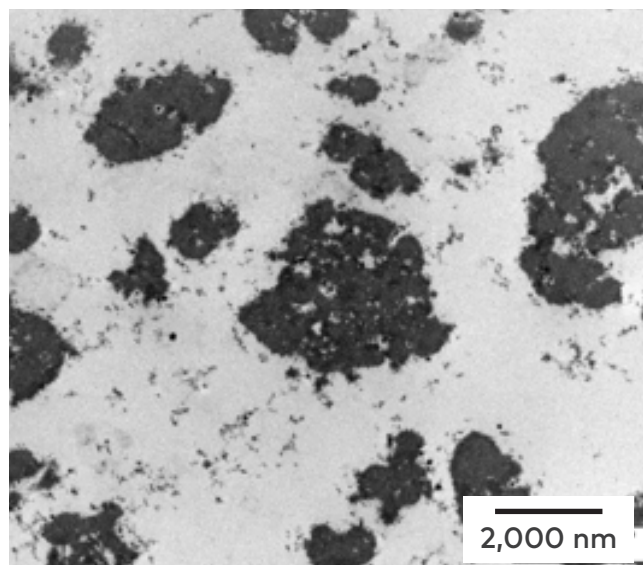
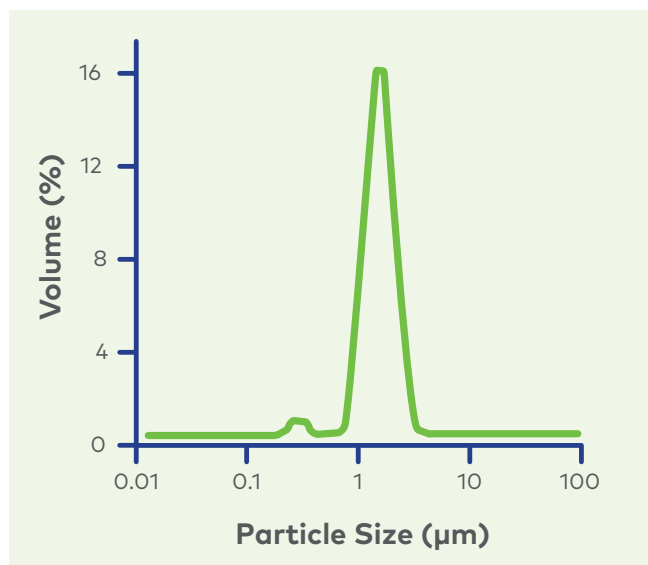
The design of whey protein ingredients with enhanced heat stability characteristics is essential for optimal performance in liquid formulations. The microparticulation of whey proteins is an advanced technology for the production of micro-aggregates with enhanced heat stability<sup>(4)</sup>.

Microparticulation is generally achieved by thermal aggregation or acid precipitation, combined with high shear and high pressure conditions<sup>(5)</sup>. Microparticulated whey protein concentrate (MP-WPC) can be regarded as a combination of native proteins and both soluble and insoluble protein aggregates of controlled size. The microparticulation conditions are well controlled so that the denatured whey protein is restricted to a certain degree of aggregation, and the aggregate particle size is tightly controlled. A commercially available microparticulated whey protein with 80% protein (Sure Protein™ Vital WPC550 from NZMP) is used here to demonstrate the functional and nutritional benefits of MP-WPC80. The protein particles formed through the microparticulation process exhibit limited interaction with each other because the number of free thiol groups that is normally available to form larger aggregates is significantly reduced<sup>(5)</sup>. This essential feature enables microparticulated whey protein to be stable under high temperature heating (i.e. retorting or UHT) and to allow it to be added as an ingredient at high concentrations with no adverse effects during processing.





**Figure 1. Particle size distribution and transmission electron microscopy image of MP WPC80 at a protein concentration of 10% (w/w).**



The small protein particle size (Figure 1) is critical for good suspendability in beverage applications to obtain a long shelf life with no sedimentation. The size of the microparticulated protein particles is

also important in delivering the desired mouthfeel; particles from 0.1 to 3 µm impart a creamy mouthfeel whereas aggregates > 3 µm cause a powdery to gritty sensation<sup>(6)</sup>.

## A WHEY PROTEIN THAT TICKS ALL THE BOXES

During this protein modification, it is essential to ensure that the whey protein has the same nutritional properties that are desired by manufacturers and consumers alike. Although previous research identified a minor difference between intact whey protein and a microparticulated product<sup>(7)</sup>, this utilised an old model of protein quality rather than the current gold standard of the PDCAAS. Using the PDCAAS method, there is no measurable difference between a standard WPC and the microparticulated product (Table 1). Another unique factor of whey protein is its rapid digestion, which results in a pronounced peak of amino acids in the blood following consumption, and this pronounced peak is associated with an increased muscle protein synthesis response<sup>(1)</sup>. We have conducted additional research<sup>(8)</sup>, which examined the consumption of MP-WPC compared to standard WPC, on the post-meal amino acid kinetics and the muscle protein synthesis response in middle aged men. This data indicates that the consumption of a beverage containing MP-WPC results in the same plasma amino acid response and the subsequent muscle protein synthesis response, as that achieved from the consumption of standard WPC.

**Table 1. Protein quality assessment of three whey protein ingredients (unpublished observations).**

	Protein Digestibility	Protein Digestibility Corrected Amino Acid Score (PDCAAS)
Micro-particulated whey protein	98.7%	1.00
Whey protein concentrate	98.8%	1.00
Whey protein isolate	99.1%	1.00

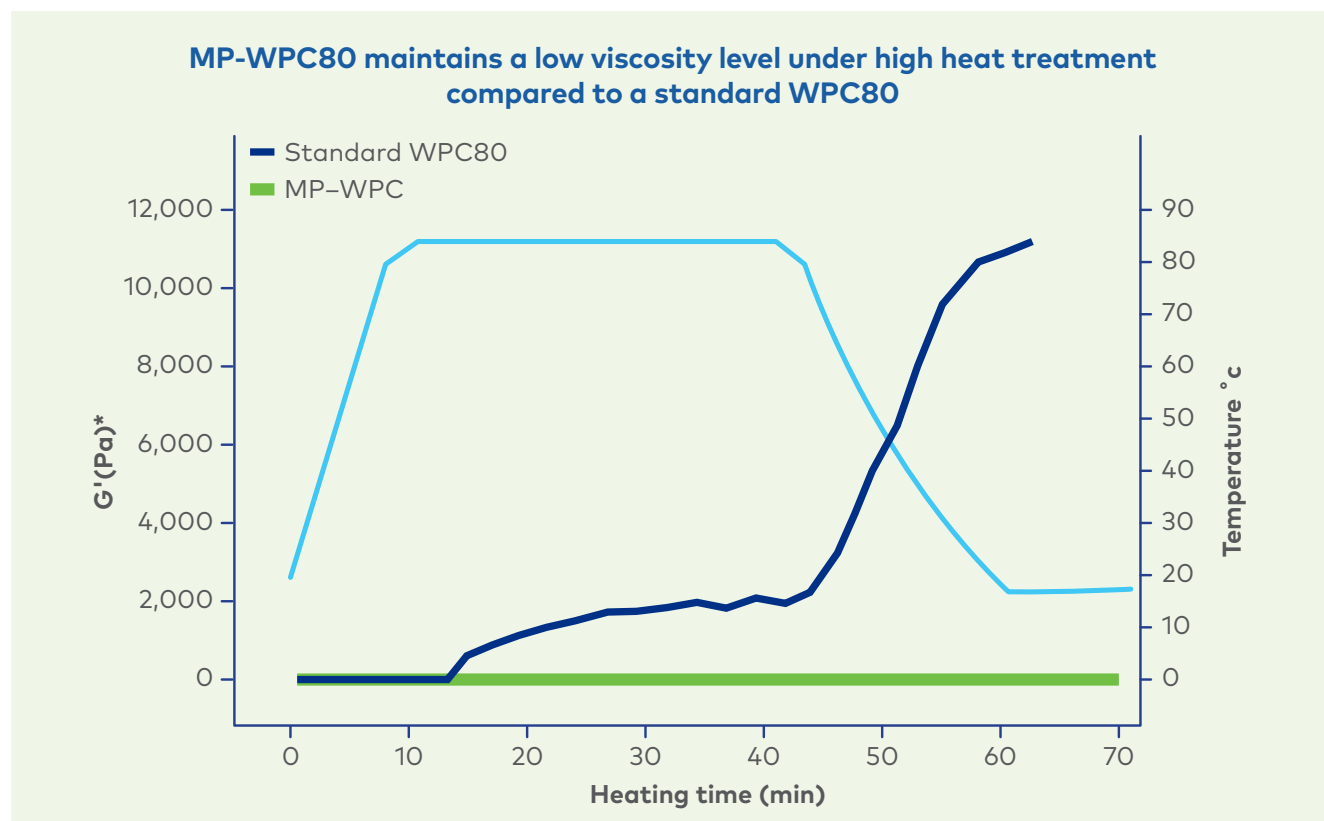
Thus, a microparticulated whey protein ingredient provides the full nutritional value of a standard WPC while delivering good thermal stability with no gelation or sedimentation upon processing and after a prolonged shelf life (12 months) at ambient temperature.

Figure 2 outlines the gelation behaviours of standard WPC and MP-WPC, as characterised by the change in the storage modulus ( $G'$ ) during heating and holding for 30 min at 85°C. For a standard whey protein concentrate (WPC80) solution at a protein concentration of 15% w/w, a significant increase in  $G'$  is evident upon heating, corresponding to the formation of a strong gel. In contrast, a protein solution prepared with MP-WPC80 under the same conditions does not form a gel and the  $G'$  remains stable throughout the complete temperature profile. This indicates that MP-WPC has a great potential as an ingredient for high protein beverage applications, for which gelation on thermal processing is undesirable.

An example of high protein emulsion systems, similar to medical nutritional beverages, is used here to demonstrate the enhanced heat stability of MP-WPC under retort conditions in comparison with a standard WPC (Figure 3). When a neutral pH (pH 7.0) emulsion of standard WPC is subjected to a retort treatment of 120°C for 10 min, a strong gel network is formed at a protein content of 4%. Confocal laser scanning

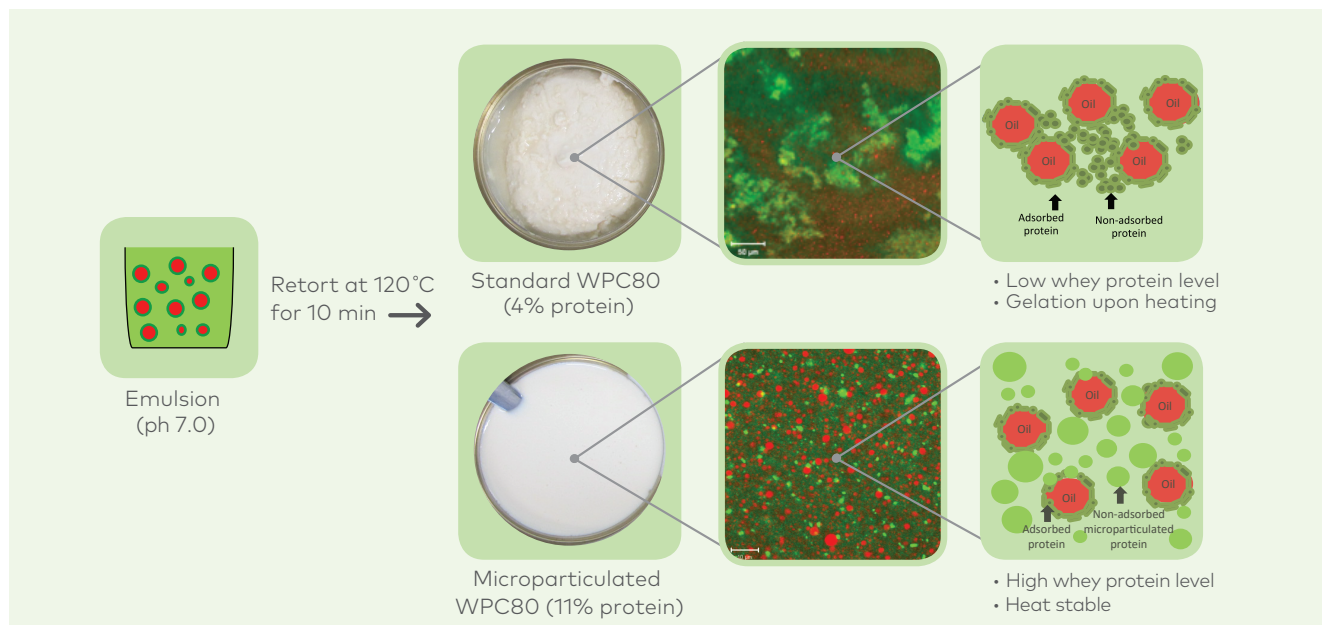
microscopy (CLSM) of the retorted emulsion confirms the likely gelation mechanism of the standard WPC. When standard whey protein is used in oil/water emulsions, part of the protein is adsorbed around the oil droplets and the excess non-adsorbed protein is present in the aqueous phase. Upon heating, the non-adsorbed proteins unfold and interact, producing large aggregates that, in turn, act as "glue" between adsorbed whey protein layers of neighbouring droplets. However, when MP-WPC is used, visible aggregation or gelation does not occur, even up to much higher protein concentrations (11%, w/v) upon retorting under the same conditions. CLSM images of retorted emulsions support that the micro-size protein particles in MP-WPC are in a stable, non-reactive conformation; they remain as non-adsorbed protein in the continuous phase and do not contribute to further aggregation upon retort heat treatment(9). The results confirm that microparticulated protein particles lack the ability to form larger aggregates and remain inert in the aqueous phase. This allows a higher protein content to be added into liquid formulations without compromising the texture.

Figure 2. Changes in  $G'$  during the heating of standard WPC80 and MP-WPC80 (15% w/v). The line indicates the temperature profile when samples were heated from 20 to 85°C at 4°C/min, held for 30 min, then cooled to 20°C at the same scan rate and held for 5 min at 20°C.



\* $G'$  refers to the elastic modulus, and reflects elastic behavior of a material when deformed.

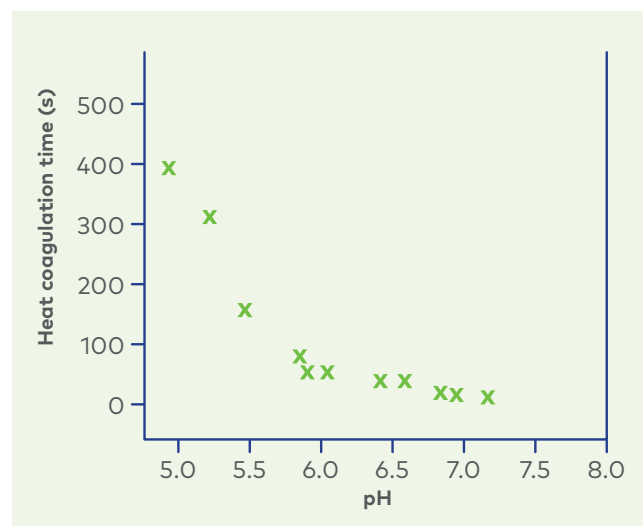
**Figure 3.** Comparison of the heat stabilities of model oil/water emulsion systems (10% oil w/v) prepared with MP-WPC80 at a protein content of 11% (w/v) and standard WPC80 at a protein content of 4% (w/v) under retorting conditions of 120 °C for 10 min. Reprinted from Food Hydrocolloids, 47, Cakir-Fuller E, Enhanced heat stability of high protein emulsion systems provided by microparticulated whey proteins, 41–50 (2015), with permission from Elsevier.



Another unique property of MP-WPC80 is its stability to pH ranges in which a standard whey protein exhibits limited thermal processability. Whey proteins are prone to aggregation on heating at a pH near the isoelectric point (pI) of the protein (pH 5.0–5.2) because the net charge of the proteins is close to zero and protein–protein interactions are favoured. Typically, whey proteins can be used only when the pH of the beverage is sufficiently distant from the pI of whey proteins to avoid aggregation. However, microparticulated whey protein provides surprisingly high heat stability as the pH approaches the pI.

Figure 4 shows how the heat stability of model medical beverages produced with MP-WPC (10% protein, 1.6 kcal/mL) increases significantly around pH 5.0. The heat stability of the beverages was determined by the heat coagulation time, defined as the time required to observe the formation of visible aggregates during heating in an oil bath at 140 °C. The same behaviour can also be observed under retorting conditions, when the same formulation does not form a gel and remains as a low viscosity liquid at pH 5.1 after retorting whereas lumps are visible at high pH ranges (pH > 6.5). MP-WPC provides significantly high heat stability at pH 5.0, which no other whey protein type can match at 10% protein (Figure 5).

**Figure 4.** Heat coagulation time (at 140 °C) of model medical beverages at various pH levels. All beverages contained microparticulated whey protein at a protein content of 10% (w/v), carbohydrates at 14% (w/v) and fat at 6.2% (w/v).

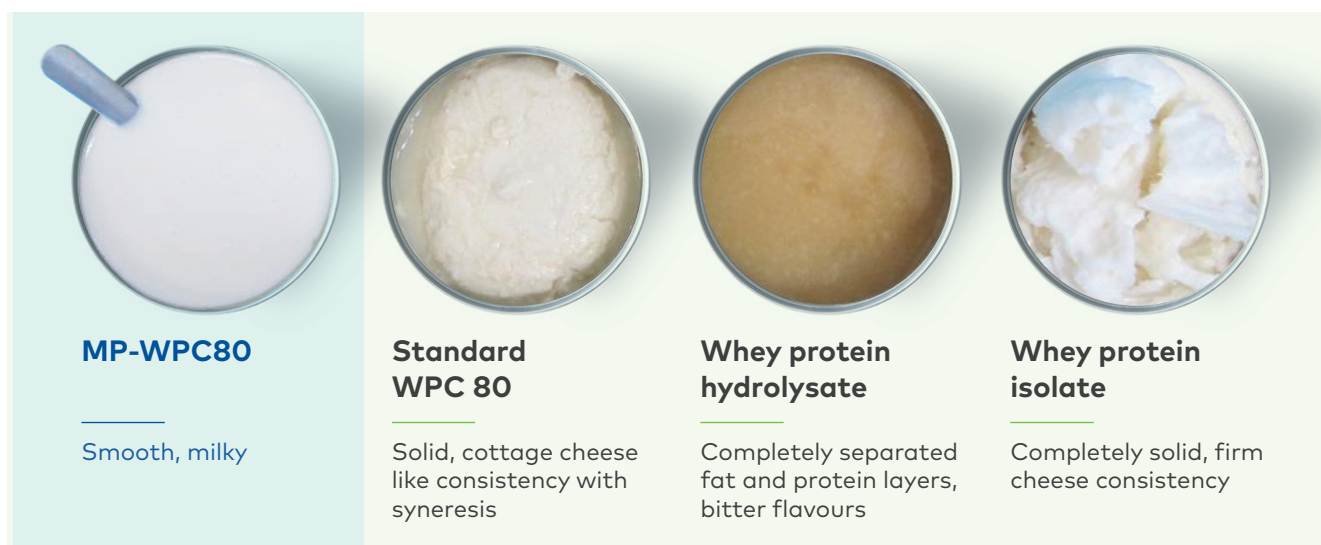


These pictures show the different visual appearances of the same formulation at two different pH levels after retorting at 120 °C for 10 min.





Figure 5. Visual appearances of retort-treated (120 °C for 10 min) model medical beverages produced using different sources of whey protein at a protein content of 10% (w/v), carbohydrates at 14% (w/v), fat at 6.2% (w/v) and pH 5.0.



Thermal processing of the liquid compositions in the pH range 5.0–5.5 also provides an advantage in flavouring options because a wider variety of flavours, including exotic fruity flavours such as mango, lemon, lime and berries, can be chosen rather than being restricted to common flavours like vanilla and chocolate. Also, it is well known that high temperature processing at neutral pH can lead to the generation of sulphurous off-flavours

in whey-protein-containing formulations. Lower pH has been shown to reduce the heat-activated sulphhydryl (–SH) groups of whey protein that evolve during heating at temperatures above 90 °C<sup>(10)</sup>. Microparticulated whey protein provides flavour benefits by enabling thermal processing at pH ranges below neutral pH, thus reducing the formation of sulphury/eggy flavours.



# Conclusion

In summary, the benefits of a microparticulated whey protein, such as SureProtein™ Vital WPC550, in liquid nutritional formulations are listed in Table 2. This microparticulated whey protein is designed to overcome the current challenges that the food industry encounters with high protein products and provides an opportunity for incorporating high concentrations of whey protein in ready-to-drink (RTD) beverage formulations without altering the textural qualities and maintaining the nutritional properties.



**Table 2. Benefits of MP-WPC in liquid nutritional formulations.**

Properties	Benefits
Nutritional value	Identical to that of standard WPC ingredients
Heat stability	Use of high protein concentration, ease of processability for RTD beverages, long shelf life
Acid stability	Wide range of pH applications, flavour benefits
Small particle size	No sedimentation, no powdery or gritty mouthfeel
Low viscosity	Easy to drink, no gelation upon storage
Flavour	Negligible sulphury notes upon heating, compatible with a wide variety of flavouring options
Minimal interaction with other components	Range of product formulations from low fat, low carbohydrate options to nutritionally dense compact formulation alternatives
Colour, opacity	Milky appearance

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## ABOUT THE AUTHORS

**Esra Cakir-Fuller** is a Senior Research Scientist at Fonterra Research and Development Centre, Palmerston North, New Zealand.

She joined Fonterra in 2011 after completing her PhD in Food Science at North Carolina State University. Her research focuses on using advanced technologies to develop new dairy protein ingredients with unique functional properties. This includes the design of heat-stable whey protein ingredients for UHT beverage applications. Her research goal is to provide an understanding of the physical and chemical mechanisms that control functionality so that the desired sensory and textural properties can be obtained. She is also actively involved in intellectual property management.



**Aaron Fanning** is a human nutritionist, working as a Science Manager (Nutrition) at the Fonterra Research and Development Centre in New Zealand.

Since joining Fonterra in 2004, Aaron has largely worked as a Research Scientist, responsible for the management of nutritional innovation projects to enrich our understanding of the nutritional value of dairy proteins, especially whey protein. This includes the management of animal and human research programmes in areas such as satiety, sports performance and recovery, obesity management, and the role that dietary proteins play in muscle loss with ageing and illness.



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## CONTACT

**Fonterra Co-operative Group**  
109 Fanshawe Street  
Auckland 1010, New Zealand  
+64 9 374 9000

**Fonterra (Japan) Limited**  
20F 2-16-2 Konan Minato-ku  
Tokyo 108-0075  
+81 3 6737 1800

**Fonterra (USA) Inc**  
Fonterra Co-operative group limited  
8700 W Bryn Mawr Avenue,  
Suite 500N, Chicago, Illinois 60631  
+1 847 928 1600

**Fonterra Commercial Trading (Shanghai)**  
268 Middle Xizang Road  
Shanghai 200001, China  
+86 21 6133 5999

**Fonterra (Europe) Coöperatie U.A.**  
Barbara Strozilaan  
Amsterdam 1083HN, Netherlands  
+31 20 707 5300

**Fonterra (SEA) Singapore Pte Ltd**  
#15-01 Frasers Tower, 182 Cecil Street  
Singapore 069547  
+65 6879 2977

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