

**EAT 1: Phase Transition in Edible Applications (A Session Dedicated to David Pink)**

*Chairs: Gianfranco Mazzanti, Dalhousie University, Canada; and David A. Pink, St. Francis Xavier University, Canada*

**An Alternative to the Avrami Model in Fat Crystallization: A Chemical Potential Approach (CPA)** Alejandro G. Marangoni\*, *University of Guelph, Canada*

The Avrami model is, and will continue being, the workhorse for characterizing the crystallization kinetics of fats. However, the model was created for simpler systems and triglyceride mixtures can at times display complex and baffling crystallization behavior. Here we explore an alternative method for the characterization of crystallization kinetics based on a chemical potential approach. We start by characterizing chemical potential changes in the system using only SFC measurement (effective supersaturation). We then simply plot these changes as a function of time. Since an initial linear region could be identified, a slope could be easily obtained, which we define as the initial velocity of crystallization. A simple mathematical manipulation of the functions also allowed us to derive a simple semi-logarithmic relationship between the supersaturation and time.

**Phase Transitions in Edible Fats and Oils**

David A. Pink\*, *Physics Dept. St. Francis Xavier University, Canada Food Science Dept., University of Guelph, Canada*

Continuous and discontinuous phase transitions and phase changes will be described using simple two-state models, for which some exact results (i.e. without approximations) are known. This leads to questions about the interactions between molecules which give rise to such transitions. The relative importance of

short-range van der Waals interactions will be compared to long-range electrostatic interactions, and the implications for polymorphic transitions described. This leads to an hypothesis and its predictions for phase transitions arising in crystalline triacylglycerol (TAG) systems. Experiments will be proposed to test it. Treating adsorption onto surfaces as phase changes, remarks will be made about the possible benefits of oxidized TAGs. Some comments might be made about glass transitions.

**Effect of Acoustic Power Level on Cavitation Events in Oil** Silvana Martini\*<sup>1</sup>, Peter Birkin<sup>2</sup>, P. Martin<sup>2</sup>, Jack Youngs<sup>2</sup>, Tadd Truscott<sup>1</sup>, and Andrew Merritt<sup>1</sup>, <sup>1</sup>*Utah State University, USA;* <sup>2</sup>*University of Southampton, United Kingdom*

High intensity ultrasound (20-23 kHz) has been used as a tool to induce the crystallization of edible lipids. Cavitation, or bubble formation, is the main physical event associated with the induction in crystallization. Previous studies have hypothesized that bubbles formed during sonication can induce primary and/or secondary nucleation in the system inducing its crystallization. The objective of this study was to characterize bubble formation in oils at various ultrasonic power levels. The formation of acoustic bubbles at various ultrasonic power levels was monitored using laser scattering through the liquid directly below the ultrasonic source, pressure measurements in the bulk, and high-speed camera imaging of the region. Results show that bubble clusters formed at the tip of

the source (a piston like emitter, PLE) collapse with varied periodicity in relation to the drive amplitude employed. The cluster periodicity is shown to extend to many cycles of the drive stimulus. In addition, the periodicity of the cluster follows a ring-up sequence which indicates the presence of different behavior linked to the transient amplitude of the tip and the bubble population at the start of the process. A bifurcated streamer is detected which exists within this sequence. This is shown to originate from two separate bubble clusters on the PLE tip; each oscillating with a 180° phase relationship with respect to the other. Finally, the collapse phase of the cluster is shown to involve a two-stage process.

**The Role of Mechanical Processing on Water Droplet Distribution in the Manufacture of Margarine** Steven Robbins\*, *Richardson International, Canada*

Water droplet distribution is an important characteristic with regards to the quality of water in oil emulsions such as margarine. The water droplet distribution affects several properties of the margarine including microbial deterioration and mouthfeel through fat phase melting properties. Mechanical processing parameters have a direct effect on water droplet distribution in emulsions such as margarine. This mechanical processing is particularly important in regard to systems with weak emulsifier systems. This study explores the effect of various mechanical processes on the water droplet distribution in a weakly emulsified soft margarine formula. On a pilot plant scale variations were made to agitation, rotor speed of the scraped surface heat exchanger, and rotor speed on the pin worker. Water droplet distributions of samples were

evaluated by NMR and microscopy. Pilot plant results were further verified by running similar trials on a commercial scale. It was determined that each of the parameters described above (agitator, rotor, and pin worker) contribute significantly to the distribution of the water droplets in a weakly emulsified margarine system.

**Influence of Droplet Size on Salt and pH-induced Attractive Gelation in Food-Protein Stabilized Nanoemulsions** Aakash Patel, Natalie Longmore, and Supratim Ghosh\*, *University of Saskatchewan, Canada*

The aim of this study was to investigate the possibility of forming gelation in nanoemulsions by inducing attractive interactions among the nanodroplets. Nanoemulsions were prepared with sodium caseinate (SC) and whey protein isolate (WPI) at different protein (2–4%) and oil (30–40%) concentrations and as a function of droplet size, salt concentration (0.1–1M), and changes in pH (below, at and above the pI of the proteins). Without salt (at pH 7) only SC could form nanoemulsion-gels where gel strength increased with an increase in protein and oil concentration and decrease in droplet size. Under similar environmental condition WPI nanoemulsions had comparable droplet size but did not form a gel, and no effect of droplet size was observed. In contrast, the addition of salt led to attractive gelation in WPI nanoemulsions due to charge screening, but no such effect was seen in SC nanoemulsions due to stronger repulsive steric interactions. While storage moduli of attractive WPI nanoemulsion gels increased with a decrease in droplet size, salt addition reduced the gel strength of SC-stabilized nanoemulsion-gels due to the loss of close packing of droplets

and their surrounding repulsive barriers. All the nanoemulsions with pH at the pI of proteins transformed into strong attractive gels made of droplet aggregates due to the complete charge neutralization and changing protein conformation, where the compressive strength of the gel increased with a decrease in droplet size. Overall, research on the effect of different environmental factors on the stability and gelation behavior of protein-stabilized nanoemulsions revealed contrasting behavior based on the interfacial properties of the proteins.

**Impact of Margarine and Shortening on Puff Pastry Attributes** Rachel E. Mertz\*, Dilip Nakhasi, and Roger Daniels, *Stratas Foods, USA*

Margarine and shortening are utilized in commercial bakery applications and differ in that margarines are typically oil and fat blends in water emulsions, while shortenings are anhydrous oil and fat blends. As partially hydrogenated vegetable base oil products continue to exit from the marketplace the challenge remains for the development and commercialization of partially hydrogenated vegetable base oil free options for use in bakery shortening and margarine ingredients which may then be utilized in demanding bakery applications like puff pastry. A critical component to acceptable puff pastry is the shortening/margarine ingredient as it must be optimal with respect to pliability for use in the dough lamination process yet resilient enough to yield acceptable puff pastry layers as the dough unit is subjected to baking. The objective of this study was to compare and contrast the impact of non-partially hydrogenated vegetable fat types (shortening vs. margarine) made with the same

base oil as it relates to puff pastry fat attributes as well as the finished good attributes.

**Evaluation of Stabilizer Type on Peanut Butter Physical Attributes** Don Gifford\*, Rachel E. Mertz, Dilip Nakhasi, and Roger Daniels, *Stratas Foods, USA*

Ground roasted peanuts (*Arachis hypogaea*) mixed with sweeteners, and salt are the primary components of a US staple known as peanut butter. Peanuts are comprised of oil, protein, and carbohydrates and when presented in a homogeneous peanut butter format require addition of stabilizers to keep the oil from separating from the other components. Peanut butter stabilizers are comprised of high melting point fats which function as structuring agents via their contribution to the development of crystalline networks robust enough to hold the peanut butter ingredients with varying hydrophilic and hydrophobic properties in suspension. Conventional peanut butter contains stabilizers at a usage rate of on average of 2.0% w/w, with a range of 1.0%–4.0% w/w. The objective of this study was to investigate six different types of stabilizers for crystalline promoting tendency and their impact on peanut butter stability and texture as a function of storage time. Digital scanning calorimetry (DSC) was used to evaluate stabilizer crystalline behavior. Peanut butters were observed for oiling out over time and texture analysis was performed on finished product during storage. The variables tested at the inclusion rate of 2.0% w/w in a standard creamy peanut butter formula were:

- Fully hydrogenated soybean oil (Soy),
- Fully hydrogenated cottonseed oil (Cotton),
- Fully hydrogenated palm stearine (PS),

- Blend of high erucic acid rapeseed oil (HEAR) and Soy (1:5 w/w),
- Blend of HEAR and Cotton (1:5 w/w), and
- HEAR and PS (1:5 w/w)

Differences in peanut butter attributes due to peanut stabilizer type employed were observed highlighting the role of peanut butter stabilizer composition on peanut butter stability and texture.

**Can Humans Detect if a Chocolate is in the  $\alpha$  or  $\beta_v$  Form?** Fernanda Peyronel\*, *Dept. of Food Science, University of Guelph, Canada*

Cocoa butter (CB) is the preferred fat used in chocolate manufacture as its composition leads to a smooth melt in the mouth. Good artisan palatable chocolate is made with CB, cocoa powder, sugar, and emulsifiers, like lecithin. Routine checks on the quality of the chocolate are performed by using X-rays in the wide-angle X-ray region (WAX). A superior texture is typically achieved when the chocolate is in a  $\beta_v$  polymorphic form. Having in mind that

polymorphism is characterized by atomic distances, on the order of few angstrom, it is natural to ask the question: can consumers feel in their mouths the difference between two polymorphic forms, like  $\alpha$  and  $\beta_v$  or are they feeling larger structures? To answer this question, CB and chocolate (made with 30% sugar) were studied using X-rays not only in the WAX region but also in the ultra-small angle (USAX) region to cover a length scale from a few angstroms to about 10 micrometers. The study focused on looking at the aggregation of the CB fat crystals in the WAX and USAX regions in the absence and presence of three ingredients: sugar, lecithin, and cocoa powder. Both CB and chocolate were tempered in order to obtain either  $\alpha$  or  $\beta_v$ . The two tempered products were analysed with X-rays at the APS synchrotron facility and were also fed to ten volunteers. This will report of the findings emphasizing that changes in a phase transition are not the only important parameters relevant to the manufacture of quality chocolates.

**EAT 2: Confectionery Fats**

*Chairs: Farnaz Maleky, Ohio State University, USA; and Linsen Liu, IOI Loders Croklann, USA*

**Fat Bloom and Anti-bloom in Confectionery Application** Linsen Liu and Guang (Gil) Wang\*, IOI Loders Croklann, USA

Compatibility issue is a typical concern for confectionery industry when lauric fat is brought into non-lauric system. This study aims to understand micro-crystalline properties when lauric fat interacts with non-lauric. And explore anti-bloom effect when special designed fat is blended into filling fats.

**Studies on the Effect of Thermal Pre-treatment on the Isothermal Crystallisation of Cocoa Butter**

Marjorie Ladd Parada<sup>1</sup>, Josélio Vieira<sup>2</sup>, Peng Siong Chong<sup>2</sup>, Michael Ries<sup>1</sup>, Michael Rappolt<sup>1</sup>, and Malcolm J.W Povey<sup>1</sup>, <sup>1</sup>University of Leeds, UK; <sup>2</sup>Nestlé Product Technology Centre, UK

Cocoa butter (CB) is responsible for the texture and stability of chocolate, characteristics that can only reach optimum levels when CB crystallises in the most stable form ( $\beta$ -V). Thus, the relevance of understanding how different parameters affect CB's crystallisation. However, there is little consistency, in literature, in the temperature used to melt CB prior to either isothermal or dynamic crystallisation studies. Moreover, given the diverse composition of CB, the authors consider that the most commonly used temperatures in both literature and industry (50 to 60°C) are not enough to start with a fully molten product. Therefore, the aim of this study was to understand the effect of heating West African CB at three different

temperatures (50, 80 and 110°C) prior to isothermal crystallisation. A variety of techniques were used, small and wide-X-Ray scattering, DSC, NMR and polarised microscopy were used. From these, it was observed that by heating CB at higher temperatures prior to isothermal crystallisation at 20°C, the kinetics of crystallisation were affected: slowing down the start of crystallisation, but enhancing polymorphic transformation. The previous is of relevance, not only from a fundamental point of view but also from an industrial one. This is because the use of higher melting temperatures (of either cocoa butter or cocoa liquor) has the potential to make the current tempering process more efficient. However, further studies are needed to validate such observations.

**Functional Properties of Fats and Emulsifiers in Candy Application** Linsen Liu, Guang (Gil) Wang, and Aliess Bedford\*, IOI Loders Croklann, USA

Pho fats were traditionally used in candy industry to provide structure and functionality. This paper reviews the performance of caramel and fudges made from palm based, pho-free fats and monoglycerides. The fat ingredient drives texture and sensory based on their melting point, crystallization behavior, and type of TAG profile. The type of emulsifiers can further leverage the eating experience, as decided by emulsifier's physical properties. The study confirms that candy manufacturers can have broad choice in making the best pho-free candies.

**Shea-based Shortenings. How to Overcome the Post-hardening Effect** Krish Bhaggan, Raul F. Petrut\*<sup>1</sup> and Jun Ma, *IOI Loders Croklaan, The Netherlands*

Post-hardening during fats storage or shelf-life, is a well-known phenomenon that can lead to processing complications and unwanted quality defects in the final product. Most frequently post-hardening is directly proportional related to one or more polymorphic transition(s) occurring during a specific period of time and depending on storage conditions. In the present work a Shea (*Vitellaria paradoxa*) based fat was developed, engineered, and processed under controlled conditions. The main goal of this study was to overcome the post-hardening effect for the Shea based fat. For this purpose, a combination of techniques such as pulsed nuclear magnetic resonance (p-NMR), differential scanning calorimetry (DSC), X-RAY powder diffraction and texture measurements were employed. Two Shea based fats were blended and modified (SB), in order to enrich the TAG composition and tailor it for specific applications. After melting, the fat was shock-cooled ( $\sim 10\text{C/s}$ ) until  $180\text{C}$ , at which it was isothermally crystallized for 72h. Upon cooling, the  $\alpha$  polymorphic form developed and started to grow. As saturation was reached,  $\alpha$  form transformed directly into  $\beta$ , without intermediate transitioning into  $\beta'$ . The  $\beta$  form continued to grow at the expense of  $\alpha$ , until the end of crystallization. Only  $\beta$  form was observed for the SB after the tempering period. This resulted in the absence of post-hardening of SB during the investigated 12 weeks of storage ( $180\text{C}$ ), which was confirmed by hardness measurements.

**Confectionary Coating and Filling Fat: A Review** Linsen Liu and Guang (Gil) Wang\*, *IOI Loders Croklann, USA*

Coating fats are widely used in confectionary products. While filling fat market is strong in Europe, we see higher demand in recent years from NA. The solid fat content (SFC) and crystalline structure drive mouth-feel for both coating and filling fats. Coating fat requires very high solid at cold and ambient temperature and follows sharp melting curve. Filling fat selection can be very customized to meet different texture expectation. This review article presents different formulations with palm fractions that leads to different eat quality for confectionary products made from CBE, CBR and different filling fats.

**The Solubilization-Recrystallization-Diffusion Model to Quantify Oil Migration Kinetics in Cocoa Butter** Alejandro G. Marangoni\*, *University of Guelph, Canada*

Oil migration in confectionery products can lead to undesirable changes in quality including softening and bloom formation. The factors responsible for oil migration are still matter of debate and the exact mechanism unknown. Here we review the commonly used effective diffusion and capillary movement approaches and demonstrate how they are limited and hard to discern from each other. We then introduce a new way to modelling and understanding oil migration through cocoa butter using a simple but novel Solubilization-Recrystallization-Diffusion approach to the problem. The power and simplicity of the model will be demonstrated in the goodness of fit to complex oil migration patterns. The parameters derived from the model also offered a glimpse into the factors

responsible for oil migration in confectionery products.

**Synthesis of Cocoa Butter Equivalent by Enzymatic Interesterification of Illipe Butter and Palm Mid-fraction** Adiguna Bahari and Casimir C. Akoh, *University of Georgia, USA*

This study aims to synthesize a cocoa butter equivalent (CBE) structured lipid from a blend of illipe butter (ILL) and palm mid-fraction (PMF) by means of enzymatic interesterification. Physical and chemical attributes of the CBE and cocoa butter (CB) were analyzed. The synthesized CBE closely matched triacylglycerol (TAG) profile range of CB and is therefore hypothesized to show similar physical and chemical characteristic with CB. TAG profile, fatty acid constituents, melting and cooling behavior, crystal morphology and polymorphism were determined using high performance liquid chromatography (HPLC), gas chromatography (GC), differential scanning calorimetry (DSC), polarized light microscopy (PLM) and X-ray diffraction (XRD), respectively. Four enzymatically interesterified blends of ILL:PMF at different weight ratios were analyzed for their TAG profile. The ILL:PMF ratio of 10:3 (IB30) (w/w) at 5% enzyme load and 30 minutes reaction time showed similar TAG results with CB. The TAG values of IB30 were: glycerol-1, 3-dipalmitate-2-oleate (POP) at  $19.1 \pm 1.0$  mol%, glycerol-1-palmitate-2-oleate-3-stearate (POST) at  $42.7 \pm 1.0$  mol% and glycerol -1-3 distereate-2-oleate (StOSt) at  $29.9 \pm 0.3$  mol%. The melting and cooling profile of IB30 and CB showed no significant difference. X-ray diffraction of IB30 and CB displayed very strong peaks at  $4.6 \text{ \AA}$ , representing a  $\beta$  polymorph. This result shows that the cocoa butter equivalent IB30 closely mimics the properties of a cocoa butter.

**Polymorphic Transition and Bloom in Cocoa Powder** Paige Palmieri and Richard W. Hartel, *University of Wisconsin-Madison, USA*

Cocoa powder is highly valued for its color in beverage and confectionery applications; however, its color may be dulled if it is improperly tempered. Though bloom has been frequently observed in cocoa powder manufacturing, the nature of cocoa butter crystallization and bloom in cocoa are poorly documented in the literature. By assessing commercial cocoa powders with different processing histories, this study takes a comprehensive approach towards understanding crystallization as it occurs across the spectrum of cocoas. Cocoa powders were crystallized isothermally in a differential scanning calorimeter (DSC) at temperatures ranging from 20–25°C. Onset of crystallization was evaluated using both isothermal and scanning methods and polymorphic transitions were monitored using the stop-and-return method. In all experiments, references of pure cocoa butter served as points of comparison. Results showed that crystallization onset of cocoa butter in cocoa powder occurred at temperatures of  $25.0 \pm 0.3^\circ\text{C}$ , whereas crystallization in cocoa butter references initiated at significantly lower temperatures. This indicates that the cocoa powder matrix is promoting crystallization of cocoa butter in cocoa powder. Differences in crystallization behavior due to processing, which determines cocoa fat content, degree of alkalization and matrix composition, are currently under investigation. Such differences have the potential to influence a cocoa powder's responsiveness to tempering and its resistance to bloom.

**The Art and Science of Ganache** Jade McGill<sup>1</sup> and Richard W. Hartel\*<sup>2</sup>, <sup>1</sup>*Nassau Candy, USA*; <sup>2</sup>*University of Wisconsin-Madison, USA*

Ganache is arguably the premier confection because of its smooth texture and wonderful flavor release, prized by confectioners worldwide for use in truffles. Composed of cream and chocolate, the properties of this oil-in-water emulsion are governed by the complex multi-phase structure—partially-crystalline lipid emulsion, sugar and cocoa particles, and aqueous continuous phase. If these structures are not

controlled properly, ganache can be too firm or too soft, grainy, or even exhibit oil separation. This presentation will discuss and document the structure development over the different stages of ganache preparation. We will discuss the role of the lipid phase (cocoa butter and milk fat) and particulate structure (cocoa particles, sugar crystals, milk powder) on ganache microstructure, texture, and rheology. Differences in ganache that are well known to confectioners will be explained in terms of their microstructural differences.



**EAT 2.1: Delivery and Dispersed Systems**

*Chairs: D errick Rousseau, Ryerson University, Canada; and Christopher Gregson, Ingredion, USA*

**Modelling the Effect of Confectioner's Sugar on Processing Interactions in Palm Oils** Ryan West\* and D errick Rousseau, *Ryerson University, Canada*

The addition of non-fat ingredients, such as sugar, to a confectionery fat not only obfuscates the relationship between its microscopic and macroscopic properties but also alters its processing response which then questions our ability to extrapolate from the research of bulk fats. The purpose of this study was to discern processing responses of palm oils both in the absence (0 wt. %) and presence (50 wt. %) of confectioner's sugar. Oils were cooled at either 1, 5, or 10°C·min<sup>-1</sup> under shear to a final temperature of 20 °C where weekly measurements were made up to four weeks. Furthermore, the cooling endpoint was either under (+8 °C) or overshoot (–5 °C) from the final temperature to explore additional processing effects and interactions. Polynomial subset models were then generated from this data to predict properties of the oils, such as solid fat content, elasticity, and firmness with sugar, cooling rate, endpoint deviation, and sample time as independent variables. We observed that the addition of confectioner's sugar had created a porous system for fat crystallization and network growth which resulted in increased elasticity and firmness. Likewise, the response of palm oil to processing effects and interactions was exacerbated in the presence of sugar highlighting the importance of interfacial characterization in such systems. With limited studies on the use of palm oil in confectionery applications, it is our wish to establish these

models for industry as predictive tools to optimize production.

**Flavor Partitioning into Short-chain Phospholipids: Effects of Self-assembled Structure.** Andrew P. Karman, Stephanie R. Dungan, Susan E. Ebeler, and Nitin Nitin, *University of California, Davis, USA*

The partitioning of oils between short-chain phospholipids and their surrounding aqueous continuum is potentially related to the aggregate shape, size and internal structure. In order to investigate this hypothesis, solubilization of d-limonene into an aqueous mixture composed of diacylphosphatidylcholine (DiCnPC | n=6,7) self-assembled aggregates was studied. Solubilization isotherms were developed using headspace measurements collected by solid-phase microextraction (SPME) sampling methods and quantification of gas phase concentration was performed using gas chromatography/mass spectrometry (GC/MS). A pseudo-phase model combined with a mass balance allowed the determination of the critical micelle concentrations and the aggregate-solution partition coefficients. In addition, dynamic light scattering measurements were used to assess changes in aggregate size and shape at varying limonene concentrations. At dilute limonene concentrations, the partition coefficients for DiC6PC and DiC7PC were determined to be 1650 M<sup>-1</sup> and 3500 M<sup>-1</sup>, respectively. At higher limonene concentrations, partitioning into DiC6PC aggregates became a function of the total amount of limonene in the mixture, while

partitioning behavior in DiC7PC aggregates did not. Interestingly, dynamic light scattering measurements suggest a shape transition for DiC7PC aggregates at high limonene concentrations, from a relatively monodisperse rod-like form into polydisperse, globular microemulsion droplets. Our results indicate complex interactions between DiCnPC aggregate shapes and the thermodynamic environment for limonene solubilization inside the micelle.

**Thermal Analysis of Cough Drops Using Microstructure Evolution Analysis** Matt Vanden Eynden\*<sup>1</sup>, Roland Ramsch<sup>2</sup>, Giovanni Brambilla<sup>2</sup>, Pascal Bru<sup>2</sup>, and Gerard Meunier<sup>2</sup>, <sup>1</sup>*Formulaction, Inc., USA*; <sup>2</sup>*Formulaction, France*

Cough drops and other pharmaceutical edibles are complex matrices that often contain sugar-derived materials such as glucose, sorbitol and maltitol rather than fats. Essential oils are then added to act as the active ingredients in order to treat throat pain and ease coughing reflexes. A substance such as this can undergo complete melting at temperatures above 140°C but phase change events such as melting or polymorphic transitions occur well before this temperature. Detecting of these events will lead to an overall better profile of the material for quality control, production process and enhanced storage qualities. By utilizing Multispeckle Diffusing Wave Spectroscopy (MS-DWS) we can visualize the phase transitions of these essential oils present in various cough drops while analyzing them in their bulk state where crushing or shearing the sample is not required. As many as five different cough drops were analyzed, both sugar-based and sugar-free, to provide the phase change data on these complex samples. Results show that every oil- and waxed-based

component can be identified, independent of the entire melting of the sample matrix. This will allow for identification of materials within a sample as well as the ageing profile of such crystal structures as they age, providing more insight into long-term shelf storage stability.

**Milk Fat Globules, A Novel Carrier for Delivery of Vitamin D<sub>3</sub>** Maha Alshehab<sup>1</sup>, Mariza Gomes Reis<sup>2</sup>, Li Day<sup>2</sup>, and Nitin Nitin<sup>1</sup>, <sup>1</sup>*University of California, Davis, USA*; <sup>2</sup>*AgResearch, Grasslands Research Centre, New Zealand*

Vitamin D<sub>3</sub> is a fat-soluble substance that is required for optimal human health and must be obtained from exogenous sources. Encapsulation of vitamin D<sub>3</sub> is a leading approach for its delivery in many food and drug formulations. In this study, we aim to investigate the feasibility of encapsulating and stabilizing vitamin D<sub>3</sub> in intact milk fat globules (MFGs). The intact lipid bodies were isolated from raw bovine and ovine milk, and then ethanolic solution of vitamin D<sub>3</sub> was mixed with MFGs to induce encapsulation via simple diffusion. Loading was evaluated using UV absorbance of extracted vitamin D<sub>3</sub>. Stability of encapsulated compound under simulated gastric digestion conditions was evaluated using LC-MS to detect acid degradation products. Up to 123µg/g milk fat and 93µg/g milk fat, of vitamin D<sub>3</sub> were loaded into bovine and ovine MFGs, respectively. These levels are significantly higher than the recommended daily intake of 20µg of vitamin D<sub>3</sub> for adults and children above the age of 4. Encapsulated compound produced no degradation products after three hours of incubation in simulated gastric fluid at 37°C. In contrast, approximately 8% of ethanolic solution of vitamin D<sub>3</sub> dispersed in aqueous gastric fluid was degraded. The results demonstrate that this

novel method is simple and inexpensive and can be developed for food and pharmaceutical applications.

### **Enhanced Antimicrobial and Mycotoxin Inhibitory Activity of Clove Oil in Water Nanoemulsion**

Jiajia Rao and Jing Wan\*,  
*North Dakota State University, USA*

Clove oil has a wide range of antimicrobial activities but limited application in aqueous food systems due to its high volatility and hydrophobicity. In this study, clove oil was selected as a model essential oil to form clove oil-in-water nanoemulsions which were further evaluated their antimicrobial properties against toxic fungi (*Fusarium graminearum*). The pure clove oil in water emulsion was highly unstable against droplet growth due to Ostwald ripening. Incorporation either  $\geq 75$  wt% of corn oil, or  $\geq 50$  wt% of medium chain triacylglycerol (MCT) into clove oil before nanoencapsulation could prevent Ostwald ripening. The influence of oil composition on antimicrobial activity of clove oil was investigated by agar dilution method. Moreover, inhibitory activities towards mycotoxins production in two chemotype isolates of *Fusarium graminearum* were also assessed. The results suggested that the composition of oil phase, i.e., ripening inhibitor type and concentration, in clove oil-in-water nanoemulsions had a remarkable impact on antimicrobial activity as well as inhibition of mycotoxins production. In general, under the same clove oil concentration in oil phase, the addition of MCT decreased the antimicrobial and mycotoxins inhibitory activities of clove oil more than corn oil. Our study also indicated that clove oil encapsulated in nanoemulsions had significantly enhanced inhibitory activities against

mycotoxins production compared with bulk clove oil. These results have important implications for the design of essential oil based nanoemulsions as effective antimicrobial and detoxification delivery systems in food or other industries.

### **Emulsified Lipid Crystallinity Affects Early *in vitro* Lipolysis and Beta-carotene Bioaccessibility**

Samantha M. Hart, Xinjie Lin\*, Surangi K.P.H. Thilakarathna, and Amanda Wright, *University of Guelph, Canada*

TAG crystallinity has wide-ranging and well-established implications for food product quality. However, impacts on lipid digestion and bioactive delivery are not as well understood. This study investigated the impact of solid versus liquid lipid state on *in vitro* digestive lipolysis and the bioaccessibility of encapsulated beta-carotene (BC). Oil-in-water emulsions (15 wt% cocoa butter containing 0.25 wt% Span 60 and 0.25 wt% Tween 60, and with or without 0.1 wt% BC) were prepared by microfluidization (M110-EH, 100 MPa, 5 passes, 80°C). The hot emulsion was either crystallized in an ice bath for 20 minutes and then held at 4°C for 24 h to generate samples with crystallized emulsion droplets (SE (without BC) and SE-BC (with BC)) or held at 50°C for 24 h before storage at 25°C to produce emulsion samples with liquid droplets (LE and LE-BC). Particle size distributions, morphology, and zeta potential were similar for LE-BC and SE-BC and, under accelerated lighting conditions, BC degradation was extensive for both samples. With exposure to simulated *in vitro* gastric and duodenal conditions at 25°C, the solid droplets had attenuated lipid hydrolysis within 120 minutes of duodenal digestion and BC bioaccessibility within 240 minutes ( $p < 0.05$ ). Therefore, for compositionally equivalent

emulsions, lipid solid state delayed digestive lipolysis. These results help to clarify the role of dietary lipid physical state on gastrointestinal digestion and bioactive release.

**Spray Drying Flavor Encapsulation Process at 25–100°C** Charles Beetz, Daniel M. Schlipf, and Jason Z. Li, *ZoomEssence, USA*

Traditional spray dry flavor encapsulation operates at temperatures on the order of 200°C. High temperatures were deemed necessary to overcome the large latent heat and heat capacity of water. Attempts to address the problems associated with high temperature drying, such as powder quality degradation due to loss of volatile and oxidation of temperature sensitive constituents, have been only at the level of chemistry of the encapsulation materials. ZoomEssence has taken a different approach to preserving the high-quality properties of flavor constituents, by re-engineering the spray drying process to operate at considerably lower temperature on the order of 40–50°C. The changes associated with this radical departure from common practice required development of new approaches to slurry/emulsion processing, development of atomization processes accommodating new emulsion viscoelastic properties and unique drying chamber design permitting long particle residence times. The powders resulting from the new low temperature spray drying process have substantially superior properties across the board from retention of flavor constituents, fully dense particles that deliver higher amounts of flavor enabling substantial reduction in usage rates and enables fast solubility, which will be primary focus to discuss.

**Encapsulation of Lactase ( $\beta$ -galactosidase) into Novel Hydrogel Beads for the Effective Treatment of Lactose Intolerance** Zipei Zhang\*, Ruojie Zhang, and D. Julian McClements, *University of Massachusetts Amherst, USA*

Individuals who suffer from lactose intolerance can alleviate many of their symptoms by ingestion of lactase ( $\beta$ -galactosidase) with lactose-containing foods. However, this enzyme is deactivated when exposed to highly acidic gastric fluids, which reduces the amount reaching the small intestine. Oral delivery systems are therefore needed to protect lactase in the stomach, and then release it in an active form in the small intestine. In this study, carrageenan-based hydrogel beads were fabricated that contained lactase and a buffer ( $\text{Mg}(\text{OH})_2$ ). This buffer was selected because it is insoluble under alkaline conditions, but soluble under acidic conditions, and can therefore maintain a neutral pH inside the beads when they are dispersed in a low pH solution. Small ( $D = 255 \text{ nm}$ ) and large ( $D = 2610 \text{ nm}$ ) hydrogel beads were prepared to compare the impact of bead dimensions on the retention of lactase activity. A ratiometric fluorescence method based on confocal laser scanning microscopy was developed to measure changes in the internal pH of the hydrogel beads before and after exposure to simulated gastric conditions. After exposure to stomach conditions, the internal pH of buffer-free beads dropped steeply (from around pH 7.0 to below pH 4.0), but that of buffer-loaded beads remained fairly constant (from around pH 7.2 to pH 6.6). When exposed to small intestine conditions, lactase encapsulated in buffer-loaded beads maintained its enzyme activity, whereas lactase encapsulated in buffer-free beads did not.

These results suggest that buffer-loaded hydrogel beads may be useful for delivery of acid-labile enzymes.

**Effect of Water Addition on Physical Properties of Emulsion Gels** Thais Silva\*<sup>1</sup>, Daniel B. Arellano<sup>1</sup>, and Silvana Martini<sup>2</sup>, <sup>1</sup>Unicamp, Brazil; <sup>2</sup>Utah State University, USA

*Abstract Pending*

**Insect Lipids as Food Ingredients: Oil Extraction, Characterization and Perspectives as Food Ingredient.** Daylan A. Tzompa-Sosa<sup>1</sup>, Liya Yi<sup>2</sup>, Hein H.J van Valenberg<sup>2</sup>, Martinus A.J.S. van Boekel<sup>2</sup>, and Catriona M.M. Lakemond<sup>2</sup>, <sup>1</sup>Ghent University, Belgium; <sup>2</sup>Wageningen University, The Netherlands

Insects are as one solution to the global challenges regarding protein scarcity. This created a new industry that currently counts with more than 300 insect producing companies worldwide. One challenge of this new industry is the lack of technological knowledge, such as oils and fat applications. The use of insect oils into food and feed applications requires a deep understanding on their chemical and physical

characteristics. Therefore, the aim of this study was to characterize the lipids from four insect species, namely yellow mealworm (YM), lesser mealworm (LM), cricket (Cr) and cockroach (Cr) extracted with an aqueous extraction. We characterize the oils obtained with the aqueous extraction in terms of FA composition (GC-FID), thermal profile (DSC), volatile compounds (GC-MS) and colour (colorimeter). Fat yield varied among insect species ranging from 60% to 19% of the total fat. These oils showed a low crystallization point (< 8°C) and had a wide crystallization range (7 to –53°C). The clear separation between crystallization and melting peaks indicates that oil fractionation is possible. These insect oils showed a bright yellow-reddish colour being yellow its distinctive colour, which is similar to other table oils. YM, LM and Cr oil contained desirable aroma compounds related to grassy, sweet, herbal, fruity, citrus, sweet-like, acid vinegar like, buttery aroma. In contrast, Cr oil had an unpleasant aroma which was related to the presence of butanoic acid, isovaleric acid, and valeric acid. The characteristics of YM, LM and Cr oil makes them suitable as food ingredient.

**EAT 3: Nano-, Micro- and Macrostructure**

*Chairs: Silvana Martini, Utah State University, USA; and Alejandro G. Marangoni, University of Guelph, Canada*

**Determination of Phase Transition Temperatures of Micro Crystals from Sequential Microscopic Images**

Hironori Hondoh<sup>1</sup>, Mio Aoki<sup>2</sup>, Seiya Takeguchi<sup>3</sup>, and Satoru Ueno<sup>1</sup>,  
<sup>1</sup>Graduate School of Biosphere Science, Hiroshima University, Japan; <sup>2</sup>Hiroshima University, Japan;  
<sup>3</sup>The Nisshin OilliO Group, Ltd./Hiroshima University, Japan

Polymorph of fat crystals determines a quality of foods, cosmetics, and pharmaceutical products. Differential scanning calorimetry (DSC) is widely used to measure melting points of fat crystals in products to determine the polymorph of them. However, DSC melting curve contains all data of crystals, such as melting, polymorphic transformation, and even growth. Therefore, it is hard to determine the phase transition temperatures of each component from DSC curve. Polarized optical microscopy (POM) is highly sensitive technique to observe fat crystal since crystals can be detected as bright spots in dark field. The brightness is proportional to the mass of crystals if the crystals at an extinction angle are omitted. Therefore, the changes in the brightness from crystals will behave similarly to heat flow in DSC measurement. In this presentation, we are going to talk the usefulness of microscopic images to determine phase transition temperatures of each component in natural fat. Time-lapse sequential images during cooling and heating, (crystallization and melting) were recorded under POM. The average brightness of the images were obtained from these images by using software ImageJ. The differential in the brightness were plotted as a

function of temperature. The results were compared with DSC curve. The relative height of peaks in POM brightness was different from the DSC curve, however, POM brightness showed similar behavior to DSC curve. We could observe the melting behavior of crystals in small area from POM images, and interpret the more details of DSC results with POM brightness.

**Addition of Phytosterol Esters to Palm Oil Influences its ‘Equilibrium’ and Isothermal Crystallization Behavior**

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

Phytosterol esters (PEs) are often used as an ingredient in functional food formulations for their cholesterol lowering effect. In a previous study we investigated the non-isothermal crystallization and melting behavior of a commercial PE mixture in blends with palm oil (PO). The occurrence of different polymorphic forms was mapped as a function of temperature and PE concentration. These results enabled research on the impact of adding the PEs to PO under industrially more relevant crystallization conditions. Therefore the objective of the current study was on the one hand to investigate the influence of PE addition on the ‘equilibrium’ crystallization state of PO in order to evaluate whether PE addition gives desired properties to the end product. On the other hand we investigated the crystallization kinetics of PO after addition of PEs in order to assess the potential impact in related food products under

processing conditions. DSC, NMR, X-ray diffraction, microscopy and texture analysis experiments were performed. It was found that PE addition had a major influence on each level of the crystalline structural hierarchy (primary crystallization, polymorphism, network formation and textural properties) of PO in the 'equilibrium' state. Furthermore, upon increasing PE addition isothermal PO crystallization started later, was slower and less crystals were formed. After correcting for the difference in the degree of supercooling of the PE-PO blends the only effect which remained was the delay in polymorphic transition from  $\alpha$  to  $\beta'$ .

#### **Tailoring Promotion or Retardation of Nucleation Kinetics of Fats with Emulsifiers**

Katsuyoshi Saitou<sup>1</sup>, Ken Taguchi<sup>2</sup>, Rika Homma<sup>1</sup>, Masao Shimizu<sup>1</sup>, Koichi Yasunaga<sup>1</sup>, Yoshihisa Katsuragi<sup>1</sup>, Satoru Ueno<sup>3</sup>, and Kiyotaka Sato\*<sup>4</sup>,  
<sup>1</sup>Kao Corporation, Japan; <sup>2</sup>Graduate School of Integrated Arts and Sciences, Hiroshima University, Japan; <sup>3</sup>Graduate School of Biosphere Science, Hiroshima University, Japan; <sup>4</sup>Hiroshima University, Japan

Controlling crystallization processes of fats largely must be acted at a nucleation stage under supercooled conditions, and the addition of emulsifiers/surfactants is a powerful tool for tailoring the crystal nucleation kinetics. Many researchers studied the promotion mechanisms of nucleation by template effects by the additives. However, few studies have been conducted to examine the retardation effects, despite that the prohibition of crystal nucleation is required for cooking oils, oil-based biodiesel etc. This paper in the first makes a brief review of recent studies of promotion/retardation of fat crystallization with various additives. Then, the main focus is paid to the addition of food

emulsifiers, polyglycerine fatty acid esters (PGFEs), which showed remarkable retardation effects of the precipitation of high-melting saturated fatty acid moieties in diacylglycerol (DAG) oil. Having observed the occurrence of birefringence with polarized crossed-Nicols microscopy, shear-rate-dependent viscosity changes and X-ray diffraction patterns, we found that the retardation of crystallization of DAG-oil is caused by the formation of liquid crystal-like supramolecular complex structures composed of high-melting fractions of DAGs and PGFEs and the supramolecular structures may disturb the formation of critical nuclei of high-melting DAG fractions during the pre-nucleation crystallization stage.

#### **The Coalescence Behavior of Fat Globules in the Presence of Protein, mono/diglycerides and Polysorbate 80** Abbey E. Thiel and Richard W. Hartel, *University of Wisconsin-Madison, USA*

The microstructure of many foods is composed of partially coalesced fat globule networks that result in certain textural and rheological characteristics. Often in these formulations, emulsifiers are included to lower the interfacial tension between two immiscible phases. In the current study, micromanipulation was used to observe the coalescence, or strain, between two fat globules in the presence of protein, mono/diglycerides, and polysorbate 80 (PS80). Strain is defined as the difference in length of the coalesced mass and the initial diameters of the two globules. The ratio of mono/diglycerides to PS80 was varied from 0:0, 80:20, 90:10, to 100:0 always at a constant level of 2.5% protein. For fat globules at the same solid fat content, when no mono/diglycerides nor PS80 were included, droplets underwent nearly full

coalescence with an average strain value of 0.33. Whereas emulsions containing any ratio of mono/diglycerides to PS80 underwent lower strains of 0.12–0.14 producing partially coalesced structures. No statistically significant difference could be seen in strain between the ratios 80:20, 90:10, and 100:0 mono/diglycerides to PS80. Protein levels varying from 1%–5.5% were investigated under a constant ratio of 90:10 mono/diglycerides to PS80. All protein levels resulted in partially coalesced doublets that were not statistically different in strain. Interestingly, when the interface was composed of protein, mono/diglycerides, and PS80, coalescence took place through a thin oil neck that grew slowly over time, in contrast to previous research where coalescence was instantaneous.

#### **Adsorption Mechanisms for Hydrophobic Food Surfactants at an Oil-Water Interface**

Jennifer A. Staton and Stephanie R. Dungan,  
*University of California, Davis, USA*

The ability to create stable emulsions and foams remains a non-trivial task in many fields, including the food and cosmetic industries. Emulsions in the food industry are commonly stabilized by hydrophobic surfactants such as lecithin, which is a mixture of long-chain water insoluble phospholipids. With enough energy, lecithin may be dispersed as vesicles in water. These vesicle dispersions can then be used to deliver lipid to the oil-water interface of interest, creating a stable emulsion. Understanding how hydrophobic surfactants like lecithin transport and adsorb to an oil-water interface is important for optimizing emulsification processes. Despite this, the mechanism of adsorption for a dispersion of hydrophobic surfactants to an oil-water interface remains unclear. We investigated

the adsorption dynamics of two long-chain phosphatidylcholines, dilauroyl or dimyristoyl phosphatidylcholine, to an oil-water interface from a dispersion of vesicles in water. Adsorption dynamics were tracked using dynamic surface tension measurements obtained by drop profile tensiometry for various concentrations and convection strengths. These results were compared to the adsorption dynamics for a dispersion of commercially available sunflower lecithin containing >90wt% phosphatidylcholines and <5wt% lysolecithin. We previously developed theoretical expressions for possible contributing mechanisms for monolayer formation at an air-water interface from a dispersion of phospholipid vesicles. We utilized these expressions to compare with our results at an oil-water interface with consideration for possible micellar adsorption from lysolecithin. Success of this work may lead to the development of more robust processing conditions in several areas, including the stabilization of emulsions and the design of flavor delivery enhancers.

**Stability Studies of Pickering Emulsions Based on Different Types of Oils and its Application in Chocolate** Cunhong Chen<sup>1</sup>, Yanchao Liu<sup>2</sup>, Hong Zhang<sup>3</sup>, Yanlan Bi<sup>2</sup>, Qi Shen<sup>1</sup>, Zhenbo Xu<sup>1</sup>, and Xuebing Xu<sup>4</sup>, <sup>1</sup>*Wilmar (Shanghai) Biotechnology Research & Development Center Co., Ltd., China*; <sup>2</sup>*Henan University of Technology, China*; <sup>3</sup>*Wilmar (Shanghai) Biotechnology Research & Development Center Co., Ltd., Denmark*; <sup>4</sup>*Wilmar Global Research and Development Center, China*

*Abstract Pending*



**Particulate Effects in Chocolate on Fat Bloom during Storage**Jiayang Jin\* and Richard W. Hartel, *University of Wisconsin-Madison, USA*

Chocolate can be considered as a dispersion of solid particles in liquid fats. Solid particles such as crystallized cocoa butter, cocoa powder and sugar particles make up about 90–95 % of the mass in chocolate while only 5–10 % is in the liquid phase. Thus, the type of particles, particulate composition, shape, and nature of particles may influence bloom formation during storage. In this study, chocolate model systems were formulated by gradually replacing cocoa powder with different crystalline and amorphous sugars. The effects of sugar type and sugar concentration on fat bloom were investigated by following whiteness index (colorimeter), stereomicroscopy with image analysis, and visual evaluation of bloom. Also, interactions of different sugar particles in cocoa butter were quantified by Casson viscosity, sedimentation volume and surface tension in order to validate its correlation with the previous bloom results. All three methods of measuring bloom confirmed reducing sugar concentration (more cocoa powder) and adding 0.5 % lecithin significantly decreased the rate of bloom and the final bloom extent. Further, sucrose had the highest bloom level over the other three sugars, whether crystalline or amorphous. Bloom results showed strong and positive correlation with the particulate interaction results confirming that surface properties of particles as well as the particulate interactions during fat migration have important effects on bloom.

**Examining Aerated Peanut Butter Systems Containing Lactic Acid Esters of Monoglycerides Compared to Traditional Samples**Kaustuv Bhattacharya\*<sup>1</sup>, Niall Young<sup>2</sup>, and Henrik Kragh<sup>2</sup>,  
<sup>1</sup>*DuPont Nutrition & Biosciences ApS, Denmark*;  
<sup>2</sup>*DuPont Nutrition & Biosciences ApS, Denmark*

Peanut butter is a very popular food product, primarily in the US, but also has a huge market in South Africa and neighboring countries. Different variations of the traditional peanut butter classics of smooth and crunchy are now beginning to become popular, e.g. chunky, creamy / spreadable, fluid, and aerated. This work investigates the aeration of peanut butter containing high melting fat-based stabilizers and lactic acid esters of monoglycerides. Samples were prepared using a scraped surface heat exchanger for structuring and Mondomix for incorporation of air as a continuous process. The aerated peanut butter had a considerably different texture and mouthfeel compared to conventional type and showed very good stability against oiling out. The samples were analyzed using a wide range of techniques such as confocal laser imaging, rheology and microscopy. Tribology, the study of friction and lubrication between interacting surfaces in relative motion was used to quantify and gain understand the difference in mouthfeel.

### EAT 3.1a/LOQ 3b: Manufacture and Stabilization of W/O and O/W Emulsions for Optimal Shelf-life

*Chairs: Tanu Tokle, Qualitech, USA; Ann-Dorit Moltke Sørensen, Technical University of Denmark, Denmark; and Chandra Ankolekar, Kemin Industries Inc., USA*

#### **Stability and Functionality of Colloidosomes as Delivery Systems for Small Molecules**

Umut Yucel\*, *Kansas State University, USA*

Colloidosome particles, similar to Pickering emulsions but with smaller initial adsorption energies can be obtained, by surrounding a core particle by smaller wall-forming particles. We formulated colloidosome particles from base-emulsions prepared with liquid and solid lipids (refined coconut oil composed of lauric and capric acid, and hydrogenated palm stearin), and different emulsifiers (sodium caseinate, pectin, chitosan). The liquid lipid core served to encapsulate small molecules: limonene as a model flavor compound, and a hydrophobic nitroxide radical, PTMIO. Real-time kinetic release of limonene was measured using a mass spectrometer coupled to atmospheric pressure compound ionization (APCI-MS), and compared to the phase behavior and reactivity of PTMIO as analyzed by an electron paramagnetic resonance (EPR) spectrometer. The base-emulsions prepared at two particle sizes 160 nm to 600 nm. The net surface charge of the caseinate emulsions was -40 mV at pH 6.5, and +25 mV at pH 3.5, pectin emulsions -30 mV at pH 3.4, and chitosan emulsions +35 mV at pH 3.5. The particle aggregates formed by controlled mixing of emulsions with opposite surface charge and observed as an increase in the apparent particle size (> 1000 nm). The formation of a solid wall limited the release of limonene, which regenerated by removal of the wall with pH or thermal changes. The behavior of PTMIO was

similar to limonene as monitored by deconvolution of the complex EPR spectra to individual signals coming from aqueous and lipid phases. Such systems can be used to encapsulate labile small molecules, and their targeted delivery.

#### **Impact of Phospholipids and Tocopherols on the Oxidative Stability of Soybean Oil-in-Water Emulsions**

Gautam Samdani\*, D. Julian McClements, and Eric A. Decker, *University of Massachusetts Amherst, USA*

Phospholipids can regenerate oxidized tocopherols and help delay lipid oxidation. Extent of synergism between tocopherol, phosphatidylethanolamine (PE) and phosphatidylserine (PS) is affected by various factors like the location of antioxidants. Emulsifier type and tocopherol homologue can alter the location of antioxidants and affect the interactions between tocopherol and phospholipids. Three  $\mu\text{mol}$  tocopherol/kg emulsion and 15.0  $\mu\text{mol}$ /kg emulsion of PE or PS were dissolved in oil and emulsions were prepared. Tween 20 or bovine serum albumin (BSA) was used as emulsifier and the continuous phase contained 10mM imidazole/acetate buffer at pH 7. Lipid hydroperoxides and hexanal were measured as lipid oxidation products and the lag phase was determined. Further investigation was carried out to find the partitioning of phospholipids in the aqueous phase to understand the mechanism. With Tween 20 as the emulsifier,  $\alpha$

and  $\delta$ -tocopherol had a hexanal lag phase of 2 and 4 days respectively. PE and PS both extended the lag phase to 7 days in presence of  $\delta$ -tocopherol. Whereas, PS extended the lag phase to 5 days and PE could not exhibit any synergism with  $\alpha$ -tocopherol. With BSA as the emulsifier,  $\alpha$  and  $\delta$ -tocopherol had a lag phase of 4 and 7 days respectively. PE and PS extended the lag phase to 8 days and 11 days respectively in presence of  $\delta$ -tocopherol and to 9 and 8 days respectively in presence of  $\alpha$ -tocopherol. Phospholipids could potentially be used with tocopherols to improve the oxidative stability of emulsions. PE was more effective with BSA whereas PS was equally effective with both emulsifiers.

#### **Effect of Droplet Size and Interfacial Crystallization on the Rheology of Fat Crystal-stabilized Water-in-Oil Emulsions**

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

Water droplets as rheology modifiers in fat crystal-stabilized emulsions is a novel research area. This study investigated how fat crystal-stabilized emulsion rheology is impacted by aqueous droplet interactions with continuous phase fat crystals. 20% water-in-oil emulsions were prepared with the continuous phase consisting of canola oil, hydrogenated soy oil (HSO) and one of 3 emulsifiers: glycerol monooleate (GMO) and glycerol monostearate (GMS) to promote interfacial crystallization, and polyglycerol polyricinoleate (PGPR) to limit it. Small (Sm) and large (Lg) droplet size distributions (DSD) were prepared for each surfactant. LgDSD and SmDSD GMS emulsions displayed the highest LVR  $G'$  values followed by GMO and PGPR. Reinforcement

( $R = G'_{\text{emulsion}}/G'_{\text{network}}$ ) values increased for each surfactant over time. On day 0, R values for SmDSD were higher than LgDSD for PGPR and GMO stabilized emulsions. The reverse was observed for GMS-stabilized emulsions. By day 28, both SmDSD and LgDSD GMS emulsions reached similar R maxima. Similar trends, but lower R values were observed for GMO emulsions. PGPR emulsions displayed the least reinforcement and least effect of DSD. Power-law fitting of viscosity showed that DSD did not affect shear thinning behaviour within surfactants. Consistency followed similar trends to  $G'$  and reinforcement. This experiment showed that the interface and droplet size impact overall consistency and reinforcement in droplet filled emulsions, most significantly in freshly-made emulsions. By considering the droplet interface as a tunable, functional component within a network, it is possible to create novel fat-stabilized emulsions with desired consistencies without changing characteristics such as solid fat content.

#### **Label Friendly EDTA Alternative for Oxidative Stability Improvement in Food Emulsions**

Lan Ban\*, Yvonne Gildemaster, and Joan Randall,  
*Kemin Food Technologies, USA*

Chelating agents like ethylenediaminetetraacetic acid (EDTA) sequester metal ions and are widely used as antioxidant in food emulsions. EDTA is very cost effective for the quality of processed foods. However, it has posed a negative image, especially in the consumer food sector, that arises from its synthetic origin, non-biodegradable nature, and being a possible environmental hazard. Major players in the food industry have placed it in the list of ingredients that manufacturers are removing in the next few

years. On the other hand, there is no effective replacement yet that could be validated to match the performance of EDTA, especially in acidic processed foods. The objective of this study was to find natural ingredients that match the performance to EDTA, from the same chelating function or from different modes of actions. Various natural plant extracts were screened and three candidates (spearmint extract, green tea extract and rosemary extract) were evaluated further as combinations aided by Design of Experiment. The best combination and dosage

were identified and validated in mayonnaise and ranch dressing systems. The results have shown that first, there was a positive correlation between the dosage of this blend and its performance. Second, the major driven force of antioxidant potential was from spearmint extract. Third, at the treatment level that was slightly below its flavor threshold, this blend was very close in performance to EDTA in mayonnaise. The continuation of this work will hopefully to provide the consumer food industry with label friendly options to replace EDTA.

### **EAT 3.2/H&N 3.1: Influence of Fat Composition and Structure on in Foods on Metabolic Status**

*Chairs: Amanda Wright, University of Guelph, Canada; and Marie-Caroline Michalski, INRA, France*

#### **Introducing the Importance of Molecular and Supramolecular Lipid Structures on Metabolism and Beyond** Marie-Caroline Michalski\*, *INRA, France*

The health impact of dietary lipids must now encompass approaches beyond their energy content and fatty acid profile. In fact, dietary fatty acids are building blocks of different lipid molecules such as triacylglycerols and phospholipids, organized in various supramolecular structures such as emulsion droplets, which can be naturally present or incorporated in more or less complex food matrixes. This lecture will present our recent works on the impact of fat emulsified structure on postprandial lipid metabolism and fatty acid beta-oxidation in obese and normal-weight men, leading to the concept of « fast vs slow lipids ». We will see how the postprandial kinetics of lipid absorption can modulate metabolic endotoxemia, which originates from interactions between dietary lipids and the gut microbiota and can contribute to metabolic inflammation in obese subjects. Regarding minor lipid structures of important functional interest, we will see how surface active agents used in food formulation such as emulsifiers, and notably vegetal vs milk phospholipids, can modulate lipid metabolism and inflammation. Finally, the food matrix effect will be highlighted with vegetal and dairy examples. This new knowledge in the field of lipid metabolism will serve as an introduction for the following lectures of this translational session.

#### **Is the Food Matrix an Important Factor for Lipid Bioaccessibility and Their Subsequent Metabolism?** Sylvie Turgeon\*, *INAF, Laval University, Canada*

Several studies have linked food structure and texture to different kinetics of nutrients delivery. Changes in some nutrients' release rate such as lipids could induce different physiological effects (e.g., reduction of postprandial lipemia). However, little is known on the contribution of dairy food structure, especially cheese, on nutrients release rates. The aim was to discriminate the effect of cheese attributes on lipid release and absorption. The effect of milk fat composition (olein vs stearin rich-fractions) and calcium of cheddar cheeses were studied in vitro and in vivo. In cheddar-type cheese with regular and high calcium content, the stearin fraction exhibited lower plasma TAG responses compared to the olein fraction in the rat model. In vitro study revealed that lipolysis and the overall fatty acids bioaccessibility were also reduced in cheese containing the stearin fraction due to a lower degradation of the matrix. In a second study commercial cheeses including: young- and aged-cheddars, regular- and light-cream cheeses, parmesan, feta, camembert, mozzarella, sliced processed cheese were digested. At the end of the in vitro gastric digestion, cheddar (slow) and cream cheese (fast) presented different disintegration attributed to their texture and manufacturing processes. The in vivo human study revealed that cream cheese, but not cheddar, induced a more important

increase in TAG concentrations than butter ( $\Delta$  vs baseline: +44% vs +24%) at 2h. At 6h, the response was attenuated with cream cheese compared with cheddar ( $\Delta$  vs baseline: +14% vs +42%). These studies demonstrate that cheese matrix per se modulates postprandial lipid metabolism in humans and animals.

**Citric Acid Esters-stabilized Emulsions During *in vitro* Digestion: Effect of the Physical State of Emulsifier** Qing Guo, Nick Bellissimo, and D errick Rousseau\*, *Ryerson University, Canada*

The objective of this study was to investigate the role of Pickering stabilization on *in vitro* lipid digestion of oil-in-water (O/W) emulsions. Different concentrations of glyceryl stearate citrate (GSC) and glyceryl oleate citrate (GOC) (0.5 and 5 wt%) were used to stabilize emulsions prepared with valve homogenization. Initial emulsion properties were characterized by static/dynamic light scattering, confocal/polarized light microscopy, and differential scanning calorimetry. *In vitro* digestion included three phases: oral processing, gastric digestion and intestinal digestion. During digestion, structural changes, particle size, zeta-potential, and free fatty acid release were monitored. Results showed that a solid shell formed around dispersed oil droplets when using GSC. However, during storage, the shell with 5% GSC resulted in oil droplet flocculation, though gentle mixing re-distributed droplets. All other emulsions did not undergo changes in droplet size. During oral processing, no significant changes in particle size or microstructure were observed in any emulsion. During gastric digestion, severe coalescence occurred in emulsions stabilized by 0.5% GSC and GOC whereas 5% GOC emulsions underwent less

coalescence. Flocculation dominated 5% GSC emulsions. During intestinal digestion, oil droplet coalescence was evident in all emulsions with the smallest increase in particle size in 5% GSC emulsions. Intestinal lipid digestion of 0.5% GSC and GOC emulsions was greatly delayed. Counter-intuitively, 5% GOC and GSC emulsions were digested rapidly during the early stage of intestinal digestion, however presence of the GSC interfacial shell retarded lipid digestion. In conclusion, lipid digestion was modulated by manipulating the physical state of emulsifiers.

**Impact of Emulsion Droplet Physical State on *in vitro* Lipid Digestion** Surangi K.P.H.

Thilakarathna\*, and Amanda Wright, *University of Guelph, Canada*

Food grade compositionally equivalent liquid (LE) and solid (SE) emulsion particles with similar size distributions ( $D_{3,2}$   $0.28\pm 0.08$  &  $0.23\pm 0.08$ ;  $D_{4,3}$   $0.55\pm 0.04$  &  $0.56\pm 0.11$   $\mu\text{m}$ , for LE and SE respectively,  $p>0.05$ ) and charge ( $-47.3\pm 0.6$  and  $-42.2\pm 0.4$  mV, respectively,  $p>0.05$ ) were prepared using palm stearin (10wt%) and the acid-unstable emulsifier Span 60 (0.4wt%) to study the impact of physical state on *in vitro* lipid digestion. Hot homogenized emulsion samples were either undercooled (LE) or crystallized (SE) and held at 37°C for all analyses. The SE peak melting temperature was  $52.6\pm 0.4$ °C and x-ray diffractometry indicated presence of the  $\beta$ -polymorph. Exposure to the gastric phase of digestion induced minimal crystallization in LE and significant flocculation in SE. The rate and extent of duodenal phase lipolysis was greater for LE compared to SE ( $p<0.05$ ) within the first hour, but no significant differences were observed, thereafter. Following *in vitro* digestion, undigested SE lipids remained in the  $\beta$ -form, and

a shift to higher end of melt temperature occurred. When duodenal digestions were performed without the gastric phase, LE and SE lipolysis did not differ from each other ( $p > 0.05$ ), but a faster rate and higher maximum lipolysis were observed ( $p < 0.05$ ), related to colloidal stability. Shear conditions also impacted colloidal stability, of the SE, in particular, with implications for digestibility results. These findings support that physical and colloidal states impact emulsion droplet *in vitro* lipolysis.

**Monounsaturated Fats and Stearic Acid: Summary of Impact on Human Cardiometabolic Outcomes** Dariush Mozaffarian\*, *Friedman School of Nutrition & Health Policy, Tufts University, USA*

Demand for palm alternatives is growing across many key categories in the food market. A key opportunity includes structuring fats that include combinations of monounsaturated fats, i.e. oleic acid, and the saturated fat, stearic acid. In humans, monounsaturated fats such as oleic acid can improve cardiovascular and metabolic health outcomes, while stearic acid tends to show neutrality on cardiovascular blood lipid parameters. An up-to-date review of the science from human clinical trials and epidemiological cohorts supports this. Findings are reviewed across cardiovascular outcomes, including myocardial infarction and stroke, and their risk factors, such as blood cholesterol and other lipids; key metabolic outcomes, including diabetes, and its risk factors, such as blood glucose and A1c are included. The review provides further clarity on the source of fats, such as plant versus animal, and various food categories, for their impact on these health outcomes. These findings have important

implications for the acceptability by the food industry and regulatory authorities of new structuring fats as alternatives to palm oil.

***In vitro* and *in vivo* Evidence of Dietary trans-vaccenic Acid Retroconversion to trans-palmitoleic Acid** Etienne Guillocheau\*, Garcia Cyrielle, Léo Richard, Daniel Catheline, Philippe Legrand, and Vincent Rioux, *Agrocampus-Ouest, France*

**Objectives and hypothesis:** High levels of circulating trans-palmitoleic acid (TPA, C16:1 n-7 trans) are associated with a lower risk of metabolic syndrome. It was actually assumed that TPA arises from dietary trans-vaccenic acid (TVA, C18:1 n-7 trans) through the  $\beta$ -oxydation pathway. This study aimed at providing evidence of such retroconversion.

**Methods used:** Fresh rat hepatocytes were incubated with growing amounts of TVA to assess the conversion rate. Inhibitors of mitochondrial and peroxisomal  $\beta$ -oxydation were also used. Sprague-Dawley pregnant rats were fed during the last week of pregnancy plus two weeks of lactation, either with a TVA-diet or with the corresponding cis isomer (2% of total energy). Pups were exclusively fed with maternal milk for two weeks. TPA content was assessed in the main organs of both dams and pups.

**Results:** TPA was properly identified in hepatocytes whenever TVA was supplemented. The conversion rate was estimated at 10%. Triacylglycerols secreted by hepatocytes did contain TPA. Blocking peroxisomal  $\beta$ -oxydation significantly decreased the conversion rate. TPA was quantified in the dams fed the TVA-supplemented diet and their pups, excepted in the brain. Importantly, TPA was found in the maternal milk.

**Conclusions:** Liver ensures the retroconversion of dietary TVA to TPA, which can be exported to other tissues. Circulating levels of TPA are

explained by dietary intakes of TVA. Given epidemiological data about TPA, future research is needed to assess dietary intakes of TVA.



**EAT 4: Lipid Gels: Application and Functionality in Edible Products**

*Chairs: Michael Rogers, University of Guelph, Canada; and Serpil Metin, Cargill Inc., USA*

**Oil Gel: Its Historic Development and Technical Hurdles to Overcome for Future Commercialization.**

Linsen Liu, *IOI Lodgers Croklann, USA*

Oil gel has been one of the focused research areas in oil chemistry since 1990s. This paper reviews its historic development and technical hurdles to overcome for future commercialization.

**Peptide-based low molecular weight organogelators (LMOGs): structural influence of side chain, chain length and D/L configuration on gelation behavior**

Yaqi Lan\* and Yong Cao, *South China Agricultural University, China*

Molecular gels, comprised of low molecular weight organogelators (LMOGs) have been widely studied in structuring edible oils and providing novel routes for potential hard-stock fat replacement with low saturated and zero trans fats. However, lack of food-grade organogelators limits the wider application and further development of molecular gels as potential fat replacers. Discovery of novel food-grade organogelators have become urgent and must be vigorously pursued. Peptide-based gelators are a class of compounds with strong potential serving as food-grade gelators, due to their structural simplicity, biocompatibility and versatility. In order to investigate how the structure of peptides affects their gelation behavior, a total of 15 oligopeptides were synthesized based on four natural amino acid building blocks—leucine, phenylalanine, tyrosine and tryptophan. One of the tyrosine-based peptide was found to gel 7 solvents out of 12

tested. The gelation behavior, melting profile, fiber morphology and crystal packing of the resultant gels were drastically affected by the polarity of side chains, chain length, D/L configuration as well as whether the peptides are in linear or cyclic forms. Such results may provide valuable information assisting the development of a priori tools for rational design of peptide-based organogelators.

**Physical Properties, Microstructure and Intermolecular forces of Soybean Oil Oleogels**

**Structured by Different Polysaccharides** Zong Meng<sup>1</sup>, Keyu Qi<sup>2</sup>, and Yuanfa Liu<sup>3</sup>, *<sup>1</sup>School of Food Science and Technology, Jiangnan University, China; <sup>2</sup>School of Food Science and Technology, State Key Laboratory of Food Science and Technology, Jiangnan University, China; <sup>3</sup>School of Food Science and Technology, State Key Laboratory of Food Science and Technology, Jiangnan University, China*

Edible oleogels were prepared by different kinds of hydroxypropyl methyl cellulose (HPMC) with methylcellulose (MC) or using HPMC as the main emulsifier in combination with the usage of thickening agents such as carboxymethyl cellulose (CMC), xanthan gum, sodium alginate, arabic gum, guar gum, flaxseed gum or locust bean gum through emulsion-templated method. Polarizing light microscope (PLM) as well as scanning electron microscope (SEM) was used to gain information on the microstructure of the samples. Fourier transform infrared spectroscopy (FTIR), and X-ray diffraction (XRD) were used to evaluate intermolecular forces between the polysaccharides in the oleogels. It was found that oil-water interface layers of the emulsions were

strengthened by polysaccharides (HPMC and xanthan gum (XG) or MC and XG), and it prohibited oil droplets from coalescing during drying. The higher viscosity grade resulted in better structure with respect to emulsions, soft solids and oleogels compared to that of lower viscosity grade for both HPMC and MC. Gel strength and oil binding capacity of oleogels were related to the mechanical strength of emulsions as well as to the network of soft solids. Oleogels with semi-crystalline structure were formed by the binding of liquid oil to polysaccharides, which were stabilized by the intramolecular or intermolecular molecular hydrogen bonds between polysaccharides. This investigation presents a route to produce polymer-based oleogels which have the potential to be used in different food materials.

**Natural Saponin-based Emulsion Templates for Edible Oil Structuring** Xiaquan Yang\*, *South China University of Technology, China*

Edible oil structuring has received considerable interest in recent years due to its application potential in foods, cosmetics, and pharmaceuticals. In this paper, we report the application of emulsion template strategy to produce these edible oil structuring materials (emulsion gels, oleogels, oil powder), by using the naturally occurring triterpenoid saponins as molecular building blocks. We show the fabrication of stable emulsions and subsequent oil powder and oleogels by utilization of the spontaneously self-assembly of quillaja saponin at the oil-water interface. Emulsions with hierarchical structure were successfully developed and can be easily converted into a transparent oleogel with very high oil content (99%) upon water evaporation. Further, we

successfully tune the color performance of structured emulsions and oleogels by manipulating the spatial locations of bio-colorants with different types and content in the hierarchy architecture. Then, we show the nanoscale fibrillar assemblies from supramolecular self-assembly of saponin glycyrrhizic acid (GA) can be used to fabricate structured emulsion systems (gelled emulsions). The GA nanofibrils form a multilayer assembly at the oil-water interface, forming unique multilamellar shells with high electrostatic repulsive force, which can provide superior stability for the saponin fibril-stabilized emulsion droplets and the whole emulsion gel during storage and heating. These natural saponin-based emulsion templates open up the possibility of the formulation design in bioactive oil structuring and encapsulation as novel ingredients and delivery vehicles in functional foods and beverages. We expect these liquid oil-based functional soft solids using natural saponin as building blocks can find novel applications in commercial food products.

**Photoprotective Mechanism of Supramolecular Oleogels on Retinyl Palmitate** Yixing Tian and Nuria C. Acevedo\*, *Iowa State University, USA*

Ultraviolet radiation may cause significant degradation of retinyl palmitate (RP) leading to the loss of its biological activity. The protective mechanism of RP taking place in policosanol oleogels (PCOs) was studied, particularly, the UV-barrier matrix effects, molecular immobilization and free radical-mediated reaction. UV-blocking action was tested by placing a layer of 7% PCO (w/w) as barrier between UVA source and 1% RP in soybean oil. Structural effect on RP photostability was studied by cooling 7% and

12% PCOs with 1% RP (w/w) at different rates. The remaining % RP was measured by HPLC after 0 to 4 days of irradiation. PCOs microstructure and RP location in the network was studied by polarized light and fluorescence microscope. Matrix mobility was studied by low resolution NMR. Peroxide (PV) and p-anisidine values (p-AV) of 7% PCOs were determined up to 35 days of storage at 40° C. PCOs can efficiently block UVA energy absorption and further dampen the UVA mediated degradation. PCOs prepared at higher cooling rates had smaller crystal particle area sizes and provided better RP protection due to molecular immobilization. Microscopies and matrix mobility results suggested that PCOs efficiently immobilized RP in the network and improved RP photostability by reducing molecular collision. PV and p-A.V. results indicated that PCOs can improve oil oxidative stability and further protect RP from free radical-mediated reaction. In conclusion, the protective mechanism of RP in PCOs is a combined effect of physical UV-barrier action, molecular immobilization and inhibition of free radical-mediated reaction.

#### **Interaction between Different Lipid Structuring Agents in Organogels**

Thais Silva\*<sup>1</sup>, Silvana Martini<sup>2</sup>, and Daniel B. Arellano<sup>1</sup>, <sup>1</sup>Unicamp, Brazil; <sup>2</sup>Utah State University, USA

Abstract Pending

#### **Engineering Mechanical Properties of Edible Oleogels Based on Ethylcellulose and Lecithin**

Mayra Aguilar-Zarate\*<sup>1</sup>, Jorge F. Toro-Vazquez<sup>1</sup>, and Alejandro G. Marangoni<sup>2</sup>, <sup>1</sup>Universidad Autónoma de San Luis Potosí, Mexico; <sup>2</sup>University of Guelph, Canada

We investigate a strategy to engineer mechanical properties (i. e., elasticity and plasticity) of edible oleogels based on ethylcellulose (EC) using lecithin (PC) as a surfactant. The samples were formulated with 10%, 11% or 12% commercial grade EC of 20 cP and 1%, 3% or 5% of commercial grade PC with unsaturated (PC<sub>20</sub>) or saturated (PC<sub>90</sub>) fatty acid (FA) chains and high oleic canola oil (HOCO) as the solvent. Mechanical properties were studied using SAOS and LAOS rheological methods and texture analysis, the mesostructure was observed in SEM and molecular interactions were identified by FTIR. Results showed that the incorporation of PC in EC oleogels increased their viscoelasticity (e.g., 10% EC: 18359 ± 2159 Pa vs. 10% EC + 1% PC<sub>20</sub>: 183900 ± 15856 Pa), and mechanical strength (e. g., 10% EC: 90.2 ± 0.8 g<sub>force</sub> vs. 10% EC + 1% PC<sub>20</sub>: 1780.2 ± 133.6 g<sub>force</sub>). The elastic to plastic transition (i.e., yield stress) was more affected by EC content, and to a lesser extent by the presence of PC. However, when PC<sub>90</sub> was used, the stress required to induce elastic to plastic transition was higher (5614.5 ± 994.7 Pa) than with PC<sub>20</sub> (2878.8 ± 0.489 Pa). This result suggests more effective incorporation of PC<sub>90</sub> with EC molecules (i.e., hydrogen bonds formation and the straight FA chains accommodation), causing more resistance to deformation. Additionally, we will present the Pipkin diagram of our EC-PC oleogels to show that the rheological behavior of this novel EC oleogels mimics that of commercial edible fats.

**Crystallization Behavior of Low Saturated, Non-Hydrogenated Fat Systems Structured with Different Oleogels - Monoglycerides, Vegetable Wax and its Combinations.**

Fernanda Davoli<sup>1</sup>, Serpil Metin<sup>1</sup>, and Paul Smith<sup>3</sup>, <sup>1</sup>*Cargill, USA*; <sup>2</sup>*Cargill Global Foods Research, Belgium*

Vegetable waxes and monoglycerides are known for their properties as fat crystallization nucleators and they have been studied as structuring agents for low saturated fat systems. Each material has a different chemical structure and so has differing effects on a fatty system. This study aims to analyze crystallization behavior of a specific low saturated fat blend when added by sunflower wax, two types of monoglyceride and its combinations, by analyzing rheology, thermal profile and microstructure. The fat system containing up to 4% of structuring agents were prepared and crystallized with careful processing control in a pilot scale SSHE. Systems containing single additives and combinations were studied. Different ratios of sunflower wax and monoglyceride were tested. Canola oil and palm stearin was used for the base fat system. Fat system structure showed different properties when sunflower wax or the monoglycerides were added as single additive or in combinations. Variation of the structuring systems produced different crystal morphology and rheology. Synergistic effects were observed on fat system structure when sunflower wax and monoglyceride were added in combination. Thermal profile of the fat systems including the blend of additives showed the individual nucleation behavior of the sunflower wax and monoglycerides. This research aim a better understanding of the crystal network structure formed when different additives are used and the potential synergistic effects among them,

which is important for the development and manufacture of functional low saturated fat systems.

**Whey Protein and Oleogel Interactions Within Oleocolloid Matrices** Clifford Park, Rafael Jimenez-Flores, and Farnaz Maleky, *Ohio State University, USA*

Recently, studies have investigated physical and thermal properties of various oleogel systems and examined their possible applications in food formulation. Although these researchers provided detailed information for oleogel formation under different processing conditions, an in depth understanding of oleogel interaction with non-fat food components is missing through the literature. Hence, the objectives of this study are developing oleocolloid matrices (made of oleogel and high concentration of whey protein) and investigating the system's thermodynamics and microstructural properties. Different controlled processing techniques with a careful selection of ingredient concentrations were used to form 4 different oleocolloid systems made of whey protein isolate, rice bran wax, and high-oleic soybean oil. The developed networks' thermal properties were analyzed using differential scanning calorimetry (DSC). DSC analysis revealed the direct effects of oleogel type and concentration on whey protein denaturation and the matrices' thermal properties. Specifically, melting behavior of oleocolloids were influenced significantly depending on the rice bran wax concentration. To further assess the possible associations between oleogels and whey protein, all the formed matrices were visualized via confocal laser microscopy. The applied microscopy analysis confirmed the extent of protein-lipid

interactions at the presence of different oleogels. This study outcome helps better understand of oleocolloid matrices and may facilitate their applications in food products enriched with milk proteins.

#### **Influence of Polar Compounds and Fatty Acid Composition on the Formation of Organogels**

Eckhard Floeter, Maria Scharfe, and Yassin Ahmane, *Technical University of Berlin, Germany*

Given that saturated and trans fatty acids are known to increase the risk to suffer from cardiovascular diseases by increasing the blood cholesterol level, it is recommended to reduce their daily intake to a minimum. Fat compositions like palm or milk fat, which consist i.a. of crystallized triacylglycerol (TAG) fractions, contain considerably high amounts of saturated fatty acids, but provide unique texture and rheology to foods. Sources of mono- and polyunsaturated fatty acids cannot match these properties in their native state. To this end, it is necessary to transform an oil into a gel with the help of structuring agents. Self-assembled fibrillar networks of  $\beta$ -sitosterol and  $\gamma$ -oryzanol have not

only risen the attention of researchers due to their oil gelling abilities, but also for lowering blood cholesterol. The presentation given will focus on the influence of polar components of vegetable oils on the physical properties of oleogels, with a focus on the  $\beta$ -sitosterol and  $\gamma$ -oryzanol structuring system. Interestingly, not only the gel hardness, but also phase transition temperatures alter as the oil deteriorates. The erratic quality of vegetable oils is of course the result of natural variation as well as alternating storage conditions and time. To achieve a consistent gel quality and consequently food quality it is inevitable to understand the role of polar matter within the organogel network. For this purpose, it is crucial to analyze vegetable oils with different content of polar material with regard to their physical and chemical properties prior to gelation and linking the data to their resulting oleogels. In our contribution we attempt to shed some light on the existing scattered and inconsistent indications of the role that fatty acid composition and the level of polar components play in the formation of oleogels.

**EAT 4.1/LOQ 4b: Food Structuring to Reduce Lipid Oxidation**

*Chairs: Hong-Sik Hwang, USDA, ARS, NCAUR, USA; Alex Kripps, Caldic USA, USA; and Yaqi Lan, South China Agricultural University, China*

**Formation of Free-flowing Fish Oil-loaded Hollow Solid Lipid Micro- and Nanospheres Using Carbon Dioxide**

Junsi Yang and Ozan N. Ciftci\*, *University of Nebraska-Lincoln, USA*

Effectively incorporating fish oil into foods and beverages is a major challenge due to their low water solubility and easy degradation during processing and storage. Therefore, the objective of this study was to develop novel free-flowing fish oil-loaded hollow solid lipid micro- and nanospheres (HSLs) that can be added into foods and beverages. Fish oil was loaded into HSLs in a single step process based on atomization of the CO<sub>2</sub>-expanded fully hydrogenated soybean oil. Fish oil-loaded HSLs (d<sub>50%</sub>= 5.6 μm) were obtained using 50 μm nozzle diameter and 200 bar expansion pressure, with loading efficiencies up to 97%. All particles were spherical and in the dry free-flowing form. Surface with wrinkles was observed when the initial fish oil concentration was increased to 50%. Shell thickness of the spheres increased with decreasing pressure. Onset melting temperature of the fish oil-loaded HSLs decreased from 66°C to 62°C with increasing fish oil content, while major polymorphic form transformed from α to β. The loaded fish oil showed increased oxidative stability compared to crude fish oil (p<0.05). Nanospheres were successfully separated from microspheres by filtration, and formed clear liquid when added into water.

**Natural Wax Oleogels-A Method to Prevent Oxidation of Fish Oil**

Hong-Sik Hwang<sup>1</sup>, Matthew Phaner<sup>2</sup>, Jill Moser<sup>1</sup>, and Sean Liu<sup>3</sup>, <sup>1</sup>USDA, ARS, NCAUR, USA; <sup>2</sup>University of Michigan-Flint, USA; <sup>3</sup>USDA, ARS, USA

Oleogels (or organogels) are formed by immobilization of oil by an oleogelator. Therefore, it was hypothesized that immobilization of oil could also prevent the oxidation of oil. This study was focused on preventing oxidation of fish oil, an omega-3 oil, due to its beneficial health effects such as reducing the incidence of heart attacks, reducing inflammation and the brain development in fetuses. This study also aimed to provide useful information on oxidation of oleogels, which are promising alternatives to trans/saturated fats. Fish oil oleogels were prepared with four different natural waxes, rice bran wax, sunflower wax, candelilla wax, and beeswax. Oil oxidation was monitored with peroxide value, conjugated diene value, eicosapentaenoic acid (EPA), and docosahexaenoic acid (DHA) at 35°C and 50°C. 3% wax-fish oil oleogels showed slower oxidation than the bulk fish oil at 35°C. The melting point is an important factor when choosing wax for this method at higher temperatures since beeswax was not as effective as other waxes at 50°C due to its lower melting point. A new analytical method, color penetration measurement method, was developed in this study, which can be used to predict the oxidation rate of oleogel. Cooling oleogel at a faster rate could significantly reduce the oxidation rate of the oleogel. Prooxidant activity of wax was observed and

therefore, a larger amount of wax is not recommended to increase the protective effect.

### **Self-assembled Colloidal Complexes of Polyphenol–gelatin and their Stabilizing Effects on Emulsions**

Chaoying Qiu\*, Yu Huang<sup>1</sup>, Zhen Zhang<sup>2</sup>, Ying Li<sup>3</sup>, and Yong Wang<sup>1</sup>, <sup>1</sup>*Jinan University, China*; <sup>2</sup>*South China University of Technology, China*; <sup>3</sup>*Guangdong Saskatchewan Oilseed Joint Laboratory, Dept. of Food Science and Engineering, Jinan University, China*

This research studies the in-depth characteristics including the binding interactions and morphological structure of tannic acid (TA)/grape seed proanthocyanidins (GSP) and gelatin (GLT) colloidal complexes, and evaluated the stability and lipid oxidation of emulsions formed by the colloidal complexes. Polyphenol and GLT (1.2 wt%) self-assembled complexes were fabricated by varying the mass ratio (1:16, 1:8 and 1:4) and pH in the range of 3–7. TA and GSP can form stable colloidal complexes with GLT at the nanoscale at pH 6, as shown by the particle size results, and the complexes exhibited a spherical morphology as seen by transmission electron microscopy. Hydrogen bonding was the main binding force for the interaction between polyphenols and GLT. The antioxidant activity of GLT was greatly improved after complexing with polyphenols. The oil/water emulsion formed by the complexes had a smaller droplet size and higher lipid oxidation stability during storage. This was largely due to the physical barrier formed by polyphenol–GLT colloidal complexes at the oil–water interface, which can prevent the pro-oxidant from penetrating into oil. These results clarified the structural, morphological and antioxidant properties of polyphenol–gelatin non-covalent complexes, which is of great value

for their application in food solutions as well as in emulsion systems.

### **Ability of SDS Micelles to Increase the Antioxidant Activity of $\alpha$ -tocopherol**

Raffaella Inchingolo<sup>1</sup>, Sezer S. Kiralan<sup>1</sup>, Sibel Uluata<sup>1</sup>, MariaTeresa Rodriguez Estrada<sup>2</sup>, D. Julian McClements<sup>3</sup>, and Eric A. Decker<sup>3</sup>, <sup>1</sup>*University of Massachusetts, USA*; <sup>2</sup>*University of Bologna, Italy*; <sup>3</sup>*University of Massachusetts Amherst, USA*

The physical location of antioxidants in oil-in-water (O/W) emulsions can affect their ability to inhibit lipid oxidation. In this study, the effect of sodium dodecyl sulfate (SDS) below and above its critical micelle concentration (CMC) on the partitioning behavior of  $\alpha$ -tocopherol in stripped soybean O/W emulsion was investigated. Aqueous phase partitioning of lipophilic  $\alpha$ -tocopherol (70%) was observed at levels above SDS CMC (5–7 mM). Subsequently, the impact of antioxidant location and SDS concentration on antioxidant activity was determined by monitoring the formation of lipid hydroperoxides and headspace hexanal in emulsions. Results showed that lag phase extension of lipid oxidation increased when tocopherol was solubilized in SDS micelles. The mechanism of increased tocopherol activity at high SDS concentrations was further investigated in O/W emulsions made from medium chain triacylglycerols (a non-oxidizable lipid). Tocopherol location and concentration were monitored over 32 hours in emulsions with and without the presence of the metal chelator EDTA. Results suggest that SDS above its CMC decreased aqueous phase tocopherol degradation and that tocopherol loss was largely due to aqueous metal initiated free radicals. Overall, these results show that micelle

solubilization of tocopherol into the aqueous phase by an emulsifier (SDS) greatly enhanced the ability of tocopherol to inhibit lipid oxidation. Data presented herein suggests that this technology could be used to increase the activity of tocopherols that are naturally found in foods.

**Impact of Reduced Oxygen Environment and Natural Antioxidants on the Oxidative Stability of Oil-in-Water Emulsions** Eric A. Decker<sup>1</sup> and David R. Johnson\*<sup>2</sup>, <sup>1</sup>*University of Massachusetts Amherst, USA*; <sup>2</sup>*Kalsec Inc., USA*

Consumer concerns over synthetic food antioxidants have led researchers to seek alternative natural, or 'clean' label, solutions to prevent lipid oxidation in emulsified systems. Developing natural antioxidant strategies for emulsified systems is particularly difficult due to increased surface area, presence of transition metals, and decreased efficacy compared to synthetic antioxidants. As a result, there remains a need to develop new strategies and optimize current antioxidant strategies in oil-in-water (O/W) emulsion applications. In previous work, it was shown that 1% fish O/W emulsions that were packaged with total oxygen reduction

concentrations of  $\geq 93\%$  exhibited a three-fold increase in oxidative stability compared to saturated oxygen conditions. Unfortunately, reaching total package oxygen reduction concentrations of  $\geq 93\%$  may not be cost effective or even a feasible strategy for emulsified foods. Total package oxygen reduction concentrations of 60–80% may be more practical. In the present work, the impact of how naturally derived polar and nonpolar antioxidants function under saturated and 60–80% reduced oxygen atmospheres in 1% stripped fish O/W emulsions was determined. Lipid oxidation, as measured by lipid hydroperoxides and TBARS, was inhibited by lipophilic antioxidants in O/W emulsions whereas aqueous phase antioxidants promoted lipid oxidation. Notably, the combination of 60–80% O<sub>2</sub> reduction did not appear to enhance functionality of the natural antioxidants. Further studies of O/W emulsions using natural extracts in more complex emulsified matrices (mayonnaise) demonstrated the effectiveness of natural antioxidants compared to the synthetic additive EDTA. Results presented provide a reference for efficacy of natural antioxidants in model and complex emulsified matrices.



## EAT 5/IOP 5: Waxes and Phase Change Materials

*Chairs: Nuria Acevedo, Iowa State University, USA; and Chelsey Castrodale, Clasen Quality Chocolate, USA*

**Multiple  $\beta$  Forms of Tripalmitin in Different Crystallization Pathway** Seiya Takeguchi\*<sup>1</sup>, Hironori Hondoh<sup>2</sup>, Hidetaka Uehara<sup>3</sup>, and Satoru Ueno<sup>2</sup>, <sup>1</sup>*The Nisshin OilliO Group, Ltd./Hiroshima University, JAPAN*; <sup>2</sup>*Graduate School of Biosphere Science, Hiroshima University, Japan*; <sup>3</sup>*The Nisshin OilliO Group, Ltd., Japan*

Polymorphic transformation of fat crystals, such as fat bloom in chocolate, will be a cause of deterioration of foods. Therefore, it is important to understand polymorphic behavior of fat crystals. Tri-saturated triacylglycerol is known to have three polymorphs,  $\alpha$ ,  $\beta'$  and  $\beta$ . In addition, some researchers suggested the existence of extra structures. However, the details remain unidentified. Here we report that tripalmitin (PPP) shows different  $\beta$  forms depending on their crystallization history. PPP was crystallized in  $\alpha$  or  $\beta'$  forms from melt, and then they were transformed into  $\beta$  forms ( $\beta_4$  from  $\alpha$ , and  $\beta_2$  from  $\beta'$ ) by solid-solid phase transition by gradually increasing temperature. Additional heat treatment was applied for further phase transformation to  $\beta_3$  and  $\beta_1$ . The following results were obtained.

- 1) From the polarized microscopy, the  $\beta_2$  changed its morphology during transformation from  $\beta'$ , while  $\beta_4$  kept the same morphology as  $\alpha$  form.
- 2) From the X-ray diffraction measurement, we confirmed the  $\beta_4$  transformed into  $\beta_3$  ( $\alpha$  route) and  $\beta_2$  transformed into  $\beta_1$  ( $\beta'$  route) because  $\beta_4$  ( $\beta_2$ ) and  $\beta_3$  ( $\beta_1$ ) had different short spacing.

- 3) From the differential scanning calorimetry measurements, the order of melting points were  $\beta_4 < \beta_3 < \beta_2 < \beta_1$ . These results indicated that PPP have four different polymorphs,  $\beta_4$  and  $\beta_3$ , which were transformed from  $\alpha$  form, and  $\beta_2$  and  $\beta_1$ , which were transformed from  $\beta'$  form.

**The Effect of Processing on Hybrid Shortenings Containing Diacylglycerols** Iris Tavernier<sup>1</sup>, Tom Rimaux<sup>2</sup>, Koen Dewettinck<sup>3</sup>, and Ian T. Norton<sup>4</sup>, <sup>1</sup>*Ghent University, Belgium*; <sup>2</sup>*Vandemoortele R&D Centre, Belgium*; <sup>3</sup>*University of Gent, Belgium*; <sup>4</sup>*Chemical Engineering, University of Birmingham, UK*

Oleogelation has attracted a lot of attention as possible alternative for saturated and trans-fat structuring of food products. Despite the development of numerous food-grade oleogels, they are still under-appreciated in the food industry. This reluctance to move from fundamental research to actual product development is related to the unknown effect of actual processing conditions on these newly developed products. Oil structuring using solely diacylglycerols (DAGs) have received little attention so far. However, they are known to form crystallite networks in a relatively similar way as TAGs. Furthermore, at concentrations of over 40%, 1,3-DAGs possess nutritional benefits compared to TAGs. In the current research, palm oil DAGs were combined with palm oil TAGs in various ratios, forming hybrid systems. Samples were prepared both statically, without shear or rapid cooling, and dynamically, in a bench-top scraped surface heat exchanger. Results

demonstrate the drastic effect of processing on the texture of the final products, which could be related to the different amount of crystalline matter (DSC) and the different crystalline microstructure (PLM). The functionality of the statically crystallized samples could not predict the behavior of dynamically crystallized samples. Furthermore, post-crystallization effects were more pronounced for the samples with a high concentration of DAGs, which is relevant in terms of further product development. This research clearly demonstrates that a thorough understanding of the processing parameters is essential for efficient product and process development. Furthermore, it is also shown that only realistic processing conditions allow the assessment of the true potential of alternative structuring techniques.

#### **Engineering Lipid Properties Through**

**Glycerolysis** Reed A. Nicholson\* and Alejandro G. Marangoni, *University of Guelph, Canada*

Partial glycerols are commonly used as food ingredients because of their emulsification properties. Additionally, monoacylglycerols (MAGs) and diacylglycerols (DAGs) can be found at varying concentrations in some types of edible oils, the most famous being palm oil, which is known to contain DAGs at concentrations of 5–8%. The presence of these molecules alters the crystallization behaviour of palm oil and is thought to contribute to its unique characteristics. The purpose of this research is to investigate the effect that partial glycerols have on the crystallization and melting properties of various edible oils. Glycerolysis reactions were performed at 65°C for various lengths of time in the presence of an excess of glycerol using *Candida antarctica* lipase B as the catalyst.

Differential scanning calorimetry (DSC) demonstrated changes in crystallization behaviour of peanut, cottonseed, and soybean oils, caused by the presence of partial glycerols. The onset of crystallization for peanut oil increased from 2°C to 21°C. For cottonseed oil, this temperature increased from –3°C to 21°C, and for soybean oil the onset was raised from –6°C to 10°C. Furthermore, pulsed nuclear magnetic resonance was used to investigate the melting profile of these modified oils. Solid fat content measurements demonstrated differences in the melting profiles of these modified oils, confirming the earlier onset of crystallization and delay in melting observed through DSC. This research will help to provide a better understanding of how partial glycerols can be used to tailor the physical properties of oils for their use in food applications.

#### **Developing Vegetable Oil Based Wax**

**Coating Alternatives** Tong Wang\* and Tao Fei, *Iowa State University, USA*

The demand from industry for “green” coating materials has been increasing in recent years due to the environmental concerns as well as the availability and supply fluctuation of imported specialty natural waxes. We have explored minimal and feasible modification methods to make vegetable hardstock have the performance of paraffin and carnauba waxes. Structure-function relationships are studied and established to provide direction for desirable and tunable properties. The effect of hydrocarbon chain length, pendent and terminal hydroxyl group, and type of linkage of the liner chain on physical properties of the bulk materials are demonstrated. These properties and laboratory-scale coating performance are compared to the

benchmark commercial products. Hardness, cohesiveness, melting profile and water resistance of the alternative coating compare well to paraffin wax (hardness of 1.40 mm vs. 1.85 mm penetration, cohesiveness of 1300 g.mm vs. 1500 g.mm, melting point of 67°C vs. 65°C, and water repellency of 90° vs. 100° surface contact angle). Our carnauba-like material has similar hardness (0.10 mm vs. 0.10 mm), much higher melting point (145°C vs. 82°C) and better water repellency (65° vs. 45°) compared to carnauba wax. Working with commercial partners, we expect to have these technologies adopted by the various industries that use waxes in their product formulations.

**An Emerging Natural Wax: Sorghum Wax from Bioethanol Production** Jeffrey T. Cafmeyer\*, *Battelle, USA*

Wax from grain sorghum has long been suggested as a potential alternative to high-melting, high-hardness natural waxes such as carnauba. However, the uses and potential of sorghum wax have remained largely unexplored due to the lack of a readily available source and process. Recently the bioethanol industry has begun to diversify its feedstocks and in turn has increased its use of grain sorghum. This has created opportunities to collect the sorghum wax resulting from bioethanol production resulting in several millions of pounds potentially available for use. Efficient wax isolation methods that can be performed without affecting ethanol production are under development. Significant sorghum wax quantities are now accessible for sampling to industrial evaluators with the goal of identifying uses for a domestic natural wax product that increases the value of grain

sorghum for both the bioethanol producers and sorghum farmers.

**Role of Rice Bran Wax on Crystallization and Rheological Properties of Oleogels from Rice Bran Oil** Khakhanang Wijarnprecha\*<sup>1</sup>, Pravit Santiwattana<sup>2</sup>, Sopark Sonwai<sup>3</sup>, and Dérick Rousseau<sup>4</sup>, <sup>1</sup>*Department of Food Technology, Silpakorn University, Thailand*; <sup>2</sup>*Thai Edible Oil Co., Ltd., Thailand*; <sup>3</sup>*Silpakorn University, Thailand*; <sup>4</sup>*Ryerson University, Canada*

The crystallization and rheological properties of oleogels consisting of 0.5–25 wt% rice bran wax (RBX) in rice bran oil (RBO) were explored. RBX was an efficient, thermoreversible oleogelator capable of structuring RBO at concentrations as low as 0.5 wt% RBX. A qualitative temperature-composition phase diagram showed that oleogels containing higher concentrations of RBX were the most resistant to melting. Polarized light microscopy revealed the presence of a network of interlinked, long aspect ratio wax crystal needles up to 50 μm in length in oleogels at higher RBX concentrations. Upon heating, RBX crystals did not undergo any polymorphic transition, based on the short spacings at ~4.16 and ~3.73 Å, indicative of an orthorhombic subcell, and d001 long spacing at 74–76 Å that persisted until RBX fusion. This long spacing was ascribed to the presence of wax esters consisting of long chain saturated fatty acids (C24 and C22) esterified to C28–C34 saturated fatty alcohols. During cooling from 90 to 20°C, the increase in oleogel viscosity resulting from the RBX liquid-solid phase transition was corroborated by the DSC-based crystallization onset and enthalpy data. Similarly, elastic moduli and hardness both rose with increasing RBX concentration. This study, which demonstrated that RBX can structure RBO with

distinct concentration-dependent properties, serves as the foundation for the development of oleogel-based approaches to saturated and trans fats replacement in processed foods.

**Phase Change Analysis of Waxes and Wax Blends by Thermal Microstructure Evolution**

**Analysis** Matt Vanden Eynden\*<sup>1</sup>, Roland Ramsch<sup>2</sup>, Giovanni Brambilla<sup>2</sup>, Pascal Bru<sup>2</sup>, and Gerard Meunier<sup>2</sup>, <sup>1</sup>*Formulaction, Inc., USA*; <sup>2</sup>*Formulaction, France*

Different raw wax materials clearly have different melting and crystallization profiles which can make the formulation of wax blends difficult in regards to achieving a homogeneous crystal structure. In addition to the raw content, heating and cooling types and rates will also have an influence of the resulting mixture. To analyze this, an accurate, reproducible method must be

employed to effectively measure the T50 profiles of these mixtures. Here, we propose using Multi-Speckle Diffusing Wave Spectroscopy (MS-DWS) as a method to monitor the phase change profiles of these mixtures during heating and cooling ramps. This technology utilizes a light scattering method on bulk samples in order to monitor the microstructure evolution of the crystal structures within the wax formulations. This is accomplished by correlating Brownian motion of particles during a phase change event to crystal structure evolution. Specifically, varying cooling profiles of select Beeswax and Candelilla blends will be shown as they are monitored for variances in crystallization structure profiles. This will allow for facile analysis of wax blending formulations as well as to assess the raw material quality of the waxes.

## EAT 5.1/S&D 5.1: Complex Phenomena at Interfaces

*Chairs: Sam Adamy, Church & Dwight Co. Inc., USA; and Ozan N. Ciftci, University of Nebraska-Lincoln, USA*

**Complex Interfaces: Role in Foam and Emulsion Behavior of Rinse-off Cosmetics** Edward DiAntonio<sup>1</sup>, Hani Fares<sup>1</sup>, Martin S. Vethamuthu\*<sup>1</sup>, and Seher Ozkan<sup>2</sup>, <sup>1</sup>Ashland Specialty Ingredients G.P., USA; <sup>2</sup>Ashland Specialty Ingredients, USA

This presentation will review progress of how the interface influences the formation and stability of emulsions and foams. The main function of emulsions is to provide moisturization, occlusion or conditioning benefits to substrates such as skin or hair. A key challenge has been understanding and optimizing the factors effecting the stability of emulsion droplets from destabilization mechanisms such as sedimentation/creaming, flocculation, coalescence, and tolerance to temperature and freeze thaw cycles under equilibrium and kinetic conditions. Attention is focused on the effect of polymer molecular structure, interfacial rheology, competitive adsorption and interfacial structure and composition both in bulk formulation and the interface.

**Effect of Emulsifiers on the Interfacial Tension of Fat-reduced W/O Emulsions Added with a High Behenic Stabilizer** Marisol Cordova-Barragan<sup>1</sup>, Jaime D. Pérez-Martínez<sup>1</sup>, and Elena Dibildox Alvarado<sup>2</sup>, <sup>1</sup>Lab. Biopolímeros Alimentarios, Facultad de Ciencias Químicas, Universidad Autónoma de San Luis Potosí, Mexico; <sup>2</sup>Universidad Autónoma de San Luis Potosí, Mexico

Soy lecithin and monoglycerols from rapeseed and palm oils were studied in their effect on the interfacial tension in fat-reduced W/O emulsions added with a high behenic

stabilizer (HBS). The interfacial tension of the emulsion was measured with each emulsifier and with the blend of them, all added to the oil phase, composed of palm oil, palm stearin and palm kernel oil. The emulsifiers blend decreased the interfacial tension of the emulsion from 11.7 to 2.1 dynes/cm ( $p < 0.05$ ); being the soy lecithin the one that contributed the most to this decrease (i.e., 11.7 to 2.8 dynes/cm;  $p < 0.05$ ). Even the HBS did not modified the interfacial tension, it influenced the crystallization behavior of the monoglycerols blend, where the HBS interacted with the high melting point components of the monoglycerols by increasing the Tonset of crystallization and the enthalpy of the first exotherm (46.6 vs 52.1°C and 57.2 vs 96.9 J/g;  $p < 0.05$ ). The addition of 0.9% of HBS also interacted with the medium melting point components of the blend. The data showed that the monoglycerols, in addition to reduce the interfacial tension, co-crystallize with the HBS, while the soy lecithin only reduces the interfacial tension, originating stable fat-reduced W/O emulsions.

**Surfactant Effects on Fat Crystallization at the Oil-water Interface** Nicole Green\*<sup>1</sup>, Stephen R. Euston<sup>2</sup>, and Dérick Rousseau<sup>1</sup>, <sup>1</sup>Ryerson University, Canada; <sup>2</sup>Heriot-Watt University, United Kingdom

We have previously shown that the addition of water to shear-crystallized fat+oil systems can form encapsulated droplets surrounded by Pickering crystal shells in the presence of certain lipophilic emulsifiers. We further explored the

interfacial behaviour 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 dioleate (GDO), and polyglycerol polyricinoleate (PGPR). The complex branched molecular structure of PGPR prevented any interfacial crystallization. Results for the glycerol-based emulsifiers were concentration-dependent: GMS shells grow thicker with the inclusion of more emulsifier or fat, whereas higher concentrations of GMO allow for fat crystal “satellite” attachment. Experimental results are compared to coarse-grained simulations of GMO and PGPR at a tristearin/water interface.

#### **Characterizing Adsorption Kinetics and Wetting Behavior of Polyelectrolyte Complexes (PECs)**

Claire Dentinger\* and David Scheuing,  
*Clorox, USA*

A wide variety of different pairs of oppositely charged polymers can interact electrostatically and form polyelectrolyte complexes (PECs) in solution. Under appropriate synthesis conditions these will form stable colloidal particles with dimensions on the order of 100 nm in diameter. PECs are also able to electrostatically adsorb to solid surfaces and in some cases can modify the properties of the solid surface. FTIR measurements are used to characterize the adsorption kinetics of PECs to solid surfaces under different solution conditions and contact angle is used to understand how PECs’ adsorption can modify the wetting characteristics of a surface.

#### **Physical Modification of Faba Bean Proteins Significantly Improves Interfacial and Emulsifying Properties of O/W Emulsions**

Yan Ran Tang and Supratim Ghosh\*, *University of Saskatchewan, Canada*

Protein concentrates from pulses has shown the ability to stabilize oil-in-water emulsions. In this research, faba bean protein concentrates were centrifuged to remove the insoluble fraction, and the supernatant with soluble proteins was utilized for efficient emulsification at pH2 and pH7. Prior to emulsification, the protein solutions were either homogenized or heat treated to investigate the effect of physical modification on interfacial and emulsifying properties. 5wt% oil-in-water emulsions were prepared with 0.5wt% soluble faba bean protein (SFBC) using multiple passes through a high-pressure homogenizer. The resulting emulsions were stored for 30 days and characterized by visual observation, droplet size, charge, creaming velocity under accelerated gravitation and microstructure. At pH2, all emulsions were extremely stable with lower creaming velocity, while at pH7, cream layer separation was observed after 30 days storage. All freshly prepared emulsions had an average droplet size in the range of 0.3 to 0.5  $\mu\text{m}$ , which was not significantly affected by pH or types of protein modification. However, after 15 days, droplet size of heat-treated protein-stabilized emulsions significantly increased due to droplet and protein aggregation. Zeta potential of the oil droplets decreased with protein modification, indicating interfacial protein aggregation upon modification due to exposure of hydrophobic groups. These results were explained by interfacial rheology and structural changes of the proteins under different pH and physical modifications. Overall,

SFBC showed great potential for improved emulsification and long-term stability of oil-in-water emulsions for food applications.

**Crystal-melt Interfacial Energy Effects on the Surface Nucleation of Triglycerides** Alejandro G. Marangoni\*, *University of Guelph, Canada*

Triacylglycerols (TAGs) nucleate from the melt or solution to form homoepitaxially stacked molecular lamellae, resulting in the formation of thin anisotropic crystalline nanoplatelets. A modified 2D Gibbs-Thomson equation for the formation of a "TAG island" nucleus on a surface was used to estimate the surface energy of the

nanocrystals as  $70\text{mJ/m}^2$ . This value of this surface energy strongly depends on the radius of the surface nucleus. When height and diameter of the nucleus were similar, the value of this surface energy was  $\sim 10\text{mJ/m}^2$ , which is typical of TAGs. The surface energy of TAG nanocrystals was then modulated by addition of specific emulsifiers, which allowed the controlled change, both increase and decrease, in nanoplatelet thickness in the range 20–30nm, by homoepitaxial growth of single 4nm molecular lamellae.

**EAT-P: Edible Applications Technology Poster Session**

*Chair: Supratim Ghosh, University of Saskatchewan, Canada*

**1. Influence of Dairy Emulsifier Type and Droplet Size on Gastrointestinal Fate of Corn Oil Emulsion: In vitro Digestion.**

Li Liang<sup>1</sup>, Xingguo Wang<sup>2</sup>, Qingzhe Jin<sup>2</sup>, and D. Julian McClements<sup>3</sup>,  
<sup>1</sup>State Key Laboratory of Food Science and Technology, School of Food Science and Technology, Jiangnan University, China;  
<sup>2</sup>Jiangnan University, China; <sup>3</sup>University of Massachusetts Amherst, USA

The lipid in most commercial infant formula is emulsified by dairy protein or other citrate glyceride, mono- or di-glyceride, which has apparently different interface properties with breast milk. Milk is a kind of natural emulsion with big droplet size and special interface, named milk fat globule membrane (MFGM), a tri-layer phospholipids structure and inserted with some other polar lipids and proteins. The gastrointestinal fate of milk fat is influenced by the interface properties, such as composition, size and structure, which are associated with dairy processing and manufacturing procedures. The development of processing technology makes it possible to get commercial MFGM from buttermilk serum, and some infant formula supplemented with MFGM were commercially available recent year. To determine the influence of dairy emulsifier type and droplet size on the gastrointestinal fate of lipid, the corn oil emulsions coated with different dairy emulsifiers, including lactoferrin, caseinate sodium, whey protein isolate (WPI),  $\alpha$ -lactalbumin  $\beta$ -lactoglobulin or phospholipids obtained from MFGM, and different sizes emulsions coated with MFGM were prepared and studied under a simulated gastrointestinal tract model (GIT).

The emulsifier type exhibited significant influence on the initial digestion rate. There was a initial lag phase in all the emulsion coated with dairy proteins, especially emulsion surrounded by caseinate sodium,  $\alpha$ -lactalbumin and  $\beta$ -lactoglobulin. The lag phase was not presented in the emulsion coated with MFGM. The digestion extent was decreased with the reduce of droplet size, which can be attributed to the available surface area to lipolysis.

**2. X-ray Study on Melt Crystallization Kinetics of Triacylglyceride Molecular Compound System.**

Ken Taguchi<sup>1</sup>, Ryuichi Ikoma<sup>2</sup>, Akihiko Toda<sup>2</sup>, Hironori Hondoh<sup>3</sup>, Satoru Ueno<sup>3</sup>, and Kiyotaka Sato<sup>2</sup>,  
<sup>1</sup>Graduate School of Integrated Arts and Sciences, Hiroshima University, Japan; <sup>2</sup>Hiroshima University, Japan; <sup>3</sup>Graduate School of Biosphere Science, Hiroshima University, Japan

Triacylglycerides (TAG) are main ingredients of fat and used in many edible fats products such as chocolate in crystalline state. It is hence important to know the crystal polymorphism and crystallization kinetics of TAG molecules in particular for the mixture system of TAG components because the fats are usually present in multicomponent system with different types of TAG species. We have investigated the melt crystallization kinetics of the TAG binary system consisting of POP and PPO using the time-resolved X-ray diffraction measurement and polarized optical microscopy (POM), and also examined the local structure using microbeam X-ray diffraction method. It was found that only for the TAG systems containing racemic PPO (racPPO), the SAXD peaks corresponding to the



chain length structure appears before the WAXD peaks from the crystalline sub-cell structure. Although the polymorphic transitions were not observed by X-ray measurement, the POM showed the reduction of growth rate and morphological change of spherulites in the later stage of crystallization. From the microbeam X-ray diffraction study, the crystallites size of first growth stage of spherulites is smaller than that of later stage after morphological change; the subcell structure also changes very slightly between the first and later stage of growth. The results indicate that the structure with relatively disordered chain packing is formed in the early stage of melt crystallization of the TAG crystals containing racemic body and the stereoisomer of TAG molecules plays a key role for the structure formation.

**3. Cocoa Butter Substitute Produced by Enzymatic Inter-esterification of Binary Blends Containing *Irvingia gabonensis* Seed Fat.** Sabine Danthine<sup>1</sup>, Juste Yamoneka Wasso<sup>1</sup>, Paul Malumba<sup>1</sup>, Georges Lognay<sup>2</sup>, and Christophe Blecker<sup>2</sup>, <sup>1</sup>University of Liège, Belgium; <sup>2</sup>University of Liège, Belize

*Irvingia gabonensis* seed fat (IGF) is a lauric fat with a high amount of solids at room temperature, with contains high quantities of myristic acid (50%) and lauric acid (37%). Yamoneka et al. (2015) recently showed that this  $\beta'$ -tending fat presents a sharp melting profile similar to that of tempered CB. However, its complete melting is around 40°C which is too high for confectionery applications. In order to overcome this issue, binary fat blends made of *Irvingia gabonensis* seed fat combined with liquid oils, either rapeseed oil (RO), groundnut oil (GO), palm super olein (PSO) or *Dacryodes edulis* pulp

oil (DPO) were prepared. Those blends were then enzymatically interesterified in order to improve their melting profiles. The binary blend that showed a similar profile with CB and palm kernel stearin (PKS) was chosen as the best potential new speciality fat. Compatibility between this new speciality fat and CB was evaluated by constructing phase diagrams from pNMR and XRD data. The interesterified blends with 90% of IGF and 10% of DPO was chosen as the new speciality fat because its profiles was close to that of CB and showed similar characteristics to PKS. The results indicated that the specialty fat produced from IGF and DPO could be used as CBS in confectionery industries (alone or mixed in low proportion with CB).

**4. Electrostatic Deposition of Chitosan on Lecithin Stabilized Emulsion Inhibits Mycotoxin Production in *Fusarium graminearum*.** Dianhui Wu<sup>1</sup>, Jiajia Rao<sup>1</sup>, and Jian Lu<sup>2</sup>, <sup>1</sup>North Dakota State University, USA; <sup>2</sup>School of Biotechnology, Jiangnan University, China

**Objective:** Different molecular weight (MW) of chitosan were electrostatically deposited on lecithin stabilized emulsion and their deoxynivalenol (DON) inhibitory efficacy of *Fusarium graminearum* were evaluated.

**Methods:** A concentrated primary emulsion was prepared by homogenizing 10 wt% medium chain triglycerides (MCT) with 2 wt% lecithin. Positively charged chitosan solution (0.02–0.5 wt%) with different MW was then deposited on the interfacial of primary emulsion to form multilayer emulsion by electrostatic adsorption. Mean particle size and  $\zeta$ -potential of emulsions were measured and pH stability of emulsions were studied in pH 3.0–6.0. In addition, the impact of chitosan deposited on multilayer emulsions interface and dissolved in solution at pH 5.0 on

inhibition of DON production by *F. graminearum* isolates was investigated in rice culture.

**Results:** The electrical charges of multilayer emulsions went from negative (–31.2 mV) to positive and were stable at around +50 mV when chitosan concentration exceeded 0.02 wt%. The mean particle diameters of multilayer emulsions increased as the increase of chitosan concentration. Physically stable chitosan emulsions with the size of 0.4–0.5  $\mu\text{m}$  at pH 5.0 could be formed at 0.1 wt% chitosan. Mycotoxins inhibition rate were measured after 5 days incubations. In general, mycotoxins inhibitory activities of chitosan based multilayer emulsions were better than that of the chitosan solutions and the highest DON inhibition rate (85%) was observed in low MW chitosan multilayer emulsion.

**Conclusion:** These results of current study have important implications for the design and utilization of chitosan as effective detoxification agent in food or other industries.

#### 5. Extraction of Carotenoids and Antioxidant Compounds from Guava Processing Waste.

Renan S. Lima<sup>1</sup>, Itaciara L. Nunes, Sandra Regina S. Ferreira<sup>2</sup>, and Jane Mara Block<sup>\*3</sup>, <sup>1</sup>Federal University of Santa Catarina, Brazil; <sup>2</sup>Federal University of Santa Catarina, Brazil; <sup>3</sup>UFSC, Brazil

Guava (*Psidium guajava*) is a tropical fruit originating in the Americas which is rich in bioactive compounds such as carotenoids and phenolics. In guava processing around 30% of the fruit is lost in the form of residues (peels, seeds, and part of the pulp). However, this waste also presents a considerable amount of bioactive compounds. The objective of this study was to extract the carotenoids and the phenolic compounds present in guava processing waste. Carotenoids extraction was performed through

maceration of the dehydrated residue (final moisture = 6.11%), and two solvents were tested —acetone and ethyl acetate. The extraction of the phenolic compounds was performed with a probe-type ultrasound varying extraction time (3, 6, 9 minutes), solvent (water, ethanol, water: ethanol – 50:50, water: ethanol – 30:70, water: ethanol – 10:90) and solvent concentration (15, 25, 35 mL). Ethyl acetate showed a higher extraction yield for carotenoids when compared to acetone (53.14  $\mu\text{g/g}$  and 29.50  $\mu\text{g/g}$  of total carotenoids, respectively). The higher yield for the extraction of the phenolic compounds was achieved using 15 mL of water: ethanol (50:50) for 3 minutes (920.24 mg/100 g). The results showed that guava waste is a potential source for the extraction of carotenoids and phenolics. Also, the use of ultrasound, a green technology, with a low amount of time and solvent concentration, allowed for the extraction of a high quantity of phenolics.

#### 6. Profile of Volatile Compounds of Dark Chocolate Formulated with Cocoa Butter Equivalent.

Cristiano S. Souza, and Jane Mara Block\*, UFSC, Brazil

Cocoa butter equivalent (CBE) are fats used for replacing part of the cocoa butter (CB) in chocolate due to its high cost, low milk-fat tolerance, lack of stability at elevated temperatures and tendency to bloom. The effect of this replacement on the volatile compounds profile of dark chocolate is not well known. In this work samples of dark chocolate with 15% of cocoa butter; 10% of cocoa butter and 5% of CBE, and 5% of cocoa butter and 10% of CBE, were studied. The volatile compounds were identified and quantified using a solid phase microextraction with gas chromatography

(SMPE-GC). In the samples studied 27 different volatile compounds were identified. The compounds phenylacetaldehyde, methylpyrazine, 2,6-dimethylpyrazine, 2-ethyl-5-methylpyrazine, 2-ethyl-3,5-dimethylpyrazine, tetramethylpyrazine, trimethylpyrazine, 3-ethyl-2,5-dimethylpyrazine, phenethyl alcohol, 2-acetylpirrol, acetophenone and isovaleric acid were detected at significantly higher levels ( $p \leq 0.05$ ) in the sample formulated only with CB. The group of pyrazines showed a decrease of more than 50% for the samples formulated with CB and CBE. The results obtained showed that the replacement of CB by CBE in dark chocolate may negatively influence the profile of volatile compounds responsible for the flavor of dark chocolate.

#### 7. Characterization of Soybean Oil Organogels Structured with Candelilla Wax and Monoglycerides.

Natalia Martinez<sup>1</sup>, Natani Amaro<sup>2</sup>, Thaís Jordânia<sup>2</sup>, Gabriel D. Fernandes<sup>3</sup>, Bruno Irigaray<sup>1</sup>, Iván Jachmanián\*<sup>1</sup>, and Daniel Barrera-Arellano<sup>2</sup>, <sup>1</sup>*UdelaR, Uruguay*; <sup>2</sup>*Laboratorio de óleos e gorduras, FEA, UNICAMP, Brazil*; <sup>3</sup>*Fats and Oils Laboratory. School of Food Engineering. UNICAMP. Brazil*

The objective of this work was the characterization of soybean oil organogels structured with a mixture of candelilla wax (CLW) and monoglycerides (MAG) in different proportions. Organogels were prepared according to four formulations (F), with the following percentages of structuring agents: 1% CLW + 1% MAG (F1), 2% CLW + 2% MAG (F2), 2% CLW + 1% MAG (F3) and 2% CLW + 0% MAG (F4). Thermal properties (DSC), visual stability, hardness (Texturometer), and microcrystalline structure (Polarized light microscopy) were

determined. The organogel prepared according F2 showed the highest on-set crystallization temperature (39°C), while that prepared according F1 showed the lowest one (32°C). Accordingly, both formulations showed the highest and the lowest end-set melting temperature, respectively (72 and 68°C). Although all organogels containing 2% CLW were “totally firm,” that structured without MAG was the hardest at room temperature (F4: 3,33 N). While the addition of MAG to 1 or 2% produced a softener effect (F3: 1,60 N and F2: 0.32 N, respectively). Organogels prepared using both structuring agents showed heterogeneous microcrystalline structures and non-uniform distribution of microcrystals. These results showed that CLW is an efficient oleogelator for soybean oil, and that MAG incorporation at different proportions permitted the moderation of organogels hardness. Thus, organogels with very different properties attractive for different applications can be obtained.

#### 8. Filler-matrix Interactions to Control Texture of Oil-continuous Systems.

Auke de Vries and Déric Rousseau, *Ryerson University, Canada*  
In foods, pharmaceuticals or cosmetics, filler particles are often added to modify textural properties of the product. These filler particles can be solid (suspensions), liquid (emulsions) or gaseous (foams). Examples in food products include oil droplets in a casein matrix (cheese), air bubbles entrapped in an aggregated fat globule matrix (whipped cream), or solid sugar and cocoa particles in a fat crystal matrix (chocolate). An important aspect is whether the filler particle interacts with the continuous matrix. When there is no interaction between the

particle and the matrix, the particle acts as an ‘inactive filler’ whereas if the particle interacts with the matrix, the particle acts as an “active filler.” Depending on the modulus of the filler versus the matrix, the modulus of the composite material can decrease (for inactive fillers) or increase (for active fillers). Despite growing knowledge on this topic, only a few studies have described these effects for water-in-oil emulsions. Recent work in our lab has shown that, depending on the emulsifier, dispersed water droplets can behave either as an inactive or an active filler in a fat crystal matrix, resulting in vastly different textures. From these and other results, we present a conceptual model, based on the concept of active versus inactive fillers, that captures important parameters to control the final texture of water-in-oil emulsions or solids-in-oil suspensions. By increasing our knowledge in this area, greater flexibility can be achieved in product formulations without altering the textural properties.

#### 9. Structural and Mechanical Properties of Palm Oil in the Presence of Air and Sugar.

Dérick Rousseau and Hardeep Devgan\*,  
*Ryerson University, Canada*

The goal of this research was to assess the role of added sugar (50 wt%), lecithin (0.15 wt%) and aeration on the microstructural, crystallization and mechanical properties of two types of palm oil over 4 weeks, with the intent being to explore whether the presence of dispersed sugar, lecithin and air would promote palm fat crystallization. Mixtures were cooled from 60 to 20°C at 5 °C/min with stirring at 100 rpm in a lab-scale scraped-surface heat

exchanger. Microstructure was examined using confocal microscopy and polarized light microscopy whereas fat crystal properties were assessed with pulsed NMR and DSC. Small-deformation rheology examined the evolution in viscoelasticity. With addition of sugar and aeration, there was a reduction in enthalpy and a slight increase in solid fat content after the first week in both palm fats. Addition of sugar also resulted in an increase in the elasticity both palm fats, yet both aeration and addition of lecithin reduced elasticity. Once the role of air in fat-sugar composites are understood, mixtures with a reduced proportion of palm-based fat can be reduced by optimizing the role of sugar as an active, synergistic filler.

#### 10. Fat-sugar Interactions Measured by Force Spectroscopy. Dérick Rousseau, and Nicole Green\*, *Ryerson University, Canada*

Sugar particles are integral to many fat-continuous confectionery systems, yet their effect on fat crystallization remains undetermined. Necessary particulate matter (i.e., sugar) has been found to promote heterogeneous nucleation, yet recently published work from our group has shown that sugar suppresses fat crystal growth in palm oil-based systems. The incorporation of necessary emulsifiers further complicates the problem. We use atomic force microscopy (AFM) to characterize the surface topology and then force spectroscopy to calculate the interaction between sample and cantilever tip through measurements of the cantilever deflection. We attach sugar particles to tipless cantilevers, then we measure the interactions between fat and sugar in the presence or absence of emulsifiers.

**11. Tailoring Crystalline Structure using High Intensity Ultrasound to Reduce Oil Migration.**

Silvana Martini<sup>1</sup>, Zachary Cooper<sup>1</sup>, Juhee Lee<sup>1</sup>, and Véronique Gibon<sup>2</sup>, <sup>1</sup>Utah State University, USA; <sup>2</sup>Desmet Ballestra Group, Belgium

The objective of this study was to use high intensity ultrasound (HIU) to change the crystalline structure of fats and delay oil migration. Three fats with different level of saturation were tested: one soybean oil-based fat, one palm-based fat, and one palm kernel oil-based fat. HIU was used to generate various crystalline networks that can affect oil migration. Results show that oil migration is driven by crystal size and hardness but also by the total content of saturated fatty acids and by the type of TAGs that form the crystalline network. Oil migration of fats with medium chain fatty acids and high level of saturation was not affected by crystal size nor by the type of crystalline network obtained. When medium chain fatty acids are not present in the fat and when low levels of saturations are present, oil migration was significantly reduced by using HIU. This reduction in oil migration can be explained by a promotion in the crystallization of low melting point TAGs that can form a stronger crystalline network. Overall, these results show that HIU can be used to change the crystalline structure of fats and reduce oil migration, especially in fats with low level of saturation.

**12. Sonocrystallization of a Tristearin-free Fat.**

Jeta V. Kadamne<sup>1</sup>, Maria A. Moore<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 objective of this study was to fractionate a purified interesterified fat to eliminate tristearin (SSS) and to evaluate the crystallization behavior of the tristearin-free fat. The

fractionated sample was crystallized with and without the application of high intensity ultrasound (HIU) by supercooling the sample at 2°C. In the absence of SSS, the crystallization process was driven by low melting point triacylglycerols (TAGs) such as OSS and OOS (O: oleic and S: stearic acid). The use of HIU resulted in slightly higher ( $p > 0.05$ ) crystallinity in the sample based on the solid fat content (SFC), but there were no microstructural differences. In addition, an increase in the enthalpy of melting was observed upon sonication, also indicating higher crystallinity. Stronger intramolecular forces were formed in the sonicated samples as evidenced by increased viscoelastic parameters such as the elastic ( $G'$ ) and storage modulus ( $G''$ ).  $G'$  values increased from  $138.25 \pm 41.30$  to  $939.73 \pm 277.45$  Pa while the  $G''$  increased from  $39.15 \pm 8.98$  to  $149.77 \pm 16.00$  Pa ( $p < 0.05$ ). Change in viscosity was not observed as a consequence of sonication. This study showed that HIU was effective in changing the crystallization behavior of SSS-free fats with low-melting TAGs.

**13. Lipid Composition and Antioxidant Property of Sea Buckthorn Oils Extracted by Supercritical and Subcritical Technologies.**

Li Zheng<sup>1</sup>, Longkai Shi<sup>1</sup>, Zhao Chenwei<sup>2</sup>, Qingzhe Jin<sup>1</sup>, and Xingguo Wang<sup>1</sup>, <sup>1</sup>Jiangnan University, China; <sup>2</sup>State Key Laboratory of Food Science and Technology, School of Food Science and Technology, Jiangnan University, China

Sea buckthorn (*Hippophaë rhamnoides* L.) oils (SBO) are widely used in food, medicinal and cosmetic industries, but comprehensive study of their lipid characteristic (fatty acid and triacylglycerol), phytochemical (tocopherol/tocotrienol, phytosterol, flavonoid, carotenoid, polyphenol), oxidative stability and

free radical scavenging capacity are few. In the present study, above profiles of four SBO obtained from SB pulp and seed by using supercritical and subcritical technologies were investigated and compared. The distributions of the main fatty acids in the SB pulp oils (C16:1, C16:0 and C18:1 (n9)) and seed oils (C18:2, C18:3 and C18:1 (n9)) showed significant difference ( $P < 0.05$ ). The main triacylglycerols in the pulp oils were POPO, PoPPo and OPO. In contrast, LOL, OLO and LLnO were the dominant triacylglycerols in the seed oils. Further, SB pulp oils with higher SFA, flavonoid, carotenoid, polyphenol contents showed preferable oxidative stability than the counterparts ( $P < 0.05$ ). However, free radical scavenging capacities of the seed oils were significantly higher than the former. Principal component analysis (PCA) and hierarchical cluster analysis (HCA) showed apparent distinctions between the test SB pulp and seed oils, and the results observed in this study proved that the raw material used for oil production was more important than processing method in terms of the final SBO products.

**14. Chemical Characterization and Antioxidant Capacity of Sesame Oils Extracted by Supercritical, Subcritical and Conventional Techniques.** Longkai Shi, Li Zheng, Ruijie Liu, Ming Chang, Qingzhe Jin, and Xingguo Wang, *Jiangnan University, China*

In this study, profiles of chemical characterization, oxidative stability and in vitro antioxidant capacity of sesame oils obtained from supercritical and subcritical techniques and conventional methods (hot pressing, cold pressing, solvent extraction and aqueous extraction) were studied and compared. Their similarities and differences were evaluated using

multiple chemometrics like principal component analysis, soft independent modeling of class analogies, hierarchical cluster analysis and multiple linear regression. The results showed that a large proportion of fatty acids and triacylglycerols were not significantly influenced by the processing technologies (except for LLn, SOA, C18:3n-6 and C22:0). However, significant differences of minor component, oxidation stability and free radical scavenging activity among the test oil samples were observed. Supercritical sesame oils were more excellent than the subcritical sesame oils and oils obtained from the traditional methods, especially in terms of  $\gamma$ -tocopherol, lignan and polyphenol contents and antioxidant capacity, thus indicating that CO<sub>2</sub> fluid technology was a desirable alternative to extract sesame oils with rich nutrition and superb physiological activity. The use of CO<sub>2</sub> supercritical fluid in the present study was associated with high efficiency and antioxidant activities of the obtained sesame oils. These results indicated that this technology had the potential to work as a satisfactory approach to produce specific sesame oil products for health care and cosmetic use. Further, oils obtained from roasted sesame seeds exhibited higher oxidative stability and antioxidant capacity, thus declaring that high temperature roasting was a critical issue that influenced the quality of the final sesame oil product.

**15. Control of Protein Digestion under Simulated Gastrointestinal Conditions using Biopolymer Microgels.** Ruojie Zhang, Zipei Zhang, and D. Julian McClements, *University of Massachusetts Amherst, USA*

Controlling the rate and extent of protein digestion within different regions of the human

gastrointestinal tract (GIT) is important for regulating hormonal responses (such as hunger, satiety, and satiation) and immune responses (such as allergenicity). In this study, hydrogel beads (biopolymer microgels) were fabricated by injecting a solution of anionic alginate molecules into a solution of cationic calcium ions using a vibrating extrusion device. A model food protein (whey protein isolate, WPI) was mixed with the alginate solution prior to bead formation. The impact of thermal processing (80°C, 15 min) of the WPI before or after microgel formation was examined to determine the impact of protein denaturation and aggregation on encapsulation efficiency and retention. Heat-denaturation of the protein prior to microgel formation led to the highest encapsulation efficiency and retention, which was attributed to the formation of a cold-set protein gel inside the beads. Simulated GIT studies indicated that protein encapsulation in the microgels retarded its digestion in the stomach (around 3.7% digested), but not in the small intestine (around 19.6% digested). The denatured and native proteins were digested differently in different GIT regions: denatured protein digested faster in the stomach (around 11% digested), whereas native protein digested faster in the small intestine (around 41% digested). These results could provide valuable information for the design of microgel-based delivery systems to regulate protein digestion and peptide release in the GIT.

**16. Physicochemical, Functional and Sensory Properties of Margarine Supplemented with Bush Mango Kernel and Njangsa Seed Oils.**

Anh Nguyen, Peace C. Asuzu, Benjamain M. Bougouneau, Samuel A. Besong, and Alberta N.A. Aryee\*, *College of Ag. & Related Sciences,*

*Department of Human Ecology, Delaware State University, USA*

Though both Njangsa seed oil (NSO) and bush mango kernel fat (BMKF) have been reported to have high functional and nutritional potential, their application in product development is limited. To encourage their use, this study investigated the effect of supplementing margarine with various proportion of BMKF and NSO, up to 20 and 80%, respectively, and stored over a 3-month period at 4°C on their physicochemical, functional and sensory properties, compared to commercial alternatives; Land O'Lakes margarine (LLM) and Blue Bonnet spread (BBS). Margarine 1, 2, 3 and 4 contained; 40% coconut oil and 60% NSO (CN4060), 20% BMKF and 80% soybean oil (BS2080), 20% BKMF and 80% NSO (BN2080) and 60% coconut oil and 40% soybean oil (CS4060), respectively. These oils, fats and blends were analyzed before and after margarine preparation for their fatty acid composition, thermal properties, texture, color, melting profile, solid fat content, antioxidant properties, free fatty acid content, peroxide value, and para-anisidine value. There were significant differences in the melting enthalpy values of all the margarines and spread, and their thermograms show distinct peaks. Hardness was in the order; LLM > CN4060 > BN2080 > CS4060 > BS2080 > BBS, while adhesiveness was; BBS > CS4060 > BS2080 > CN4060 > BN2080 > LLM. Experimental results show that the properties of the all margarines were influenced by the blends used, and margarine made from NSO and/or BMKF may be potential competitors to commercial brands, and sources of valuable polyunsaturated fatty acids and polyphenolic compounds.