654 Effect of hydrodynamic cavitation on particle size of casein micelles, protein interactions and heat stability of skim milk. Harsh Dahiya*[1], Hasmukh A. Patel[1], and Thom Huppertz[1,2], *[1]South Dakota State University, Brookings, SD, [2]NIZO Food Research, Ede, the Netherlands.*

Hydrodynamic cavitation (HC) is a process of vaporization, bubble generation followed by bubble collapse in a flowing liquid brought about by a decrease in pressure followed by a subsequent increase in pressure. We are currently applying this technology in the processing of milk and milk products. Therefore, the objective of this preliminary study was to investigate the effect of hydrodynamic cavitation (HC) on some important properties of milk such as particle size of casein micelles, interactions of proteins and heat stability of skim milk (SM). Pasteurized skim milk (3.5% protein and 9% total solids) was preheated to 50°C and then subjected to 2 sets of HC treatments, namely, HC at 20, 40, and 60 Hz at sufficiently high flow rate (950 L/h) to avoid any temperature increase during HC (T1) and HC at 60 Hz at low flow rates (200 L/h) to allow scale-free heating of skim milk increasing its temperature up to 90°C (T2) using APV Cavitator (supplied by SPX, Denmark) fitted with 4-row rotor in 6mm housing.The samples obtained from T1, T2 and untreated (control) skim milk samples were analyzed for changes in the particle size of casein micelles using Malvern Zetasizer Nano ZS and heat stability using the heat coagulation time (HCT) test at 140°C. The protein interactions in the whole sample and serum phase obtained from these samples were also studied using SDS-PAGE. SM subjected to T1 and T2 did not cause significant changes ($P < 0.05$) to the casein micelle size and HCT (165–171 nm and >5 min) compared with that in control sample (168 nm and >5 min respectively). On the other hand, samples subjected to T2 exhibited significantly higher levels ($P < 0.05$) of whey protein denaturation ($P < 0.05$) compared with those subjected to T1, which was attributed to the heat generated due to cavitation during T2. The high molecular weight aggregates were also generated in samples subjected to T2 due to extensive denaturation of whey proteins and their interactions with casein micelles. The results of this study suggested that HC can be promising technique that can be potentially used as an alternative technology for scale-free heating of milk with minimal effect on important properties of milk.

Key Words: hydrodynamic cavitation, denaturation, scale-free

655 Optimization of milk atomization by viscosity measurement. Luc K. Belliere, Corentin Thierry*, Valerie Lefevre, and Philippe Burg, *Sofraser, Villemandeur, France.*

Every year, very large quantities of powdered milk are produced worldwide (~5 billion tonnes). Optimization of the manufacturing is the key to ensure product yield and profitability. This can be achieved by optimizing product viscosity during the drying and atomization of the milk. During drying, water is removed to reduce the energy required in the atomization column. Good viscosity control leads to a better evaporation and therefore lower water content. During atomization, droplet size has a direct effect on the heat required for drying and therefore the energy required to produce powdered milk. One of the methods to optimize atomization is by controlling the viscosity of the fluid before spraying as viscosity has a direct effect on droplet size. The viscometer used during the trial (MIVI, Sofraser) is a viscometer at resonance frequency working at a high shear rate. The active part of the sensor is a vibrating rod held in oscillation at its resonance frequency where the amplitude of the movement varies according to the viscosity of the product. The viscometer was rated for 500 bar and 200°C, with a full-scale range of 200 cP. The trials were performed at a Dutch milk processing company where the sensor was installed on a flow through-cell before the atomizer. The equipment was tested on 3 different products at the following operating conditions: atomization pressure between 150 and 225 bars, temperature in the cell ~75°C and flow rate of 2,800 L/h. The viscometer was used to control the viscosity of the incoming milk from the dryers and ensure the milk was within the optimal viscosity range for atomization. The setpoint viscosity for the 3 different formulations was 20, 50, and 180 cP. The viscometer allowed maintaining viscosity within ±1 σ for 85 to 90% of points and a maximum difference of 3% between setpoint and mean measurement. Depending on product 1 σ is between 5 and 10% of setpoint. Higher casein to whey protein ratio gave more stable results, as well as higher carbohydrate to fat ratio. This will not be explained as it is not part of the study. Finally, during the trials, the use of a viscometer allowed 2% energy savings which represent about $15,000 to $20,000/year (based on $0.07/kWh).

Key Words: process optimization, powdered milk, atomization

656 Effect of membrane channel geometry on limiting flux and serum protein removal during skim milk microfiltration. Michael C. Adams, Emily E. Hurt, and David M. Barbano*, *Cornell University, Ithaca, NY.*

Our objectives were to determine the limiting fluxes (LF) and serum protein (SP) removal factors (SPR) of 2 100-nm ceramic microfiltration (MF) membranes: one with 4-mm round retentate flow channels (RFC) and one with 4-mm equivalent-diameter diamond-shaped retentate flow channels (DFC). Retentate and permeate were continuously recycled to the feed tank and a uniform transmembrane pressure (TMP) (TMP at the inlet minus TMP at the outlet) was maintained at 25 ± 3 kPa using a permeate recirculation pump. The LF for each membrane was determined by increasing flux once per h from 45 $kg \cdot m^{-2} \cdot h^{-1}$ until flux did not increase with increasing TMP. Temperature, average cross-flow velocity, and protein concentration in the retentate recirculation loop were maintained at 50°C, 7 $m \cdot s^{-1}$, and 8.5 ± 0.03%, respectively. Experiments were replicated 3 times and the Proc GLM procedure of SAS was used for statistical analysis. The LF of the DFC membrane (71 $kg \cdot m^{-2} \cdot h^{-1}$) was lower ($P < 0.05$) than the LF of RFC membrane (88 $kg \cdot m^{-2} \cdot h^{-1}$). Reynolds numbers based on the hydrodynamic diameter of the retentate flow channels were calculated for each membrane. Differences in Reynolds numbers between the membranes were proportional to the differences in LF. Permeate produced using the DFC membrane contained more ($P < 0.05$) protein than the permeate produced using the RFC membrane due to additional casein passage through the DFC membrane. SPR was calculated by dividing true protein in the permeate by SP in the permeate portion of the feed to describe the ease of SP passage through each membrane. Higher SPR indicate higher rates of SP passage. After accounting for casein contamination in each of the permeates with SDS-PAGE, the DFC membrane SPR remained higher ($P < 0.05$) than the RFC membrane SPR. Though DFC membrane LF was lower, DFC permeate removal on a modular basis was higher due to the increased module membrane surface area of the DFC membrane relative to the RFC membrane (2.07 m^2 vs. 1.41 m^2). Depending on the

size of the system, using DFC membranes could reduce the capital cost of a MF system due to a reduction in the number of stainless steel modules.

Key Words: microfiltration, channel geometry, limiting flux

657 Effect of soluble milk components on limiting flux and serum protein removal during skim milk microfiltration. Michael C. Adams, Emily E. Hurt, and David M. Barbano*, *Cornell University, Ithaca, NY.*

The tendency of calcium to promote microfiltration (MF) membrane fouling is well documented, but the role of lactose has not been studied. Milk protein concentrate that is 85% protein on a dry basis (MPC85) contains less calcium and lactose than skim milk (SM). Our objectives were to determine the limiting fluxes (LF) and serum protein (SP) removal factors (SPR) of 0.1 μm ceramic graded permeability membranes that were fed with 3 different milks: SM, MPC85 that had been standardized to the protein content of SM with reverse osmosis (RO) water (MPC), and MPC85 that had been standardized to the protein and lactose contents of SM with RO water and lactose monohydrate (MPC+L). Retentate and permeate were continuously recycled to the feed tank. The LF for each feed was determined by increasing flux once per h from 55 $kg \cdot m^{-2} \cdot h^{-1}$ until flux did not increase with increasing transmembrane pressure. Temperature, pressure drop across the membrane length, and protein concentration in the retentate recirculation loop were maintained at 50°C, 220 kPa, and 8.77 ± 0.2%, respectively. Experiments were replicated 3 times and the Proc GLM procedure of SAS was used for statistical analysis. The LF of SM (91 $kg \cdot m^{-2} \cdot h^{-1}$) was lower ($P < 0.05$) than the LF of MPC+L (124 $kg \cdot m^{-2} \cdot h^{-1}$) due to the role of calcium in fouling. The LF of MPC+L was lower ($P < 0.05$) than the LF of MPC (137 $kg \cdot m^{-2} \cdot h^{-1}$) due to the higher viscosity contributed by lactose. Permeates produced from the MPC and MPC+L contained more ($P < 0.05$) protein than the SM permeate due to the transfer of micellar casein into the reduced-calcium sera of the MPC and MPC+L. SPR was calculated by dividing true protein in the permeate by SP in the permeate portion of the feed to describe the ease of SP passage through the membrane. After accounting for the nonmicellar casein with SDS-PAGE, no differences ($P > 0.05$) in SPR were detected among the 3 feeds below the LF. As the fluxes approached the LF, SPR decreased ($P < 0.05$) due to fouling. Feeding a MF system with MPC instead of SM will reduce the required membrane surface area, but the permeate protein composition will be different.

Key Words: microfiltration, calcium, lactose

658 Comparison of 3 different variable selection strategies to improve the predictions of fatty acid profile in bovine milk by mid-infrared spectrometry. Hélène Soyeurt*[1], Yves Brostaux[1], Frédéric Dehareng[2], Nicolas Gengler[1], and Pierre Dardenne[2], *[1]University of Liège-Gembloux Agro-Bio Tech, Gembloux,Belgium, [2]Walloon Agricultural Research Centre, Gembloux,Belgium.*

Mid-infrared (MIR) spectrometry is used to provide phenotypes related to the milk composition. Foss spectrum contains 1,060 datapoints. The number of reference values required to build a calibration equation is often lower than the spectral variables mainly due to the cost of chemical analysis. Problems of collinearity and overfitting appear when this high dimensional data set is used. This research will study the interest of using variable selection (VS) approach before the use of partial least square regression (PLS). The data set included 1,236 milk spectra related to their fatty acid (FA) contents. Saturated (SFA), monounsaturated (MUFA), polyunsaturated (PUFA), short chain (SCFA), medium chain (MCFA), and long chain FA (LCFA) were studied. The data set was randomly divided in 3 groups which were used to create 3 calibration and validation data sets. Three different VS methods were compared. The first strategy was based on the part of trait variability explained by each considered variables (R2VS). The second method was based on the regression coefficient estimated after PLS procedure divided by the standard deviation of the considered spectral variable (BSVS). The third strategy permitted to underline the uninformative variables which were the ones having the lowest ratio of average regression coefficient to their corresponding standard deviation estimated after a leave-one out cross-validation (UVEVS). For UVEVS and BSVS, the cutoff was determined from the known uninformative region of MIR milk spectrum. The cutoff for R2VS was determined by testing different thresholds ranged between 5 and 40%. The most interesting cutoff for R2VS was 25%. The worst results in terms of validation root mean square error of prediction (RMSEPv) were obtained using a full PLS (i.e., without VS). The maximum difference (g/dl of milk) of RMSEPv obtained from the full PLS and from the PLS using selected variables were 0.156 for SFA, 0.139 for MUFA, 0.011 for PUFA, 0.025 for SCFA, 0.164 for MCFA, and 0.188 for LCFA. R2VS gave the best results for all studied traits followed by UVEVS and then BSVS. In conclusion, the use of VS improved significantly the performance of FA MIR equations.

Key Words: milk, fatty acid, infrared

659 Factors influencing laboratory performance of oven drying total solids on whole milk. David M. Barbano* and Chassidy Coon, *Cornell University, Ithaca, NY.*

Milk analysis proficiency testing has been carried out monthly by a group 10 laboratories for about 10 years. Patterns of differences in total solids (TS) results among labs have been observed, but the causes of some of these differences (i.e., systematic increase or decrease in difference from the all-laboratory mean value as function of milk total solids level) have not been identified. Our objective was to identify specific sources that cause these variations in results among laboratories. The atmospheric force air oven method number 990.20 of the Association of Official Analytical Chemists was used. A set of 14 milks with a range of TS content from about 8.4 to 15.2% were tested in duplicate by 10 different labs and replicated in 4 mo. In mo 1 and 3, the 14 milks were tested on each of 3 different days by the same analyst and in mo 2 and 4, the 14 milks were tested on each of 3 different days by the different analyst within each lab. The differences from the all-lab mean with statistical outliers removed were analyzed using Proc GLM of SAS to test for effects of lab, day, sample, and their interactions. The ANOVA terms for lab and lab by sample interaction were significant ($P < 0.05$) and explained most of the variation. The lab by sample interaction manifested itself as some labs having upward slopes, while other laboratories had downward slopes of the residual plot of 28 differences from the 14 sample all lab means as TS increased. The direction of the slope, when it occurred, was a function of laboratory or technician within laboratory. Follow-up work was conducted to identify causes of this behavior of TS results. Oven temperatures and oven temperature recovery rates were within method specifications for all labs. Attention was focused on the interaction of the analyst and balance. At the various weighing steps, the weights were recorded 3 times: immediately, after the balance indicated the weight was stable, and 7 s after the indication of stability. Based on these observations, a series of sensitivity analyses were done. The accuracy of TS results was most sensitive to variation (both random and systematic) in control of the balance zero during the steps of weighing the empty pan and the pan plus dry solids.

Key Words: milk, solids, oven drying

660 Greek-style yogurt manufacture: A case study for eco-efficiency assessment in dairy processing. Yves Pouliot*[1], Alain Doyen[1], Catherine Houssard[2], Adriana Paredes Valencia[1], Scott Benoit[1], Dominique Maxime[2], and Manuele Margni[2], *[1]STELA Dairy Research Center, Université Laval, Québec, QC, Canada, [2]CIRAIG, CIRODD, École Polytechnique de Montréal, Montréal, QC, Canada.*

Greek-style yogurt is characterized by a higher protein content (>10% w/v) compared with conventional products (4–5% w/v). The protein concentration is typically achieved by ultrafiltration (UF) or centrifugation processes after milk fermentation by yogurt starter cultures. However, this approach requires 3 times more milk than the traditional yogurt and it generates Greek yogurt co-product acid whey permeate for which the subsequent valorization represents a challenge. Although the concentration step increases the commercial value of yogurt, depending on the processing options selected, its manufacture affects the use of milk constituents and on the process environmental footprint. The concept of eco-efficiency (EE) provides an assessment of the environmental performance of a product system in relation to its value. EE is a practical tool for managing environmental data (e.g., Life cycle analysis or LCA) and value aspects (e.g., financial, functional, sensory) in parallel. In a first part of our study, we have compared the environmental impact of Greek-style yogurt production from 2 different processing options, i.e., performing the UF concentration step before or after fermentation step. Pilot-scale experiments were performed to characterize both processes in terms of water use, energy consumption and waste generation such as permeate (acid or not). The relative environmental impact of both processes will be characterized by means of a comparative LCA. The value aspects of Greek-style yogurt manufacture in the EE equation will address its direct commercial value, but also the value (or costs) of co-products valorization (or disposal). Our research aims at developing an EE-based approach and provide a decision-support tool to help manufacturers identifying and selecting most eco-efficient processing options for the production of Greek-style yogurt.

Key Words: eco-efficiency, dairy processing, yogurt