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HIGH HYDROSTATIC PRESSURE MODIFICATION OF WHEY PROTEIN CONCENTRATE FOR IMPROVED FUNCTIONAL PROPERTIES

S.-Y. Lim, B. G. Swanson and S. Clark
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Whey protein concentrate (WPC) has many applications in the food industry. Previous research demonstrated that treatment of whey proteins with high hydrostatic pressure (HHP) can enhance solubility and foaming properties of whey proteins. The objective of this study was to use HHP to improve functional properties of fresh WPC, compared with functional properties of reconstituted commercial whey protein concentrate 35 (WPC 35) powder. Fluid whey was ultrafiltered to concentrate proteins and reconstituted to equivalent total solids (8.23%) as reconstituted commercial WPC 35 powder. Solutions of WPC were treated with 300 and 400 MPa (0- and 15-min holding time) and 600 MPa (0-min holding time) pressure. After HHP, the solubility of the WPC was determined at both pH 4.6 and 7.0 using UDY and BioRad protein assay methods. Overrun and foam stability were determined after protein dispersions were whipped for 15 min. The protein solubility was greater at pH 7.0 than at pH 4.6, but there were no significant differences at different HHP treatment conditions. The maintenance of protein solubility after HHP indicates that HHP-treated WPC might be appropriate for applications to food systems. Untreated WPC exhibited the smallest overrun percentage, whereas the largest percentage for overrun and foam stability was obtained for WPC treated at 300 MPa for 15 min. Additionally, HHP-WPC treated at 300 MPa for 15 min acquired larger overrun than commercial WPC 35. The HHP treatment of 300 MPa for 0 min did not improve foam stability of WPC. However, WPC treated at 300 or 400 MPa for 15 min and 600 MPa for 0 min exhibited significantly greater foam stability than commercial WPC 35. The HHP treatment was beneficial to enhance overrun and foam stability of WPC, showing promise for ice cream and whipping cream applications.

HIGH HYDROSTATIC PRESSURE MODIFICATION OF WHEY PROTEIN CONCENTRATE FOR IMPROVED BODY AND TEXTURE OF LOWFAT ICE CREAM

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Previous research demonstrated that application of high hydrostatic pressure (HHP), particularly at 300 MPa for 15 min, can enhance foaming properties of whey protein concentrate (WPC). The purpose of this research was to determine the practical impact of HHP-treated WPC on the body and texture of lowfat ice cream. Washington State University (WSU)-WPC was produced by ultrafiltration of fresh separated whey received from the WSU creamery. Commercial whey protein concen-

trate 35 (WPC 35) powder was reconstituted to equivalent total solids as WSU-WPC (8.23%). Three batches of lowfat ice cream mix were produced to contain WSU-WPC without HHP, WSU-WPC with HHP (300 MPa for 15 min), and WPC 35 without HHP. All lowfat ice cream mixes contained 10% WSU-WPC or WPC 35. Overrun and foam stability of ice cream mixes were determined after whipping for 15 min. Ice creams were produced using standard ice cream ingredients and processing. The hardness of ice creams was determined with a TA-XT2 texture analyzer. Sensory evaluation by balanced reference duo-trio test was carried out using 52 volunteers. The ice cream mix containing HHP-treated WSU-WPC exhibited the greatest overrun and foam stability, confirming the effect of HHP on foaming properties of whey proteins in a complex system. Ice cream containing HHP-treated WSU-WPC exhibited significantly greater hardness than ice cream produced with untreated WSU-WPC or WPC 35. Panelists were able to distinguish between ice cream containing HHP-treated WSU-WPC and ice cream containing untreated WPC 35. Improvements of overrun and foam stability were observed when HHP-treated whey protein was used at a concentration as low as 10% (wt/wt) in ice cream mix. The impact of HHP on the functional properties of whey proteins was more pronounced than the impact on sensory properties.

MEASUREMENT OF THE OXIDATION–REDUCTION POTENTIAL OF CHEDDAR CHEESE

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The objective was to develop a method to measure the oxidation–reduction (redox) potential of hard cheeses such as cheddar and to investigate the impact on this parameter of measurement temperature, and factors associated with electrochemical cell design such as distance between reference and working electrodes and depth into the cheese of the platinum electrodes. For this purpose, a novel, self-sealing, platinum working electrode was constructed which was thin and flexible enough to be inserted directly into the cheese sample. A calomel electrode was used as the reference electrode and the circuit was completed with a 3 M KCl salt bridge. The physical orientation of electrodes, such as distance between reference electrode and working electrode, had a substantial effect on equilibrium time for redox potential measurement. The time required for redox potential to reach equilibrium was 2 d in cheddar cheese and the optimum distance between the platinum and calomel electrodes was 2.5 cm. The fastest equilibration time was obtained when the working electrode was inserted 5 or 6 cm into the cheese. Temperature also had an important effect on redox potential. The shortest time to reach equilibrium of potential was at room temperature (20 °C), but it was not practical to keep cheese at this temperature for a period of 2 d. Therefore, redox measurement at 12 °C was recommended in spite of the longer equilibration time compared with room temperature. The results of this study suggest that the novel platinum working electrode allows reproducible measurement of the oxidation–reduction potential of cheddar cheese.

WHEY PROTEIN CONCENTRATE AND GUM TRAGACANTH AS FAT REPLACERS IN NONFAT YOGURT: CHEMICAL, PHYSICAL, AND MICROSTRUCTURAL PROPERTIES

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The effect of whey protein concentrate (WPC) and gum tragacanth (GT) as fat replacers on the chemical, physical, and microstructural properties of nonfat yogurt was investigated. The WPC (7.5, 15, and 20 g/L) and GT (0.25, 0.5, 0.75, and 1 g/L) were incorporated into the skim milk slowly at 40 to 45°C with agitation. The yogurt mixes were pasteurized at 90°C for 10 min, inoculated with 0.1% starter culture, and incubated at 42°C to pH 4.6, then refrigerated overnight at 5°C. A control nonfat yogurt and control full fat yogurt were prepared as described, but without addition of WPC and GT. Increasing amount of WPC led to the increase in total solids, total protein, acidity, and ash content, whereas GT did not affect chemical parameters. Increasing WPC caused a more compact structure consisting of robust casein particles and large aggregates. Firmness was increased and susceptibility to syneresis was decreased as WPC increased. No significant difference was observed for firmness and syneresis of yogurt fortified with GT up to 0.5 g/L compared with control nonfat yogurt. Increasing the amount of gum above 0.5 g/L produced softer gels with a greater tendency for syneresis than the ones prepared without it. Addition of GT led to the coarser and more open structure compared with control yogurt.

FACTORS REGULATING ASTRINGENCY OF WHEY PROTEIN BEVERAGES

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A rapidly growing area of whey protein use is in beverages. There are 2 types of whey protein-containing beverages: those at neutral pH and those at low pH. Astringency is very pronounced at low pH. Astringency is thought to be caused by compounds in foods that bind with and precipitate salivary proteins; however, the mechanism of astringency of whey proteins is not understood. The effect of viscosity and pH on the astringency of a model beverage containing whey protein isolate was investigated. Trained sensory panelists (n = 8) evaluated the viscosity and pH effects on astringency and basic tastes of whey protein beverages containing 6% wt/vol protein. Unlike what has been shown for alum and polyphenols, increasing viscosity (1.6 to 7.7 mPa·s) did not decrease the perception of astringency. In contrast, the pH of the whey protein solution had a major effect on astringency. A pH 6.8 whey protein beverage had a maximum astringency intensity of 1.2 (15-point scale), whereas that of a pH 3.4 beverage was 8.8 (15-point scale). Astringency decreased between pH 3.4 and 2.6, coinciding with an increase in sourness. Decreases in astringency corresponded to decreases in protein aggregation as observed by turbidity. We propose that astringency is related to interactions between positively charged whey proteins and negatively charged saliva proteins. As the pH decreased between 3.4 and 2.6, the negative charge on the saliva proteins decreased, causing the interactions with whey proteins to decrease.

EFFECTS OF CUTTING INTENSITY AND STIRRING SPEED ON SYNERESIS AND CURD LOSSES DURING CHEESE MANUFACTURE

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Recombined whole milk was renneted under constant conditions of pH, temperature, and added calcium, and the gel was cut at a constant firmness. The effects of cutting and stirring on syneresis and curd losses to whey were investigated during cheese making using a factorial design with 3 cutting modes designed to provide 3 different cutting intensity levels (i.e., total cutting revolutions), 3 levels of stirring speed, and 3 replications. These cutting intensities and stirring speeds were selected to give a wide range of curd grain sizes and curd shattering, respectively. Both factors affected curd losses, and correct selection of these factors is important in the cheesemaking industry. Decreased cutting intensity and increased stirring speed significantly increased the losses of fines and fat from the curd to the whey. Cutting intensities and stirring speeds in this study did not show significant effects on curd moisture content over the course of syneresis. Levels of total solids, fines, and fat in whey were shown to change significantly during syneresis. It is believed that larger curd particles resulting from low cutting intensities coupled with faster stirring speeds resulted in a higher degree of curd shattering during stirring, which caused significant curd losses.

MICROBIOLOGICAL, CHEMICAL, AND SENSORY CHARACTERISTICS OF SWISS CHEESE MANUFACTURED WITH ADJUNCT LACTOBACILLUS STRAINS USING A LOW COOKING TEMPERATURE

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The effect of nonstarter *Lactobacillus* adjunct cultures on the microbial, chemical, and sensory characteristics of Swiss cheese manufactured using the "kosher make procedure" was investigated. The kosher make procedure, which uses a lower cooking temperature than traditional Swiss cheese making, is used by many American cheese manufacturers to allow for kosher-certified whey. Cheeses were manufactured using a commercial starter culture combination and 1 of 3 non-starter *Lactobacillus* strains previously isolated from Swiss cheeses, *Lactobacillus casei* A26, *L. casei* B21, and *Lactobacillus rhamnosus* H2, as an adjunct. Control cheeses lacked the adjunct culture. Cheeses were analyzed during ripening for microbial and chemical composition. Adjunct strain *L. casei* A26, which utilized citrate most readily in laboratory medium, dominated the *Lactobacillus* population within 30 d, faster than the other adjunct cultures. There were no significant differences in *Propionibacterium* counts, *Streptococcus thermophilus* counts, protein, fat, moisture, salt, and pH among the cheeses. Free amino acid concentration ranged from 5 to 7 mmol/100 g of cheese at 90 d of ripening and was adjunct strain dependent. Lactic, acetic, and propionic acid concentrations were not significantly different among the cheeses after a 90-d ripening period; however differences in propionic acid concentrations were apparent at 60 d, with the cheeses made with *L. casei* adjuncts containing less propionic acid. Citric acid was depleted by the end of warm room ripening in cheeses manufactured with adjunct *L. casei* strains, but not with adjunct *L. rhamnosus*. Cheeses made with *L. casei* A26 were most similar to the control cheeses in diacetyl and butyric/isobutyric acid abundance as evaluated by elec-

tronic nose during the first 3 mo of ripening. The 4 cheese types differed in their descriptive sensory profiles at 8 mo of age, indicating an adjunct strain-dependent effect on particular flavor attributes. Adjunct *Lactobacillus* spp. affected the flavor profile and concentration of some flavor compounds in Swiss cheeses produced with the kosher make procedure. Use of adjunct *Lactobacillus* cultures provides Swiss cheese makers using a low cooking temperature with a means to control the dominant *Lactobacillus* strain during ripening, reduce citrate concentration, and modify cheese flavor.

INFLUENCE OF SALT-TO-MOISTURE RATIO ON STARTER CULTURE AND CALCIUM LACTATE CRYSTAL FORMATION

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The occurrence of L(+)-lactate crystals in hard cheeses continues to be an expense to the cheese industry. Salt tolerance of the starter culture and the salt-to-moisture ratio (S:M) in cheese dictate the final pH of cheese, which influences calcium lactate crystal (CLC) formation. This research investigates these interactions on the occurrence of CLC. A commercial starter was selected based on its sensitivity to salt, less than and greater than 4.0% S:M. Cheddar cheese was made by using either whole milk (3.25% protein, 3.85% fat) or whole milk supplemented with cream and ultrafiltered milk (4.50% protein, 5.30% fat). Calculated amounts of salt were added at milling (pH 5.40 ± 0.02) to obtain cheeses with less than 3.6% and greater than 4.5% S:M. Total and soluble calcium, total lactic acid, and pH were measured and the development of CLC was monitored in cheeses. All cheeses were vacuum packaged and gas flushed with nitrogen gas and aged at 7.2°C for 15 wk. Concentration of total lactic acid in high S:M cheeses ranged from 0.73 to 0.80 g/100 g of cheese, whereas that in low S:M cheeses ranged from 1.86 to 1.97 g/100 g of cheese at the end of 15 wk of aging because of the salt sensitivity of the starter culture. Concentrated milk cheeses with low and high S:M exhibited a 30 to 28% increase in total calcium (1,242 and 1,239 mg/100 g of cheese, respectively) compared with whole milk cheeses with low and high S:M (954 and 967 mg/100 g of cheese, respectively) throughout aging. Soluble calcium was 41 to 35% greater in low S:M cheeses (low-salt whole milk cheese and low-salt concentrated milk cheese; 496 and 524 mg/100 g of cheese, respectively) compared with high S:M cheeses (high-salt whole milk cheese and high-salt concentrated milk cheese; 351 and 387 mg/100 g of cheese, respectively). Because of the lower pH of the low S:M cheeses, CLC were observed in low S:M cheeses. However, the greatest intensity of CLC was observed in gas-flushed cheeses made with milk containing increased protein concentration because of the increased content of calcium available for CLC formation. These results show that the occurrence of CLC is dependent on cheese milk concentration and pH of the cheese, which can be influenced by S:M and cheese microflora.

NEW STRETCH TEST FOR CHEESE

Stable Micro Systems has launched a pioneering new Cheese Extensibility Rig. Designed to scientifically evaluate the stretchability of cheeses like mozzarella, this test helps food manufacturers gauge the consumer appeal of cheese used in snack foods, sauces and toppings.

The extensibility of cheese is an important textural characteristic in a wide range of food applications – in particular, pizza. Freezing, shredding, thawing and even cooking cheese can have a significant impact on its textural characteristics. Reduced-fat products also display very different characteristics compared to full-fat versions. All this may result in a texture with unpleasant mouthfeel. Previously, one of the most common ways to test the stretchability of cheese was to lift it with a fork and assess the force required to stretch it, as well as the length to which it stretches. This method is inherently subjective and unreliable.

Responding to the need for an objective, repeatable test method for cheese, Stable Micro Systems developed its new rig. Used in conjunction with a TA.XTplus texture analyzer, the rig comprises a microwavable vessel, sample retainer and double-sided fork probe. The cheese is cut into small cubes and microwaved in the vessel until melted. The sample retainer is slotted into the vessel, which is securely fastened to the base of the texture analyzer. After the fork probe is attached, the arm of the texture analyzer pulls the fork upwards through the molten cheese and Exponent software measures the force required to stretch it, and the distance to breakpoint. Typical results show that the longer the distance, the stretchier the cheese.

For repeatability and replication of consumer experience, a PT100 temperature probe may be used to monitor the temperature of a sample. The test can then be programmed to start when a chosen target temperature is attained.

The innovative components of the rig have been produced using new rapid prototyping techniques, which use advanced direct laser sintering technologies that generate complex three-dimensional objects quickly and directly from computer-based models devised by Computer Aided Design (CAD). This method is particularly useful for the creation of complex or customer-specific components and results in robust, high-quality fixtures that can be produced rapidly according to need.

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