Symposium: Dairy Foods: Emerging Non-Thermal Food Processing Technologies-Their Potential in Dairy Systems

642 Introduction to non-thermal processing technologies and dairy systems.

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Gone are the days when dairy companies could rely exclusively on sales of milk, cheese, powder and butter to thrive. In the 21st century, innovation in the dairy industry will be essential in enhancing international competitiveness in a truly global market. Such innovation will also be critical in meeting consumer demands for ‘miracle foods' that are not only safe and nutritious, but also natural, economical to manufacture, convenient, great tasting, environmentally-friendly, and enhance health and well-being – quite a challenge! In meeting these challenges, we must look beyond the norm and traditional, often to new and novel approaches that when adapted and applied in dairy systems will result in innovation together with consumer acceptability. Several non-thermal processing technologies, notably high pressure, power ultrasonics, and pulsed electric field, are creating an impact in food processing around the world. While these technologies have been largely viewed as alternative non-thermal techniques to enhance microbiological safety and quality, they are increasingly being developed for a range of other applications in dairy systems, including (a) improved processing effectiveness; (b) differentiation of ingredients and products including ‘tailored' functionality; (c) preservation of heat-labile bioactives; (d) modulation of enzyme activity; (e) improved microstructure through component interactions; and (f) hypoallergenic products. Commercial exploitation of these developments will be dependent upon a sound understanding of the science and technology of the observed effects, suitably scaled equipment, and economic viability. The major non-thermal processing technologies will be introduced, together with an overview of their current and potential applications in dairy systems. This overview will set the scene for subsequent presentations exploring the science underpinning the observed effects, and how this science understanding can accelerate and strengthen commercialization of these non-thermal dairy processes.

Key Words: Non-Thermal Processes, Dairy Products, Functionality

643 Dairy proteins under pressure: Static high pressure processing to modulate the functionality of dairy proteins.

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The effects of high pressure processing (HPP; ≤ 400 MPa) at 25°C and at elevated temperatures (≤ 90°C) on the (1) physico-chemical properties of skim milk (2) properties of stirred yoghurt made from pressure treated skim milk and (3) functional properties of other end products were examined. Changes in the calcium and phosphate equilibria and protein aggregates (composition and size) were observed with HPP, the extent of changes depending on the magnitude of the pressure and heat applied. The particle size of the casein micelles decreased with increasing applied pressure when pressure treated at 25°C, suggesting the disintegration of the micelles. When pressure treated at elevated temperatures, the particle size increased with increasing applied pressure, possibly due to aggregation of disintegrated micelles with eventual precipitation at 400 MPa. These reformed new micelles are anticipated to have distinct physico-chemical and functional properties compared to the original micelles. When compared to stirred yoghurts made with milk given only a conventional heat treatment (90°C/10 min), the magnitude of the pressure applied at 25°C to milk did not affect the viscosity of the yoghurt when a subsequent conventional heat treatment was given to pressure treated milk prior to inoculation. When milk was pressure treated at elevated temperatures with no subsequent heat treatment prior to inoculation, yoghurts of lower viscosities were obtained. In other applications, pressure treatment of raw materials or end products resulted in products of different functionalities. Taken together, the results suggest the ability to promote physico-chemical changes through HPP of raw material or end products, translating to different degrees of changes in end-products. HPP is opening opportunities to control and create novel protein structuring capabilities, thereby potentially reducing the need for additives in formulations and opportunities for cleaner labels.

Key Words: Casein, High Pressure, Properties

644 High pressure treatment and bovine milk proteins.

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High-pressure (HP) treatment of milk has significant effects on proteins. Casein micelles may aggregate or disintegrate and whey proteins denature, depending on the pressure applied. This may, in turn, alter the functional properties of products like cheese, yoghurt and protein-based ingredients. Milk protein co-precipitates, acid gels and microfiltration retentates made from HP-treated skim milk were studied. Protein co-precipitates were made from milks adjusted to two pH values (6.8 or 7.5) and unheated, heat-treated (HT, 90°C for 10 min) or treated at 250 MPa for 30 min, or 400 or 600 MPa for 10 min at 40°C. Co-precipitate recovery was highest from milks that were either HT or HP-treated at 600 MPa, followed by milk HP-treated at 400 or 250 MPa. Co-precipitates made from HP-treated milks had better emulsification properties and heat stability than those made from HT milk. Differences in the whey protein composition of co-precipitates made from either HT or HP treatment were also clear. In separate experiments, reconstituted skim milk subjected to either heat treatment (HT, 85°C for 10 min) or HP- treatment alone (250 MPa or 600 MPa for 30 min at 20°C) or combined HT and HP treatment was used for making stirred yoghurt using a commercial starter culture. Yoghurt made from milk HP-treated at 600 MPa exhibited significantly higher water-holding capacity and was less susceptible to shear-thinning than yoghurt made from HT milk. Scanning electron micrographs indicated that HP treatment at 600 MPa alone or in combination with HT resulted in a more compact gel network and lower porosity than HT. In separate studies, when phosphocasein (PC) was reconstituted in simulated milk ultrafiltrate, HP-treated, and processed through a laboratory scale micro-filtration (MF) plant using a 1.4-micron membrane with co-current permeate flow, quantitative but not qualitative differences in protein partition between permeate and retentate occurred.

Key Words: High Pressure, Milk, Functionality

645 Microstructural effects in thermo-sonicated yogurt and other dairy products: Understanding and exploiting the science.
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One of the main goals of nonthermal technologies is to optimize the quality and safety of processed products minimizing the use of heat. Ultrasound has had positive effects on the final quality of milk and other dairy products where important improvements include enhanced color, appearance, texture, and stability. Scientifically speaking, these improvements are due to the homogenization effect in milk generated by ultrasonic waves. From a microstructural perspective, a new and fascinating universe emerges where important changes occur in the milk microstructure and size of fat globules, as reflected in macro scale, revealing whiter color, better appearance and physical properties. Fat globules (average size, 4 μm) in raw milk are disrupted by ultrasound and reduced in size (smaller than 1 μm); thousands are generated with similar volume and appearance. Ultrasound, combined or not with thermal treatments, could reduce specific quality problems in other dairy products like yogurt, a product highly consumed worldwide. Thermo-sonication involves two simultaneous processing steps: pasteurization and homogenization. As with milk, this dual process improves the quality of the yogurt characteristics, yielding a more homogeneous protein/fat matrix, better stability, whiter color, and improved texture, resulting from a reduction and regrouping of milk components and interaction with the yogurt remaining ingredients. Indeed thermo-sonication is a viable alternative for processing milk, yogurt, and other diary products, with important cost/time savings as well.

Key Words: Ultrasound, Microstructure, Dairy Products

646 Membrane and other processing technologies for dairy fluids: Effectiveness of ultrasound in enhancing productivity.
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In water the interaction between (ultra)sound waves and dissolved gas nuclei results in acoustic cavitation, nuclei grow by rectified diffusion and inertial collapse of resonance-sized microbubbles. Acoustic cavitation generates physical effects, including agitation, microstreaming, and enhanced mass transport. In some conditions near adiabatic collapse generates very high temperatures and pressures within the cavitation bubbles leading to the formation of reactive radicals that can be managed or used for desired chemical transformations. Ultrasound use in the dairy industry includes cleaning plastic cheese moulds, and at low sub-cavitation intensity for monitoring product quality of Swiss cheeses, the presence of flat sour spoilage in aseptically packaged milk and levels in tanks. Ultrasonic spectroscopy is now an accepted laboratory tool for analysing molecular level transformations that can occur during processing dairy products.
Historically, the main impediment to applying ultrasound in dairy processing was the lack of suitable equipment for large scale application. Currently, equipment suitable for production scale exists, but the specific knowledge of application to dairy processing is lacking. Laboratory studies determine that ultrasound can be effective in reducing microbial counts in milk, inhibiting or enhancing enzymic activity, improving the quality of cheeses and yoghurts, incorporating nutraceuticals, raising the productivity of membrane processing, and reducing fouling of heated surfaces. Based on laboratory studies, the use of ultrasound for killing microorganisms or inhibiting enzymes have been dismissed as being of little advantage in terms of effectiveness and high energy usage whilst adding to processing complexity. However, for other applications the ultrasonic energy required is low and scaling up to production scale with significant savings in processing cost is feasible.

Key Words: Ultrasound, Membranes, Enzymes

647 Microbial safety and bioactive efficacy: Effectiveness of pulsed electric field processing of dairy fluids.
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Value-added dairy ingredients with demonstrated biological properties, including lactoferrin (LF) and lactoperoxidase (LP), have attracted great attention in recent years due to applications in functional foods and nutraceuticals. Most of these bioactive dairy ingredients are proteins and their biological properties are often compromised during conventional heat processing. In the current study, the effect of pulsed electric field (PEF) in combination with moderate temperatures (30-70°C) on the survival of microorganisms and the activity of LF and LP in milk was evaluated.
PEF treatments were conducted using an OSU-4 system with a field intensity of 33 kV/cm, pulse width 2 μs, total treatment time 20 μs, and total specific energy input 120 kJ/L. For each temperature, controls were prepared by processing samples in the PEF unit without the electric pulses.
In the challenge experiments using inoculated (10^{6-7} CFU/ml) UHT milk, PEF resulted in >6 log reduction on *Pseudomonas fluorescens* ATCC 948 and *Salmonella* Typhimurium ATCC 14028 at 60°C. However, *Listeria monocytogenes* NCTC 11994 and *Enterococcus faecalis* ATCC 19433 required 65 and 70°C, respectively, to achieve a 6-log inactivation. The controls at the respective temperatures had less than 1 log reduction. PEF treatment at 5-10°C below the temperatures identified above resulted in only 1-2 log reduction on each of these target organisms.
PEF treatment at 65°C of cold stored raw milk (with an initial total plate count of 10^6 CFU/ml) resulted in a 5 log reduction, and the count of enterobacteriaceae was reduced from 10^2 to <1 CFU/ml. Over 85% of the LF (by ELISA) and LP (by enzyme activity assay) were recovered after the PEF treatment.
These results suggest that PEF in combination with mild heat can be used for effective microbial inactivation in milk while preserving LF and LP activities.

Key Words: Pulsed Electric Field, Lactoferrin, Lactoperoxidase

648 High pressure processing of colostrum.
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Bovine colostrum is rich in bioactive components, such as immunoglobulins and lactoferrin, that may provide health benefits to consumers. Delivering these bioactive components in a consumer-friendly format with a commercially-useful shelf-life is a challenge, because they are relatively sensitive to denaturing by traditional thermal preservation.

Colostrum consumer products are generally formulated dry, in formats such as powders, tablets or capsules or as a fresh pasteurised liquid with a shelf-life of several days. Immunoglobulins in particular can not withstand UHT or heat-sterilisation processes, although they do survive thermal pasteurisation well. Unfortunately immunoglobulin proteins are particularly heat-sensitive under acidic conditions, where microbial stability might be achieved by milder thermal processing than at near neutral pH. The effect of pressure on immunoglobulins as a function of pH is found to be the opposite of the effect of heat; specifically immunoglobulin proteins are less sensitive to pressure denaturation under acidic conditions than they are at near-neutral. This finding creates the possibility of using high pressure processing, a non-thermal food preservation technology, to produce a ready-to-drink colostrum beverage with a commercially-useful shelf-life. High pressure processing offers microbial stability in acidified dairy systems, as spoilage micro-organisms that can grow are inactivated by pressure (eg lactic acid bacteria, yeast and mold) and micro-organisms that are not inactivated by pressure cannot grow (eg bacterial spores). Immunoglobulins and other bioactive components in colostrum are well-retained under the high pressure processing conditions that are required to achieve microbial stability in an acidified colostrum beverage model.

Key Words: High Pressure Processing, Colostrum, Immunoglobulin

649 Enhancing the quality of whey protein functionality using high pressure. S. Clark*, X. Liu, S.-Y. Lim, J. Chauhan, and C. Padiernos, *Washington State University*, *Pullman*.

Four studies were designed to investigate the potential for high hydrostatic pressure (HHP) of whey protein concentrate (WPC) to improve the quality of lowfat ice cream and lowfat whipping cream. The initial study investigated flavor-binding properties of WPC treated at 600 MPa for 30 min at an initial temperature of 50ºC. The treatments enhanced binding of certain flavor compounds but not others, suggesting a need for follow-up studies in real food systems. Subsequent studies involved treatment of fresh, ultrafiltered Cheddar cheese whey (fresh WPC) at 300 MPa for 15 min at an initial temperature of 25ºC. The treatment maintained fresh WPC solubility and demonstrated improved foaming properties of fresh WPC. A variety of lowfat ice cream mix and lowfat whipping cream products were formulated and evaluated using instrumental and sensory analysis tests. Headspace-SPME-GC demonstrated that lowfat ice cream with HHP-treated fresh WPC plus diacetyl exhibited higher concentration of diacetyl than untreated fresh WPC plus diacetyl after 1 day of storage, but the diacetyl binding was not maintained up to day 14. Additionally, sensory evaluation revealed that panelists could not distinguish between ice cream containing untreated or HHP-treated fresh WPC. Although flavor was minimally impacted, HHP treatment of fresh WPC enhanced overrun and foam stability of ice cream and whipped cream. Additionally, sensory panelists were able to distinguish some differences among ice creams and whipped creams. HHP can alter foaming properties of fresh WPC significantly enough for differences to be noted in a product even when the modified ingredient is used at levels as low as 10% in a formulation.

Key Words: Whey Protein, Ice Cream, High Pressure