Emulsifying properties of extracted Okra (*Abelmoschus esculentus* L.) mucilage of different maturity index and its application in coconut milk emulsion

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**Abstract**

The emulsifying properties of extracted okra (*Abelmoschus esculentus* L.) mucilage at different maturity indices (1, 2 and 3) were studied. The okra mucilage was prepared using water extraction method and was determined their viscosity at different temperature (10, 30, 50 and 70°C), water holding capacity (WHC), oil holding capacity (OHC), as well as their emulsion capacity (EC) and emulsion stability (ES). Results found that okra with maturity index 2 produced the highest percentage yield of mucilage (1.46%) and followed by index 1 (1.10%) and index 3 (0.31%) (p<0.05). The viscosity of okra mucilage with maturity index 3 was the lowest, and it decreased as temperature was increased in the reaction. The WHC of okra mucilage with maturity index 3 obtained the highest capacity (4.84%), while the OHC of okra mucilage with maturity index 2 obtained the highest capacity (8.54%). Based on these findings, okra mucilage index 2 was selected to be added into oil-in-water (O/W) emulsion system of coconut milk at different percentage of 0.25%, 0.50% and 1.0%. Results revealed that okra mucilage (maturity index 2) at 1.0% percentage in coconut milk obtained the highest value in emulsion capacity (EC) and emulsion stability (ES). Thus, this study concluded that okra plant have potential to be used as emulsifying agent in food emulsion system.

**Introduction**

Okra (*Abelmoschus esculentus* L.) is a flowering plant of the Malvaceae family which is also known as lady’s fingers, gumbo, banyia or bami or bhindi (Georgiadis et al., 2011). This plant was formerly name as *Hibiscus esculentus*, and was originated from India but now it is grown widely in other areas including Middle East, Africa and Southern State of USA. Okra has three different sizes; large (L), medium (M) and small (S) with length of more than 15 cm, between 10 to 15 cm and between 7 to 10 cm, respectively. Its quality can be maintained up to 7-9 days if was kept at temperature ranged from 8 to 12°C with relative humidity of 90 to 95% (FAMA, 2008).

Mucilage is a plant hydrocolloid which is a polymer of a monosaccharide or mixed monosaccharide (Deogade et al., 2012). In fact, polysaccharide mucilage is highly hydrophilic substances with high molecular weight molecules. The polysaccharides are soluble and dispersible in water due to their ability to interact with water and swell. The swelling properties are characterised by the entrapment of large amount of water between the polymer chains and branches. Thus, mucilage can be used as one of the food additives, to modify the food quality in terms of food stability, texture and appearance properties by acting as emulsifiers, thickeners, gelling agents or texture modifiers.

The chemical compositions, molecular structures, monosaccharide sequences, glycoside linkages configuration and position in the backbone and side chains are some of the factors that can affect the functional properties of natural plant mucilage (Mirhosseini and Amid, 2012a).

Previously, there were many studies on the physicochemical and functional properties of polysaccharide from other plants include Durio zibethinus seed (Mirhosseini and Amid, 2012b), Ferula galbaniflua (Milani et al., 2007), and rhizomes of lotus (Shad et al., 2011). However, there were very little information had been reported on the functionality of okra mucilage and its application in foods. Therefore, the objectives of this study were to evaluate the emulsifying properties of okra mucilage and its application as emulsifier in coconut milk.

**Materials and Methods**

*Samples of okra*

Okra plant with different maturity index (1, 2
and 3) was purchased fresh from supplier in Tanjong Karang, Selangor, Malaysia. The maturity indices were evaluated based on color and texture of okra as stated by Federal Agricultural Marketing Authority (FAMA) (2008). The maturity indices of okra are determined as in Table 1.

<table>
<thead>
<tr>
<th>Maturity indices</th>
<th>Physical properties</th>
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<tbody>
<tr>
<td>1</td>
<td>Light green coloured with soft texture</td>
</tr>
<tr>
<td>2</td>
<td>Light green coloured, but its texture is hard</td>
</tr>
<tr>
<td>3</td>
<td>Green whitish or green yellowish, the barke texture and its end is not easily broken</td>
</tr>
</tbody>
</table>

Measurement of water holding capacity (WHC) and oil holding capacity (OHC)

The WHC and OHC of okra mucilage were determined according to the method of Gallah and Dubasi (2010). One gram of okra powder was added into 10 ml of distilled water (for WHC) or corn oil (for OHC). The mixture was then vortexed for 2 minutes. Next, the mixture was centrifuged at 3000 rpm for 30 minutes before any excessive water or oil was decanted. The WHC and OHC were then calculated by dividing the weight (g) of water or oil absorbed by 100 g of okra mucilage.

Measurement of emulsifying properties

The emulsifying properties of okra mucilage were determined by evaluating its emulsifying capacity (EC) and emulsifying stability (ES). Both were done according to the method of Naji et al. (2013). For EC, an oil-in-water emulsion system was prepared at room temperature (~26°C) by adding 6 mL of corn oil into 60 mL of 1% (w/w) of mucilage solution. Next, the emulsion was mixed at 2000 rpm for 10 minutes. After that, the emulsion was homogenised at 9600 rpm for 1 minute. Finally the suspension was centrifuged at 4000 rpm for 10 minutes. However, for ES, the emulsion was heated first in water bath (80°C) for 30 minutes and subsequently cooled under running tap water before the mixture was centrifuged at 4000 rpm for 10 minutes. The EC and ES of okra mucilage were calculated using following formula:

$$EC \text{ or } ES (%) = \frac{e}{t_v} \times 100$$

where, $e$ is the volume of emulsion after being centrifuged and $t_v$ is total volume of mixture.

Emulsifying properties of okra mucilage in coconut milk

Coconut milk system was prepared according to Chappellaz et al. (2010) with modifications. First, fresh shredded coconut (purchased from supplier in Shah Alam, Selangor, Malaysia) was mixed using magnetic stirrer with warmed water (60°C) at a ratio of 1:1 (w/v) for 5 minutes before the coconut milk was extracted. Then, the coconut milk was added with 0.25%, 0.50% and 1.00% okra mucilage solutions. The mixture was first mixed using magnetic stirrer at 50°C for 5 minutes, and were continuously mixed for another half an hour at room temperature (~26°C) and homogenised at 9600 rpm for 1 minute. This mixture were then analysed for EC and ES according to the method by Naji et al. (2013) as described above.
Statistical analysis

All analyses were performed in triplicate for each treatment. Data was subjected to analysis of variance (ANOVA) to determine the significant difference among treatments at 5% level using SPSS Version 15.0.

Results and Discussion

Yield extraction of okra mucilage

This study found that among three different maturity indices of okra, the okra with maturity index 2 produced the highest mucilage yield (1.46%) followed by okra with maturity index 1 (1.10%) and maturity index 3 (0.31%). This result was in line with the study conducted by Sreeshma and Nair (2013) that reported the okra mucilage content increased from index 1 to index 2 and then gradually decreased from the fruit tissues at maturity index 3.

The increasing in mucilage content from okra with maturity index 1 to index 2 was due to growth and development of the okra itself. This was supported by Sreeshma and Nair (2013) who explained that mucilage contribute to moisture balance of the fruit and prevent it from drying out. In contrast, the declining in mucilage content as okra matures (index 2 to index 3) is due to degradation process. From the results in this study, it shows that mucilage content of okra at maturity index 3 decreased and it could be due to drying out as the fruit matures. According to Western et al. (2000), mucilage is the pectinous matrix of cell layers which undergoes degradation process as it enters senescence period.

Viscosity of okra mucilage

The viscosities of okra mucilage at different maturity index decreased as the temperature increased from 10 to 70°C (Figure 1).

Water holding capacity (WHC) and oil holding capacity (OHC) of okra mucilage

Water holding capacity (WHC) was defined as the ability of a substance to associate with water under limited water conditions (Singh, 2001). The ability of gums to hold water producing gels or highly viscous solution is desirable in industrial application (Tosin et al., 2010). This characteristic was also important to reduce vaporisation rate and alter freezing rate (Amid and Mirhosseini, 2012). As shown in Figure 2, the WHC of okra mucilage with maturity index 3 was significantly highest (p<0.05) as compared to maturity index 2 and index 1.

Indeed, the high value of WHC of okra mucilage can be related with the presence of polysaccharide in mucilage (Al-Sayed et al., 2012) including rhamnose, galacturonic acid, galactose, glucose and glucuronic acid (Lengsfeld et al., 2004; Deters et al., 2005). Miguel and Belloso (1999) stated that WHC represents the percentage of hydrophilic fraction, which has a greater affinity to absorb water. Thus, it might be concluded that okra mucilage maturity index 3 has highest polysaccharide fraction as compared to mucilage with maturity index 1 and 2. However, further study is needed in order to confirm...
the interaction in this food system.

Oil holding capacity (OHC) of a substance is the capacity of the substance for oil absorption (Phimolsiripol et al., 2011). In this study, different maturity indices of okra led to a significant different (p<0.05) in OHC. The okra mucilage with maturity index 2 has the highest OHC as compared to other indices. However, okra mucilage with index 1 has the lowest of both WHC and OHC. Its stabilising effect on an emulsion could arise mainly from its high thickening property where it has the highest viscosity compared to other indices. According to Thanatcha and Pranee (2011), high OHC value of okra mucilage was due to the presence of non-polar side chains and hydrophobic fraction such as protein and fat which may bind the hydrocarbon units of oil, thus inducing a higher capacity of oil absorption.

**Emulsifying capacity (EC) and emulsifying stability (ES) of okra mucilage**

Emulsifying capacity (EC) measures the ability of emulsion to retain its system after subjected to centrifugal force. As shown in Figure 3, the EC of okra mucilage with index 3 was significantly highest (p<0.05) as compared to other maturity indices. According to Thanatcha and Pranee (2011), high OHC value of okra mucilage was due to the presence of non-polar side chains and hydrophobic fraction such as protein and fat which may bind the hydrocarbon units of oil, thus inducing a higher capacity of oil absorption.

![Figure 3. Emulsifying capacity (EC) and emulsifying stability (ES) of okra mucilage with maturity index 1, 2, and 3](image)

**Application of okra mucilage in coconut milk**

According to the result obtained in this study, okra mucilage with maturity index 2 was chosen to be added into coconut emulsion since it produced the highest yield (1.46%) and OHC (854.25 g/100 g). In addition, the EC and ES properties of okra mucilage with maturity index 2 was also not significantly different (p<0.05) with mucilage of maturity index 1 and 3. This also seems economical extract to be used as stabiliser or emulsifier in coconut milk emulsion as this extracted okra mucilage produced highest yield after extraction.

![Figure 4. Emulsifying capacity (EC) and emulsifying stability (ES) of coconut milk containing different percentage of okra mucilage with maturity index 2](image)

Contrary to this, EC of maturity index 2 and 3 of okra mucilage is lost by heat treatment at 80°C for 30 minutes (lower ES than maturity index 1). This phenomenon was similar to study conducted by Garti et al. (1999) on gum arabic solution. The loss of arabic gum solution EC by thermal treatment was related to denaturation of proteinous matter by heating. Nevertheless, high EC and ES of okra mucilage indicates that mucilage were able to act as stabiliser in an oil-in-water (O/W) emulsion similar to cress seed gum (92%) and xanthan gum (100%) (Naji et al., 2012).

The EC of the emulsion system for all percentage are lower than EC. According to Onsard et al. (2006), the emulsifying properties of coconut proteins are affected by temperature. Coconut proteins have been shown to denature and coagulate when being heated at 80°C (Tangsuphoom and Coupland, 2008), thus effecting the ES. Therefore, high value of EC and ES of coconut milk added with okra mucilage reflect the ability of okra mucilage to act as a stabiliser in the emulsion.
Conclusion

From this study, it was found that okra mucilage have a potential to be used as a natural emulsifier and stabiliser in food especially in food emulsion system. The mucilage with maturity index 2 has highest yield percentage and OHC. It has medium WHC and exhibit medium viscosity at different temperature. Due to these, index 2 mucilage can be categorised as better stabiliser for emulsion and moderate thickener as compared with okra mucilage index 1 and 3 and was chosen to be added in an oil-in-water emulsion (coconut milk) as a stabilizer. However, the application of okra mucilage in food emulsion system needed to be exploited further to clarify the components that provide the improvement of food stability system.

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