



Formulation of Nanostructured Lipid Carrier from a Mixture of Red Palm Oil and Palm Stearin

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ABSTRACT

Red palm oil can be a source of beneficial ingredients in various foods due to its high total carotene level. This work examined the influence of red palm oil to palm stearin ratio on the Nanostructured Lipid Carrier's turbidity, transmittance, viscosity, β -carotene content, color lightness, and hue. For this purpose, Nanostructured Lipid Carriers were prepared by hot homogenizing red palm oil and palm stearin at several ratios (1:9, 2:8, 3:7, 4:6, and 5:5 (w/w)). According to the present investigation, the ratio of red palm oil to palm stearin primarily affected the turbidity, transmittance, viscosity, β -carotene concentration, color brightness, and hue of NLCs. Furthermore, the study found that adding red palm oil significantly raised the NLC's β -carotene content and turbidity. The ratio of red palm oil to palm stearin that produced the most stable NLC was 5:5 (w/w)

INTRODUCTION

Red palm oil (RPO), a derivative of crude palm oil (CPO), has the potential to be incorporated into the formulation of a variety of food products. Red palm oil contains significant total carotene (580 ppm). It also includes additional lipophilic bioactive compounds, particularly essential fatty acids, tocopherols, and tocotrienols (El-Hadad et al., 2010). However, the non-polar compounds cannot be effectively dispersed in water-based foods, making it challenging for the food manufacturer to formulate RPO as a source of functional nutrients.

Formulating RPO into a delivery system that improves the dispersion of hydrophobic substances in a polar environment can overcome the components' limited solubility. Utilizing an emulsion-based carrier system in different materials, notably food, can optimize the stability and bioavailability of hydrophobic or hydrophilic bioactive by enhancing their encapsulation and transfer efficiency (McClements, 2015). Lipid-based carrier systems enhance biocompatibility, biodegradability, and controlled release and are simple to large scales (Silva et al., 2011). In addition, some food industries are innovating by formulating lipophilic bioactive plant or animal components into functional foodstuffs. Nanostructured Lipid Carriers (NLCs) are delivery systems consisting of liquid and solid lipid matrices stabilized by surfactants (Ghasemiyeh & Mohammadi-Samani, 2018).

In previous studies on NLC, olein (liquid fraction) and stearin (solid fraction), which are obtained from CPO processing have been used as liquid and solid lipid blends (Zheng et al., 2013; Rohmah et al., 2019). For NLC formulations, the application of a mixture of palm stearin (PS) and red palm oil has yet to be published. PS and RPO are considered edible lipids. The incorporation of RPO, a source of essential unsaturated fatty acids, and PS, notable for its abundance of saturated palmitic and stearic fatty acids, is expected to function as a carrier for bioactive molecules naturally occurring in RPO.

The type of lipids and surfactants utilized in an NLC system significantly impact the particle diameter, turbidity, viscosity, and encapsulation effectiveness. They will further impair the NLC's capacity to transport bioactive components (Shah et al., 2016). NLC formulations can potentially incorporate non-ionic and hydrophilic surfactants, such as Tween 80. Tween 80 (Polysorbate 80) has a high Hydrophile Lipophile Balance (HLB) value of 15. In addition, it is safe for ingestion and stable to emulsified substances, such as those found in NLC carrier systems (Prieto & Calvo, 2013). This present study assesses the influence of the red palm oil to palm stearin (w/w) ratio on the turbidity, transmittance, viscosity, β -carotene content, color brightness, and hue of the resulting NLC systems.

METHODOLOGY

Materials

This work employed red palm oil (Salima, Bogor, Indonesia), palm stearin (PT. Smart Tbk., Surabaya, Indonesia), Tween 80 (Merck, Darmstadt, Germany), and double distilled water as the materials. The chemicals utilized for analyses were of pro-analysis grade.

Preparation of NLC

The production of NLC was carried out by the utilization of the hot homogenization process (Zhu et al., 2015) with different ratios of red palm oil (RPO) and palm stearin (PS) (1:9, 2:8, 3: 7, 4:6, and 5:5 (w/w)). The ratio of lipids to Tween 80 (w/w) applied for all treatments was 1:6. NLC was manufactured by heating the RPO and PS combination at 60°C for 15 minutes. In addition, a mixture of Tween 80 and water is heated to 60°C. The two mixes were blended and agitated with Ultra-Turrax at 24,000 rpm for 30 minutes in a water bath. It was then sonicated at 20 kHz for 15 minutes and cooled to 27±2°C for one day.

Physicochemical Characterization

Tests carried out on NLC were turbidity (Fletcher & Morris, 1995), transmittance (Redha & Susilo, 2020), viscosity (Rohmah et al., 2019), β-carotene content (Triplett & Rathman, 2009), color brightness and Hue (Hutchings, 1994).

Statistical Analysis

The statistical analysis of the data in this study was performed using Design Expert 13.0, and the results were presented as mean values accompanied by their corresponding standard deviations. The differences among the treatments were examined utilizing the Least Significant Different (LSD) method at a significance level of 5%.

RESULTS AND DISCUSSION

Turbidity, Transmittance, and Viscosity of NLC

The ratio of red palm oil to palm stearin (w/w) had a highly significant effect ($p < 0.01$) on the turbidity, transmittance, and viscosity of NLC (Table 1).

Table 1. Effect of Red Palm Oil, Palm Stearin Ratio on NLC Turbidity, Transmittance, and Viscosity

Red Palm Oil: Palm Stearin Ratio (w/w)	Turbidity (%)	Transmittance (%)	Viscosity (dPa.s)
1 : 9	0.839±0.05 a	33.561±1.06 c	17.33±0.12 a
2 : 8	0.769±0.10 a	38.739±0.26 d	18.83±0.81 b
3 : 7	0.888±0.09 ab	33.732±0.89 c	20.17±0.27 c
4: 6	1.008±0.02 b	16.644±0.85 b	22.67±0.38 d
5 : 5	1.002±0.03 b	12.943±0.78 a	24.67±0.84 e

Note: The mean followed by the same letter in the same column is not significantly different in the LSD test with $\alpha = 0.05$

The increase in turbidity and decrease in NLC transmittance coincided with the increase in the red palm oil portion in the NLC formulation. However, in the range of red palm oil: palm stearin ratios between 1:9 and 5:5, the NLC system

could still be considered stable. The use of some palm oil as a matrices NLC lipids have reported by Wun How et al. (2011), who use Tween 80 as a surfactant and hydrogenated palm oil as solid lipids. Zheng et al. (2013) employed the high-pressure homogenization technique to produce NLC, utilizing a blend of MCT (Medium Chain Triglycerides) and solid lipids (comprising of palm oil and PS), along with Tween 80 serving as a surfactant. Figure 1 depicts various stable condition NLCs.

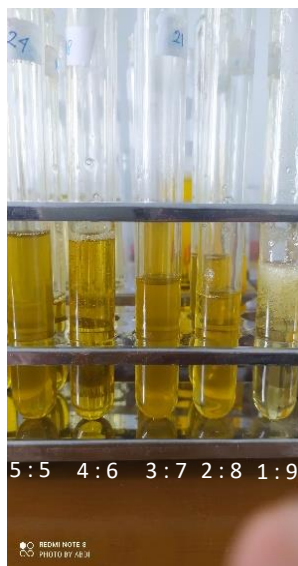


Figure 1. The NLC Visual Observation on Various Red Palm Oil: Palm Stearin Ratios

Rohmah et al. (2019) demonstrated that the lipid: surfactant ratio was more effective in determining the stability of NLC, as surfactants have a significant impact on the stability of the oil-in-water emulsion system. Prior research has indicated that a rapid decrease in surface tension can reduce particle aggregation and recrystallization phenomena ((Han et al., 2008; McClements & Rao, 2011). Other research publications (Witayaudom & Klinkesorn, 2017; Karn-orachai et al., 2014; Ziani et al., 2012) have highlighted the critical part performed by the concentration and composition of surfactants, as well as the surfactant: oil ratio, in determining the stability of NLC.

The decrease in turbidity and increase in NLC transmittance may have been caused by the stearin fraction's ability to retard the homogenization-induced molecular diffusion process. Weiss et al. (2008) found that the presence of lipids in the solid phase can reduce the rate of molecular diffusion processes in NLC, thereby enhancing bioactive components' retention and chemical stability. Furthermore, both red palm oil and palm stearin are obtained from an identical source material, namely crude palm oil (CPO), which results in a high degree of compatibility. Consequently, combining these two fractions of palm oil proves to be a highly effective blending method. In their study, Zheng et al. (2013) employed the stearin fraction and various other lipids derived from the identical oil source to develop stable nanostructured lipid carriers (NLC) characterized by a particle size ranging from 150 to 350 nm.

Table 1 indicates that the increase in the proportion of palm stearin in the formulation leads to a reduction in the viscosity of NLC. The viscosity is affected by the interaction between lipids and surfactants. According to Rohmah et al. (2019), low-density lipids are particularly vulnerable to system instability, resulting in coalescence, flocculation, and cream formation on the system's surface. Palm stearin is a solid fraction that is obtained during the processing of palm oil. According to Sue & Pantzaris (2017) study, palm stearin predominantly comprises saturated fatty acids, including 1-2% myristic acid, 47-74% palmitic acid, and 4-6% stearic acid. An increase in the stearin proportion within the formulation leads to a corresponding increase in the solid fraction quantity, ultimately resulting in an increased viscosity of the NLC.

β-Carotene Content, Color Brightness, and Hue of NLC

The analysis of variance indicates that the ratio of red palm oil to palm stearin (w/w) had a significant impact ($p < 0.01$) on the β-carotene content of NLC (Table 2).

Table 2. Effect of Red Palm Oil: Palm Stearin Ratio on β-carotene Content, Color Brightness, and Hue of NLC

Red Palm Oil: Palm Stearin Ratio (w/w)	β-carotene Content (ppm)	Color Brightness	Hue
1 : 9	43.6±1.39 a	50.91±0.35 d	80.22±0.80 c
2 : 8	50.3±1.37 b	47.29±1.58 d	88.54±0.94 d
3 : 7	62.9±0.52 c	42.59±0.67 cd	82.16±0.59 c
4 : 6	78.9±1.57 d	41.12±0.98 b	79.78±0.35 b
5 : 5	80.5±1.23 d	40.11±0.06 a	77.74±0.41 a

Note: The mean followed by the same letter in the same column is not significantly different in the LSD test with $\alpha = 0.05$

Enhancing the red palm oil to stearin ratio elevates the β-carotene content. It may be due to the high total carotene found in red palm oil (El-Hadad et al., 2010). According to Mezzomo & Ferreira (2016), β-carotene is a group of carotenoids used as antioxidants and pigments in food. In addition, β-carotene possesses anti-cancer and anti-inflammatory activities (Gloria et al., 2014; Kawata et al., 2018). Gammone et al. (2015) and Saini et al. (2015) indicate that β-carotene is crucial in preserving vision health and lowering the potential of coronary heart disease. The digestion of β-carotene tends to be ineffective and unstable due to its inability to dissolve in water, reducing bioavailability in the human body (Gul et al., 2015). However, this limitation can be circumvented by including a carrier system based on lipids (Pan et al., 2016).

The color brightness of NLC diminished as the proportion of red palm oil in the formulation increased (Table 2). It is due to β-carotene being present in the NLC. The β-carotene molecule belongs to the carotenoid family. This class of compounds produces a spectrum of colors, from red to orange to yellow (Rodriguez-Amaya, 2015).

The color spectrum of the samples is shown by hue, or °Hue, a characteristic of the visual experience in which the perceived area correlates to the color observed, such as red, green, yellow, or blue, separately or in combination with other chromatic colors (Pramesti, 2014). Table 3 exhibits the correlation between Hue and the produced colors. The NLCs produced in this research (refer to Table 2) tend to provide color descriptions within the Yellow Red (YR) spectrum, as the Hue values obtained range from 77.74 to 80.22 (refer to Table 2). The finished products obtain a reddish hue primarily from red palm oil and Tween 80 as critical constituents.

Table 3. The Relationship between Hue and Color Description

Hue	Color Description
18-54	Red (R)
54-90	Yellow Red (YR)
90-126	Yellow (Y)
126-162	Yellow Green (YG)
162-198	Green (G)
198-234	Blue Green (BG)
234-270	Blue (B)
270-306	Blue Purple (BP)
306-342	Purple (P)
242-18	Red Purple (RP)

Source : Pramesti (2014)

CONCLUSIONS AND RECOMMENDATIONS

The findings demonstrated that increased red palm oil: palm stearin ratio (w/w) in the NLC formulation results in elevated NLC β -carotene and turbidity levels. Despite the highest level of NLC turbidity produced, the emulsion exhibits stability. A higher weight-to-weight ratio of palm oil to palm stearin reduced NLC transmittance, color brightness, and hue. The use of red palm oil with a 5: 5 palm oil to palm stearin ratio remains feasible for the manufacture of stable NLCs with the following characteristics: turbidity of 1.002%, transmittance of 12.943%, viscosity of 24.67 dPa.s, β -carotene content of 80.5 ppm, color brightness of 40.11, and hue of 77.74.

FURTHER STUDY

The scope of this study is limited to emulsion systems that comprise a restricted number of constituents, especially red palm oil and palm stearin. Further research is necessary concerning applying palm oil-based NLC in more complex food matrices.

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