Encapsulation of ginger oleoresin with a combination of maltodextrin and skim milk powder as wall material

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Abstract. Ginger oleoresin has active ingredients that are very sensitive to temperature, light, process and storage conditions. Its thick and sticky physical properties also make it difficult in application and handling. Encapsulation is the solution to overcome this problem. The purpose of this study is to select the concentration of maltodextrin and skim milk powder as wall material, the ratio of emulsifier to oleoresin, and to determine the best formulation affected by the ratio of wall material to oleoresin on the characteristics of encapsulated ginger oleoresin. The best formula for encapsulation is from the ratio of maltodextrin and skim milk powder 0.5 : 1.0 as wall material and oleoresin concentration is 15% of the wall material. This treatment resulted in 92.31% encapsulation efficiency. Increase of maltodextrin concentration leads to increase emulsion viscosity, decrease emulsion stability and increase solubility in water, meanwhile increase of skim milk powder and oleoresin concentration leads to increase the encapsulation efficiency. GC-MS analysis of essential oils in oleoresin and in microcapsules show that there is no different composition of active compounds. The application of ginger oleoresin microcapsules on instant ginger tested by hedonic test found that the highest score consisted of 0.3 g of microcapsules in formula.

Keywords: encapsulation, ginger oleoresin, maltodextrin, skim milk powder, spray drying

1. Introduction

Oleoresin ginger is a ginger rhizome extract consisting of volatile components (essential oils) and non-volatiles (resins and gums) with its main ingredients are shogaol, gingerol, zingerone, and paradol [1]. The bioactive component contained in ginger oleoresin has functional properties as anti-inflammatory, antioxidant, antibacterial, and antithrombocyte. The potential application of ginger oleoresin in food and pharmaceutical products is very broad. However, the bioactive component is very sensitive to temperature, light, process condition and storage [2]. Thick and sticky physical properties of ginger oleoresin make it difficult to use and handle. Ginger oleoresin is also lipophilic so it does not dissolve and dispersible in water and aqueous food matrix. Encapsulation technology is a solution to this problem [3].

Encapsulation is one of the methods to ease the handling, increase solubility, stability, protect from toxicity, increase pharmacological activity, slow release, and protect from physical and chemical
degradation of active ingredients [4]. The protective role of encapsulation technology is to form membranes or wall materials around droplets or encapsulated material particles [5]. Encapsulation technology can be done by several methods, such as spray drying, fluid bed coating, coacervation, spray-chilling/cooling, melt injection, freeze/vacuum drying and other methods. The spray drying method is a method of spraying material directly through a sprayer that is contacted with hot air to produce a powder with a size of 10-50 µm [6]. Spray drying method is widely used in the food industry because it is more flexible, simple operation, continuous, fast and economical [7]. The result from encapsulation is a spray dried powder which makes it easier to handle and use as active ingredients.

The application of spray drying encapsulation technology to ginger oleoresin has been carried out with different types of wall material. Polysaccharide like maltodextrin is commonly used for wall material, because it provides good oleoresin stability against oxidation, low viscosity at high concentrations and has high water solubility [8]. However, maltodextrin is weak in reducing interface tension and oil-retention ability [9]. Encapsulation of ginger oleoresin using a maltodextrin result in a small encapsulation efficiency of 22.13%, meaning that there is still a lot of ginger oleoresin that is not encapsulated [10].

Efforts to optimize the efficiency of ginger oleoresin encapsulation are continued by combination of wall material. The combination of polysaccharide and protein is very good for oil-retention ability and can reach high encapsulation efficiency [11]. Proteins such as milk protein have excellent amphiphilic character by providing the physicochemical and functional properties needed for microencapsulation of hydrophobic core material [11]. Skim milk powder is the most commonly used milk protein for food during spray drying. Skim milk powder is considered as a good encapsulation agent because it is a cheap, easy to obtain, and very efficient coating material for food. Therefore, it is necessary to conduct research on the selection of a combination of maltodextrin and skim milk powder as wall material and ginger oleoresin concentration to produce the best characteristics of ginger oleoresin microcapsules. This result can provide preliminary information on the development of ginger oleoresin encapsulation in applications for food products.

2. Materials and methods

2.1. Materials
The materials used in the study were fresh ginger from Kemang Bogor Central Market, 96% ethanol, DE 10-12 maltodextrin, tween 80, skim milk powder from PT Fonterra and aquades.

2.2. Methods
The methods used include the extraction of ginger oleoresin, the encapsulation process by spray drying method and the formulation of microcapsules on instant ginger.

2.2.1. Ginger oleoresin extraction. Ginger rhizome was sorted to get good raw materials. Then, ginger was sliced up to 5-10 mm thick and dried in oven at a temperature of 50-60 °C for 20 h until the water content reached 8-10%. Dried ginger was powdered using a disc mill to the size of 30-40 mesh to obtain ginger flour. A 2000 mL beaker glass was prepared for maceration of ginger flour with 96% ethanol in a ratio of 1: 6 and stirred for 2 h. The maceration process was then carried out for 24 h for the extraction of ginger oleoresin. After the maceration process was completed, a mixture was separated into ginger pulp and ethanol extract. Furthermore, ginger extract was evaporated to remove 96% ethanol using a rotary vacuum evaporator at a temperature of 50-60 °C to produce thick ginger oleoresin. Analysis of ginger oleoresin characteristics included visual appearance, aroma, specific gravity, refractive index, essential oil content and the yield.
2.2.2. Encapsulation with spray drying. Ginger oleoresin, aquadest and tween 80 were weighed and mixed in a beaker glass. The mixture was then carried out in oil in water (O/W) emulsion process with a 750 rpm stirrer speed for 30 min without heating. The wall material and distilled water were weighed then mixed to obtain a solution of the coating material. The coating solution was then homogenized using Ultra-Turrax homogenizer at a speed of 3500 rpm for 2 min. Furthermore, the speed was increased to 15000 rpm and the O/W emulsion was slowly poured into the coating solution for 5 min to get the ginger oleoresin emulsion which was ready for spray drying. Ginger oleoresin emulsions were introduced into the main chamber via a peristaltic pump and the feed flow rate was controlled by the pump rotational speed. The inlet and outlet air temperatures were 170 ± 2 and 70 ± 2 °C, and the feed flow rate was 15 ± 2 ml/min. Finally, the encapsulated powder would be collected in a closed container. The experimental design in the process of ginger oleoresin encapsulation was a complete factorial randomized design with two factors. The first factor was the comparison of the maltodextrin wall material and skim milk powder (0.5: 1.0, 1.0: 1.0, 1.0: 0.5) and the second factor was the concentration of ginger oleoresin from the wall material (10%, 15%).

2.2.3. Microcapsule formulation in instant ginger. The best ginger microcapsule resulted from the encapsulation process of oleoresin was then formulated into instant ginger (Table 4). The experimental design in the formulation of ginger oleoresin microcapsules in instant ginger was a complete randomized design of one factor that was amount of ginger oleoresin microcapsules. Formula was analysed by hedonic rating organoleptic test with colour, aroma, taste, after taste and overall parameters to get the best ginger oleoresin microcapsule formula of instant ginger. Each formula was diluted in 150 mL hot water, stirred well until homogeny. The hedonic rating test is used to rank the panellist’s preference level for the overall attributes of each sample by level 1 = very dislike; 2 = dislike; 3 = neutral; 4 = like; 5 = very like [12]. The panellists involved were semi-trained panellist from 30 students of IPB Darmaga.

Table 1. Formulation of ginger oleoresin microcapsules on instant ginger.

| Material (g) | Formula |
|-------------|---------|
|             | F1 | F2 | F3 | F4 | F5 |
| Microcapsule| 0.1 | 0.2 | 0.3 | 0.4 | 0.5 |
| Lactose     | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 |
| Sucralose   | 0.014 | 0.014 | 0.014 | 0.014 | 0.014 |

3. Results and discussion

3.1. Characteristics of ginger oleoresin

Table 2. Comparison of ginger oleoresin characteristics.

| Parameter               | Research          | References             |
|-------------------------|-------------------|------------------------|
| Appearance              | dark brown thick  | dark brown thick liquid^a|
|                         | liquid            | strong ginger aroma    |
| Aroma                   | strong ginger     | strong ginger aroma^a  |
| Density 25°C (g cm⁻³)   | 1.02              | 1.02-1.04              |
| Refractive Index 20°C    | 1.475             | 1.488-1.497^a          |
| Essential oil % (v/w)   | 19.38             | 18.35^a                |
| Yield % (w/w)           | 11.96             | 12.52                  |

^aSource: Essential Oil Analysis no. 243
The type of ginger used to produce ginger oleoresin in this study was white, small ginger (*Zingiber officinale* var. Amarum). Table 2 showed the results of the quality characteristics of ginger oleoresin. The quality of ginger oleoresin especially its appearance, aroma and essential oil content was in accordance with the quality standards based on Essential Oil Analysis (EOA). The appearance and aroma of oleoresin was dark brown, thick liquid and strong ginger aroma. The result of density measurement showed that the density of ginger oleoresin was greater than the density of water at the same temperature. Ginger oleoresin essential oil content (19.38% v/w) was met EOA standard (18-35% v/w).

Based on the determination of the concentration and ratio of wall material (maltodextrin and skim milk powder), and surfactant (Tween 80), the ginger oleoresin emulsion formula was arranged (Table 3).

### Table 3. Ginger oleoresin emulsion formula.

| Process          | Material          | Formula          |
|------------------|-------------------|------------------|
| Emulsification O/W | Ginger oleoresin | 10% and 15% of wall material |
|                  | Tween 80         | SOR 1.375        |
|                  | Aquadest         | 46.67%           |
| Homogenization   | Wall material    | 20%              |
|                  | Aquadest         | 33.33%           |

The formulation was applied to the emulsion preparation method. Oil in water (O/W) emulsion process was used to make emulsions between oleoresin ginger, tween 80 and aquadest using hot plate stirrer. While the homogenization process was a mixing of the O/W emulsion, wall material and distilled water with homogenizer. Aquadest was divided into emulsion and wall material dispersion. The reference for aquadest requirement was 46.67% in the O/W emulsion to make nanoemulsion by inversion phase emulsification method [13] using a 50 g as weight bases with an oil of 5% and an emulsifier to oil ratio (EOR) of 0.5 and 1.0.

### 3.2. Characteristics of ginger oleoresin emulsion

The use of oleoresin concentrations and coating materials was based on the results of previous study (Table 3). The emulsification process was carried out with the O/W emulsion process and homogenization. The results of emulsification were further characterized by the value of viscosity and emulsion stability.

#### 3.2.1. Emulsion viscosity

The analysis of variance showed that the comparison of the wall material and the concentration of ginger oleoresin significantly affected the emulsion viscosity. Duncan's test at 5% level showed that the overall ratio of coatings was significantly different (Figure 1).
Viscosity is the resistance of flowing material due to the friction or resistance of the material to changes in shape if it given a certain force. Factors affecting viscosity in the emulsion are the dispersed phase volume fraction. Interaction between ratio of wall material and concentration of oleoresin to the emulsion viscosity was significant. Increasing the concentration of maltodextrin and decreasing the concentration of skim milk powder as well as increasing the concentration of oleoresin can reduce the amount of water volume in the emulsion system. There was a linear relationship between a decrease in water volume and an increase in emulsion viscosity. This happened because the increase in hydrogen bonds caused a decrease in the distance between molecules and an increase in flow resistance of the emulsion [14].

3.2.2. Emulsion stability. The analysis of variance showed that the ratio of wall material and oleoresin concentration significantly affected the emulsion stability. Duncan's test at 5% level showed that ratio of wall materials was significant. Therefore it can be seen that the emulsion stability decreased with an increase of oleoresin concentration and maltodextrin ratio of wall material (Figure 2). Shamaei et al. [15] stated that emulsion stability was determined by measuring phase separation after 24 h storage at room temperature. Microencapsulation efficiency can be maximized by preparing emulsions with high stability [16]. The analysis of variance also found a significant interaction between the ratio of the wall material and oleoresin concentration to the emulsion stability. Increasing the ratio of maltodextrin and increasing the concentration of oleoresin can reduce the volume of water resulting in an increase of viscosity. Masters [17] said that the higher emulsion viscosity, the higher droplet size in the emulsion, the stability was decreased. Therefore, minimum droplet size can have an impact to the optimum stability of the emulsion during storage.
10% ginger oleoresin, 15% ginger oleoresin

Figure 2. Emulsion stability of ginger oleoresin emulsion

3.3. Characteristics of ginger oleoresin microcapsule
Emulsion of ginger oleoresin was then encapsulated using a spray drying method. All treatment produced ginger oleoresin microcapsules which have a similar appearance (Figure 3). Therefore, to find out the best microparticle it was necessary to characterize water content, bulk density, encapsulation efficiency and water solubility.

Figure 3. Results of ginger oleoresin encapsulation. O1 = Oleoresin 10%; O2 = Oleoresin 15%; P1 = coating material (0.5: 1.0); P2 = (1.0: 1.0); P3 = (1.0: 0.5).

3.3.1. Water content. Water content was an important parameter during storage to maintain product stability. High water content will trigger oxidation and biological damage due to the growth of bacteria and fungi. The analysis of variance showed that the ratio of wall material and oleoresin concentration
significantly affected the water content of ginger oleoresin microcapsules. Duncan's test at 5% level showed that all ratio of wall materials was significantly affected; this indicated that water content decreased with increasing of maltodextrin concentration (Figure 12). Maltodextrin has low molecular weight and simple molecular structure so that the water in the maltodextrin solution easily evaporated during the drying process [18]. While skim milk powder has a water content ranging from 3-7% so that the higher the concentration the higher the water content of microcapsules [19]. The emulsion viscosity increased with increasing concentration of maltodextrin and ginger oleoresin. A linear relationship existed between an increase of the emulsion viscosity and a decrease in the water volume [14]. Decrease of water volume in emulsion was thought to be related to the decrease in water content in ginger oleoresin microcapsules. Carneiro et al. [20] reported that increasing the viscosity of the emulsion could reduce the water content of microcapsule.

![Figure 4. Water content of ginger oleoresin microcapsule.](image)

**Figure 4.** Water content of ginger oleoresin microcapsule.

3.3.2. *Encapsulation efficiency.* The analysis of variance showed that the ratio of wall material and oleoresin concentration significantly affected the efficiency of ginger oleoresin encapsulation. Duncan's test at 5% level showed that the encapsulation efficiency of coating ratio of 0.5: 1.0 was significantly different from other ratio (Figure 5). Encapsulation efficiency is an important factor in microencapsulation in protecting the active ingredients inside. Encapsulation efficiency showed the presence of oil phase on the surface of powder particles and showed the ability of the coating material to prevent leakage of the inner oil phase due to the washing process.
3.3.3. Solubility in water. The release of active ingredients from microcapsule when applied in products depends on water solubility. A good microcapsule is characterized by its ability to release its active ingredient. The higher microcapsule solubility in water, the easier it is to release. Analysis of variance showed that the concentration of oleoresin had no significant effect on water solubility of ginger oleoresin microcapsules. However, the ratio of wall material had a significant effect on the water solubility of microcapsules. Duncan’s test at 5% level showed that the solubility in water at the ratio of maltodextrin to skim milk 1.0 : 1.0 and 1.0 : 0.5 was not different, but both were significantly different from the ratio of 0.5 : 1.0 (Figure 6).

The results showed that increasing the concentration of maltodextrin can produce high solubility (Figure 6). The highest solubility in water was 98.67%, while the lowest value was 92.86%. Maltodextrin as a coating can dissolve in cold water perfectly so that it is fast in releasing the active ingredient. Maltodextrin is also known to have a high dextrose equivalent (DE) value. The higher the DE value, the higher the level of solubility.
3.3.4. **GC-MS analysis of selected ginger oleoresin microcapsule.** The results of characterization of ginger oleoresin microcapsules showed that the best formula was from the ratio of maltodextrin to skim milk powder 0.5: 1.0 with 15% oleoresin concentration. One important parameter of microcapsules is the encapsulation efficiency. In this formula, the encapsulation efficiency was 92.31% (Figure 5). The selected formula was analysed by gas chromatography-mass spectrometry (GC-MS) to find out the compounds contained in ginger oleoresin essential oil.

| Composition       | % area Oleoresin | % area Microcapsule |
|-------------------|------------------|---------------------|
| Zingiberene       | 23.96            | 17.76               |
| Ar-curcumene      | 20.82            | 16.16               |
| β-sesquiphellandrene | 17.38           | 12.18               |
| β-bisabolene      | 9.47             | 6.81                |
| Farnesene         | 6.52             | 4.73                |
| Citral            | 3.13             | 2.24                |
| Z-citral          | 1.96             | 2.82                |

Chromatogram of GC-MS analysis showed that there were seven highest peaks of active compounds from oleoresin essential oil and selected microcapsule essential oil (Table 4). The seven highest peaks were zingiberene, ar-curcumene, β-sesquiphellandrene, β-bisabolene, farnesene, citral and z-citral. Those compounds were dominant and commonly contained in ginger essential oil. Mahboubi [21] reported that ginger essential oil contained α-zingiberene (29-40%), β-sesquiphellandrene (10-14%), ar-curcumene (5-11%) and β-bisabolene (2.5-9%). Some other studies also report that ginger essential oil contained citral compounds, farnesene, and z-citral [22].

3.3.5. **Hedonic score of ginger oleoresin microcapsule in instant powder.** The formulation of microcapsules in instant ginger resulted in five formulas (Table 1). The formulation was carried out using ginger oleoresin microcapsule, sucralose and lactose. Instant ginger production was generally carried out by a crystallization of ginger extract that requires a lot of sugar as crystallizing agent [23]. Non-calorie artificial sweetener has been used to replace high-calorie sugar. Substitution of sugar with sweetener and the application of microcapsule can change the method of instant ginger production only by compounding microcapsules and artificial sweeteners.

Sensory analysis was performed to obtain the selected formula based on the level of consumer preference (hedonic test) by increasing the ginger oleoresin microcapsule level in five formulas. Organoleptic testing was done by rating test which presented differences between samples. The analysis of variance showed that the parameter microcapsule concentration significantly affected hedonic test results. Hedonic test results showed the best overall score of all parameters was a formula with ginger oleoresin microcapsules of 0.3 g (Figure 7). The colour with the highest hedonic score was a formulation with ginger oleoresin microcapsules of 0.5 g. However, this value was not significantly different from the use of 0.3 g microcapsules (Table 5). Therefore, a formula with 0.3 g of ginger oleoresin microcapsules was chosen. The preference level for the colour parameters and after taste formula was between neutral and like. The value can be enhanced by the introduction of healthy instant ginger products as a low calorie food.
Figure 7. Spider web of hedonic test of F1 (0.1 g microcapsule), F2 (0.2 g microcapsule), F3 (0.3 g microcapsule), F4 (0.4 microcapsule), and F5 (0.5 microcapsule).

4. Conclusions and suggestions

4.1. Conclusions
Ratio of wall material and oleoresin concentration affects the characteristics of ginger oleoresin microcapsules. Based on the ratio of maltodextrin and skim milk powder (0.5: 1.0; 1.0: 1.0; 1.0: 0.5), it can be concluded that increasing of maltodextrin and decreasing skim milk powder increases the viscosity of emulsion, decreases emulsion stability and increases water solubility in microcapsules. While increasing the concentration of skim milk powder and oleoresin concentration can increase the efficiency of ginger oleoresin encapsulation. The encapsulation formula with ratio of wall material maltodextrin and skim milk powder 0.5 : 1.0, and ginger oleoresin 15% of wall material, produces encapsulation efficiency of 92.31%. Ginger oleoresin and microcapsule had essential oil which consists of seven major compounds, i.e. zingiberene, ar-curcumene, β-sesquiphellandrene, β-bisabolene, farnesene, citral and z-citral. This proves that encapsulation with maltodextrin and skim milk powder can protect the active ingredients from loss and decomposition. The application of ginger oleoresin microcapsules in instant ginger was evaluated by hedonic test; formula with 0.3 g microcapsule is the most liked by panelist.

4.2. Suggestions
Application of ginger oleoresin microcapsules in various food and beverage products needs to be developed. Beside their organoleptic quality, they also have functional property as antioxidant, antispasmodic and anti-inflammatory.

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