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THERMAL RESISTANCE OF LISTERIA MONOCYTOGENES SCOTT A IN ULTRAFILTERED MILK AS RELATED TO THE EFFECT OF DIFFERENT MILK COMPONENTS

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Pasteurization parameters for grade A milk are well established and set by regulation. However, as solids levels increase, an increased amount of heat is required to destroy any pathogens present. This effect is not well characterized. In this work, the effect of increased dairy solids levels on the thermal resistance of Listeria monocytogenes was examined through the use of ultrafiltered (UF) milk, reconstituted milk powder, and the milk components lactose and caseinate. From the results obtained, lactose and caseinate did not appear to affect thermal resistance. In addition, the level of milk fat, up to 10% of the total solids in UF whole milk, did not result in statistically significant changes to thermal resistance when compared with UF skim milk. Reconstituted skim milk powder at 27% total solids (D62-value = 1.16 ± 0.2 [SD] min, z = 5.7) did result in increased thermal resistance, as compared with reconstituted skim milk powder at 17.5% (D62-value = 0.86 ± 0.02 min, z = 5.57) and UF whole milk at 27% total solids (D62-value = 0.66 ± 0.07 min, z = 5.16). However, that increase appeared to be due to the increase in salt levels, not to increases in caseinate, fat, or lactose. Consequently, total solids, as a single measure, could not be used to predict increased thermal resistance of L. monocytogenes in concentrated milk.

HEAT STABILITY OF RECONSTITUTED, PROTEIN-STANDARDIZED SKIM MILK POWDERS

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The authors determined the effects of standardization material, protein content, and pH on the heat stability of reconstituted milk made from low-heat (LH) and medium-heat (MH) nonfat dry milk (NDM). Low-heat and MH NDM were standardized downward from 35.5% to 34, 32, and 30% protein by adding either edible lactose powder (ELP) or permeate powder (PP) from skim milk ultrafiltration. These powders were called standardized skim milk powders (SSMP). The LH and MH NDM and SSMP were reconstituted to 9% total solids. Furthermore, subsamples of reconstituted NDM and SSMP samples were set aside to measure heat stability at native (unadjusted) pH, and the rest were adjusted to pH 6.3 to 7.0. Heat stability is defined as heat coagulation time at 140°C of the reconstituted LH or MH NDM and SSMP samples. The entire experiment was replicated 3 times at unadjusted pH values and 2 times at adjusted pH values. At an unadjusted pH, powder type, standardization material, and protein content influenced the heat stability of the samples. Heat stability for reconstituted LH NDM and SSMP

was higher than reconstituted MH NDM and SSMP. Generally, decreased heat stability was observed in reconstituted LH or MH SSMP as protein content was decreased by standardization. However, adding ELP to MH SSMP did not significantly change its heat stability. When pH was adjusted to values between 6.3 and 7.0, powder type, standardization material, and pH had a significant effect on heat stability, whereas protein content did not. Maximum heat stability was noted at pH 6.7 for both reconstituted LH NDM and SSMP samples, and at pH 6.6 for both reconstituted MH NDM and SSMP samples. Furthermore, for samples with adjusted pH, higher heat stability was observed for reconstituted LH SSMP containing PP compared with reconstituted milk from LH SSMP containing ELP. However, no statistical difference was observed in the heat stability of reconstituted milk from MH NDM and MH SSMP samples. We conclude that powder type (LH or MH) and effect of standardization material (ELP or PP) can help explain differences in heat stability. The difference in the heat stability of powder type may be associated with the difference in the pH of maximum heat stability and compositional differences in the standardization material (ELP or PP).

MICELLAR CASEIN CONCENTRATE PRODUCTION WITH A 3X, 3-STAGE, UNIFORM TRANSMEMBRANE PRESSURE CERAMIC MEMBRANE PROCESS AT 50°C

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The production of serum protein (SP) and micellar casein from skim milk can be accomplished using microfiltration (MF). Potential commercial applications exist for both SP and micellar casein. The research objective was to determine the total SP removal and SP removal for each stage, and the composition of retentates and permeates, for a 3×, continuous bleed-and-feed, 3-stage, uniform transmembrane pressure (UTP) system with 0.1-µm ceramic membranes, when processing pasteurized skim milk at 50°C with 2 stages of water diafiltration. For each of 4 replicates, about 1,100 kg of skim milk was pasteurized (72°C, 16 s) and processed at 3× through the UTP MF system. Retentate from stage 1 was cooled to <4°C and stored until the next processing day, when it was diluted with reverse osmosis water back to a 1× concentration and again processed through the MF system (stage 2) to a 3× concentration. The retentate from stage 2 was stored at <4°C, and, on the next processing day, was diluted with reverse osmosis water back to a 1× concentration, before running through the MF system at 3× for a total of 3 stages. The retentate and permeate from each stage were analyzed for total nitrogen, noncasein nitrogen, and nonprotein nitrogen using Kjeldahl methods; sodium dodecyl sulfate-PAGE analysis was also performed on the retentates from each stage. Theoretically, a 3-stage, 3× MF process could remove 97% of the SP from skim milk, with a cumulative SP removal of 68 and 90% after the first and second stages, respectively. The cumulative SP removal using a 3-stage, 3× MF process with a UTP system with 0.01-µm ceramic membranes in this experiment was 64.8 ± 0.8, 87.8 ± 1.6, and 98.3 ± 2.3% for the first, second, and third stages, respectively, when calculated using the mass of SP removed in the permeate of each stage. Various methods of calculation of SP removal were evaluated. Given the analytical limitations in the various methods for measuring SP removal, calculation of SP removal based on the mass of SP in the skim milk (determined by Kjeldahl) and the mass SP present in all of the permeate produced by the process (determined by Kjeldahl) provided the best estimate of SP removal for an MF process.

EFFECT OF PRESERVATIVES ON THE ACCURACY OF MID-INFRARED MILK COMPONENT TESTING

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The objective was to determine the effect of commonly used milk preservatives on the accuracy of fat, protein, and lactose content determination in milk by mid-infrared (mid-IR) milk analysis. Two producer raw milks (Holstein and Jersey) and 2 pasteurized modified milks, 1 similar to Holstein milk and 1 similar to Jersey milk were used as the 4 different milk sources. Seven different milk preservative approaches (K2Cr2O7) and 6 different bronopol-based preservatives) and a portion of unpreserved milk for each of the 4 different milks sources were tested for fat B, lactose, protein, and fat A. The experiment was replicated 3 times (28 d each) for a total of 84 d. Two mid-infrared (mid-IR) transmittance milk analyzers (an optical and a virtual filter instrument) were used. A large batch of pilot milk was prepared from pasteurized, homogenized, unpreserved whole milk, split into vials, quick frozen by immersion in liquid nitrogen, and transferred into a -80°C freezer. Pilots were thawed and analyzed on each testing day during the study. Significant increases were observed in all uncorrected readings on the pilot milks over the 84 d of the study, but the increases were gradual and small on each instrument for all components. Results from the study were corrected for these changes. A significant difference in mid-IR fat A readings was observed, whereas no differences were detected for fat B, lactose, or protein between unpreserved and preserved milks containing 0.02% K2Cr2O7. Therefore, K2Cr2O7has little or no effect on mid-IR test results. All bronopol-based preservative approaches in this study differed in mid-IR test results compared with K2Cr2O7-preserved and unpreserved milks, with the largest effect on protein results. Mid-IR uncorrected readings increased with time of refrigerated storage at 4°C for all preservative approaches, with the largest increase for protein. The rate of increase in uncorrected readings with time of storage was always higher for raw milks than for pasteurized milks, and the stability of instrument zero was lower for raw milks than for pasteurized milks. The largest economic effect of a systematic bias caused by a preservative occurs when the milks used for calibration and routine testing for payment do not contain the same preservative or when calibration milks are preserved and milks for routine testing are unpreserved. These effects can create errors in payment for large dairy processing plants ranging from several hundred thousand to over a million dollars annually.

IMPACT OF FAT REDUCTION ON FLAVOR AND FLAVOR CHEMISTRY OF CHEDDAR CHEESES

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A current industry goal is to produce a 75 to 80% fat-reduced Cheddar cheese that is tasty and appealing to consumers. Despite previous studies on reduced-fat cheese, information is critically lacking in understanding the flavor and flavor chemistry of reduced-fat and nonfat Cheddar cheeses and how it differs from its full-fat counterpart. The objective of this study was to document and compare flavor development in cheeses with different fat contents so as to quantitatively characterize how flavor and flavor development in Cheddar cheese are altered with fat reduction. Cheddar cheeses with 50% reduced-fat cheese (RFC) and low-fat cheese containing 6% fat (LFC) along with 2 full-fat cheeses (FFC) were

manufactured in duplicate. Cheeses were ripened at 8°C and samples were taken following 2 wk and 3, 6, and 9 mo for sensory and instrumental volatile analyses. A trained sensory panel (n = 10 panelists) documented flavor attributes of cheeses. Volatile compounds were extracted by solid-phase microextraction or solvent-assisted flavor evaporation followed by separation and identification using gas chromatography-mass spectrometry and gas chromatography-olfactometry. Selected compounds were quantified using external standard curves. Sensory properties of cheeses were distinct initially but more differences were documented as cheeses aged. By 9 mo, LFC and RFC displayed distinct burnt/rosy flavors that were not present in FFC. Sulfur flavor was also lower in LFC compared with other cheeses. Forty aroma-active compounds were characterized in the cheeses by headspace or solvent extraction followed by gas chromatography-olfactometry. Compounds were largely not distinct between the cheeses at each time point, but concentration differences were evident. Higher concentrations of furanones (furaneol, homofuraneol, sotolon), phenylethanal, 1-octen-3-one, and free fatty acids, and lower concentrations of lactones were present in LFC compared with FFC after 9 mo of ripening. These results confirm that flavor differences documented between full-fat and reduced-fat cheeses are not due solely to differences in matrix and flavor release but also to distinct differences in ripening biochemistry, which leads to an imbalance of many flavor-contributing compounds.

RHEOLOGICAL PROPERTIES AND MICROSTRUCTURE OF CHEDDAR CHEESE MADE WITH DIFFERENT FAT CONTENTS

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Reduced- and low-fat cheeses are desired based on composition but often fall short on overall quality. One of the major problems with fat reduction in cheese is the development of a firm texture that does not break down during mastication, unlike that observed in full-fat cheeses. The objective of this investigation was to determine how the amount of fat affects the structure of Cheddar cheese from initial formation (2 wk) through 24 wk of aging. Cheeses were made with target fat contents of 3 to 33% (wt/wt) and moisture to protein ratios of 1.5:1. This allowed for comparisons based on relative amounts of fat and protein gel phases. Cheese microstructure was determined by confocal scanning laser microscopy combined with quantitative image analysis. Rheological analysis was used to determine changes in mechanical properties. Increasing fat content caused an increase in size of fat globules and a higher percentage of nonspherical globules. However, no changes in fat globules were observed with aging. Cheese rigidity (storage modulus) increased with fat content at 10°C, but differences attributable to fat were not apparent at 25°C. This was attributable to the storage modulus of fat approaching that of the protein gel; therefore, the amount of fat or gel phase did not have an effect on the cheese storage modulus. The rigidity of cheese decreased with storage and, because changes in the fat phase were not detected, it appeared to be attributable to changes in the gel network. It appeared that the diminished textural quality in low-fat Cheddar cheese is attributed to changes in the breakdown pattern during chewing, as altered by fat disrupting the cheese network.

EFFECT OF HEAT TREATMENTS ON STABILITY OF B-LACTAMS IN MILK

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The presence of residues of antimicrobial substances in milk may have serious toxicological and technical consequences. To date, few studies have been done to evaluate the effect of heat treatments on ß-lactam residues in milk. However, the few studies that have been conducted estimate losses of antimicrobial activity under different combinations of temperature and time using microbiological methods. The aims of this study were to calculate the kinetic parameters for the degradation of ß-lactam antibiotics in milk and to develop prediction models to estimate the concentration losses of these compounds in conventional dairy heat treatments. To do so, we employed a quantitative HPLC method to calculate losses in concentrations of 10 ß-lactam antibiotics in milk with different combinations of temperature and time. Increasing the temperature from 60°C to 100°C decreased the half-life of amoxicillin (372 to 50 min), ampicillin (741 to 26 min), cloxacillin (367 to 46 min), and penicillin G (382 to 43 min). These increases in temperature caused further degradation in cephalosporins, which was accompanied by a decrease in half-life times to reach very low values; for instance, 4, 5, and 6 min for cefoperazone, cephurexime, and cephapirin, respectively. Kinetic equations were applied to different heat treatments used in dairy processing. Heat treatments at high temperatures and long times (e.g., 120°C for 20 min) led to a further degradation of ß-lactam antibiotics with percentages close to 100% for cefoperazone and cefuroxime. In contrast, when milk was subjected to heat treatments at lower temperatures and times (e.g., 72°C for 15 s), the degradation of ß-lactam in milk did not exceed 1% for the 10 antibiotics tested.

EVALUATION OF COMMERCIALLY AVAILABLE, WIDE-PORE ULTRAFILTRATION MEMBRANES FOR PRODUCTION OF A-LACTALBUMIN–ENRICHED WHEY PROTEIN CONCENTRATE

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Commercially available, wide-pore ultrafiltration membranes were evaluated for production of a-lactalbumin (a-LA)–enriched whey protein concentrate (WPC). In this study microfiltration was used to produce a prepurified feed that was devoid of casein fines, lipid materials, and aggregated proteins. This prepurified feed was subsequently subjected to a wide-pore ultrafiltration process that produced an a-LA–enriched fraction in the permeate. We evaluated the performance of 3 membrane types and a range of transmembrane pressures. We determined that the optimal process used a polyvinylidene fluoride membrane (molecular weight cut-off of 50 kDa) operated at transmembrane pressure (TMP) of 207 kPa. This membrane type and operating pressure resulted in a-LA purity of 0.63, a-LA:ß-LG ratio of 1.41, a-LA yield of 21.27%, and overall flux of 49.46 L/m2•h. The manufacturing cost of the process for a hypothetical plant indicated that a-LA–enriched WPC 80 (i.e., with 80% protein) could be produced at $17.92/kg when the price of whey was considered as an input cost. This price came down to $16.46/kg when the price of whey was not considered as an input cost. The results of this study indicate that production of a commercially viable a-LA–enriched WPC is possible and the process developed can be used to meet worldwide demand for a-LA–enriched whey protein.

THE EFFECT OF STARTER CULTURE AND ANNATTO ON THE FLAVOR AND FUNCTIONALITY OF WHEY PROTEIN CONCENTRATE

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The flavor of whey protein can carry over into ingredient applications and negatively influence consumer acceptance. Understanding sources of flavors in whey protein is crucial to minimize flavor. The objective of this study was to evaluate the effect of annatto color and starter culture on the flavor and functionality of whey protein concentrate (WPC). Cheddar cheese whey with and without annatto (15 mL of annatto/454 kg of milk, annatto with 3% wt/vol norbixin content) was manufactured using a mesophilic lactic starter culture or by addition of lactic acid and rennet (rennet set). Pasteurized fat-separated whey was then ultrafiltered and spray dried into WPC. The experiment was replicated 4 times. Flavor of liquid wheys and WPC were evaluated by sensory and instrumental volatile analyses. In addition to flavor evaluations on WPC, color analysis (Hunter Lab and norbixin extraction) and functionality tests (solubility and heat stability) also were performed. Both main effects (annatto, starter) and interactions were investigated. No differences in sensory properties or functionality were observed among WPC. Lipid oxidation compounds were higher in WPC manufactured from whey with starter culture compared with WPC from rennet-set whey. The WPC with annatto had higher concentrations of p-xylene, diacetyl, pentanal, and decanal compared with WPC without annatto. Interactions were observed between starter and annatto for hexanal, suggesting that annatto may have an antioxidant effect when present in whey made with starter culture. Results suggest that annatto has a no effect on whey protein flavor, but that the starter culture has a large influence on the oxidative stability of whey.

CHARACTERIZATION OF HIGH-MILK-PROTEIN POWDERS UPON REHYDRATION UNDER VARIOUS SALT CONCENTRATIONS

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Rehydration of native micellar casein and native whey isolate protein powders was followed in different ionic environments. Solutions of NaCl and CaCl2 in the concentration range of 0 to 12% (wt%) were used as rehydration media. The rehydration profiles obtained were interpreted in terms of wetting, swelling, and dispersion stages by using a turbidity method. Two behaviors were observed depending on the salt concentration. For native micellar casein powder, a significant change was observed between 3 and 6% NaCl and between 0.75 and 1.5% CaCl2. The first behavior (low salt concentration) presents a typical rehydration profile: quick wetting, swelling, and long dispersion stage. The dispersion stage of the second behavior (high salt concentration) was significantly shortened, indicating a strong modification of the protein backbone. The rehydration of whey protein powder was less influenced by salts. At low salt concentrations, a typical profile for whey powders was observed: wetting with lump formation and no swelling followed by a quick dispersion. At high CaCl2 concentrations, no turbidity stabilization was observed, indicating a possible protein unfolding and denaturation. Additionally, the changes in secondary structures of the 2 proteins upon salt increase were followed by Fourier transform infrared spectroscopy and confirmed the different profiles observed.