M43 Evaluation of the effects of gamma irradiation treatment on the compositional, textural, color, volatile profile, and microbiological quality of an artisanal hard-pressed cheese. F. Nyamakwere1, G. Esposito2, K. Dzama1, P. Gouws1, T. Rapisarda1, G. Belvedere1, and E. Raffrenato2,3, 1Stellenbosch University, Stellenbosch, South Africa, 2RUM&N Consulting, Reggio Emilia, Italy, 3Consorzio per la Ricerca nel settore della Filiera Lattiero-Casearia e dell’agroalimentare, Ragusa, Italy.

Irradiation treatment can be an effective way of reducing the incidence of food-borne pathogens on cheese, thus improving food safety. The objective of this study was to evaluate the efficacy of γ-irradiation against Listeria monocytogenes, Excherichia coli, coliforms and aerobic colony counts (ACC). At the same time effects on cheese composition, texture, color and odor properties were evaluated. The cheeses were manufactured at 4 farms using raw milk under artisanal processing conditions and aged for 60 dd. Samples were of either 250 or 500 g. The Cobalt-60 γ-irradiator was used at a maximum dose of 5.0 kGy, dose rate of 1 kGy/h and source strength was 150 kCi. Cheese samples both before and after treatment were analyzed by the “SMart Nose” system, by gas chromatography-mass spectrometry-olfactometry. Data were analyzed with the irradiation treatment and sample weight as the main fixed factors. Moisture, pH, total nitrogen, fat in dry matter, water activity were reduced (P < 0.05) and salt and salt in moisture increased (P < 0.05) after the irradiation treatment. All values were within the acceptable range for hard cheese. Dose and treatment length altered water-holding capacity and some enzymatic and bacterial activities affecting the monitored parameters. All color parameters (lightness, redness, yellowness, chroma and hue angle) were decreased (P < 0.05) by the irradiation treatment. Hardness and chewiness values increased (P < 0.05), whereas, cohesiveness and springiness decreased (P < 0.05). The amounts of β-casein decreased (P < 0.05) after the treatment. SMart Nose on the principal component analysis and Odor Active Compounds showed differences (P < 0.05) between the non-irradiated and irradiated samples. The irradiation treatment caused a significant (P < 0.05) reduction of L. monocytogenes, E. coli, coliforms and ACC on the treated cheese samples. Results and the low cost suggest the potential use of the irradiation treatment as an affordable method to effectively control food pathogens for resource limited producers.

Key Words: volatile profile, ionizing radiation, microbial safety


Pladolens is a new Russian semi-hard cheese that is slightly sour and dense, elastic, homogeneous throughout the mass and has uneven holes with irregular slit-like shape. The mass fraction of moisture, salt, fat (dry matter) and pH are 44.0 ± 1.0%, 1.75 ± 0.25%, 45.0 ± 5.0%, and 5.3 ± 0.1, respectively. The aim of this study was to evaluate the viability of probiotics (lactobacillus and bifidobacteria) in Pladolens during ripening (1 mo, T = 10 ± 2°C, relative humidity 85–90%) and storage (3 mo, T = 3 ± 3°C, relative humidity 80–85%). The cheese samples were produced using starter cultures in combination with 2 mixtures of probiotics including mixture 1: L. lactis ssp. lactis, L. lactis ssp. cremoris, L. lactis ssp. lactis biovar. diacetylactis and Leuc. lactis or Leuc. mesenteroides ssp. cremoris, L. plantarum, B. longum and B. bifidum, and mixture 2: L. lactis ssp. lactis, L. lactis ssp. cremoris, L. lactis ssp. cremoris, L. acidophilus, L. acidophilus, Lact. casei, and B. adolescentis. Lactobacilli and bifidobacteria were grown in Rogosa agar and TOS-MUP agar with subsequent incubation of 72 h, respectively. The smallest real difference (SRD) was used to determine the extent of measurement error with 8 replications. A large number of lactobacillus live cells were observed in the cheese samples inoculated with both types of cultures after 90 d. In the samples inoculated with the mixture 1, the number of bifidobacteria after the press and 90 d storage were 2.0 × 10^8 cfu/g and 8.9 × 10^7 cfu/g, respectively, while in the mixture 2, the number of bifidobacteria was in the range of 8.5 × 10^8 cfu/g after the press and 9.0 × 10^8 cfu/g after 90 d of storage. Although the survival rate of bifidobacteria in the cheese samples was higher than after the press, no significant differences were observed during ripening and storage (SRD < 2.0, P > 0.05). The results demonstrated the high viability of lactobacillus and bifidobacteria in Pladolens during ripening and storage until the expiration date (3 mo).

Key Words: Pladolens, semi-hard cheese, probiotics

M45 Manufacture of imitation Mozzarella cheese without emulsifying salts using acic curd and micellar casein concentrate. A. R. A. Hammam* and L. E. Metzger, Dairy and Food Science Department, South Dakota State University, Brookings, SD.

Imitation Mozzarella type cheese (IMC) is a dairy, partial or non-dairy food based on the source of protein and fat used in the formulation. IMC has the same basic principles of manufacture as process cheese (PC) and it is prepared by blending dairy ingredients and non-dairy ingredients with the aid of heat, shear, and emulsifying salts to produce a homogeneous product. Emulsifying salts are critical for the functional characteristics of IMC because they improve the emulsification characteristic of casein by displacing the calcium phosphate complexes that are present in the insoluble calcium-paracaseinate phosphate network in the casein containing ingredients. The objective of this study was to manufacture IMC using a combination of acid curd (AC) and micellar casein concentrate (MCC) that would provide the required emulsion capacity without the use of emulsifying salts. The formulations were targeted to produce IMC with 18.0% protein, 49.0% moisture, 20.0% fat, and 1.5% salt. In the IMC formulation, the AC was blended with MCC so that the formula contained a 2:1 ratio of protein from AC relative to MCC. Additional dairy and non-dairy ingredients (milk permeate, vegetable oil, and salt) were also utilized in the formulations. The IMC was prepared by mixing all ingredients in a kitchen aid to produce a homogeneous paste. Approximately 25 g of the mixture was cooked in the rapid visco analyzer (RVA) for 3 min at 95°C with a 1000 rpm stirring speed during the first 2 min and 160 rpm during the last min. The cooked IMC was then transferred into molds and refrigerated until further analysis. This trial was repeated 3 times using 3 different batches of AC. No significant differences (P > 0.05) were detected in the cooked viscosity (7500 cP), hardness (95.0 g), melting temperature (50.0°C), melting diameter (31.5 mm), and stretchability (12.3 cm) of IMC made from different AC and was similar to typical IMC produced with emulsifying salts. We conclude that IMC can be made with no emulsifying salts when the formulation utilizes a 2:1 ratio of protein from AC relative to MCC.

Key Words: micellar casein concentrate, acid curd, imitation mozzarella cheese

M46 Liquid chromatography-tandem mass spectrometry analysis of glycomacropeptide from whey protein isolate. Y. Qu*, B. J. Kim, and D. Dallas, Oregon State University, Corvallis, OR.

κ-Casein glycomacropeptide (GMP), a 64-amino-acid peptide, is released from κ-casein after rennet treatment and is one of the major peptides in whey protein isolate (WPI). GMP has anti-inflammatory and antibacterial actions. GMP has 2 major amino acid sequences and many different modifications including glycosylation, phosphorylation and oxidation, yet no previous work has provided a comprehensive profile of all the different distinct GMP forms present in whey. The full characterization of the composition and structure of GMP is important to help to understand the
bioactivity of GMP. We therefore aimed to develop an analytical method to profile GMP and GMP peptide fragments in WPI using Orbitrap mass spectrometry combined with a nano-liquid chromatography (LC). A commercial WPI was dissolved in water and purified by C18-solid-phase extraction and characterized by a nano-LC/Orbitrap MS/MS under electron-transfer/higher-energy collision dissociation mode. MS and MS/MS results were interpreted using Byos (Byonic and Byologic) processing and manual spectral inspection to verify structures. Forty-five distinct intact GMP forms were identified in the WPI. One intact GMP was without any modification, 5 intact GMP forms were glycosylated only, 4 were phosphorylated only, one was oxidized only, 3 were both phosphorylated and oxidized, 22 were for both glycosylated and phosphorylated and 8 were glycosylated, phosphorylated and oxidized. Four O-linked glycosylations (HexNAc1Hex1, HexNAc1Hex1NeuAc1, HexNAC1Hex1NeuAc1, HexNAc1Hex1NeuAc2) were present on the GMP. In addition to intact GMP, 186 distinct GMP-derived peptides were identified in the WPI, likely generated from partial hydrolysis during whey processing or storage. These glycopeptides were between 9 and 63 amino acid length. We have demonstrated the efficacy of this novel analytical approach to comprehensively profile the range of GMP and GMP-derived structures in whey protein isolates. Our comprehensive profile of all the different distinct GMP forms present in whey provides some fundamental information on determining how GMP is digested in human and understanding the bioactivity of GMP.

Key Words: glycocomacropptide, LC-MS/MS, whey

M47 Effect of inulin on the microbiological and organoleptic characteristics of synbiotic yogurt. D. G. Kamel*, Dairy Science Department, Assiut University, Assiut, Egypt.

Nowadays, there is an interest in adding probiotics and probiotics (synbiotic) to yogurt due to its health benefits. The objective of this work was to study the effect of different concentrations of inulin (0.2, 0.4, and 0.6%) on microbiological and chemical characteristics of probiotic yogurt. The yogurt was manufactured with Lactobacillus delbrueckii ssp. bulgaricus (Lb), Streptococcus thermophilus (St), and Bifidobacterium bifidum (Bb). Raw milk was received, pasteurized, and divided into 4 aliquots portions. All portions were inoculated with 1% Lb, 1% St, and 15% Bb. The first portion was utilized as control (T1) while 0.2, 0.4, and 0.6% of inulin were added to the second (T2), third (T3), and fourth (T4) portions, respectively. All treatments were inoculated at 40°C until a pH of 4.6 was reached. Subsequently, the yogurt was cooled and stored at 4°C for 16 d. Titratable acidity, sensory evaluation, Bb count, and total bacterial count (TBC) were determined during the storage. This experiment was repeated 3 times using 3 different batches of raw milk. The results showed that the addition of inulin has no significant effect (P > 0.05) on the titratable acidity of the yogurt during the 16 d of storage. There were no significant differences (P > 0.05) in the sensory evaluation of T1, T2, T3, and T4. The TBC increased (P < 0.05) over time in T1, while it was decreased (P < 0.05) with increasing the concentration of inulin in T2, T3, and T4. However, the addition of inulin increased (P < 0.05) the viability of Bifidobacterium bifidum during the storage. We conclude that inulin can be utilized in the manufacturing of synbiotic yogurt by incorporation with probiotic, which, in turn, enhances the growth of Bifidobacterium bifidum and antimicrobial activity that decreased the TBC. The impact of inulin in the texture of probiotic yogurt during 16 d of storage will be evaluated in subsequent studies by determining the rheological characteristics.

Key Words: probiotic yogurt, inulin, Bifidobacterium bifidum

M48 Microbial degradation of FD&C Red No. 40 in strawberry-flavored milk. C. Rush* and J. Waite-Cusic, Oregon State University, Corvallis, OR.

Most high-temperature short-time (HTST) fluid milk processors declare their products are consumable 3 to 5 d after code date with minimal changes occurring in flavor and color. Flavored milks tend to display more significant quality defects near the end of shelf life which can negatively impact future purchase decisions. Most strawberry milk products include color additives, including FD&C Red No. 40 and/or red beet concentrate. The objective of this study was to observe the color degradation over shelf life in HTST strawberry-flavored milks dyed with FD&C Red No. 40 and to investigate a microbial cause for the color loss. Commercially available strawberry-flavored milks with FD&C Red No. 40 listed as a colorant (n = 2 brands, 3 separate lots) were obtained from local markets. At the code date, the milk was aseptically aliquoted into 50-mL conical tubes and stored at 7°C. Samples were analyzed daily for changes in pH, color, texture, and organoleptic properties (aroma). Once a defect was detected, the sample was spread plated on tryptic soy agar (TSA) and strawberry milk agar (standard methods agar with 10% vol/vol strawberry milk). Visual color degradation began one day post code date (2–4 log cfu/mL) displayed via white streaks on the surface of the sample. Seven days post code date (4–6 log cfu/mL) the samples with only FD&C Red No. 40 as the color agent were visually absent of the pink color (vibrant pink to opaque white) and samples with a secondary color agent had considerably reduced in color (vibrant pink to very light pink). Colonies were streaked on strawberry milk agar that contained FD&C Red No. 40 to select the color-degrading isolates. These isolates will undergo further sequencing to identify the species responsible for the degradation of FD&C Red No. 40 in strawberry-flavored milk.

Key Words: strawberry milk, FD&C Red No. 40, shelf-life

M49 Production and physico-chemical characterization of functional ice cream with whey and buttermilk powder. A. F. Cruz*, R. T. Pfrimer†, L. Damasceno‡, D. S. Fernandes‡, L. A. F. Silva†, E. S. Nicolau‡, and C. Gebara†, †School of Veterinary Medicine and Animal Science, Federal University of Goiás, Goiânia, Goiás, Brazil, ‡Food Research Center, School of Veterinary Medicine and Animal Science, Federal University of Goiás, Goiânia, Goiás, Brazil.

Consumers have sought healthier foods, with less chemical substances, fat, and sugar content. Natural ingredients are attractive for ice cream production, especially when it reduces thickeners and stabilizers. The use of dairy coproducts, such as whey and buttermilk, as ingredients in the manufacture of food products, is already a worldwide reality. Its use on dairy foods giving a sustainable destination to these coproducts, valuing the environmental appeal. For ice cream production, whey and buttermilk powder can be used due to their high protein content, excellent technological and nutritional characteristics. This work aimed to develop and characterize ice creams produced with whey and buttermilk powder. Formulations were produced with concentrations of whey and buttermilk between 5 and 15%, concentration of milk/cream between 70 and 90%, 10% of sugar, and 1% of emulsifier. The ice cream mix was pasteurized for 70°C for 30 min, and then churn it with the ice cream machine for 80 min. After that, the ice creams were stored at −18°C. Physico-chemical characterization was done by official methods, and results were evaluated by ANOVA and Tukey test (P < 0.05) for mean comparison. They presented pH between 6.24 and 6.50, acidity between 0.19 and 0.47 g acid lactic/100 g moisture between 53.67 and 67.93%, ash between 0.92 and 1.69%; lipids between 8.94 and 9.89%, and lactose content between 7.85 and 18.09%. The results of colorimetry were lightness (L*) between 75.63 and 79.53, a* parameter between −0.80 and −1.73, b* parameter between +10.65 and +14.83. The formulation with higher contents of whey and buttermilk presented higher acidity, ash, lactose content, and trend to yellow color (+b*). The ice cream with a lower concentration of whey and buttermilk
presented higher pH, moisture, lipids, lightness, and trend to green color (-a*). Ice cream production using whey and buttermilk is an innovative and viable alternative for the dairy industry, being able to bring technological benefits to the final product and benefits to the consumer’s health.

Key Words: dairy products, functionality, innovative product

M50 Influence of protein content on acidity of fermented dairy beverages with buttermilk and gabiroba pulp (Campomanesia xanthocarpa). L. Damasceno*, R. T. Pfrimmer, C. F. Cardoso, E. C. Nogueira, E. S. Nicolau, and C. Gebara, 1Food Research Center, School of Veterinary Medicine and Animal Science, Federal University of Goiás, Goiânia, Goiás, Brazil; 2School of Agronomy, Federal University of Goiás, Goiânia, Goiás, Brazil; 3School of Veterinary Medicine and Animal Science, Federal University of Goiás, Goiânia, Goiás, Brazil; 4Maroca Dairy Industry, Piranhas, Goiás, Brazil.

Milk is extremely nutritious and a complete food. The proteins, especially caseins, are one of the most important constituents to technological aspects and can directly influence the physical, chemical and nutritional characteristics of fermented products. The aim of this work was to correlate the influence of protein content with variation in acidity of fermented dairy beverages with buttermilk and gabiroba pulp (Campomanesia xanthocarpa). They were formulated by designing simplex centroid mixtures with different levels of milk (40–56%), whey (0–44%), buttermilk (0–44%) and gabiroba pulp (10–20%). The beverages were analyzed for acidity, proteins and protein fractions, after manufactured after that weekly for 84 d, using official methods. The results were calculated statistically by ANOVA and the media were compared using the Scott-Knott test (P < 0.05). The acidity of the formulations on the first day presented results between 0.34 to 0.56 (g / lactic / 100mL) and that beverages with a higher protein content (2.12 to 2.24%) and caseins (1.69 to 1.88%) had a higher concentration of milk and varied values of whey, milk and pulp in their composition, indicating that milk was the ingredient that determined the highest acidity and protein content. The interactions of mathematical models confirm this result through the prediction equations that demonstrated that the interactions of ingredients with milk were antagonistic, that is, they not influence the increase in acidity. The increase in acidity over 84 d (increasing from 0.46 to 0.56 g lactic acid / 100mL) demonstrates an occurrence of post-acidification. However, as suggested minor changes in the acidity part of the beverages due to the natural acidity of milk, attributed to caseins, despite being an acidic component, it acts as a buffering agent, controlling post-acidification. Thus, the higher milk concentration of the formulations determined high acidity values, however the proposed agent, controlling post-acidification. Thus, the higher milk concentration of milk and varied values of whey, milk and pulp in their respective presentation of the isolates to the Listeria monocytogenes EGD-e reference genome discovered 110,342 high-quality single nucleotide variants (hqSNVs). The presence of genes related to capsular glycan, cell wall/ capsular LTP, biotin biosynthesis, and carbohydrate metabolism associated with amino sugars such as chitin were correlated with the biofilm formation. Further studies in this regard would help us identify the genes associated with colonization, and serve as potential targets for novel approaches such as autoinduction interceptors for preventing or limiting Listeria adhesion.

Key Words: whole-genome sequencing, biofilm, Listeria


Acid whey (AW) from Greek yogurt is an underutilized by-product and a challenge for the dairy industry. One valued-added scheme is the fermentation of AW -with or without the addition of lactase- by yeast such as Saccharomyces, Brettanomyces and Kluyveromyces spp. to produce new styles of fermented beverages. Previous research in our group observed changes in fermentation performance with lactate addition. Therefore, this work aims to describe the fermentation kinetics of dairy-relevant sugars by S. cerevisiae, K. marxianus and B. claussenii in simulated AW conditions to study alcoholic fermentation as an alternative for AW’s reinsertion into the food supply chain. For this purpose, 4 preparations of yeast nitrogen base with amino acids with 40 g/L of lactose (LAC), glucose (GLU), galactose (GAL) or a 1:1 mixture of glucose and galactose (GLU+GAL), with a final pH of 4.20, were used as fermentation media. Each medium was inoculated with S. cerevisiae, K. marxianus or B. claussenii to achieve an initial concentration of 4 × 10^6 cfu/mL in 500 mL and incubated at 25°C under anaerobic conditions, while density, pH, cell count, ethanol and organic acids were monitored. Statistical analysis was done using Tukey’s HSD test. Results indicated that K. marxianus had a similar or better performance compared with S. cerevisiae, whereas B. claussenii sugar consumption rate was substantially lower. In particular, densities showed that there is no significant difference in the time that K. marxianus and S. cerevisiae need for the complete depletion of GLU (2 d, P > 0.05) and GAL (3 d, P > 0.05), and that GLU+GAL consumption was significantly faster in the presence of K. marxianus (3 d, P < 0.05). On the other hand, B. claussenii exhibited significant differences in sugar utilization while in LAC vs GLU+GAL, not completing the fermentation for the latter (P < 0.05); a phenomenon that will be explored further. These results provide a deeper understanding of dairy sugar utilization by relevant yeast, allowing for future work to optimize fermentations to improve valued-added beverage and ingredient production from AW.

Key Words: acid whey, fermentation, ethanol

M53 Preliminary studies on the use of fluorescence spectroscopy and chemometrics for classification of nonfat dry milk based on spore counts. C. Qian*, D. Vega, K. Bonilla, R. Phebus, and J. Amamcharla, Kansas State University, Manhattan, KS.

Nonfat dry milk (NDM) is a popular ingredient in a wide range of shelf-stable food products. However, high spore containing NDM can lead to ropiness and introduce unwanted lipase and protease activity. The thermophilic and mesophilic spores can enter into raw milk through the
cow, feed, and beddings at the farm level. Further, spore counts can increase during the manufacture of NDM due to the concentration factor as well as contamination from the matured biofilms formed on the equipment. Therefore, the spore count is a critical quality indicator to be monitored during production. Previous research suggests that dipicolinic acid (DPA) is present in the core of endospore and can be used as a fluorophore of interest for rapid detection of spores. This objective of this study was to use DPA fluorescence spectra and chemometrics to develop classification models based on the spore levels. Commercial NDM samples (n = 40) were procured within the United States. The reference spore counts (cfu/g of NDM) were obtained by heating reconstituted NDM (10%) at 100°C for 30 min, plated on Tryptic Soy Agar, and incubated at 55°C for 48 h. To release all available DPA and to remove interferents, the reconstituted NDM (10%) was autoclaved at 121°C for 30 min followed by acidification and centrifugation. The terbium chloride was added to the supernatant buffered to pH 5.6 to enhance the DPA fluorescence signal. Emission spectra of terbium DPA complex were collected between 450 and 650 nm fixed at the excitation of 270 nm. Classification models were developed using partial least square quadratic discriminant analysis (PLS-QDA), forward selection quadratic discriminant analysis (FS-QDA), and random forest (RF). It was found that random forest provided the highest mean classification accuracy of 87% while FS-QDA and PLS-QDA showed the mean accuracy at 84% and 83%, respectively (validated using bootstrapping technique). The results suggest the potential of using fluorescence spectroscopy to classify the NDM based on spore counts.

Key Words: Bacillus endospores, classification models, dipicolinic acid

M54 Low-level microbial contaminants in whey multiply rapidly on food contact surfaces under production conditions. B. Selover* and J. Waite-Cusic, Oregon State University, Corvallis, OR.

As the time between sanitation events increases, bacteria can attach and grow on equipment and surfaces potentially developing biofilms that could impact dairy product quality. Prudent sanitation schedules should be implemented to mitigate biofilm development; however, scientific evidence is lacking to inform these decisions. The purpose of this study was to demonstrate the potential for naturally low levels of non-starter bacteria in Cheddar cheese whey to attach and develop biofilms on representative surfaces within the potential of a typical production day (18 h). Whey was collected after cutting Cheddar cheese curds during normal production activities at the Oregon State University Creamery. Whey was rapidly cooled and held at 4°C until use. The whey was preheated to 35°C and pumped (1.1 L/h) through a lab-scale CDC bioreactor containing polypropylene and stainless steel coupons. Bulk whey from the bioreactor was sampled at 0, 12, 15, and 18 h and enumerated for starter lactic acid bacteria, coliforms, Acinetobacter and Pseudomonas. Coupons of each material were removed at 12, 15, and 18 h and analyzed for bacterial attachment and growth using standard enumeration methods and scanning electron microscopy (SEM). The experiment was replicated 3 times. Non-starter bacteria increased in whey from 1.8 Log cfu/mL to 6.4 Log cfu/mL in 18 h, while starter bacteria remained constant at 7.6 Log cfu/mL. After 18 h, coliform levels on coupons increased to 6.4 Log cfu/cm², whereas Acinetobacter and Pseudomonas counts each increased to 4.9 Log cfu/cm². Whey pH was effectively maintained at 5.9–6.4 throughout the experiment. Bacterial attachment occurred at about the same rate on both materials after 18 h. SEM showed even distribution of attached bacteria on stainless steel, whereas polypropylene harbored biofilms only in manufacturing defects (cracks, crevasses). These results demonstrate that naturally low levels of bacterial contamination in whey can lead to significant bacterial growth on manufacturing surfaces within an 18 h production shift. These findings can inform sanitation schedules for cheese and other dairy manufacturers.

Key Words: biofilm, whey, microbiology

M55 The effect of whey protein hydrolysate as a binder on the physical characteristics of agglomerated whey protein isolate. B. Zaitoun*, J. Amamchara¹, K. Silveru¹, A. Suprabha Raj¹, and N. Palmer², ¹Kansas State University, Manhattan, KS, ²Glanbia Nutritional, Twin Falls, ID.

Wet agglomeration involves spraying a liquid binder on the powder in a fluidized bed chamber causing adhesion of wet particles due to viscous bridges between the particles. These bridges are then consolidated by the continuous supply of hot air to form agglomerated particles. The agglomerates have a porous structure and consequently improve dissolution rate and decrease apparent bulk density. The objective of this study was to evaluate the effect of whey protein hydrolysate (WPH) as a liquid binder on the physical properties of the agglomerated whey protein isolate (WPI). Three lots of WPH were obtained from a commercial manufacturer. A Top-Spray fluid bed granulator (Midi-Glatt, Germany) was used. The experiment was conducted in triplicate based on a 3 × 3 × 2 factorial design with pre-wet mass (60, 100, and 140 g), WPH concentration (15, 20, and 25%), and flow rate (11 and 16 rpm). The nozzle pressure, fluid bed pressure and fluid bed temperature were set at 0.65 bar, 0.45 bar, and 60°C, respectively. Agglomerated WPI samples were stored at 25°C and analyzed for particle size and shape, bulk density, and tapped density. The size and shape characteristics of agglomerates were evaluated using Morphology G3-ID (Malvern Instruments Ltd., UK). The mean circle equivalent diameter (CED), circularity, elongation, and convexity were 15.18 μm, 0.74, 0.273 and 0.95, respectively. No significant differences were observed for the CED and convexity (P > 0.05) for the main effects. The WPH concentration, pre-wet, and flow rate significantly (P < 0.05) influenced the elongation of the WPI agglomerates. Bulk densities of agglomerates were between 0.22 and 0.31 g/cm³. Pre-wet mass significantly (P < 0.05) influenced the bulk density of the particles. This might be due to the differences in the formation and breakage of the agglomerates. Tapped densities for the agglomerated samples were between 0.29 and 0.40 g/cm³ and no significant difference was observed (P > 0.05) between the main effects. Overall, pre-wet mass had the major effect on the agglomerates physical properties followed by the flow rate and the WPH concentration.

Key Words: agglomeration, whey, physical characteristics