

## EAT 1: Lipid Gels

*Chairs: Ashok Patel, International Iberian Nanotechnology Laboratory, Portugal; and Arjen Bot, Unilever R&D Vlaardingen, The Netherlands*

### **Ethylcellulose and Stearyl Alcohol: Stearic Acid (EC/SO:SA) Mixed Oleogels: Characterizing the Influence of EC as a Function of SO:SA Ratio**

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In a recent study, we reported on the influence of ethylcellulose (EC; 6 wt%) on the crystallization behavior of a 7:3 mixture of stearyl alcohol and stearic acid (SO:SA; 5 wt%) in vegetable oil. However, both the types of crystals present (pure or mixed) and the microstructure are dictated by the SO:SA ratio. Therefore, the goal of the present work was to characterize the effect of EC on the mixed EC/SO:SA gelator system across the entire range of SO:SA ratios. Wide-angle X-ray diffraction patterns of the SO:SA gels were not affected by the addition of EC, indicating the polymorphism of the SO:SA crystals were not altered by the presence of EC. Additionally, the intensity of SAXS peaks were greatly diminished, suggesting that for all SO:SA ratios, the presence of EC alters the spatial organization of the crystallites. The peak and onset melting temperatures of the mixed system were also statistically equivalent to that of the pure SO:SA formulations, with the only exception being the 10:0 formulation. Light micrographs showed that EC altered the organization of the crystal network in all formulations, producing thin, arched clusters of needle-like crystals. Finally, the total solid fat content (SFC) at temperatures below 30°C increased in the mixed gels, particularly for those having a greater stearic acid content (3:7 and above). Gel strength was generally higher for the mixed gels, particularly for those containing pure crystals. This impact was associated with the

observed increase in SFC, as well as the changes to the spatial arrangement of the crystal network.

### **Organogelation Under Different Shearing and Cooling Rate Conditions of Selected Gelators**

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Self-assembly of low molecular mass organic molecules (LMOGs) in an organic solvent result in the development of one-dimensional structures that interact further at junction zones to make three-dimensional networks. This 3D-network physically traps the solvent resulting in a system with viscoelastic and thermoreversible properties. In the present study, we investigated the combined effect of shearing and cooling rate, in the rheological properties of organogels (2% in safflower oil) using as LMOGs (R)-12-hydroxystearic acid (HSA), and primary (R)-12-hydroxyoctadecanamide; HOA) and secondary (R)-N-octadecyl-12-hydroxyoctadecanamide; OHOA) amides derived from HSA. Shearing was applied during cooling, just until achieving the melting temperature ( $T_M$ ), and then continuing cooling under static conditions until attaining 15°C. Four cooling rate protocols, constant cooling rates of 1°C/min (CR1) or 10°C/min (CR10) in the shearing and static stages, and variable cooling rates for the shearing and static stages (VR1-10 and VR10-1). These results show that for a given LMOG solution, the use of different cooling rates above and below  $T_M$ , has effect on the microstructure and organogels' rheology. Under static conditions, the cooling rate applied below  $T_M$  determines the fiber diameter and the extent of fiber branching. The

shear rate effect depended on the cooling rate applied, the relative polarity and the molecular weight of the LMOG. We concluded that the relaxation time of the molecules as cooling proceeds plays an important role on the LMOG susceptibility to shear induced crystallization.

**Controlled-release Microemulsion: A Novel Organogel** Mehdi Nouraei\*, and Edgar Acosta, *University of Toronto, Canada*

Organogels made with low molecular-weight gelators (LMWG) are soft materials that can be used as prolonged-release delivery systems for lipophilic actives. Previous work on organogel delivery systems shows this prolonged delivery has been controlled by the diffusion through the gel network, and is dependent on the oil/water partition coefficient of the active. Although a partition-controlled delivery is useful in some applications, the ideal scenario for gel-type delivery system is when the released is controlled by the rate of erosion of the gel. To introduce this characteristic into an organogel system, we hypothesize that introducing a self-micro emulsifying delivery system (SMEDS) in the organogel system could produce the erosion-controlled effect. SMEDS are mixtures of surfactants, oil, and lipophilic actives that upon contact with water form oil-swollen micelles (Type I microemulsions) spontaneously. To this end, we gelled lecithin-linker SMEDS with  $\beta$ -sitosterol and  $\gamma$ -oryzanol used as gelators dissolved in hot SMEDS. Upon cooling, the liquid SMEDS forms an organogel. The organogel firmness, melting point, storage modulus ( $G'$ ) increased with increasing the mixed gelator concentration. Upon exposure to an aqueous phase and mild agitation, the gelled SMEDS undergoes a self-eroding process in which SMEDS slowly microemulsifies leaving the gelator network structure behind. Ibuprofen was used as a model ingredient to study in-vitro release kinetics

of the gels. This method allows to extend the other-wise immediate microemulsion of SMEDS into a process that can last in the order of hours to weeks, depending on the configuration of the delivery system.

**To Gel or Not to Gel—Lessons Learned in Predicting Gelation of Oils** Michael Rogers\* and Andrew Singh, *University of Guelph, Canada*

Rational design of small molecular gelators is an elusive and herculean task, despite the rapidly growing body of literature devoted to such gels over the past decade. The process of self-assembly, in molecular gels, is intricate and must balance parameters influencing solubility and those contrasting forces that govern epitaxial growth into axially symmetric elongated aggregates. Although the gelator-gelator interactions are of paramount importance in understanding gelation, the solvent-gelator specific (i.e., H-bonding) and nonspecific (dipole-dipole, dipole-induced and instantaneous dipole induced forces) intermolecular interactions are equally important. Solvent properties mediate the self-assembly of molecular gelators into their self-assembled fibrillar networks. Herein, solubility parameters of solvents, ranging from partition coefficients ( $\log P$ ), to Henry's law constants (HLC), to solvatochromic  $E_T(30)$  parameters, and Kamlet-Taft parameters ( $\beta$ ,  $\alpha$ , and  $\pi$ ), and to Hansen solubility parameters ( $\rho$ ,  $d$ ,  $h$ ), are correlated with the gelation ability of numerous classes of molecular gelators.

**Oleocolloids Matrices Designed for Food Systems** Clifford Park\*<sup>1</sup>, Rafael Jimenez-Flores<sup>1</sup>, and Farnaz Maleky<sup>2</sup>, <sup>1</sup>*The Ohio State University, USA*; <sup>2</sup>*Ohio State University, USA*

Traditional studies in oleogels (a form of oleocolloid) have had a focus on substitution of saturated fats for unsaturated oils to generate textures similar to foods rich in saturated fats.

However, texture development of oleocolloids containing proteins and oils is poorly understood. This work responds to the challenge of understanding effects of proteins and oil combinations in an oleocolloid system. We developed a new processing technology to structure protein and vegetable oils and studied the systems' physical stability and rheological properties over time. Oleocolloids with a range of functionality were structured by combining different concentrations of animal or plant proteins, water, and different emulsifiers and processing under different heating, cooling, and mixing conditions. Samples' physical stability was examined by monitoring both oil and water loss and a better stability was shown for the oleocolloid matrices made of whey protein, compared to those of soy and pea proteins. Interestingly, the addition of emulsifier helped the systems' water retention, but resulted in a higher oil loss in these samples. To assess rheological properties, a strain sweep test was performed and storage moduli were measured. It was also showed that oleocolloids made with whey protein exhibited the greatest degree of elasticity with a higher storage moduli compared to the networks made with plant proteins. These results clearly document the importance of oleocolloid chemistry for dictating the relevant parameters on their functionality. However, further analysis on thermal properties, solid fat content, and microstructure is required for the successful development of oleocolloid matrices.

**Next Generation Multifunctional Oil Structuring Agents for Trans Fat Alternatives—A Nanotechnology Enabled Platform** George John\*,  
*The City College of New York, USA*

Promotion of public health by delivering healthy food is a subject of research with national importance. Vegetable oils are frequently

structured to enhance their organoleptic and mechanical properties. The crystalline composition of oil-based formulations greatly impacts the optical and textural properties of gel and cream formulations. By modifying the viscosity and rheology with renewable raw materials, a variety of liquid oils may be structured into fats. The present research aims at utilizing the self-assembly concept of nanotechnology to develop a healthy and amphiphilic oil-structuring agent (trans fat alternatives). By conjugating active substrates to develop an array of molecular gelators they serve as programmed functional materials derived from biomass. Chosen precursors for oil gelling amphiphiles (medium chain fatty acids and non-reducing sugars) are FDA approved and GRAS materials; hence the amphiphiles are non-toxic and exhibited high cell viability at concentration  $\sim 50$   $\mu\text{g}/\text{mL}$ . Sugar-based gelators readily formed nanoscale lamellar structures to form a coherent network at very low concentrations (1-3% wt/v), which entrapped and immobilized wide range of lipophilic oils. The efficiency was computed in terms of mechanical, thermal and structural properties and found to be a function of type and concentration of structuring agents. By developing structuring alternatives to chemically processed oil formulations of the future will not only be sustainable, but tailored by structure to function as needed.

**Engineering Oleogel Structure for an Effective Protection of Retinyl Palmitate Activity** Yixing Tian\* and Nuria C. Acevedo, *Iowa State University, USA*

Retinyl palmitate (RP) [all-trans] photostability was analyzed in 10% w/w policosanol oleogels (PCO) prepared at different cooling rates (0.5, 5 and 20°C/min) in order to analyze the effect of matrix structure on its ability to protect RP activity. RP was incorporated in 0.04%, 0.1% and 1% w/w

concentrations. PCO rheological properties were studied by oscillatory stress sweep tests. Low resolution NMR was used to study matrix mobility. All-trans RP content was analyzed by NP-HPLC after 0.5, 1, 2, 3, and 4 days of UVA (365 nm) irradiation. RP stability was significantly higher in PCO upon irradiation when compared with that in liquid soybean oil. Furthermore, cooling rate processing played a significant role in RP protection; the faster the cooling rate, the higher the RP photostability. PCO blocked energy absorption from UVA and further dampened the UVA mediated ionic photodissociation and free radical reaction due to matrix immobilization. This protection was more significant at high cooling rates due to the large number of small crystals formed in the network, which was confirmed by PLM. The rheology results showed that complex moduli  $G^*$  and yield stress  $\sigma^*$  increased with increasing cooling rate, which correlated well with the increase in RP stability. Fast cooling rates translated into less mobile matrices (low T2 values) showing high oil binding capacity. The results of this work suggest that it would be possible to engineer the structural properties of PCO with cooling rate processing in order to effectively protect and potentially deliver bioactive components.

#### **Rheology-structure Relationships in Bakery Fats**

Alejandro G. Marangoni\* and Braulio A. Macias Rodriguez, *University of Guelph, Canada*

The functionality of bakery fats was assessed in terms of their rheological behavior. We consider the special case of laminating shortening, high-trans-saturated fats, and compare it to all-purpose and cake shortenings. Using large amplitude oscillatory rheology (LAOS), we obtained elastic and viscous nonlinear rheological “fingerprints” relevant to material performance. We found that laminating shortening experienced, slightly less softening and dramatically less shear thinning than

all-purpose and cake shortening, suggesting increased plastic deformation and energy dissipation in the former. Structural characterization using Ultra-Small Angle X-ray Scattering and Scanning Electron Microscopy revealed the presence of three hierarchy levels and layered microstructures in laminating shortening in contrast to only two hierarchies and random microstructures in all-purpose or cake shortenings. We suggest that the increased resistance to flow, as shown by rheology, imparted by the structural features of laminating shortening contribute to their ability to retain shape and delay fracture during lamination/layering processes. We also found that in achieving laminating functionality, the exact molecular composition for the macroscopic behavior do not matter as long as the nonlinear rheological fingerprint is matched.

#### **Physical Properties of Beeswax, Sunflower Wax, and Candelilla Wax Mixtures and Organogels** Jill Moser\*, and Hong-Sik Hwang, *USDA, ARS, NCAUR, USA*

There is increased interest in natural waxes as alternatives to partially hydrogenated oils and saturated fats as oil structuring agents. Using relatively low concentrations (0.5-5%), natural waxes are able to form crystalline networks, or organogels, which bind liquid oil. Each natural wax is uniquely composed of long-chain hydrocarbons, long chain fatty acid alcohol esters, long chain alcohols, or mixtures of these and other components in various proportions. The composition and purity of each wax type plays a role in determining the physical properties of organogels, such as the level of wax needed to bind oil, the melting and crystallization properties, and the firmness and rheological properties. The melting and crystallization properties of binary mixtures of beeswax, sunflower wax, and candelilla wax were investigated, along with the physical

properties of organogels made with the wax mixtures. Each wax combination had unique thermal properties, but beeswax: candelilla wax mixtures were most interesting because the melting point of mixtures ranging from (w:w) 20:80 to 90:10 beeswax: candelilla wax was lower than either pure component (63.7°C and 64.9°C, respectively). Organogels made with

beeswax:candelilla wax at several ratios also had lower melting and crystallization temperatures and higher firmness compared to the pure wax organogels. These results have future implications for designing organogels using combinations of materials to achieve desirable physical properties that can be modified for different applications.

## EAT 1.1: Phase Transition in Edible Applications

*Chairs: Farnaz Maleky, Ohio State University, USA; and Musfirah Zulkurnain, Ohio State University, USA*

### **Characterization of the Polymorphism of Milk Fat within Processed Cheese Products** Pere R. Ramel\* and Alejandro G. Marangoni, *University of Guelph, Canada*

Using differential scanning calorimetry (DSC) and x-ray diffraction (XRD), we demonstrate that the polymorphism of milk fat within processed cheese can be fully characterized. The similarities found in the diffraction patterns of similar products from various brands and the disappearance of the diffraction peak corresponding to the  $\beta$  polymorph after the thermal treatment of processed cheese products indicate that XRD can be utilized by the food industry as an alternative method for profiling and determining the thermal history and stability of processed cheese products (e.g., during shipping and storage). Furthermore, results of our study show that the incorporation of milk fat in food affects fat polymorphism. A higher ratio of the  $\beta$  polymorph to the  $\beta'$  form is found in processed cheese products and cream while milk fat in bulk form is found mostly in the  $\beta'$  polymorph. Using microscopy, we propose that the embedding or dispersion of milk fat globules within the protein matrix and/or presence of other ingredients force triacylglycerols to pack in their most stable crystalline form. Creation of a model cheese system is suggested in order to identify the factors (i.e., processing conditions, specific ingredients) that influence milk fat polymorphism. Characterization of the polymorphism of milk fat within processed cheese provides better understanding of the crystallization behavior of fats as affected by the food matrix. Furthermore, the results of the study could provide insights into the functionality of milk fat within food at the nano- or molecular scale.

### **Mechanism of Lipid Crystallization Under High Pressure Treatments** Musfirah Zulkurnain\*, V.M. (Bala) Balasubramaniam, and Farnaz Maleky, *Ohio State University, USA*

The mechanism of lipid crystallization under high pressure has been identified to be dependent on a combination of pressure and temperature. A phase diagram showing the dependence of the crystallization temperature (in the range of 41.3–102.4 °C) on pressure levels (from 0.1–400 MPa) has been established for fat models made of fully hydrogenated soybean oil and soybean oil (30/70% w/w). The high pressure treatments were conducted in three steps: (1) compression at 12.4 MPa/s, (2) cooling under high pressure, and (3) decompression in 4 s. The instantaneous formation of small crystals at both meso- and nano-scales during adiabatic compression and the effects of these structural properties on the samples solid fat content (SFC) and viscoelastic properties were documented at low (100 MPa) and high pressure (400 MPa) levels. Increase in holding time under pressure while cooling from 1 min to 10 min increased SFC by 8.5%, evident for crystal growth during isobaric cooling. However, different structural properties were documented when the onset of crystallization happens during cooling under isostatic pressure regardless of pressure levels. This observation was supported by different polymorphic behaviors during storage. In conclusion, the formation of different structural properties under high pressure treatments suggests different mechanisms of lipid crystallization during rapid compression step under the influence of quasi-instantaneous volume reduction versus during cooling under isostatic pressure condition.

**A Structure-based Model for Moisture Diffusion in Lipids** Sravanti Paluri\*<sup>1</sup>, Dennis R. Heldman and Farnaz Maleky, *Ohio State University, USA*

The objective of this investigation was to evaluate the effect of cooling rate with constant shear rate on moisture diffusion in lipids. Lipid samples with 100/0, 80/20, 60/40 w/w ratios of trilaurin and triolein were crystallized by cooling from 60 to 38 °C at fast (13 °C/min) or slow (0.7 °C/min) rates and 200/s shear rate. Effect of crystallization conditions and composition on structural attributes- solid fat content (SFC), void fraction, crystal size, and fractal dimension (Dbox) were analyzed. An increase in cooling rate under constant shear rate caused a decrease in crystal size and an increase in Dbox. Moreover, dissolution of trilaurin in triolein was evident when addition of 20% and 40% -by-weight triolein decreased SFC from 92% (in pure trilaurin) to 39% and 16%, respectively. A novel model for moisture diffusion in lipid networks based on fractality was proposed wherein diffusivity is a function of SFC, void fraction, Dbox, and molecular diffusivity of water in liquid oil and air. This model was validated with experimental moisture uptake data measured by imaging two-layered lipid-agar gel systems for two months at 38 °C. Predicted moisture uptakes generated by using measured structural data in the proposed model were in closer agreement with experimental uptake data than models from literature. Effective diffusivity for moisture uptake in lipid samples increased as SFC and Dbox decreased. Surprisingly, vapor phase diffusion in void fractions was the predominant mode of mass transport in samples even though the void fractions were only 1-7% of total volume.

**Crystallization Behavior of Triacylglycerol Under Super Rapid Cooling** Kengoh Nakanishi\*<sup>1</sup>, Takashi Ishiguro<sup>2</sup>, and Satoru Ueno<sup>3</sup>, <sup>1</sup>Miyoshi Oil & Fat Co., Ltd./Hiroshima University, Japan; <sup>2</sup>Miyoshi Oil & Fat Co., Ltd., Japan; <sup>3</sup>Graduate School of Biosphere Science, Hiroshima University, Japan

Industrial manufacturing process of edible oil

and fat products such as margarine involves super rapid cooling process with a rate of more than 100 °C/min. However, the transformation of triacylglycerol has not been clarified with cooling rate of more than 15 °C/min. In this study, we aimed to elucidate the crystallization behavior of the single component system of triacylglycerol under rapid cooling. We have been focused on binary system of 1,3-dioleoyl-2-palmitoyl-sn-glycerol(OPO) and 1,3-dipalmitoyl-2-oleoyl-sn-glycerol(POP). We are especially interested in the crystallization behavior of them under rapid cooling. Samples of OPO and POP were purified more than 99 %. The power compensation DSC was employed for calorimetric measurement. Polymorphic transformation behavior under rapid cooling was performed by the synchrotron radiation X-ray diffraction at BL-6A station in Photon Factory, High Energy Accelerator Research Organization, Tsukuba, Japan. As a result, POP was mainly formed the alpha phase in a single component and its diffraction peak was 4.6 nm under rapid cooling. However, POP in the OPO:POP = 1:1 mixture was formed the sub-alpha phase and its diffraction peak was 5.2 nm under rapid cooling. On the other hand, a new exothermic peak was observed with a single component of POP at rate of more than 55 °C/min and a new diffraction peak of 5.2 nm was observed at the beginning of the crystallization of POP. However, the diffraction peak was immediately disappeared in the single component of POP. In conclusion, we suggest that OPO affected a stability of POP crystal under rapid cooling.

**Effects of High Intensity Ultrasound Frequency on Fat Crystallization** Roberta C. Silva\*, Juhee Lee, and Silvana Martini, *Utah State University, USA*

In order to examine the effect of ultrasound frequency and high agitation on sonocrystallization processes, interesterified soybean oil (45% saturated fat) was crystallized at 44°C without and with the application of high intensity ultrasound (HIU) and with the application of high agitation.

Two frequencies were used (20 and 40 kHz) and compared with agitation by Ultraturrax (6,000 and 24,000 rpm). Two tip amplitudes (24  $\mu\text{m}$  and 108  $\mu\text{m}$ ) and three pulse durations were evaluated (5, 10, and 15 sec) for both frequencies tested. Sonication affected induction time, solid fat content (SFC), crystal morphology and viscoelasticity in both frequencies. Sonication applied using 20 kHz frequency significantly reduced crystal size, increased viscosity ( $435.92 \pm 173.29$  Pa.s to  $80218.33 \pm 15384.32$  Pa.s) and SFC ( $0.24 \pm 0.02\%$  to  $4.54 \pm 0.38\%$ ). No significant difference was observed between amplitudes (24  $\mu\text{m}$  and 108  $\mu\text{m}$  in 5 and 10 sec), while 108  $\mu\text{m}$  for 15 seconds the crystallization were significant delayed. The frequency of 40 kHz also increased the crystallized area compared to treatment without HIU, however the size of the crystals formed were larger than those formed with 20 kHz. In addition, the values of SFC ( $3.69 \pm 0.03\%$ ) and viscosity ( $3942.33 \pm 1459.71$  Pa.s) were smaller. In this frequency the amplitude level of 24  $\mu\text{m}$  for 10 sec showed the smallest values of viscosity ( $47.51 \pm 30.51$  Pa.s) and SFC ( $2.14 \pm 0.04\%$ ) while 108  $\mu\text{m}$  did not generate any significant difference when applied using the different pulses' duration. Agitation by Ultraturrax (24,000 rpm) improved the properties of SFC ( $5.47 \pm 0.11\%$ ) and crystallized area, the viscosity was lower ( $34846.42 \pm 29650$  Pa.s) than the one obtained at 20 kHz due to bigger size of the crystals.

**Molecular Asymmetry and Entropy of TAGs Related to Their Phase Behavior** Karoline Kroener, and Alejandro G. Marangoni\*, *University of Guelph, Canada*

Mixing behavior between TAGs is important in the design of many industrial fat products such as cocoa butter equivalents, which can have strong influence on stability. Here we propose a simple calculation for quantifying molecular asymmetry in TAG mixtures. The molecular asymmetry factor is linearly related to the entropy of melting of the fats studied, thus indicating that indeed the asymmetry

factor is inversely proportional to the structural entropy of the TAG mixture. The relationship between the asymmetry for two different fats and the resulting phase behavior, i.e., compatible vs. incompatible, will be explored phenomenologically.

**Low Saturated Baking Fats Using Novel Algae Butter Hard Stock** Long Zou\*<sup>1</sup>, Flavio Galhardo<sup>2</sup>, and Blum Eelco<sup>3</sup>, <sup>1</sup>*Bunge Oils, USA*; <sup>2</sup>*Bunge Ltd., USA*; <sup>3</sup>*TerraVia, USA*

The objective of this study is to evaluate the structuring properties of StOSt-enriched lipids from algae (called algae butter) for different bakery applications (e.g., roll-in, pastry, cookie, icing, filling). A simple physical blend approach using algae butter and liquid oils was adopted. The results showed that compared to other traditional hard stocks (e.g., palm-based), this novel fat system allowed for a significant reduction in saturates, up to 50% in some applications, without significant changes in the recipes and preparation methods. Moreover, the baked goods obtained presented an improved mouth feel due to the sharp melting properties of the baking fat. In sum, algae butter was demonstrated to be a healthy, clean-label, and exceptional performance hard stock for bakery applications.

**Impact of Nitrogen Concentration on Bakery Shortening Texture and Color** Rachel E. Mertz\*, Dilip Nakhasi, and Roger Daniels, *Stratas Foods, USA*

Bakery shortenings function to impart lubricity, and texture to baked goods. In the manufacture of bakery shortening generally 8 – 12% of nitrogen is introduced into an oil blend after it has been subjected to a scraped surface heat exchanger prior to packaging. This gas functions to improve shortening texture and color. With the GRAS revocation of partial hydrogenation (PH), partial hydrogenation free oil blends have migrated to compositions based on palm oil (PO), physical blends of liquid oil and fully hydrogenated oil (PB) or enzymatically interesterified liquid oil and fully



hydrogenated oil (IEPB). The objective of this study was to compare and contrast the impact of nitrogen concentration levels in PH, PO, PB, and IEPB bakery shortenings as it relates to bakery shortening textural attributes and color.

**Phospholipase C Treatment of Cream Impacts on the Cream to Butter Phase Transition and Improves Lipid Protein Separation** Arjen Sein\*, Kees Muijlwijk, Mariette Uijen and Linda de Lange, DSM Biotechnology Center, The Netherlands

Milk fat globules in unhomogenized milk and dairy cream are stabilized by a layer of phospholipids. Butter and butter oil are made from dairy cream by specific phase inversion processes, yielding in addition also a protein-rich serum phase, called butter milk or butter serum respectively. Phospholipids play a crucial role in this process. By treatment with the enzyme phospholipase C, phospholipids are hydrolyzed into diacylglycerides and phosphate compounds. As a consequence, the emulsifying capacity of phospholipids is broken down. Full hydrolysis for phosphatidyl choline and phosphatidyl ethanolamine was shown by advanced 31P NMR, also sphingomyelin was hydrolysed partly. This can be explained by quality of fit of the several phospholipids in the active site of the enzyme. By a special NMR analysis protocol a closed mass balance was shown.

The hydrolysis of phospholipids results in major changes in the process for making butter or butter oil:

- The phase separation in the butter oil process is improved: a better lipid/serum phase separation, already during incubation the phase separation starts. Increased lipid yield is however difficult to quantify on lab scale.
- The resulting buttermilk or butter serum phase contains substantially less lipids. This was quantified by 31P NMR and by gas chromatography (FAME method). Furthermore, as phospholipids reduce the air/water interfacial tension more than proteins do, the reduced level of phospholipid in the serum phase is also proven by a significant difference in interfacial tension. Serum from a separation process after phospholipase C treatment of the cream has an interfacial tension that is more than 10 mN/m higher than from untreated cream. This leads to a protein phase with better functional properties such as foaming and reduced rancidity notes.
- The phase transition from cream to butter takes longer. For this a special method was developed to measure phase inversion by churning on a rheometer, showing a difference in average phase inversion time of 167 seconds ( $P < 0.02$ ) between untreated and phospholipase C treated cream.

The presentation will explain how the enzyme works, and will show how the impact of phospholipase C treatment materializes in properties of the serum phases, butter, and butter oil.

Sein, Uijen; Use of phospholipase C, WO2016166149

**EAT 2: Confectionary Fats (*Session Dedicated to Ralph Timms*)**

*Chairs: Dérick Rousseau, Ryerson University, Canada; and Alejandro Marangoni, University of Guelph, Canada*

**The Fat Man's Tale** Ralph E. Timms\*, *Retired, UK*

At Cambridge University, besides chemistry I studied metallurgy which provided a good grounding in crystallography and phase behaviour. I learnt about the then new techniques of NMR, infra-red & visible spectroscopy and computing, leaving me well equipped to apply these techniques when I joined Unilever Research in 1970. At Unilever, I investigated fundamental aspects of: confectionary fat design, phase diagrams, triglyceride analysis, alternative SOS fats and fat fractionation leading to new insights into the production of confectionary fats. Of particular importance were: the phase behaviour to real fat blends; the development of improved methods of fractionation; an analytical method for the quantification of vegetable fats in cocoa butter. During six years at the Food Division of CSIRO, Australia's government research organisation, I worked mainly on milk fat, including analytical methods for the detection and quantification of vegetable fats in milk fat. While with the CSIRO I was invited to assist the Palm Oil Research Institute of Malaysia (PORIM, now MPOB). Thus began a long association with the Malaysian palm oil industry including six years with Sime Darby. I then worked as a private consultant travelling all over the world, including chairing one of the Programme Advisory Committees of the Malaysian Palm Oil Board and many years on ISO and EU committees and research programmes. In 1995 with three colleagues, Britannia Food Ingredients was founded. This was a wonderful opportunity to use my experience in the creation of a modern refinery specialising in the production of confectionary fats.

**Current Situation and the Future of Confectionary Fats** Kiyotaka Sato\*, *Hiroshima University, Japan*

Ralph E. Timms is the pioneer to open the door of lipid technology for materials designs of confectionary fats, and his scientific and technological achievements are represented in his book, *Confectionary Fats Handbook*. We have its Japanese translation version which has been welcome by confectionary fat technologists. On behalf of our colleagues, I have a pleasure to highlight the current situation and the future of confectionary fats, which will be driven by physical and chemical researches in the following technological areas: (1) to be much healthier in such as high cacao content, low fat/sugar content, aeration, vitamin C-added, probiotics and (2) to reveal new textures in such as emulsified chocolate, complex filling and heat resistance.

**Trading Phases: Importance of Fat Physical Properties!** Kevin W. Smith\*, *Fat Science Consulting Ltd., UK*

Many products rely on the physical properties of fat for their specific characteristics. In turn, the physical properties of the fat are determined by its specific composition, the phases of the fat (liquid, solid, polymorphic), and the manner in which those phases have been formed. The history of fat technology has been one of discovering the ways in which to characterize fats, and determining the impact of these characteristics in practical applications. This lecture will bring an overview of developments in this understanding from the last few decades and apply them to the study of cocoa butter equivalents and confectionary fats. The melting of blends of the three main cocoa butter triacylglycerols after stabilization at 40°C will be

compared with an extended stabilization procedure.

**Mathematical Approaches to Estimating Thermal Properties of Acylglycerides** Arun S. Moorthy<sup>\*1</sup>, Gianfranco Mazzanti<sup>2</sup>, Leendert H. Wesdorp<sup>3</sup>, and Alejandro G. Marangoni<sup>4</sup>, <sup>1</sup>*National Institute of Standards and Technology, USA*; <sup>2</sup>*Dalhousie University, Canada*; <sup>3</sup>*Wesdorp Raad en Daad, The Netherlands*; <sup>4</sup>*University of Guelph, Canada*

To date, the most comprehensive model for predicting enthalpy of fusion and melting temperatures of pure triglycerides (TAGs) was presented by Wesdorp in his doctoral thesis, "Liquid-multiple solid phase equilibria in fats: theory and experiments". The model is formulated as a set of non-linear equations with a vast and sensitive parameter space; solving model equations and generating usable properties is a non-trivial task. The Triglyceride Property Calculator is an interactive web implementation of the methods of Wesdorp, allowing users to explore the complex mathematical formulation and generate TAG property estimates through simply specifying the TAGs molecular composition and polymorphic form. The Triglyceride Property Calculator can be accessed at <http://www.crcfoodandhealth.com> as an available software tool. In this seminar, we guide the audience through the theory underlying the Triglyceride Property Calculator, highlighting (i) key contributions in the field that informed our work, and (ii) features and limitations of mathematical approaches. Software usability is demonstrated through interactive examples. Additionally, future model extensions and software improvement opportunities are discussed.

**Innovations That Have Had a Significant Impact on the Commercialization of Chocolate and Related Products** Neil Widlak\*, *Consultant, USA*

Chocolate is one of the most successful food products since the discovery of Cacao in Mesoamerica around 1900 BC. Although cacao, the principle ingredient of chocolate has not changed over time, many technical innovations have been made to better understand and improve the physical properties of cacao lipids to maximize the value of chocolate and chocolate related products. This paper will review the most significant innovations that have a significant impact on the success of chocolate, with a focus on the lipids in chocolate and related products. And provide a review of how we can ensure innovators, such as Ralph Timms, can continue make significant innovations in lipid and chocolate technologies.

## EAT 2.1: Delivery and Dispersed Systems

*Chairs: Koen Dewettinck, Ghent University, Belgium; and Iris Tavernier, Ghent University, Belgium*

### **Effect of Protein Types on the Formation of Nanogels from Nanoemulsions** Aakash Patel\* and Supratim Ghosh, *University of Saskatchewan, Canada*

Gelation behavior of sodium caseinate (SCN) and whey protein isolate (WPI) was investigated as a function of protein (1 – 5 wt%) and oil (30 and 40 wt%) concentration. Nanoemulsions were prepared by multiple cycles of high-pressure homogenization at 20,000 psi and characterized by droplet size distribution and rheology. Only SCN was able to form nanogel where gel strength increased with increase in protein and oil concentration and decrease in droplet size. When plotted as a function of droplet size, plateau storage moduli ( $G'_p$ ) of all nanoemulsions with a constant oil concentration merged into a single line, confirming the critical importance of droplet size on nanogelation. Surprisingly, WPI-stabilized nanoemulsions did not form nanogel, and no effect of droplet size on gelation behavior was observed, although their droplet sizes were similar to those with SCN. DLVO inter-droplet interaction potential for both the nanoemulsions was calculated. SCN-stabilized nanodroplets showed significantly higher repulsive interaction and inter-droplet separation due to a larger steric barrier, which led to a higher effective oil volume fraction ( $\phi_{\text{eff}}$ ) and random jamming of nanodroplets giving rise to a strong gelation behavior. Repulsive interaction among the WPI-stabilized nanodroplets and their inter-droplet separation were much lower due to a smaller steric layer, leading to a lower  $\phi_{\text{eff}}$  and much lower gel strength. Re-plotting the  $G'_p$  data with  $\phi_{\text{eff}}$  merged all data points for SCN nanoemulsions with different protein and oil concentration into a single line, confirming the driving force of inter-droplet

separation and increased  $\phi_{\text{eff}}$  behind the nanogelation process.

### **New Food Emulsions Stabilized by Colloidal Lipid Particles with Tailored Microstructure** Claire C. Berton-Carabin, Karin Schroën, Anja Schroder\*, and Joris Sprakel, *Wageningen University & Research, The Netherlands*

Particle-stabilized emulsions are emerging in the food area, but their implementation is still limited. It is not only challenging to produce particles with high efficiency, but also made of biobased materials, in sufficient quantity and whose production enables industrial applications. In particular, lipid-based particles could be promising, but have hardly been considered so far. In this work, we aim to develop colloidal lipid particles (CLPs) as interface stabilizers in oil-in-water (O/W) emulsions, and to understand how particle properties affect their ability to stabilize emulsions. Our CLPs are produced by hot high pressure homogenization of high melting point fats in water, and subsequent cooling. O/W emulsions are prepared either manually or by high pressure homogenization. Emulsions prepared with CLPs show unprecedented stability compared to emulsifier-stabilized emulsions. Varying the lipid solid-liquid ratio leads to particles with distinct crystalline nanostructure and morphology, resulting in tunable emulsion stabilization performance e.g., by tuning their wettability and affecting inter-particle interactions. Lath-like tripalmitin form jammed, fully covered, cohesive interfacial layers that prevent relaxation of emulsion droplets into a spherical shape, and form a three-dimensional network in the continuous aqueous phase. CLPs consisting of tripalmitin and

tricaprylin are polycrystalline platelet-like particles that form O/W emulsions with spherical, bridged droplets covered by a thin particle layer. CLPs are a promising type of Pickering stabilizers for O/W emulsions, due to their simplicity of preparation, tunable properties, effectiveness, and resistance against homogenization conditions. This versatile approach to interfacial design opens up perspectives for development of novel delivery systems for active ingredients.

***In vitro* Digestion of O/W Emulsions: Role of the Physical State of the Dispersed Oil Phase** Qing Guo\*, Nick Bellissimo, and D errick Rousseau, Ryerson University, Canada

Objective: The aim of this study was to modulate emulsified lipid digestion by manipulating the physical state of dispersed oil droplets in whey protein-stabilized O/W emulsions. Methods: Different whey protein emulsions were prepared by varying the ratio of soybean oil (SO) to fully hydrogenated soybean oil (FHSO) (10% + 0% , 7.5% + 2.5%, 5% + 5% , 2.5% + 7.5% and 0% SO + 10% FHSO). Emulsion crystalline structure and melting behaviour were investigated by X-ray diffraction and differential scanning calorimeter, respectively. The evolution in particle size distribution, structural changes during oral, gastric and intestinal digestion, and free fatty acid (FFA) release were all investigated to explore the influence of physical state and internal structure of oil droplets on lipid digestion. Results: All emulsions were stable during oral digestion. During gastric digestion, the mixed 5% SO + 5% FHSO emulsions were more stable than the fully liquid (10% SO + 0% FHSO) and solid (0% SO + 10% FHSO) emulsions. Flocculation and coalescence occurred upon intestinal digestion of all emulsions with the liquid oil being hydrolyzed quickly. The melting point of emulsions containing FHSO was much higher than 37  C, with the presence of solid fat

within the dispersed oil droplets greatly limiting lipolysis. Solid fat content was strongly correlated with the rate of lipid digestion ( $R^2 = 0.929$ ). FFA release was modeled using the Weibull distribution function. Conclusions: These findings indicate that lipid digestion can be modulated by the physical state and crystalline structure of the oil phase.

**Hollow Solid Lipid Micro-and Nanospheres: Novel Carriers for Fish Oil** Junsu Yang\*, and Ozan N. Ciftci, University of Nebraska-Lincoln, USA

Effectively incorporating omega-3 oils into foods and beverages is a major challenge for the food industry, because they are lipophilic and vulnerable to oxidation during processing and storage. Therefore, the objective of this study was to develop novel fish oil-carriers in a simple and clean way that will form easy-to-use free flowing powder formulation and protect fish oil. Fish oil was loaded into hollow solid lipid micro- and nanospheres of fully hydrogenated soybean oil using a single step green process based on atomization of the CO<sub>2</sub>-expanded lipids. Fish oil was successfully loaded into the hollow spheres with loading efficiencies up to 97%. Fish oil-loaded solid lipid spheres ( $d_{50\%} = 278$  nm) were obtained using 50  m nozzle diameter and 200 bar expansion pressure. The process allowed us to control the shell thickness of the spheres by adjusting the pressure. Onset melting point of the fish oil-loaded spheres decreased from 66 C to 62 C with increasing initial fish oil content, while major polymorphic form transformed from  $\alpha$  to  $\beta$ . Oxidative stability of the loaded fish oil increased significantly compared to free fish oil (p

**Plant Proteins Can Partly Replace Dairy Proteins in Lycopene-loaded Emulsions to Enhance**

**Physicochemical Stability** Kacie K.H.Y. Ho\*<sup>1</sup>, Karin Schroën<sup>2</sup>, M. Fernanda San Martín-Gonzalez<sup>1</sup>, and Claire C. Berton-Carabin<sup>2</sup>, <sup>1</sup>*Purdue University, USA*; <sup>2</sup>*Wageningen University & Research, The Netherlands*

Dairy proteins, such as whey protein isolate (WPI) and sodium caseinate (SC), are known to stabilize oil-in-water (O/W) emulsions by adsorbing at the interface. Plant proteins, such as soy (SPI) and pea (PPI) protein isolates are interesting alternatives due to their lower environmental impact and wide availability compared to traditional dairy proteins. In this study, physicochemical emulsion stability and lycopene encapsulation efficiency was investigated.

**Objective:** To compare the effects of interfacial proteins from different sources (dairy, plant, or binary dairy-plant blend) on the emulsion stability and encapsulation efficiency. **Methods:** The physicochemical stability of lycopene-loaded emulsions stabilized by proteins (WPI, SC, SPI, PPI) or binary blends (WPI or SC with plant protein) was assessed by droplet size measurement (DLS) and lycopene release during storage (0-14 days). To characterize the interfacial behavior of proteins, interfacial tension and dilatational rheology measurements were conducted with a drop tensiometer. **Results:** All emulsions were stable ( $d_{4,3} \sim 0.3-0.5 \mu\text{m}$ ) throughout storage, except for the SC blends, which exhibited phase separation after 3 days. Lycopene retention was higher for WPI blends ( $\sim 88-99\%$ ) compared to emulsions stabilized by a single protein ( $\sim 65-87\%$ ). SC formed relatively viscous films at the oil-water interface, while others were viscoelastic. Various effects were found, and interestingly WPI blends showed potential synergy. **Conclusions:** Stability of lycopene-loaded emulsions can be modulated by interfacial composition and plant proteins may

partially replace dairy proteins and enhance stability for emulsion applications.

**Cosolubilization of DHA and Curcumin as Synergistic Anti-inflammation Nutraceuticals** Ketty Uzilevsky, Abraham Aserin and Nissim Garti\* *Casali Center of Applied Chemistry Department of Chemistry, Hebrew University, Israel*

The triglyceride of docosahexaenoic acid (TG-DHA) is an important nutraceutical present in large quantities in human organs, especially in the brain. It has recently also been established that TG-DHA acts as an anti-inflammation agent. Curcumin, a polyphenolic is another important nutraceutical with a variety of activities, including treatment of "Silent Chronic Inflammation". Both nutraceuticals are insoluble in water and exhibit low bio-availability. In this study we cosolubilize them together in one oil-based softgel. The two compounds, at maximum loads, are solubilized in modified nanodroplets that are fully dilutable. The results demonstrate successful loading of Curcumin and DHA in specially designed novel fully dilutable food-grade microemulsions based on nonionic surfactants. We first solubilized both the ethyl ester of DHA (EE-DHA, synthetic) or the natural triglyceride omega fatty acids (TAG-DHA) in the concentrate (6 wt%). If the curcumin is added to the same mixture (cosolubilization), the maximum load of the two nutraceuticals was 3wt% Curcumin and 3wt% DHA. The characterization of empty and loaded microemulsions was carried out by advanced analytical and structural methods, including self-diffusion NMR (SD-NMR) and small angle X-ray scattering (SAXS). The droplets were monodispersed of 5-10 nm. The solubilized nutraceuticals are localized, at  $>70 \text{ wt}\%$  water dilution, at the interface and in the oil core of the droplets, resulting in swelling of the droplets, reduced viscosity and other physical properties.

**Fat Crystal-stabilized Pickering Water-in-Oil Emulsions for Controlled Release Applications** Xin Zhao<sup>1</sup>, and D errick Rousseau\*<sup>2</sup>, <sup>1</sup>*Guangdong Industry Technical College, China*; <sup>2</sup>*Ryerson University, Canada*

Water-in-oil (W/O) emulsions offer the possibility of encapsulating water-soluble compounds within discrete droplets present in oil-continuous processed foods. Here, W/O emulsions stabilized by glycerol monostearate (GMS) Pickering fat crystal shells were evaluated as controlled release matrices using NaCl as a model compound dispersed within the dispersed aqueous droplets. The release of encapsulated salt from the dispersed water droplets towards the external aqueous phase was measured using a conductivity meter. Results showed that the GMS shells prevented salt diffusion as long as the shell was in the solid state, showing that Pickering crystals are effective barriers against diffusion. Sorbitan monooleate, which was added to alter emulsion stability, resulted in concentration-dependent removal of the interfacially-bound GMS crystals which resulted in droplet flocculation and coalescence. As a result, NaCl was released from the now-unstable emulsions. This study shows for the first time that the use of competing emulsifiers can be used to modulate the release of solutes from fat crystal-stabilized W/O Pickering emulsions.

**Surfactant-mediated Fat Crystallization at the Oil-water Interface** Nicole Green\*, and D errick Rousseau, *Ryerson University, Canada*

We have previously shown that the addition of water to shear-crystallized fat/oil systems can form encapsulated droplets surrounded by Pickering crystal shells. We further explored the propensity for interfacial crystallization using a temperature-controlled drop shape tensiometer to monitor the onset and progress of crystallization over time. A single water drop in an oil/fat/emulsifier medium was observed from 80 C to room temperature. The emulsifiers studied were glycerol monostearate

(GMS), glycerol monooleate (GMO), glycerol distearate (GDS), glycerol dioleate (GDO), and polyglycerol polyricinoleate (PGPR). The effect was dependent on emulsifier type, with the presence of an unsaturated bond in the nonpolar moiety reducing the likelihood of interfacial crystallization of fat. Further, the complex branched molecular structure of PGPR prevented any interfacial crystallization. Results for the glycerol-based emulsifiers were also concentration dependent, with reduced concentrations of GMS yielding attached “satellites” of fat crystal spherulites rather than a complete interfacial crystal shell.

**Crystallization Behaviour of Roll-in Fats in the Matrix of Laminated Dough Products** Kristin Mattice\* and Alejandro G. Marangoni, *University of Guelph, Canada*

It has been well established that  $\beta'$  polymorphs are desirable for shortenings to have optimum laminating properties. When laminated doughs are baked, the high temperatures are sufficient to erase any existing crystal forms, creating the opportunity for shortenings to partially or completely crystallize in a different polymorphic form upon cooling. Crystalline structures of shortenings used in dough lamination have previously been studied; however, it is unique to investigate the crystallization of fat contained within a baked dough matrix. X-ray diffraction revealed that the crystalline properties of shortenings within the baked products depend on the type of shortening used. It appears that shortenings produced by partial hydrogenation will largely retain their  $\beta'$  polymorphism after baking, while shortenings produced without any partial hydrogenation will experience at least partial conversion from  $\beta'$  to  $\beta$  polymorphism over one week of storage at room temperature. Changes in melting behaviour, as observed through differential scanning calorimetry, reflected the polymorphism changes. The behaviour of each fat within the matrix is different than that observed when baked alone. Incorporation of isolated matrix components

to the fats revealed that it is gelatinized wheat starch which causes the changes in crystallization behaviour. Given the large quantity of fat used in laminated dough production, the properties of the fat have a significant influence those of the final product. Therefore, any polymorphic conversion could impact the eating experience. Results from this experiment provide new insights regarding the physical properties of fats within laminated dough products.

**Self-assembling Behavior of Glycerol Monoundecenoate in Water: Efficient Lamellar Gelled System for Concrete Curing** Gildas Nyame Mendendy Boussambe<sup>1</sup>, Romain Valentin\*<sup>1</sup>, Jean-Francois Fabre<sup>2</sup>, and Zéphirin Mouloungui<sup>3</sup>, <sup>1</sup>INRA, France; <sup>2</sup>LCA UMR1010 INRA-INP/ENSIACET, France; <sup>3</sup>Laboratoire de Chimie Agro-Industrielle, France

The aim of this study was to highlight the behavior of the glycerol monoundecenoate (GM-C11:1) in different, diluted and concentrated states because many industrial applications such as concrete industry need some systems for the retention of water. Self-assembling properties of GM-C11:1 in water and upon solid inorganic surfaces were investigated in diluted state with surface tension experiments, AFM and Cryo-TEM

studies. In concentrated state, the gelling properties in presence of water were investigated by polarized light microscopy, DSC and SAXS experiments. GM-C11:1 at 0.1mg/mL self-assembles at the liquid/air interfaces as aggregates of about 20 nm in diameter, organized into concentric forms. These aggregates were spherical globules composed of several molecules of GM-C11:1. At higher concentrations (1 mg/mL and 10 mg/mL), GM-C11:1 was able to coat uniformly liquid/air and liquid/solid interfaces. In bulk GM-C11:1 form spontaneously aggregates and vesicles. In more concentrated state, GM-C11:1 assembles into lamellar gel in water. By cross-referencing SAXS and DSC findings, we were able to distinguish between interlamellar water molecules strongly bound to GM-C11:1 and other molecules remaining unbound and considered as “mobile” water. Here, GM-C11:1 appears to be an effective molecule for surface treatments for which water retention is the key parameter. This work allowed to finalize a very efficient industrial product GM-C11:1-based, for the curing of concrete. This study on the understanding of self-assembling and the water retention properties is the beginning of an industrial success in the building and public works industry's. Ref : Boussambe (2015) JAOCS, Valentin (2013) OCL, Valentin (2012) JCIS.



### EAT 3: Nano-, Micro-, Macrostructure

*Chairs: Alejandro Marangoni, University of Guelph, Canada; and Pere Ramel, University of Guelph, Canada*

**Thermodynamic Considerations for Molecular Gel Formation** Yaqi Lan<sup>\*1</sup>, Maria G. Corradini<sup>2</sup>, and Michael Rogers<sup>3</sup>, <sup>1</sup>South China Agriculture University, China; <sup>2</sup>University of Massachusetts Amherst, USA; <sup>3</sup>University of Guelph, Canada

Low molecular weight organogelators (LMOGs) are capable of self-assembling themselves to form continuous gel networks in organic liquids such as edible oils. They have been utilized as novel alternatives to substitute hard-stock fats in foods and cosmetics to lower the level of saturated fats and eliminate artificial trans fats. However, challenges exist when implementing organogels into food systems, e.g., a lack of food-grade gelators and the inability to modify the supra-molecular structure of these materials. Design of new and unique food-grade molecular gel systems become urgent and must be vigorously pursued. However, rational design of small molecular gelators is an elusive task and majority of new gelators were discovered by serendipity. Information behind the mechanism of self-assembly as well as guidelines to facilitate the prediction of gelation behavior would be of great importance for us to develop a priori tools for designing new and unique molecular gel systems. Solvent properties play a crucial role in mediating the self-assembly of molecular gelators and their growth into SAFiNs. Herein, solubility parameters of solvents are presented as quantitative tools to elucidate the gelation behaviors of LOMGs. Thermodynamically derived solubility parameters such as Hansen solubility parameters ( $\delta_p$ ,  $\delta_d$ ,  $\delta_h$ ), and Modified Separation of Cohesive Energy Density (MOSCED) model are among the most effective parameters when correlated with the gelation ability of numerous classes of molecular gelators. These tools will greatly aid in the development of novel gelators without solely relying on serendipitous discoveries.

**Restructuring of Palm Mid Fraction by Interesterification Improved Its Consistency and Crystallization Rate** Noor Lida Habi Mat Dian\*, Miskandar Mat Sahri, Sivaruby Kanagaratnam, and Rafidah Abd Hamid, Malaysian Palm Oil Board, Malaysia

Fractionation of palm olein (POo) with iodine value (IV) of 56-58 to produce super POo (IV > 62) is a common practice in POo importing countries. Palm mid fraction (PMF, IV 40-50) is the co-product of the process and is abundance in supply. PMF is rich in symmetrical SUS (S, saturated; U, unsaturated fatty acid) triacylglycerol (TAG), mainly 1,3-dipalmitoyl-2-oleyl-glycerol and 1,3-dipalmitoyl-2-linoleyl-glycerol. This TAG composition has a unique solid fat content (SFC) profile which is high below 20°C and very low below 25°C. Such sharp melting profile is undesirable in the manufacture of solid fat products. SUS TAGs also have low crystallization rate, resulting in low productivity, and stabilized in  $\beta$ -triple chain packing which might lead to the formation of granular crystals in solid fat products upon storage. Restructuring the SUS TAG molecules by interesterification (IE) can improve the SFC profile and crystallization rate of PMF. Results showed that IE reduces the SUS TAG content of PMF from 60.8% to 36.5%, and increases the trisaturated TAG content from 2.3% to 16.8%. This modification results in a favorable increase in the SFC. The SFC at 25°C drastically increased from 9.0% before IE to 34.0% after IE. Crystallization rate also increased. PMF took about 30 minutes at 5°C and 10°C, and 60 minutes at 15°C to complete its crystallization. The structured PMF (St-PMF) took only 15 minutes to fully crystallize at 5°C, 10°C and 15°C. Increase in the SFC and crystallization rate makes St-PMF highly suitable as structural fat for solid fat products.

**Aggregation of Crystalline Nanoplatelets and the Effects of Constant Shear Using Dissipative Particle Dynamics**

David A. Pink\*<sup>1</sup>, Beth Townsend<sup>2</sup>, Fernanda Peyronel<sup>2</sup>, and Alejandro G. Marangoni<sup>3</sup>, <sup>1</sup>*St. Francis Xavier University, Canada*; <sup>2</sup>*Dept. of Food Science, University of Guelph, Canada*; <sup>3</sup>*University of Guelph, Canada*

Crystalline Nanoplatelets (CNPs) are the most stable solid aggregates of triacylglycerol (TAG) molecules in edible oils at room temperature (Acevedo&Marangoni (2010) *Cryst. Growth Des.* 10, 3327 & 3334). The question arises, into what structures do CNPs aggregate? The question is relevant if one wants to replace (hydrogenated) trans fats: a replacement should exhibit similar oil-binding capacity. This is determined, partly, by the structures into which the CNPs aggregate.

Theoretical models and computer simulation of unsheared model tristearin solids in triolein oil, reported that CNPs aggregated to form 'sandwich-like' structures (TAGwoods) under fast or slow cooling. USAXS studies of fast-cooled samples supported this. However, many processes involve shear and it is important to understand what CNP aggregates, if any, can form in a shear field. We shall present coarse-grained models of CNPs and the effects of constant shear with a range of shear rates. If we want to model spatial structures of aggregating objects then we need to use a Particle-Based model. To model a flowing sheared particle-based fluid requires that we use computer simulation that is in accord with the Navier-Stokes equation for which the boundaries might undergo change as CNP aggregates form, distort and breakup. We used Dissipative Particle Dynamics to model the system of CNPs in a sheared TAG fluid and computed structure functions,  $S(q)$ , and 2-particle correlations to interpret the results. We shall report on CNP orientation and aggregation under a wide range of flow and shear rates, and relate our results to experimental work.

**Extraction of Gossypol and Purification of Cotton Oil and Cotton Meal Using Novel Liquid Nano Vehicles**

Yael Prigat and Nissim Garti\* *Casali Center of Applied Chemistry The Hebrew University of Jerusalem, Israel*

These very good qualities of the cotton glands are hindered by the presence of the toxic gossypol. Its removal is expensive. Nowadays the major use of cotton seeds and meal are for ruminant feeding of some ruminant animals that appear to be resistant to gossypol in low dosage, but high doses can cause gossypol binding to blood proteins. In humans and non-ruminant animals gossypol is considered toxic with content

**Effects of High Intensity Ultrasound and Emulsifiers on Crystallization Behavior of Palm Oil**

Zong Meng\*, Hongjuan He, and Yuanfa Liu, *Jiangnan University, China*

The objective of this research is to evaluate the crystallization behavior of palm oil (PO) as affected by the use of high intensity ultrasound (HIU) and by the addition of five types of common emulsifiers, namely, mono- and di- glycerides (MDG), monoacylglycerols (MAG), polyglycerol fatty acid esters (PGFEs), sucrose palmitate (SP), and sodium stearyl lactylate (SSL). The SFC, isothermal crystallization behavior, crystal morphology and polymorphism characteristics were evaluated system. Results were shown that HIU parameters had an important influence on the crystallization rate. Under certain HIU time (90s), the crystallization rate of PO increased with increasing HIU power in the range of 47.5 ~ 237.5W; but when the power reach 427.5W, since thermal effects, the HIU will suppress the PO crystallization; while under certain HIU power (237.5W), the crystallization rate increased with the HIU time increasing in the range of 30 ~ 60s; when the time was extended to 90s, no significant promoting effect generated; when extended time to 120s, the crystallization rate is smaller than that of 90s; when continue to extend the time to more than 240s, HIU inhibited PO crystallization. Different

emulsifiers can also produce different effects on PO crystallization rate. PGFEs could promote crystallization, SSL and SP could restrain crystallization, while the effects of MAG and MDG to crystallization rate were not obvious. The crystal dispersed more evenly; the average particle diameter of the crystal reduced and the amount of crystals increased by the application of HIU, but the polymorphism did not show obvious change.

### **Engineering the Crystallization Behavior of Triacylglycerols using High Behenic Acid Stabilizers**

Ga Yae Kim\*, and Alejandro G. Marangoni,  
*University of Guelph, Canada*

High behenic acid stabilizer (HBS) was used to stabilize oils and accelerate the nucleation of fats. HBS stabilized liquid oil more effectively when there were more high-melting triacylglycerols (HMTs) (melting point > 30 °C) in the oil to be stabilized. Chromatographic analyses showed that peanut oil (PeO) had the largest amount of HMTs among three oils studied. Maximum oil stabilization efficiency of HBS in PeO was correlated with the lowest critical gelation concentration (6.5 %) and the highest nucleation rate. On the other hand, the effect of HBS on the nucleation rate of fats was inversely correlated to the amount of HMTs present in fats as the nucleation of fats with a high level of HMTs (> 67 %) was mostly controlled by the native HMTs of fats. The formation of new fraction was observed between HBS and high-melting fraction of palm oil and anhydrous milk fat. Newly formed crystals were observed under polarized light microscope, making the microstructure denser. The mechanism of HBS on oil stabilization and nucleation enhancement was to co-crystallize with HMTs present in the “host” fat/oil, resulting in a formation of new fraction. The molecular compatibility between HBS and the “host” fat/oil is prerequisite for the oil stabilization and the nucleation enhancing effect of HBS to be effective.

### **Modification of Butter Physical Properties Using High Intensity Ultrasound** Jiwon Lee\*, and Silvana Martini, *Utah State University, USA*

High intensity ultrasound (HIU) can promote crystallization of fats, but its effects on crystallization of emulsions are still unknown. Crystallization behavior of cream influences the final quality of butter. The effects of HIU on cream and butter were evaluated. HIU (20 kHz; 108µm) was applied for different durations (0, 10, 30, 60 or 90s) to matured cream (300g; 40% fat) that was kept at 7.5°C for 90 min with slow agitation. After maturation and sonication, the cream was churned at 7.5°C until butter grains were produced. Cream's solid fat content, melting behavior and droplet size distribution were measured after HIU treatment. Butter was characterized by melting behavior, water content, and firmness. HIU did not affect droplet size distribution of cream and water content of butter. Sonicating cream for 30, 60 and 90s slightly decreased solid fat content due to the temperature increase (1-5°C) during HIU application. Cream sonicated for 10s had the lowest onset temperature and highest enthalpy of second peak. All butter samples showed two melting peaks approximately at 16 and 33°C. HIU treatment for 10, 30 and 60s significantly increased the firmness of butter. The least spreadable butter was obtained when HIU was applied to cream for 10s. This butter had the lowest onset temperatures and highest enthalpies for both melting peaks. Significantly lower enthalpies were observed in the butters that were treated with HIU for 60 and 90s compared to non HIU treated butter, but all the differences in enthalpies disappeared after 24 hr storage at 5°C.

**Formation of Phytosterol Nanoparticles Using Novel Nanoporous Bioaerogels** Ali Ubeyitogullari, and Ozan N. Ciftci\*, *University of Nebraska-Lincoln, USA*

The potential of many bioactive lipid compounds, such as phytosterols, to improve human health remains untapped due to their poor bioavailability. Incorporation of free phytosterols into foods is a major challenge from a technological and food quality standpoint because phytosterols are high melting point crystalline powders that are insoluble in water and poorly soluble in fats and oils. This poor water solubility severely limits phytosterols' bioavailability. The main objective of this study was to form phytosterol nanoparticles using novel nanoporous bioaerogels made of starch to enhance solubility of phytosterols, and, in turn, their bioavailability. Nanoporous starch aerogels (NSAs) (60 m<sup>2</sup>/g surface area) were generated using a green method based on supercritical carbon dioxide (SC-CO<sub>2</sub>) drying. Phytosterol nanoparticles were formed in the NSAs via novel SC-CO<sub>2</sub> impregnation process. Nanopores of the NSA acted as a mold to prevent formation of bigger phytosterol crystals and led to the formation of phytosterol nanoparticles and decreased their crystallinity, which later led to enhanced solubility of the phytosterols in water and gastrointestinal fluids. Fast cooling rates generated isolated phytosterol nanoparticles, whereas slow cooling formed sheet-like structures made of phytosterol nanoparticles. The size of phytosterol particles ranged between 58 and 87 nm. Impregnation did not create any chemical bonding with the NSA matrix. This is a novel green approach to forming water-insoluble (lipophilic) bioactive nanoparticles with decreased crystallinity; enabling addition of water-insoluble bioactives into low-fat foods and beverages to promote health; and maximizing the utilization of water-insoluble bioactives.

### EAT 3.1: Saturated Fat Reduction

*Chairs: Paul Smith, Cargill Global Foods Research, Belgium; and Silvana Martini, Utah State University, USA*

#### **Impacts of TAG-TAG Molecular Interactions for the Formation of Functional Fats** Kiyotaka Sato\*<sup>1</sup>, Laura Bayes-Garcia<sup>2</sup>, and Shimpei Watanabe<sup>3</sup>, <sup>1</sup>Hiroshima University, Japan; <sup>2</sup>University of Barcelona, Spain; <sup>3</sup>Fuji Oil Co. Ltd., Japan

In accordance with increasing demands for replacing trans fats with suitable alternatives and reducing saturated fats, molecular designs of novel edible fats are required. One of many trials is to form new types of fat blends through specific mixing behavior to form molecular compound (MC) crystals, which are based on molecular interactions between saturated-monounsaturated mixed acid triacylglycerols (TAGs). This paper, in the first, reviews recent research of mixing behavior of binary mixtures among POP, PPO, OPO and OOP, and ternary mixtures of SOS/SSO/OSO. Then, we report physical properties of novel fat blends made of SOS/SSO/OSO and POP/PPO/OPO as the major TAGs, in which oleic acid moiety increased and saturated fatty acid moieties decreased by more than 10% compared with cocoa butter. With X-ray diffraction, DSC, optical microscopic methods, we confirmed that the two ternary mixtures revealed stable polymorphic form of MC crystals of double-chain length structure and high degree of fat bloom stability when they were employed as confectionery fats.

#### **Influence of the Addition of Phytosterol Esters on the Crystallization of Palm Oil** Eva Daels\*<sup>1</sup>, Bart Goderis<sup>1</sup>, and Imogen Foubert<sup>2</sup>, <sup>1</sup>Katholieke Universiteit Leuven, Belgium; <sup>2</sup>Katholieke Universiteit Leuven Kulak, Belgium

Phytosterols are plant-based compounds which have nutritionally beneficial properties, more specifically a blood cholesterol lowering effect. In

the form of phytosterol esters (PE) they can be used as an ingredient in functional food formulations. Scientific publications on the influence of PE addition on the crystallization of edible fats are however very much lacking. Therefore, the objective of this study was to in depth investigate the effect of PE addition on palm oil (PO) crystallization in order to stimulate new science-based edible applications of this technology. A commercially available blend of PE was used to examine the influence of PE addition on the crystallization behavior of PO in the equilibrium state. The interdependence of different structure levels (primary crystallization and polymorphism, network formation, and macroscopic properties) was analyzed with several experimental techniques (DSC, X-ray diffraction, NMR, polarized light microscopy, and texture profile analysis). It was observed that PE addition clearly has a major influence on each of the structure levels. PE showed a very particular crystal network structure and a very particular crystal structure that was different from what is generally observed in triglyceride fats. PE and PO crystallized separately, but not fully independently since antagonistic interactions occurred. The binary phase diagram for the PE-PO system revealed eutectic behavior due to immiscibility in the solid state. Finally, the hardness of the blends decreased with an increasing PE concentration and could be predicted by the melting enthalpy rather than the solid fat content.

**Wax Crystallization in Emulsion-templated**

**Oleogelation** Iris Tavernier\*<sup>1</sup>, Tom Rimaux<sup>2</sup>, and Koen Dewettinck<sup>3</sup>, <sup>1</sup>*Ghent University, Belgium*; <sup>2</sup>*Vandemoortele R&D Centre, Belgium*; <sup>3</sup>*University of Gent, Belgium*

Consumer concerns about the negative health effects of saturated fat consumption have resulted in an increased interest in alternative liquid oil structuring techniques. Recently, our group developed a novel oil structuring method using only un-modified proteins, creating structured oils with a very high elastic modulus. The approach consists of the production of highly concentrated oil-in-water emulsions ( $\phi_{oil} > 0.6$ ) stabilized with soy protein isolate, followed by the evaporation of the water phase after which the liquid oil is trapped in a physical network of soy protein film. The major drawback of this approach is the limited structure recovery of this protein stabilized oleogel after applying shear, with even liquid oil partially leaking out of the system. In the current research, the oil within the structured protein network was gelled with candelilla wax, resulting in a system less sensitive to structure breakdown. Both protein network and gelled oil provide structure and a synergistic effect was obtained in terms of gel strength and thixotropic recovery. Furthermore, a lower amount of wax was required to obtain a gel with high firmness, decreasing the waxy mouthfeel upon consumption. The microstructure of the samples was elucidated with polarized light microscopy and cryo-SEM and they were characterized rheologically with oscillatory measurements, analysis of thixotropy and temperature sweeps. By combining two oleogelation methods, in casu wax-based oleogelation and the emulsion templated approach, the advantages of both systems are exploited and the disadvantages attenuated. This research therefore demonstrates that combining oleogelation methods further diversifies the

possible applications of oleogels in food products.

**Emulsion Droplets as Rheological Modifiers in a Fat-crystal Network Stabilized Emulsion**

Ruby R. Rafanan\* and D errick Rousseau, *Ryerson University, Canada*

Filler materials are embedded particles within a matrix that can alter the rheological profile of composite mixtures. This effect is dependent on a number of factors, two of which are particle size and surface characteristics. Emulsion droplets are well-known to affect rheological behaviour, but specific trends considering droplet surface interactions with the surrounding matrix have not been studied in detail as filler particles have been. A Pickering emulsion droplet possesses interfacially adsorbed solids and can elicit different interactions with the surrounding matrix than classical liquid interfaces. Pickering (PEs) and classical liquid interface (CEs) in fat crystal-stabilized emulsions were compared to determine the effect of droplet size and interfacial characteristics on the rheological profile. Hydrogenated soy oil served as the fat phase. PEs were manufactured using glycerol monooleate to promote interfacial crystals. CEs were formed using polyglycerol polyricinoleate. Two different droplet size distributions (Sm:  $d_{50}=1.5\mu\text{m}$ , Lg:  $d_{50}=15\mu\text{m}$ ) were compared. Lg PEs displayed higher  $G'$  values than Sm PEs, but no change in the LVR. Both displayed frequency dependent increases in  $G'$  with  $\tan \delta$  consistently less than 1. Conversely, both Sm and Lg CEs showed lower  $G'$  values than PEs with similar LVR strain values.  $\tan \delta$  increased above 1 at higher frequencies under constant stress. This clearly shows that the consistency of fat-crystal network emulsions can be controlled by manipulating the interactions between the droplet interface and the network. This is highly advantageous in product development to more efficiently attain a desired texture with minimal

formula changes in various network-based products.

**Interesterified *trans*-free Fats Rich in sn-2 Nervonic Acid Prepared Using Acer Truncatum Oil and Palm Oil** Peng Hu\*<sup>1</sup>, Liangli Yu<sup>2</sup>, and Xuebing Xu<sup>3</sup>, <sup>1</sup>*Wilmar Biotechnology R&D Center (Shanghai) Co., Ltd., China*; <sup>2</sup>*Dept. of Nutrition and Food Science, University of Maryland, USA*; <sup>3</sup>*Wilmar Global Research and Development Center, China*

This study obtained *trans*-free fats containing nervonic acid, a fatty acid with beneficial effects for mental health. Four fats containing 1.28–2.41% (w/w) nervonic acid were prepared by chemical or enzymatic interesterification of palm stearin (PS), Acer truncatum oil (ATO) and palm kernel oil (PKO). The chemical procedure was catalyzed using MeONa, whereas the enzymatic procedure was catalyzed with a 1,3-specific lipase. As a result, the interesterified fats showed a similar fatty acid profile to their corresponding physical blends measured by gas chromatography, but contained more nervonic acids at the sn-2 position, which was more conducive to metabolism and absorption. The content of tripalmitoylglycerol (PPP) and 1,3-dipalmitoyl-2-oleoyl glycerol (POP) or 1,2-dipalmitoyl-3-oleoyl glycerol (PPO) in the interesterified fats decreased significantly, resulting in improved plasticities. All interesterified fats showed a satisfactory content of tocopherols and oxidative stability. In addition, the interesterified fats had solid fat content (SFC) values of less than 2% at 40 °C, which contributed to a better mouth feel, while the SFC values of their physical blends exceeded 10%. A combination of differential scanning calorimetry, X-ray diffraction spectroscopy and polarized light microscopy results suggested that the interesterified fats formed spherulitic needle-like crystals in the  $\beta'$  form, while the physical blends formed dendritic crystals in the  $\beta$  form. These data indicated that the *trans*-free

interesterified fats rich in nervonic acid may have a great potential in margarine applications.

**Soybean Oil Partial Hydrogenation Using High Voltage Atmospheric Cold Plasma Treatment without Trans Fatty Acids** Ximena Yopez\*<sup>1</sup>, Hanna S. Gracz<sup>2</sup>, and Kevin M. Keener<sup>3</sup>, <sup>1</sup>*Purdue University, USA*; <sup>2</sup>*North Carolina State University, USA*; <sup>3</sup>*Iowa State University, USA*

Partially hydrogenated oils are considered unsafe to use as food ingredients due to their high content of *trans*-fatty acids (TFA). High Voltage Atmospheric Cold Plasma (HVACP) has been investigated as a novel technology to hydrogenate soybean oil without the formation of TFA. The goal of this study is to determine if HVACP can hydrogenate soybean oil at room temperature and atmospheric pressure, without a metal catalyst, using hydrogen and nitrogen gas. A 5.0 g soybean oil sample was exposed to HVACP treatment, by triplicate for times up to 1.5 h. The effect of HVACP treatment was evaluated by measuring iodine value, fatty acid composition, NMR, and nitrogen content. Optical emission spectroscopy was used to identify some of the hydrogen and nitrogen species involved in the reactions. During treatment a solid oil fraction developed on the top surface of the oil. After treatment two sample fractions were analyzed. The liquid sample which consisted of approximately 95%, and a solid sample which consisted of approximately 5% of the original sample. Results showed a decreasing iodine value with increasing treatment time. At 1.5 hours the liquid fraction decreased from an initial IV of 130 to an IV of 122, whereas the solid fraction decreased to an IV of 90. The fatty acid composition for both samples showed a significant increase in saturated fatty acids. <sup>1</sup>H-NMR studies showed a triglyceride chemical structure. This study demonstrates that HVACP can partially hydrogenate vegetable oils without producing TFA, without requiring

additional heat, high pressure, or metal catalyst.

**The Impact of Cooling Rate and Sugar Volume Fraction on Palm Oil Crystallization** Kyle Vollett, Ryan West, and D errick Rousseau\*, *Ryerson University, Canada*

Confectionery products are semi-solid suspensions consisting of particulates such as sucrose crystals dispersed throughout a continuous fat phase. As opposed to simple fats, where triglyceride crystallization continues unobstructed until a space-filling structure is reached, the crystallization pathway of confectionery systems can be significantly influenced by the presence of a dispersed phase, which may represent up to 70 vol % in some commercial products. The effects of sugar volume fraction and cooling rate on the relative viscosity profiles and fat crystallization rates and polymorphic transitions of two palm oils mixed with sugar were monitored using rheology, thermal analysis and polarized light microscopy. Two fats were investigated: a standard palm oil and a palm mid-fraction blend, each mixed with confectioner's sugar at volume fractions of up to 0.37. Samples were cooled from 60 to 20 C at 0.4, 1.0 or 4.0  C/min on a rheometer stage using a vane-in-cup geometry at a shear rate of 100 rpm. Increasing sugar volume fraction increased both the magnitude and rate of crystallization at all volume fractions as it likely provided a larger nucleating surface area as the fat-sugar blends were mechanically agitated. The increase in sugar content also promoted direct melt crystallization of the  $\beta'$ -form that bypassed the  $\alpha$ -form altogether. Finally,  $\beta$  crystal formation was hindered at higher sugar volume fractions. These results were highly dependent on volume fraction and cooling rate.

**Innovation Focused on Health and Nutrition: Oxidative Stability and Functional Performance of Low Saturate High Oleic Canola Oil** Diliara Ilassonova\* and Amir Saberi, *Cargill Inc., USA*

Innovation focused on health and nutrition is one of the strongest trends in modern edible oils industry. Supported by consumer-centered marketing research one target for improving nutritional value of the oils was identified as reduction in saturated fat without compromising oil oxidative stability. After a decade of breeding work, Cargill scientists developed new specialty canola plant producing oil with the lowest saturated fatty acid content among all edible oils. Clear Valley<sup> </sup> Low Saturate canola oil contains less than 4.5% saturated fatty acids. New high oleic low linolenic and low saturate oil demonstrated high stability with an oxidative stability index (OSI) over 17 hours at 110 C and strong resistance to degradation during frying. Flavor development, volatile profile and oxidative stability of low saturate canola oil, specialty and commodity oils has been evaluated by accelerated oven test (Schaal oven), quantitative descriptive sensory and head space analysis. New oil has slower hydro peroxides formation, less volatile compounds and less flavor degradation when compared to other oils. Clear Valley<sup> </sup> Low Saturate canola is commercialized specialty high stability oil that delivers flavor and oxidative stability along with the lowest saturate fat content on the market.



## EAT 4 / H&N 4.1: Lipid Structure and Health

*Chairs: Ignacio Vieitez, UdelaR, Uruguay; and Amanda Wright, University of Guelph, Canada*

### **The Role of Food Structure in Lipid Digestibility and Bioavailability** Harjinder Singh\*, *Massey University, New Zealand*

Dietary lipids are derived from plant and animal sources and they are an important source of energy, carrier of lipid-soluble vitamin and constituents of cellular membranes. In natural foods, such as milk, grains, nuts, eggs, meat and fish, lipids are present in the form of complex structures in which triglyceride particles are coated with a stabilising layer of membrane phospholipids and proteins. Ingestion of these foods breaks down the surrounding structures and releases the lipid droplets from the locating matrix, and the droplet interfacial layers are significantly modified during the digestion process. The interfacial structures of the droplets play a key role in the rate of release and subsequent uptake of fatty acids in gastrointestinal tract. In processed foods, lipids are mostly incorporated within the food matrix in the form of emulsions, where emulsified lipids play a major role in determining the texture, flavour and taste profile of processed foods. In addition, the structural attributes of emulsions and the properties of interfacial droplet layers play a key role in the kinetics of lipid digestion and release of lipid-soluble components. In these systems, the digestion and absorption characteristics of lipid emulsions can be controlled by choosing certain critical parameters, such as the size of the lipid droplets, the type of emulsifier, the type of emulsion and the type and structure of the triglycerides. This kind of knowledge is critical to developing new foods aimed at satiation and subsequent energy regulation and prevention of coronary heart disease.

### **Effect of the Interactions Between Sorbitan Monostearate and Candelilla Wax on Soybean Oil Gelation** Carolina M. Teixeira<sup>1</sup>, Thais V. Sarau<sup>1</sup>, Roberta C. Silva<sup>2</sup>, Luiz A. Gioielli<sup>1</sup>, and Juliana N.R. Ract\*<sup>1</sup>, *<sup>1</sup>University of Sao Paulo, Brazil; <sup>2</sup>Utah State University, USA*

Oleogels are considered a promising alternative to trans and saturated fats on the formulation of food products. The objective of this study was to evaluate the interactions of sorbitan monostearate (SMS) and candelilla wax (CW) as organogelators (OG) for soybean oil (SO) structuring, aiming at replacing simultaneously saturated and trans fats in tablespread formulations. SMS/CW blends in different proportions were evaluated for their structuring ability in soybean oleogels prepared using different concentrations of those blends. Visual analysis, yield value determination, and thermal behavior of the different oleogels stored for 24 h at 5, 25, and 35 °C were performed. An oleogel prepared with the 40/60 (SMS/CW) blend presented the highest yield value among all the oleogels prepared with OG at 6%, suggesting a synergistic interaction between SMS and CW. A tablespread was prepared using this oleogel as the lipid fraction and compared to a commercial margarine containing 23.6% of saturated fatty acids. The yield value of the commercial margarine was 3.3 times higher than the tablespread formulated with the selected organogel at 5 °C, a ratio that was gradually decreasing with temperature increase, until both spreads did not present any yield value at 25 °C. The tablespread prepared with the oleogel was spreadable, although softer than a commercial reference, presented satisfactory appearance, and contained only 14.5% of saturated fatty acids originally

present in soybean oil.

### **Effect of Palmitic Acid's sn-position and Solid Fat Content on Fasting Lipid Profile in Mice** Tong

Wang\*, *Iowa State University, USA*

Lipid randomization and interesterification change triacylglycerol (TAG) structure and fat's solid fat content profile. This study was designed to investigate how these changes affect lipid metabolism. Kilogram quantity of POP, PPO, and POO were obtained from a natural source or synthesized. The POP and PPO pair of fat was used to study the effect palmitic acid sn-distribution, and the pair of POO and a mixed fat made of PPP, OOO and POP was used to study the effect of solid fat content. Feed intake and body weight of mice were monitored during the trial, and serum lipid profile was determined after 6-week feeding. The pair of fats with different solid fat content did not significantly affect the concentrations of total serum cholesterol, HDL cholesterol, TAG, and non-esterified fatty acid (NEFA). However, the PPO fat significantly reduced feed intake, body weight and serum glucose concentration as compared to POP. These results suggest that the presence of solid fat at the level examined in this study does not affect lipid metabolism and lipemia, however, PPO significantly affects feed intake and NEFA and glucose concentrations. Palmitic acid at the sn-2 position of the TAG may have significant effect on appetite, which may be mediated via the gut receptors.

### **Effects of Liquid Coconut Oil vs. Oleogel on Human Blood Triglycerides, Glucose, Insulin, and Appetite**

Sze-Yen Tan<sup>1</sup>, Elaine W.Y Peh<sup>1</sup>, Alejandro G. Marangoni\*<sup>2</sup>, and Christiani J. Henry<sup>1</sup>, <sup>1</sup>*Singapore Institute for Clinical Sciences, Singapore*; <sup>2</sup>*University of Guelph, Canada*

We aimed to examine if coconut oil in a liquid or an oleogel form, affect blood triglycerides, glucose,

insulin, and appetite when co-ingested with a carbohydrate-rich meal. This was a randomised, controlled crossover study where eligible participants attended a baseline visit where baseline demographics were measured. On test days, participants arrived at the laboratory after an overnight fast of 10 hours. Upon arrival, the cannulation of the antecubital vein was performed and fasting capillary glucose, plasma insulin and triglycerides, and appetite sensations were measured. Following that, orange juice and rice porridge alone (control), or with 22.25g of coconut oil (CO) or 25g of coconut oleogel (CG) (22.25g coconut oil + 2.75g ethylcellulose to form oleogel) was consumed. Subsequently, capillary blood glucose, plasma insulin and triglycerides were measured at fixed intervals for 6 hours. Appetite sensations were also measured using visual analog scales every 30 minutes. Sixteen healthy young adult males completed the study (age=27±6 years, weight = 65.5±5.5kg, BMI=21.9±1.7 kgm<sup>-2</sup>). After test meals, glucose, insulin, triglycerides and appetite sensations changed significantly (time effects, p

### **Structuring Lipids for Possible Infant and Prenatal Maternal Nutrition** Casimir C. Akoh\*, *University of Georgia, USA*

Lipases are used in lipid structuring to add value, produce functional, healthful, and nutraceutical lipids to benefits human health. For infants, lipids contribute most of the energy needed for proper nutrition, growth, and development. To mimic the lipid composition of human milk fat (HMF), physically blended oils have been used in infant formula. Breast feeding has long been accepted as the best for infant feeding. With new interest in the nutritional needs of the infant, it is possible to target these needs using specific structured lipids (SLs). Our objective is to produce SLs as infant formula fat analogs that

mimic breast milk fat in composition using lipases. These SLs contain functional and physiologically important fatty acids for the infant. The HMF analogs were enzymatically prepared by acidolysis and interesterification reactions using different oils and fats substrates catalyzed specific and non-specific lipases. Some of the SL products can serve as infant formula fat analogs or as nutraceutical lipids intended for pregnant women. The SLs have high sn-2 palmitic acid content and comparable fatty acid composition to HMF. Fatty acids such as stearidonic (SDA), eicosapentaenoic (EPA), docosahexaenoic (DHA), gamma-linolenic (GLA), arachidonic (ALA), and oleic acids, were important components of the HMF analogs. Both DHA and ARA are important in brain development and cognitive functions of the infant. The HMF analogs should improve absorption of fatty acids and calcium. These HMF analogs may be incorporated into infant formulas to enhance the development and growth of infants or as nutraceutical lipids by pregnant mothers.

#### **Knowns and Unknowns of Polar Phytosteryl**

**Conjugates.** Laura Nyström\*, Laboratory of Food Biochemistry, Institute of Food, Nutrition and Health, Switzerland.

*Abstract pending.*

#### **Sequential Crystallization of High and Low Melting Waxes to Improve Oil Structuring in Wax-based**

**Oleogels** Iris Tavernier\*<sup>1</sup>, Chi Diem Doan<sup>2</sup>, and Koen Dewettinck<sup>3</sup>, <sup>1</sup>*Ghent University, Belgium*; <sup>2</sup>*Laboratory of Food Technology & Engineering, Ghent University, Belgium*; <sup>3</sup>*University of Gent, Belgium*

Today, a considerable amount of research is focusing on structuring oil-based products with alternatives for trans and/or saturated fats. Several studies have shown the potential of wax-based oleogels. Possibly, combining different waxes could

open up even more opportunities for designing tailor-made wax-based materials with specific properties for various food applications. The main objective of this study was to investigate the effect of combining a high-melting wax (sunflower or rice bran wax) with a low-melting wax (berry wax or BEW) on the crystallization and gelation behavior of the corresponding wax-based oleogels in rice bran oil (RBO). Since sunflower wax (SW) and rice bran wax (RBW) have a similar chemical composition but a very different crystallization behavior, they were also combined in a wax-based oleogel to examine the occurrence of co-crystallization and/or crystal co-existence. Phase diagrams confirmed the sequential melting of the high- and low-melting waxes and the simultaneous melting of RBW and SW. For all three combinations (RBW:SW, SW:BEW and RBW:BEW) two different crystal morphologies could be discerned and powder XRD analysis gave no indication of the presence of co-crystals. Small amplitude oscillatory experiments (amplitude sweeps and frequency sweeps) and textural studies revealed the reinforcement of the high-melting wax crystal network with the addition of the low-melting berry wax, which most probably crystallizes in the voids remaining after crystallization of the high-melting wax. This research provides opportunities for successfully combining high- and low-melting substances in creating semi-solid materials with a wide variety in rheological and textural properties.

#### **Antioxidant Capacity of Different Bioactives in an Oil-like-Structured Heterogeneous Medium**

**Designed for Food Applications** Maria Chatzidaki\*<sup>1</sup>, Maria Zoumpanioti<sup>1</sup>, Giorgos Sotiroudis<sup>1</sup>, Erwann Durand<sup>2</sup>, Jérôme Lecomte<sup>3</sup>, Claire Bourlieu<sup>4</sup>, Aristotelis Xenakis<sup>1</sup>, and Pierre Villeneuve<sup>5</sup>, <sup>1</sup>*NHRF, Greece*; <sup>2</sup>*CIRAD, France*; <sup>3</sup>*CIRAD, Greece*; <sup>4</sup>*UMR IATE - INRA/CIRAD/UM2/SupAgro, France*; <sup>5</sup>*CIRAD/INRA,*

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During the last decades there has been an increasing interest from food industry towards edible water-in-oil (W/O) heterogeneous systems similar to vegetable oils' structure and able to solubilize bioactive molecules of different polarities. In this context, effective delivery systems of antioxidants (AO) maximizing their activities in various environments are highly needed. The use of a W/O microemulsion as carrier of AO could be a solution. Such system, based on medium chain triglycerides, was tested to deliver phenolic acids (p-hydroxybenzoic, protocatechuic and gallic), alcohols (tyrosol and hydroxytyrol) and esters. Propionic esters isomers of hydroxyphenyl acetic (HPA) acid were also synthesized using lipase from *Candida antarctica*. All the AO components were tested either delivered in free forms or in W/O microemulsion using complementary antioxidant tests in lipophilic (EPR), heterogeneous (CAT) or hydrophilic (ORACFL) environments. The most efficient bioactives were then evaluated for their ability to reduce the level of reactive oxygen species (ROS) using fibroblast cell lines producing high ROS levels. It was found that the bioactives had a different behaviour in the presence of the oil-like carrier probably due to their partial partition at the interface. In ORACFL for instance micro-emulsion induced higher equivalent Trolox system for most AO. The cellular response of fibroblast was also different when the antioxidants were delivered in the microemulsion instead of DMSO. Altogether, these experiments proposed an integrated approach of the physicochemical and other parameters that modulate the AO activity in various environments that are encountered in food products or along the digestive tract.

**Sonocrystallization of Interesterified and Physical Blends of High Oleic Sunflower Oil (HOSO) and Tristearin** Jeta V. Kadamne\*<sup>1</sup>, Ebenezer A. Ifeduba<sup>2</sup>,

Casimir C. Akoh<sup>2</sup>, and Silvana Martini<sup>1</sup>, <sup>1</sup>Utah State University, USA; <sup>2</sup>University of Georgia, USA

The physical (PB) and interesterified (IE) blends of high oleic sunflower oil and tristearin with 20 and 30% stearic acid at the sn-2 position were crystallized without and with application of high intensity ultrasound (HIU). The IE samples were crystallized at supercoolings ( $\Delta T$ ) of 12, 9, 6 and 3 °C while PB were crystallized only at  $\Delta T = 12$  °C due to their slow crystallization characteristics. The PB crystallized faster and had higher SFC than IE at  $\Delta T = 12$  °C and HIU did induce crystallization in the PB samples. Induction in crystallization with HIU was observed at  $\Delta T = 6$  and 3 °C for IE C18:0 20% while at  $\Delta T = 9, 6$  and 3 °C for IE 30%. HIU induced the formation of smaller and more crystals in all samples. The DSC profiles of IE 20% samples showed that HIU induced fractionation in the sample along with crystallization of lower melting TAGs. While in the IE C18:0 30% samples, the high and low melting TAGs crystallized separately and HIU induced their co-crystallization. HIU significantly improved the viscosity,  $G'$  and  $G''$  of the IE 20% samples except at  $\Delta T = 12$  °C. While the  $G'$  and  $G''$  of IE 30% did not increase significantly, the viscosity increased significantly at  $\Delta T = 9, 6$  and 3 °C and it increased from  $1526.5 \pm 880.3$  to  $6818 \pm 901.4$  Pa.s. at  $\Delta T = 3$  °C. These IE fats with improved crystallization properties can be used as trans fat alternatives.

## EAT 5 / S&D 5.2: Interfacial Phenomena in Complex Food Systems

*Chairs: Nitin Nitin, University of California, Davis, USA; and Ozan Ciftci, University of Nebraska-Lincoln, USA*

### **Effect of Membrane-associated Peptide on the Dynamics of Bicontinuous Microemulsions via Quasi-elastic Neutron Scattering and Neutron Spin-echo**

Douglas G. Hayes\*<sup>1</sup>, Veerendra K. Sharma<sup>2</sup>, Volker S. Urban<sup>2</sup>, Hugh M. O'Neill<sup>2</sup>, S. Venkatesh Pingali<sup>2</sup>, Michael E. Ohl<sup>2</sup>, Eugene Mamatov<sup>2</sup>, and Madhusudan Tyagi<sup>3</sup>,  
<sup>1</sup>University of Tennessee, USA; <sup>2</sup>Oak Ridge National Laboratory, USA; <sup>3</sup>National Institute of Standards and Technology, USA

A grand challenge for the soft matter scientific community is to obtain a deeper understanding of dynamics at several different length and time scales. This paper will describe the short- and long-range dynamics of bicontinuous microemulsions (BMEs), a potentially useful biomembrane mimetic system, by quasi-elastic neutron scattering (QENS) and neutron spin echo (NSE), respectively. The investigation focuses upon the effect of melittin on BMEs formed by water/sodium dodecyl sulfate (SDS)/1-pentanol/dodecane. Melittin is an antimicrobial peptide (AMP) with potential utility as an agent against antibiotic-resistant microorganism and cancer, among others, and penetrates within the surfactant monolayers of the BMEs. (BMEs may be a potentially valuable delivery system for AMPs.) QENS analysis indicated two distinct motions of the BME surfactant monolayers, namely (i) lateral motion of the surfactant on the surface of the oil channels and (ii) internal motion of the surfactants. It is found that melittin hindered both the lateral and the internal motion, thereby acting as a stiffening agent. NSE analysis indicated that melittin has a slight, lesser, impact on the long-range dynamics.

### **Structuring Food Emulsions Through Lipid Crystallization at the Oil-Water Interface** Dérick Rousseau\*, Ryerson University, Canada

Incorporation of emulsions into processed foods offers significant possibilities in regards to texture improvement, cost reduction, and health enhancement. In both oil-in-water and water-in-oil emulsions, an emerging tool is the use of direct lipid crystallization at

the oil-water interface, which can strongly impact emulsion kinetic stability against coalescence and phase separation, functionality and rheology. This presentation outlines some of the factors that govern interfacial crystallization, notably emulsion dispersed phase volume fraction, lipid surface activity and liquid-solid phase transition temperature as well as molecular complementarity between the crystallizing lipid and interfacially-bound emulsifier. Specific examples of the impact of interfacial crystallization discussed include the ability of crystalline shells to transform water-in-oil emulsions into reservoirs for the controlled release of aqueous compounds as well as their capacity to protect oil cargos during in vitro digestion of oil-in-water emulsions.

### **The Effect of Interfaces in Nanodroplets Loaded With Nutraceuticals on Their Release from Drinks to Human System** Nissim Garti\*, Hebrew University, Israel

Dilutable microemulsions (DME) are nanodroplets composed of oil phase, surfactants, cosurfactants and cosolvents (no water) and other ingredients that facilitate formation of concentrates with the capability of being diluted with any amount of water and inverting from W/O to bicontinuous and to O/W nano structures. The phase diagrams describing these formulations are termed "U-type phase diagrams" and the structures are termed "umbrella type droplets". The concentrates are loaded (solubilized) with bioactives (guest molecules) that are lipophilic and insoluble in water. The systems are transparent, Newtonian and thermodynamically stable. The bioactives are, in most cases, located at the interface of the structures along any dilution stage. The loaded nutraceuticals are, upon dilution, forming soft drinks. The structures are consisting also of additional ingredients allowing the bioactives to 'survive' the acidic conditions of the human stomach and are aimed to be released from the guts jejunum membrane "on demand" to the blood stream. We will bring few such examples including CBD (the non narcotic fraction of Cannabis) and other antioxidants and nutraceuticals.

The formulations are derived from Monte Carlo Dynamic Simulations calculations, and advanced analytical tools, to determine the location of the solubilized nutraceuticals at any stage of its dilution and across the guts membrane.

***In situ* Observation of Template Effects of Emulsifiers with Different Fatty Acid Moieties** Chinami Ishibashi\*<sup>1</sup>, Hondoh Hironori<sup>2</sup>, and Satoru Ueno<sup>2</sup>, <sup>1</sup>*Hiroshima University, Japan*; <sup>2</sup>*Graduate School of Biosphere Science, Hiroshima University, Japan*

Template effect is the promotion of fat crystallization by crystallized emulsifiers that were nucleated prior to fat. Although an impurity effect also promotes a nucleation of fat crystals on the surface of an emulsifier, the crystallization mechanism is different between template and impurity effects. Many previous studies reported that the similarity in fatty acid composition between a fat and an emulsifier should be important for the template effect. An emulsifier crystal having similar fatty acid packing to a fat crystal would provide a favorable spot for fat crystal nucleation. The molecular interaction at the fat-emulsifier interface will promote the orientation of fat crystals. However, there are few reports about the fat crystal orientation promoted by the template effect, and the difference between template and impurity effects are not concerned so much. The purpose of this study is *in situ* observation of crystallization behavior of fat crystals on an emulsifier crystal in order to reveal the difference between the template and the impurity effects. We used palm-mid-fraction (PMF) as an oil phase and sorbitan tripalmitate (STP), sorbitan tristearate (STS) and sorbitan tribehenate (STB) as an emulsifier. The results were as follows; (i) When fatty acid moiety of emulsifier were similar to those of fat, PMF crystals oriented along the STP or STS crystals, suggesting template effect. (ii) When fatty acid moiety of emulsifier did not show the similarity to those of fat, PMF randomly crystallized around STB crystals, suggesting impurity effect.

**Thermodynamics and Adsorption Mechanisms for Hydrophobic Food Surfactants at Interfaces** Stephanie R. Dungan\*, *University of California, Davis, USA*

Lipid amphiphiles are found widely in foods and other biological materials. Their tendency to accumulate and lower the energy of interfaces plays a critical role in food processing and in metabolic actions such as digestion and cellular transport. Interpretation of interfacial phenomena is often based on studies of water-soluble molecules, whose behavior is heavily influenced by the hydrophobic effect. Instead, in this presentation, the behavior of water-insoluble surfactants at oil/air, oil/water and air/water interfaces will be discussed. Equilibrium surface tension (oil/vapor) measurements of various triacylglycerol or free fatty acid molecules as a function of temperature were used to assess surface excess internal energy and entropy. Length of the acyl chain is the main feature to influence surface excess energy, in contrast to degree of saturation or triacyl or monoacyl character. These findings clarify the very subtle effects of composition on surface tension of food oil mixtures. Our understanding of the behavior of lipid phases alone can then be extended to oil/water mixtures, where lipid amphiphiles have a much more pronounced and complex effect on interfacial tension. Dynamic interfacial and surface tensions were also probed, using drop profile tensiometry, for caprylic acid, monocaprylin and phosphatidylcholine. When the amphiphile is dissolved as individual molecules in a triglyceride or water phase, transport to the interface is driven by diffusive mechanisms. Phospholipid transport kinetics are more complex, as these molecules are nearly soluble in both triglyceride and water. Their adsorption kinetics are much slower, and heavily dependent on the structure of the vesicle dispersion.

**An In-depth Look at Bakery Applications of a Structured Monoglyceride Gel** Alejandro G.

Marangoni<sup>1</sup>, and Kaustuv Bhattacharya\*<sup>2</sup>, <sup>1</sup>*University of Guelph, Canada*; <sup>2</sup>*DuPont Nutrition & Biosciences ApS, Denmark*

After successfully addressing the use of trans fat in the food industry the focus is now on reduction of saturated fats and in certain parts of the world palm oil and its derivatives due to sustainable issues. The primary approach has been replacing fats rich in saturated fatty acids with structured liquid oils using

different ingredients and techniques. But not all solutions are food approved or have wide range acceptable application opportunities. The present work is based on oleogel emulsion technology using an emulsion structured by crystalline multi-layers of monoglyceride interspersed with water in presence of anionic co-emulsifiers in the alpha polymorphic form. This technology is appropriate for manufacturers of oils and fats, bakery products, and others, who want to improve the sustainability footprint and health benefits of their existing products. By using this technology, 'palm free', zero trans and reduced saturated fats can be claimed. The solution is oil source independent providing freedom of choice for the manufacturer. A diverse range of bakery applications including analytical data on the emulsion oleogel and dough containing such using NMR, Confocal laser imaging and Rheology will also be highlighted.

**Improve Foam Properties—Multifunctional Cellulose Polymer** Terry Crutcher\*<sup>1</sup> and Bert Kroon<sup>2</sup>, <sup>1</sup>*Ashland Specialty Ingredients G.P., USA*; <sup>2</sup>*Ashland Specialty Ingredients, The Netherlands*

Many household and personal care wash applications exhibit trade mark foamability and rheological aesthetics that consumers have come to expect and enjoy. The foam profile of a consumer product may serve as an indicator of its performance in the minds of many end users. It is becoming more of a challenge to deliver cost efficient and robust foam performance as traditional foaming ingredients like alkanolamides and alkyl sulfates are of toxicological concern. Today there is a need for better more efficient eco-friendly foaming technologies that satisfy finished goods manufacturers' desire for more sustainable high performance products with reduced surfactant/chemical content in the effluent. It has been found that a modified polysaccharide derivative reduces the surface tension at the air liquid interface sufficiently to boost and stabilize foaming in care compositions like hand dish detergent, hand soap, and hard surface cleaners. Additionally these naturally derived cellulosic polymers build rheology, improve skin feel, and mildness of cleansing compositions in which they are incorporated. Research will be presented to validate

equivalent foamability at reduced surfactant concentration. The data to confirm the foam enhancing properties of a multifunctional naturally derived modified hydroxypropyl methyl cellulose polymer.

**Interfacial Interaction and Emulsification Behaviour of Lentil Protein Isolate and Fenugreek Gum Complexes** Supratim Ghosh\* and Natalie Longmore, *University of Saskatchewan, Canada*

The aim of this work was to improve solubility and emulsification behaviour of lentil protein isolates (LPI) by their interaction with fenugreek gum (FG). Complex formation between the protein and polysaccharide molecules was studied as a function of pH (7 to 1.5), and mixing ratios (1:3 to 3:1). The soluble complexes at pH 2 and 7 were further used to investigate the interfacial and emulsification behaviour. At a total biopolymer concentration of 0.1 wt% significant decrease in oil/water interfacial tension was observed. From 23.9 mN/m for pure oil/water interface, it decreased to ~17 and ~13 mN/m, at pH 2 and 7, respectively. No significant change in interfacial tension between the LPI-FG complex and pure LPI was observed. In contrast, presence of FG significantly decreased interfacial storage modulus and the values were higher at pH 2 compared to pH 7, which was ascribed to strong -ve charge on both the biopolymers at pH 7 leading to a weaker interfacial interaction. The mixed biopolymer solutions were used to prepare 1 wt% oil-in-water emulsions using multiple passes through a high pressure homogenizer at pH 2 and 7. Stable emulsions were generated at both pHs where the average droplet diameters were less 500 nm. Results showed that presence of FG significantly improved emulsification behaviour of LPI due to improved solubility, and lowering of the interfacial modulus of the complex. Interfacial complexation between LPI and FG could be a novel way to utilize natural ingredients in the development of food emulsions for beverage application.

## EAT-P: Edible Applications Technology Poster Session

Chair: Michael Rogers, University of Guelph, Canada

### 1. Structural and Mechanical Properties of Palm Oil in the Presence of Air and Sugar Hardeep Devgan\*, and D errick Rousseau, Ryerson University, Canada

Air incorporation is often used in the food industry as a means to improve product volume and texture. The aim of this research was to explore the impact of aeration on a 1:1 wt% ratio blend of palm oil and confectioner's sugar containing lecithin. Over a period of four weeks, product density, blend texture and microstructure were assessed. Replicates were first controllably cooled in a benchtop scraped-surface heat exchanger from 60°C to 28°C at 5°C/min and then transferred to a Hobart stand mixer equipped with a paddle blade to incorporate air. Aeration expectedly decreased product density with increased mixing time, which also resulted in the incorporation of more, smaller air bubbles within the fat-sugar matrix. Whipping also significantly altered product texture, though this was heavily-dependent on the duration of aeration. The study serves as the foundation for the design of aerated palm oil-sugar blends containing lower amounts of palm oil while maintaining product texture.

### 2. Impact of pH, Temperature, and Molecular Environment on Curcumin Stability: Aqueous Solutions vs. Emulsions Mahesh M. Kharat\*, and David J. McClements, University of Massachusetts Amherst, USA

Objective: The application of curcumin in food systems is often challenging due to its poor water solubility, high chemical instability, and low oral bioavailability. In this study, the impact of pH, storage temperature, and molecular environment on the physical and chemical stability of pure

curcumin was examined in aqueous solutions and in oil-in-water emulsions. Methods: Stability of curcumin and its crystallization were studied using a spectrophotometric method. Physicochemical properties of emulsion were studied using static/dynamic light scattering and microscopy. Results: Unlike curcuminoids, pure curcumin was highly unstable in alkaline aqueous solutions (pH  $\geq 7.0$ ) and tended to crystallize out of acidic solutions (pH  $< 7$ ). This was mainly due to the changes in the molecular structure of curcumin under different pH conditions. When incorporated into oil-in-water emulsions (30% MCT, 1 mg curcumin/g MCT,  $d_{32} \approx 298$  nm) its water dispersibility and chemical stability were improved. When incubated at 37 °C for 1 month, curcumin retention was  $>85\%$  in emulsions stored under acidic conditions (pH  $< 7$ ), whereas 62, 60, and 53% was retained by emulsions stored at pH 7.0, 7.4, and 8.0, respectively. Emulsions stored under acidic conditions presented a little change in yellow color, but it faded when stored under alkaline conditions. No droplet aggregation or creaming was observed in emulsions stored for 31 days at ambient temperature. Conclusion: These results suggest that emulsion-based delivery systems may be suitable for enhancing the water dispersibility and improving the chemical stability of curcumin, which would enable its application in foods and supplements.

### 3. Enhance the Color and Physical Stability of Curcumin Using Emulsion-based Delivery System Bingjing Zheng\*, University of Massachusetts Amherst, Food Biopolymers and Colloids Lab, USA

Curcumin was incorporated into an aqueous solution and three different delivery



systems: dimethyl sulfoxide, excipient emulsion, emulsion-filled alginate beads, and emulsion-loaded chitosan beads. Hydrogel beads were fabricated from curcumin-emulsion contained polysaccharides (alginate or chitosan) using an extrusion device combined with ion gelation (calcium or tripolyphosphates). All four matrices samples incubated in both pH7 and pH3 conditions at 55°C for 14 days, respectively. Initially, lipid droplets protected curcumin from pH changed color alteration. Only curcumin solution in pH7 had a color change into orange-brownish and others remained yellow. After acidic incubation, the color yellow ( $b^*$  value) of the samples decreased in following order: curcumin emulsion (8%) > curcumin solution (27%)> chitosan beads (42%) > alginate beads (80%); after neutral incubation, the color yellow ( $b^*$  value) of the samples followed a similar order: chitosan beads (33%)> curcumin emulsion (68%) > curcumin solution (83%) >alginate beads (93%). The results showed curcumin was more stable in acidic condition than in neutral condition. The anionic alginate beads were not suitable to encapsulate curcumin because it was an originally negatively charged gel that could cause the degradation of curcumin; conversely, the cationic chitosan beads protected the curcumin from the neutral condition and slowed the degradation rate. Overall, these results provide valuable information for the development of emulsion-based delivery systems to encapsulate and protect curcumin for functional food applications.

**4. In vitro Digestion of a DHA-enriched Emulsion: Pectin's Effects on Digestibility and Bioaccessibility** Xinjie Lin, and Amanda Wright\*,  
*University of Guelph, Canada*

With the continued popularity of functional foods, attention to ingredient digestive interactions, including between dietary fibres and

lipids, is warranted. This study investigated how high methoxyl apple pectin (0.00, 5.68, or 100.00 mg/5.0 g emulsion), combined with variable gastric pH (2.0, 3.0 or 4.8), impacted the digestion of a DHA-rich algal oil lecithin-stabilized emulsion ( $D_{3,2} = 0.137 \pm 0.001 \mu\text{m}$ ) under simulated upper gastrointestinal conditions. At low gastric pH (2.0 and 3.0), the emulsion was extensively destabilized. The addition of a low, but not high, level of pectin reduced the destabilization at pH 3.0. The maintenance of small lipid droplets during the gastric phase was associated with ultimately higher DHA bioaccessibility (>69%,  $p < 0.05$ ) and higher early, but not eventual, lipolysis in the duodenal phase. Samples containing 100.00 mg pectin/5.0 g emulsion had the lowest overall lipolysis and DHA bioaccessibility across all pH values ( $p < 0.05$ ). Therefore, pectin content and gastric pH interactively impacted emulsion digestion. Also, samples with higher in vitro gastric stability had higher lipid digestibility and DHA bioaccessibility. To investigate the impact of a food matrix on pectin effects, the presence of applesauce (pH = 3.4,  $0.778 \pm 0.016$  mg GAE/g (wet weight) total phenolics,  $10.45 \pm 0.03$  wt% total solids) was investigated. Compared to the presence of pectin alone, the applesauce with matched pectin content led to further emulsion destabilization and limited lipolysis and DHA bioaccessibility. These results support the rational design of emulsions that maintain gastric structure for the delivery of long chain polyunsaturated fatty acids.

**5. Chemical Synthesis of Pure Docosapentaenoic and Its Derivatives from Icosapentaenoic Acid**

Hiroshi Tabata\*, Tadahiro Tsushima, Jun Fujii, Kazuhiro Miyake, Yoshihisa Misawa, Masashi Otani, and Naomichi Baba, *Bizen Chemical C. Co. Ltd., Japan*

Docosapentaenoic acid (DPA) is a minor

component of fish oil, and a polyunsaturated fatty acid with 22 carbon atoms with five non-conjugated all-cis double bonds. DPA has been highlighted in recent years with its specific biological activities different from EPA and DHA. Despite the importance of DPA in its potential benefits, characteristic biological properties have not been fully understood yet due to the lack of pure DPA in a large amount. We have successfully produced DPA with higher than 70 % purity from fish oil so far. In the present study, aiming at increasingly higher purity, chemical syntheses have been developed based on improved malonic ester synthesis affording DPA ethyl ester with higher than 98% purity through five steps from EPA ethyl ester. This process includes direct conversion of malonic acid derivative obtained from EPA ethyl ester to DPA ethyl ester instead of DPA free fatty acid by refluxing the derivative in propionic acid. The present study also includes syntheses of novel phospholipid derivatives of DPA.

**6. Effect of Essential Oils on the Crystallization Behavior of Cocoa Butter** Zachary Cooper\*, and Silvana Martini, *Utah State University, USA*

Cocoa butter (CB) was crystallized with and without the addition of essential oils (EsO) at 20 and 21 °C. The EsO was added at a 0.13% level and consisted of a mixture of cinnamon oil (0.11%, nutmeg oil (0.01%), and clove oil (0.01%). Two crystallization peaks were observed during isothermal crystallization of CB in a differential scanning calorimeter (DSC). The first peak had an induction time ( $t_c$ ) of 0.4 +/- 0.1 min and the second one of 37.9 +/- 0.3 min for the CB crystallized at 20 °C and 2.1 +/- 0.6 min and 52.3 +/- 2.0 min for the CB crystallized at 21 °C. No significant difference ( $p > 0.05$ ) was observed in the  $t_c$  for the first peak when the sample was crystallized at 20 and 21 °C with the addition of EsO nor for the second peak of the samples crystallized

at 20 °C. A significant ( $p < 0.01$ ) increase in  $t_c$  was observed when CB was crystallized with the EsO at 21 °C. This suggests that the EsO delayed the polymorphic transformation associated with these two crystallization peaks. In addition, the EsO significantly induced the crystallization of CB at 21 °C as measured by solid fat content (SFC) but did not affect its crystallization at 20 °C. CB crystallized at 21 °C without the EsO reached a SFC of 30.9 +/- 1.3% after 140 min at crystallization temperature, while samples crystallized with the EsO reached a final value of 56.1 +/- 0.6%.

**7. Sonocrystallization of Interesterified Soybean Oil in High Oleic Sunflower Oil: Effects of Chemical Composition, Sonication Power, and Duration**

Juhee Lee\*, Roberta C. Silva, and Silvana Martini, *Utah State University, USA*

The aim of this study was to investigate sonocrystallization behavior of interesterified soybean (IESBO – 45% saturated fat) oil diluted with high oleic sunflower oil (HOSFO). A 20:80 IESBO:HOSFO sample was crystallized at 25 °C without and with the application of high intensity ultrasound (HIU – 20 kHz) using tip amplitudes of 24 µm and 108 µm and pulse durations of 5, 10, and 15 sec. In addition, a 50:50 IESBO:HOSFO was crystallized at 32 °C without and with the application of HIU using the same tip amplitudes for only 10 sec. In general, sonication induced crystallization, decreased crystal size, and increased elasticity in both samples. This effect was more significant for the 50:50 sample. An exception to this behavior was observed in the 20:80 sample sonicated for 10 sec using the 24 µm tip amplitude where a delay in crystallization was observed resulting in lower elasticity ( $p > 0.05$ ). Sonication applied at 108 µm amplitude for 10 sec was the most affective at reducing crystal size and increasing elasticity from 62 ± 6 Pa to 175 ± 13 Pa for the 20:80 sample ( $p < 0.001$ ) and from 534 ± 74 Pa to 21,774 ± 2,547 Pa for the 50:50 sample ( $p <$

0.0001). In general, sonication decreased melting peak temperature ( $T_p$ ) ( $p < 0.001$ ) and increased melting enthalpies ( $p < 0.01$ ) in the 50:50 samples only. These results show that lipid sonocrystallization is driven by sonication process parameters such as tip amplitude and duration and by sample chemical composition.

**8. Temperature Effect on Foamability, Foam Stability, and Foam Structure of Milk** Raymond Sanedrin\*<sup>1</sup>, Katrin Oetjen<sup>2</sup>, Christine Bilke-Krause<sup>2</sup>, Mania Madani<sup>2</sup>, and Thomas Willers<sup>2</sup>, <sup>1</sup>KRUSS USA, USA; <sup>2</sup>KRUSS GmbH, Germany

Milk is a daily consumed product and its intriguing foaming properties are important e.g. when processing dairy-based foams such as whipped cream or cappuccino-style beverages. Dairy foams are colloidal systems formed by air bubbles, water, and surface active proteins. Temperature is a very important parameter influencing the foaming behavior of milks containing lipids. We investigated the temperature dependence of foamability, foam stability and foam structure between 5 and 60°C for four types of milk: ultra-high temperature processed milk and pasteurized milk, each with 1.5 and 3.5% fat content. All foam measurements were performed using the KRÜSS DFA100. We found that foamability and foam stability exhibit a strong minimum at 25°C thereby extending the existing literature with novel data. These and our temperature dependent dynamic surface tension data of the investigated milks support the idea that the state of the milk-fat globule is responsible for detrimental effects on the foaming behavior. In this talk, we explain how at ~25°C the partially crystalline state of the milk-fat globules negatively affects foaming properties. Finally, we determined for the first time the temperature and time dependence of the foam structure (bubble size distribution) for all investigated milks. With this the

aging behavior of the foams can be characterized and differences in foam structure's homogeneity can be related to foam stability.

**9. Physical Properties of Sodium Caseinate-stabilized Nanoemulsions Prepared by a Combination of a High-energy Homogenization and Evaporative Ripening Methods** Juan M. Montes de Oca-Avalos<sup>1</sup>, Roberto J. Candal<sup>2</sup>, and Maria L. Herrera\*<sup>3</sup>, <sup>1</sup>ITPN- UBA- CONICET, Argentina; <sup>2</sup>3IA- UNSAM, Argentina; <sup>3</sup>University of Buenos Aires, Argentina

Nanoemulsions have been prepared by high and low-energy homogenization methods. The objective of the present study was to investigate the formation of sodium caseinate (NaCas)-stabilized nanoemulsions using a combination of a high-energy homogenization and evaporative ripening methods. The effects of protein concentration and sucrose addition on physical properties were analyzed by dynamic light scattering, Turbiscan analysis, confocal laser scanning microscopy and small angle X-ray scattering. In all nanoemulsions the ratio NaCas/sunflower oil was 0.6. Aqueous phase contained sucrose in concentrations of 0, 2, 4, 6, or 8 wt.% and NaCas in concentrations of 1.0, 2.0, 3.0, or 4.0 wt.%. Results show that using the evaporative method, stable monodispersed nanoemulsions were obtained with a mean diameter between 100-200 nm and a narrow distribution. If ethyl acetate was not added to the sample, conventional emulsions in the range of micrometers were obtained with a polydispersed 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. Nanoemulsions were more stable than conventional emulsions and the destabilization

mechanisms were different indicating that protein behavior changed with droplets scale.

#### 10. Thermal and Oxidative Stability of Oleogel

**Margarine** Thais L.T Silva\*, Kamila F. Chaves, and Daniel B. Arellano, *Unicamp, Brazil*

Organogels have been used as a promising alternative to replace trans and saturated fatty acids in lipid based food as margarine, spreads, and shortenings. This work aimed was to produce and evaluate the thermal and oxidative stability of margarine reduced in saturate fatty acids using oleogels technology. The commercial and oleogel margarine, CM and OM respectively, was evaluated during six months at 5°C, in different times (T0, T1, T2, T3, T4 e T5), regarding oxidative stability (OSI) at 110°C in Rancimat, peroxid value (PV) and thermal cyclization (5-35°C). CM showed irreversible structure loss at 35°C since T0. The OM showed small oil exudation at 35°C, however, this exudation was reversible when sample returned to storage conditions, at all times. OSI presented significant changes, CM had induction time in T0 22.32 hours while OM presented 30.02 hours, at T5 the difference was smaller but OM still remained greater. PV of OM was higher in the first times (T0, T1 e T2), but at the end, values were statistically similar. The higher PV found was 2.64 meq O2/Kg for OM at T5, which represents considerable low values after six months of storage. The OM is a margarine with a reduction of 36% of saturated fatty acids, and though the higher amounts of unsaturated fat, this sample showed better oxidative and thermal stability than CM.

#### 11. Oil/Water Interfacial Tension and Transport Kinetics of Lipid-based Amphiphiles to the Interfaces

Tong Xu\*, and Stephanie R. Dungan, *University of California, Davis, USA*

In chemical and physical processes such as emulsification, oil/water interfaces are created very rapidly. The knowledge of interfacial tension

and mass transfer mechanisms of surfactants have important implications for processing and final product structure. The objective of our research was to investigate the interfacial energy and transport kinetics of lipid-based amphiphiles with poor water solubility, including free fatty acids and monoglycerides, in different oil media using a drop profile tensiometer. The addition of both monocaprylin and caprylic acid to tricaprylin decreased oil/water interfacial tension dramatically and caused the tension to decrease over time. Monocaprylin was particularly effective, decreasing tricaprylin tension by over 80% for the concentration of 0.1M. Purchased corn oil contained native components that promoted a substantial and time-dependent decrease in the interfacial tension. Fatty acid addition at low concentrations actually increased the tension, due to apparent interactions between native amphiphiles and the fatty acid. Purification using magnesium silicate removed the native amphiphiles, yielding a much higher and time-independent interfacial tension. This tension was now reduced by addition of fatty acid at all concentrations. It is diffusion-limited for the transport of these amphiphiles to a pendant water droplet interface. For the monoglyceride, possible roles of self-assembled structures in the triglyceride were also probed. The observation of interfacial tension and complex kinetics in our research can be harnessed to improve processes such as oil uptake, wetting, nucleation, emulsification and detergency. Our results are of particular significance in the utilization of GRAS, lipid-based amphiphiles, including those native to commercial food oils.

**12. In vitro Digestion of Organogel Based Nanoemulsion with Candelilla Wax**

Kubra Sislioglu\*<sup>1</sup>, Ihsan Karabulut<sup>2</sup>, and D. Julian McClements<sup>1</sup>, <sup>1</sup>*University of Massachusetts, Amherst, USA*; <sup>2</sup>*Inonu University, Turkey*

Co-ingested digestible lipids (such as triacylglycerols) promote the bioavailability of lipid-soluble bioactive agents (such as drugs, nutraceuticals, and vitamins) by increasing the amount of mixed micelles formed in the small intestine. Lipid-based delivery systems are therefore being designed to enhance the bioavailability of lipid-soluble bioactive agents, including nanoemulsions, nanoliposomes, and solid lipid nanoparticles (SLN). Solid lipid nanoparticles are digested more slowly than liquid lipid nanoparticles, and may therefore be used to control the release of encapsulated bioactive agents in the gastrointestinal tract (GIT). However, SLN's may expel encapsulated substances during storage due to their highly ordered crystalline structure. In this study, nanostructured lipid carriers (NLC) were developed to overcome this problem, which consist of nanoparticles containing a mixture of solid and liquid lipids. Candelilla wax, which is capable of a liquid-to-gel transition at low concentrations due to organogelation, was used to prepare the nanoemulsions instead of solid fat. The impact of lipid phase composition on the gastrointestinal fate of Candelilla wax NLCs was determined using a simulated GIT model. Changes in particle size, charge (zeta-potential) and microstructure of the samples was measured after exposure to mouth, stomach, and small intestine conditions. Nanoemulsions and NLC behaved similarly in the simulated GIT in terms of their particle properties, but digestion of the lipid particles by lipase was inhibited in the presence of candelilla wax. This phenomenon may be used to create delivery systems that can control the release of encapsulated bioactive agents in the GIT.

**13. Ultrasound as a Tool to Enhance Physical Properties in Binary Mixtures of Cocoa Butter-CB**

**Equivalents** Nayma I. Murillo Hernandez<sup>1</sup>, Elena Dibildox Alvarado\*<sup>1</sup>, and Silvana Martini<sup>2</sup>, <sup>1</sup>*Universidad Autónoma de San Luis Potosí, Mexico*; <sup>2</sup>*Utah State University, USA*

High-intensity ultrasound (HIU) and low-frequency (20 kHz) was tested to enhance the physical properties and remove eutectic points of mixtures of cocoa butter (CB) with cocoa butter equivalents (CBE). CBE is similar to the CB in chemical composition. This work aimed at studying the effect of HIU on phase behavior and physical properties of mixtures of CB-CBE extender (CBEE) at 5 and 50% (w/w), and CB-CBE improver (CBEI) at 5%. Fat mixtures were crystallized under tempering, with and without application of HIU at 400 W/cm<sup>2</sup> by 5 seconds. Microstructure study showed that sono-crystallized mixtures developed greater quantity of small and homogeneous crystals, that the mixtures without sonication. Mixtures with 5 and 50% of CBEE showed a significant increase in hardness (25 and 20%, respectively). Likewise, both compositions showed higher elastic properties (higher G'). These CBEE mixtures did not show increase in the melting temperature (i.e. 32.53 °C, 32.93 °C) and its X-RD patterns were characteristic of the  $\beta_2V$  form. The 5% of CBEI generated low solid fat content values, hardness and viscoelastic properties; and caused a decrease in melting temperature, known as eutectic effect. Such behavior of mixture CBEI disappeared when HIU was applied generating a strong crystal lattice (6400 gforce v.s. 2350 gforce), better viscoelastic values (Higher G'), as well as shown a significant increase (p<0.05) in the melting temperature (33.60 °C v.s. 30.11 °C), which corresponds to the melting of  $\beta_2V$  crystals. HIU had an important effect enhancing the functional properties in cocoa butter the mixtures.

#### 14. Organogels Developed Through Mixtures of Monoglycerides and Phosphatidylcholine at Low Concentrations

Jorge F. Toro-Vazquez\*<sup>1</sup>, Mayra Aguilar-Zarate<sup>1</sup>, Flor Alvarez-Mitre<sup>2</sup>, Miriam A. Charo-Alonso<sup>1</sup>, and Marisol Dávila-Martínez<sup>1</sup>, <sup>1</sup>Universidad Autónoma de San Luis Potosí, Mexico; <sup>2</sup>Universidad Autónoma de San Luis Potosí, Mexico

The development of organogels is the result of molecular self-assembly of gelator molecules, through short-range intermolecular interactions that results in the formation of 3D crystal networks that immobilize organic solvents. The phosphatidylcholine (PC) and monoglycerides (MG) develop viscoelastic organogels in a vast variety of solvents. However, gel formation with these molecules requires of high concentrations and, sometimes the addition of a co-surfactant. We investigated the organogelation of safflower (SO) and mineral oil (MO) using combinations of commercial MG (i.e., monostearate + monopalmitate) and saturated PC at concentrations lower than the critical gelling concentration of each molecule (< 3% MG and < 4% PC). We studied the organogelation of the MG + PC mixtures in SO and MO through infrared spectroscopy, microscopy, solid phase content (SPC), rheological ( $G'$ ,  $G''$ ) and textural measurements. In VO we obtained gels after 24 hours at 15°C in mixtures of 0.25%, 0.5% and 1% of PC in the presence of 2% MG, achieving the maximum  $G'$  and textural values in the 2% MG + 0.25% PC organogel. In MO we achieved the maximum  $G'$  and texture values in the 2% MG + 2.5% PC organogel. These results showed that under these conditions a synergistic molecular interaction occurred between PC and MG. Nor  $G'$  nor the texture parameters observed a particular relationship with the SPC. Additionally, we observed that a low concentration of PC modifies the lamellar organization of MG, resulting in the

formation of microstructures that physically trap the oil. The infrared studies showed that MG-PL interaction is mediated through hydrogen bonds. These MG-PL interactions were modified through the addition of low amounts of water, affecting positively the elastic properties of the organogels.

#### 15. Effect of Different Formulations and Heat Treatment on the Physicochemical Properties of Freeze-dried Microencapsulated Chia Oil

Claudia N. Copado, Vanesa Y. Ixtaina, and Mabel Tomás\*, CIDCA (CONICET-UNLP), Argentina

The objective of this work was to investigate the influence of the oil concentration, the protein/carbohydrate ratio in the wall, and the effect of the heat treatment on the physicochemical properties of chia oil microencapsulated with sodium caseinate and lactose by freeze-drying. Chia O/W emulsions were composed by NaCas (10% wt), lactose (10 and 20% wt/wt), and chia oil (10, 15, and 20% wt/wt). These emulsions were microencapsulated by freeze-drying in laboratory scale equipment for 48 h. The encapsulation efficiency ranged from 41.43% to 83.96%, being microcapsules with the lowest total solids percentage (10% oil and 10% wt/wt lactose) the best condition for the highest efficiency. The moisture content of microcapsules ranged between 0.31% to 2.23% d.b., while water activity ( $a_w$  25°C) was ~0.500. The dispersibility of microcapsules was assessed following the change in droplet obscuration and mean diameter as a function of time, recording that powders dissolve in water at 25°C with agitation in ~1 min. The accelerated oxidative test (Rancimat) revealed the highest induction time value for microcapsules formulated with 10% oil+20%lactose with heat treatment (~52h). Results showed that a higher oil concentration presented a lower induction time and that higher lactose concentration and the heat treatment offers protection against oxidation.

**16. Formulation of an Edible Oleogel to be Used as a Marinade of a Seafood Dish** Cecilia B.

Arnaud<sup>1</sup>, Laurence J. Pottier<sup>1</sup>, Marie I. de Lamballerie<sup>1</sup>, and Nuria C. Acevedo\*<sup>2,1</sup> *Oniris Nantes Atlantic National College of Veterinary Medicine, Food Science and Engineering, France;* <sup>2</sup>*Iowa State University, USA*

A study on the stabilization of an oil-based sauce by organogelation for a ready-to-eat cold dish was carried out in order to obtain a stable and homogeneous marinade, motionless on the raw piece of seafood and able to melt rapidly at room temperature. Monoglycerides of fatty acids (MAG) were chosen as the ideal gelator because they are food-grade, approved by the regulation and can be used at low concentrations to promptly form oleogels. MAGs were added to canola oil at 2 or 3% w/w and the samples were stored at 4°C for one week. 3% of MAGs is the lowest concentration reported in the literature for oil organogelation; nonetheless in this study 2% was the minimal concentration that formed a gel upon a few hours of storage. Changes in the thermal and physical properties of the prepared oleogels were characterized at 4°C and before and after 30min storage at room temperature (20°C) by Differential Scanning Calorimetry (DSC), small deformation rheology, opacity determination. Destabilization (by centrifugation) of the gels was studied at both temperatures. It was observed that a significant phase separation occurred after 30min at room temperature.  $T_m$  was  $16.59 \pm 1.33^\circ\text{C}$  for both MAG % suggesting desirable thermal properties; however 2% MAG oleogels melted significantly faster than 3% MAG at room temperature. As expected the gels opacity was higher than that of canola oil and it was similar for both MAGs concentrations and storage time. The results show that 2% to 3% MAG oleogels are feasible candidates for the stabilization of oil-based suspensions.

**21. Determination the Chemical and Sensorial Characteristics of Different Type of Flavored Butters** Alev Y. Aydar\*<sup>1</sup>, and Fatma Süeda Atsi<sup>2</sup>,

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Butter is one of the most indispensable and traditional foods of the Mediterranean diet. In our study, butters flavored with different type of spices, herbs and sweeteners are studied to determine their chemical and sensorial properties. The acidity, total oil content, salt content, Reichert Meissl number, total phenol compounds of butters were determined. To determine the consumer acceptance of flavored butters the sensory analysis was conducted by panel test. The sensory quality of butters were evaluated by 20 panellists. Panelists evaluated the overall acceptability of each butter (taking into account positive and negative taste), using a nine point hedonic scale 1–9 (1 = dislike extremely, 9 = like extremely).

**22. Kinetic Phase Behavior of Tripalmitin and 1,3-dipalmitoyl-2-stearoyl-sn-glycerol; Effect of Cooling and Melting Rate** Krish Bhaggan\*, *IOI*

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Formulation of most lipid-based products requires the use of solid fats to provide the necessary functionality, desirable texture as well as good stability. The conventional approach for structuring oils relies on the use of high melting triacylglycerols as the building blocks. The crystallization and subsequent crystal network formation of these high melting crystalline triacylglycerols creates a structural framework that can physically trap liquid oil resulting in the desired texture and stability. The most functional of these high-melting triacylglycerols have been produced by fully hydrogenating oils such as palm oil or other soft oils, resulting in a complex mixture of saturated triacylglycerols. In this study, the kinetic phase behavior binary mixtures of tripalmitin (PPP)

and 1,3-dipalmitoyl-2-stearoyl-sn-glycerol (PSP), mainly present in hydrogenated palm oil, was studied by means of Differential Scanning Calorimeter and powder XRD at different cooling and heating rates. It was found that the PPP-PSP mixtures displayed different types of phase developments. When the mixtures are cooled at 10°C/min, all samples crystallized in the alpha form and during heating (5°C/min) pure PPP and samples having up to 20% PSP, transformed via beta-prime to beta form. Other mixture transformed to beta prime and an eutectic phase behavior is observed at 30% PSP. Samples crystallized at 1°C/min and having 30% and more PSP, crystallized in the beta prime form and transformed during heating (5°C/min) to a stable beta prime form. Pure PPP and up to 20% PSP crystallized in the alpha form and transformed via beta prime to stable beta form.

**23. Supercritical CO<sub>2</sub> Promoted Efficient Solvent-free Lipase-catalyzed Production of Mono- and Diacylglycerols from Soybean Oil** Nazanin Vafaei\*,  
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Reducing the caloric and fat content of convenience foods has resulted in a significant growth in the market for food emulsifiers. Monoacylglycerols (MAGs), or mixtures with diacylglycerols (DAGs), are the most commonly used emulsifiers in the food industry. DAGs have beneficial effects in reducing human visceral fat. Applying supercritical-CO<sub>2</sub> (SC-CO<sub>2</sub>) as a low temperature technology for producing DAGs and MAGs is the focus of this study. A SC-CO<sub>2</sub> system was developed for the enzymatic alcoholysis of MAGs and DAG-enriched oil from soybean oil in order to exclude the use of organic solvents. The reaction for producing DAG-enriched oil was conducted under SC-CO<sub>2</sub> and/or atmospheric conditions at 60°C, 75 bar using a glycerol/soybean

oil at a molar ratio of 1:2 and the Novozyme 435 lipase. Production of MAGs, with and without the lipase, were conducted under SC-CO<sub>2</sub> condition at 70°C, 276 bar using 1,2-propandiol/soybean oil at a volume ratio of 3:4. Nuclear magnetic resonance (NMR), specifically 31P-NMR, was used to determine the composition of the MAG and DAG-enriched oil. A much higher yield of total DAG (38%) was obtained under SC-CO<sub>2</sub> conditions compared to the reaction conducted under atmospheric conditions (5.5%). MAG synthesis was greater under enzymatic conditions with the highest yield for the total MAG mix with DAG being 45% after 4 hours, compared to 1.2% for the non-enzymatic reaction. These findings contribute to the development of green approaches to value-added processing of soybean oil and address a critical industrial demand for solvent-free production of heat-sensitive emulsifiers at low temperatures.

**24. A Bakery Application Review of Partially Hydrogenated Shortening Alternatives** Alison Gladness<sup>1</sup>, Joshua Tuinstra\*<sup>2</sup>, and Frank Flider<sup>3</sup>,  
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An application review of partially hydrogenated oils (PHO) alternatives is investigated in cookie, cake, and icing shortenings. PHO shortenings have long been the preferred bakery shortening due to its stability, temperature working range, functionality, and commercial availability. A yearlong self-life study of various PHO alternatives exploring both domestic and tropical alternatives compare the oxidative stability, application review, and texture analysis at time 0, 6 months, and 1 year time. Palm oil is a common alternative due to its saturated fatty acid profile with additional alternatives focusing on interesterifying (IE) liquid domestic oils, like soybean and canola, with fully hydrogenated soybean hard fat. IE blends allow a variety of



melting profile possibilities and when combined with stable high oleic oils can offer a superior product similar to the stability and functionality of PHO shortenings.

#### 25. Development of CBIs with High Stearic Contents via Canola and Sunflower Oils Processing

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Cocoa Butter Improvers (CBIs) are specific fat fractions able to modify the crystallization patterns and adjust the physical-chemical properties of cocoa butter. The application of CBI in the formulation of chocolates allows to correct and standardize chocolates attributes (structural, sensorial and nutritional characteristics) even under adverse regional and seasonal variations of the cocoa crop. A 45:55 blend of high oleic sunflower oil (HOSO) containing approximately 80% of oleic acid and fully hydrogenated canola oil (FHCO) with 90% of stearic fatty acids, respectively, were used as raw materials. The mixture was first chemically interesterified, at 100°C for 20 minutes using 0.4% (m/m) of sodium methoxide as catalyst. The interesterified fat system was then dissolved in acetone, at 45°C, in a 1:4 (w/v) ratio, and the solution fed to a crystallizer for fractionation under agitation. The cooling rate used was 0.2°C/min and three crystallization temperature were tested: 18, 19 and 20°C. The olein fractions presented high StOSt/StStO/OStSt content (above 25%) and a residual content (below 2%) of trisaturated (StStSt) TAGs. In a second stage the olein fraction was further fractionated for the separation of the triunsaturated and diunsaturated TAGs. The stearin and olein fractions were evaluated according to the composition in TAGs, solids content and thermal behavior. Preliminary results indicate an insignificant residual content in trisaturated TAGs in the stearin fractions, thermal behaviors similar

to pure StOSt samples, melting point and solids content higher than that of cocoa butter, turning them in CBIs potentially suitable for improving soft cocoa butter.

#### 26. Stereospecific Analysis of Fatty Acids in Triacylglycerols of Marine Fish Oils with Lipase DF Hydrolysis

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Positional distribution of fatty acids in triacylglycerols (TAGs) affects both physiochemical characteristics and functional properties of fats and oils. Marine fish is an important source of healthy omega-3 long chain-polyunsaturated fatty acids (LC-PUFAs), particularly, eicosapentaenoic (EPA) and docosahexaenoic acids (DHA). In this study, TAGs of selected marine fish oils (anchovy, tuna and salmon oils) were isolated and subjected to stereospecific hydrolysis by an sn-1, 3-specific lipase (lipase DF). After lipase hydrolysis, the released free fatty acids and sn-2-MAG were isolated by thin-layer chromatography (TLC). The TAG and sn-2-MAG were converted to fatty acid methyl esters (FAMES) and analyzed by gas chromatography (GC). Results showed that TAG of these marine fish oils were mainly made up of unsaturated fatty acids accounting for ~60%, including monounsaturated fatty acids (MUFAs) (25.36-36.78%) and polyunsaturated fatty acids (PUFAs) (28.12-37.52%). PUFAs were preferentially located at sn-2 position except for EPA, which was randomly distributed. While MUFAs were mainly bonded in sn-1,3 position and the proportion of sn-1,3 saturated fatty acids (SFAs) was a little more than that of sn-2 SFAs. The ratio of DHA at sn-2 position was higher than other PUFAs, thus enhancing its digestion and absorption. Especially in salmon, the sn-2 DHA ratio was up to nearly

70%, therefore the bioavailability of DHA in salmon oil was the highest. Additionally, the ratio of n-3/n-6 PUFAs was much higher than 1:4, which was in accordance with the FAD/WHO recommendation. In conclusion, lipase DF can be used in determination of positional distribution of fatty acids in marine fish oil.

**27. High Oleic Palm Olein** Noor Lida Habi Mat Dian\*<sup>1</sup>, Miskandar Mat Sahri<sup>1</sup>, Tan Chin Ping<sup>2</sup>, and Lai Oi Ming<sup>2</sup>, <sup>1</sup>*Malaysian Palm Oil Board, Malaysia*; <sup>2</sup>*Universiti Putra Malaysia, Malaysia*

Oleic acid is a monounsaturated fatty acid (MUFA) that is recognized by the public as a healthy fatty acid. Nutrition research also shows that oils with high oleic acid may offer excellent health benefits. Diets high in oleic acid lower the risk of coronary heart disease and stroke, as well as reduce the harmful LDL cholesterol levels and decreases risk for cancer. Palm olein (POo), the liquid fraction obtained from single fractionation of palm oil (PO) contains about 45-50% oleic acid. Many studies reported that nutritionally, POo behaves like olive oil which is high in oleic acid (>75%), as more than 90% of its oleic acid is located at the sn-2 position of its triacylglycerol (TAG) backbone. However, technically POo has a limitation from the nutritional standpoint as its fatty acid composition does not comply with FAO/WHO's recommendation for a diet with low saturated and higher monounsaturated (MUFA) and polyunsaturated (PUFA) fatty acids. This paper reports on the characteristics of high oleic POo derived from fractionation of enzymatically directed interesterified (EDIE) PO. EDIE of PO was able to increase its triunsaturated (U3) TAG concentration from 4.3% to 27.6%. Subjecting the EDIEed PO to fractionation resulted in POo fractions with concentrated U3 TAGs (34.6-43.0%) mainly OOO (21.8-26.4%) and OOL/OLO (11.7-15.0%), and diunsaturated-monosaturated TAGs (33.8-40.2%) mainly POo (27.5-23.3%) and POL

(6.4-9.6%). The concentration of MUFA, PUFA, and saturated fatty acid of the POo fractions are 55.0-62.0%, 12.0-13.6%, and 25.0-33.3%, respectively.