106th AOCS Annual Meeting and Industry Showcases

Edible Applications Technology Division Technical Program Abstracts

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EAT 1: Delivery and Dispersed Systems

Chairs: D. Rousseau, Ryerson University, Canada; and S. Ghosh, University of Saskatchewan, Canada

Microbial Cells as Colloidal Particles: Pickering Oil-in-Water Emulsions Stabilized by Bacteria and Yeast. H. Firoozmand and D. Rousseau*, Ryerson University, Canada.

We employ thermally-inactivated microbial cells, either yeast (*Saccharomyces cerevisiae*) or lactic acid bacteria (*Lactobacillus acidophilus* or *Streptococcus thermophilus*) to generate and stabilize model oil-in-water emulsions containing up to 80wt% dispersed oil. Emulsions containing 4-8wt% added microbial cells were highly stable and did not demonstrate visible phase separation for one year. Microstructurally, in the emulsions at high oil weight fractions, the droplets were in a hexagonal-like close-packed arrangement and were fully covered by cells. From a textural perspective, these emulsions were self-supporting and exhibited a mayonnaise-like consistency. Mechanistically, the microbial cells acted as Pickering-type stabilizers by preferentially residing at the oil/water interface. Using confocal microscopy to directly visualize the interfacially-bound yeast cells, three-phase contact angles of 30 ± 9° were measured, demonstrating their propensity to stabilize oil-in-water emulsions. The possible applications of such systems include the design of processed food emulsions with an 'all-natural' designation as well as the possible replacement of common synthetic surfactants used in the food industry.

Formation of Edible Filled Hydrogels by Spontaneous Emulsification. J. Komaiko and D.J. McClements, University of Massachusetts Amherst, USA.

The incorporation of nanoemulsions into clear hydrogels was investigated to produce optically translucent filled hydrogels using food-grade ingredients. Nanoemulsions were produced using the spontaneous emulsification (SE) technique, which simply involves the addition of an organic phase (oil + surfactant) into a stirring aqueous phase. A model system was optimized by looking at surfactant-to-oil ratio (SOR), surfactant type, surfactant location, oil type, and preparation temperature. Next, gelatin was incorporated into the aqueous phase so that translucent filled hydrogels could be formed. A model gelatin and commercial gelatin dessert system were tested for optical and rheological properties, of which there were no appreciable differences between the filled and unfilled hydrogels. This approach may prove useful for the fortification of functional food gels with lipophilic bioactive agents, such as nutraceuticals, flavors, antimicrobials, or oil-soluble vitamins.

Crystallization of Fats to Control Emulsion Structure for the Manufacture of Bakery Systems. F. Davoli[2], D. Karleskind[1], S. Metin[2], and P. Smith*[1], [1]Cargill, Belgium, [2]Cargill, USA.

Bakery systems require that the fat performs at various stages of the overall baking process from the initial manufacture of a dough or batter through the baking and to the eventual eating of the product. In order to replicate the performance of the fat its behaviour at all these stages must be understood and controlled. There is a drive to reduce the levels of saturated fats (SAFA) in baked goods. However SAFA can provide much of the functionality. In this work we have manufactured low SAFA water in oil emulsions and used them to replace bakery shortenings.

Control of crystallisation is necessary to create the required structures. In particular crystallisation control is to create stable shells around droplets andprovide appropriate network structuring.

In this work we investigate the effect of composition and processing on the formation of the shells. The effect of the fat composition and the role of emulsifiers (especially lecithin, PGPR and monoglycerides) are developed. After manufacture the properties of systems were studied by rheological and textural tests. Finally systems were used for baking in different applications (cookies and pastries). Relationships between the production, the shell and bulk structures and the product performance were demonstrated. Thereby the required attributes for the manufacture of high quality bakery ingredients are revealed.

CLA-rich Eggs in Mayonnaise: Emulsion Stability and Rheological Properties. S. Shinn and A. Proctor, University of Arkansas, USA.

Standards of Identity for mayonnaise define it as a semi-solid oil-in-water emulsion made of egg yolk, vegetable oil, and vinegar. Egg yolk provides excellent emulsifying properties to the mayonnaise because it contains hydrophobic and hydrophilic proteins, phospholipids, and cholesterol. It was

recently determined that conjugated linoleic acid (CLA) enriched eggs had significantly greater concentrations of phospholipids containing linoleic acid. This may affect the emulsion stability of a mayonnaise prepared with CLA-rich eggs. Another study determined that fresh and 20 day old CLA-rich yolks were significantly more viscous than fresh control yolks. Consumers have indicated that viscosity is an important and desirable sensory attribute in mayonnaise. Therefore, the objectives of this study are to compare the emulsion stability and rheological properties of CLA-egg mayonnaise, relative to a control. Emulsion stability will be determined by centrifugation to quantify the amount of oil separation that occurs. Mayonnaise viscosity, yield stress and elasticity/loss modulus will be determined to characterize flow and mouth-feel characteristics. The possibility of enhanced rheological properties from CLA-rich mayonnaise along with the health benefits associated with CLA may warrant the addition of a CLA-rich mayonnaise to the marketplace.

Antioxidant Potential of Some Turkish Olives and Their Corresponding Extra Virgin Olive Oils in Bulk Oil and Oil-in-Water Emulsions. T.M. Keceli, University of Cukurova, Turkey.

Some properties of olives and their corresponding extra virgin olive oils were evaluated. It was found that variety has significant effect on both some properties and antioxidant activity of olives and their corresponding extra virgin olive oils. Ayvalik, Nizip and Odemis olives had higher oil content and their corresponding extra virgin olive oils had higher chlorophyl, caretenoid content ($p<0.05$). Ayvalik, Halhali, Hasebi, Nizip and Odemis olive extracts were more effective as radical scavenger than BHT and BHA ($p<0.05$). Ayvalik, Nizip and Odemis olive extracts showed better or similar antioxidant activity in bulk refined olive oil than control, BHT and BHA($p<0.05$). Halhali, Nizip and Odemis extra virgin olive oil extracts showed better protection in refined olive oil-in-water emulsions than control, BHT and BHA ($p=0.05$). It was concluded that extracts from some olives and extra virgin olive oils may have food additive value for oils and oil containing foods.

Oil Diffusivity Through Solid Fat Crystal Networks. N.L. Green and D. Rousseau, Ryerson University, Canada.

Oil migration in chocolate and chocolate-based confections leads to undesirable visual and textural changes. Establishing ways to slow this unavoidable process would increase shelf life and reduce consumer rejection. We use fluorescence recovery after photobleaching (FRAP) to explore the effect of crystal structure on calculated diffusion coefficients in solid fat/liquid oil mixtures. Differences in interfacial tension between the solid fat (here, hydrogenated canola oil) and oil (light mineral oil or canola oil) lead to unique primary crystal clusters, yet those differences do not affect diffusion at low solid fat content. However, this trend deviates, which we ascribe to the influence of the differing crystal cluster structures. We connect our results to both the fractal model of fat crystals and relationships developed for polymer gel systems.

Effects of Emulsifiers on Crystallization Behavior of Palm-based Blend and Emulsified Systems. H. Zhang[1], C. Chen[1,2], Y. Bi[1,2], and X. Xu[1], [1]Wilmar (Shanghai) Biotechnology R&D Center, China, [2]Henan University of Technology, China.

Palm oil is frequently used in plastic fats due to their ability to form small and highly stable ß' polymorph. However, it has considerably slower crystallization rate and unusually long a-lifetime which led to post-hardening in plastic fats. Emulsifiers can be used to overcome this shortcoming. Present study investigated the effects of emulsifiers on crystallization behavior of palm-based blend and emulsified systems. Sucrose esters were found to significantly affect the crystallization behavior of palm-based blend and emulsified system possibly due to its ring structure. Sucrose esters with similar acyl chain length as palm oil (palmitoyl- and stearoyl) were found to accelerate crystallization rate, promote transition from a to ß' crystals and enhance formation of fine crystals in palm-based blend. Meanwhile, sucrose esters with dissimilar acyl chain length (lauryl and erucyl) delayed transition from a to ß' crystals which lead to formation of large crystals in palm-based blend. When added to emulsified system subjected to high degree of supercooling, palmitoyl- and stearoyl-based sucrose esters were found to stabilize the ß' crystals following temperature cycling. This indicate palmitoyl- and stearoyl-based sucrose esters were able to prevent or delay formation of post-hardening in plastic fats.

Effect of Water Content and Interfacial Stabilizer on the Rheological Behavior of a Crystal Network-stabilized Water-in-Oil Emulsion. R.R. Rafanan and D. Rousseau, Ryerson University, Canada.

Fat crystal network-stabilized water-in-oil (w/o) emulsions consist of water droplets surrounded by surfactants encased within a 3-dimensional fat crystal network. The interface can consist of liquid state surfactants or adsorbed amphiphilic solids (Pickering stabilization). How these different interfaces interact with the surrounding fat crystal network is not widely understood. Investigating these interactions is of great importance to control textural properties of the final product. Pickering (PK) and non-Pickering (NP) stabilized w/o emulsions containing a fat crystal network were evaluated via deformation tests to determine viscosity, and the elastic and viscous moduli. PK emulsion droplets were more stable under quiescent conditions, but more susceptible to shear deformation than NP emulsions. Increasing solid crystal adsorption to the droplet surface correlates to an increase in G', yielding a more solid product. This indicates that the droplet surface characteristics appear to be a significant contributor to rheological behaviour in fat crystal networks.

Effect of Oil Concentration, Droplet Size, and Storage Time on the Gelation Behavior of Nanoemulsions. V. Erramreddy and S. Ghosh*, University of Saskatchewan, Canada.

Canola oil-in-water nanoemulsions (NEs) with varying oil content (30-60 wt%) were prepared with different amount (0.5 to 15 times CMC) of sodium dodecyl sulfate (SDS) by multiple passes through a homogenizer at 20,000psi. samples of NEs were collected after each pass and their gel strength was determined using a rheometer. It was observed that irrespective of oil conc. and droplet size gelation in repulsive NEs was observed as the effective oil phase volume fraction (f_{eff}) reached a critical value of maximal random jamming (f_{MRJ}=0.64) where the electrical double layer (EDL) around the nanodroplets become comparable to their diameter leading to a significant increase in f_{eff}. At high SDS conc. depletion interaction generated by excess SDS micelles lead to attractive gelation with a higher gel strength compared to the repulsive ones. Although the NEs remain stable over a period of 90 days, their gel strength, except the one with 15 CMC SDS, decreased by 80-90%. For repulsive nanogels this drop could be explained by the change in the properties of the EDL, which significantly alters the f_{eff} responsible for gelation. In attractive nanogels depletion results in slippery diffusion-limited cluster aggregation that rearranged with time making the cluster more compact and lowering the f_{eff} below f_{MRJ}.

EAT 2: Functional Fats with Reduced Saturated Fats

Chairs: N. Widlak, Consultant, USA; and A. Bedford, Bunge Oils, Inc., USA

High Oleic Soybean Oil: Effects of Substituting High Oleic Oils for Other Fats and Oils on Cardiovascular Disease Risk Factors: A Systematic Review. P.J. Huth[1], V.L. Fulgoni, III[2], and B. Larson[3], [1]PJH Nutritional Science, LLC, USA, [2]Nutrition Impact, USA, [3]JG Consulting Services, LLC, USA.

High oleic soybean oils (HO-SBOs) are trait-enhanced vegetable oils containing >70% oleic acid and low levels of a-linolenic acid, trans fatty acids (TFA), and saturated fatty acids (SFA. There is little evidence on the effect of consuming HO-SBOs on coronary heart disease (CHD) risk factors and coronary heart disease risk. We systematically reviewed the available clinical evidence on substituting HO-oils compositionally similar to HO-SBOs (i.e. >70% oleic) for equivalent amounts of fats and oils rich in SFA, TFA, or n-6 polyunsaturated fatty acids [(PUFAs); i.e. linoleic acid] on plasma lipids and lipoproteins. Studies that replaced diets high in saturated fats with equivalent amounts of HO-oils (>70% oleic) showed significant reductions in plasma total cholesterol (TC), LDL-cholesterol (LDL-C), and apolipoprotein B (Apo B) (mean % change: -8.0%, -10.9%, -7.9%, respectively) whereas most showed non-significant changes in HDL-cholesterol (HDL-C), triglycerides (TAGs), TC/HDL-C ratio, and apolipoprotein A-1 (Apo A-1). Studies that replaced TFA-containing oil sources with HO-oils showed significant reductions in plasma TC, LDL-C, Apo B, TAGs, TC/HDL-C ratio and increased HDL-C and Apo A-1 (mean % change: -5.7%, -9.2%, -7.3%, -11.7%, -12.1%, +5.6%, +3.7%, respectively). Most studies that replaced oils high in n-6 PUFAs with equivalent amounts of HO-oils showed non-significant increases in TC, LDL-C, Apo B, TAGs, HDL-C, Apo A-1, and a non-significant decrease in the TC/HDL-C ratio. These results strongly suggest that replacing fats and oils high in SFA or TFA with HO-SBOs would favorably affect plasma lipids and lipoproteins. Furthermore, replacing diets high in SFA or TFA with either HO-SBOs or vegetable oils high in n-6 PUFAs (e.g. SBO, sunflower oil, corn oil) would have favorable and comparable effects on CHD risk factors and overall CHD risk.

Oleogel in Dairy: Processed Cheese Product. H. Huang, J.W. Harper, and F. Maleky, Ohio State University, USA.

Numerous studies documented that edible oleogel is a promising approach for reducing the solid fat content of food products. Therefore, the objective of this study is to examine the application of oleogel as a fat replacer in cheese product. Soybean oil oleogel, gelled with organogelators, was introduced to a mixture of non-fat ingredients to make a processed cheese product. Physical properties of samples, such as meltability, rheological properties and textural acceptability were tested and compared with commercial processed cheese products. Current results suggest vegetable oil oleogels as suitable saturated fat replacers in processed cheese products.

Key Physical and Microstructural Properties Underlying Roll-in Shortening Functionality. B.A. Macias-Rodriguez and A.G. Marangoni, University of Guelph, Canada.

Roll-in shortenings are very plastic fats tailored to laminate dough layers and resist high stresses during the manufacture of puff pastries. A major problem associated with these products is their high content of unhealthy saturated (SAFA) and trans fatty acids (TFA). This study compared the structure at different length scales (molecular, nano, microstructure) of 8 shortening types to better understand the functionality of roll-in shortenings. SAFA and TFA amounted to 40-50% w/w, and tri or disaturated TAGs were prevalent in all samples. X-ray diffraction spectra revealed mixed b' and b polymorphs for all samples except for palm and cotton-seed based icing and roll-in shortenings (b'). Similar (001) plane domain sizes (300-400 Å) were observed. DSC profiles (42-50°C peak melting) were comparable while SFC differed (25-35% at 16°C). Elastic modulus (1-3 MPa) and yield stresses (300-750Pa) did not correlate with SFC. Instead, creep-recovery parameters successfully fingerprinted differences among shortenings. A greater resistance to deformation and lower compliance values (1.5×10^{-6} Pa^{-1}) were determined for roll-in shortenings relative to other samples. Future studies are merited to elucidate the aggregation of crystalline nanoplatelets and the nonlinear rheological behavior

which may also be involved in roll-in functionality.

Synergistic Enhancement of Ethylcellulose Oleogels for Fat Replacement. A.J. Gravelle, M. Davidovich-Pinhas, S. Barbut, and A.G. Marangoni*, University of Guelph, Canada.

It has recently been reported that the mechanical properties of ethylcellulose (EC) oleogels can be altered through two distinct strategies: i) incorporating certain surface active molecules in the oil phase and ii) tailoring solvent polarity using oil-soluble components. In the present study, oleic acid and oleyl alcohol were used as surfactant-like additives (0-20wt%). Large deformation analysis demonstrated the dose-response behaviour of these gels followed a simple Langmuir binding curve, suggesting a site-specific interaction between EC and the surfactants. A shift in the onset of melting was observed for these additives in the presence of EC, upon gel formation. Solvent polarity was manipulated by substituting the oil phase with either castor oil or mineral oil (0-20wt%). Gel strength was found to be linearly correlated to solvent polarity. Optimization of EC solubility using Hansen Solubility parameters produced a strong gel which behaved as a thixotropic paste after applying shear. T_2 relaxation values were negatively correlated to mechanical strength, indicating the additives assist in immobilizing the oil phase. This work provides new insight into the mechanism behind solvent/gelator interactions in EC oleogels and suggests the use of synergistic interactions can help tailor functional properties and mimic fat functionality.

Oil Binding Capacity of Palm Oil Based Structural Fat in Reduced Saturated Fatty Acids Blends for Margarine and Spreads. S. Kanagaratnam*[1,2], M. Mat Sahri[1], M.E. Hoque[2], and A. Spowage[2], [1]Malaysian Palm Oil Board, Malaysia, [2]University of Nottingham Malaysia Campus, Malaysia.

The oil binding capacity (OBC) of structural fats play a vital role in determining the amount of solid fats (saturated) required to form a stable solid structure in margarines and spreads. The OBC determines the liquid-solid balance in the blends, which in turn indicated the stability. This study evaluated the OBC of palm oil fractions (POFs) as structural fat in oils blends and mainly focusing on blends with reduced saturated fatty acids (SFA) (= 25%). POFs of IV 30, 20, 12 and 10 were evaluated with soft oils such as sunflower oil, soybean oil and canola oil. Soft oils to POFs blends with ratios of 97.5:2.5, 95.0:5.0, 92.5:7.5, 90.0:10.0 and 87.5:12.5 (w/w) were texturized and evaluated. The OBC and the solid fat profile of the blends were the main criteria to determine suitable blends for margarine and spreads. OBC in this study was defined as the ability of the texturized blends resist the centrifugal force applied to distort the crystal structure and remain intact. The study concluded POFs IV 20, IV 12 and IV 10 were effective structural fat in the evaluated reduced SFA blends. However POF IV 30 was not an effective structural fat in these blends.

Functional Structuring Edible Oils, Utilizing Non-hydro Techniques for Use in Shortening and Margarine Systems with Significant Reduction in Saturated Fatty Acids. A Novel Approach. D.K. Nakhasi, N. Higgins, and V.P. Jain, Bunge North America, Inc., USA.

Utilization of proprietary non-lipid ingredients, crystallization processes (triglyceride mismatch) and non-hydro techniques provides the capability to reduce all purpose, emulsified shortenings and margarine spreads' saturate levels by greater than 40%. The technology is based on two separate but contributing inventions. A unique hard stock base, and fiber addition, once combined, enable the shortening & spread system to trap and bind large amounts of free oil, while still contributing structure.

This technology successfully provides us the means to achieve functional shortenings and spreads with saturates at 15 -19%. Nutritional analysis indicates that it is virtually *trans* free with greater than 40% reduced saturated fatty acid when compared to conventional reduced trans shortenings and margarines.

Applications results have revealed that this technology can be used in many all-purpose emulsified shortening and spread applications. These functional products confer nutritional benefits of reduced saturates without affecting the taste or mouth feel of the finished product.

Oil Binding Capacity of Palm Oil Based Structural Fat in Reduced Saturated Fatty Acids Blends for Margarine and Spreads. J. Minal, Malaysian Palm Oil Board, USA.

The oil binding capacity (OBC) of structural fats play a vital role in determining the amount of solid fats (saturated) required to form a stable solid structure in margarines and spreads. The OBC determines the liquid-solid balance in the blends, which in turn indicated the stability. This study evaluated the OBC of palm oil fractions (POFs) as structural fat in oils blends and mainly focusing on

blends with reduced saturated fatty acids (SFA) (= 25%). POFs of IV 30, 20, 12 and 10 were evaluated with soft oils such as sunflower oil, soybean oil and canola oil. Soft oils to POFs blends with ratios of 97.5:2.5, 95.0:5.0, 92.5:7.5, 90.0:10.0 and 87.5:12.5 (w/w) were texturized and evaluated. The OBC and the solid fat profile of the blends were the main criteria to determine suitable blends for margarine and spreads. OBC in this study was defined as the ability of the texturized blends resist the centrifugal force applied to distort the crystal structure and remain intact. The study concluded POFs IV 20, IV 12 and IV 10 were effective structural fat in the evaluated reduced SFA blends. However POF IV 30 was not an effective structural fat in these blends.

Commercial Factors for Considering Alternative Fats. N. Widlak, Consultant, USA.

Finding and incorporating new fat systems as alternatives or reductions in saturate fats in foods continues to be a priority of food manufacturers. However, discovering a fat system that may satisfy technical and nutritional objectives, may not meet other commercial hurdles required by food manufacturers, such as; economic, regulatory, operational, procurement and marketing. This paper is intended to provide an overview of both technical and non-technical factors which must be considered prior to implementing new ingredients to replace or reduce saturated fats in foods. Understanding these factors should help researchers focus on new systems that meet commercial feasibility requirements and improve chances of commercial success and hasten the development process.

EAT 3: Structuring Edible Oils—The Future of Lipid Gels

Chairs: M.A. Rogers, University of Guelph, Canada; and J. Komaiko, University of Massachusetts Amherst, USA

Water Binding Capacity of Rice Bran Wax as an Organogelator. E. Cramer, D. Heldman, and F. Maleky, Ohio State University, USA.

In foods, oleogels have the potential to provide the nutritional benefits of unsaturated fats, while displaying the physical functional properties of saturated fats. Current publications indicate that rice bran wax makes and effective organogelator, but there is less information on the physical properties of the gel network in the presence of water, and how well the gel can hold water. Varying percentages of water were mixed with soybean oil and rice bran wax to form an emulsion. An emulsifying agent was added to test for its effects on the gel. The emulsions were allowed to set into a solid gel. Shear stress measurements on the gels showed that the change in water content affected the firmness of the gels. Samples were able to hold on to water for over a week. Different water contents resulted in different water binding capacities. The presence of the emulsifier changed the water binding capacity of the samples. This information will make it easier to predict the interaction of oleogel and water in a food system.

Molecular Gels Based on Stratum Corneum Lipids. M.A. Rogers, University of Guelph, Canada.

The stratum corneum (SC) lipid membrane bilayer "mortar", containing free fatty acids, ceramides and cholesterols, is mimicked to exploit the unique co-crystallization of these molecules into self-assembled fibrillar networks. These SC mimicked molecular gels allow for novel materials to be developed including hardstock fat replacers. The structure and physicochemical properties of the molecular gels comprised of various ratios of stearic acid (SA), β-sitosterol (β-ss) and ceramide III (CerIII), as the molecular gelators, and canola oil as the primary liquid phase are investigated herein. In this study, 8 of 21 ratios formed elastic opaque molecular gels; and of those gels, seven had 'fiber-like' crystallites as their primary building blocks to generate a space filling three-dimensional crystal network effectively entraining the liquid oil. Although the remaining 13 ratios were incapable of forming molecular gels they had interesting microstructures that did not form a continuous 3D matrix capable of immobilizing the oil.

Rheological Properties of Organogels of 12-Hydroxystearic Acid, (R)-12-hydroxyoctadecanamide (HOA), and *N*-Octadecyl-12-Hydroxyoctadecanamide Developed Under Shearing. J.F. Toro-Vázquez, A. de la Peña-Gil, M.A. Charó-Alonso, F. Alvarez-Mitre, and J.A. Morales-Rueda, Universidad Autónonoma de San Luis Potosi, Mexico.

Using safflower oil as the liquid phase, we investigated the organogelation properties of (R)-12-hydroxystearic acid (HSA), (R)-12-hydroxyoctadecanamide (HOA), and (R)-N-octadecyl-12-hydroxyoctadecanamide (OHOA). Among the gelator molecules investigated the amides were the most polar, with the primary amide, HOA, having an additional hydrogen atom than the secondary amide, OHOA. Consequently, HOA can develop more extensive H bonding with other molecules than OHOA, and particularly than HSA. The objective was to investigate the relationship between the gelator's molecular structure with the gels' micro-structure that determines the rheological properties of 2% organogels developed under particular shearing and cooling rates conditions. The organogels were developed by applying a particular shear rate (0 to1200 s^{-1}) during cooling just until achieving metastable conditions (i.e., 5-10°C above the gelator crystallization temperature), then to allow the development of the organogel under quiescent conditions until achieving 15°C at 1°C/min or 10°C/min. We measured the elastic (G') and loss (G") modulus during cooling and after 60min at 15°C.

Closing in on the Ability to Predict New Food Grade Gelators. Y. Lan[1] and M.A. Rogers[2], [1]Rutgers University, USA, [2]University of Guelph, Canada.

During the past decade tools have been developed to predict new food grade gelators. A path of systemic parameters will now aid us in developing neural networks and artificial intelligence systems to screen over one million food grade compounds ranging from antioxidants to flavors. These are the first of a series of tools to remove the guess work in selecting compounds capable of structuring oil.

The Role of Hydrogen Bonds in Ethyl-cellulose Gelation. M. Davidovich-Pinhas, A.J. Gravelle, S. Barbut, and A.G. Marangoni, University of Guelph, Canada.

Ethylcellulose-structured oleogels have been recently shown to have a wide range of applications in food, cosmetics and pharmaceuticals. The characterization of the thermo-gelation mechanism and properties of ethylcellulose/canola oil oleogels was performed using rheology and thermal analysis. The sol-gel transition was studied using temperature sweep experiments at different cooling/heating rates. Hysteresis was detected in all samples with higher cross-over temperature during the heating compared to the cooling stage. Thermal analysis detected no evidence for thermal transitions contributed to secondary conformational changes, suggesting gelation mechanism that does not involve secondary ordered structure formation. The involvement of intermolecular hydrogen bonds in the formation of the EC network was confirmed using a rheological approach where a decrease in the storage modulus was observed with increasing temperature. This observation was further confirmed using Attenuated total reflection (ATR). The role of hydrogen bonds in the formation of the physical network was further examined using different setting gelation temperatures. EC oleogels demonstrated the ability to re-arrange with respect to the last setting temperature to which they were subjected. These results provide important insight into the ethyl cellulose/canola oil gelation mechanism.

Organogellators as Fat Replacement in Cream Cheese Products. M. Limbaugh, W.J. Harper, and F. Maleky, Ohio State University, USA.

Cheese is a dairy product rich in protein and calcium; however, it typically contains high amounts of undesirable saturated fats. The objective of this study was to develop a low saturated fat cream cheese product utilizing edible oleogels to solidify vegetable oils. The edible oleogels were composed of rice bran wax and ethylcellulose organogellators combined vegetable oils and other non-fat ingredients to produce a cream cheese. Oleogel cream cheese samples were compared to three commercial cream cheese spread products. The successful microstructural incorporation of oleogels into cream cheese was confirmed utilizing Confocal Laser Scanning Microscopy. Nuclear Magnetic Resonance was utilized to determine product fat and moisture contents. This method confirmed an approximate 25% reduction in total fat content. Samples displayed comparable spreadability and hardness values to the full-fat control using textural analysis.

The Effects of Shear and Cooling Rate on the Oil Binding Capacity of Wax Oleogels. A.I.E. Blake and A.G. Marangoni, University of Guelph, Canada.

The effect cooling rates (1.5°C/min and 5°C/min) and shear ($50s^{-1}$)on the oil binding capacity of rice bran wax (RBX), sunflower wax (SFX), and candelilla wax (CLX) oleogels was determined using centrifugation. The oil binding capacities of oleogels containing a commercial food stabilizer prepared under the same cooling and shear conditions were used as an industrial benchmark. For wax oleogels, faster cooling resulted in the formation of smaller crystals with a higher surface area for adsorption, reducing oil loss. Shear under low cooling rates decreased oil loss for RBX oleogels, and increased oil loss for SFX and CLX wax oleogels. Under rapid cooling, shear increased crystal size for all gels, but reduced oil loss only for RBX and CLX gels. These changes in oil binding capacity were related to changes in crystal length, determined using optical light microscopy, in an effort to elucidate the role of oil adsorption and oil entrapment as oil binding mechanisms. With this knowledge, the oil binding capacity of wax oleogels can be tailored through the use of selective processing methods and conditions.

EAT 4: *trans* Lipids: Solutions and Regulation

Chairs: V.P. Jain, Bunge Oils, Inc., USA; and M. Willson, LipoLogic Consultancy LLC, USA

Consequences of the PHO GRAS Removal on Industry. D.K. Strayer, Bunge North America, USA.

With the removal of GRAS for partially hydrogenated oils, the Fats & Oil must evaluate how they manufacture, store, and use PHO in their facilities if this product is still manufacture for export, non-food applications, and limited food applications. This paper will investigate the regulatory implications of continued manufacture and use of PHO in an operation.

Effect of Different Oil Base on Puff Pastry Margarine Properties. X. Mao, Z. Zhang, Y. Li, X. Yang, Y. Zhang, and P. Hu*, Wilmar (Shanghai) Biotechnology Research & Development Center Co., Ltd., China.

Hydrogenated fats and animal fats are often regarded as the essential fats which provide plasticity in margarine products. However, more and more vegetable oils are used based on health concerns. In this study, comparative studies were carried out among three commercial puff pastry margarine (PPM) which respectively based on tallow, hydrogenated fats and interesterified (IE) vegetable oils. Although they showed similar solid fat content (SFC), the tallow based and hydro based PPM showed higher crystallization rate and more stable beta prime polymorph than the IE based PPM. Moreover, the former two PPM performed better laminating properties than the latter PPM in bakery test. In order to modify the crystallization properties of IE based PPM, a new PPM based on interesterification of shea olein and palm stearin was developed. It showed similar results in crystallization rate comparing with tallow based and hydro based PPM. Furthermore, the laminating property was also improved. This may be due to that the POS content in the new PPM was increased to similar level of tallow based PPM.

***trans* Fats Solution: Novel Approach Using Palm Oil.** N.L. Habi Mat Dian[1,2], M. Mat Sahri[1], L. Oi Ming[2], and T. Chin Ping[2], [1]Malaysian Palm Oil Board, Malaysia, [2]Universiti Putra Malaysia, Malaysia.

Consumption of *trans* fats is associated with an increase of cardiovascular disease risk. Therefore, trans fats should be replaced in food products. Palm oil (PO) offers excellent alternative to *trans* fats. Directed interesterification (IE) of PO increased the percentage of tripalmitin from about 4% to about 26%, 6.5 times higher than initial amount found in the mother oil. DSC melting profile showed that the interesterified PO had two distinctive well separated peaks indicating easy of fractionation. The high melting endothermic peak of interesterified PO showed major shift in melting points, i.e., toward the higher temperature region (from about 45°C before IE to about 55.0°C after IE). Single step fractionation of the interesterified PO produced palm stearin (POs) with iodin value (IV) of less than 10 (POs-IV<10). The POs-IV<10 has very rapid crystallization rate and crystallized in a mixtures of ß and ß' crystals. The POs-IV<10 could be used as an excellent alternative to *trans* fats. The POs-IV<10 as it is, blended or restructured with vegetable oil via IE, and texturized, produced a *trans* free hardstock with excellent oil binding capacity and was able to perform as effective structural fat in the formulation of trans free reduced saturated solid fat products.

Oil Stabilization in Peanut Butter Using Food Grade Polymers in Order to Replace Hydrogenated Vegetable Oil. R. Tanti, S. Barbut, and A.G. Marangoni, University of Guelph, Canada.

Solid fats play a crucial role in many food applications including spreadable products such as nut butters. These products, for example almond butter and peanut butter, are made by grinding roasted nuts thereby creating a dispersion of small nut particles in oil. Fully hydrogenated and/or partially hydrogenated vegetable oils are typically used as stabilizers in peanut butter in order to prevent oil separation. In this study, the application of three cellulose derivatives (ethylcellulose (EC), methylcellulose (MC) and hydroxylpropyl methylcellulose (HPMC)) as stabilizers in peanut butter are investigated. Centrifugal accelerated stability testing showed a 27% reduction in oil leakage as compared to the unstabilized control at addition levels as low as 0.5% wt./wt. HPMC in peanut butter. At addition levels of 2% in peanut butter, no oil loss was observed. Textural quality of the peanut butter was investigated using a texture analyzer (TA-XT2, Stable Micro Systems) cylindrical probe penetration test. A centrifugal oil binding assay as well as microscopic imaging of these three chemically distinct polymers will be used to elucidate the mechanism of oil entrapment and

demonstrate the potential of these polymers as stabilizers in oil unstable food systems.

The Influence of Emulsifiers and Crystallizers on Margarine and Shortening Applications with Removal of Partially Hydrogenated Oils and *trans* Fats. A.M. Jensen, Palsgaard A/S, Denmark.

The relationship between coronary heart disease (CHD) and *trans* fatty acids initiated the trend to remove *trans* fatty acids from margarine, spreads, shortenings and fat compounds. Due to the removal of *trans* fatty acids It was not only the melting behavior and mouthfeel that were changed in the margarine and fat recipes, but also crystallization behavior and process parameters were affected by the new trans free fat compositions.

Reduction of production capacity in e.g. margarine production facilities started the focus on whether crystallizers could reduce some of the more negative side effects that "non *trans*" fat systems caused the margarine and fat industry. But it was not only a question of speeding up the fat crystallization. The effect of even small changes in process parameters could result in a significant change in the consistency of the finished margarine to a larger extent than the industry had been accustomed to-when partly hydrogenated and trans fatty acids containing fat types were used in margarine and shortening recipes.

The presentation will give an understanding of potential solutions for the fats and oil industry.

***trans*/PH Fat—Challenges and Approaches to Eliminate It.** G. Yang and G. Cherian, Kellogg NA, USA.

Due to increased consumer health concerns and new labeling requirements associated with *trans* fatty acids (TFA), food industry has taken the initiative to eliminate TFA in a number of different food products. There are significant challenges in designing *trans* fats free oil options that have similar functional performance and oxidative stability as the partially hydrogenated soybean oil with minimal impact on cost and product nutrition. A functional hard fat (stock) that provides the functionality and a base oil that has satisfied oxidative stability need to be uniquely blended as "Designer Fat" fat for each food system. Food formulation and process modification are useful levers for ensuring smooth transition without impact on food quality and consumer liking of the products.

Palm Oil as a Versatile Alternative to Partially Hydrogenated Vegetable Oil. G.P. McNeill, IOI Loders Croklaan, USA.

Since the FDA announced their intention to ban PHO (Partially Hydrogenated Oils) in 2013, food manufacturers have been faced with an extremely difficult task – eliminate all PHO from their products. This will require the identification of suitable potential alternatives to PHO and a need to evaluate them in a wide range of many different kinds of applications. In 2015, the FDA will likely announce a date by which all foods must be free of PHO and with the alternatives in place.

The introduction of PHO more than 50 years started a "golden age" in the field of baking, frying and snack food manufacturing due to the ease of "tailor making" products by tweaking the PHO process. The extremely versatile and broad range of PHO products available today, have now turned into a major barrier for formulators faced with a small suite of natural oils and other solutions on the market today.

This presentation will outline current possible solutions with an emphasis on palm oil, which is promising to be the most versatile solution for PHO substitution by far.

The Role Soybean Oil has Played in Low *trans* Solutions. M. Peitz, ADM Oils, USA.

Soybean oil is a key oil source globally, and is second only to palm oil in supply. In the US soybean oil is the predominate oil produced as a result of the demand for soybean meal. Soybean oil continues to provide offerings for low *trans* solutions as conversions are made away from partially hydrogenated vegetable oil sources.

This presentation will review how industry has and is changing from the use of partially hydrogenated soybean oil to that of straight liquid soybean oil, interesterified soybean oil, new trait-enhanced offerings, blends of soybean oil with various source of solid fat and the utilization of fully hydrogenated soybean oil. Also discussed will be the benefits and challenges of these conversions.

Soybean oil presents numerous options for low *trans* alternatives and with evolving technology, global supply, functional modification techniques is a viable oil source to look to for solutions.

Enrichment of Yogurt with Stearidonic Acid Soybean Oil in Complex Coacervates Modified for Enhanced Stability. E.A. Ifeduba and C.C. Akoh, University of Georgia, USA.

Yogurt containing stearidonic acid soybean oil (SDASO) microencapsulated within gelatin-gum Arabic complex coacervates (CC) and subsequently modified by transglutaminase (TC) or Maillard conjugation (MC) was developed. The homogenization speed used for emulsification was varied (250 or 2500rpm) while biopolymer and core to wall ratios were kept at 1:1 and 3:1, respectively. The peroxide (PV) and *p*-anisidine values of SDASO in unmodified and modified microcapsules were measured after 60 days of storage at 4°C. The heat stability of microcapsules was ascertained from the percentage of microencapsulated oil released in the yogurt milk base after heating at 85°C for 30min. Analysis of modified microcapsules by SDS-PAGE confirmed the presence of cross-linked gelatin in TC and gelatin-gum Arabic conjugates in MC. Microcapsules produced at 2500rpm were more thermostable than those produced at 250rpm. Among microcapsules produced at 2500rpm, the percentage of microencapsulated oil released after heat treatment was 5.0, 3.4, and 1.9% for CC, TC, and MC, respectively. Furthermore, the initial PV of SDASO (0.5meq/Kg oil) increased to 40.3, 28.2, and 12.3meq/Kg oil in CC, TC, and MC, respectively, after 60 days. The covalently modified gelatin-gum Arabic coacervates offered noticeable improvements in heat and oxidative stability.

Conjugated Linoleic Acid (CLA): 30-Year Research. Y. Park, University of Massachusetts, USA.

CLA is a collective term for geometric and positional isomers of conjugated octadecadienoic acid. Since the identification of CLA as an anti-carcinogenic principal from beef in the 1980s, it has been studied for a wide range of biological activity, which includes reducing development of atherosclerosis, enhancing growth of animals, modulating immune responses, and interestingly reducing body fat while enhancing lean body mass. Moreover CLA's tremendous effects on lipid metabolism contribute, either directly or indirectly, to its effects on muscle and bone metabolisms. CLA fed animals showed increased activity levels and endurance capacity, which may be linked to its effects on increasing energy expenditure and fat utilization. In addition, CLA shifted bone marrow mesenchymal stem cell balance between bone marrow adiposity and bone cell formation in favor of bone mass, resulting in reducing marrow adipocytes and increasing osteoblasts. These suggest a great potential for CLA to be used to improve body composition along with current efforts to control obesity.

EAT 4.1/AM 2: Imaging Fat Crystal Networks at Different Length Scales

Chairs: G. Sekosan, Bunge North America, USA; and K. Koch, North Dakota State University, USA

Crystallization Behavior of Molecular Compound in the Binary System of 1,3-dioleoyl-2-palmitoyl-*sn*-glycerol and 1,3-dipalmitoyl-2-oleoyl-*sn*-glycerol. K. Nakanishi[1], Y. Mikiya[1], T. Ishiguro[1], M. Sato[2], and S. Ueno[3], [1]Miyoshi Oil & Fat Co., Ltd., Japan, [2]Japan Synchrotron Radiation Research Institute, Japan, [3]Hiroshima University, Japan.

Molecular compound (MC) forms in binary system of 1,3-dioleoyl-2-palmitoyl-*sn*-glycerol (OPO) and 1,3-dipalmitoyl-2-oleoyl-*sn*-glycerol (POP). It has been reported that MC forms thermodynamically stable beta form and at the 1:1 concentration ratio of OPO and POP under cooling process with cooling rate of less than 15°C/min. Industrial manufacturing process of edible oil and fat products such as margarine, however, involves rapid cooling process with cooling rate of more than 100°C/min. We revealed the crystallization behavior of MC in the binary system of OPO and POP under rapid cooling. We mixed OPO and POP at a concentration ratio of 1:1 and analyzed the mixture by changing the cooling rate from 1°C/min to 150°C/min by differential scanning calorimetry. Polymorphic analysis under slow, 5°C/min, or rapid, 40°C/min, cooling conditions was performed by using synchrotron radiation X-ray diffraction at BL19B2 of SPring-8, Hyogo, Japan.

The main results are as follows; POP and OPO crystallized individually without the formation of MC under the rapid cooling, while MC was formed under the slow cooling. In heating process subsequent to the rapid cooling process, MC was finally formed after OPO and POP individually caused polymorphic transformation into the phases with alpha or beta form.

Unpredictable Binary Systems of Triacylglycerols. P.K. Batchu[1,2], P.D. Wentzell[1], and G. Mazzanti[1,2], [1]Dalhousie University, Canada, [2]Institute for Research in Materials, Canada.

The composition, polymorphic form and proportion of the solid phases formed during crystallization affect physical properties like melting point, spreadability etc., of fat based foods. One of the steps to better understand crystallization is to be able to predict the composition and distribution of crystalline phases that would be formed from a liquid mixture of fats at any temperature. Time resolved small and wide angle x-ray diffraction patterns were obtained from crystallizing binary mixtures of trilaurin and trimyristin at different temperatures and the linear kinetic segregation (LKS) model (Los and Flöter, 1999) was tested to see if it has the capability to explain experimental phase formation. An empirical model was developed to estimate the composition and the amount of each crystalline phase formed at any point of time during the crystallization process. The (LKS) model was partially successful in explaining the formation of crystalline phases highlighting a need for improved models.

The Effects of Emulsifiers on the Formation and Morphology of Crystal Spheroids. T. Tran, A. Lim, and D. Rousseau, Ryerson University, Canada.

The effect of different emulsifiers [Span 60, Span 65, Span 80, Tween 80, glycerol monopalmitate (GMP), and glycerol monostearate (GMS)] on the shear-crystallization behavior of a model fat system [10wt% fully-hydrogenated canola oil (HCO) and 90wt% canola oil CO)] at various shear rates (400-2000 s^{-1}) was studied. Samples were crystallized between a rheometer's parallel plate geometry at 1.0°C/min which produced spheroidal crystal structures. Average crystal size decreased with increasing shear rate. The presence of emulsifiers significantly reduced crystal size ($P<0.05$) but there were no differences between the different emulsifiers. Crystal spheroid morphology was greatly dependent on the emulsifier used – crystal spheroids were formed for systems with Span 60, Span 65, Span 80, GMP, and GMS, but not for systems containing Tween 80. It was proposed that the bulky hydrophilic headgroup of Tween 80 was incompatible with the triglycerides of HCO (mostly tristearin) and hindered crystal spheroid formation. The other emulsifiers had more compatible structures that enabled them to be integrated into the spheroids' crystal matrices. In this study, we have further characterized the formation of crystal spheroids and revealed additional methods of tailoring their morphology.

Semi-empirical Treatment of Anomalous Moisture Transport into Sheared Lipids Using Magnetic Resonance Imaging. S. Paluri, M. Shavezipur, A. Abduljalil, D. Heldman, and F. Maleky, Ohio State University, USA.

This work investigates the effect of shearing on moisture diffusivity and mechanism of moisture migration in lipids. Three lipid samples: cocoa butter (CB), palm kernel oil (PO) and 20% w/w cocoa powder in palm kernel oil (CPPO) were prepared by two methods- shearing during crystallization and static crystallization. Samples' moisture uptake from a water source was measured using Magnetic Resonance Imaging and their effective diffusivity values were determined. It was observed that sheared samples had a better moisture barrier property compared to static samples. Furthermore, the mechanism of migration was found to be different between sheared and non-sheared cocoa butter samples. Regardless of processing technique, palm oil samples exhibited Fickian-diffusion controlled moisture migration. Whereas the mixture of palm oil and cocoa powder samples showed relaxation-mechanism controlled migration due to the presence of hydrophilic cocoa powder particles.

Modelling the Effects of Shear on Solid Fats Aggregation in Edible Oils. B. Townsend[1], B. Quinn[2], A. MacDonald[3], T. Gordon[4], C. Hanna[4], A.G. Marangoni[1], and D.A. Pink[2,1], [1]University of Guelph, Canada, [2]St. Francis Xavier University, Canada, [3]OneZero Software, Canada, [4]Boise State University, USA.

The aggregation of triacylglycerol (TAG) crystalline nanoplatelets (CNPs) (Acevedo & Marangoni 2010) in semi-solid fats during edible oils processing is important for determination of their functionality. Although such systems have been modeled (Pink et al 2013), they were modeled in non-flowing liquid oils. Edible oils, however, are sheared during processing. The effects of shear on the formation of solid fat structures, though highly relevant, have been unexplored theoretically. A model has now been developed to predict the aggregation structures of solid CNPs immersed in liquid oils when shear is applied. CNPs were modelled as rigid planar arrays of spheres interacting with each other and with surrounding spheres representing the liquid oil. The model was simulated using Dissipative Particle Dynamics within the software package Fluidix©. Systems of semi-solid fats without an applied shear, resulted in the self-assembly of linear stacks of CNPs (TAGwoods). Our results suggest that in the presence of shear, these TAGwoods, if formed, exhibit a distorted (non-linear) shape as suggested by observations. Larger structures are affected by shear. Predictions will be presented for outcomes of USAXS experiments. Our results might have consequences for functionality.

Self-organizing Aggregation in Complex Edible Oils. D.A. Pink[1,2], B. Quinn[1], F. Peyronel[2], and A.G. Marangoni[2], [1]St. Francis Xavier University, Canada, [2]University of Guelph, Canada.

Self-organizing aggregation structures are likely to play key roles in creating functionality in edible oils. Here we describe mesoscale models to show how different aggregation structures can arise in complex oils. We carried out modelling and computer simulations on three systems: (1) oils in which the majority solid phase is essentially-insoluble in a complex liquid phase. We considered cooling mechanisms whereby solids are 'created' at various rates which compete with the 'diffusion'processes that bring about aggregation. (2) oils in which the solid phase is significantly soluble in the liquid phase so that solid particles can dissolve and reform. Now there will be competition between characteristic solid-formation rates, solid re-structuring, and diffusion times. (3) The presence of minority components in the liquid oil of (1). Here we have different ways in which essentially-insoluble solid particles can be coated thus leading to a range of structures which suggest mechanisms via which oil binding capacity can be enhanced. We predict structures which can form together with the results of USAXS experiments. Other experiments, designed to detect key details of the model assumptions or predictions, will be proposed.

Effect of High Intensity Ultrasound on the Crystallization Behavior of Palm Oil in a Flow Cell. Y. Ye and S. Martini*, Utah State University, USA.

High intensity ultrasound (HIU, 20 kHz) was used to change the crystallization behavior of palm oil in a continuous system (flow cell). Different power levels (75, 110, and 180W) and pulse duration (continuous application, 5, 10 and 15sec pulses) were used to optimize the crystallization process at 35°C. Physical properties of the crystalline network formed such as microstructure, solid fat content, melting profile, polymorphism, and viscoelasticity were measured. Results showed that the application of HIU at lower power level (75W) was the most efficient processing condition at generating higher crystallization rate which was evidenced by higher values of the Avrami

constant, *k*. The nucleation mechanism was also affect by sonication with lower Avrami indices, *n*, obtained for the sonicated samples. Higher power levels resulted in a significant increase in the temperature of the sample resulting in the melting of crystals and therefore in a delay in the crystallization. The use of HIU at low power levels (75 W) in a continuous manner generated a crystalline network with higher SFC, higher elasticity, and a sharper melting profile.

Colloidal Inorganic Particle-based Edible Oleogels and Bigels. A. Patel*, B. Mankoc, and K. Dewettinck, Ghent University, Belgium.

The basic building blocks which are recently being explored as structurants for oil gelation include crystalline particles (e.g. waxes), polymeric strands (e.g. cellulose derivatives) and crystalline fibres (e.g. 12 hydroxy stearic acid etc.).
In the current paper, we report for the first time, the use of colloidal inorganic particles, SiO_2 (a food-grade additive, E 551) as new structurants to fabricate clear gels in sunflower oil. Oleogels with high gel strength (G' > 10,000Pa), high resistance to flow (s_Y > 100Pa), temperature stability and a good thixotropic recovery (> 70 %) were obtained at 10-15%wt of SiO_2. Cryo-SEM (along with energy-dispersive X-ray spectroscopy) revealed an interesting 'chain-like' arrangement of SiO_2 aggregates which is responsible for creating a structural framework. The fact that the positive results were only seen with hydrophilic SiO_2 (and not with functionalized hydrophobic SiO_2) strongly suggests that hydrogen bonds among surface silanol groups (Si-OH) contributed to the network formation of colloidal particles. Moreover, water phase (structured using food hydrocolloids) was added to oleogel in different proportions to obtain stable 'bigels' with interesting microstructures (as seen under cryo-SEM and confocal microscope) and excellent rheological properties.

Thermodynamic Estimates of Solid Fat Content. L. Rong[1,3], A.G. Marangoni[2], and G. Mazzanti[1,3], [1]Dalhousie University, Canada, [2]University of Guelph, Canada, [3]Institute for Research in Materials, Canada.

Food industry scientists need to predict multicomponent solid fat compositions because fat solid solutions define food texture and physical properties. Experiments were conducted with two multicomponent fats of known composition (23 and 30 Triacylglycerols) to determine solid fraction (via NMR), phase fraction, polymorphic form (via XRD) and thermal melting profile (via DSC). A database including melting temperature and enthalpy was digitized. Wesdorp's methodology, implemented in MATLAB, was used to estimate the equilibrium mole fractions of each phase. The program estimates melting temperatures and enthalpies absent from the database, and estimates interaction parameters for a 2-suffix Margules model. These parameters were used to find the composition at equilibrium for each phase. The estimated overall melting enthalpy of the mixtures was compared to the value obtained by DSC. Several predicted temperature values using Wesdorp's coefficients were unsatisfactory; hence an alternative approach was developed. The estimated overall melting enthalpies agreed well with the experimental enthalpies.

Refined Concepts on the Structures of Liquid Triacylglycerols. G. Mazzanti[1,2], L. Lin[1], R. Sanderson[1,2], O. Qatami*[1,2], and D.A. Pink[3], [1]Dalhousie University, Canada, [2]Institute for Research in Materials, Canada, [3]St. Francis Xavier University, Canada.

The structure and distribution of triglycerides (TAGs) in fats affects the properties of the final products, in terms of texture, appearance and mouth feel. A few debates and models have been developed on the distribution of TAG molecules in the liquid, but they are not consistent with the actual density of oils or our X-ray scattering (XRS) data. Four pure liquid TAG samples were examined by XRS at temperatures up to 210°C. WAXS data are consistent with the liquid phase of alkanes and other aliphatic molecules. SAXS data are similar to those produced by alcohols and fatty acids, whose molecules associate via polar groups. Therefore, we developed a new conceptual model to describe the clustering of liquid TAGs as "Loose Multimers" and from it estimated that they consist approximately of 5 to 9 molecules. The average number of molecules decreases with temperature and increases with molecular weight.

EAT 5: Confectionary Fats and Oils

Chairs: K. Sato, Hiroshima University, Japan; and A.G. Marangoni, University of Guelph, Canada

Effects of Thermal Treatments on the Polymorphic Behavior of Confectionery Fats: From Pure Components to End Products. L. Bayés-García[1], T. Calvet[1], M.A. Cuevas-Diarte[1], E. Rovira[2], K. Sato[3], and S. Ueno[3], [1]University of Barcelona, Spain, [2]Enric Rovira S.L., Spain, [3]Hiroshima University, Japan.

Thermal treatments applied to fats are highly significant to obtain specific polymorphic forms, which may be of special interest for pharmaceutical, cosmetic and food areas, in particular for confections. We examined the influence of thermal treatments on the polymorphic crystallization and transformations of principal triacylgycerols (TAGs) of edible fats and oils[1,2], but also of end food products of chocolate by using DSC and X-ray diffraction (laboratory-scale and synchrotron radiation source). We observed significant effects of the cooling-heating rates and the supercooling degree on the polymorphic behavior of TAG samples. More stable forms were directly obtained by decreasing the rates of cooling, whereas less stable forms predominated at high cooling rates. We confirmed that the nature of the polymorphic transformations (melt-mediated or solid state) largely depended on the heating rates. As to the end product, new textures of chocolate revealing soft mouth-feel can be obtained by tailoring rapid cooling and subsequent heating treatments, which enabled the formation of thin layers of cocoa butter crystals with slightly lower melting point compared to that of normally-tempered chocolate.

- L. Bayés-García et al., *CrystEngComm*, 2013, 15, 302.
- L. Bayés-García et al., *J. Phys. Chem. B*, 2013, 117, 9170.

Potential of an Ultrasonic Shear Reflection Technique to Monitor the Isothermal Crystallization Behavior of Cocoa Butter In-line. A. Rigolle, J. Hettler, K. Van Den Abeele, and I. Foubert, KULeuven Kulak, Belgium.

The correct crystallization of cocoa butter in chocolate is crucial to obtain the desired quality characteristics. However, most of the currently used techniques to monitor fat crystallization are off-line techniques. Here, we propose an ultrasonic shear wave reflection technique based on low intensity ultrasound and we show that this technique has the potential to measure the crystallization behavior in-line. An inverse model allows to deduce relevant ultrasonic parameters that provide information about the crystallization kinetics and the microstructure development by analyzing the behavior of the measured shear reflection coefficient. In this study, the isothermal crystallization behavior of cocoa butter has been monitored and compared using three techniques: ultrasonic shear reflectometry, Differential Scanning Calorimetry and Polarized Light Microscopy. In order to understand the impact of the crystallization on the measured ultrasonic parameters, limonene was added to cocoa butter. The results suggest that shear reflectometry especially monitors the microstructure development, which makes the technique particularly interesting as a complementary monitoring tool to other techniques that monitor primary crystallization.

Quantifying Aggregation of Triacylglycerol Systems, *in situ*, from Angstroms to Micrometers in One Shot. F. Peyronel[1], A.G. Marangoni[1], and D.A. Pink[2], [1]University of Guelph, Canada, [2]St. Francis Xavier University, Canada.

Ultra small angle X-ray scattering (USAXS) is an emerging technique that allows *in situ* characterization of triacylglycerol (TAG) systems and covers length scales from ~100nm to ~10µm. It is important for the edible oil industry to understand how aggregation structures arise and it is at these length scales that the molecular aggregation into crystallites, and their subsequent aggregation, takes place. We have used USAXS to characterize systems such as hydrogenated palm kernel, cocoa butter and shea butter. We compare those results with our work on model systems: tristearin in triolein. In that work, six structural levels were identified for scattering pertaining to the range from angstroms to micrometers: polymorphism (Level 1, WAXS), molecular aggregates (level 2, SAXS) and larger-scale aggregation (Levels 3 to 6, USAXS). Here we concentrate on the latter. We will report on the size of the primary crystal units, crystalline nanoplatelets, and its aggregates. Larger aggregates will be shown to give rise to fractal structures or nanovoids/nanospaces depending upon the solid fat content. In all cases, we appeal to mathematical modelling to identify structures. We will touch on

the implications of these findings for the choice of healthy fat-replacers.

Chemical and Enzymatic Transesterification of High Oleic Algae Oil, High Oleic Sunflower Oil, Shea Stearin with Palm Stearin, and Fully Hydrogenated Cottonseed Oil to Synthesize Cocoa Butter Equivalents. S. Mirzaee Ghazani[1], C. O'Sullivan[1], R. Bond[2], W. Rakitsky[2], and A.G. Marangoni[1], [1]University of Guelph, Canada, [2]Solazyme Inc., USA.

Fat blends, formulated by blends of palm stearin, fully hydrogenated cottonseed oil with high oleic acid algae oil, high oleic sunflower oil, and shea stearin in different ratios, were subjected to chemical and enzymatic interesterification to synthesize cocoa butter equivalent. Sodium methoxide and Lipozyme TL IM were selected as catalyst for chemical and enzymatic esterification, respectively. The optimum reaction time, temperature, water content and molar ratio of oils and fats blends were determined to produce the highest yield of POS, SOS, and POP triacylglycerols. The following parameters, before and after the interesterification reactions, were determined: fatty acid and triacylglycerol compositions, melting point, crystallization temperature, solid fat content, and XRD analysis.

Enzymatic Acidolysis Synthesis of Cocoa Butter Improver and Its Application Evaluation. Z. Meng, X. Wang, and Y. Liu, Jiangnan University, China.

Cocoa butter improver (CBI), a product rich in 1,3-distearoyl-2-oleoyl-glycerol (SOS) was synthesized by enzymatic acidolysis of high oleic acid sunflower oil (HOSO) and stearie acid (SA) in a solvent-free system by Lipozyme RM IM. The impact factors of reaction time, reaction temperature, and substrate molar ratio (SA:HOSO) on the content of SOS and the total contents of 1,2-distearoyl-3-oleoyl-glycerol (SSO) and tristearate (SSS) were optimized by the response surface method, and the corresponding optimum conditions obtained as follows: 2h, 70°C and 4.46:1. In these conditions, the content of SOS and the total contents of SSO and SSS achieved were 41.05% and 0.63%, respectively, which showed that the predicted values of the models were perfectly appropriate to the values of practical experiments. After purification under the optimal short-range molecular distillation, 95% ethanol extraction and acetone fractionation, the content of SOS in the target CBI product can reach 86.00%, indicating the great potential for industrial production. The CBI product obtained herein has an increased potential for manufacturing chocolates with improved resistance against chocolate bloom caused by high temperatures or temperature fluctuations, by increasing the hardness and temperature resistance properties of cocoa butter when addition of CBI.

Boundaries of the Memory Effect in Pure Triacylglycerols. Y. Wang[1], O. Qatami[1,2], and G. Mazzanti[1,2], [1]Dalhousie University, Canada, [2]Institute for Research in Materials, Canada.

It is well known, in the fats and oils processing industry and science, that recrystallization of materials soon after melting may lead to the formation of crystalline polymorphs that were present in the solid. Conversely, more unstable crystalline forms are obtained after heating for long time at high temperatures. This phenomenon is known as memory effect or crystal memory. However, the specific time-temperature boundaries for different polymorphs of pure triacylglycerols (TAGS) have not been systematically studied. Four pure mono-saturated TAGs (12, 14, 16 and 18 carbons) were studied using DSC and XRD, and their time-temperature boundaries for the memory effect were determined. It was found that the boundaries depend on the heating and cooling rates. This is a consequence of the fact that the 'boundary' is the result of the convolved effects of temperature and time. These data are to be used as the basis for modeling the melting/liquid structure of TAGs, as well as the nucleation phenomena that precede crystallization.

Thermodynamic and Polymorphic Study on Phase Behavior of Ternary Mixture of SOS/SSO/OSO for Application to Confectionery Fats. S. Watanabe[1], K. Shiozaki[1], M. Togashi[2], M. Sato[2], and K. Sato[3], [1]Oil and Fat Development Department, Japan, [2]Chocolate Development Department, Japan, [3]Hiroshima University, Japan.

The phase behavior of ternary triacylglycerol (TAGs) mixtures of SOS (1, 3-Distearoyl-2-Oleoylglycerol), SSO (1, 2–Distearoyl-3-Oleoylglycerol), and OSO (1, 3-Oleoyl-2-Stearoylglycerol) was examined using X-ray diffractometry (XRD) and differential scanning calorimeter (DSC). Twenty samples were prepared by mixing pure three TAGs (>98.0%). Crystallization was carried out by cooling at 5°C for 60 minutes after melting at 80°C for 10 minutes and incubating at 60°C for 30 minutes, and the aged samples were

obtained by incubating at 28°C for 10 days after the crystallization.

From the results of XRD and DSC analysis of the simple cooling samples and these aged samples, both eutectic and soild-solution phases were obtained. Eutectic phases were observed at the concentration range of SOS/SSO/OSO = 50/25-50/0-25. On the other hand, solid-solution phases were observed at the concentration range of SOS/SSO/OSO = 50/0-20/50-30. We found that all aged samples showed stable be-ta polymorphic form having the melting points around 38 to 40°C and that these mixtures are suitable for confectinery fats.

EAT 5.1/S&D 5.1: Emulsions and Foams

Chairs: T. Tokle, Kalsec Inc., USA; and E.J. Acosta, University of Toronto, Canada

Enhancing the Bioavailability of Lipophilic Nutraceuticals in Fruits and Vegetables: Excipient Food Design. D.J. McClements[1,2], [1]University of Massachusetts Amherst, USA, [2]King Abdulaziz University, Saudi Arabia.

The oral bioavailability of many lipophilic nutraceuticals in fresh and processed fruits and vegetables is limited due to various physiochemical and physiological mechanisms: poor release from food matrices; low solubility in gastrointestinal fluids; metabolism or chemical transformation within the gastrointestinal tract; low epithelium cell permeability. The bioavailability of these nutraceuticals can be improved by controlling their release, solubilization, transport, metabolism, and absorption within the gastrointestinal tract. This presentation discusses the impact of food composition and structure on oral bioavailability, and how this knowledge can be used to design *excipient foods* for improving the oral bioavailability of lipophilic nutraceuticals. The composition and structure of excipient foods is specifically designed to promote the bioavailability of co-ingested nutraceuticals.

Beverage Emulsions. Y. Fang, PepsiCo Research and Development, USA.

Beverage emulsions are typically oil in water emulsions and the oil phase consists largely of essential oil. The emulsions provide two important characteristic to the final product, first is flavor and secondly, it gives the beverage a cloudy appearance. It is possible to separate the flavor emulsion and the cloud emulsion, the latter can be made of an oil that is mostly neutral in flavor contribution such as vegetable oils or medium chain triglycerides. This paper highlights some of the unique challenges in beverage emulsions, and the role of the different components in the oil phase.

Emulsions Stabilized by Edible Colloidal Particles. C.C. Berton-Carabin and K. Schroën, Wageningen University, The Netherlands.

The ability of colloidal solid particles to physically stabilize emulsions has been known since the pioneering work of Ramsden and Pickering in the 1900's, but substantial interest in this area has been rising only recently. Regarding food applications, studies on food-grade Pickering emulsions are still scarce, yet definitely represent a growing research field.

The present work gives an overview of the latest trends in food-grade particles for emulsion stabilization, including our own results. In particular, different kinds of edible particles that have been successfully applied for this purpose (e.g., starch granules, chitin nanocrystals, solid lipid nanoparticles) are presented. Special attention is given to manufacturing strategies for the particles, including chemical modifications to induce dual wettability by oil and water, which is required for effective stabilization. The potential advantages of using particles rather than conventional food emulsifiers in terms of emulsion performance are discussed.

Finally, the challenges that have to be faced for the development of food-grade Pickering emulsions are addressed, including the acceptability of nanoparticles in foods, the prediction of the particle stabilizing efficiency, and the possible changes undergone by particles post-adsorption.

HLD-NAC Guided Formulation of Self Micro Emulsifying Delivery System (SMEDS). M. Nouraei and E.J. Acosta, University of Toronto, Canada.

Self micro emulsifying delivery systems (SMEDS) are among promising lipid- based delivery systems that enhance the solubility and the bioavailability of lipophilic active ingredients. Conventional SMEDS are composed of oil, surfactant(s) and co-surfactant/co-solvents. Linker-based lecithin SMEDS are a novel approach in formulating biocompatible SMEDS. The objectives of this work were to calculate the characteristic curvature (Cc) of the SMEDS surfactant/linkers by employing the HLD-NAC equation of state and examine the use of HLD to predict the phase behavior of the SMEDS with changes in surfactant linker ratio. The phase behavior of several combinations of ethyl caprate (a food grade fatty acid ester) as oil, lecithin as the main surfactant, glycerol mono-oletae as lipophilic linker and polyglycerol-6-caprylate as hydrophilic linker was investigated, guided by ternary phase diagram.

For the first time, the HLD approach was applied to characterize the properties of the linker -based SMEDS using formulation scanning technique. The results showed the presence of a wide area of single

phase fully dilutable system when exposed to simulated intestinal fluid (FeSSIF). With an increase in lipophilic linker to surfactant ratio, as predicted by HLD, the 2-phase region decreases. However, this was accompanied by an increase in the area covered by the liquid crystal region.

Transport of Self-emulsifying Systems Through Unsaturated Porous Media. A. Stammitti and E.J. Acosta*, University of Toronto, Canada.

Emulsified oil transport through porous media is important for many applications, particularly for enhanced oil recovery. Previous work focused on developing surfactant formulations that display ultralow interfacial tension (IFT) to facilitate the emulsification/mobilization of oil from reservoirs. However, little attention has been paid to wettability changes or drop-solid interactions. In this work, two sets of formulations were prepared using toluene and Heptol (heptane-toluene) as oil phases, and SDHS surfactant with varying NaCl concentrations as aqueous phase. These systems were characterized by IFT, emulsion stability and solid-liquid-liquid contact angle (CA) on glass. Results show that as the formulation approach the phase inversion point, the surface tends to be equally wet by the aqueous and the oil phase. Combined flooding–imbibition experiments were performed on initially empty dry-packed sand columns, and the total oil recovered after 24hour imbibition was measured. For both oils, minimum recovery was observed at conditions that produce maximum emulsion stability. Conversely, maximum recovery was obtained with formulations that produce minimum emulsion stability. These observations will be discussed in light of the potential drop-solid interactions that are neglected in the transport of emulsions through porous media.

Methods to Predict Emulsion Formation and Stability: A Map to the Land of Emulsions. E.J. Acosta, University of Toronto, Canada.

The objective of this presentation is to review the spectrum of approaches used to understand the formation and estability of emulsions, and the guidelines to select the applicable model to a specific set of conditions.

On the aspect of the formation of emulsions, the concept of shear vs. inertia-controlled emulsification will be discussed, and the characteristic numbers that can be used to define these processes. A new concept of film emulsification will be briefly described. Emulsion stability will first be discussed in terms of processes of creaming/sedimentation, and coalescence. We will discuss the different resistance terms that apply in different cases, and the role that polymers, particles and surfactants can play in emulsion stabilization. Potential misconceptions around the role of Ostwald Ripening mechanisms, particularly for nanoemulsion stability predictions will be discussed.

EAT-P: Edible Applications Technology Poster Session

Chairs: M.A. Rogers, University of Guelph, Canada; and F. Maleky, Ohio State University, USA

1. **Effect of Aqueous Phase Composition on Particle Size and Stability of Sunflower Oil/Sodium Caseinate Nanoemulsions.** J.M. Montes de Oca Avalos[1], R.J. Candal[2], and M.L. Herrera*[1], [1]Instituto de Tecnologia en Polimeros y Nanotecnologia, Argentina, [2]Instituto de Investigacion e Ingenieria Ambiental, Argentina.

Many nanoemulsions are currently formulated with synthetic surfactants. The objective of the present work was to prepare transparent nanoemulsions using a natural emulsifier. Nanoemulsions were prepared by using the evaporative ripening method. In this method, a volatile organic compound (such as ethyl acetate) was removed from the sample by a thermal process at low pressure which produces a droplet shrinkage down to nanometer sizes. Maintaining fix concentrations of 1.64wt.% sunflower oil and 0.98wt.% sodium caseinate, several concentrations of sucrose or trehalose were added to the system: 0, 2, 4, 6, 8, 10% w/w. Analysis were performed by dynamic light scattering techniques, determining the size distribution and the zeta potential of the samples. Results show that using the evaporative method, stable monodispersed nanoemulsions were obtained with a mean diameter between 100-200nm and a narrow distribution. If ethyl acetate was not added to the sample, conventional emulsions in the range of micrometers were obtained with a polidispersed distribution. Moreover, increasing the disaccharide concentration, narrower size distributions were obtained and micrometer droplet sizes, which appeared in a very small amount for low disaccharide concentrations, disappeared.

2. **Determination of Free Fatty Acids and Organic Acids in Goat Cheeses.** I. Vieitez, N. Callejas, B. Irigaray, V. González, A. Arechavaleta, S. Jiménez, L. Panizzolo, A. Gámbaro, and M.A. Grompone, Universidad de la República (Udelar), Uruguay.

Lipolysis of triglycerides plays an essential role in the sensory properties of cheeses; some free fatty acids (FFAs) have been shown to contribute directly to the aroma characteristics of many types of cheeses. Besides, flavor profiles of cheeses are also influenced by substances such as organic acids (OAs) that are formed by fermentation (antibacterial activity).

The aim of this work was to characterize the profile of FFAs and OAs in goat cheeses elaborated in Uruguay. Analyses were performed on ten fresh and six ripened goat cheeses.

Determination of FFAs was made by GC equipped with NUKOL column. Extraction method was described by Lencioni et al. (1998). Determination of OAs was made by HPLC system equipped with a UV detector set a 210nm with with Rezex ROA-Organic Acid H+ column. Analyses were performed isocratically at 1.0 mL/min, 65°C and the mobile phase was 0.005M H2SO4 with acetonitrile (up to 20%). Extraction method was described by Bouzas et al. (1993).

The main difference between the two types of cheeses was the higher amounts for short FFAs from 4:0 to 10:0 for ripened, that gives characteristic odors and flavors to these cheeses. In both types of cheeses the main OAs found was lactic followed by propionic acid.

The total value, and the quantities of each of FFAs and OAs, is an initial approach that allowed to characterize Uruguayan goat cheeses.

3. **Amylose Inclusion Complexation of Ferulic Acid via Lipophilization.** J.A. Kenar, D. Compton, F.C. Felker, and G.F. Fanta, USDA, ARS, USA.

Ferulic acid is an interesting phytochemical that exhibits antioxidant, anti-inflammatory, antimicrobial, UV-absorber, and anticarcinogenic activities. These properties make it of interest in food formulations, cosmetics, polymer, and pharmaceutical applications. However, delivery of ferulic acid in these applications is challenging due to its low bioavailability and tendency to degrade during processing. To overcome these issues various encapsulation technologies have been proposed. Amylose-guest inclusion complexes may provide an interesting method to protect and deliver bioactive molecules. Steam jet-cooking is a rapid and continuous process that we have previously used to prepare amylose inclusion complexes from fatty acids and starch. Unfortunately, ferulic acid does not readily form inclusion complexes with amylose. Therefore, we examined the use of steam jet-cooking to form an inclusion complex between amylose and octadecyl ferulate, a ferulic acid ester that contains a long alkyl chain. The long alkyl chain serves as a hydrophobic moiety that can be

complexed by amylose and effectively complex the ferulic acid. In this work we describe the physicochemical characteristics of the amylose-octadecyl ferulate inclusion complexes by DSC, X-ray analysis, and SEM among other techniques, and describe potential applications.

4. **Submicron Emulsions Designed to Stabilize Blueberry Extract in Foods.** K. Latorre[1], P. Cabral[2], and A. Medrano*[1], [1]Universidad de la República (Udelar), Uruguay, [2]Nuclear Research Center, Uruguay.

The objective of this study was to develop, characterize and compare blueberry extract loaded submicron-emulsions systems. The generation of emulsions in the submicron range may be able to protect phenolics compounds through processing, transportation, storage, and digestion. Oil in water emulsions of different volumetric fractions (0.05-0.75) were prepared by rotary homogenization (RH, 20000 RPM, 1min) and high pressure homogenization (HPH, 500-1200 bar, 1 to 5 cycles). RH and HPH systems containing various levels of hydrocolloids (pectin: 0.05-0.7 mg/mL; guar gum: 0.1-0.2mg/mL), ß-Lg (0.5 to 3.5% w/v) were evaluated for emulsifying capacity, stability (light backscattering), and droplet profile (dynamic light scattering). Blueberry extract content incorporated to the emulsion was assessed by determination of quercitin by HPLC (UV detection). Optimum conditions for stability using RH were found with a particle size <500nm, and concentration of 2.2% (m/v) ß-Lg and between 0.1-0.2% (m/v) of guar gum. Emulsions made by HPH achieved a 4-10 fold reduction in droplet size and higher stability without using hydrocolloids. Stability increased with the number of HPH cycles. HPH emulsions shown higher percentage of blueberry extract encapsulation. To conclude, HPH emulsions were effective to the incorporation of antioxidant extract and their future incorporation in foods.

5. **Changes in Lipid Substances in Rice During Grain Development.** N.H. Kim[1], J. Kwak[2], J.Y. Baik[1], M. Yoon[2], J. Lee[2], S.W. Yoon[1], and I.H. Kim[1], [1]Korea University, Republic of Korea, [2]Rural Development Administration, Republic of Korea.

Lipid substances, such as fatty acids, ?-oryzanol, policosanols, and tocols (tocopherol + tocotrienol), were investigated in two rice cultivars, Ilpum and Dasan, during rice development. In both cultivars, the oil level decreased steadily after it reached its maximum level. Additionally, there were differences in the fatty acid composition, depending on the rice developmental stage, between the two cultivars. The ?-oryzanol level increased during rice development, and there were differences in the composition of ?-oryzanol between the two cultivars. The policosanols level drastically decreased during the early stage of rice development in the two cultivars. The total tocols level showed a downward trend during rice development. The predominant tocol isomer in Ilpum was a-tocopherol during rice development. In Dasan, the predominant tocol isomer was a-tocopherol at the early stage, but it was ?-tocotrienol at the later stage. This study provided information on the levels and composition of lipid substances, such as fatty acids, ?-oryzanol, policosanols, and tocols during rice development.

6. **Liposomes as Delivery Systems for Antioxidant Hydrolysates in Functional Foods.** A. Fernandez, M. Cabrera, M. Fernandez, P. Cabral, and A. Medrano*, Universidad de la República (Udelar), Uruguay.

The objective of this work was to evaluate the viability of the antioxidant hydrolysates incorporation into liposomes (L) and study their biodistribution. Bioactive food peptides are encrypted within the sequence of food proteins. This bioactive peptides are receiving special attention due to health benefits. L are concentric phospholipidic bilayers membranes that encase aqueous compartments in which antioxidant hydrolysates could be protected during digestion. Infostat program version 2011 was used for statistical analysis of the results. L were elaborated using hand shaken method with phosphatidilcolin and colesterol in clorophorm-methanol. L characterization was done by determination of temperature and transition enthalpy through DSC. L formation was analized by droplet size profile using a Coulter Counter Multisizer. Global stability was determined by light scattering measurements using a vertical scan analyzer (Turbiscan). The content of antioxidant hydrolysates in the L was determined by HPLC. In order to evaluate the biodistribution of the L and hydrolysate, they were labeled with 99mTc (? emission) through HYNIC (bifunctional agent) observing L resistance to gastric medium reaching the bloodstream with subsequent distribution in all organs and tissues. L presented stability and retention in a 60% of the hydrolysed fractions.

7. **Emulsions Loaded with Epigallocatechin-gallate: Digestion Behaviour, Bioactive Release, and Anti Proliferative Activity of the Digestates on Caco-**

2 Cells. S. Sabouri, E. Arranz, A. Guri, and M. Corredig, University of Guelph, Canada.

The effect of the stearic sucrose ester (SE) S-170 on crystallization behavior and polymorphism of two stearins obtained from a new variety of high stearic high oleic sunflower oil was studied by pulsed nuclear magnetic resonance, X-ray scattering using synchrotron light and differential scanning calorimetry. There was always a crystallization temperature below which SE S-170 accelerated crystallization and above which SE S-170 delayed nucleation and growth. SE S-170 was efficient as a seed for high supercooling (low crystallization temperatures) but this efficiency diminished at low supercooling (temperatures close to the melting point) when few crystals were formed. Depending on crystallization temperature, SE S-170 promoted crystallization of forms with more polymorphic similarity and inhibited occurrence of' forms with unit cells significantly different. SE S-170 significantly diminished total melting enthalpies when the effect was a delay in crystallization. With addition of SE S-170 polymorphic forms ß'$_1$ and ß$_2$ may be obtained as the main form. This is very relevant from the technological point of view. Depending on the application, SE S-170 may help obtain the required polymorphic form: ß'$_1$ form for spreads and ß$_2$ polymorph for chocolate production.

8. **Influence of Solvents on Extractability of Lipids from *Gloeothece* sp., and Effects on Antioxidant Capacity.** H.M. Amaro, A.C. Guedes, I. Sousa-Pinto, and F.X. Malcata*, University of Porto, Portugal.

Microalgae are ubiquitous, nutritionally nonfastidious able to produce active compounds with wide biotechnological potential. Lipid components, chiefly carotenoids and PUFA, are largely recognized for their therapeutic applications; hence, cost-effective and environment-friendly extraction is in order. The aim of this work was to evaluate the influence of 4 distinct food-grade solvents upon extractability of specific lipids (i.e. carotenoids and PUFA) from microalga *Gloeothece* sp., and further assess their effect upon their final antioxidant activity – via overall antioxidant salvaging (DPPH), and specific blocking of superoxide ($O2^{-\bullet}$) and nitric oxide ($NO^{-\bullet}$) radicals.
Acetone performed well on total carotenoids, up to 1.806±0.080$\mu g_{TC}/g_{DW}$, of which 79% was lutein, and attained the best IC_{25} for $NO^{-\bullet}$ (6.3μg_{DE}/mL). Despite their good performance in carotenoid extraction, ethanol proved especially remarkable in extracting PUFA, viz. 13.219±0.233$\mu g_{FA}/g_{DW}$, of which 76% was linoleic acid; and the best IC_{25} measured by DPPH and $O2^{-\bullet}$, i.e. 273.7μg_{DE}/mL and 30.0μg_{DE}/mL, respectively.

The major conclusion drawn is that the profile of lipids extracted by organic solvents is critical upon the antioxidant performance of said extracts – which appears to hinge, in particular, on the balance between carotenoids and PUFAs.

9. **Inhibiting Nucleation and Crystal Growth of High Melting Point Lipids in Cooking Oil.** J. Neddersen[1], B. Forrest[2], and M. Nielsen[3], [1]DuPont Nutrition & Health, USA, [2]DuPont Nutrition & Health, Australia, [3]DuPont NHIB, Denmark.
Nutrition and Health, Australia, [3]DuPont NHIB, Denmark.

Palm based cooking oil is common in tropical and subtropical climates. One quality aspect of retail cooking oil is to stay liquid, transparent and crystal free throughout shelf life. To address this need, palm olein, particularly with IV > 58, is used. Nevertheless, palm olein can begin to crystallize, reducing oil clarity and saleability. This behaviour becomes more apparent with storage in air-conditioned stores and cooler climates and weather (temperatures below 18°C).

To address the problem, producers have several options available to them. Examples include fractionating to a higher iodine value, addition of low melting point oils and the addition of surfactants that interfere with crystal growth and nucleation. Sorbitan tristearate and polyglycerol esters are well known crystal inhibitors.

More recently, we have discovered that stearoyl lactylates can also interfere with onset of crystallization in palm olein based cooking oils, both in their own right and by potentiating the effect of other crystal inhibitors. The capacity of emulsifier combinations to inhibit crystallization in a range of cooking oils containing palm olein across the temperature range 0°C to 18°C will be shown. Emulsifier dosages typically between 300-500ppm produce a 5-10 fold improvement in delay of precipitation of lipids in the cooking oil.

10. **Development of Zero *trans*/Low Sat Fat Systems, Structured with Sorbitan Monostearate and Fully Hydrogenated Crambe Oil.** G.R. Comote, T.G. Kieckbusch, and G.M. Oliveira*, University of Campinas, Brazil.

Currently, lipid scientists are searching for alternatives or solutions to a concern widely discussed by health organizations around the world,

namely, the demand to limit the amount of saturated fat intake by the population. The present work considers the development of a lipid systems with zero *trans* fat and low contents of saturated fatty acids (low sat) maintaining equivalent functionality of commercial partially hydrogenated fats. Palm oil (PO) was used as zero *trans* fat basis and canola oil (CO) as a source of low sat lipids. The functional attributes of theses mixtures were adjusted by the incorporation of a structuring agent (sorbitan monostearate - SMS) and a crystallization modifier (fully hydrogenated crambe oil - FHCR). Blends of PO with CO were formulated and the effects of adding 5% of a mixture of FHCR and SMS (50:50) to the samples were evaluated. The technical performance of these additives was evaluated. The results indicated a reduction in the content of saturated fatty acids up to 76.33%, compare to standard sample, therefore implying in a decay in solid fat content (SFC). However, the additives increased the consistency of the samples and proved to be effective in the formation of a homogeneous structural network, ensuring the continuity of the liquid oil in the lipid matrix.

11. **Effect of Aqueous Phase Composition on the Physicochemical Stability of Chia O/W Emulsions.** L.M. Julio[1], V.Y. Ixtaina[1], J.R. Wagner[3], S.M. Nolasco[2], and M.C. Tomás*[1], [1]Centro de Investigación y Desarrollo en Criotecnología de Alimentos (CIDCA) (CONICET La Plata-UNLP), Argentina, [2]Universidad Nacional del Centro de la Pcia. de Bs. As., Argentina, [3]Universidad Nacional de Quilmes (UNQ), Argentina.

The effect of different aqueous phase composition on the stability of chia O/W emulsions was evaluated. O/W emulsions were prepared by homogenizing 10wt% chia oil with 90%wt aqueous solution (600 bar), stored ~1 month at 4.0±0.5°C. Six formulations were prepared with sodium caseinate (NaCas) (10% wt/wt) and a chia protein-rich fraction (PRF) (2% wt/wt) as emulsifiers, lactose or maltodextrin (10% wt/wt) and presence or absence of chia mucilage (0.2% wt/wt). Stability of emulsions was evaluated by the evolution of backscattering (BS) profiles, ?-potential, apparent viscosity, particle size distribution, mean diameter (D[4,3]) and peroxide value (PV). The particle size distribution was monomodal for NaCas-Lac emulsions with and without mucilage added and bimodal for the other systems. The initial D[4,3] was 0.3-0.4µm and 17-18µm for NaCas and PRF-based emulsions, respectively. Increases on particle size of NaCas-based emulsions during storage were observed. PRF-based emulsions destabilized by creaming a few minutes after their preparation, while BS profiles of NaCas-stabilized emulsions did not exhibit important changes during the storage. The apparent viscosity was NaCas-Mltdx?NaCas-Lac?PRF-Mltdx, which increased with chia mucilage addition. ?-potential was -30mV and -20mV for emulsions with NaCas and PRF, respectively. The systems recorded low PV levels.

12. **Effects of High Pressure Treatment on Structure and Physical Properties of Fat Blends of Fully Hydrogenated Soybean Oil.** M. Zulkurnain, F. Maleky, and B. Balasubramaniam, Ohio State University, USA.

Mixture of fully hydrogenated soybean oil (30% w/w) with soybean oil was crystallized under high pressure from the melt at various pressures levels up to 600MPa under controlled thermal conditions using a laboratory scale high pressure kinetic tester. The pressure vessel was at controlled temperature during the process. The effects of initial temperature, process temperature, application of pulses and duration under pressure were studied. The control samples were also crystallized with the same cooling rate under ambient pressure (0.1MPa). The effects of high pressure crystallization on structural and physical properties of the samples were studied using X-ray diffraction, differential scanning calorimetry, and rheometer. The microstructure was quantified using polarized light microscopy and box-counting fractal dimension. Significant texture and structure changes was observed as pressure levels increases. Results obtained from fractal dimensional analysis were also in agreement with the texture analysis results and provided good correlations with the results. The study demonstrated that high pressure technology can modify fat crystal network and crystallization properties of lipids.

13. ***In vitro* Digestion of Interesterified Stearic Acid-rich Blends: Compositional and Physical Property Investigations During Digestion.** S.H. Thilakarathna[1], M.A. Rogers[1], Y. Lan[2], S. Huynh[1], and A.J. Wright[1], [1]University of Guelph, Canada, [2]Rutgers University, USA.

Interesterification (IE) was found to impact stearic acid (SA) absorption when human volunteers consumed a 70:30 wt% high-oleic sunflower and canola stearin blend (NIE; 23.3% SSS; Tm~67°C) vs. the same blend following chemical (CIE; 0.5% SSS) and enzymatic (EIE; 0.4% SSS) IE (Tm~23-40°C;

Robinson *et al*. *Lipids*, 2009,**44**:17-26). To extend our understanding of why differences occurred, NIE, CIE, and EIE were fed to the TNO TIM-1 simulated digestion model. Lipid digestion, bioaccessibility (i.e. absorption of free FA (fatty acids)), and changes in undigested lipid composition and physical properties were compared. TIM-1 FA absorption was higher with IE ($p<0.05$; EIE:36.2% & CIE:28.6% > NIE:16.6%). Oleic acid bioaccessibility was higher than that of SA for NIE and vice versa for IE blends ($p<0.05$). SA was more concentrated (~87%) in the NIE undigested triacylglycerols (TAG), corresponding to relatively higher Tm of the undigested lipids. The results point to the impact of TAG composition and physical properties on lipid absorption. For practical purposes, TIM-1 lipid absorption for NIE, CIE, and EIE was compared with lipolysis results from a batch gastro-duodenal digestion model. Similar trends were observed between the two methods in a correlation analysis ($r=0.9396$;$p<0.05$).

14. **The Effects of Applesauce and Pectin on the *in vitro* Digestive Stability, Digestibility, and Bioaccessibility of a DHA-rich Algal Oil Emulsion.** X. Lin and A.J. Wright, University of Guelph, Canada.

Lipid digestibility and bioaccessibility (solubilization in the aqueous phase) are impacted by interactions between food and gastrointestinal constituents, including gastric pH which varies with ingested food. This work studied how applesauce and high-methoxyl apple pectin (0.0, 0.28 and 5mg/mL total pectin in digesta), combined with variable gastric pH, affected the *in vitro* digestion of a DHA-rich algal oil lecithin-stabilized emulsion (10:1.2:88.8 oil:lecithin:water, $d_{3,2}$=157.7±5.6nm). Simulated 2h gastric (pH=2, 3 or 4.8) and 2h duodenal (pH=7) digestions were conducted in a 37°C shaking water bath. Both low gastric pH (2 & 3) and addition of applesauce and/or pectin destabilized emulsion before duodenal digestion. Higher gastric pH led to faster initial lipolysis, while the presence of 5mg/mL pectin negated the difference ($p>0.05$). Similarly, the emulsion treated with gastric pH 4.8 had the greatest extent of lipolysis ($p<0.05$) at low pectin concentrations (≤0.28mg/mL), but no differences were observed with 5mg/mL pectin among different gastric pH. DHA bioaccessibility was reduced in the presence of applesauce/pectin ($p<0.05$) with the highest transfer obtained at gastric pH 4.8 (36.3%). Pectin content and gastric pH had interactive impacts on emulsion digestion.

15. **Physical and Oxidative Stability of Fish Oil Nanoemulsions Produced by Spontaneous Emulsification.** R. Walker[1], E.A. Decker[1,2], and D.J. McClements[1,2], [1]University of Massachusetts Amherst, USA, [2]King Abdulaziz University, Saudi Arabia.

Emulsion-based delivery systems offer many potential benefits for incorporating omega-3 oils into foods and beverages. Nanoemulsions are emulsion-based delivery systems that are gaining popularity because of their ease of preparation, small particle size, relatively high stability, high bioavailability, and production of optically transparent emulsions. Fish oil nanoemulsions are particularly susceptible to lipid oxidation because of their high degree of lipid unsaturation, high surface area of exposed lipids, and greater light penetration. In this study, spontaneous emulsification, a low-energy method, was used to fabricate fish oil nanoemulsions. The influence of surfactant-to-oil-ratio (SOR) on particle size, turbidity, and physical stability was evaluated. Furthermore, the oxidative stability of these nanoemulsions was compared to emulsions produced by microfluidization, a high-energy method. The effect of particle size and SOR on oxidation was monitored by lipid hydroperoxides and thiobarbituric acid reactive substances. Optically transparent nanoemulsions were formed and maintained physical stability after being held at 37°C for 14 days. In addition, fish oil nanoemulsions produced by high- and low-energy methods had similar oxidative stability at 55°C for 14 days. These results demonstrate that spontaneous emulsification can produce fish oil nanoemulsion that are both physically and chemically stable for fortification of clear food systems.

16. ***In vitro* Digestibility and ß-carotene Release from Ethylcellulose Oleogels.** C. O'Sullivan[1], M. Davidovich-Pinhas[2], A.J. Wright[1], and A.G. Marangoni[1], [1]University of Guelph, Canada, [2]Technion, Israel.

The lipolysis and release of ß-carotene (BC) from canola oil ethylcellulose (EC) oleogels was investigated using a 3-phase *in-vitro* digestion model, simulating oral, gastric, and duodenal phases. BC was chosen as a model lipophilic molecule and was dissolved in canola oil at 0.1wt% before preparation of the oleogels. Gels were prepared with varying EC concentrations (10-14% w/w) and different polymer molecular weights (28.6, 51.9, and 72.8kDa).

Results showed that although lipolysis of the oleogels was not significantly different compared to liquid oil, the amount of BC released to the aqueous phase was lower in the gelled samples made with higher molecular weight EC. When increasing the molecular weight from 28.6 to 72.8kDa, BC transfer from the gel to the aqueous phase decreased from 32 to 16% after 3 hours of intestinal digestion ($P<0.05$). The decrease in BC transfer was hypothesized to be due to BC interactions with the polymer, reducing BC's ability to transfer to the aqueous phase structures. Investigations are ongoing to characterize the nature of these interactions.

This research illustrates the potential to modulate delivery of lipophilic molecules using EC oleogels.

17. **Effect of *trans, trans* CLA Egg Enrichment from CLA-rich Soy Oil on Yolk Fatty Acid Composition, Viscosity, and Physical Properties.** S. Shinn, A. Proctor, N. Anthony, and A. Gilley, University of Arkansas, USA.

CLA egg accumulation studies using *cis, trans* isomers have been effective, but reported adverse egg quality. *Trans, trans* (*t,t*) CLA isomers have shown superior nutritional effects in rodent studies, but reports of *trans, trans* (*t,t*) CLA-rich yolks are limited. The objectives were to determine the effect of *t,t* CLA-rich soy oil in feed on egg yolk viscosity, and yolk quality during refrigerated storage. Yolk fatty acids, viscosity, weight, index, moisture, pH, and vitelline membrane strength (VMS) were determined at 0, 5, 10, 20 and 30 storage days. CLA had minimal effect on fatty acid profiles, relative to *cis, trans* reports. CLA-rich yolk viscosity was greater than controls, and this feature and VMS were retained during storage. Yolk weight and index were not affected by *t,t* CLA-rich soy oil. CLA eggs maintained their quality throughout storage better than the controls and were of greater quality than reported previously for CLA eggs.

18. **Structuration of Low Saturated Lipid Blends Using Phytosterols.** M.H. Masuchi, B.G. Zaia, A.P.B. Ribeiro, and T.G. Kieckbusch, University of Campinas, Brazil.

Fats and oils intended for food applications are required to present low levels of saturated fatty acids (low sat) and absence of *trans* fatty acids (*zero trans*), constituents associated with cardiovascular diseases. Lipid materials should also display appropriate technological and sensorial characteristics for consumer acceptability. Blends of palm oil and canola oil (50:50, w/w) added with different concentrations of free phytosterols (2, 4, 6, 8 and 10%, w/w) were produced and evaluated in terms of solid fat content (SFC) by nuclear magnetic resonance, microstructure at 25°C by polarized light microscope and consistency at 15, 20 and 25°C by a texture analyzer. The additions of phytosterols at all concentrations induced increases in consistency specially at the lowest temperature (15°C). The differences in crystallization morphology between blends with and without phytosterols were notable, since this structuring agent decreased the crystal diameter and increased the packing density of the fat crystal networks. These results suggest that additions of free phytosterols to low sat lipid materials can improve their structuration ability and increase their applications in the food industry

19. **Organogelation of 12-hydroxystearic Acid and Monoacylglicerides in Mineral Oil and Safflower Oil Free of Polar Lipids.** J.F. Toro-Vázquez, I. Romero-Regalado, M.A. Charó-Alonso, J.A. Morales-Rueda, and F. Alvares-Mitre, Universidad Autónoma de San Luis Potosi, Mexico.

Using mineral oil (MO) or safflower oil free of polar lipids (SFO) as solvent, we investigated the organogelation of (R)-12-hydroxystearic acid (HSA) in blends with a commercial monoglyceride (MSG) using DSC, rheology, and microscopy. We hypothesize that the primary and/or secondary -OH groups of the monoglyceride might interact with the 12-OH of the HSA. This intermolecular interaction might limit the self-assembly of the gelator molecules, or develop HSA-MSG co-assemblies that result in organogels with particular physical properties. The results show that a blend of 2% HSA and 4% MSG, resulted in the development of organogels structured by co-crystals. These organogels showed melting temperature, micro-structure and rheological properties different from those observed by the organogels developed by the individual gelators. In particular, the organogels developed in the MO by the 2% HSA - 4% MSG blend was clearer, with higher elasticity, and structured by smaller crystals than the same organogel developed in SFO. The presence of 2% HSA decreased the temperature of development of the sub-α phase of the MO in both the MO and the SFO system. Evidently, HAS, and MSG developed co-assemblies with stability toward segregation was solvent dependent.

20. **Structuring Emulsions W/O with Palm Hardfat and Soy Lecithin.** V.S. Santos, C.C. Ming, and L.A.G Gonçalves, University of Campinas, Brazil.

Emulsions are widely industrially used, since a large variety of food products are obtained through fat emulsification. The fat crystallization behavior may substantially change when the fat is emulsified. In this context, the aim of this study was to evaluate the effect of palm hardfat (PH) and deoiled soy lecithin (SL) as structuring agents of palm oil (PO) based emulsions. Were prepared water-in-oil (W/O) emulsions comprising 20% of aqueous phase and 80% of oil phase (w/w). The alone and along effect of the structuring agents was studied, in proportions of 1% SL, 3 and 5% of PH. The emulsions were static crystallized at 5°C during 24h, followed by 24h at 25°C (analysis temperature), finally the hardness parameter was evaluated by texture analysis (compression/extrusion). When 3 and 5% of PH were used alone, resulted in harder emulsions (288.55±18.62gf and 579.76±11.89gf, respectively) than when SL and PH were used along (138.75±29.71gf and 387.36±89.50gf, respectively). This fact suggest that the PH form more compact networks crystals and the presence of SL change the interaction between crystals, forming crystals networks with greater elasticity, resulting in softer emulsions. Lastly, PH and SL were efficient structuring agents and texture modifiers in PO based emulsions.

21. **The Unsaturation Extent and Chain Length Effect of the Constituents Fatty Acids of Phosphatidylcholine in the Thermo-mechanical Properties of Edible Organogels.** J.F. Toro-Vázquez, M. Martinez-Avila, J.A. Morales-Rueda, F.M. Alveres-Mitre, and M.A. Charó-Alonso, Universidad Autonoma de San Luis Potosi, Mexico.

The phosphatidylcholine (PC), commonly known as lecithin, is widely used as emulsifier in the food, pharmaceutical, and cosmetic industry. Due to its amphipathic properties, in an apolar environment (i.e., vegetable oil) the PC develops inverse self-assembled structures that in the presence of a low amount of polar molecules and specific time-temperature conditions develop wormlike structures. These structures entangle forming a three-dimensional organization that entraps the solvent developing systems with viscoelastic properties. In this investigation we studied the thermo-mechanical properties of organogels developed by PC in high oleic safflower oil (HOSFO). We used different PC varying in the unsaturation extent and chain length of fatty acids: L-a-phosphatidylcholine (composed by palmitic and linoleic acids), hydrogenated L-a-phosphatidylcholine (composed by palmitic and stearic acids), 1, 2-dipalmitoyl-*sn*-glycero-3-phosphocholine, and 1,2-dilinoleoyl-*sn*-glycero-3-phosphocholine. After heating PC solutions in HOSFO for 30min at 150°C the cooling DSC thermogram and rheogram (*G'* and *G"*) was determined until achieving 15°C. From the rheograms we calculate the structure development rate as d(*G'*)/d(time during cooling).

22. **Novel Approaches to Maximize Gelator Efficiency in Ethylcellulose Oleogels.** R. Nicholson, A.J. Gravelle, S. Barbut, and A.G. Marangoni, University of Guelph, Canada.

Ethylcellulose (EC) is the only food-grade polymer known to date that is able to gel triglyceride oils. These oleogels find applications as fat mimetics used to decrease saturated and *trans* fats, as petrolatum replacers, and as heat resistance enhancers in chocolate. However, a relatively high concentration of polymer must be used in order to produce stable oleogels, in the range 7-11%. The goal of the current research is to decrease EC critical gelation concentration (CGC) by addition of specific additives and the use of shear and/or cooling rate. Addition of free oleic acid to oil-EC melts at concentrations = 0.4% resulted in a significant increase in mechanical strength upon gel setting. Gentle mixing during cooling and prior to gelation was also found to increase gel hardness upon gel setting. Lastly, reheating the gels to 100°C following gelation also produced firmer gels. Using the above strategies, we have been able to reduce the CGC of EC in canola oil from 6% to as low as 2%. This work has the potential to expand the use of EC oleogels in food applications, and will help develop a further understanding of the mechanisms responsible for the observed effects.

23. **Biophysical Aspects of Lipid Digestion in Human Breast Milk and Similac™ Infant Formulas.** F. AlHasawi[1] and M.A. Rogers*[2], [1]Rutgers University, USA, [2]University of Guelph, Canada.

Physico-chemical properties of human breast milk were compared to four types of Similac™ infant formulas, and correlated with *in vitro* free fatty acid bioaccessibility using TIM-1. Viscoelastic measurements, as a function of pH (pH 6.5 to 3.0) and shear, showed lower viscosities in human breast milk. Droplet size and distribution measurements

showed distinct differences between the tested infant milk products. A lag period was present explicitly in the bioaccessible free fatty acid release profile of human breast milk, supported by a longer calculated induction time when a model for lipolytic generation of free fatty acids as a function of time was fitted into the free fatty acid release profile trends. Also, rate of lipolysis was found to be higher in human breast milk compared to Similac™ infant formulas. A strong positive correlation was found between rate of lipolysis and droplet surface area per gram, explicitly for the Similac™ infant formulas. However, human breast milk did not follow that trend, suggesting the involvement of possibly other factors in rate of lipolysis in human breast milk.

24. **Modification of Physical Properties of Palm-based Diacylglycerol Oil.** C.P. Tan[1], S.P. Ng[1], and I.A. Nehdi[2], [1]Universiti Putra Malaysia, Malaysia, [2]King Saud University, Saudi Arabia.

The present study resolves the solidification problem and improves the pourability, flow behavior, texture and thermal behavior of palm-based diacylglycerol (DAG) oil by adding emulsifiers and/or crystallization inhibitor to the palm-based DAG oil. The palm-based DAG oil includes palm kernel oil-based DAG, palm oil-based DAG, palm olein-based DAG, palm mid fraction-based DAG, and palm stearin-based DAG. The emulsifier and/or crystallization inhibitor comprises sucrose esters of fatty acids, polyglycerol esters of fatty acids, sorbitan esters of fatty acids, polyoxyethylene sorbitan esters (polysorbates), mono and diglycerides of fatty acids, lecithin and polyglycerol polyricinoleate. The modified palm-based DAG oil of the present study was comprised of 80wt.% or more DAG and 0.005% to 5.0wt.% emulsifier and/or crystallization inhibitor. The modification of palm-based DAG oil with emulsifiers and/or crystallization inhibitor offered greater functionality. The process to modify the physical properties and flow behavior of palm-based DAG oil is useful for a variety of food system preparations in either water in oil (W/O) or oil in water (O/W) type emulsions.

25. **Modeling Oil Diffusion Process in Fat Crystal Network.** H. Wang and F. Maleky, Ohio State University, USA.

Abstract pending.

26. **Study and Control of Added Synthetic Antioxidants in the Kinds of Vegetable Oils.** L. Rashidi[1], Z. Gholami[2] and Zh. Shabani[3], [1]Standard Research Institute, Iran, [2]Tarbiat Modares University, Iran, [3] Islamic Azad University Iran.

A simple, rapid and accurate analytical method was applied for determination of the used synthetic phenolic antioxidants (SPAs) in the vegetable oils including propyl gallate (PG), tertiary butyl hydroquinone (TBHQ), butylated hydroxyl anisole (BHA), and butylated hydroxyl toluene (BHT). For this purpose, HPLC using the gradient method was applied. Under the recommended conditions, separation of the four SPAs was achieved in the less than 14 min. In this method, the SPAs were extracted by the mixture solvents of methanol/acetonitrile (1:1, v/v) and then subjected to the vortex/ultrasonic treatment. The extracts were next kept in a freezer (-20 ºC) for 2 h to precipitate the co-extracted components in the mixture. The upper layer injected to HPLC. Recovery percent of the each of SPAs were obtained in the ranges 100, 38% for PG, 96.13% for TBHQ, 81.3% for BHA and 70% for BHT. The method was applied to the evaluation of SPAs in the 60 samples of vegetable oils. Moreover, the correlation between the used synthetic antioxidants in the oils with oxidative stability and peroxide value was investigated. Results showed that the oxidative stability was directly related with the amount of used SPAs and indirectly with peroxide value in the oil samples.

27. **The Development of a Choline Rich Cereal Based Functional Food Incorporating Egg Lecithin.** J. Asomaning, E.D. Lewis, J. Wu, R.L. Jacobs, C.J. Field, and J.M. Curtis*, University of Alberta, Canada.

Recent studies have shown that dietary choline intakes often fall short of the daily recommended intake[1]. The aims of this research were to develop a choline rich cereal based functional food through extrusion, and to study the effects of processing and storage on the stability and retention of choline. Egg yolk lipids were extracted using ethanol to produce an egg yolk extract (EYE) of high choline content. The extruded product contained corn meal, wheat flour, sugar, salt and EYE and was made using a twin-screw extruder with an exit temperature of 120°C. Products were packaged and stored at -20°C and room temperature for 12 weeks. Initial processing decreased the total fat and total choline content by up to 40% and 30% respectively. However, both the total fat and choline content did not significantly

change during the stability study. The cereal product had a choline content of 114mg per 35g serving, equivalent to the choline content of a medium sized egg. A shelf-stable EYE containing functional food product would provide an alternative way for consumers to meet their adequate intake of choline.

[1] Lewis et al. British Journal of Nutrition, **112(1),** 112-121 (2014)

28. **Effect of High Intensity Ultrasound (HIU) on the Crystallization Behavior of Interesterified and Physical Blends of High Oleic Sunflower Oil (HOSO) and Tripalmitin.** J. Kadamne[1], E.A. Ifeduba[2], C.C. Akoh[2], and S. Martini[1], [1]Utah State University, USA, [2]University of Georgia, USA.

Physical (PB) and interesterified (IB) blends of high oleic sunflower oil and tripalmitin with 20% and 30% of C16:0 were crystallized with and without the application of high intensity ultrasound (HIU) at supercooling values of 3, 6, and 9°C. Melting points of IB and PB with 20% of C16:0 were 16.1 ± 0.7°C and 48.8 ± 1.2°C and with 30% of C16:0 were 28.0 ± 0.3°C and 55.7 ± 0.7°C, respectively. Viscoelasticity, solid fat content (SFC), melting behavior, and crystal morphology were measured after 60min of crystallization. In general, viscosity and G' values were higher for IB compared to PB with 20% C16:0 at all supercoolings. Viscosity and G' values of 20% IB were 286.9 ± 44.1Pa.s and 23060 ± 1310Pa, respectively and for PB were 14.7 ± 0.7Pa.s and 289.7 ± 71.7Pa.s respectively at 9°C supercooling. Application of HIU significantly increased viscosity and G' values of all samples. On the contrary, viscoelastic properties of 30% IB were in general lower than PB. However, HIU increased viscosity and G' values of 30% IB to levels above those obtained for PB. In general, SFC data showed an induction in crystallization for samples with higher G', especially for 30% IB at low supercoolings. PLM data shows that at same supercooling, PB form larger crystals than IB and that HIU induced the formation of smaller crystals in IB and PB samples.

29. **Rheology and Phase Behavior of Binary Wax Blends in Soybean Oil.** S. Jana and S. Martini, Utah State University, USA.

The objective of this study is to analyze rheology parameters of 2.5% binary wax systems consisting of beeswax (BW), rice bran wax (RBW) and sunflower wax (SFW) in soybean oil (SBO) and evaluate the melting behavior and microstructure using differential scanning calorimeter (DSC) and microscopy, respectively. Viscoelastic parameters (G', G'') analyzed in SBO at 2.5% of pure waxes shows that RBW has higher G' value (31360.0± 973.3Pa) followed by SFW (26702.5± 2177.2Pa) and BW having the lowest (90.7±74.4Pa). Addition of BW in SFW at 80% concentration increased G' and G'' values but BW addition in RBW decreased those values at all concentrations tested. G' and G'' values showed an increasing trend in RBW/SFW systems as SFW content increases obtaining higher G' and G'' values than the pure components. Enthalpy values of RBW/BW decreased from 4.25± 0.0 (pure RBW) to 1.1±0.1 (pure BW). The addition of 80% BW to SFW increased the enthalpy of the system from 2.6±0.0J/g (pure SFW) to 3.5±0.1J/g (mixture). Enthalpy values showed a decreasing trend in RBW/SFW mixtures as SFW concentration increased. Changes observed in G' can be attributed to changes in enthalpy values and changes observed in crystal morphology.

30. **The Influence of Functional Ingredients on Margarines and Spreads Application Properties.** K. Bhattacharya, P.G. Kirkeby, B. Sehested, and R.A. Trinderup, DuPont Nutrition Biosciences ApS, Denmark.

Margarine and spreads are characterized as crystallized water-in-oil emulsions. Consisting of approximately 80-15% fat, the quality of emulsion depends on the composition of the fat phase as it impacts the texture of the final product by providing specific structural and sensory properties. However, the processing conditions and the use of functional ingredients in the fat phase and water phase, such as emulsifiers, hydrocolloids and antioxidants, also play important roles in achieving a defined quality of the final emulsion. Depending on the nature of emulsifiers and fat blend, the emulsion can be used for applications such as spreading, baking, lamination, shallow frying etc. When liquid oils are used to replace *trans* and saturated fats, there is often a loss of structural integrity of the emulsion or food matrix, resulting in reduction of texture and oiling-out issues. Structuring emulsifiers can be used to impact fat crystallization providing an improved fat crystal network which prevents oiling out and contribute to overall emulsion stability. Our present work at DuPont Nutrition & Health covers details on the formulation of various margarines along with evaluation information on final products and analyses covering Soild Fat Content (SFC), surface imaging, water droplet distribution, and Confocal laser imaging.

31. **Physical Characteristics of Peanut Butter Influenced by Fully Hydrogenated Flixweed Oil *Descurainia sophia* (L.) as a Stabilizer.** L. Ahmadi, X. Gao, and J. Vandermey, Brescia University College at Western University, Canada.

Flixweed is an abundant weed grown in Canada's Prairie Province. The functional benefits provided by flixweed oil candidate it as an alternative to current commercial stabilizers. The average oil percentage of the seed samples was 40.4%, a relatively high oil content. The extracted flixweed oil was fully hydrogenated (FHFO) and was added to lab made peanut butter in quantities of 1%, 1.5%, and 2% by weight of product. A sample containing 1.5% commercial stabilizer (w/w) and a blank containing no stabilizer were prepared as well. Each of these was stored at 4, 21, and 40°C, and tested at 1, 6, 12, and 18 weeks for oil separation test and texture characteristics including hardness, adhesiveness, cohesiveness, and gumminess. FHFO improved the oil holding capacity of peanut butter at 1%, 1.5% and 2% (w/w). Peanut butter containing FHFO at a quantity of 2% (w/w) showed the least oil separation and had comparable or less oil separation than the 1.5% commercial stabilizer sample. Other physical properties such as hardness, adhesiveness, cohesiveness, and gumminess were comparable between these two samples as well. The fatty acid profiles of commercial stabilizer and FHFO have been shown to be very similar.

32. **Maillard Reaction Products as Encapsulating Agents for Functional Lipid Palm-based Medium– and Long-chain Triacylglycerol.** Y.Y. Lee, T.K. Tang, C.P. Tan, N.B.M. Alitheen, and O.M. Lai*, Universiti Putra Malaysia, Malaysia.

Maillard reaction products (MRP), which can acquire anti-oxidant property besides creating smaller and stable emulsion was utilized as encapsulation agent to enhance the microencapsulation efficiency (ME) of structured lipid palm-based medium-and long-chain triacylglycerol (MLCT). MRP was produced by heat treatment of solution containing maltodextrin (M): sodium caseinate (SC): soy protein (SP) and was emulsified with MLCT before spray drying. The effect of temperature (20°C, 40°C, 60°C, 80°C, 100°C), time (2hr, 4hr, 8hr), mixture of M:SC:SP (1:0:1, 1:2:3, 1:1:2, 1:2:3, 0:1:1) and carbohydrate +protein: water ratio (1:5 and 1:8) on degree of glycation (Dg) was investigated. Dg was determined via amount of block amino acid. When heat treatment and incubation time increased, ($P<0.05$) the Dg increased too. Dg was also higher ($P<0.05$) at high water to solid content. Different M:SC:SP blends have different Dg with 0:1:1 ratio being the lowest. Glycation can also reduce the emulsion size besides lowering moisture and surface oil content of the spraydried powder. MRP can act as natural emulsifier besides conferring certain beneficial properties on MLCT powder.

33. **Development of Functional Beverages from Blends of *Hibiscus sabdariffa* Extract and Selected Fruit Juices for Optimal Antioxidant Properties.** O.M. Ogundele[1], O.O. Awolu[1], A.A. Badejo[1], T.N. Fagbemi*[1,2], and I.D. Nwachukwu[2], [1]Federal University of Technology, Nigeria, [2]University of Manitoba, Canada.

The demand for functional foods and drinks with health benefit is on the increase. The synergistic effect from mixing two or more of such drinks cannot be overemphasized. This study was carried out to formulate and investigate the effects of blends of two or more of pineapple, orange juices, carrot and *Hibiscus sabdariffa* extracts (HSE) on the antioxidant properties of the juice formulations in order to obtain a combination with optimal antioxidant properties.

Experimental design was carried out using optimal mixture model of response surface methodology which generated twenty experimental runs with antioxidant properties as the responses. The DPPH (1,1-diphenyl–2 picrylhydrazyl) and ABTS [2,2'-azino-bis(3- ethylbenzothiazoline-6-sulphonic acid)] radical scavenging abilities, Ferric Reducing Antioxidant Potential (FRAP), vitamin C, total phenolics, and total carotenoids contents of the formulations were evaluated as a test of antioxidant property. In all the mixtures, formulations having HSE as part of the mixture showed the highest antioxidant potential. The statistical analyses showed that formulations containing pineapple, carrot, orange and HSE of 40.00, 16.49, 17.20 and 26.30% respectively produced optimum antioxidant potential and was validated to be acceptable by consumers, making them viable ingredients for the production of functional beverages possessing important antioxidant properties with potential health benefits.

34. **Effect of the Stearic Sucrose Ester S-170 on Physical Properties of High Stearic High Oleic Sunflower Oil Stearins.** J.A. Rincon-Cardona[1,2], R.J. Candal[2], and M.L. Herrera[1], [1]Instituto de Tecnologia en Polimeros y Nanotecnologia, Argentina, [2]Instituto de Investigacion e Ingenieria Ambiental, Argentina.

The effect of the stearic sucrose ester (SE) S-170 on crystallization behavior and polymorphism of two stearins obtained from a new variety of high stearic high oleic sunflower oil was studied by pulsed nuclear magnetic resonance, X-ray scattering using synchrotron light and differential scanning calorimetry. There was always a crystallization temperature below which SE S-170 accelerated crystallization and above which SE S-170 delayed nucleation and growth. SE S-170 was efficient as a seed for high supercooling (low crystallization temperatures) but this efficiency diminished at low supercooling (temperatures close to the melting point) when few crystals were formed. Depending on crystallization temperature, SE S-170 promoted crystallization of forms with more polymorphic similarity and inhibited occurrence of ß' forms with unit cells significantly different. SE S-170 significantly diminished total melting enthalpies when the effect was a delay in crystallization. With addition of SE S-170 polymorphic forms $ß'_1$ and $ß_2$ may be obtained as the main form. This is very relevant from the technological point of view. Depending on the application, SE S-170 may help obtain the required polymorphic form: $ß'_1$ form for spreads and $ß_2$ polymorph for chocolate production.

35. **Cocoa Butter Alternative from Rice Bran Oil by Enzymatic Acidolysis.** P. Kosiyanant[2], G. Pande[1], W. Tungjaroenchai[2], and C.C. Akoh[1], [1]University of Georgia, USA, [2]King Mongut's Institute of Technology, Thailand.

The aim of the experiment was to add value to rice bran oil (RBO) by using Lipozyme RMIM lipase to produce cocoa butter alternative (CBA). CBA was synthesized using RBO, palm olein (PO), and stearic acid (SA) as substrates. The optimal condition for the reaction were: RBO:PO:SA of 1:2:6, temperature 65°C, reaction time 12h, and Lipozyme RMIM lipase (10%) with agitation at 200rpm. Physical blends (PB) of CBA with cocoa butter (CB) were prepared at 5 different ratios. Results showed that CBA contained higher stearic acid than CB. Oleic acid was the major fatty acid at the *sn*-2 position of CBA but lower than CB. The triacylglycerol (TAG) molecular species of CBA were a little different from CB and contained in addition PLS, SLS, and PLP. The level of saturated fatty acids affected the melting thermogram. The PB at 70:30 CBA: CB, its fatty acid profile, and the main TAG species were similar and the thermal behavior was close to CB. Therefore, enzymatically prepared CBA from RBO could be used as a replacer by blending the CBA with CB at 70:30.

36. **CLA-rich Soy Oil Shortening Production and Characterization.** S.E. Mayfield[1], A. Patel[2], A. Proctor[1], K. Dewettinck[2], and D. Van de Walle[2], [1]University of Arkansas, USA, [2]University of Gent, Belgium.

Conjugated linoleic acid-rich soy oil (CLARSO) has numerous health benefits, including serum cholesterol lowering properties. This oil has been used to produce CLA-rich margarine that provided the recommended daily value of CLA and showed physical characteristics similar to commercially available margarine. The objective of this study was to produce CLA-rich shortening and analyze its physical properties relative to those of commercially available and soy oil control shortenings. CLARSO and soy oil shortenings were prepared with 60-80% oil. The complex modulus G' was measured as a function of strain; the solid fat content and DSC behavior were each determined in triplicate. As the oil level increased, the G' values decreased, and the 60-65% CLARSO shortenings were not significantly different from the partially hydrogenated oil (PHO) shortening. The 60-65% CLARSO shortenings had significantly lower SFC values than did PHO, despite having similar rheology. There was no significant difference in SFC between CLARSO and corresponding soy oil controls. Greater enthalpy was observed upon crystallization of CLARSO samples relative to soy oil, indicating CLARSO produced a more stable crystal structure. In general, CLARSO samples had similar properties to PHO despite having a much lower SFC and may therefore serve as a PHO replacer.

37. **Cyanogenic Glycosides and Secoisolariciresinol Diglucoside in Flaxseed Meal Fortified Gluten-free Bread.** R. Boonen[1,2], J. Liu[3], Y.Y. Shim[1,3], C.M. Olivia*[1], and M.J.T. Reaney[1,3,4], [1]Prairie Tide Chemicals Inc., Canada, [2]Wageningen University, The Netherlands, [3]University of Saskatchewan, Canada, [4]Jinan University, China.

Flaxseed (*Linum usitatissimum* L.) meal, the co-product of flaxseed oil industry, has been associated with many potential health benefits. This study investigated the utility of flaxseed meal as an ingredient in gluten-free (GF) bread. Flaxseed meal

(0, 10, and 20%, w/w) was included in GF-Bread dough. The concentration of flaxseed metabolites, secoisolariciresinol diglucoside (SDG) and cyanogenic glycosides (CG) were determined in the fortified flour, dough, and bread during storage (0, 1, 2, and 4 weeks) at various temperatures (-18, -4, and 20°C). SDG content was stable within the storage times tested and not affected by the storage temperature. However, the CGs, including the mono-glycosides of linamarin and lotaustralin and the diglycosides of linustatin and neolinustatin, were not detected in the flaxseed meal fortified dough and the baked GF-bread by ^{1}H-NMR. The content of linamarin and/or linustatin was the highest in both flaxseed meal and flaxseed flour and the CG content decreased over time in flaxseed dough and bread but not in flaxseed meal fortified flour. This study indicated the health-promoting compound (SDG) survives the baking steps, while the CG were degraded.

38. **Structural Impact of Butter in Puff Pastry.** D.J.E. Kalnin[1], S. Breau[1,2], P. Saguez[1], F. Sobolewski[1]; [1]PHILOLAO, France, [2]ENILIA, France.

In France, the majority of butter production is used in industrial bakery and biscuit pastry production. The largest volumes are consumed to produce puff pastry where the butter moiety is up to 30% of the product. Butter as a functional ingredient, must meet specific texture and hence structural requirements.

As of today measurement tools such as texture analysis is sufficient for sorting butters to allow their use on a production lines, but this is only one aspect of functionality that is taken into account. The purpose of this study is to understand the functionality of butter through assessment of the crystalline stat combined with the SFC content measured in standard conditions supplemented by optical microscopy and differential scanning calorimetry.

The combination of analytical techniques used in this study together with the French butter making industry to date allows not only to understand the density of crystal network installed in the butter but also to determine a profile of crystal sizes crystal forms as well as SFC. Previous studies have shown the relationship between the crystal size and the ability of butter to perform as a functional ingredient in puff pastry. We were able to identify critical factors for the fabrication of puff pastry in standard conditions to establish the structure functionality relationship between the butter and its performance in puff pastry.