MICROSTRUCTURE, RHEOLOGICAL PROPERTIES AND STABILITY OF OLEOGELS DERIVED FROM PALM OLEIN, PALM MID FRACTION AND SOYBEAN OIL BLENDS

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By

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Thesis Submitted to the School of Graduate Studies, Universiti Putra Malaysia, in Fulfilment of the Requirements for the Degree of Doctor of Philosophy

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Organogelation is an alternative method of structuring edible oils used to produce low saturation solid fat products. Many studies on oleogels involve the use of soft vegetable oils. However, these highly unsaturated oils are mostly thermally unstable and exhibit poor physical properties. Therefore, palm-based liquid oil could be a better choice for the preparation of oleogels due to its balanced fatty acid composition. In oleogel systems, the rheology, stability, physical and microstructural properties of the oleogels are greatly influenced by the preparation temperature and gelator type and dosage, as well as the type of liquid oil used. Therefore, this dissertation focuses on the influence of various factors on the characteristics of palm-based oleogels and the possibility of using palm-based liquid oil in the formation of oleogels.

First, gelator screening was conducted through the inverted vial method. Polyglycerol behenice acid ester (PBA), sunflower wax (SFW) and fully hydrogenated palm-based monoacylglycerol with high stearic (MGHO) were selected, whereas fully hydrogenated palm stearin iodine value of 2 (PSIV2), hard palm stearin iodine value of 14 (PSIV14) and fully hydrogenated palm-based monoacylglycerol with high palmitic (MGHP) were removed from further investigation due to their low effectiveness in gelling palm superolein. The results indicated that storage temperature and duration significantly affected the characteristics of the superolein oleogels. Palm superolein tended to crystallize at 5 °C, causing a tremendous increase in the hardness from 1.6 g to 340 g when storage temperature for SFW oleogles was reduced from 25 °C to 5 °C. Similar observation was found for the other oleogels as well due to the crystallization of the superolein at low temperature. At 15 °C, the oleogels derived from SFW and MGHO showed increasing trends in the enthalpy of melting from 4.8 Jg^{-1} to 7.7 Jg^{-1} and 9.4 Jg^{-1} for SFW oleogels and from 7.1 Jg^{-1} to 12.1 Jg^{-1} and 14.7 Jg^{-1} for MGHO oleogels upon storage (from day 1 to day 3) due to the slow crystallization behavior of superolein. PBA oleogels delayed the crystallization of superolein, as no significant changes in properties were observed during the three days of storage. SFW oleogels formed uniform and

continuous crystalline structures that efficiently trapped superolein within their structures. Therefore, SFW oleogels were the most stable compared to the other oleogels. In contrast, despite their high hardness (23.1 g) and solid fat content (7.6%), MGHO oleogels were the least stable due to the formation of irregularly sized crystals with loose entanglement. Therefore, MGHO was removed from further investigation due to its poor performance in organogelation.

The effects of gelator dosage and liquid oil types on the characteristics of PBA and SFW oleogels were very complicated. The gelator dosage showed positive linear effects on the rheological, thermal and physical properties of PBA and SFW oleogels. However, the gelator dosage effect became less significant when POoIV56 and SBO:PMF (7:3) were used due to their higher saturation content. POP has been identified as a possible key compound in POoIV56 and SBO:PMF (7:3) contributes to differences in the oleogels' characteristics. The POP in SBO:PMF (7:3) had a higher degree of freedom compared to that in POoIV56 due to its incompatibility with the low-melting TAGs in SBO. Therefore, the POP in the SBO blend had a greater interaction affinity with the PBA and SFW gelators, thus improving the rheological, thermal and physical properties of the oleogels. According to microstructural analysis by XRD, the SFW oleogels derived from SBO and PMF blends exhibited a more complex crystalline system, in which crystals with lamellae sizes of 42.8 Å and 68.9 Å were concurrently present in the oleogel system. This result show that the PMF in the SBO formed cocrystals within the SFW gel structure, and therefore improved the gel strength and stability. The oleogels formed with other liquid oils showed insignificant differences in affecting the oleogels properties. Their G'_{LVR}, G''_{LVR}, critical stress, and ΔH values were much lower than those of oleogels formed with POoIV56 and SBO:PMF (7:3). These findings showed that the TAG components in the oils such as POoIV64, POoIV72, SBO, SBO:IV64 (1:1), SBO:PMF (9:1) and SBO:PMF (4:1), did not interfere with the formation of a gel structure; thus, their rheological and thermal profiles were mainly dependent on gelator dosage.

In conclusion, the stability of oleogels is attributed to microstructural factors and intermolecular interactions in oleogel formation but is less dependent on the hardness and SFC. This study also showed that PMF could be used to enhance the strength and characteristics of oleogels, especially those of oleogels formed with soft vegetable oils. This study also showed that palm liquid fractions have the potential to be used to form oleogels with satisfactory strength and stability. This new finding could be extended to real food products in the future, whereby palm liquid fractions and blends of PMF with soft vegetable oils could be used as major ingredients in solid fat production to make margarine, shortening replacements and meat products.

Abstrak tesis yang dikemukakan kepada Senat Universiti Putra Malaysia sebagai memenuhi keperluan untuk ijazah Doktor Falsafah

MIKROSTRUKTUR, SIFAT RHEOLOGI DAN KESTABILAN OLEOGEL DARIPADA ADUNAN MINYAK SAWIT OLEIN, PECAHAN SEPARA SAWIT (PMF) DAN MINYAK SOYA

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Organogelasi merupakan cara alternatif untuk penstrukturan minyak dalam penghasilan produk lemak yang mengandungi ketepuan yang rendah. Kebanyakan penyelidikan berkenaan dengan penghasilan oleogel melibatkan penggunaan minyak sayuran lembut. Tetapi, minyak-minyak ini mengandungi ketaktepuan yang tinggi dan kurang stabil dari segi terma dan fizikal. Maka, minyak berasaskan sawit boleh menjadi pilihan yang lebih baik dalam penghasilan oleogel disebabkan oleh komposisi asid lemak yang lebih seimbang. Dalam sistem oleogel, rheologi, kestabilan, sifat-sifat fizikal dan mikrostruktur amat dipengaruhi oleh suhu penghasilan, jenis gelator dan dos gelator yang digunakan, serta jenis minyak yang digunakan. Oleh itu, kajian untuk tesis ini tertumpu kepada kesan faktor-faktor tersebut dalam pencirian oleogel serta penggunaan minyak sawit dalam pembentukan oleogel.

Pada mulanya, pemilihan gelator dijalankan berdasarkan cara menerbalikkan botol. Ester poligliserol asid behenik (PBA), wax bunga matahari (SFW) dan ‘fully hydrogenated palm-based monoacylglycerol with high stearic’ (MGHO) telah diuji, manakala ‘fully hydrogenated palm stearin’ dengan bernilai iodin 2 (PSIV2), ‘hard stearin’ bernilai iodin 14 (PSIV14) dan ‘fully hydrogenated palm-based monoacylglycerol with high palmitic’ (MGHP) telah disingkirkan daripada penyiasiatan lebih lanjut. Keputusan menunjukkan bahawa suhu dan tempoh simpanan telah menjejaskan ciri-ciri oleogel superolein yang dihasilkan. Penghabluran minyak superolein berlaku pada suhu 5 °C, dan mengakibatkan peningkatan kekerasan dari 1.6 g kepada 340 g apabila suhu penyimpanan oleogel SFW diturunkan dari 25 °C kepada 5 °C. Permerhatian yang serupa telah dikesan bagi oleogels yang lain disebabkan oleh penghabluran minyak superolein pada suhu yang rendah. Pada 15 °C, oleogel yang dihasilkan daripada SFW dan MGHO menunjukkan tren peningkatan dalam entalpi peleburan iaitu dari 4.8 Jg^{-1} kepada 7.7 Jg^{-1} dan 9.4 Jg^{-1} bagi oleogel SFW dan 7.1 Jg^{-1} kepada 12.1 Jg^{-1} dan 14.7 Jg^{-1} bagi oleogel MGHO, semasa simpanan dari hari pertama kepada hari ketiga. In adalah disebabkan oleh sifat superolein yang menghablur secara perlahan pada suhu tersebut. Oleogel PBA tidak menunjukkan tren ini kerana molekul PBA melambatkan process penghabluran ini. Oleogel SFW

adalah antara yang paling stabil kerana ia membentuk hablur yang seragam dengan struktur hablur berterusan yang dapat memegang minyak superolein dengan lebih cekap. Sebaliknya, oleogel MGHO adalah antara yang paling tidak stabil walaupun ia menunjukkan sifat kekerasan (23.1 g) dan kandungan lemak pepejal (7.6%) yang paling tinggi. In adalah kerana MGHO membentuk hablur yang tidak bersaiz seragam dengan susunan yang longgar yang menyebabkan minyak senang dikeluarkan daripada strukturnya. Maka, MGHO telah disingkirkan daripada eksperimen seterusnya.

Kesan dos gelator dan jenis minyak pada sifat-sifat oleogels PBA dan SFW adalah agak rumit. Secara umumnya, kuantiti gelator yang digunakan telah menunjukkan kesan linear positif pada sifat rheologi, kesan terma dan sifat fizikal. Akan tetapi, kesan kuantiti gelator ini menjadi kurang ketara apabila minyak POoIV56 dan SBO:PMF (7:3) digunakan untuk penghasilan oleogel. POP telah dikenalpasti sebagai kompaun utama yang menyebabkan perbezaan dalam sifat-sifat oleogels tersebut. POP dalam SBO:PMF (7:3) mempunyai darjah kebebasan yang lebih tinggi berbanding dengan POoIV56 kerana POP mempunyai keserasian yang rendah dengan trigliserida minyak SBO yang bertakat lebur rendah. Maka, POP dalam adunan SBO mempunyai afiniti yang lebih tinggi terhadap gelator-gelator PBA dan SFW yang boleh membentuk struktur yang lebih kuat, seterusnya meningkatkan sifat rheologi, terma dan fizikal bagi oleogel-oleogel tersebut. Berdasarkan analisis-analisis mikrostruktur, oleogel SFW yang dihasilkan daripada adunan SBO dan PMF mununjukkan sistem penghabluran yang lebih rumit. Hablur dengan saiz lamellae 42.8 Å dan 68.9 Å didapati muncul dalam sistem oleogel tersebut dengan serentak. Ini menunjukkan bahawa PMF dalam SBO membentuk ko-kristal dalam struktur SFW dan seterusnya meningkatkan kekuatan dan kestabilan oleogel tersebut. Oleogel-oleogel yang dihasilkan daripada minyak-minyak yang lain pula tidak menunjukkan perbezaan yang ketara dalam sifat-sifat oleogel. Ini menunjukkan bahawa komponen-komponen TAG dalam POoIV64, POoIV72, SBO, SBO:IV64 (1:1), SBO:PMF (9:1) dan SBO:PMF (4:1) tidak menjejaskan pembentukan struktur gel, maka sifat-sifat oleogelnya adalah hanya bergantung kepada kuantiti gelator yang digunakan sahaja.

Kesimpulannya, kestabilan oleogel adalah amat bergantung kepada faktor mikrostruktur dan interaksi antara molekul-molekul yang berada dalam sesuatu sistem oleogel. Kestabilan adalah kurang bergantung kepada sifat kekerasan dan SFC. Penyelidikan ini juga telah menunjukkan bahawa PMF boleh digunakan untuk menambahbaikkan kekuatan dan ciri-ciri oleogel, terutamanya oleogel yang dibentukkan daripada minyak sayuran lembut. Penyelidikan ini juga menunjukkan minyak berasaskan sawit adalah berpotensi tinggi untuk menghasilkan oleogel yang mempunyai kestabilan dan kekuatan yang agak memuaskan. Penyelidikan ini boleh dilanjutkan kepada penggunaan dalam produk makanan, di mana oleogel daripada minyak olein dan adunan PMF dengan minyak sayuran lembut boleh digunakan sebagai bahan utama dalam pembuatan marjerin, pengganti shortening dan produk daging.

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This thesis was submitted to the Senate of Universiti Putra Malaysia and has been accepted as fulfilment of the requirement for the degree of Doctor of Philosophy. The members of the Supervisory Committee were as follows:

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This is to confirm that:

- the research conducted and the writing of this thesis was under our supervision;
- supervision responsibilities as stated in the Universiti Putra Malaysia (Graduate Studies) Rules 2003 (Revision 2012-2013) are adhered to.

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LIST OF ABBREVIATIONS

ANOVA	Analysis of Variance
BE	Beeswax
BEW	Berry Wax
CLW	Candelilia Wax
CRBW	Carnauba Brazilian Wax
Cryo-SEM	Cryo-scanning Electron Microscopy
DAG	Diacylglycerol
DSC	Differential Scanning Calorimeter
FA	Fatty Acid
FAL	Fatty Alcohol
FAME	Fatty Acid Methyl Esther
FFA	Free Fatty Acid
FID	Flame-ionization Detector
GRAS	Generally Regarded as Safe
ΔH	Enthalpy of Melting
HC	Hydrocarbon
IV	Iodine Value
LDL	Low-density Lipoprotein
LVR	Linear Visco-elastic Region
MCT	Medium-chain Triacylglycerols
MG	Monoglyceride
MGHO	Fully Hydrogenated Palm-based Monoacylglycerol with High Stearic
MGHP	Fully Hydrogenated Palm-based Monoacylglycerol with High Palmitic
MUFA	Monounsaturated Fatty Acid

RBW	Rice Brans Wax
PBA	Polyglycerol Behenic Acid Ester
PLM	Polarized Light Microscope
PMF	Palm Mid Fraction
pNMR	Pulsed Nuclear Magnetic Resonance
POoIV64	Superolein with Iodine Value of 64
POoIV72	Top Olein with Iodine Value of 72
PSIV2	Fully Hydrogenated Palm Stearin Iodine Value of 2
PSIV14	Hard Palm Stearin Iodine Value of 14
SAXS	Small Angle Diffraction
SAFin	Self-assembly Fibriliar Network
SBO	Soybean oil
SFA	Saturated Fatty Acid
SFC	Solid Fat Content
SFW	Sunflower Wax
TAG	Triacylglycerol
Tfm	Fully Melted Temperature
Tm	Peak of Melting
U-HPLC	Ultra High-Performance Liquid Chromatography
WAXS	Wide Angle Diffraction
w/w	Weight/Weight
WE	Wax Ester
XRD	X-ray Diffraction

CHAPTER 1

INTRODUCTION

1.1 Background and Problem Statement

Oils and fats are generally composed of triacylglycerols (TAGs), in which their physical appearance depends on the chemical nature and physical properties of the constituent fatty acids attached to the glycerol backbone. For centuries, oils and fats have been well-known as some of the most important materials for food applications. Applications of fats before the 19th century mainly relied on empirical knowledge mainly resulting from observations (O'Brien, 2000). Today, fats and oils applications are mostly based on the understanding of their chemistry through scientific research.

For many edible purposes, it is desirable to produce solid fats. Traditionally, fat products are structured of high melting TAGs containing *trans* and saturated fatty acids. These fatty acids are crucial in food applications because they provide several functionalities to food products, such as shortening power, plasticity and elasticity (Edmund and Marangoni, 2012). However, *trans* and saturated fats have shown negative impacts on human cardiovascular health (Tavernier et al., 2017; Zetzl and Marangoni, 2011). According to the World Health Organization (WHO), cardiovascular disease (CVD) is one of the major causes of death globally (Voon et al., 2019). Numerous clinical studies and meta-analyses have shown that the intake of *trans* fatty acids increases serum LDL (“bad cholesterol”) and decreases serum HDL (“good cholesterol”) (Katan et al., 1995; Kodali, 2014; Marangoni and Garti, 2011). On the other hand, the intake of saturated fat increases serum lipid concentrations (both LDL and HDL), which could also contribute to CVD (Voon et al., 2019). The overall impact of *trans* fat on CVD is approximately double that of saturated fat due to the higher LDL:HDL ratio (Kodali, 2014). Therefore, recently, the USA Food and Drug Administration (FDA) proposed the complete removal of partially hydrogenated oils (*trans* fats) from human food (Kushairi *et al.*, 2018).

Therefore, a new strategy for structuring edible oils is required to reduce the usage of *trans* and saturated fats. However, the reduction of saturated and *trans* fatty acids in the diet has become a major challenge to food manufacturers because these fatty acids play an important role in structuring fats to provide functionality in food products (Edmund and Marangoni, 2012). In the food industry, there have been many attempts to find alternative components that can provide the desired features of texture, structure, stability and taste that are normally found in animal and vegetable fats or hydrogenated oils (Marangoni and Garti, 2011). Organogelation has become a possible alternative to replace these conventional fats, as it reduces the *trans* and saturated fats for food purposes. The purpose of organogelation is to produce low-saturation solid fat products using lower amounts of saturated components and higher amounts of liquid oil components. The process involves soft matter systems with liquid oil as the continuous phase, entrapped in a three-dimensional network structure formed by self-assembled gelator molecules.

Many trials have been conducted by researchers to apply oleogels in various food products. Hwang et al. (2013) studied the use of sunflower wax, rice bran wax and candelilla wax in gelling soybean oil. The gels were tested for their suitability for incorporation into margarine. Jang et al. (2015) investigated the use of candelilla wax for structuring canola oil and the gel was then used as an alternative to shortening in baked products such as cookies. Yılmaz and Öğütcü (2015a) produced olive oil oleogels from beeswax and sunflower wax and applied the oleogels as spreadable fat and butter alternatives. Most of the studies on oleogel preparation involve the use of soft vegetable oils such as sunflower oil, soybean oil, safflower oil, olive oil, canola oil and rice bran oil (Doan et al., 2015; Jang et al., 2015; Toro-Vazquez et al., 2007; Yılmaz and Öğütcü, 2015a). These highly unsaturated oils have disadvantages for use as the main ingredients for oil structuring, as they are thermally unstable and exhibit poor physical properties, especially when used in food processing applications that requires high processing temperatures. Furthermore, Sacks et al. (2017) reported that excessive consumption of polyunsaturated fatty acids (PUFA) may be detrimental to antioxidant-compromised individuals, although polyunsaturated fatty acids have shown a positive effect in reducing CVD risk when replacing saturated fat.

Therefore, palm olein could be a better choice for the preparation of oleogels due to its balanced fatty acid composition that contains moderate amounts of saturation as compared to conventional fats and other soft vegetable oils. According to Ahmad Tarmizi and Siew (2008), palm oleins showed much higher stability than high-oleic sunflower oil during prolonged frying (80 hours) at 180 °C, in which frying using palm oleins only produced minimal breakdown products, such as free fatty acids, and polar and polymer compounds. The high stability of palm olein against oxidative deterioration during food processing is due to its low linoleic acid content (Voon et al., 2019). Although palm olein contains higher saturated fatty acids than other soft vegetable oils, it shows no significant differences in affecting lipoprotein markers compared to other dietary oils such as canola oil, high-oleic sunflower oil, olive oil, coconut oil *etc*. as reported by Voon et al. (2019) in their most recent meta-analysis. Moreover, the authors concluded that saturated fatty acid-rich palm olein diet did not show any significant adverse effect on established surrogate lipid markers of CVD risk.

As previously mentioned, these liquid fractions from palm oil contain higher saturated contents than other vegetable oils. The role of palm olein in organogelation could be different from that of other vegetable oils, in which the saturation content of olein may interfere positively or negatively with the formation of gel network. Few studies discussed the use of palm-based products such as palm oil, palm olein, superolein or top olein for the preparation of oleogels (Baran et al., 2014; Pradhan et al., 2014). Therefore, this thesis was conducted to investigate the possibility of using palm-based oleins in the preparation of oleogels. The replacement of these highly unsaturated soft vegetable oils with palm-based oleins is expected to improve the chemical and physical stability of oleogels, which can then be applied as a potential material in food products.

A few organogelators were selected in this study including polyglycerol behenic acid ester (PBA), sunflower wax (SFW), fully hydrogenated palm-based monoacylglycerols (MGHP and MGHO), hard palm stearin (PSIV14), and fully hydrogenated palm stearin (PSIV2). Of these gelators, SFW is the most popular gelator and has shown great potential in gelling various vegetable oils (Blake et al., 2014; Hwang et al., 2015; Hwang et al., 2011, 2012; Patel et al., 2015). There are also numerous studies that have investigated the use of monoglyceride (MG) as a gelling material, in either oil or oil-in-water systems (Bin Sintang et al., 2017a; Da Pieve et al., 2011). Regarding the other materials, their usage as gelling agents has still not been well studied.

1.2 Objectives of the Study

In concordance with the research background and justifications presented above, the overall objectives of the study were to investigate the effects of gelator types, gelator dosages, liquid oil type, and preparation temperature on the rheological and physicochemical characteristics of palm-based oleogels and their relation to the stability of the oleogels. To be more specific, the research was conducted to achieve the following objectives:

1. To screen suitable gelators (polyglycerol esters, sunflower wax, fully hydrogenated palm-based monoacylglycerols, hard palm stearin IV of 14 and fully hydrogenated palm stearin IV of 2) for the formation of palm superolein oleogels, and to investigate the effect of storage temperature and duration on the rheological and thermal characteristics of the superolein oleogels.

2. To study the effect of storage temperature (5 °C, 15 °C and 25 °C) and duration (day 1 to day 3) on the physical and microstructure properties of various superolein oleogels and their relationship to oleogel stability.

3. To evaluate the effect of liquid oil type (palm olein fractions, palm mid fraction with soybean oil blends) and gelator dosage (1% w/w to 9% w/w) on the rheological and thermal properties of oleogels made from polyglycerol esters and sunflower wax.

4. To investigate the effect of liquid oil type (palm olein fractions, palm mid fraction with soybean oil blends) and gelator dosage (1% w/w to 9% w/w) on the structural and physical properties of polyglycerol esters and sunflower wax oleogels and their relationship to oleogel stability.

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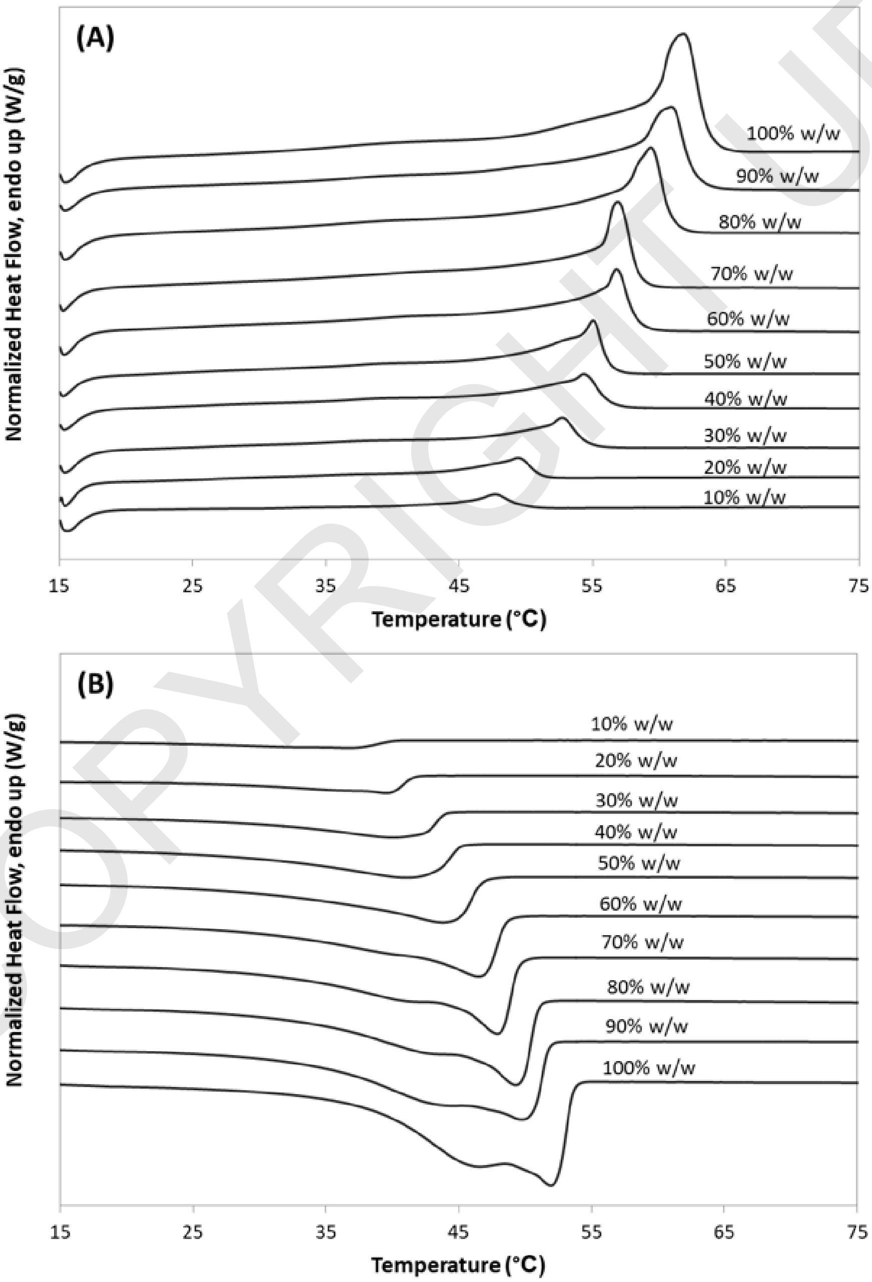
APPENDICES

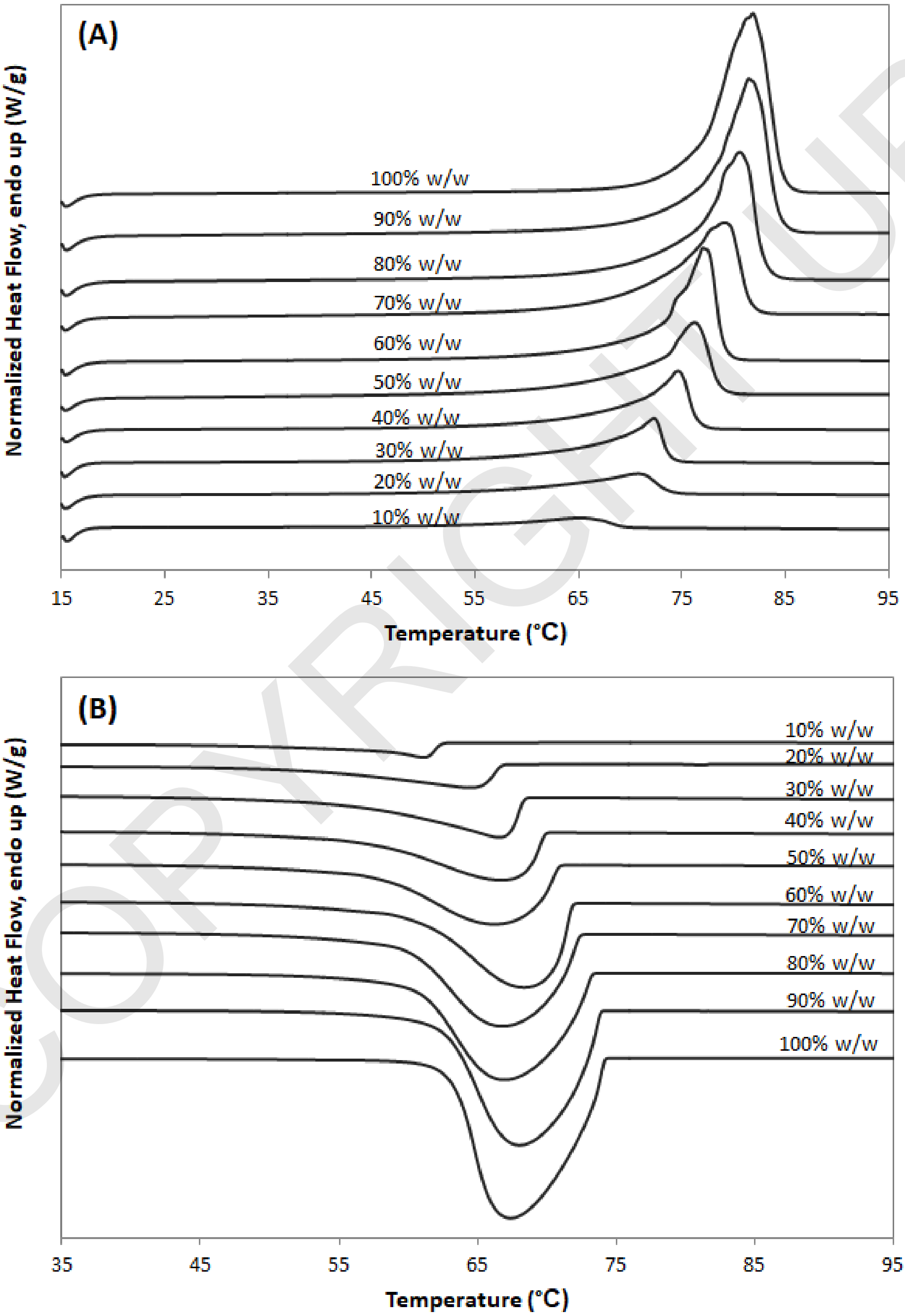
Appendix A-1:

(A) Melting and (B) Cooling Thermograms of Top Olein Oleogels Produced with 10% w/w to 100% w/w of PBA Organogelator



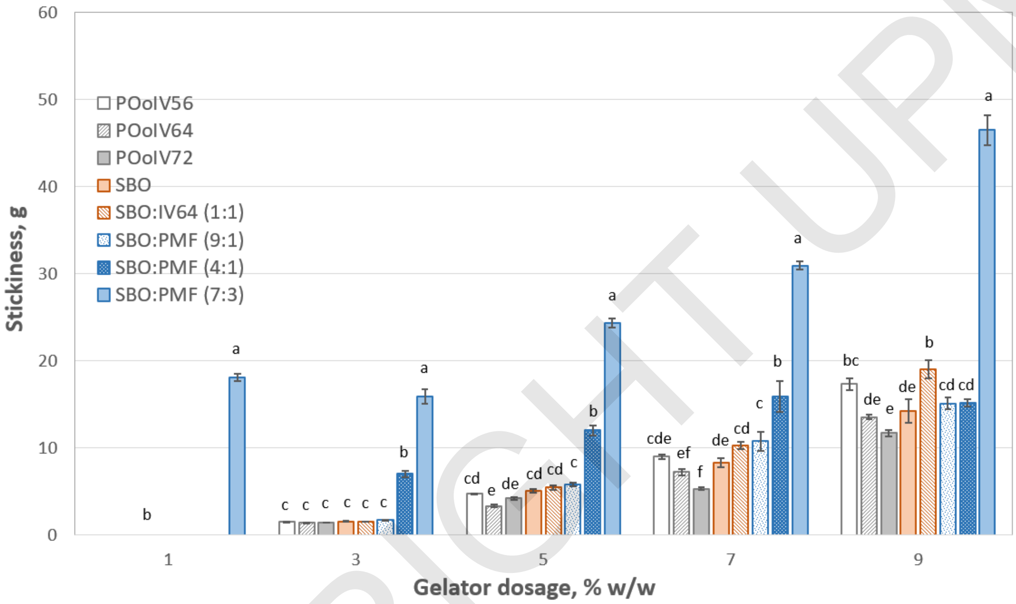
Appendix A-2:

(A) Melting and (B) Cooling Thermograms of Top Olein Oleogels Produced with 10% w/w to 100% w/w of SFW Gelator



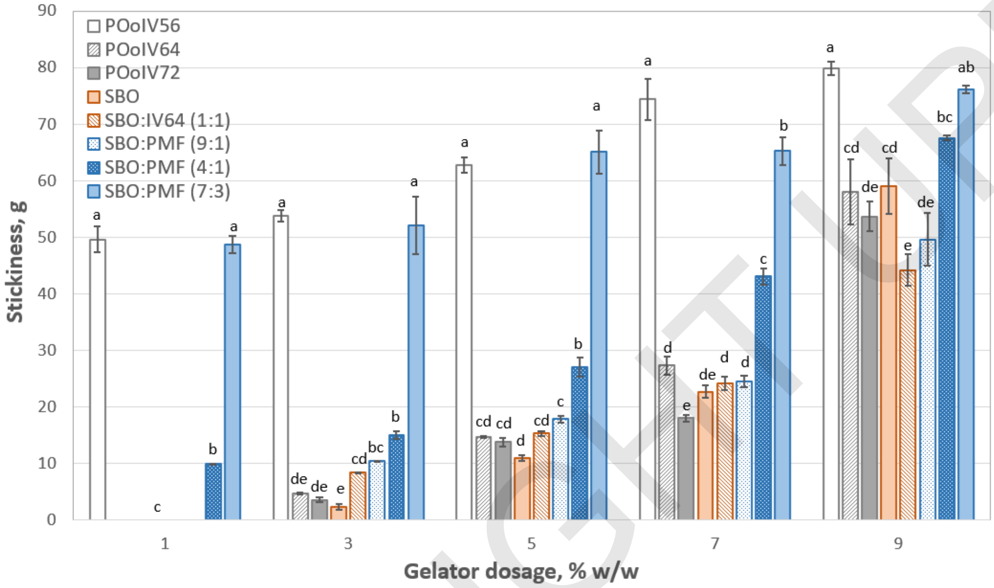
Appendix A-3:

Comparison of Stickiness of Oleogels Formed with Combinations of Different Liquid Oils and 1 to 9% w/w PBA Gelator at 15 ºC



Appendix A-4:

Comparison of Stickiness of Oleogels Formed with Combinations of Different Liquid Oils and 1 to 9% w/w SFW Gelator at 15 ºC



BIODATA OF STUDENT

Saw Mei Huey was born in April 1983 in Taiping, Perak. She completed her primary and secondary educations at the schools in Taiping before continuing her high school education at Sekolah Menengah King Edward VII, Taiping. She received a Bachelor of Science degree (with Distinction) in Applied Chemistry in August 2006. In December 2007, she got married and subsequently pursued her master's degree program at the same university, where she researched the palm new products from enzymatic interesterification and fractionation. She received her Master of Science degree in August 2010 with publication of two referred scientific journals from her master work. She has been working as a research officer at Malaysian Palm Oil Board (MPOB) since 2007, under Analytical and Quality Development Unit. She had authored a total of five referred scientific journals scientific journals, resulting from her research work in MPOB. She is currently in the doctoral program at University of Putra Malaysia with full sponsorship from MPOB.

LIST OF PUBLICATIONS

Publication Resulting from this Thesis:

A. Referred Scientific Journals

Saw, M. H., Lim, W. H., Yeoh, C. B., Badlishah, S. B. and Tan, C. P. (2020). Screening of Organogelators for Structuring Palm Superolein. *Journal of Oil Palm Research* 32: 152-158.

Saw, M. H., Lim, W. H., Yeoh, C. B., and Tan, C. P. Effect of Storage Temperature and Duration on Rheological and Thermal Characteristics of Superolein Oleogels. *Food Research International* FOODRES-D-20-02537. Under review.

B. Proceedings of Conferences/Seminars

Saw, M.H., Zaliha, O., Lim, W.H. and Tan, C.P. Effect of temperature on physical and morphological properties of palm-based and soybean oil-based oleogels. Presented at National Seminar on *Palm Oil Milling, Refining, Environment and Quality 2016*, 29-30 November 2016, Kuala Lumpur, Malaysia. (Poster).

Saw, M.H., Zaliha, O., Lim, W.H. and Tan, C.P. Effect of preparation conditions on stability and characteristics of different types of superolein oleogels. Presented at *International Palm Oil Congress & Exhibition 2017*, 14-16 November 2017, Kuala Lumpur, Malaysia. (Poster).

Saw, M.H., Yeoh, C.B., Lim, W.H. and Tan, C.P. Effect of Preparation Conditions on Rheological Properties of Superolein Oleogels. Presented at *National Seminar on Palm Oil Milling, Refining, Environment and Quality 2018*, 27-28 November 2018, Kuala Lumpur, Malaysia. (Poster).