

The Comparative Effects of Maltodextrin and Carrageenan on Encapsulation Characteristics of Moringa Leaves Herbal Drink Extract (*Moringa oleifera* Lamk.)

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Abstract. Moringa (*Moringa oleifera* Lamk.) leaves are a potential herbal beverage ingredient due to the bioactive compounds that show antioxidant properties. To protect the compounds, encapsulation has been proven effective as a suitable method. Therefore, this study aims to investigate the effect of different ratios of maltodextrin and carrageenan as encapsulating agents on the physicochemical characteristics of encapsulated Moringa leaves herbal drink extract. Analysis was also carried out to determine the optimal ratio for producing high-quality encapsulates. The experiment used a randomized block design with 9 treatments of maltodextrin (M) and carrageenan ratio, comprising MK0 (10:0), MK1 (9.5:0.5), MK2 (9:1), MK3 (8.5:1.5), MK4 (8:2), MK5 (7:3), MK6 (6:4), MK7 (5:5), and MK8 (0:10). The results showed that maltodextrin-carrageenan ratio significantly influenced yield, solubility, color (L*, a*, b*), antioxidant activity (IC₅₀), and sensory scores (color, aroma, taste, acceptability), while moisture content was not affected. The optimal ratio was 9:1 (MK2), with 95.95% yield, 4.24% moisture, 87.76% solubility, L* 77.95, a* 1.43, b* 22.25, IC₅₀ 69.24 ppm, and good sensory attributes. Microstructural analysis showed heterogeneous shapes and sizes, 5–90 µm in length and 2–53 µm in width. This ratio effectively produced encapsulated Moringa extract with desirable characteristics.

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1 Introduction

Moringa (*Moringa oleifera Lamk.*) is widely cultivated in Indonesia due to high nutrients and potential as a medicinal ingredient. This plant is also called The Miracle Tree, Tree for Life, and Amazing Tree, because all parts, ranging from leaves, fruit, seeds, flowers, bark, stem, to roots, have extraordinary benefits [1]. Moringa leaves are the most frequently used due to high content of bioactive compounds, including tannins, steroids, triterpenoids, flavonoids, saponins, and anthraquinones, which function as antioxidants [2]. Moreover, leaves also contain protein, β -carotene, vitamin C, and important minerals such as iron and calcium [3].

The phytochemical compounds in Moringa leaves have been used in various fields, including food, health, pharmaceuticals, preservation, beauty, and agriculture [4]. In the food industry, a common application is the production of herbal drink using dry powdered herbal products, which are practical, long-lasting, and low in moisture. With the development of technology, this drink is now often produced as instant beverages, which are superior to regular dry powders because of the dissolution in room-temperature water, as well as absence of boiling and pulp [5].

The production of instant herbal drink often uses encapsulation method, which includes coating the core ingredients with a protective layer to prevent damage to the active compounds [6]. One common ingredient is maltodextrin, characterized by easy solubility, tastelessness, creation of a protective barrier, and the ability to bind active compounds [7]. However, to overcome the limitations of maltodextrin, carrageenan is often added as an extra ingredient. Carrageenan has strong gel properties, acts as an emulsifier, helps maintain the stability of active compounds, and is considered safe for consumption [8].

Based on the above description, the purpose of encapsulation is to protect Moringa leaves from environmental damage. Important factors influencing the success of encapsulation include the type of encapsulant, the ratio of its use, and the concentration of the solution. Therefore, this study was conducted using a combination of maltodextrin and carrageenan to examine how varying the ratio of the encapsulants affects the characteristics of Moringa leaves extract encapsulation and identify the optimal formula for producing an instant herbal drink.

2 Materials and Methods

2.1 Study Location and Time

This study was conducted from January to April 2023 in the Process Engineering and Quality Control Laboratory, Food Analysis Laboratory, and Post-Harvest Engineering Laboratory at the Faculty of Agricultural Technology, Udayana University. An experiment was also performed in MERO Foundation Laboratory in Tulamben Village, Kubu Sub-district, Karangasem Regency, for Scanning Electron Microscope (SEM) test.

2.2 Materials and Tools

Materials used in this study included raw materials and chemicals. Specifically, raw materials were Moringa leaves collected from a garden in Guliang Kangin Traditional Village, Bangli District, Bangli Regency, Bali Province. The chemicals used were distilled water, DPPH solution, methanolic PA, and encapsulants such as maltodextrin and carrageenan.

The equipment used in this study included various laboratory instruments and supporting tools. The main instruments were a spectrophotometer (Bhiochrom), a drying oven (Blue M), a magnetic stirrer (AND, GF-300), a homogenizer (Sonifier Branson), a vortex mixer (Barnstead Thermolyne), an analytical balance (Shimadzu), a color reader (PCE-CSM 1), and a scanning electron microscope (JSM-IT200, JEOL). Additionally, a blender (Miyako), a spatula, 60-mesh and 40-mesh sieves, coarse filter paper, Whatman No. 1 filter paper, and

baking paper were used. The glassware included beakers, volumetric flasks, petri dishes, test tubes, micropipettes, droppers, graduated cylinders, mortars, and Erlenmeyer flasks. Other equipment comprised aluminum foil, desiccators, thermometers, and various utensils such as a portable gas stove, an electric stove, pans, sieves, and basins.

2.3 Study Procedure

1. Material Preparation

Moringa leaves were collected from the third to seventh green stems, sorted, washed with running water, and blanched at 100°C for approximately 30 seconds. Subsequently, leaves were dipped in cold water, drained, and dried in an oven at 50°C ± 2°C for 24 hours until moisture content reached about 8% (7.97%) [9].

2. Preparation of Moringa Leaves Herbal Drink Extract

The dried Moringa leaves were ground into a powder using a blender and sieved through a 60-mesh sieve. The 2 g of Moringa leaves powder was brewed with 200 mL of water at 70°C and stirred for 3 minutes. The extract solution was filtered through coarse filter paper and Whatman No. 1 paper. [10].

3. Preparation of Moringa Leaves Herbal Drink Extract Encapsulation

Encapsulation solution was prepared by dissolving maltodextrin and carrageenan (10% of the solution volume) with leaves extract to reach a total volume of 100 mL and homogenized for 30 minutes. After homogenization, the solution was poured into Petri dishes lined with 3 mm thick baking paper and dried at 50°C ± 2°C until it reached a moisture content of ±3%. Once dried, the product was crushed, ground, and sieved through a 40-mesh sieve [11].

2.4 Data Analysis

This study used a Randomized Block Design (RBD) with nine levels of maltodextrin (M) and carrageenan (K), each replicated twice, totaling 18 experimental units. Data were analyzed using Analysis of Variance (ANOVA), and when the effect was significant (P<0.05) or very significant (P<0.01), the DMRT test was performed. The best treatment was determined based on the overall results of sensory test.

1. Yield

The yield of Moringa leaves herbal drink was divided by encapsulant used. The result was multiplied by 100% [12] using the formula below:

$$\text{Yield (\%)} = \frac{\text{weight of encapsulated powder (g)}}{\text{weight of encapsulant (g)}} \times 100\%$$

2. Moisture Content

A fine sample weighing approximately 2 g was dried in an oven at 105°C for 4 hours, cooled in a desiccator for 15 minutes, and weighed until a constant weight was achieved (difference < 0.2 mg) [12]. Moisture content (%) was calculated using the standard formula:

$$\text{Moisture Content (\%)} = \frac{\text{initial weight (g)} - \text{final weight (g)}}{\text{initial weight (g)}} \times 100\%$$

3. Solution

A 1 g sample was dissolved in 50 mL of distilled water, filtered using dried Whatman No. 1 filter paper, and weighed. The filter paper and residue were dried at 105°C for 3 hours, cooled in a desiccator, and weighed [13]. The solubility value was expressed as the percentage of residue retained on the filter paper, calculated using the standard formula:

$$\text{Water solubility (\%)} = \left(1 - \frac{c - b}{\frac{a \times (100 - ka)}{100}} \right) \times 100\%$$

Where:

- a = weight of sample used (g)
- b = weight of filter paper (g)
- c = weight of filter paper and residue (g)
- ka = moisture content of sample (%)

4. Color Intensity L, a^* , and b^*

Color intensity measurement of encapsulated extract of Moringa leaves herbal drink was carried out using a color reader with parameters L (brightness), a^* (green–red), and b^* (blue–yellow) [14].

5. IC₅₀ Antioxidant Activity

A total of 10 mg of encapsulate was dissolved in PA methanol to obtain a stock solution of 1000 ppm, and diluted to concentrations of 0, 2, 4, 6, 8, and 10 ppm in 5 mL. Each sample (1 mL) was mixed with 1 mL of a 0.004% DPPH solution and incubated in the dark for 30 minutes. Subsequently, absorbance was measured at 517 nm using a UV-Vis spectrophotometer [15]. Antioxidant activity was calculated using the standard formula:

$$X = \frac{Y - B}{A} \times 1000$$

Where:

- X = sample concentration (ppm)
- Y = 50% inhibition power
- A = X coefficient obtained from the linear regression equation
- B = constant obtained from the linear regression equation

6. Sensory Test

Sensory test was conducted using scoring (color, aroma, and taste) and hedonic (overall preference) methods. Samples were prepared by dissolving approximately 10 g of encapsulated powder in 200 mL of water at 70°C, followed by stirring for 3 minutes. A total of 20 semi-trained panelists, comprising students familiar with herbal drink, were selected through a duo-trio test before participating in the scoring and hedonic tests. These panelists assessed the color, aroma, taste, and overall preference of the brew [16].

7. Scanning Electron Microscope (SEM) Test

Morphological analysis of encapsulated Moringa leaves herbal drink was conducted using SEM with a JSM-IT200 (JEOL) instrument. SEM was operated at standard operating parameters of 5.0 kV, a working distance (WD) of 9.9 mm, and a Probe Current (PC) of 30.0 mm. Measurements were made at several magnifications, including 100x, 500x, 1500x, 2500x, and 5000x.

3 Results and Discussion

3.1 Yield

ANOVA showed that the ratio of maltodextrin to carrageenan had a significant effect ($P < 0.01$) on yield. Based on the results, the average yield of encapsulated Moringa leaves herbal drink is shown in Figure 1.

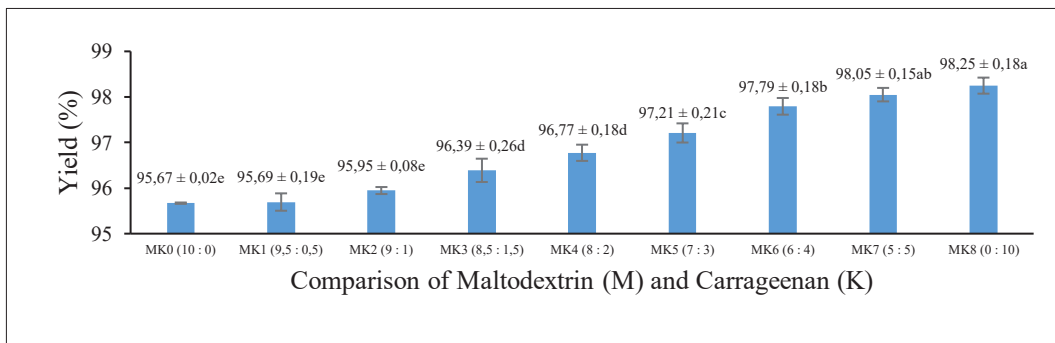


Fig. 1. Graph of the average yield of encapsulated Moringa leaves herbal drink extract (%)

According to Figure 1, the highest yield was obtained in MK8 treatment at 98.25%, which was not significantly different from MK7. The lowest yield was observed in MK0 treatment at 95.67%, comparable to MK1 and MK2. The increase in yield was influenced by carrageenan content. This is because a higher concentration of carrageenan in the film matrix improves the total solids, thereby increasing the yield, due to the higher molecular weight of carrageenan compared to other coating materials [17]. Carrageenan is also capable of forming gels and increasing solution viscosity, which contributes to the high yield [8]. Similar results were reported in encapsulation of cassava leaves with maltodextrin–carrageenan, which produced a yield increase of approximately 98.9% [18]. The highest yield of 95.64% was achieved in encapsulation of button flower extract using a combination of gum arabic and carrageenan [19].

3.2 Moisture Content

ANOVA showed that maltodextrin and carrageenan ratio had no significant effect ($P>0.05$) on moisture content of encapsulated Moringa leaves herbal drink extract. The average moisture content is shown in Table 5 and Figure 2.

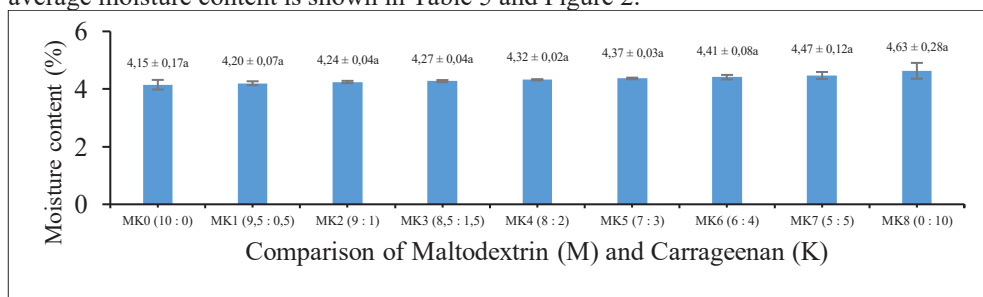


Fig. 2. Graph of average moisture content of encapsulated Moringa leaves herbal drink extract (%)

According to Figure 2, moisture content of encapsulated Moringa leaves herbal drink extract ranged from 4.15 to 4.63% and complied with the SNI 01-4320-1996 standard for traditional drink powders (3–5%). Variations in maltodextrin to carrageenan ratio did not significantly influence moisture content, as the drying process was conducted to achieve the standard range. Maltodextrin contains free hydroxyl groups that can bind water, which evaporates easily during drying [20]. Meanwhile, carrageenan is hygroscopic and can also bind water [21]. Similar results were observed in maltodextrin-carrageenan ratios (95:5, 90:10, 85:15), which did not significantly affect moisture content, with values ranging from 6.35 to 6.70% [18].

3.3 Solubility

ANOVA showed that maltodextrin and carrageenan ratio had a highly significant effect ($P < 0.01$) on the solubility of encapsulated Moringa leaves herbal drink extract. The average solubility value is shown in Figure 3.

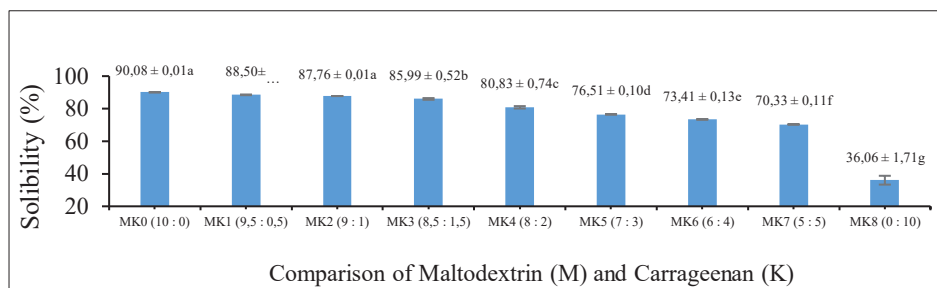


Fig. 3. Graph of the average solubility value of encapsulated extract of Moringa leaves herbal drink (%)

Based on Figure 3, the highest solubility was observed in MK0 treatment at 90.08%, which was not significantly different from MK1 and MK2. The lowest solubility was shown by MK8 at 36.06%. Further observation showed that increasing the concentration of carrageenan tended to decrease solubility because carrageenan formed an insoluble gel in cold water [22]. These results were in line with the study on encapsulation of kenop flower dye extract, which experienced a decrease in encapsulation solubility from 92.69% to 32.12% as carrageenan content increased [19].

3.4 Color Intensity (L, a*, b*)

Analysis of diversity showed that the ratio of maltodextrin and carrageenan had a very significant effect ($P < 0.01$) on brightness (L), redness (a*), and yellowness (b*) of encapsulated extract. The average values at L, a*, and b* levels of encapsulated Moringa leaves herbal drink are shown in Table 1.

Table 1. Average values of brightness level (L), redness level (a*), and yellowness level (b*) of encapsulated Moringa leaves herbal drink extract

| M : K | Brightness Level (L) | Redness Level (a*) | Yellowness Level (b*) |
|---------------|----------------------|--------------------|-----------------------|
| MK0 (10:0) | 79.68 ± 0.04a | 1.05 ± 0.07g | 18.88 ± 0.04g |
| MK1 (9.5:0.5) | 78.50 ± 0.28a | 1.13 ± 0.11g | 19.13 ± 0.11g |
| MK2 (9:1) | 77.95 ± 0.42a | 1.15 ± 0.00g | 19.75 ± 0.71g |
| MK3 (8.5:1.5) | 75.63 ± 0.60b | 2.03 ± 0.04f | 24.68 ± 0.11f |
| MK4 (8:2) | 73.18 ± 0.11c | 2.38 ± 0.04e | 25.53 ± 0.11e |
| MK5 (7:3) | 72.93 ± 0.04c | 2.50 ± 0.07d | 26.42 ± 0.39d |
| MK6 (6:4) | 71.65 ± 0.28d | 2.73 ± 0.00c | 28.50 ± 0.00c |
| MK7 (5:5) | 68.63 ± 0.25e | 3.03 ± 0.4b | 32.53 ± 0.88b |
| MK8 (0:10) | 60.88 ± 0.95f | 3.23 ± 0.4a | 35.55 ± 0.14a |

Description: Different letters behind the mean value indicate a very significant difference ($P < 0.01$)

3.4.1 Brightness Level (L)

Based on Table 1, the highest brightness value was obtained in MK0 treatment (79.68), which was not significantly different from MK1 and MK2, while the lowest value was shown by MK8 (60.88). The increase in brightness was attributed to the white nature of

maltodextrin, which provided a brighter effect on the product. Increasing maltodextrin concentration from 10% to 20% improved the brightness of encapsulation [23]. Similarly, a previous study showed that increasing carrageenan concentration led to a decrease in the average brightness level of the cassava leaves dye, with values of 52.9, 32.9, and 26.9 [18].

3.4.2 Redness Level (a*)

The highest average redness level (a*) value was obtained in MK8 (3.23), while the lowest value was observed in MK0 (1.05), which was not significantly different from MK1 and MK2. Further observation showed that increasing the concentration of carrageenan caused more liquid to be trapped in gel structure. This made the bond between gel and liquid tighter, thereby producing a darker color [22]. The condition triggered a browning reaction during the drying process, which increased the intensity of the reddish color in the encapsulate. Similar results also showed that increasing the concentration of carrageenan was directly proportional to the rise in the redness level [18].

3.4.3 Yellowness Level (b*)

MK8 treatment produced the highest yellowness level (b*) of 35.55, while the lowest was observed in MK0 at 18.88, which was not significantly different from MK1 and MK2. This increase was related to the high carrageenan concentration, where the addition of carrageenan caused an increase in the intensity of browning reaction during the drying process. A larger amount of carrageenan was able to bind the liquid more tightly in the gel, causing a darker, yellow-colored product [22]. The consistency of this result was strengthened by other studies that reported an improvement in the yellowness value of the encapsulate as carrageenan concentration increased, with results of 22.0, 25.3, and 28.5, respectively [18].

3.5 Antioxidant Activity

The analysis of diversity showed that the comparison treatment of maltodextrin and carrageenan had a very significant effect ($P < 0.01$) on antioxidant activity IC_{50} of encapsulated extracts, as presented in Figure 4.

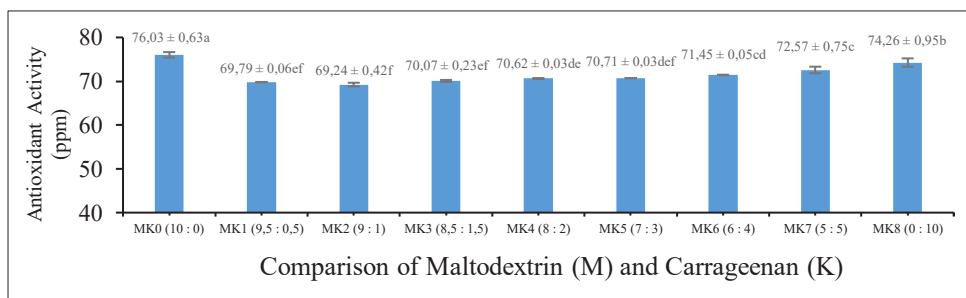


Fig. 4. Graph of the average value of antioxidant activity (IC_{50}) of encapsulated Moringa leaves herbal drink extract (ppm)

As shown in Figure 4, the average value of antioxidant activity, based on IC_{50} , in all treatments was classified as strong, falling in the range of 50–100 ppm [24]. The highest antioxidant activity was obtained in MK2 (9:1) with an IC_{50} value of 69.24 ppm, while the lowest was found in MK0 (0:10) at 74.26 ppm. The low antioxidant activity in MK0 was caused by an extremely high concentration of maltodextrin, which reduced the viscosity of the solution [25]. This made the coating layer (shell) formed less strong and unable to protect the active components from loss during the drying process. Similarly, a previous study on

microalgae phycocyanin encapsulation showed a decrease in antioxidant capacity of phycocyanin as maltodextrin concentration increased from 10% to 30% [26].

Excessively high concentrations of carrageenan negatively affected antioxidant activity. Based on the results in Figure 4, adding a certain amount of carrageenan could increase antioxidant activity, which decreased at higher concentrations. This was due to the low solubility of the encapsulate, as carrageenan absorbed large amounts of water and forms a high-viscosity gel. Therefore, the active compounds, acting as free radical scavengers, were trapped in the matrix and could not function optimally [27].

3.6 Sensory Test

Based on the analysis of diversity, the comparison treatment of maltodextrin and carrageenan had a highly significant effect ($P < 0.01$) on color, aroma, taste, and overall acceptability of encapsulated Moringa extract. The average value is presented in Table 2.

Table 2. Average scoring values for color, aroma, taste, and overall acceptance of encapsulated Moringa extract

| M:K | Color Scoring | Aroma Scoring | Taste Scoring | Overall Acceptance Scoring |
|---------------|---------------|---------------|----------------|----------------------------|
| MK0 (10:0) | 2.70 ± 0.47d | 4.05 ± 0.39a | 2.95 ± 0.22a | 5.40 ± 0.50b |
| MK1 (9.5:0.5) | 2.75 ± 0.44d | 4.05 ± 0.22a | 2.90 ± 0.31ab | 5.55 ± 0.51b |
| MK2 (9:1) | 2.75 ± 0.44d | 4.05 ± 0.39a | 2.90 ± 0.31ab | 5.85 ± 0.49a |
| MK3 (8.5:1.5) | 2.75 ± 0.44d | 3.65 ± 0.49b | 2.80 ± 0.41bc | 5.30 ± 0.47b |
| MK4 (8:2) | 2.95 ± 0.39cd | 3.25 ± 0.44c | 2.75 ± 0.44cd | 5.10 ± 0.31c |
| MK5 (7:3) | 3.20 ± 0.41bc | 3.05 ± 0.39cd | 2.70 ± 0.47cde | 4.60 ± 0.50d |
| MK6 (6:4) | 3.30 ± 0.47b | 2.85 ± 0.37de | 2.20 ± 0.41def | 3.95 ± 0.39e |
| MK7 (5:5) | 3.80 ± 0.41a | 2.60 ± 0.50e | 2.10 ± 0.31ef | 3.40 ± 0.50f |
| MK8 (0:10) | 4.00 ± 0.32a | 2.20 ± 0.41f | 2.05 ± 0.22f | 3.25 ± 0.44f |

Description: Different letters behind the average value indicate a very significant difference ($P < 0.01$)

3.6.1 Color Scoring

The highest color score was obtained in MK8 treatment (4.00; greenish yellow), while the lowest value was shown by MK0 (2.70; yellow), which was not significantly different from MK1–MK4. Increasing the concentration of maltodextrin tended to produce a brighter brew color, while carrageenan had a darker and greenish color. Panelists assessed that the dominance of maltodextrin produced a bright yellow color, in line with studies on instant pumpkin drink [28] [29]. However, the addition of carrageenan in higher amounts strengthened the intensity of green color in bilimbi (*Averrhoa bilimbi*) jam [30].

3.6.2 Aroma Scoring

The highest aroma scores were obtained in treatments MK0, MK1, and MK2, with an average value of 4.05, characterized by a distinctive aroma of Moringa leaves. In comparison, the lowest score was observed in MK8, with a value of 2.20, indicating an uncharacteristic aroma. The decrease in aroma intensity at high carrageenan concentrations was attributed to an increase in solution viscosity, which reduced the distinctive aroma of the raw material [31]. Similar results were observed in the pineapple jelly candy study, where increasing carrageenan concentrations led to reduced aroma intensity [32]. Panelists also assessed that the use of excessive carrageenan could produce a fishy sea aroma. In comparison, the

combination of maltodextrin and carrageenan at moderate concentrations still retained the distinctive aroma of Moringa leaves, although it was slightly unpleasant. The addition of maltodextrin in higher amounts tended to dull the aroma, but not significantly, due to the neutral and odorless nature [33].

3.6.3 Taste Scoring

The results in Table 2 showed that the highest taste score was obtained in MK0, with a value of 2.95 (slightly bitter), which was not significantly different from MK1 and MK2. In comparison, the lowest score was shown by MK8, with a value of 2.05 (indicating a non-bitter taste). The bitter taste of Moringa leaves was caused by the tannin content [34]. Based on observation, increasing the concentration of maltodextrin could mask the bitter taste due to its neutral nature [28]. Panelists assessed that the combination of maltodextrin and carrageenan could reduce the intensity of the bitter taste. However, at excessively high concentrations, drink became thicker, resembling a gel, which caused a decrease in taste quality. This was because carrageenan binds large amounts of water, forming a dense gel structure and reducing taste perception. Previous results also found that increased carrageenan concentrations in roselle and soursop leaves jelly drink decreased panelists' acceptance due to a reduction in taste [35].

3.6.4 Overall Acceptance Scoring

MK2 (9:1) obtained the highest average value in the overall acceptance test, namely 5.85 ('somewhat like'-'like'). In comparison, the lowest value was obtained in MK8 at 3.25, which was not significantly different from MK7. These results showed that the panelists preferred the encapsulated product of Moringa leaves herbal drink, which combined maltodextrin and carrageenan in a balanced ratio, because it provided a match in sensory quality in terms of color, aroma, and taste. Therefore, MK2 could be considered the most widely accepted formulation compared to the other treatments.

3.7 Best Treatment Results

Best treatment was determined based on the most important variable in this study, namely overall acceptance, yield, moisture content, solubility, brightness level (L), redness level (a*), yellowness level (b*), antioxidant activity IC₅₀, color scoring, aroma scoring, and taste scoring. The results obtained showed that the best treatment was achieved with MK2 (9:1), yielding the highest overall acceptance test result of 5.85 ('somewhat like' to 'like').

3.8 Scanning Electron Microscope (SEM)

The best encapsulated Moringa extract was analyzed for particle morphology or microstructure using SEM at 100x and 1500x magnification. Microstructure was determined using thin-layer drying (a) at 100x magnification, (b) at 1500x magnification, as shown in Figure 5. Observation showed non-uniform particles with lengths ranging from 5 to 90 µm and widths from 2 to 53 µm, which were affected by the thin-layer drying method. However, a study on encapsulating *Spirulina sp.* phycocyanin using the spray drying method produced irregular spherical particles with a diameter of 4-9 µm due to droplet shrinkage. The freeze-drying method produced coral-like structures measuring 61-98 µm in length and 20-63 µm in width [36]. This morphological variation showed that the drying method played a significant role in determining the size and shape of the resulting microencapsulates.

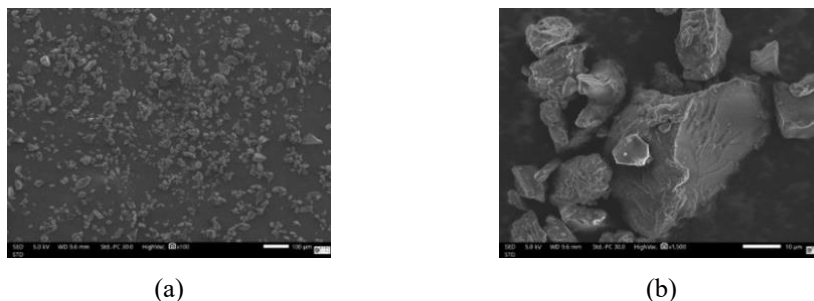


Fig. 5. Microstructure of encapsulated Moringa leaves herbal drink

4 Conclusion

In conclusion, the ratio of maltodextrin and carrageenan significantly affects the yield, solubility, color (L , a^* , b^*), antioxidant activity (IC_{50}), and sensory characteristics, but does not influence moisture content. The best treatment is obtained in MK2 (9:1), with characteristics of high yield (95.95%), low moisture content (4.24%), good solubility (87.76%), optimal brightness ($L=77.95$), strong antioxidant activity ($IC_{50}=69,24$ ppm), and panelists acceptance ranging from 'somewhat like' to 'like' (5.85). Microstructure of encapsulated Moringa leaves herbal drink shows a non-uniform shape and size, with a length range of 5–90 μm and a width of 2–53 μm .

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