Extrusion is a continuous, thermo-mechanical process that is common in food industries. In most applications, the feed material is dry particles. Thermal energy and mechanical strain is applied upon extrusion enabling the specific structural transformation of the feed material; for example, texturization by pasting or puffing of starch. Extrusion and transformation of high moisture (~50%) gel particles like casein-based gels to isotropic or anisotropic structures by, for example, 3-D print, is a major challenge of plant engineering (hygienic design, CIP) and processing. Extrusion instabilities as melt fracture or phase separation are prone to occur when exceeding a certain strain during extrusion of high moisture particles. Hence, extrusion of directly acidified casein-based gel particles was researched in small scale experiments to generate specific semi-hard isotropic or anisotropic matrices. Standardized cheese milk (3.4% protein, 3% fat) was directly acidified by addition of organic acidulants to different pH values (5.5 – 6.3) to vary calcium levels. Casein-based gel particles with different calcium levels (15.8 ± 0.9 to 31 ± 2 mg Ca g⁻¹ protein) were produced by rennet-induced coagulation to investigate thermo-rheological properties and shear behavior at large strain to design hot-melt extrusion. The gel-sol transition temperature (51.7 ± 0.2 to 60 ± 2°C) significantly \( (P < 0.001) \) decreased with declining calcium levels. Hence, extrusion die temperature was set to 60°C in capillary rheometer experiments to mimic hot-melt extrusion. The extrudate strands were evaluated visually and recorded pressure profiles were analyzed to determine critical shear rates. It was demonstrated that critical shear rate (10 to 30 s⁻¹) increased significantly \( (P < 0.001) \) with decreasing calcium levels. By exceeding the critical shear rate, extrusion instabilities occurred indicating limitation of extrusion. Hence, optimal extrusion process parameters were determined and should be considered to design hot melt extrusion of high moisture gel particles.

Key Words: extrusion, casein-based gel, oscillatory rheology

In recent years, research has explored use of microfiltered (MF) milk for cheesemaking. The goal of this study was to determine if the amount of whey protein (WP) depleted from cheesemilk via MF affects the amount of residual WP in cheese as well as functionality and quality. Casein content for all milks was kept at 25% to eliminate the confounding factor of casein concentration. Three standardized cheesemilks were made with varied casein:true protein (CN:TP) ratios: (a) control with a CN:TP ratio of 0.83, (b) 35% WP depletion, 0.89 CN:TP, and (c) 70% WP depletion, 0.95 CN:TP. Standardized cheesemilks were analyzed for chemical composition. Cheddar cheeses were aged for 9 mo and composition and functionality were evaluated at 4 d, 2 wks, 1 mo, 3, 6, and 9 mo. Cheese yield, solids recovery, and nitrogen recovery were highest in the 70% WP depleted cheese followed by the 35% WP depleted and control, respectively. Because WP are mostly lost in whey drainage steps of cheesemaking, depletion of WP from the starting cheesemilk improves cheesemaking efficiency (i.e., less of the proteins/solids in cheese are lost). Rheological properties of cheeses were monitored by small-strain oscillatory testing while heating to 85°C. Residual WP content of cheese decreased with increasing MF depletion displaying the effectiveness of MF treatment. The maximum loss tangent \( (LT_{\text{max}}) \), an index of meltability, was highest at all time points in the 70% WP depleted cheese followed by 35% WP depleted and control, respectively. \( LT_{\text{max}} \) also increased with ripening for all cheeses. At 1 mo, the temperature at which the \( LT_{\text{max}} \) occurred was highest in the control cheese followed by 35 and 70% WP depleted samples, respectively. The \( LT_{\text{max}} \) values increased with age for all cheeses while the \( LT_{\text{max}} \) temperature decreased. It is possible that residual WPmaybe inhibiting proteolysis during ripening. Hardness decreased with age for all cheeses due to proteolytic activity. MF treatment did not affect sensory attributes. Depletion of WP in cheesemilk by MF did not negatively affect quality but resulted in improved cheese efficiency.

Key Words: microfiltration, whey protein depletion, functionality


Effects of microfiltered milk with different casein:true protein ratios on the quality of Cheddar cheese. E. M. Reale*1, J. A. Lucey1, R. Govindasamy-Lucey2, M. E. Johnson2, J. Jaeggi2, Y. Lu2, and M. M. Molitor2, 1University of Wisconsin-Madison, Madison, WI, 2Center for Dairy Research, Madison, WI.

Influence of pH on whey expulsion from curd made from recombinant concentrated milk. K. Bulbana* and D. J. McMahon, Western Dairy Center, Utah State University, Logan, UT.

Whey expulsion from cheese curd is influenced by temperature, pH, cut size and cooking. Our objective was to determine the extent to which pH drop before draining influences curd syneresis, curd moisture before draining and final cheese moisture when using concentrated milk. Recombined milk (7.5 kg) was prepared by mixing micellar casein concentrate (~9% casein), cream and skim milk to 4% casein and casein-to-fat ratio of 0.68. Four levels (0.5×, 1×, 2× and 4×) of a pH-controlled bulk starter culture were used to obtain different rates of pH change. Cheesemaking involved a typical cheddar make procedure with setting at 31°C, cutting after 30 min, cooking to 38°C with 95-min set-to-drain time followed by cheddaring with 85-min drain-to-mill time. Prior to cutting, the curd was overlaid with 2 kg of ultrafiltered milk permeate to minimize curd breakage upon stirring. Initially there was rapid moisture loss from curd after cutting, followed by a linear pattern \( (R^2 > 0.95) \) until whey drainage. A faster drop in pH increased whey expulsion from the curd \( (P = 0.0002) \). With initial curd moisture levels at 5 min of 83.7 and 83.3% using 0.5× and 4× culture, respectively, curd moisture level of 75.0 and 72.8%, respectively, were obtained at 50 min (during cooking), and 65.5 and 58.5%, respectively, at 95 min (at draining). As cheese make times were fixed, curd pH at draining was lower with faster acidification, the values being 6.5, 6.4, 6.1, and 5.8 for culture additions of 0.5×, 1×, 2× and 4×, respectively. Chees pH after 14 d of refrigerated storage was likewise affected with pH of 5.4, 5.3, 5.2 and 5.1, respectively. Mean cheese moisture contents were 37.8, 37.1, 37.2, and 35.2%, respectively. Cheese moisture and pH were correlated with drain pH \( (R^2 = 0.48 \) and 0.71, respectively). To account for the increased buffering capacity of concentrated milk containing 4% casein, a drain pH of 5.9 to 6.0 would be required to obtain a cheese with d 14 pH of < 5.1. To conclude, the pH drop that occurs during cheesemaking increases rate and extent of whey expulsion and will produce cheese with lower moisture.

Key Words: micellar casein concentrate, curd syneresis, acidification
Crystals of ikaite, struvite, calcite, and brushite have been identified in cheese smears by powder X-ray diffractometry (PXRD), and ikaite and struvite exist as single crystals. Polarized light microscopy (PLM) is a well-established method in geology to identify single crystals. However, use of PLM to identify cheese crystals has not been reported previously. Specific objectives of this research were (1) to presumptively identify crystals in cheese smears using selected PLM criteria; (2) to compare identification by PLM against PXRD; and (3) to evaluate a novel treatment for smear material to improve crystal analyses by PLM and PXRD. Duplicate wheels of 4 cheeses made by different manufacturers were obtained from retail sources. Scrapings of surface smears were analyzed by PLM and PXRD using previously described methods. Crystals were categorized by PLM based on angle of extinction (AE), birefringence behavior under crossed polarizers and quartz filters, and size and shape (circularity) by image analysis. Crystals observed by PLM fell almost exclusively into 2 readily differentiated groups based on birefringence behavior and estimated angle of extinction: group 1 (n = 18) were highly birefringent with AE = 88–92º; group 2 (n = 28) had no birefringence with AE = 13–26º. Group 2 crystals were significantly larger and more circular than group 1 crystals. Group 1 and 2 were presumptively identified as struvite and ikaite, respectively, based on known birefringence and AE characteristics. Struvite was identified in all 4 cheeses by PLM but in only 3 cheeses by PXRD. Ikaite was identified in 3 cheeses by PLM but in only 2 cheeses by PXRD. These discrepancies occurred because the smear scarpings from one cheese contained excessive amorphous matter that caused extreme background noise, potentially obscuring diffractogram peaks that may have been present. To minimize noise, smear scarpings were dispersed in aqueous NaOH (pH 10) before analyses, which resulted in consistent results by PXRD and PLM. The method also rendered high quality images by PLM. Data suggest that PLM may offer a simple and inexpensive means to identify and characterize struvite, ikaite and potentially other single crystals in cheese smears.

Key Words: cheese, crystal, microscopy


Growing interest in artisan and specialty cheeses has resulted in proliferation of cheeses that contain crystals. Until recently, many of these crystals were rarely encountered in the American marketplace. Crystals are natural products of ripening, and it is important to educate consumers about them so that artisan cheeses can be appreciated to the fullest. Powder X-ray diffractometry (PXRD) was used previously to identify crystals in several cheese varieties. Objectives of this research were (1) to identify crystals in cheeses that have not been studied previously using PXRD; and (2) to combine results from this and previous PXRD studies to develop a guide for cheesemakers, retailers, and consumers. Imported Emmental, Comté, Appenzeller, Sbrinz, Mimolette, Pecorino Sardo, Manchego, and Roquefort cheeses, and domestically produced blue mold cheese that displayed visible crystals were obtained from local sources. Crystals were harvested, prepped, and analyzed by PXRD using previously described methods. Dense, hard crystals embedded in the bodies of Emmental, Comté, and Sbrinz cheeses were identified as l-tyrosine. Sbrinz also contained embedded crystals of brushite (calcium phosphate dihydrate), and Emmental contained crystals of l-tyrosine and brushite that deposited prominently along the surfaces of eyes within the cheese. Appenzeller developed crystals of calcite (calcium carbonate), ikaite (calcium carbonate hexahydrate) and struvite (magnesium ammonium phosphate hexahydrate) in the smear at the rind surface.

Mimolette contained profuse crystallization along the surface of internal eyes, which took the form of l-leucine sheets. Pecorino Sardo contained discrete internally visible crystals of l-tyrosine, calcium lactate pentahydrate, as well as traces of brushite. Manchego contained discrete internally visible crystals consisting of leucine along with brushite. Roquefort cheese contained visible internal crystals near regions where mold grew profusely, which consisted of l-tyrosine, l-leucine and brushite. Domestic blue mold cheese that displayed surface smear growth also contained crystals of ikaite and struvite in the surface smear. Results were compiled into a guide and classification scheme to aid in navigating the world of cheese crystals.

Key Words: cheese, crystals, X-ray diffractometry

180 Influence of Mozzarella and Cheddar cheese blending on quality of pizza cheese. A. Sameen*, N. Gulzar, N. Humा, A. Sahar, and M. I. Khan, National Institute of Food Science and Technology, University of Agriculture Faisalabad, Faisalabad, Pakistan.

The demand for pizza cheese is growing in Pakistan. Therefore, the present investigation was planned with the objectives to evaluate the effect of amalgamation of Mozzarella and Cheddar cheese at different levels on various quality attributes of pizza cheese. The total 7 process cheese cheeses were manufactured and designated as PC0 (100% Mozzarella), (2 mo old Cheddar cheese) PC1 (75% Mozzarella), PC2 (50% Mozzarella), PC3 (25% Mozzarella), PC4 (25% Cheddar cheese)PC5 (75% Cheddar), PC6 (50% Cheddar) and PC7 (25% Cheddar) containing different levels of Mozzarella and Cheddar cheeses respectively. Pizza cheeses were analyzed for physicochemical, texture profile, meltability, stretchability, proteolysis, and microstructure. Sensory analysis was conducted to inspect the behavior of pizza cheeses during cooking (microwave and conventional oven cooking) on pizza topping. Considerably highest moisture and acidity was observed in PC0 while their percentages decreased as the level of Cheddar cheese increased. Functional characteristics i.e., meltability and stretchability of pizza cheeses were significantly affected by the amalgamation of Mozzarella and Cheddar cheese. The results demonstrated that control sample exhibited lowest (10.17cm) meltability and highest (34.50cm) stretchability. When incorporation of Cheddar increased in the pizza cheeses the meltability increase and stretchability decreased. The pH 4.6 soluble and TCA soluble N increased significantly with the concentration and ripening months of Cheddar cheese. Electrophoresis and reverse phase HPLC results indicated that level of intact casein decreased with increasing the level and age of Cheddar cheese in amalgamated pizza cheese. Micrograph obtained from electron microscopy indicated that the size of serum channels reduced with the amalgamation of higher level of aged Cheddar cheese. Microwave oven cooking proved better for texture and flavor development. From PC1 to PC3 pizza cheese performed better regarding different textual attributes and stretchability, while PC4 to PC6 behaved well for imparting flavor, meltability, and appearance. Overall baking performance of PC1 and PC2 was preferred by the panelist. Based on different characteristics Pizza cheese manufacturer are recommended to use Mozzarella and 2-mo-aged Cheddar cheese in proportion of 75 and 25% respectively.

Key Words: Mozzarella, Cheddar, pizza cheese

181 Impact of high pressure and different storage temperatures on the properties of Gouda cheese. L. A. Jiménez-Maroto*, S. Govindasamy-Lucey2, J. J. Jaeggli2, M. E. Johnson2, and J. A. Lucey1,2, 1University of Wisconsin-Madison, Madison, WI, 2Wisconsin Center for Dairy Research, Madison, WI.
To extend the performance shelf-life of Gouda cheese intended for export, we studied the impact of high-pressure processing (HPP) and different storage temperatures on the flavor and functionality of reduced-sodium stirred curd (SC) and milled curd (MC) Gouda cheese. Batches (n = 4) of SC Gouda (37.0 ± 0.8% moisture, 33.2 ± 0.9% fat, 25.7 ± 0.3% protein, 1.2 ± 0.1% salt) and MC Gouda (37.5 ± 0.5% moisture, 32.9 ± 0.8% fat, 25.3 ± 0.4% protein, 1.2 ± 0.1% salt) were produced using a reduced proteolytic coagulant. After 1 mo of ripening, cheeses were divided into 2 groups: control (non-HPP) and HPP (600 MPa, 3 min), and stored at 3 different storage temperatures (ST) (−20, 0, or 4°C). Analyses were performed after 4, 8, and 12 mo of storage. Cheese functionality was assessed using texture profile analysis (TPA) and dynamic low-amplitude oscillatory rheology. Sensory Spectrum® and quantitative descriptive analysis were conducted with 12 trained panelists to evaluate flavor, texture, and shred attributes using a 15-point scale. TPA hardness was influenced by ST, but not HPP treatment; cheeses stored at 0°C retained their initial hardness values, while it decreased over time in cheeses stored at 4 or −20°C. Rheological maximum loss tangent (LTmax) was affected by curd type, ST, and HPP treatment; MC had higher values than SC cheeses, HPP increased the values, cheeses stored at −20°C retained their initial LTmax values, but it increased in the cheeses stored at 0 and 4°C after 4 mo and declined after 8 mo. Sensory cohesiveness scores were lower in SC than MC Gouda and decreased in non-HPP samples stored at −20°C. During storage, acidity, milkiness, and buttermilk scores decreased in all cheeses, except those stored at −20°C. Strand length of shreds was influenced by ST and HPP treatment, decreasing over time except in HPP cheeses stored at 0°C, regardless of curd type. The best option for maintaining flavor over time came from storing samples at −20°C; however, performance was best maintained up to 12 mo through a combination of 0°C storage and HPP.

Key Words: Gouda, high-pressure processing, superchilling

182 Characterization of semi-hard and hard artisanal cheeses from small-scale producers of the Western Cape Province of South Africa. F. Nyamakwere1, G. Esposito1, N. Muller2, E. Moelich2, P. Gouws2, F. Masucci3, and E. Raffrenato1, 1Department of Animal Sciences, Stellenbosch University, Stellenbosch, South Africa, 2Department of Food Science, Stellenbosch, South Africa, 3Department of Agricultural Science, Università degli Studi di Napoli Federico II, Naples, Italy.

A survey was conducted to characterize artisanal cheeses from small-scale producers of the Western Cape, South Africa. Forty artisanal cheeses were identified and classified based on type (Cheddar, Gouda, others), age (1, 3, 6 mo) and milk (raw and pasteurized). The chemical, microbiological, and sensory properties of the cheeses were investigated. Rapid sensory characterization was done using the sorting technique followed by a descriptive step. Sixteen panel members were instructed to sort samples based on similarity of flavor and texture attributes. Sensory data were subjected to DISTATIS and correspondence analysis. Chemical and microbiological data were analyzed by univariate statistical methods with main factors age, cheese and milk. Raw milk cheeses had higher ash and fat content (P < 0.05) compared with pasteurized milk cheeses. Ash content was also higher in 3 mo cheeses compared with 6 mo. However, a wide range in fat composition was observed, ranging from 23% to over 40% and generally positively correlated with moisture content. The “others” group had the highest protein content (30%) and higher pH compared with Cheddar (P < 0.05). Fifteen percent of the cheeses did not fall within standards for coliforms and 10% tested positive for E. coli. Aging affected aerobic plate counts (higher at 1 mo compared with other months; 5.6 Log cfu/g) which was negatively correlated with the lactic acid % (P < 0.05). Results for sensory characterization showed a clear differentiation between mature and young cheeses. As expected, raw milk cheeses and those from the same producers fell within same groups suggesting similar sensory characteristics. The latter was not observed for cheeses belonging to the same type. Therefore, although cheeses from small-scale producers can be classified under the same broad categories such as Cheddar or Gouda, they can still express unique physiochemical and sensory properties. Understanding physiochemical and sensory properties of artisanal cheeses will help evaluate their composition and eating quality to help expand small-scale producers marketing shares.

Key Words: Cheddar, Gouda, coliforms