Dairy Foods: Impact of Salt Reduction on Cheese

601 Influence of salt-in-moisture of full fat and low fat Cheddar cheese on microflora and flavor. D. J. McMahon*[1], C. J. Oberg[2], L. V. Moyes[2], R. E. Miracle[3], and M. A. Drake[3], *[1]Western Dairy Center, Utah State University, Logan, [2]Department of Microbiology, Weber State University, Ogden, UT, [3]Southeast Dairy Foods Research Center, North Carolina State University, Raleigh.*

Low fat (LF) cheddar cheese develops flavor during aging uncharacteristic of full fat (FF) cheese, such as rosey and burnt/brothy flavors and bitter taste. Our objective was to determine if this is a function of differences in salt-in-moisture (S/M) content. Full fat and LF curd was made (in triplicate) using 700 kg of milk and salted to produce cheese with S/M typical of LF cheese. Half the curd was pressed into blocks, and further salt was added to the remainder to make cheese with S/M typical of FF cheese. For FF cheese, high salt (HS) levels were 2.1–2.5% salt (5.4–6.4% S/M) and low salt (LS) levels were 1.4–1.6% (3.5–4.0% S/M). For LF cheese, HS levels were 2.4–3.1% (4.3–5.6% S/M) and LS levels were 1.6–2.0% (3.0–3.6% S/M). Cheese was stored at 6°C and analyzed monthly for total lactic acid bacteria (LAB), lactococci, and nonstarter LAB (NSLAB) using selective media. Sensory profiles and volatile compounds of cheeses were analyzed after 2, 5 and 7 mo using descriptive sensory analysis and gas chromatography mass spectrometry. In general, initial NSLAB levels were $< 10^4$ and NSLABs became dominant after 3 mo storage. The HS cheeses had the expected die-off of lactococci during storage to $< 10^4$ cfu/g, with this occurring faster at the highest salt level (6.4% S/M) and slower at 4.3% S/M. For LS-FF and LS-LF cheeses, lactococci remained at ~10^5 cfu/g throughout storage. All flavor attributes except milkfat were impacted by age ($P < 0.001$). Both FF and LF cheese with LS levels tended to have higher flavor attributes of sulfur, brothy, rosy, and bitter flavors. In general, LF cheese with HS level had similar flavor scores (except for milkfat flavor) to the FF cheese with LS levels. Volatiles were generally higher in FF than LF cheeses. When comparing salt levels, both LF and FF cheeses had higher concentrations of phenyl and furanone compounds known to be sources of rosy and burnt off flavors. Thus, development of undesirable flavor attributes in LF cheese was not just a function of its lower S/M content but fat content also played a role in sensory perception of flavorants.

Key words: Cheddar, low fat, flavor

602 Manufacture and sensory analysis of reduced and low sodium Cheddar cheeses. B. Ganesan*, K. Brown, D. Irish, C. Brothersen, and D. J. McMahon, *Western Dairy Center, Department of Nutrition, Dietetics and Food Sciences, Utah State University, Logan.*

Salt is used for moisture control during Cheddar cheese manufacture and also restricts off flavors from bacterial metabolism during aging. To address the technical challenges associated with making acceptable reduced salt Cheddar cheese, we made Cheddar cheese in triplicate with final salt levels of 0.75%, 1%, 1.25%, 1.5% and 1.75% (w/w) with similar post press moisture and pH ($P > 0.05$) by altering current manufacture protocols. We conducted texture profile analysis at 0 and 6 mo and initially, cheeses at different salt levels varied in hardness, springiness, and chewiness, but exhibited similar properties by 6 mo of age. The changes in properties however varied at different salt levels. For example, cheese containing 1.8% salt was initially ~40% harder ($P < 0.05$), but became softer and comparable to the others ($P > 0.05$) at 6 mo. In contrast, the 0.75 and 1.5% salt cheeses did not soften during aging. Cheese adhesiveness decreased with salt content between 1.25% and 0.75% and with age ($P < 0.05$), but varied at higher salt levels. Consumer preference (9 point hedonic scale) and descriptive (15 point intensity scale) sensory panels were conducted to evaluate liking and flavor attributes as a function of salt content, respectively. Cheese was served in the consumer panel on separate occasions either cold as cubes or melted as a quesadilla. Cubed Cheddar cheese containing 0.75% salt received ($P < 0.05$) lower liking scores at 0 or 6 mo than the other cheeses. Consumers were able to distinguish cheeses at alternate salt levels at 0 and 6 mo age ($P < 0.05$) irrespective of serving style. Salty and buttery attributes were perceived more ($P < 0.05$) with increasing salt levels by the descriptive panel at 0 mo, whereas bitter, brothy and umami attributes were perceived less ($P < 0.05$) at the higher salt levels. However, this trend reversed at 6 mo, when salty, sour, bitter, buttery, lactone/fatty acid, and umami attributes' perception all increased ($P < 0.05$) along with salt level. Our study highlights that salt plays a multi-faceted role in shaping the physical attributes and flavor perception of Cheddar cheese.

Key words: Cheddar cheese, reduced sodium, flavor

603 Growth and metabolism of *Lactobacillus casei* in a ripening Cheddar cheese model varying salt, lactate, and lactose concentrations. J.-H. Oh*[1], M. F. Budinich[1], M. A. Drake[3], R. E. Miracle[3], J. R. Broadbent[2], and J. L. Steele[1], *[1]Department of Food Science, University of Wisconsin-Madison, Madison, [2]Department of Nutrition, Dietetics, and Food Sciences, Utah State University, Logan, [3]Department of Food Science, North Carolina State University, Raleigh.*

This study focused on how varying the composition of a cheese ripening model system affects the growth and metabolism of *L. casei* M36, UW1, UW4, 32G, and 12A. The conditions that were varied included salt (1.2% and 4.8%), lactate (2.7% and 4.3%), and lactose (0.2% and 1.0%). The Cheddar cheese ripening model system employed a water extract of Cheddar cheese, Cheddar cheese extract (CCE), as the growth media, and 10-week incubation was conducted at 8°C and pH 5.2 in the absence of oxygen. During the 10-week ripening period, there were 12 time points during which the culture was enumerated and the pH determined. At select time points, organic acids and volatile compounds were quantified by high performance liquid chromatography (HPLC) and gas chromatography (GC), respectively. *L. casei* UW4 reduced the concentration of phenylacetaldehyde, a compound responsible for rosy and metallic off-flavors in Cheddar cheese, 78% relative to the control. *L. casei* M36 enhanced the accumulation of diacetyl and sulfur containing volatiles, compounds thought to enhance Cheddar cheese flavor development. Additionally, these 2 strains exhibited fast growth in CCE under the conditions examined. The results obtained suggest that UW4 and M36 strain may have utility in enhancing the flavor of reduced-sodium and reduced-fat Cheddar cheeses. This study has demonstrated that salt in the moisture is a key variable in determining the volatiles produced by non-starter lactic acid bacteria and identified 2 strains to be examined in subsequent Cheddar cheese trials with reduced salt in the moisture. Screening of a collection of genetically diverse *Lactobacillus casei* strains will allow us to select a subset of strains to be examined for their ability to dominate the microbiota and positively influence flavor development in ripening reduced-fat and reduced-sodium Cheddar cheeses.

Key words: *Lactobacillus casei*, reduced-fat Cheddar cheese flavor, volatile compounds

604 Manufacture and sensory analysis of reduced and low sodium pasta filata style Mozzarella cheeses. B. Ganesan*, K. Brown, D. Irish, C. Brothersen, and D. J. McMahon, *Western Dairy Center, Department of Nutrition, Dietetics and Food Sciences, Utah State University, Logan.*

High sodium intake negatively impacts consumer health, thus there is active interest in lowering sodium levels in dairy foods. Toward developing a healthier cheese and tackling the challenges associated with reduced sodium cheese manufacture, we made low moisture part skim Mozzarella cheese with total salt levels at 0.7, 0.9, 1.25, 1.35, and 1.8% (w/w) in triplicate, thus reducing sodium by 25 to 60%. Our manufacturing protocols yielded cheeses with similar moisture and pH ($P > 0.05$) independent of the final salt levels in cheese that allowed us to study the effect of salt on cheese properties. Further, we evaluated mozzarella cheese functionality by characterizing stretch and melt properties, and also studied flavor and acceptance using descriptive (15-point intensity scale) and consumer (9 point Hedonic scale) taste panels. At wk 2, all Mozzarella cheeses melted similarly, but by wk 8, the meltability of all cheeses increased by ~2-fold ($P < 0.05$), with the 0.9% salt cheese showing the greatest increase. Stretchability also increased 4 to 8-fold ($P < 0.05$) with storage, but varied with salt content. At wk 2, 1.8% salt cheese required the greatest stretch force, while other cheeses had similar stretch properties. Taste panels conducted at 3 wks with cold shredded cheese showed that consumers liking for Mozzarella cheese was low at 0.7 and 0.9% salt, but equally ($P > 0.05$) preferred all cheeses containing higher salt levels (1.25, 1.35, and 1.8% salt). All cheeses had acceptable liking scores when served as pizza toppings, and consumers were able to differentiate cheeses ($P < 0.05$) at alternate salt levels, e.g., 1.8% and 1.5% salt cheeses scored similar ($P > 0.05$), as did cheeses at 1.5% and 1.35% salt, but 1.35% salt cheese scored lower ($P < 0.05$) than and was discernible from 1.8% cheese. Descriptive panelists identified salty, sour, umami, bitter, brothy, lactone/fatty acid, and sulfur attributes as different across the cheeses, with the perception of each significantly ($P < 0.05$) increasing along with salt level. To our knowledge, this is the first study that investigates the role of salt as the chief variable in mozzarella cheese physical properties and flavor attributes.

605 Informatic prediction of alterations to Cheddar cheese flavor reactions and pathways due to sodium substitution. B. Ganesan* and K. Brown, *Western Dairy Center, Department of Nutrition, Dietetics and Food Sciences, Utah State University, Logan.*

Increased interest in reduced and low sodium dairy foods due to health implications generates novel issues for product manufacture. As an alternate to reduction, Na may be partly replaced with potassium or calcium, but the role played by the substituting cations in flavor development is unclear. For example, NaCl addition to Cheddar cheese induces a general stress response at the gene level in lactic acid bacteria and restricts microbial outgrowth and metabolism and consequently reduces off flavors. Once Na is reduced or replaced the metabolic routes and the resulting flavors may also be altered. For example, Ca substitution beyond 10% total salt causes bitterness in Cheddar cheese. The roles of other cations in bacterial stress are unknown, but the effect of some cations on metabolic enzymes has been characterized. K, for example, is an activator of over 40 enzymes and inhibits 25 enzymes. Similarly Ca activates 29 enzymes but also inhibits 55 enzymes. Currently we can visualize the effects of these cations only as lists inside metabolic databases. By visualizing the impact of these activating and inhibitory activities as biochemical pathways inside a metabolic database we can analyze, predict, and eventually dictate the aging process of cheeses with non-sodium cations. Henceforth, we reconstructed new metabolic databases that illustrate the effect of different salt cations on flavor-related enzymes as microbial pathways. After metabolic reconstruction and analysis we found that nearly 100 pathways of lactic acid bacteria are affected due to enzymes likely to be activated/inactivated by K and Ca. These pathways are primarily linked to sugar metabolism, acid production, and amino acid biosynthesis and degradation. Notably, some pathways controlled by K also link to assimilation of other minerals such as magnesium and iron, suggesting that K addition will also affect additional cation inclusions currently being considered. This approach will allow us to identify and tackle metabolic routes induced and inhibited by cation replacements and their effects on Cheddar cheese flavor.

Key words: reduced sodium, Cheddar cheese, flavor

606 The effect of NaCl substitution with KCl on Nabulsi cheese: Chemical composition, total viable count, microstructure and texture profile. N. P. Shah* and MM Ayyash, *School of Biomedical and Health Sciences, Victoria University, Melbourne, Victoria, Australia.*

Sodium chloride is traditionally added to cheeses as a preservative and to improve flavor. However, a positive correlation between high level of sodium and osteoporosis, kidney stones and hypertension has been found. Hence, there has been an increased interest to reduce salt in foods. This study aimed at examining the impact of NaCl substitution with KCl on characteristics of a high brined white cheese (Nabulsi). Nabulsi cheese was made and kept in 4 different brine solutions at 18% including NaCl only (A; control); 3NaCl: 1KCl (w/w; B); 1NaCl: 1KCl (w/w; C); and 1NaCl: 3KCl (w/w; D) and stored for 5 mo. Chemical composition, proteolysis, total viable count (TVC) and texture profile analysis (TPA) were assessed at monthly intervals for 5 mo. No significant effect was found among experimental cheeses in terms of chemical composition and TPA profiles. Proteolytic activities were higher in cheeses kept in brine solutions that contained higher KCl (B, C, and D) as compared with the control. At the end of the storage period, water soluble nitrogen (WSN) and 12% trichloroacetic acid (TCA)-SN in Nabulsi cheeses stored in B, C and D was higher than the control (A). Also, TVC increased significantly after 1 mo of storage for all salt treatments. Hardness and gumminess decreased significantly during storage at the same salt treatment. ESEM micrographs showed a compact and closed texture for cheeses at same storage period. Microstructure of all cheeses became more closed and compact with storage period. Calcium content negatively correlated with hardness and sodium and potassium contents during storage at same salt treatment. The results showed that KCl could partly replace NaCl without any significant effect on the general characteristics of Nabulsi cheese.

Key words: salt substitution, TPA, TVC

607 The effect of NaCl substitution with KCl on low moisture mozzarella cheese: Chemical composition, organic acid profile, soluble calcium content, functional properties, proteolysis, lactic acid bacterial population, and ACE-inhibitory peptides. N. P. Shah* and M. M. Ayyash, *School of Biomedical and Health Sciences, Victoria University, Melbourne, Victoria, Australia.*

NaCl is traditionally used as a preservative and is added to cheeses to control bacterial growth, enzymatic activities, and to improve flavor. The recommended daily intake for sodium is 2.4 g, which is equivalent to 110 mmol Na or 6.0 g NaCl; the daily sodium intake in developed countries is substantially higher than the RDI. There is a positive asso-

ciation between hypertension and salt which in turn causes cardiovascular diseases. The effect of NaCl substitution with KCl on chemical composition, organic acids profile, soluble calcium and functionality of low moisture Mozzarella cheese LMMC) was investigated. Four batches of LMMC were made, and after milling cheeses were dry salted using 4 combinations of NaCl and KCl (only NaCl (A; control), 3NaCl:1KCl (B), 1NaCl:1KCl (C), and 1NaCl:3KCl (D) at 46 g/Kg. Functionality (meltability and browning), organic acids profile and chemical composition, proteolysis, lactic acid bacteria, and ACE-inhibitory of LMMC were measured. Chemical composition showed no significant difference between experimental cheeses at same storage period, and same salt treatment. Meltability of LMMC with treatment B, C and D was higher compared with the control. The amount of soluble Ca and P increased significantly during storage with no significant difference between salt treatments. There was no significant difference in organic acid profile between salt treatments at same storage period. Substitution of NaCl with KCl had similar effect on chemical composition, organic acids profile and functional properties. In addition, LMMC salted with NaCl/KCl mixture (treatments C and D) improved functionality of LMMC compared with the control. pH value of LMMC salted with NaCl/KCl mixture (C and D) was generally higher compared with the control. ACE-inhibitory peptides in treatment D increased significantly compared with other batches. WSN, TCA-SN showed no significant difference between experimental cheeses; however, PTA-SN significantly differed.

Key words: LMMC, substitution of NaCl, functionality