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Stability and rheology of concentrated O/W emulsions based on soybean oil/palm kernel olein blends

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Abstract

Droplet size distribution and rheological properties of egg yolk-stabilized emulsions were studied before and after storage (25 °C, 30 days). The dispersed phase (70%) of the emulsions was based on soybean oil (SBO) and 10–40% palm kernel olein (PKO) replacements of SBO. Replacement of PKO resulted in a significant increase in droplet mean diameters and a decrease in rheological properties of the emulsions. All emulsion exhibited a gel-like characteristic with storage modulus higher than loss modulus and $\tan\delta$ greater than 0.3. Significant increase ($p < 0.05$) was found for droplet mean diameters and rheological properties of the emulsions after storage. Emulsion with fully SBO and the highest PKO replacement (40%) were found to be the most unstable, which was ascribed to a strong flocculation. With 10–30% PKO replacements, the emulsions displayed a better stability after storage, most probably promoted by significant content of short-medium chain fatty acids in PKO.

Keywords: Soybean oil; Palm kernel olein; Droplet size; Flow behavior; Viscoelastic; Emulsion stability; Coalescence; Flocculation

1. Introduction

Most of the food systems basically exist in emulsion form that consist of two immiscible liquids (usually oil and water), with one of the liquids dispersed as small spherical droplets. The system is typically stabilized by several types of surface active components mainly proteins and surfactants. Concentrated oil-in-water (O/W) emulsions like mayonnaises normally contain as high as 80% oil in the dispersed phase. As apposed to dilute emulsions with low amount of oil content, the droplets in concentrated emulsions are crowded together, giving the interaction between the adjacent droplets becomes important (Pal, 1997). For this reason, rheological properties and degree of stability of these emulsions would be appreciably different from those emulsions with low amount of oil. Moreover, the droplet size produced after preparation of the concentrated emulsions will directly determine their rheological properties and to certain extend, their stability.

Understand the rheology is crucial in predicting the long-term instability of the emulsions particularly due to flocculation and coalescence. Rapid increase in a storage modulus (G') upon ageing can be an indication of strong flocculation (Tadros, 2004). The flocculation of oil droplets usually result in liquid entrapment and thus the effective volume fraction of the emulsion shows an increase. Therefore, the net attraction among droplets also increases, resulting in an increase in G'. On the contrary, ageing of the emulsions is shown to result in a decrease of the storage modulus due to droplet rearrangements that led to a weaker structure (Diftis, Bilianderis, & Kiosseoglou, 2005; Paraskevopoulou, Boskou, & Kiosseoglou, 2005). In combination with the results of droplet size analysis, prediction of the droplet coalescence can also be

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done by following the decrease in emulsion viscosity (Tadros, 2004).

The rheological behavior and stability of the emulsions will be affected by the composition of the oil dispersed phase. Important findings by Driscoll et al. (2001), demonstrated that medium-chain triacylglycerides (C8–C10) showed a great miscibility with soybean oil in O/W emulsion form. The emulsion was found to be more stable as compared to emulsion containing a single long-chain triacylglycerides of soybean oil. Granger Granger, Barey, Veschambre, and Cansell (2005) conducted studies on the interface characteristics and rheological properties of O/W emulsions as affected by different type of oils (oleic oil, hydrogenated and refined coconut oils, refined palm oil). They attributed the stability of the emulsions with less unsaturated oils to interfacial interactions among the oil phase, emulsifier fatty acids and the adsorbed protein. To this far, similar study that particularly focus on the effect of the oil dispersed phase composition on the rheology of the emulsions is hardly found.

Soybean oil (SBO) is one of the major oils that have been used in emulsion products such as margarine, salad dressings and mayonnaises. Previous studies have shown that blending of SBO with other oils/fats could improve overall properties (Driscoll et al., 2001) as well as oxidative stability (Nor Hayati, Che Man, Tan, & Nor Aini, 2005) of the model emulsion systems. One of the potential oils that can be blended with SBO is palm kernel olein (PKO), a low melting fraction of palm kernel oil. Native PKO is less suitable to be used in fat-based food products as compared to palm kernel stearin (high melting fraction). However, several studies have been conducted on blends of PKO with other oils/fats in order to explore their potential uses in vanaspati (Nor Aini, Che Maimon, Hanirah, Zawiah, & Che Man, 1999), ice cream (Liew, Ghazali, Long, Lai, & Yazid, 2001), margarine (Lai, Ghazali, Cho, & Chong, 1999, 2000; Chu, Ghazali, Lai, Che Man, & Yusof, 2002) and frying oil (Chu et al., 2001). In the present study, we used blends of SBO:PKO to prepared mayonnaise-like emulsions and investigated the performance of the resultant emulsions in terms of their rheological properties and physical stability.

2. Materials and methods

Refined SBO was purchased from Moi Foods (Malaysia) Sdn. Bhd (Selangor, Malaysia). PKO was donated by Malaysian Palm Oil Board (MPOB, Selangor, Malaysia). Vinegar (7 wt%) and eggs were purchased from local supermarket from the same batch.

2.1. Emulsion preparation

Blends of SBO:PKO were prepared in the ratios of 100:0, 90:10, 80:20, 70:30 and 60:40 (w/w) and used as dispersed phases in concentrated O/W emulsions. The emulsions were prepared in a lab-scale proportion using 175 g oil blends, 50 g water, 10 g vinegar and 15 g egg yolk. The final oil concentration obtained was 70%. Egg yolk was prepared from fresh eggs following the procedure described by Anton, Chapleau, Beaumal, Delepine, and de Lamballerie-Anton (2001). A premix was first prepared with water, vinegar and egg yolk to form an aqueous phase. The oil phase was added drop wise to the aqueous phase. Homogenization was performed by using a Diax 900 high-speed homogenizer (Heidolph Inst. Gmbh & Co. Kg, Schwabach, Germany) at 11,600 rpm (6 min) under a room temperature (25 ± 1 °C). Each type of emulsions was prepared in three independent replications. Samples were stored at room temperature (25 ± 1 °C) for 30 days. The following analyses were done for both fresh (after 2 h of preparation) and stored emulsions.

2.2. Droplet size analysis

The droplet size distribution (DSD) for fresh emulsions were measured approximately 2 h after the preparation and 30 days after storage by a laser diffraction method of Mastersizer 2000 (Malvern Instruments Ltd. Worcestershire, UK). The droplet size distribution determination was based on the best-fit between the experimental measurements and Mie theory. The software used a reflective index (RI) of 1.465 (SBO) and dispersant RI of 1.33 (water) to calculate the Dispersion Index (Span) by Span = $d[90] - d[10]/d[50]$ (Palazolo, Sorgentini, & Wagner, 2004). The $d[10]$, $d[50]$ and $d[90]$ values are size values corresponding to the cumulative distribution at 10%, 50% and 90%, respectively. Thus, the $d[10]$ represents a size value below which 10% of the cumulative distribution is present. Emulsions were diluted in distilled water to a droplet concentration of less than about 0.05 wt% (to eliminate multiple scattering effects), and gently stirred (to increase the homogeneity) prior to measurement. Drops of emulsion were introduced into the sample presentation unit until the concentration reached the optimum one, indicated by the instrument.

2.3. Microstructure observation

Droplet image of the emulsions was observed under polarized light microscopy at room temperature (25 °C) for fresh and 30-day stored emulsions. A small drop of emulsion was place onto the microscope slide and carefully covered. After equilibrated for 2 min, photomicrographs (×100 magnification) were taken using Olympus BH-2 microscope (Tokyo, Japan) equipped with a video camera (Leica Q500 MC, Cambridge, UK).

2.4. Rheological measurement

The rheological measurements were performed in a controlled-stress rheometer (RheoStress 600, Haake, Karlsruhe, Germany). Oscillatory tests (mechanical spectra)