0699 In vitro screening of the anthelmintic efficacy of birdsfoot trefoil commercial varieties and cultivars against ovine *Haemonchus contortus*.

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Some forages containing condensed tannins (CT), also called proanthocyanidins (PAC), suppress gastrointestinal nematode (GIN) infections in small ruminants. The objective of this study was to investigate the anthelmintic potential of 51 commercial varieties and cultivars of birdsfoot trefoil (BFT) against *Haemonchus contortus*. The antiparasitic activity of BFT proanthocyanidin extract (BFT-PAC) and BFT aqueous extract (BFT-AqE) was tested using the following in vitro assays: 1) egg hatching and viability of L1 *H. contortus* larvae and 2) exsheathment of L3 *H. contortus* larvae. Birdsfoot trefoil powder of each variety or cultivar was analyzed for CT content (mg/g) by the 4-(dimethylamino)cinnamaldehyde method. Birdsfoot trefoil proanthocyanidin extract was prepared by isolating PAC extract from the BFT powder using solid-phase chromatography. Birdsfoot trefoil aqueous extract was prepared by soaking BFT powder in water at room temperature for 24 h. The plant matter was then removed, leaving an aqueous extract. 1) For in vitro egg hatch and viability of L1 larvae, *H. contortus* eggs were isolated from fresh feces and exposed to varying concentrations of BFT extracts for 24 h. The percentage of hatched eggs and L1 larval mortality (based on motility) were determined. 2) For in vitro exsheathment, 2,000 *H. contortus* L3 larvae were incubated in varying concentrations of BFT extracts for 24 h followed by exsheathment using CO_2. The percentage of exsheathed larvae (based on absence of sheath) was determined. Condensed tannin content ranged between 1.5 and 63.8 mg/g across 51 varieties and cultivars. Inhibition of egg hatch and larval mortality was observed with incubation in BFT-AqE; however, the concentration at which this inhibition and mortality was most effective varied among varieties and cultivars: at 3 mg/mL, percent inhibition of egg hatch and L1 mortality spanned between 0 and 100% across 51 varieties and cultivars tested. Results for incubation in BFT-PAC and results for exsheathment are pending. Preliminary results indicate that commercial varieties and cultivars of BFT-AqE inhibited egg hatch and increased larval mortality, but the degree of inhibition and mortality varied. Additional results testing BFT-PAC and testing exsheathment will provide further information about the anthelmintic efficacy of commercial varieties and cultivars of BFT for small ruminant GIN control.

Key Words: small ruminant, sheep, condensed tannin

ADSA DAIRY FOODS GRADUATE STUDENT ORAL COMPETITION

0700 Anti-obesity and antidiabetic properties of lactoferrin are independent of calorie intake.

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Whey proteins provide multiple health benefits to humans including promotion of weight loss and improving diabetic control. However, the bioactive components of whey that produce such benefits and the underlying mechanisms of action are poorly understood. Our objectives were to determine the effects of whey, and its components lactalbumin and lactoferrin, on 1) energy balance, body composition, glucose tolerance, and gut hormones and 2) key regulatory markers of glucose and lipid metabolism in liver and skeletal muscle of diet-induced obese (DIO) rats. The DIO rats were randomized to receive one of 5 isocaloric dietary treatments (n = 8/group; 40% fat and 4.63 kcal/g)—control (CON; 15% protein), whey (WH), lactalbumin (LA), lactoferrin (LF), and pair-fed WH to LF (PF)—for approximately 8 wk. The high-protein diets contained 15% added whey or its components. Food intake, meal patterns, energy expenditure, body composition, glucose tolerance, plasma hormone, and hepatic and muscle mRNA abundance were measured. Data were analyzed by linear mixed models, ANOVA, or ANCOVA. We found that 1) compared with CON, WH, LA, and LF reduced food intake, with LF producing a greater and sustained reduction of intake; 2) the hypophagia is partly due to reduced meal size and/or frequency, increased peptide YY mediated satiety, and decreased diet preference; 3) LF produced greater reductions in BW and fat mass, enhancement in energy expenditure, and improvement in glucose tolerance than PF; 4) LA decreased BW and fat mass, increased energy expenditure, and improved glucose tolerance compared with CON; 5) LA and LF decreased plasma concentrations of insulin and leptin relative to CON; and 6) LA increased the mRNA abundance of GLUT2, glucokinase, glycogen synthase, and carnitine palmitoyltransferase-1 and decreased fatty acid synthase and pyruvate dehydrogenase, whereas LF increased glucokinase and glucose-6-phosphate dehydrogenase and decreased phosphofructokinase and fatty acid synthase in the liver and both LA and LF increased muscle pyruvate dehydrogenase compared with CON. Together we demonstrate that the improvement in energy balance, lipid metabolism, and glucose tolerance by lactoferrin are beyond its hypophagic effects. Our findings have important implications for developing lactalbumin- and lactoferrin-based functional foods and nutraceuticals for weight loss and diabetic control. Funding by ALMA, AI-Bio, and Alberta Milk.

Key Words: diabetes, lactalbumin, lactoferrin, obesity, whey

0701 Effect of milk protein intake and casein:whey ratio in breakfast meals on postprandial glucose, satiety ratings, and subsequent meal intake. B. Kung*[1], S. Paré[1], A. J. Tucker[1], G. H. Anderson[2], A. J. Wright[1], and H. D. Goff[1], *[1]University of Guelph, Guelph, ON, Canada, [2]University of Toronto, Toronto, ON, Canada*.

Novel satiating dairy-based breakfast products have potential to reduce the risk of developing and improve management of type 2 diabetes and obesity. Whey and casein proteins may induce different physiological effects on blood glucose, induction of satiation, and satiety. Whey proteins have been associated with acute satiation, compared with the prolonged feelings of satiety from casein. The purpose of this work is to investigate the impact of breakfast meal milk casein:whey ratio and protein concentration on postprandial blood glucose, appetite ratings, and subsequent food intake. In a randomized, controlled, double-blinded study, healthy young adults ($n = 32$; 16 m/f, 23.4 ± 3.1 yr, and 22.2 ± 2.5 kg/m^2 BMI) consumed milk (250 mL) with normal (80:20) or modified (40:60) casein:whey protein ratio at normal (3.1%) or high (9.3%) protein concentration, or water (control), along with 2 servings of breakfast cereal. Following an overnight fast and up to 120 min following the breakfast meal, participants had their plasma glucose concentrations determined from fingerprick samples, completed a series of scale ratings to assess satiety, and consumed a weighed ad libitum pizza lunch. Repeated measures ANOVA followed by Tukey–Kramer's post hoc testing was performed. Incremental area under the curve (AUC) glucose values showed significant attenuations in postprandial plasma glucose concentration for all milk treatments, relative to control ($P < 0.05$). Also, the high-protein treatments (9.3%) had significantly attenuated glucose concentrations compared with those with lower-protein treatments (3.1%). However, there was no effect of casein:whey protein ratio on blood glucose. Treatments were not associated with differences in total AUC for individual scale ratings of Hunger, Desire to Eat, Fullness, and Prospective Consumption. Nor were differences observed in mean appetite score ($P = 0.86$) or subsequent lunch intake ($P = 0.06$). Therefore, because consumption of high-protein milk treatments with breakfast cereal was associated with the lowest plasma postprandial glucose concentration, new high-protein dairy breakfast products should be considered for product development. (Supported by a contribution from the Dairy Research Cluster Initiative.)

Key Words: appetite, dairy protein, glycemia

Table 0701.

Table 1 Overview of results after the breakfast meal (0-120 min)

	Control	9.3% MP (40:60)	9.3% MP (80:20)	3.1% MP (40:60)	3.1% MP (80:20)	P-value Treatment
Glycemia incremental area under the curve (mmol*min/L)						
Glucose[1]	258.87 ± 16.99^{a}	142.96 ± 12.310^{b}	149.62 ± 10.39^{bc}	190.16±13.01^{cd}	211.37±13.93^{d}	P<0.0001
Satiety total area under the curve (mm*min)						
Hunger[2]	4157.53 ± 329.13	4344.64 ± 367.96	4163.40 ± 336.05	4439.98 ± 382.84	4349.77 ± 366.12	NS
Desire to Eat[2]	4294.73 ± 373.50	4480.81 ± 369.78	4280.74 ± 401.08	4449.84 ± 383.79	4473.75 ± 363.70	NS
Fullness[2]	6537.63 ± 415.05	6643.59 ± 388.72	6645.71 ± 389.67	6578.09 ± 367.86	6316.38 ± 373.93	NS
Prospective Consumption[2]	4726.44 ± 404.97	4699.44 ± 394.74	4841.44 ± 456.54	5050.73 ± 434.38	4914.95 ± 430.24	NS
Mean Appetite[2,3]	4676.81 ± 340.62	4768.38 ± 366.94	4711.98 ± 379.70	4898.19 ± 364.14	4850.13 ± 365.03	NS
Food Intake						
Grams (g)[2]	314.4 ± 24.3	285.4 ± 25.3	301.7 ± 26.6	311.7 ± 23.5	302.4 ± 23.5	NS
Energy (kcal)[2]	699.7 ± 54.0	634.1 ± 56.2	668.5 ± 58.2	692.7 ± 52.3	672.0 ± 52.3	NS

All Values are ± S.E.M. n=32. NS (not significant) and MP (milk protein).
[1]Data was analyzed by treatment incremental area under the curve interaction by general linear model ANOVA (Proc Mixed) and significance was assessed using Tukey's post hoc, means in the same row with different superscripts a, b, c, d, are significantly different.
[2]Data were analyzed treatment×time×sex interaction by 3-factor ANOVA (Proc Mixed) and significance was assessed using Tukey's post hoc, means in the same row with different superscripts a, b, c, d, are significantly different.
[3]Mean appetite derived from an average of each satiety measurement.

0702 Evaluation of modified stainless steel surfaces targeted to reduce biofilm formation by common dairy related sporeformers. S. Jindal*[1], S. Anand[1], J. K. Amamcharla[2], and L. Metzger[1], *[1]South Dakota State University, Brookings, [2]Food Science Institute, Animal Sciences and Industry, Kansas State University, Manhattan*.

Development of bacterial biofilms on stainless steel (SS) surface of dairy equipment such as plate heat exchangers pose a great threat to the quality of milk and other dairy products, as the biofilm-embedded bacteria can survive thermal processing to a greater extent. Many of these are sporeformers that also form heat-resistant spores, leading to a long-term persistent contamination. Biofilms also offer cleaning challenges, as they are generally resistant to regular cleaning protocols. The main objective of this study was to evaluate different surface modifications (AMC 18, Durasan, Lindgren, and Magnaplate) of stainless steel for their resistance to biofilm formation. It was hypothesized that these coated surfaces would promote a lower deposit build-up and bacterial adhesion. Challenge studies, using vegetative cells of common dairy-related

aerobic sporeformers, namely *Geobacillus stearothermophilus* (ATCC 15952), *Bacillus licheniformis* (ATCC 6634), and *Bacillus sporothermodurans* (DSM 10599), were conducted to study the biofilm formation on the modified and native SS coupons under static conditions. Standard enumeration techniques were used to culture biofilm-embedded bacteria. The adherence of these organisms was observed to be influenced by surface energy and hydrophobicity but exhibited no relationship with surface roughness. Statistical analysis of the number of adhered cells of *G. stearothermophilus* to different native and modified SS surfaces, after 72 h of incubation, revealed significant differences in counts. Lindgren was observed to be most resistant to bacterial attachment (average 3.15 log cfu/cm^2), in comparison to the native SS surface that recorded a higher average bacterial adhesion of 5.11 logs. Similar results were obtained with *B. licheniformis* and *B. sporothermodurans*, the latter showing least attachment. Scanning electron microscopy provided the visual evidence of the extent of biofilm development and bacterial attachment on the surface of modified and native SS surfaces. In conclusion, Lindgren coating, being the most resistant to biofilm development, could potentially help in reducing the bacterial cross-contamination of milk and dairy products during processing.

Key Words: biofilms, sporeformers, surface modification

0703 Gelation properties of micellar casein concentrate when recombined with cream. Y. Lu*, D. J. McMahon, and A. H. Vollmer, *Western Dairy Center, Utah State University, Logan*.

Skim milk can be concentrated using microfiltration and evaporation to produce a highly concentrated micellar casein concentrate (HC-MCC), containing approximately 20% casein with approximately 70% of serum proteins removed during diafiltration. Understanding the gelation properties of HC-MCC and when mixed with cream to form a recombined concentrated milk (RCM) is important for using RCM for cheese manufacture. After concentration, HC-MCC forms a gel when cooled. Heating above the cold gelation temperature (up to 50°C) can break up the gel so that the individual casein micelles are solubilized. When examined using transmission electron microscopy, cold-gelled HC-MCC was observed to form a close-packed gel, which probably occurs when kinetic energy of the casein micelles is sufficiently reduced to inhibit their mobility in relation to adjacent casein micelles. Similar observations of cold gelation were made when HC-MCC was mixed with cream in casein to fat ratios of 0.8 or 1.2 as would be used for the manufacture of cheddar or part skim mozzarella cheese. At pH 6.6, an RCM with high protein can gel at cheese-making temperatures, whereas with 12% or less casein, it does not gel above 12°C. In micrograghs of cold-gelled RCM, casein micelles were less closely packed together and were partially dissociated. It appears that the protein strands that have been partially released from the casein micelles still entangle, restrict the mobility of each other, and form a fine stranded gel network. To understand challenges related to cheese making using an RCM that contains 4 times the level of casein than normally found in milk, its coagulation properties (rennet coagulation time and curd firmness) were studied using a rheometer. Reducing rennet amount can lengthen coagulation time of RCM but it does not affect curd firmness or firming rate. Decreased coagulation temperature can lengthen coagulation time and slow curd firming rate, but it also increases initial viscosity of RCM. Lowering pH of RCM to pH 6.0 did not solve the problem of curd firming being too rapid. Microstructure of RCM and its rennet coagulum indicated that the increased curd firmness probably results from the highly interlinked and longer protein strands in RCM curd. Overall, RCM with a casein level of 11 to 12% has potential for use in cheese making, provided its higher viscosity compared with milk and its fast curd firming rate can be overcome. Reducing rennet amount can be used to slow coagulation and curd firming.

Key Words: rheology, microstructure, casein micelle

0704 Thermal stability of microfiltered and ultrafiltered retentates. I. R. T. Renhe*[1] and M. Corredig[1,2], [1]*University of Guelph, Guelph, ON, Canada,* [2]*Gay Lea Foods, Guelph, ON, Canada*.

Membrane filtration technologies are widespread unit operations in the dairy industry and are often used to obtain ingredients of tailored processing functionalities. The objective of this work was to better understand the effect of partial removal of whey proteins by microfiltration (MF) on the heat stability of the retentates. Control retentates were obtained using ultrafiltration (UF). Pasteurized milk was microfiltered (80 kDa polysulfone membrane) or ultrafiltered (30 kDa cellulose membrane) in a plate and frame membrane system to reach two and four times concentration (based on volume reduction). Concentrates showed no differences in pH, casein micelle size, or minerals in the serum phase, before heating, as diafiltration was not used in this study. The reduced amount of whey protein in the MF retentates caused a significant increase in the heat stability of the retentates, compared with UF retentates. This difference was not due to ionic composition differences or to pH. Heat coagulation time decreased with protein concentration but significantly increased in MF retentates, containing less whey proteins than the corresponding UF controls. In 2x concentrates, retentates prepared with MF, containing 20% less whey proteins than UF control, showed an increase in the heat coagulation time of about 11 min. 4xMF retentates contained 17 ± 3 mg/mL of whey proteins, about 40% less whey proteins than the 4xUF control retentates. A 4x concentrate prepared by MF showed heat stability statistically similar to that of a 2xUF concentrates, with a heat coagulation time of about 38 min. The turbidity parameter

1/l*, measured by diffusing wave spectroscopy, increased after heating, with the UF retentates showing a higher value than the MF retentates, at the same protein concentration. In addition, 4xMF concentrates showed a 1/l* value comparable to that of 2xUF concentrates. In conclusion, this work demonstrated that partial removal of whey proteins by MF could be used as a means to increase heat stability of milk concentrates.

Key Words: heat coagulation time, milk concentrate, whey protein

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0705 Effect of milk protein composition on in vivo gastric digestion of a model infant formula.

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The objective of this work was to determine the effect of protein composition and, in particular, the presence of whey proteins or b-casein, on the digestion behavior of a model infant formula. An in vivo piglet model was used, as this is an established model for human infants' digestion. Three formulas optimized for piglets were prepared with the same concentration of protein and same caloric content. One formula contained only whey proteins (WP) and two others contained a casein-to-WP ratio of 40:60 but differed in the amount of β-cas. To obtain modified protein ratios, microfiltration (using polyethersulfone membrane with 80 KDa of molecular weight cut-off) was conducted on skimmed milk at either 7 or 22°C. Retentates and permeates were combined with additional whey protein and other ingredients, and after heating, the formulas were used to feed 24 piglets. The piglets were housed and fed from age 3 to 21 d, and animal behavior and health conditions were investigated. The study was performed in two blocks, sacrificing the animals after 60 and 120 min from the last meal. Gastric digesta samples were collected and studied for physicochemical properties. The tests were performed on fresh samples in less than 10 min after euthanizing. There were no differences in the properties of the curd, within a treatment, between the two blocks. All curds showed a shear-thinning behavior, with a significantly higher viscosity and a higher modulus for curds obtained from casein/WP formula, compared with the curds from WP formula. Confocal microscopy showed structures with larger voids in WP digestates, compared with those from cas/WP formula, which showed a higher density throughout the matrix. Despite differences in physicochemical properties, a pH range of 4.4 to 5.8 was measured for the gastric contents, with no significant difference observed between diets or with time of digestion. There were also clear differences in animal growth between treatments. Casein/WP formulas were shown to improve growth performance, with approximately 50% higher average daily growth and increased feed efficiency, compared with the WP formula. The results bring significant advances to our understanding of the importance of different protein ratios on the digestion of dairy matrices.

Key Words: digestion, infant formula, milk proteins

0706 Differences in high-density polyethylene milk packaging performance under light-emitting diode and fluorescent retail storage.

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The purpose of this study was to determine how commercial and designed packaging performed in the conditions of a retail dairy case with fluorescent and light-emitting diode (LED) lighting. Commercial retail cases in the Tennessee and Virginia area and the retail case used in this study were tested for light intensity (lux) within various locations on the shelf units with a hand-held light meter. Freshly processed milk (2%) was filled in high-density polyethylene (HDPE) packages with varying light protective additives (LPA). Treatments included yellow, low titanium dioxide (TiO_2; 1.3%) and high (4.9%) TiO_2; controls included translucent HDPE (0% TiO_2; light exposed [LE]) and translucent HDPE with foil overwrap (light protected [LP]). All packages were stored for 4, 8, 16, 24, 48, and 72 h under fluorescent and LED light. Riboflavin (Rb) retention and thiobarbituric reactive substances (TBARS) were measured (2 replications) as indicators of initiation and secondary oxidation products. Means were compared using ANOVA and Tukey's HSD ($\alpha = 0.05$). The polymer conducting electronic nose (eNose) analyzed headspace volatiles for milk quality for all packages under light treatments for 8 and 24 h (canonical distribution $\alpha = 0.05$) for one replication. Commercial retail cases varied from 50 to 4,700 lux, with fluorescent light having a greater variability than LED lights. The retail case used in this study fell within the light intensity range of commercial retail cases. Mean light intensity within fluorescent (1,617 ± 505 lux) and LED (929 ± 97 lux) cases were significantly different, but this difference did not affect Rb and TBARS analysis based on analysis of covariance. Light protected performed most effectively under both lights whereas LE provided inadequate protection ($P < 0.05$). Milk in yellow and high TiO_2 packages retained the highest concentration of Rb (61 and 55% retention, respectively) among LPA packages under LED through 72 h. Under fluorescent light, interactions with package and light were different from LED, suggesting light spectra and light transmittance interactions occur between light source and LPA packaging. Milk stored in the two lighting conditions each had unique volatile chemistry based on (eNose) canonical distribution. Under fluorescent light, eNose effectively separated controls from LPA packages but not under LED light, suggesting that LED does not have as much effect on volatile profile as does fluorescent light. High-density polyethylene packaging with pigments performs better under LED lights than under fluorescent lights at low lux conditions. Effective packaging should protect milk

quality regardless of light and intensity.

Key Words: light-emitting diode, milk, packaging

0707 Efficient removal of spores from skim milk using microfiltration: Spore size and surface property considerations. E. R. Griep*, Y. Cheng, and C. I. Moraru, *Cornell University, Ithaca, NY*.

Presence of spores in milk can cause numerous quality and shelf-life issues for dairy products. Microfiltration (MF) using a 1.4-µm pore size can effectively remove vegetative bacterial cells from milk and is used in commercial applications. However, this pore size may be not be equally effective in spore removal. The objective of this study was to determine the effectiveness of MF using 1.4- and 1.2-µm pore sizes for removing spores of *Bacillus licheniformis* (BL) and *Geobacillus* spp. (GEO) from skim milk. Cell size of both spores and vegetative cells was evaluated by scanning electron microscopy, surface charge by zeta potential analysis, and surface hydrophobicity by contact angle measurements, in triplicate. Commercially pasteurized skim milk was inoculated in a sterilized feed tank with a spore suspension, at about 10^6 spores/mL, and then treated by MF (in triplicate) using ceramic Isoflux membranes at 6°C, cross-flow velocity of 4.1 m/s, and transmembrane pressure between 69 and 74 kPa. Total aerobic plate count and spore count of the permeate were conducted. An unpaired *t* test was used to determine significant differences between samples at a $P < 0.05$ significance level. Vegetative cell length ranged between 2.40 and 3.82 µm and the width ranged between 0.39 and 0.64 µm. Spores were shorter and wider, averaging 1.39 to 1.58 µm in length and 0.63 to 0.88 µm in width, therefore having a higher probability to pass through a 1.4-µm membrane. Indeed, for BL (1.39-µm length × 0.63-µm width) an average spore reduction of only 2.17 log was achieved by 1.4-µm pore size. For the 1.2-µm membrane, a 4.57 log reduction was achieved. For GEO spores, their larger spore size (1.58-µm length by 0.81-µm width) allowed a practically complete removal using both pore sizes (spore counts in permeate below the detection limit). The surface properties of BL and GEO indicated that they may interact differently with the membrane. Both spore species and the ceramic membrane had negative surface charge at the milk pH, indicating slight electrostatic repulsion between them. *Geobacillus* spp. spores were hydrophilic, whereas BL spores were slightly hydrophobic; the ceramic membrane surface changes from hydrophilic (in unfouled state) to hydrophobic after adsorption of caseins during MF. Consequently, BL spores may experience slight attractive force to the membrane through hydrophobic interactions, which will facilitate their passage through the membrane. A good understanding of all factors that affect the removal of spores using MF can lead to the production of milk with lower spore count, higher quality, and increased shelf life.

Key Words: microfiltration, skim milk, spore removal

ADSA DAIRY FOODS GRADUATE STUDENT POSTER COMPETITION

0708 Unit operations before and during spray drying influence the flavor of milk protein concentrate and whole milk powder. C. Park* and M. Drake, *Southeast Dairy Foods Research Center, North Carolina State University, Raleigh*.

Flavor is a limiting factor in the application and shelf life of dried dairy ingredients. Many off-flavors are caused during ingredient manufacture, which carry through into ingredient applications and decrease consumer acceptance. The objective of this research was to investigate the effect of spray drying parameters on the flavor of milk protein concentrate (MPC) and whole milk powder (WMP). Liquid MPC70 was produced from pasteurized skim milk by ultrafiltration/diafiltration to 19% solids (wt/wt) and evaporated to 32% solids (wt/wt). Spray drying was performed with varying inlet temperature (160, 210, or 260°C) and feed solids concentration (12, 22, or 32%). Whole milk powder was produced from standardized pasteurized whole milk that was evaporated to 50% solids (wt/wt), homogenized in two stages with varying pressures (0/0, 55.1/13.8, 110/27.6, or 165/41.4 bar), and spray dried. Whole milk powder was evaluated at 0, 3, and 6 mo storage at 22°C. Sensory properties were evaluated by descriptive sensory analysis and volatile compounds were evaluated by headspace extraction (SPME) with gas chromatography mass spectrometry. Fat globule size in condensed whole milk and particle size of powders were measured by laser diffraction. Surface free fat of WMP was measured by solvent extraction. Furosine in MPC70 was analyzed by UPLC-MS. Spray drying of MPC70 at 160°C increased cardboard flavor and volatile lipid oxidation products and decreased sweet aromatic flavor and furosine concentration compared with 210 or 260°C ($P < 0.05$). Solids concentration during drying had no effect on furosine concentration ($P > 0.05$). Decreasing feed solids concentration decreased sweet aromatic flavor and increased cardboard flavor and volatile lipid oxidation products ($P < 0.05$). Increased homogenization pressure decreased cardboard flavor, volatile lipid oxidation compound concentrations, fat globule size in condensed milk, and surface free fat in WMP ($P < 0.05$). Surface free fat in powders increased cardboard flavor and lipid oxidation. These results indicate that off-flavors are decreased with increasing feed solids concentration and inlet temperature in MPC70 and with increased homogenization pressures in WMP. To decrease off-flavor intensities in WMP and MPC70, manufacturers should evaluate these parameters during ingredient manufacture.

Key Words: milk proteins, whole milk powder, unit operations