INTRODUCTION

Grapevine (Vitis vinifera L.) is one of the largest fruit crops in the world with a huge production in 2006 [1]. This fruit contains many beneficial compounds for body health, such as flavonoids, catechin and poly unsaturated fatty acids (PUFA) [2]. Most people use their flesh and throw the seeds as residues. However, the seeds themselves have a high value in commodities because of their advantages [3].

Grape seed oil (GSO) is a vegetable oil with a high content of antioxidant substances. This oil provides many benefits to the body because of its content, linoleic acid. Other useful compounds in GSO advantages [3].

Grape seed oil (GSO) from Vitis vinifera L. is a liquid vegetable oil which has been used mainly for its linoleic acid content. However, there are many efforts to convert the liquid form of the oil into a solid form due to the instability under storage condition. The aim of this study was to convert GSO into the solid microcapsules by emulsion crosslinking method with gum arabic as a coating polymer.

Methods: The GSO was formulated with gum arabic in the ratios of 1:2, 1:3, 1:4, and 1:5. Gum arabic solution was emulsified with GSO using Span 80 and glutaraldehyde. The emulsion was dropped into a beaker glass of isopropyl alcohol to form microcapsules. The microcapsules were dried at 70 °C. Then, they were characterized in terms of morphology, particle size, swelling index, water content, and entrapment efficiency.

Results: The produced microcapsules of GSO showed white yellowish color and spherical shape. The particle size of F1, F2, F3 and F4 microcapsules were 69 μm, 82 μm, 125 μm, and 131 μm, respectively. The water content of the F1–F4 ranged from 4.37±0.34 to 5.70±0.92% and swelling indexes were ranged from 5.54±0.01 to 5.94±0.04. The value of entrapment efficiency of F1, F2, F3, and F4 were 17.33±0.603, 20.73±0.678, 34.22±1.195, and 67.15±2.019%, respectively.

Conclusion: The results of this investigation showed that GSO could be converted into the solid spherical microcapsules by emulsion crosslinking method using gum arabic. Taken together, this study has provided the most promising formulation of GSO microcapsules for further production in pharmaceutical industry.

Keywords: Crosslinking emulsification, Grape seed oil, Gum arabic, Microcapsules, Microencapsulation

MATERIALS AND METHODS

Materials

GSO was purchased from Jian Hairui Natural Plant (China), linoleic acid was purchased from Sigma Aldrich (Singapura), gum arabic was purchased from Jumbo Trading (Thailand), glutaraldehyde (50% v/v) was purchased from PT. Foton Prima Perkasa (Indonesia), Span 80, butylated hydroxy toluene (BHT), hydrochloric acid (HCl), sodium hydroxide (NaOH), sodium chloride (NaCl), isopropyl alcohol and aquadest was purchased from PT. Brataco (Indonesia).

Preparation of microcapsules

Formulations were prepared with different ratios of GSO and polymer. They were shown in table 1. Crosslinked gum arabic microcapsules were prepared by emulsion crosslinking method with glutaraldehyde solution (50% v/v) as a crosslinking agent. An aqueous solution of gum arabic was prepared in aquadest. The aqueous phase was dispersed in GSO containing Span 80, an emulsifying agent, and butylated hydroxy toluene as an antioxidant. The mixture was stirred by using a homogenizer (60 °C) at 2000 rpm for 30 min. The pH of emulsion was adjusted to 3.7 with HCl solution (7 N). Glutaraldehyde solution was added to the emulsion. Then, the emulsion prepared was dropped into a beaker glass of isopropyl alcohol to form microcapsules. The microcapsules were then dried at 70 °C and stored in desiccators before used and evaluated [9].
Morphology of microcapsules

Morphology of microcapsules was evaluated using a scanning electron microscope (SEM). Sample of GSO microcapsules were placed on the sample holder and coated with gold particle using the fine particle coater. Then, the morphology was visualized under the SEM at magnification of 20,000x [9].

Percentage yield

The yield was calculated as the percentage ratio between the weight of the microcapsules recovered from each batch and the total weight of drug and polymer used to prepare the same batch [9].

\[
\text{Percentage yield} = \frac{\text{Practical yield}}{\text{Theoretical yield}} \times 100
\]

Swelling index

The swelling index of microcapsules was determined by immersing the microcapsules obtained in a phosphate buffered saline (PBS) (pH 7.4) and allowed to swell for 24 h. The weight of the swollen microcapsules was measured, and the swelling ratio was calculated according to the equation as follows:

\[
\text{Swelling index} = \frac{W - W_0}{W_0}
\]

Where W is the weight of the microcapsules after swelling in the medium, and W0 is the initial weight of the microcapsule [9].

Water content

Water content of the microcapsules was determined by using a moisture analyzer. The apparatus was preheated for 10 min before used, then a sample of GSO microcapsules (1 g) was placed on top of the aluminum container and measured at the temperature of 105 °C [11].

Particle size distribution

The particle size distribution was measured using a particle size analyser (Mastersizer 3000 MAZ 6240) by laser diffraction technique. Samples were dispersed in isopropyl alcohol under constant stirring. The average diameter and the equivalent volume diameters at 10, 50 and 90% cumulative volume were determined [12].

Crosslinking confirmation

Fourier transform infrared spectroscopy (FTIR) spectra was obtained using an FTIR spectrometer (Shimadzu® FTIR-8400). This analysis was conducted to identify the chemical bonds formed between gum arabic and glutaraldehyde. The sample was prepared by potassium bromide (KBr) disk method and scanned over the range of 400-4000 cm⁻¹. The spectra were recorded to identify certain characteristic bonds in the compounds that indicated the formation of new compounds [9].

Entrapment efficiency

A total of 2 g GSO microcapsules was placed into a beaker glass. A volume of 10 ml HCl was added into the beaker glass. The solution was extracted using diethyl ether and petroleum benzene, and this step was repeated three times. The supernatant was placed into a glass and reheated on a water bath until all of the water evaporated and oil residue was remained [13]. Entrapment efficiency of GSO microcapsules was measured by Mojonnier Tester and calculated according to the equation as follows:

\[
\text{Entrapment efficiency} = \frac{\text{Grape seed oil extract}}{\text{Theoretical grape seed oil}} \times 100\%
\]

Determination of linoleic acid

A total of 20 mg GSO extract was placed into a sample tube. A volume of 1 ml NaOH 0.5 N in methanol was added into the tube and then heated with nitrogen. The tube was heated in a water bath for 20 min. A volume of 2 ml boron trifluoride was placed into the tube and reheated for 20 min. The tube was then cooled, added with 2 ml of saturated NaCl and 1 ml of hexane, then homogenized using a vortex. The mixed solution was allowed to stand for 15 min. A 1.0 μL n-hexane layer containing methyl linoleate was drawn and injected into a gas chromatographic device [14]. The optimized gas chromatographic system was shown in table 2.

| Parameter          | Result                                      |
|--------------------|---------------------------------------------|
| Column             | Cyanopropyl methyl sil (capillary column)   |
| Mobil phase        | Nitrogen                                    |
| Detector           | Flame Ionization Detector                   |
| Injector temperature | 220 °C                                    |
| Detector temperature | 240 °C                                    |

RESULTS AND DISCUSSION

Formulation and characterization of GSO microcapsules

The characteristics of the GSO microcapsules were listed in table 3. GSO microcapsules were prepared by emulsion crosslinking method, which was dropping the GSO emulsion into isopropyl alcohol. This method is relatively easy to implement and capable to produce relatively stable globules during the storage. There are some variables that may influence the production of GSO microcapsules, such as amount of polymer (gum arabic) and crosslinking agent.

| Sample | Water content (%) | Percentage yield (%) | Particle size average* (µm) | Swelling index (%) |
|--------|------------------|----------------------|-----------------------------|-------------------|
| F1     | 4.37±0.34        | 60.33±0.34           | 69                          | 553.70±0.61       |
| F2     | 4.68±0.46        | 61.08±0.29           | 82                          | 568.97±1.25       |
| F3     | 4.98±0.17        | 78.07±0.11           | 125                         | 588.79±1.73       |
| F4     | 5.70±0.92        | 83.89±0.04           | 131                         | 594.51±3.49       |

Each value represents the mean±standard deviation of three determinations, *Particle size average was in one batch production of each microcapsules.
Shape and morphology of microcapsules

The morphology of GSO indicated that all prepared microcapsules had a spherical shape without any pores on the surface as shown in fig. 1. The surface morphology performed for all formulations were in a magnification of 20 000x. The shape of microcapsules can be affected by the temperature and the time of drying [15]. It showed that all formulations exhibited no porous formation, thus the gum arabic as a coating material was capable in protecting the active substance from environmental influences which might reduce the stability, such as light and air [15-16].

Percentage yield

The percentage yield obtained in various batches was between 60-84%, with the highest yield value was from F4. It was observed that as the polymer ratio in the formulation increased, the product yield increased [19]. The low percentage yield may be due to the microcapsules lost during the washing process.

Swelling index

Table 3 showed the swelling index of the GSO microcapsules in PBS. The swelling index was ranged from 5.53 to 5.94. The swelling of the microcapsules occurred due to the hydration of gum arabic in an aqueous environment. The higher polymer concentration in formulation would give higher value of water content and swelling index. The value of the microcapsules swelling index showed that gum arabic used as the coating agent had the characteristic of high power expander because it is a hygroscopic polymer [17, 18].

Moisture content

The measurement of the moisture content of GSO microcapsules was given in table 3. It shows that F4 had the highest moisture content with the value of 5.7%. It might be caused by the higher contain of gum arabic in the formulation, which was hydrophilic polymer, thus it was easier for F4 to contact with moist.

Particle size distribution

Fig. 2 showed the particle size distribution of the GSO microcapsules, and it was ranged between 2-500 µm. particularly, the particle size of F1 and F2 was 51.8 µm (5.68%) and 66.9 µm (6.44%), respectively. On the other hand, the particle size distribution of F3 and F4 were in the range 69-131 µm with a percentage of 6.21%. The microcapsules particle size ranged between 69-131 µm as shown in table 4.

Fig. 1: Scanning electron micrographs of GSO microcapsule (a) F1, (b) F2, (c) F3 and (d) F4, with a magnification of 20 000x

Fig. 2: Particle size distribution of GSO microcapsules

One of the important parameters in microcapsules preparation is particle size. Parameter used for the particle size distribution measurement were dv or diameter based on volume, because it can describe heterogeneity of particle size of the sample [20]. The results of the particle size distribution for all formulations, from the smallest to largest particle size, was F1<F2<F3<F4 (table 4).
revealed that F1 had the smallest $d_{v90}$ at 155 µm. It suggested that the concentration of GSO in the microcapsules affected the particle size. The higher concentration of GSO might cause the larger microcapsules particle size [21]. The particle size could also be influenced by the speed of stirring and the drug concentration in microcapsule [22-23]. Furthermore, the particle size distribution might be affected by the dispersion medium and dispersed phase due to the viscosity increase of the polymer. If the polymer concentration increases, the relative viscosity would rise, and it might affect and increase the mean particle size [24]. Dynamic light scattering (DLS) can be used to determine particle size which followed by the value of uniformity. The higher the stirring speed, the smaller the size of the microcapsules formed [22-25].

### Table 4: The of particle size measurement of the GSO microcapsules

| Formula | $d_{v10}$ (µm) | $d_{v50}$ (µm) | $d_{v90}$ (µm) | D$_{mean}$ Volume (µm) |
|---------|----------------|----------------|----------------|------------------------|
| 1       | 12.1           | 47.5           | 155            | 69                     |
| 2       | 19.3           | 63.6           | 167            | 82                     |
| 3       | 27.5           | 96.4           | 264            | 125                    |
| 4       | 28.7           | 102.0          | 279            | 131                    |

*The data was from measurements using Mastersizer 3000 and each formulation was in one batch production of each microcapsules.

### Crosslinking confirmation

The chemical interaction in the cross-linked gum arabic were observed by FTIR spectroscopy. The infrared spectra was shown in the fig. 3. In the cross-linked gum arabic spectra, there was an absorption band in the region of 3200-3600 cm$^{-1}$ which indicated the presence of OH-groups in hydrogen bonds. Based on the fig. 3, it can be seen that the hydrogen bonding intensity of the cross-linked gum arab was lower than natural gum. It was due to the fact that the OH-groups on gum arabic undergone a substitution by other groups. The spectrum also showed the characteristic bands of C-O around 1148 cm$^{-1}$. Other absorptions also appeared at the wavenumber of 1738 cm$^{-1}$.

In terms of chemical bonds formed, the absorptions appeared at the wavenumber of 1738 cm$^{-1}$. The absorption band at 1738 cm$^{-1}$ expressed the carbonyl group which could be formed due to the formation of a new acetal groups [26]. According to Distantina and Fahrurrozi (2013), the emergence of new absorption is due to the formation of the acetal group due to the interaction between the aldehyde groups on the glutaraldehyde with hydrogen in gum arabic [27]. Patel (2013) also stated that crosslinked gum arabic would result in a new cluster due to the interaction between gum arabic and glutaraldehyde in the infrared spectrum. Based on the results obtained, it showed that there had been a reaction between gum arabic with glutaraldehyde [9].

### Fig. 3: FTIR-spectrum (a) crosslinked gum arabic and (b) a natural gum arabic

### Entrapment efficiency

Table 5 showed the entrapment efficiency of the GSO microcapsules, which was ranged between 17.33 to 67.15%. F1, which was composed with the lowest polymers concentration, showed the lowest entrapment efficiency value of 17.33%. On the other hand, F4 with the highest polymer concentration, had the highest entrapment efficiency of 67.15%.

In this study, the entrapment efficiency result was similar to Ramadon (2017) [21], where the entrapment efficiency value would increase in accordance with the increase of polymer concentration. The high polymer concentration would hinder homogeneous distribution of the glutaraldehyde leading to the formation of larger microcapsules with reduced drug content and entrapment efficiency [24]. Increasing the polymer concentration would result in an increase of viscosity of the solution and the precipitation of the polymer, then it accelerates the dispersed phase to prevent the drug diffuses out [28, 30]. F1 had a low entrapment efficiency because the GSO was degraded during the manufacturing and analytical process. However, the concentration of free GSO were not calculated, so there is no supporting data to prove it.
The grape seed oil (GSO) was successfully encapsulated by crosslinking emulsification method with gum arabic as the coating agent. Thus, these findings have significant implications for the understanding of how the crosslinking emulsification method could be a good approach to encapsulate liquid material for producing a solid powder form.

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AUTHORS CONTRIBUTION

All the authors have contributed equally

CONFLICTS OF INTEREST

The authors have no conflict of interest

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