Research Article

Development of Antioxidant-Rich *Moringa oleifera* Leaf Extract Encapsulation Using Maltodextrin and Gum Arabic

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ABSTRACT

In Indonesia, moringa leaves are not widely utilized and processed despite their health benefits as cooking aids containing flavonoids for their antioxidant and anti-inflammatory properties. The antioxidants in moringa leaves can counteract oxidative stress caused by free radicals, protecting cells from damage. Encapsulation enhances the stability of antioxidants, as they are susceptible to damage from oxygen, light, heat, and dehydration. This study focused on optimizing the microencapsulation of moringa leaf extract using maltodextrin and gum arabic coating materials through oven-drying. The best results were achieved with a 3:2 ratio of extract to coating and a 3:5 ratio of maltodextrin to gum arabic. Solubility was highest at a 2:3 ratio of extract to coating, with a 3:5 coating ratio. The product demonstrated potent antioxidant activity, with an IC50 value of 81.32 µg/mL. Scanning Electron Microscopy revealed the microencapsulated product to have an irregular surface, slight cracks, and a wrinkled shape, falling within the size range of 53. 7 µm - 89. 5 µm.

Keywords: antioxidant; encapsulation; gum arabic; maltodextrin; *moringa oleifera* leaf

1. Introduction

Moringa leaf extract has various applications in the food sector, serving as a fortification ingredient to enhance the nutritional value of food and beverages. With its rich content of protein, vitamins, minerals, and antioxidants, the extract is commonly used in products like bread, biscuits, cereals, and nutritious drinks, offering health benefits and strengthening the immune system (Islam *et al., 2021)*. Additionally, moringa leaves are utilized as a natural preservative. They are also rich in flavonoids, which have antioxidant properties to extend the shelf life of food products. They are incorporated into functional foods such as healthy snacks, pasta, and plant-based milk, providing natural color, unique flavor, and significant nutritional benefits. Flavonoids have high antioxidant content and are beneficial for health. They are widely used in the pharmaceutical industry (Kurniasih *et al*., 2015). Flavonoids include aromatic compounds that are antioxidants. Antioxidants can inhibit the oxidation process that arises due to free radical reactions. The body needs antioxidants to neutralize free radicals, which can help protect the body from free radicals and reduce their negative impact (Rizkayanti *et al*., 2017). Antioxidants are compounds that play a significant role in the medical field because they can prevent or inhibit several chronic and degenerative diseases. The processing of antioxidants must be done carefully to avoid affecting their stability. One effort that can be made to enhance stability and prevent the loss of antioxidant activity is through the encapsulation process (Susilawati and Soewondo, 2022).

Encapsulation aims to protect environmentally sensitive substances, protect organoleptic properties such as color, taste, and odor, obtain controlled release of the drug substance, safely handle toxic materials, and prevent adverse effects on drug use (Basuki, 2019). The encapsulation process is formulated with ingredients that can protect the bioactive compounds of a substance called a coating material (Jafari, 2017). Utilization of moringa bioactive compounds requires an encapsulation process because the environment easily damages its characteristics, so utilization can be maximized by the encapsulation process (Sadiah *et al*., 2022).The choice of coating material is the initial stage that can affect the characteristics of microencapsulation results (Sri, 2017). The coating materials commonly used are gums, carbohydrates, and proteins (Umi *et al*., 2015). Some of the ingredients that are widely used for food encapsulation are (1) polysaccharides such as starch and its derivatives; (2) plant extracts such as gum arabic, pectin, and soy extract; (3) extracts from marine plants (carrageenan and alginate); (4) polysaccharides from animals such as dextran, chitosan, xanthan and gelatin (Agustin *et al*., 2021). This study used gum arabic and maltodextrin as the two ingredients have good retaining properties, high water solubility, and neutral taste, odor, and color (Todorovic *et al*., 2022). The use of maltodextrin has the advantage of its low viscosity properties, high solubility properties, and high binding power in forming a microencapsule matrix (Hasna *et al*., 2018). The use of gum arabic as a coating can protect volatile *compounds from oxidation and evaporation (Indah et al., 2020). In addition,* gum arabic *has bioadhesive* power, is easily obtained, and is cheap compared to gelatin and WPI (Idrus, 2013). The use of maltodextrin and gum arabic as coating materials has been widely studied due to the effectiveness of this combination in various applications, especially in microencapsulation. Maltodextrin is generally used because of its non-hygroscopic properties and good stability, while gum arabic is used because of its excellent binding ability and high viscosity, so gum arabic and maltodextrin are excellent coating materials to be combined as encapsulant materials (Marpaung and Rahmayani, 2021).

Based on previous research, no research has been conducted on utilizing antioxidants by encapsulating moringa leaf extract (*Moringa oleifera*) with a combination of maltodextrin and gum arabic coating materials using oven drying.

2. Materials and Methods

2.1. Materials

Moringa leaves (*Moringa oleifera*) were obtained from farmers in Semarang City - Central Java, Indonesia; Ethanol 96% was purchased from Merck, Germany, and gum arabic and maltodextrin were also Merck-standard.

2.2. Procedure for Making *Moringa oleifera* Leaf Extract *(maceration)*

Fresh *Moringa oleifera* leaves were placed in a container and thoroughly washed with water. The leaves were then dried in an outdoor area protected from direct sunlight for 48 hours until the moisture content was reduced to below 10%. The dried leaves were ground using a blender and sieved through a 60-mesh sieve to obtain a fine powder. A watch glass was placed on an analytical balance, and 100 grams of moringa leaf powder were weighed. The weighed moringa powder was transferred into a maceration vessel containing 1000 mL of 96% ethanol. The vessel was sealed and stored in a dry, dark location. The mixture was allowed to macerate for 72 hours with occasional stirring.

The mixture was filtered to separate the liquid extract (filtrate) from the residue. The filtrate was transferred into a round-bottom flask and evaporated using a rotary evaporator. Evaporation was carried out at 45^{o}C with a rotation speed of 60 rpm for 60 minutes. The concentrated extract was stored in a tightly sealed glass container (Purwandari *et al*., 2022).

2.3. Preparation of Encapsulation Using Oven Drying Method

The oven is prepared and heated to 45ºC. Then, the ingredients are prepared (moringa leaf extract, maltodextrin, gum arabic, and distilled water). After that, it is placed on top of the place where the thick extract, maltodextrin powder and gum arabic are taken, according to Table 1.

Table 1 Encapsulation Material Comparison Ratio

Moringa Leaves Extract (gram)	Malto dextrin (gram)	Gum Arabic (gram)	Ratio of Extract: Coating	Ratio of Coating Material (Malto dextrin: Gum Arabic)
20	-	-	1:0	2:3
15	2	3	3:1	2:3
10	4	6	1:1	2:3
7.5	5	7.5	3:5	2:3
15	3	2	3:1	3:2
10	6	4	1:1	3:2
7.5	7.5	5	3:5	3:2

A 250 mL beaker and a 10 mL measuring pipette were prepared. 10 mL of distilled water was added to the beaker. The top stirrer was added to the holder with a clamp in another beaker; maltodextrin, gum Arabic, and water were mixed. The beaker containing the coating mixture was placed on the stirrer. The stirrer was turned on and the coating was stirred for 5 minutes at 800 rpm. Moringa leaf extract was added and stirred for 3 minutes. Repeat 7 times. The pan was labeled, then the mixture was poured and dried in an oven at 40ºC, 45ºC, and 55ºC according to the specified ratio. Remove the encapsulation, cool, mix, and filter, repeat 14-21 times, and store the microcapsules in a ziplock bag.

2.4. Analysis of Data

2.4.1 Yield

Yield is the ratio between the amount of microcapsules obtained after the drying process and the amount of microcapsule-forming material calculated based on dry weight (g). The yield of moringa leaf extract can be calculated using Eq. (1)

$$\%\text{Yield} = \frac{Microcapsule\ weight\ (g)}{Microcapsule\ forming\ material\ (g)} x\ 100 \qquad (1)$$

2.4.2 Water Content and Solubility Test

Water content:
A 3-5 g sample is weighed in a dried cup, and the weight is recorded. The sample is dried in an oven at 105°C for 4 hours. After drying, it is cooled, weighed, and then further cooled in a desiccator before being weighed again. This process is repeated every 2 hours until a constant weight is achieved for water content calculation. Weigh a 3-5 g sample in a dried cup and record weight. Dry in oven at 105°C for 4 hours. Cool, weigh, then cool in a desiccator, and weigh again. Repeat every 2 hours until constant weight for water content calculation.

$$\text{Water content (\%)} = \frac{W-(W_1-W_2)}{W_1-W_2} \qquad (2)$$

Description:
W : Weight of the sample before drying (g)
W_1 : Weight of the dried sample and empty dry porcelain cup (g)
W_2 : Weight of porcelain cup (g)

Solubility Test:
1 gram of material is dissolved in 20 mL of water and filtered. The filter paper is dried at 105°C for 30 minutes, then dried with the residual material and weighed. The solubility is calculated using Eq. (3). 1 g material dissolved in 20 mL water, filtered. Filter paper dried at 105°C for 30 minutes, then dried with residual material and weighed. Solubility is calculated using Eq. (3).

$$\text{Solubility test (\%)} = \left(1 - \frac{c-b}{a\ x\frac{(100-ka)}{100}}\right) x\ 100\% \qquad (3)$$

Description:
a : Weight of the sample used (g)
b : Weight of the filter paper (g)
c : Weight of the filter paper and residue (g)
ka : Moisture content of the sample (%)

2.4.3 Analysis of Antioxidant Activity

The tests were performed using the DPPH assay with ethanol extracts of Moringa leaves at concentrations of 20, 40, 60, and 100 ppm. The DPPH reagent was prepared by dissolving 4 mg of DPPH in methanol. The sample stock solution was prepared by dissolving 213 g of Moringa leaf extract in methanol. The antioxidant activity inhibition is calculated using Eq. (4). Tests were performed using the DPPH assay with ethanol extracts of Moringa leaves with concentrations of 20, 40, 60, and 100 ppm. A DPPH reagent was created by dissolving 4 mg of DPPH in methanol. A sample stock solution was prepared by dissolving 213 g of Moringa leaf extract in methanol. Antioxidant activity inhibition can be calculated using Eq. 4.

$$\%\text{Inhibition} = \frac{Control\ Absorbance - Sample\ Absorbance}{Control\ Absorbance} x100\% (4)$$

Each sample's IC50 (Inhibition Concentration 50%) value against the DPPH solution is determined based on the linear regression equation from measuring sample concentration variations against the DPPH solution (Bayani, 2016). The DPPH assay on encapsulation provides information on the protective effectiveness of the encapsulation on the active substance from oxidative damage. The results of this assay can be used to evaluate the quality of the encapsulation and the potency of the compound (Santhi, 2023). GC-MS (Gas Chromatography - Mass Spectroscopy) analysis identifies compounds in test samples using liquid gas chromatography and mass spectrometry (Salimi *et al.*, 2019). Gas Chromatography-Mass Spectrometry (GC: Thermo Scientific Trace 1310, MS: Thermo Scientific ISQ 7000) is used for the testing method, with a sample concentration of 1000 ppm and ethanol as the sample solvent.

2.4.4 SEM Test

Scanning Electron Microscopy (SEM) is an electron microscope that produces high-resolution surface images (Van Hoten, 2020). The SEM tool uses backscattered electrons to create images from the surface of an object (Septiano *et al.*, 2021). Scanning Electron Microscopy (SEM) provides images of material mixtures (Suciyati *et al.*, 2022).

3. Results and Discussion

3.1. Effect of Coating Material Ratio on Microencapsulation Result of Moringa Leaf Extract

Table 2 Shows the yield of moringa leaf extract at different temperatures (45ºC, 50ºC, 55ºC) using initial 20 g samples.

Temperature (°C)	Weight of Moringa Leaf Extract (gram)	Yield (%b/b)
45	5.61	28.05
50	6.13	30.65
55	6.01	30.05

Temperature impacts moringa leaf extract yield, as shown in Table 2, with a good yield of 10% or higher. Rahayu *et al*., 2021 found that higher temperatures increase yields, but at 55ºC, yields may drop due to reduced moringa leaf extract. The study uses 96% ethanol solvent for a higher yield. The yield obtained at 55°C tends to be lower than at 50°C. This occurs due to the loss of specific components in the moringa leaf extract. As found in the research by Yusmita et al. (2023), the total phenol content decreases as the temperature increases. Additionally, Rahayu and Suharti (2021) study states that the rise in temperature during the extraction process causes solvent molecules to move more quickly and randomly, leading to saturation at a certain point. Beyond this saturation point, there will be no further increase in yield. In addition, the choice of solvent also affects the results obtained. The selected solvent should be able to draw the active components from the mixture. Ethanol is an effective solvent for dissolved quercetin from moringa leaves. In our research, we used 96% ethanol because this will increase the yield value significantly. Mahmud's (2022) research supports this, which states that the higher the solvent concentration, the higher the yield because the high solvent concentration meets the number of extracted compound components. However, it can also increase the number of other unwanted components.

Table 5 shows the outcomes of microencapsulation of moringa leaf extract with different ratios of coating materials at an optimum temperature of 50ºC.

Table 3 Microencapsulation Result of Moringa Leaf Extract at Optimum Temperature

Ratio of Coating Material (Maltodextrin: Gum Arabic)	Ratio of Moringa Leaf Extract Ingredients: Coating	Microencapsulated Weight of Moringa Leaf Extract (gram)	Yield (%b/b)
2:3	3:1	4.48	42.4
2:3	1:1	12.36	61.8
2:3	3:5	13.79	68.95
3:2	3:1	14.24	71.2
3:2	1:1	12.75	63.75
3:2	3:5	14.71	73.55

According to Table 3, the highest yield of moringa extract microencapsulation is 73. 55% with a coating material to Moringa leaf extract ratio of 3:5 and maltodextrin to gum arabic ratio of 3:2. Encapsulation yield above 40% signifies success. Drying time affects yield, with longer times decreasing yield due to water evaporation (Putri and Setyaningsih, 2020). Additionally, the research by Irsyad *et al*. (2017) states that the yield is also influenced by the drying time, where the longer the drying time, the lower the yield produced. This is because the components and water dissolved in the mixture increasingly evaporate. Using

a 3:2 ratio of maltodextrin to gum arabic creates a more stable emulsion, resulting in better yield, as seen in the research of Sulistiyani *et al* (2022). Their study found higher yields with more maltodextrin than gum arabic due to maltodextrin's lower viscosity. The survey conducted by Sulistiyani *et al*. (2022) titled Antibacterial Activity of Cajuputi Oil (*Melaleuca leucadendron*) Microcapsules *Against Staphylococcus aureus Bacteria* Applied to Cotton Fabric Fibers explains that the formula (2:6) results in a high yield due to the large amount of gum arabic, which increases viscosity. The larger the mass of gum arabic, the lower the yield produced. The decrease in yield is due to the relatively high viscosity of gum arabic.

3.2. Water content and solubility test

Water content and solubility are crucial to determining material quality (Anwar et al., 2021). Solubility tests reveal how well a substance dissolves in a solvent, often water, for industrial applications. In a study, varying ratios of coating materials and core extracts affected solubility values. Research by Baysan et al. (2021) states that maltodextrin's low hygroscopic property reduces the moisture content of microcapsules, enhancing storage stability and reducing moisture-related degradation. This aligns with Kataren et al. (2017), who found that gum arabic increases product moisture content due to its water-binding function and high viscosity. A coating ratio 2:3 resulted in higher solubility than 3:2. Good solubility is essential for effectively releasing active ingredients. This is consistent with the research by Khasanah et al. (2015), which states that the combination of maltodextrin and gum arabic produces microcapsule products with high water solubility. This is due to the more significant amount of coating material compared to the extract in encapsulation, which increases solubility.

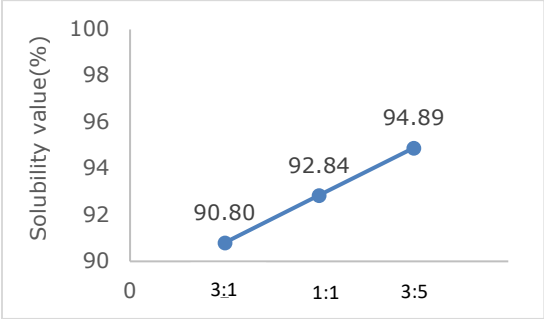

Figure 1 Solubility test of microencapsulated Moringa leaf extract with a coating of ratio 3:2

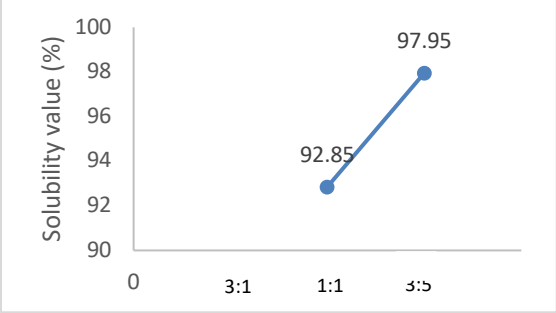

Figure 2 Solubility test of microencapsulated Moringa leaf extract with a coating of ratio 2:3

Figure 1 and Figure 2 show that the solubility test results tend to increase in both comparisons, namely 3:2 and 2:3. This is due to the large number of ingredients that the extract in the encapsulation will increase the solubility value. This is in line with the research of Marpaung *et al*. (2015), which states that the combination of maltodextrin and gum arabic produces microcapsule products with high water solubility values. Solubility is influenced by the moisture content of a material, as stated by Lumban (2022), who

explained that high moisture content causes the material to be complex to disperse in water because the material has a narrow surface area to be wetted due to its large particles, which tend to stick together and do not form pores, hence the material cannot absorb a large amount of water. The solubility value is inversely proportional to the water content value (Kania and Siswanti, 2015).

3.3 Analysis of Antioxidant Activity

Encapsulated products were tested for antioxidant activity using the DPPH method, with the IC50 value calculated from a linear regression equation.

Table 4 DPPH Test of Moringa Leaf Extracts

Concentration (ppm)	Absorbance	Blank Correct	% Inhibition
Control	0.918	0.862	0
0	0.056	0	0
10	0.545	0.489	43.27
30	0.497	0.441	48.84
50	0.407	0.351	59.28
70	0.371	0.315	63.46
90	0.347	0.291	66.24

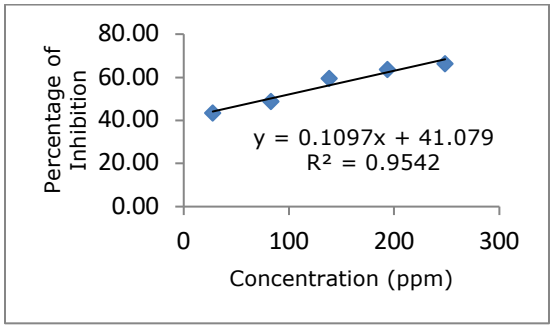

Figure 3 Effect of Inhibition percentage (%) with Concentration (ppm)

Based on Table 4 and Figure 3, the most significant percentage value of free radical inhibition (DPPH) was 66.24 %. Then, calculated by the IC_{50} formula, the IC_{50} value of 81.32 µg/ml was obtained using uv-vis spectrophotometry at a wavelength of 517 nm.

Table 5 Classification of antioxidant activity

No	Category	Concentration (µg/ml)
1	Very strong	<50
2	Strong	50-100
3	Medium	101-150
4	Weak	151-200

(Rumagit *et al.*, 2015)

Table 5 shows that the IC_{50} value of moringa leaf ethanol extract is categorized as vigorous antioxidant activity. Moringa leaf antioxidants are vigorous because moringa leaves have high phenolic and flavonoid

content. So, there is a correlation between phenolic content and increased antioxidant activity; phenolic and flavonoid content is directly proportional to the content of antioxidant values (Prayoga *et al*., 2019). These results align with research by Sadiah et al. (2022), who obtained antioxidant test results on ethanol extract of Moringa leaves showing an IC50 value of 52.74 µg. The IC50 value we found was lower than in the study, indicating strong antioxidant potential for food ingredients.

The GCMS chromatogram of moringa leaf extract in Figure 4 shows 52 peaks, indicating the presence of 52 phytochemical constituents.

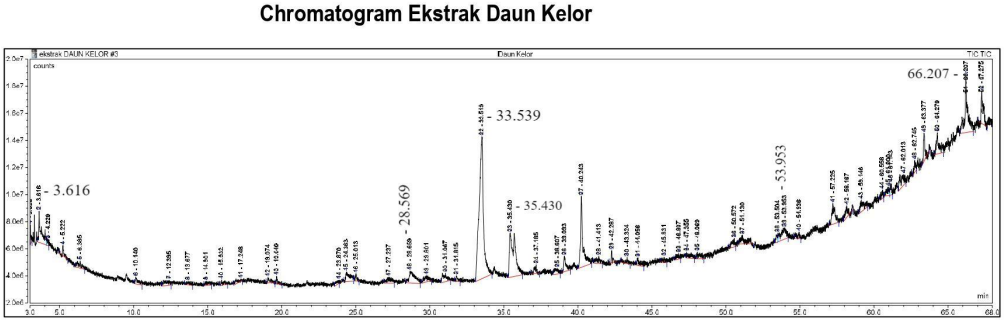

Figure 4 GCMS Analysis of Moringa Leaf Extract

Figure 4 shows the main components of moringa leaf extract with the highest relative area, namely L-Glucose (25.69%), Tetraacetyl-d-xylonic nitrile (10.05%), Ethyl iso-allocholate (6.63%), 1- Amino-3-methoxypropan-1-ol (3%), Pterin-6-carboxylic acid (acid group) (2.91%), Pregn-4-ene-3,20-dione, 17,21-dihydroxy-, bis (O- methyl oxime) (2.48%). The content of moringa leaf extract based on GC-MS test results includes carbohydrate groups, secondary metabolites, steroids, pterin acid, flavonoids, and phenolics. Phenolic compounds have pharmacological activities such as antibacterial, anti-inflammatory, antiviral, antioxidant, and anticancer (Hidayatullah *et al*., 2024).

Table 6 Components contained in Moringa leaf extract

Component	Retention time	% Relative Area	Group
L-Glucose	33.52	25.69	Carbohydrate
Desulphosinigrin	33.52	25.69	Antioxidant
D-mannose	35.43	10.05	Monosaccharide
Tetraacetyl-d-xylonic nitrile	35.43	10.05	Carbohydrate
Ethyl iso-allocholate	66.21	6.63	Steroid
1-Amino-3-methoxypropan-1-ol	3.62	3	Antibacterial
Benzeneethanamine, 2,5-difluoro-ß,3,4-trihydroxy-N-methyl	27.24	1.11	Phenolic
Hexadecanoic Acid	62.74	0.65	Fatty Acid

Table 6 shows the components contained in Moringa leaf extract. Ethyl iso-allocholate is a compound that belongs to secondary metabolites as steroid compounds. Ethyl iso-allocholate was also found in kawasita fruit (Feronia elephantum Correa), which has benefits as an antimicrobial, diuretic, anti-inflammatory, and asthmatic (Gazali *et al*., 2024). Hexadecanoic acid is an amino acid that functions as an

anti-inflammatory activity, Antioxidant, nematicide, hypocholesterolemia, anti-androgenic flavor, 5-Alpha reductase inhibitor (Tyagi *et al*., 2017). 1-Amino-3-methoxypropan-1-ol is also called Hydroxylamine. The hydroxylamine group is an inorganic compound that acts as an antibacterial against Gram-positive bacteria, as well as against Gram bacteria. Benzeneethanamine, 2,5-difluoro-ß,3,4-trihydroxy-N-methyl belongs to the phenolic group as an anti-inflammatory, antiviral, antioxidant, and anticancer. Benzeneethanamine, 2,5-difluoro-ß,3,4-trihydroxy-N-methyl was also found in phytochemical tests on Kasambi leaves (Urceola rosea). D-mannose has antibacterial effects and a positive effect on treating type I diabetes (Anindhita *et al*., 2016).

3.4 Scanning Electron Microscope

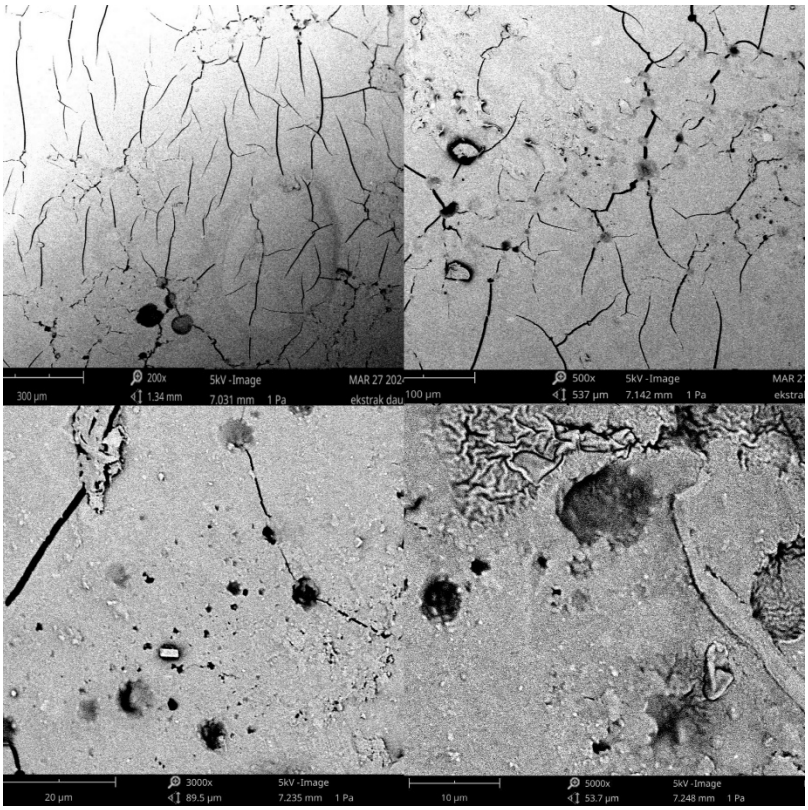

Figure 5 SEM of moringa leaf microencapsulation

SEM results of encapsulated products at 200x, 500x, 3000x and 5000x magnification are shown in Figure 5. Based on the SEM results shown in Figure 5, at 200x and 500x magnification, it can be seen that the surface of the microencapsulation has many cracks. At 3000x magnification that the product has an irregular surface, and there are few cracks on the product's surface; this indicates that there is oxygen transfer, which allows degradation due to interaction with active compounds (Carvalho *et al*., 2019). If observed through 5000x magnification, it has a different shape where the product has a more wrinkled and tight shape; this is due to maltodextrin, which cannot emulsify, while gum arabic has an excellent emulsifying ability. The presence of wrinkles is due to the release of heat from the core when the temperature is too high, and the evaporation of water is fast; the surface of the particles will harden so that the antioxidant compounds can be maintained during the encapsulation process. Factors affecting microcapsules' shape and morphology include stirring speed and solution viscosity (Srifiana *et al*., 2024). An increase in stirring speed contributes to the formation of microcapsules with smaller diameters and a decrease in microcapsule wall thickness (Hanurogo, 2019). This finding aligns with research conducted by Sulistiyani (2022), which states that emulsions stirred at high speed produce smaller microcapsules.

The SEM test's morphological results showed that the product's diameter at 200x, 500x, 3000x and 5000x magnification ranged from 1.34 µm - 537 µm. Determining the capsule type can be known based on particle size >5000 µm (macro), 1.0-5000 µm (micro), and <1.0 µm (nano). The results show that the product is included in the microencapsulation type. Microcapsules are described as a microform if they meet the value range of 1-5000 µm. In this research, maltodextrin and gum arabic wrapping material were used for the encapsulation. The encapsulation process with wrapping material can protect the active substance from external factors and increase the stability of the active ingredient so that its function can be maintained during storage. According to research by Ferdiansyah *et al*. (2017), encapsulated samples at room temperature (25°C) have a shelf life of 5.2 months longer than samples without wrapping, which only reached 0.5 months.

4. Conclusion

The best yield value of moringa leaf extract at 50°C was 30.65%. The best yield value of moringa leaf microencapsulation is 73.55% with the ratio of maltodextrin: gum arabic coating material (3:2) and the ratio of moringa leaf extract: coating material (3:5). The highest water content in the coating ratio (2:3) with an extract: coating ratio (1:1) of 2.18%. The highest solubility value in the coating ratio (2:3) with the extract: coating ratio (3:5) was 97.95%. The IC_{50} value of moringa leaf extract was obtained at 81.32 µg/ml, including the strong category because it was 50-100 µg/ml. GC-MS test results are carbohydrate groups, secondary metabolites, steroids, pterin acid, flavonoids, and phenolics. Morphology using SEM obtained an irregular surface, a few cracks, and more wrinkled if the temperature is too high. The product ranges from 1.34 µm - 537 µm and is included in the micro type because it meets the range value of 1-5000 µm.

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References

Agustin, D. A., & Wibowo, A. A. (2021). Teknologi Enkapsulasi: Teknik Dan Aplikasinya. Teknologi Separasi, 2, 202–209.

Aminah, S., & Hersoelistyorini, W. (2021). Review Artikel: Enkapsulasi Meningkatkan Kualitas Komponen Bioaktif Minuman Instan. In Prosiding Seminar Nasional Unimus (Vol. 4).

Anindita, F., Bahri, S., & Hardi, J. (2016). Ekstraksi dan karakterisasi glukomanan dari tepung biji salak (Salacca edulis Reinw). KOVALEN: Jurnal Riset Kimia, 2(2).

Anwar, C., Irmayanti, I., & Ambartiasari, G. (2021). Pengaruh Lama Pengeringan terhadap Rendemen, Kadar Air, dan Organoleptik Dendeng Sayat Daging Ayam. Jurnal Peternakan Sriwijaya, 10(2), 29-38.

Basuki, K. (2019). Perlindungan hutan. Jurnal Online Internasional & Nasional (Vol. 53, Issue 9).

Bayani, F. (2016). Analisis fenol total dan uji aktivitas antioksidan dari ekstrak buah sentul (Sandoricum koetjape Merr). Hydrogen: Jurnal Kependidikan Kimia, 4(1), 55-69.

Ferdiansyah F, Heriyanto H, Wijaya, Limantara. (2017). Pengaruh Metode Nanoenkapsulasi terhadap stabilitas Pigmen Karotenoid danUmur Simpaan Minyak dari Buah Merah (Pandanus conoideus L). AGRITECH, 37(4), 369-3

Dewi, S. R., Argo, B. D., & Ulya, N. (2018). Kandungan Flavonoid dan Aktivitas Antioksidan Ekstrak Pleurotus ostreatus. Rona Teknik Pertanian, 11(1), 1–10.

Gazali, M., Suhardani, M. N., Husni, A., Nurjanah, N., Zuriat, Z., Hasanah, U., & Syafitri, R. (2024). Aktivitas inhibisi tirosinase ekstrak etanol rumput laut Ulva lactuca secara in vitro. *Jurnal Pengolahan Hasil Perikanan Indonesia*, *27*(7), 564-585.

Hanurogo, T. B. (2019). Analisa Pengaruh Variasi Temperatur Reaksi terhadap Morfologi dan Sifat Termal Mikrokapsul Poly (Urea-Formaldehid) untuk Aplikasi Self-Healing Coating (Doctoral dissertation, Institut Teknologi Sepuluh Nopember).

Hasna, T., Anandito, B. K., Khasanah, L. U., Utami, R., & Manuhara, G. J. (2018). Effect of Maltodextrin and Whey Combination as Wall Material on The Characteristics of Cinnamon (Cinnamomum burmanii) Oleoresin Microencapsule. Agritech, 38(3), 259–264.

Hidayatullah, M., Rakhmatullah, A. N., & Perdana, D. (2024). Penetapan Kadar Fenolik Dan Flavonoid Total Ekstrak Etanol Batang Bajakah Tampala (Spatholobus littoralis Hassk). Journal of Pharmacopolium, 6(2).

Ibrahim, W., Mutia, R., Nurhayati, N., Nelwida, N., & Berliana, B. (2016). Penggunaan Kulit Nanas Fermentasi dalam Ransum yang Mengandung Gulma Berkhasiat Obat Terhadap Konsumsi Nutrient Ayam Broiler. Jurnal Agripet, 16(2), 76–82.

Idrus, S. (2013). Mikroenkapsulasi minyak ikan yang mengandung asam lemak omega-3 menggunakan gum arab sebagai bahan pelapis. Majalah Biam, 9(1), 23-29.

Indahningrum, R. putri, & Jayanti, L., D. (2020). Pengaruh Penambahan Minyak Oregano Esensial (Origanum Vulgare) Pada Aktivitas Mikroba Koloid Nano Konsentrat Protein Ikan Gabus (Channa Striata). 2507(1), 1–9.

Irsyad, M., Mappiratu, M., & Rahim, A. (2017). Produksi Antosianin Tersalut Maltodekstrin Dari Kelopak Bunga Rosella (Hibiscus Sabdariffa, L.) Dan Aplikasinya Dalam Pengolahan Pangan Fungsional. Mitra Sains, 5(1), 12-25.

Islam, Z., Islam, S. R., Hossen, F., Mahtab-ul-Islam, K., Hasan, M. R., & Karim, R. (2021). Moringa oleifera is a prominent source of nutrients with potential health benefits. International Journal of Food Science, 2021(1), 6627265.

Jafari, S. M. (Ed.). (2017). Nanoencapsulation technologies for the food and nutraceutical industries. Academic Press.

Kania, W., Andriani, M. M., & Siswanti, S. (2015). Pengaruh variasi rasio bahan pengikat terhadap karakteristik fisik dan kimia granul minuman fungsional instan kecambah kacang komak (Lablab purpureus (L.) sweet). Jurnal Teknosains Pangan, 4(3).

Khasanah, L. U., Anandhito, B. K., Rachmawaty, T., Utami, R., & Manuhara, G. J. (2015). Pengaruh rasio bahan penyalut maltodekstrin, gum arab, dan susu skim terhadap karakteristik fisik dan kimia mikrokapsul oleoresin daun kayu manis (Cinnamomum burmannii). *Agritech*, *35*(4), 414-421.

Kurniasih, N., Kusmiyati, M., Nurhasnah, Puspita Sari, R., & Wafdan, R. (2015). Potensi Daun Sirsak (Annona muricata Linn), Daun Binahong (Anredera cordifolia (Ten) Steenis), dan Daun Benalu Mangga (Dendrophthoe pentandra) Sebagai Antioksidan Pencegah Kanker. Jurnal Istek, 9(1), 162–184.

Lumban Gaol, R. (2022). Pengaruh Konsentrasi Pati Singkong Terhadap Karakteristik Tepung Whey Tahu Dengan Metode Foam Mat Drying (Doctoral dissertation, Universitas Jambi).

Mahmud, R., Dunggio, T., & Arbie, S. (2022). Uji Aktivitas Antioksidan Ekstrak Ampas Sagu (metroxylon sagu rottb) di desa Pangi Kecamatan Dulupi Kabupaten Boalemo. Jurnal Illmiah Dr. Aloei saboe, 2(1), 23-33.

Marpaung, A. L. R. P., Tafzi, F., & Rahmayani, I. (2021). Pengaruh perbandingan maltodekstrin dan gum arab pada mikroenkapsulasi ekstrak daun duku kumpeh (Lansium Domesticum Corr). Pengaruh Perbandingan Maltodekstrin dan Gum Arab pada Mikroenkapsulasi Ekstrak Daun Duku Kumpeh (Lansium Domesticum corr).

Nasution, F. M., Oktavianty, H., & Sunardi. (2023). Enkapsulasi Daun Sambiloto dengan Penambahan Ekstrak Sereh Menggunakan Metode Foam Mat Drying. Agroforetech, 1(3), 1858–1862.

Nurhasnawati, H., Sukarmi, S., & Handayani, F. (2017). Perbandingan Metode Ekstraksi Maserasi Dan Sokletasi Terhadap Aktivitas Antioksidan Ekstrak Etanol Daun Jambu Bol (Syzygium Malaccense L.). Jurnal Ilmiah Manuntung, 3(1), 91–95.

Prayoga, D. G. E., Nocianitri, K. A., & Puspawati, N. N. (2019). Identifikasi senyawa fitokimia dan aktivitas antioksidan ekstrak kasar daun pepe (Gymnema reticulatum Br) pada berbagai jenis pelarut. Jurnal Ilmu dan Teknologi Pangan, 8(2), 111-121.

Purnamasari, F. (2021). Identifikasi Senyawa Aktif dari Ekstrak Daun Sirsak (Annona muricata L.) dengan Perbandingan Beberapa Pelarut pada Metode Maserasi. Window of Health: Jurnal Kesehatan, 04(03), 231–237.

Purwandari, V., Isnaeni, I., Rahmi, R., Akbari, A. Z., & Akbari, M. Z. (2022). Formulasi Nanoekapsulasi Ekstrak Daun Kelor (Moringa Oleifera)/kitosan-natrium Tripoliposfat (NaTPP). Journal of Science and Applicative Technology, 6(2), 77-84.

Putri, A., Rusli, M. S., & Setyaningsih, D. (2020). Enkapsulasi Campuran Minyak Atsiri sebagai Produk Sediaan Aromaterapi dengan Teknik Koaservasi Kompleks. Jurnal Teknologi Industri Pertanian, 30(3), 299-307.

Rahayu, S. G., & Suharti, P. H. (2021). Pengaruh Suhu Pemanasan Daun Kelor (Moringe Oleifera) Terhadap Yield Dalam Pembuatan Hand Sanitizer Gel. Distilat: Jurnal Teknologi Separasi, 7(2), 642-648.

Rizkayanti, R., Diah, A. W. M., & Jura, M. R. (2017). Uji Aktivitas Antioksidan Ekstrak Air dan Ekstrak Etanol Daun Kelor (Moringa oleifera LAM). Jurnal Akademika Kimia, 6(2), 125.

Sadiah, I., Indiarto, R., & Cahyana, Y. (2022). Karakteristik dan Senyawa Fenolik Mikrokapsul Ekstrak Daun Kelor (Moringa oleifera) dengan Kombinasi Maltodekstrin dan Whey Protein Isolat. Jurnal Teknologi Industri Pertanian, 32(3), 273-282.

Salamah, N., & Widyasari, E. (2015). Aktivitas antioksidan ekstrak metanol daun kelengkeng (Euphoria longan (L) Steud.) dengan metode penangkapan radikal 2, 2'-difenil-1-pikrilhidrazil. Pharmaciana, 5(1), 25-34.

Salimi, Y. K., Ischak, N. I., & Ibrahim, Y. (2019). Karakterisasi asam lemak hasil hidrolisis pada minyak biji kelor (Moringa oleifera) dengan metode kromatografi gas- spektroskopi massa. Jambura Journal of Chemistry, 1(1), 6-14.

Santhi Laksmi, I. A. G. (2023). Skrining Fitokimia Dan Aktivitas Antioksidan Ekstrak Etanol Kulit Batang Alpukat (Persea americana Mill.) (Doctoral dissertation, Poltekkes Kemenkes Denpasar Jurusan Teknologi Laboratorium Medis 2023).

Septiano, A. F., Susilo, S., & Setyaningsih, N. E. (2021). Analisis citra hasil scanning electron microscopy energy dispersive x-ray (sem edx) komposit resin timbal dengan metode contrast to noise ratio (cnr). Indonesian Journal of Mathematics and Natural Sciences, 44(2), 81-85.

Sihombing, M. A., Winarto, W., & Saraswati, I. (2018). Uji efektivitas antijamur ekstrak biji pepaya (Carica papaya L.) terhadap pertumbuhan Malassezia furfur secara in vitro (Doctoral dissertation, Faculty of Medicine).

Sulistiyani, I. F., & Prasetya, A. T. (2022). Antibacterial Activity of Cajuputi Oil (Melaleuca leucadendron) Microcapsules Against Staphylococcus aureus Bacteria Applied to Cotton Fabric Fibers. Indonesian Journal of Chemical Science, 11(1), 69-80.

Srifiana, Y., Surini, S., & Yanuar, A. (2014). Mikroenkapsulasi ketoprofen dengan metode koaservasi dan semprot kering menggunakan pragelatinisasi pati singkong ftalat sebagai eksipien penyalut. Jurnal Ilmu Kefarmasian Indonesia, 12(2), 162-169.

Sri Haryani. (2017). Pemanfaatan tepung porang (Amorphophallusoncophyllus) sebagai penstabil emulsi m/a dan bahan penyalut pada mikrokapsul minyak ikan. Jurnal Teknologi Industri Pertanian, 27(1), 76–88.

Suciyati, S. W., Posman Manurung, P., Rudy Situmeang, R., & Junaidi, J (2022). Efek Variasi Konsentrasi NaOH pada Pembentukan Struktur Selulosa Cladophora sp. Jurnal Teori dan Aplikasi Fisika, 10(1).

Susilawati, E., & Soewondo, B. P. (2022). Pengaruh Nanoenkapsulasi pada Aktivitas Senyawa yang Berpotensi sebagai Antioksidan. Jurnal Riset Farmasi, 1-8.

Todorović, A., Šturm, L., Salević-Jelić, A., Lević, S., Osojnik Črnivec, I. G., Prislan, I., ... & Nedović, V. (2022). Encapsulation of bilberry extract with maltodextrin and gum arabic by freeze-drying: Formulation, characterisation, and storage stability. Processes, 10(10), 1991.

Tyagi, T. and Agarwal, M. (2017) Phytochemical Screening and GC-MS Analysis of Bioactive Constituents in the Ethanolic Extract of Pistia stratiotes L. and Eichhornia crassipes (Mart) Solms. Journal of Pharmacognosy and Phytochemistry, 6, 195-206.

Umi Khasanah, L., Anandhito, B. K., Rachmawaty, T., Utami, R., & Manuhara, G. J. (2015). Pengaruh Rasio Bahan Penyalut Maltodekstrin, Gum Arab, Dan Susu Skim Terhadap Karakteristik Fisik Dan Kimia Mikrokapsul Oleoresin Daun Kayu Manis (Cinnamomum burmannii). Jurnal Agritech, 35(04), 414.

Van Hoten, H. (2020). Analisis arakterisasi serbuk biokeramik dari cangkang telur ayam broiler. Rotor, 13 (1), 1-5.

Widyasanti, A., Arsyad, M. Z., & Wulandari, E. (2021). Ekstraksi Antosianin Kulit Buah Naga Merah (Hylocereus Polyrhizus) Menggunakan Metode Maserasi. Jurnal Agroindustri Vol, 11(2),72-81.

Yunita, E., & Khodijah, Z. (2020). Pengaruh konsentrasi pelarut etanol saat maserasi terhadap kadar kuersetin ekstrak daun asam jawa (Tamarindus indica L.) secara spektrofotometri UV-Vis. PHARMACY: Jurnal Farmasi Indonesia (Pharmaceutical Journal of Indonesia), 17(2), 273-280.

Yusmita, L., Arziyah, D., & AR, M. R. A. (2023). Efektivitas Suhu Ekstraksi Terhadap Total Fenol Ekstrak Daun Kelor (Moringa Oleifera Lam). Jurnal Penelitian Dan Pengkajian Ilmiah Eksakta, 2(2), 154-157.