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MANUFACTURE OF MODIFIED MILK PROTEIN CONCENTRATE UTILIZING INJECTION OF CARBON DIOXIDE

C. Marella, P. Salunke, A.C. Biswas, A. Kommineni & L.E. Metzger
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The objective was to use carbon dioxide to produce MPC80 with improved functionality. In this study, reduced-calcium MPC80 (RCMPC) was produced from skim milk that was subjected to injection of 2,200 ppm of CO₂ before UF, along with additional CO₂ injection at a flow rate of 1.5 to 2 L/min during UF. A control MPC80 (CtrlMPC) was also produced from the same lot of skim milk without injection of CO₂. The above processes were replicated 3 times, using different lots of skim milk for each replication. All the UF retentates were spray dried using a pilot-scale dryer. Skim milk and UF retentates were tested for ζ-potential (net negative charge), particle size, and viscosity. All the MPC were stored at room (22 ± 1°C) and elevated (40°C) temperatures for 6 mo. Solubility was measured by dissolving the dried MPC in water at 22°C and at 10°C (cold solubility). Injection of CO₂ and the resultant solubilization of calcium phosphate had a significant effect on UF performance, resulting in 10 and 20% loss in initial and average flux, respectively. Processing of skim milk with injection of CO₂ also resulted in higher irreversible fouling resistances. Compared with control, the reduced-calcium MPC had 28 and 34% less ash and calcium, respectively. Injection of CO₂ resulted in a significant decrease in ζ-potential and a significant increase in the size of the casein micelle. Moreover, RCMPC had a significantly higher solubility after storage at room temperature and at elevated temperature. This study demonstrates that MPC80 with a reduced calcium and mineral content can be produced with injection of CO₂ before and during UF of skim milk.

COMPOSITIONAL AND SENSORY DIFFERENCES OF PRODUCTS OF SWEET-CREAM AND WHEY BUTTERMILK PRODUCED BY MICROFILTRATION, DIAFILTRATION, AND SUPERCRITICAL CO

A. Olabi, S. Jinjarak, R. Jimenez-Flores, J.H. Walker & H. Daroub
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The objectives were to assess the compositional properties and sensory

characteristics of ingredients produced by treating sweet-cream and whey-cream buttermilks with microfiltration (MF), diafiltration (DF), and supercritical CO₂ (SFE) extraction. Sweet-cream buttermilk (CBM) and buttermilk resulting from churning the residual fat from whey processing (whey buttermilk, WBM) were used. Using MF or microfiltration followed by diafiltration (MF-DF), they obtained resulting retentates that were dried and then were subjected to SFE treatment. Control buttermilks, SFE resulting products, and MF and MF-DF SFE and all treated retentates products totaled 16 samples (2 types × 4 treatments × 2 batches). Eleven trained panelists assessed samples using descriptive analysis. Sweet-cream buttermilk was higher in protein and lactose, whereas the WBM had similar total protein, mainly β-LG and α-LA but very low lactose. The resulting samples in order of concentration for fat and lactose were control samples > SFE treated > MF treated > DF = MF-SFE and DF-SFE. Sodium dodecyl sulfate-PAGE protein profiling showed negligible casein for WBM versus CBM and less whey proteins for CBM versus WBM, as expected. Whey buttermilk was more yellow, salty, sour, and rancid than CBM. Regarding the treatments, significant differences were obtained on homogeneity, opacity, rancid odor, cardboard and sour flavors, sweet and salty tastes, viscosity, and mouthcoating, where SFE-treated samples showed lowest rancid odor and cardboard flavor.

EFFECT OF HOMOGENIZATION AND PASTEURIZATION ON THE STRUCTURE AND STABILITY OF WHEY PROTEIN IN MILK

P. X. Qi, D. Ren, Y. Xiao & P. M. Tomasula
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The effect of homogenization alone or in combination with high-temperature, short-time (HTST) pasteurization or UHT processing on the whey fraction of milk was investigated using highly sensitive spectroscopic techniques. In pilot plant trials, 1-L quantities of whole milk were homogenized in a 2-stage homogenizer at 35°C (6.9 MPa/10.3 MPa) and, along with skim milk, were subjected to HTST pasteurization (72°C for 15 s) or UHT processing (135°C for 2 s). Other whole milk samples were processed using homogenization followed by either HTST pasteurization or UHT processing. The processed skim and whole milk samples were centrifuged further to remove fat and then acidified to pH 4.6 to isolate the corresponding whey fractions, and centrifuged again. The whey fractions were then purified using dialysis and investigated using the circular dichroism, Fourier transform infrared, and Trp intrinsic fluorescence spectroscopic techniques. Results demonstrated that homogenization combined with UHT processing of milk caused not only changes in protein composition but also significant secondary structural loss, particularly in the amounts of apparent antiparallel β-sheet and

α -helix, as well as diminished tertiary structural contact. In both cases of homogenization alone and followed by HTST treatments, neither caused appreciable chemical changes, nor remarkable secondary structural reduction. But disruption was evident in the tertiary structural environment of the whey proteins due to homogenization of whole milk as shown by both the near-UV circular dichroism and Trp intrinsic fluorescence. In-depth structural stability analyses revealed that even though processing of milk imposed little impairment on the secondary structural stability, the tertiary structural stability of whey protein was altered significantly. The following order was derived based on these studies: raw whole > HTST, homogenized, homogenized and pasteurized > skimmed and pasteurized, and skimmed UHT > homogenized UHT. The methodology demonstrated in this study can be used to gain insight into the behavior of milk proteins when processed and provides a new empirical and comparative approach for analyzing and assessing the effect of processing schemes on the nutrition and quality of milk and dairy product without the need for extended separation and purification, which can be both time-consuming and disruptive to protein structures.

EFFECTS OF SPRAY-DRYING CONDITIONS ON THE CHEMICAL, PHYSICAL, AND SENSORY PROPERTIES OF CHEESE POWDER

N. Koca, Z. Erbay & F. Kaymak-Ertekin
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In this study, 24 cheese powders produced under 7 different conditions were used to investigate the effects of spray-drying parameters (e.g., inlet air temperature, atomization pressure, and outlet air temperature) on the quality of white cheese powder. Composition, color, physical properties, reconstitution, and sensory characteristics of white cheese powders were determined. The results revealed that the white cheese powders produced in this study had low moisture content ratios and water activity values. High outlet air temperatures caused browning and enhanced Maillard reactions. Additionally, high outlet air temperatures increased wettability and dispersibility and decreased the solubility of white cheese powders. Free fat content was positively correlated with inlet air temperature and negatively correlated with outlet air temperature and atomization pressure. Sensory analyses revealed that white cheese powder samples had acceptable sensory characteristics with the exception of the sample produced at an outlet air temperature of 100°C, which had high scores for scorched flavor and color and low scores for cheese flavor.

DECOLORIZATION OF CHEDDAR CHEESE WHEY BY ACTIVATED CARBON

Y. Zhang, R. Campbell, M. A. Drake & Q. Zhong
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Colored Cheddar whey is a source for whey protein recovery and is decolorized conventionally by bleaching, which affects whey protein quality. Two activated carbons were studied in the present work as physical means of removing annatto (norbixin) in Cheddar cheese whey. The color and residual norbixin content of Cheddar whey were reduced by a higher level of activated carbon at a higher temperature between 25 and 55°C and a longer time. Activated carbon applied at 40 g/L for 2 h at 30°C was more effective than bleaching by 500 mg/L of hydrogen peroxide at 68°C. The lowered temperature in activated-carbon treatments had less effect on protein structure as investigated for fluorescence spectroscopy and volatile compounds, particularly oxidation products, based on gas chromatography-mass spectrometry. Activated carbon was also reusable, removing more than 50% norbixin even after 10 times of regeneration, which showed great potential for decolorizing cheese whey.

WHEY PROTEIN ISOLATE IMPROVES ACID AND BILE TOLERANCES OF *STREPTOCOCCUS THERMOPHILUS* ST-M5 AND *LACTOBACILLUS DELBRUECKII* SSP. *BULGARICUS* LB-12

L. A. Vargas, D. W. Olson & K. J. Aryana
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The objective was to determine the influence of added WPI on acid tolerance and bile tolerance of pure cultures of *Streptococcus thermophilus* ST-M5 and *Lactobacillus bulgaricus* LB-12. The WPI was used at 0 (control), 1, 2 and 3% (wt/vol). Assessment of acid tolerance was conducted on pure cultures at 30-min intervals for 2 h of acid exposure and bile tolerance at 1-h intervals for 5 h of bile exposure. Use of 1, 2, and 3% WPI improved acid tolerance of *Strep. thermophilus* ST-M5 and *Lb. bulgaricus* LB-12. The highest counts for acid tolerance of *Strep. thermophilus* ST-M5 and *Lb. bulgaricus* LB-12 were obtained when 3% WPI was used. Use of 2 and 3% WPI improved bile tolerance of *Strep. thermophilus* ST-M5 and *Lb. bulgaricus* LB-12 over 5 h of bile exposure. The use of WPI is recommended to improve acid and bile tolerance of the yogurt culture bacteria *Strep. thermophilus* ST-M5 and *Lb. bulgaricus* LB-12.

MICROFILTRATION: EFFECT OF RETENTATE PROTEIN CONCENTRATION ON LIMITING FLUX AND SERUM PROTEIN REMOVAL WITH 4-MM-CHANNEL CERAMIC MICROFILTRATION MEMBRANES

E. E. Hurt, M. C. Adams & D.M. Barbano
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The objective was to determine if the limiting flux and serum protein (SP) removal were different at 8, 9, or 10% true protein (TP) in the microfiltration (MF) retentate recirculation loop using 0.1- μm ceramic graded permeability membranes with 4-mm-channel diameters operated at 50°C using a diluted milk protein concentrate with 85% protein on a total solids basis (MPC85) as the MF feed. The limiting flux for the MF of diluted MPC85 was determined at 3 TP concentrations in the recirculation loop (8, 9, and 10%). The experiment was replicated 3 times for a total of 9 runs. On the morning of each run, MPC85 was diluted with reverse osmosis water to an MF feed TP concentration of 5.4%. In all runs, the starting flux was 55 kg/m² per hour, the flux was increased in steps until the limiting flux was reached. The minimum flux increase was 10 kg/m² per hour. The limiting flux decreased as TP concentration in the recirculation loop increased. The limiting flux was 154 ± 0.3 , 133 ± 0.7 , and 117 ± 3.3 kg/m² per hour at recirculation loop TP concentrations of 8.2 ± 0.07 , 9.2 ± 0.04 , and $10.2 \pm 0.09\%$, respectively. No effect of recirculation loop TP concentration on the SP removal factor was detected. However, the SP removal factor decreased from 0.80 ± 0.02 to 0.75 ± 0.02 as flux was increased from the starting flux of 55 kg/m² per hour to the limiting flux, with a similar decrease seen at all recirculation loop TP concentrations.

MICROFILTRATION: EFFECT OF CHANNEL DIAMETER ON LIMITING FLUX AND SERUM PROTEIN REMOVAL

E. E. Hurt, M. C. Adams & D.M. Barbano
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The objective was to determine the limiting flux and serum protein (SP) removal at 8, 9 and 10% true protein (TP) in the retentate recirculation loop using 0.1- μm ceramic graded permeability (GP) microfiltration (MF) membranes with 3 mm channel diameters (CD). An additional objective was to compare the limiting flux and SP removal between 0.1- μm ceramic GP membranes with 3 mm CD and previous research using 4-mm CD membranes. The MF system was operated at 50°C, using a diluted milk protein concentrate with 85% protein on a total solids basis (MPC85) as the MF feed. The limiting flux for the MF of diluted MPC85 was determined at 8, 9, and 10% TP concentration in the recirculation loop. The experiment using the 3-mm CD membranes was replicated 3 times for a total of 9 runs. On the morning of each run MPC85 was diluted with reverse osmosis water to

a MF feed TP concentration of 5.4%. In all runs the starting flux was 55 kg/m² per hour, the flux was then increased in steps until the limiting flux was reached. For the 3-mm CD membranes, the limiting flux was 128 ± 0.3, 109 ± 4, and 97 ± 0.5 kg/m² per hour at recirculation loop TP concentrations of 8.1 ± 0.07, 9.2 ± 0.04, and 10.2 ± 0.03%, respectively. For the 3-mm CD membranes, increasing the flux from the starting to the limiting flux decreased the SP removal factor from 0.72 ± 0.02 to 0.67 ± 0.01; however, no difference in SP removal factor among the target recirculation loop TP concentrations was detected. The limiting flux at each recirculation loop target TP concentration was lower for the 3- compared with the 4-mm CD membranes. The differences in limiting fluxes between the 3- and 4-mm CD membranes were explained in part by the difference in cross-flow velocity (5.5 ± 0.03 and 7.0 ± 0.03 m/s for the 3- and 4-mm CD membranes, respectively). The SP removal factor was also lower for the 3- compared with the 4-mm CD membranes, indicating that more membrane fouling may have occurred in the 3- versus 4-mm CD membranes.

QUANTIFICATION OF WHEY IN FLUID MILK USING CONFOCAL RAMAN MICROSCOPY AND ARTIFICIAL NEURAL NETWORK

R. Alves da Rocha, I. M. Paiva, V. Anjos, M. A. M. Furtado & M. J. V. Bell
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In this work, they assessed the use of confocal Raman microscopy and artificial neural network as a practical method to assess and quantify adulteration of fluid milk by addition of whey. Milk samples with added whey (from 0 to 100%) were prepared, simulating different levels of fraudulent adulteration. All analyses were carried out by direct inspection at the light microscope after depositing drops from each sample on a microscope slide and drying them at room temperature. No pre- or posttreatment (e.g., sample preparation or spectral correction) was required in the analyses. Quantitative determination of adulteration was performed through a feed-forward artificial neural network (ANN). Different ANN configurations were evaluated based on their coefficient of determination (R^2) and root mean square error values, which were criteria for selecting the best predictor model. In the selected model, we observed that data from both training and validation subsets presented $R^2 > 99.99\%$, indicating that the combination of confocal Raman microscopy and ANN is a rapid, simple, and efficient method to quantify milk adulteration by whey. Because sample preparation and postprocessing of spectra were not required, the method has potential