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Physicochemical Characteristics of Encapsulated Black Pepper (*Piper nigrum* L.) Extract: Comparison of Maltodextrin and Gum Arabic Concentrations as Coating Materials

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ABSTRACT

Black pepper (*Piper nigrum* L.) contains piperine, its main alkaloid compound. However, piperine has low bioavailability due to its poor solubility in water. To address this issue, encapsulation is used. The objective of this study is to produce a water-soluble and stable black pepper extract encapsulated powder. The study encapsulated piperine using three concentrations of maltodextrin and gum arabic ratio as coating materials, namely MG1 (75:25), MG2 (25:75) and MG3 (0:100). The mixture was then combined with 30 % piperine extract using an ultrasonic processor and dried for 6 hours at 60°C in a vacuum dryer. The study results indicate that the concentration of maltodextrin and gum arabic MG1 positively affected the physicochemical characteristics of black pepper extract encapsulation. The MG1 exhibited a solubility level of 86.26 % in water, an encapsulation efficiency value of 78 % and a piperine content was stable at value of 7.08 - 7.49 % during storage.

1. Introduction

Black pepper (*Piper nigrum* L.) is a plant from the Piperaceae family that grows in tropical areas with sufficient rainfall throughout the year. Pepper is known as the 'King of Spices' and is one of the most important spices in global trade. India is the main pepper producer in the world, followed by Indonesia, which became the fourth largest producer of black pepper in 2004 [1]. Lampung City and Bangka Island in Sumatra, as well as West and East Kalimantan, are the primary areas for pepper production in Indonesia. According to Rukmana *et al*., [2], Lampung City is the largest supplier of black pepper, accounting for 80 % of the total production [1]. Pepper has been used in traditional Chinese and Indian medicine to treat a variety of ailments, including pain, fever, influenza, migraine headaches and to enhance appetite and accelerate blood flow [3].

Pepper contains about 0.4-7 % volatile oil, which contributes to the aroma and spicy taste of pepper. The pharmacologically active compound piperine ranges from 2-9 % of pepper plants [4]. However, piperine has solubility problems and a low dissolution rate in water, so this is a factor that

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limits its use. Black pepper extract has potential as a therapeutic alternative to synthetic drugs, provided it has good solubility in water to enter circulation and have a therapeutic effect [5]. Low solubility reduces bioavailability and limits therapeutic effect. Therefore, increasing solubility is necessary [5].

Pepper extract is utilized in the food industry as a flavouring or cooking spice and can be processed into beverage and food products. One such processed beverage product is instant drink. However, the low solubility of pepper extract in instant beverage products poses a challenge for consumer acceptance. The form and solubility of the instant drink when dissolved significantly affect the product's marketability [6]. Encapsulation techniques are being explored as a solution to this problem.

Encapsulation is a technique used to protect sensitive material components and reduce the degradation of active compounds by entrapping the core material in a coating material. This technique provides benefits such as controlling the release of active ingredients [7]. This process can also protect the active ingredients from adverse environmental influences such as oxidation, hydrolysis, evaporation or heat degradation, resulting in a longer shelf life and better process stability for the active ingredients. The solubility level and stability of the encapsulate during storage are influenced by several factors, including the concentration of the coating material used.

Coating ingredients are added to increase the volume, functional properties and taste of food products. It is important to use a non-toxic coating that does not react with the core material during the drying process. The type of coating can also affect the fusion process in the body when consumed. The coating material used in drying may consist of only one type of coating or a combination of several different types of coatings. This fragment discusses the characterization of powders, specifically referencing the use of maltodextrin and gum arabic as common coating materials in the encapsulation process [8].

Rahmanto *et al*., [9] found that adding gum arabic can enhance the plasticity, fiber content and nutritional value of a product. Kania *et al*., [10] noted that gum arabic has the advantage of high solubility and low viscosity. However, its use in the food industry is limited due to fluctuating prices and limited supplies. Therefore, a companion binder for gum arabic is needed that has a more stable price and availability, such as maltodextrin. Maltodextrin was chosen as a coating material due to its affordability, commercial availability and frequent use in the food industry [11].

According to Ningtias *et al.*, [12], the addition of maltodextrin to drying ingredients is necessary to produce a high-quality product that is well-liked by panelists. Maltodextrin has the ability to maintain compounds such as antioxidants and beta-carotene and can bind free water content of a material without damaging it when exposed to heat. Additionally, it has the advantages of fast dispersion, high solubility, film-forming ability, low hygroscopic properties and the ability to inhibit crystallization.

The research is aimed to investigate the effect of the ratio of coating ingredient concentrations on the solubility and stability of black pepper encapsulated powder during storage. Encapsulation is achieved using high-energy process techniques, such as homogenizers (ultrasound processors) [13].

2. Methodology

2.1 Black Pepper Oleoresin Preparation

The black pepper was ground using a grinder and macerated for 24 hours in a 1:10 ratio with 95.6 % ethanol. The resulting mixture was filtered, and the filtrate was extracted using a Rotary Evaporator BUCHI type R-210, made in Switzerland. Filtrate was extracted at a temperature of 50°C.

2.2 70 % Alcohol Preparation

A 100 mL volumetric flask was filled with 73 mL of technical alcohol with a concentration of 95.6 %. A small amount of distilled water was added to the flask, which was then filled with distilled water up to the 100 mL mark and homogenized.

2.3 Encapsulated Piperine Preparation

To prepare the nanoencapsulation, 3 grams of 30 % piperine extract is mixed with 70 mL of 70 % alcohol. Three different fillers, maltodextrin and gum arabic, were used in four treatments: MG_1 (75:25), MG_2 (25:75) and MG_3 (0:100). MG_1 (5.25:1.75 grams), MG_2 (1.75:5.25 grams) and MG_3 (0:7 grams). The weight of the fillers used were: The filler material was then mixed with 30 mL of distilled water and homogenized. The piperine extract dissolved in 70 % alcohol was added slowly to a beaker containing the filler dissolved in distilled water while stirring. The solution is then homogenized using an ultrasonic processor for 15 mins. Afterward, the solution was poured into a silicone pan and dried using a vacuum dryer oven (B-One type VOV-50, China). The solution dried at 60°C for 6 hours. Finally, the dried material was ground using a mortar and sieved with an 80 mesh.

Table 1
Sample formulation

Sample	Oleoresin (gram)	Maltodextrin (gram)	Gum Arabic (gram)
MG_1	3	5.25	1.75
MG_2	3	1.75	5.25
MG_3	3	0	7

2.4 Encapsulated Piperine Color

Nanoencapsulation color testing was referred [14]. The color analysis was performed using a chromameter-type spectrophotometer CM-5 (Konica, Japan). The sample was prepared and inserted into the spectrophotometer. The results were expressed as L*, a* and b*. The L* value indicates lightness or darkness, a* determines redness or greenness and b* determines the yellowness or bluish value.

2.5 Encapsulated Piperine Water Content

The water content of the nanoencapsulation was analyzed using the AOAC 2005 [15] thermogravimetric method. The cup was heated at 105°C for 1 hour, then cooled in a desiccator for 30 mins and weighed (W2). This process was repeated until a constant weight was achieved. The piperine-encapsulated powder, weighing 2 grams (W), was placed in the cup and heated at 105°C for three hours. The samples were cooled in a desiccator for 30 mins after three hours and then weighed. This process was repeated until a constant weight (W1) was obtained. The samples were then dried again at 105°C for 30 mins and cooled in a desiccator for 15 mins. The water content in the encapsulated powder is calculated using the following formula:

$$\text{Water Content (dry based)} = \frac{\text{W} - (\text{W1} - \text{W2})}{\text{W1} - \text{W2}} \times 100\% \quad (1)$$

2.6 Encapsulated Piperine Particle Size and Zeta Potential

Ma *et al.,* [16] conducted research on particle size analysis and zeta potential using the Particle Size Analyzer (PSA) and nanoparticle analyzer (Horiba type SZ-100, Japan). Samples were prepared and analyzed for particle size and zeta potential. The scattering of electrons on the surface of the sample was detected by the detector to determine the particle size and zeta potential.

2.7 Encapsulated Piperine Water Solubility

To test the solubility of piperine, 1 gram of microcapsules was weighed and added to 100 mL of distilled water. The mixture was then filtered using a vacuum filter. The filter paper was dried in an oven at 105°C for 30 mins before use and weighed (b). The filter paper, along with the residue, was then dried for an additional three hours at 105°C. After cooling in a desiccator for 15 mins, the paper was weighed again (c).

$$\text{Solubility} = \left(1 - \frac{\text{c} - \text{b}}{\frac{100 - \%\text{Water Content}}{100} \times \text{a}}\right) \times 100\ \% \quad (2)$$

2.8 Encapsulated Piperine Solubility Time

The procedure for dissolution time testing involves weighing 2 grams of microcapsule powder and dissolving it in 20 mL of cold water with continuous stirring. The speed of dissolution can be calculated using a stopwatch. The powder should dissolve in less than 5 mins.

2.9 Encapsulation Efficiency of Piperine Extract

The calculation of encapsulation efficiency (% EE) was researched by [17]. To calculate encapsulation efficiency, a standard solution and curve are prepared and the extracted content in the nano encapsulation is calculated.

2.9.1 Standard curve

The extract was weighed at 25 mg and dissolved in a 1:1 ratio of ethanol-chloroform in a beaker. It was then transferred to a 100 mL volumetric flask and adjusted to the mark with ethanol-chloroform, resulting in a 2 mg/mL solution. The standard solution was pipetted into 10 mL volumetric flasks at 0.1 mL, 0.2 mL, 0.3 mL, 0.4 mL, 0.5 mL and 0.6 mL and adjusted to the limit mark with ethanol-chloroform (1:1). Prepare a blank solution containing ethanol-chloroform (1:1) and transfer each solution into a cuvette. Calculate the absorbance of each solution at a wavelength of 340 nm.

2.9.2 Total Piperine extract content

The nanoencapsulation was dissolved in 10 mL of ethanol-chloroform (1:1) after being weighed at 10 mg. To dilute the sample, 0.2 mL was taken and placed in a 10 mL flask with ethanol-chloroform (1:1). The resulting mixture was then centrifuged at a speed of 1000 rpm and filtered to dissolve the

nanoencapsulation. A blank containing ethanol-chloroform (1:1) was prepared and the filtrate was put into a cuvette. The absorbance at a wavelength of 340 nm was then calculated.

2.9.3 Surface Piperine extract content

To determine the encapsulation efficiency, 10 mg of nanoencapsulation was dissolved in 10 mL of ethanol-chloroform (1:1) on filter paper. The resulting solution was diluted by adding 0.2 mL to a 10 mL flask of ethanol-chloroform (1:1). After centrifugation at 1000 rpm, the nanoencapsulation was dissolved and filtered. A blank containing ethanol-chloroform (1:1) was prepared and mixed with the filtrate. The absorbance at a wavelength of 340 nm was then calculated. Encapsulation efficiency is calculated using the following formula:

$$\mathrm{EE} = \frac{\text{Piperine total} - \text{Piperine surface}}{\text{Piperine total}} \times 100\ \% \quad (3)$$

2.10 Encapsulated Piperine Content

The concentration of piperine content was tested using a UV-Vis spectrophotometer at a wavelength of 340-350 nm.

2.10.1 Piperine standard curve

To create a piperine standard curve, 50 mg of piperine standard was weighed and added to a 50 mL volumetric flask containing 35 mL of ethanol. Next, 5 mL of the stock solution was transferred to a 50 mL measuring flask and adjusted to the mark. From the second stock solution, 0.5, 1, 1.5, 2, 2.5 and 3 mL were taken and added to a 50 mL volumetric flask, which was then adjusted to the mark. The blank was filled with ethanol. The solution was then adjusted to the mark.

2.10.2 Piperine content in Black Pepper encapsulated powder

The sample was weighed at 25 mg and mixed with 10 mL of ethanol in an Erlenmeyer flask. The mixture was then refluxed for 45 mins, cooled and filtered into a 25 mL volumetric flask, which was adjusted to the mark. The remaining residue was transferred to the filter and washed with the same solvent. Next, 0.3 mL of the stock solution was pipetted into a 10 mL volumetric flask and the mark was reached with ethanol. The solution was then incubated for 15 mins in the dark. Ethanol was used as a blank and the absorbance of the solution was measured at a wavelength of 341.5 nm.

2.11 Statistical Evaluation

The experimental research method was utilized in this study. The test comprised of six treatments, each with three replications. The resulting data was analyzed using a one-way ANOVA analysis of variance, followed by Duncan's test with a 95 % confidence level, using the IBM SPSS 26.0 statistical software program.

3. Results and Discussion

3.1 Encapsulated Piperine Color

The color system utilized is the CIE (Commission Internationale de l'Eclairage) standard scale, characterized by value parameters: L* (Lightness), a* (Redness) and b* (Yellowness). The test results indicate that the L* color in the piperine encapsulation sample is quite high, suggesting that all samples have a light color. The samples all have a negative a* value, indicating a green colour and a positive b* value, indicating a yellow color.

Table 2 shows that the addition of maltodextrin and gum arabic as coating materials with different concentration ratios has a significantly different effect at the 95 % confidence level on the color parameters of L* encapsulated piperine with the addition of maltodextrin and gum arabic MG_1 (75:25), MG_2 (25:75) and MG_3 (0:100) ranged from 73.08 to 75.58. The resulting value is positive (+), indicating a high brightness parameter. The encapsulant in various samples appears white due to the physical colour of the coating material, maltodextrin, which does not produce colour [18].

Table 2
Encapsulated Piperine colour

Sample	L*	a*	b*
MG_1	75.58 ± 0.01^c	-3.20 ± 0.01^a	36.04 ± 0.01^b
MG_2	74.09 ± 0.01^b	-1.55 ± 0.01^b	35.38 ± 0.01^a
MG_3	73.08 ± 0.00^a	-1.37 ± 0.01^c	35.31 ± 0.05^a

The MG_1 sample has the highest average colour value in the a* notation at -3.20 ± 0.01, while the MG_3 sample has the lowest a* value at -1.37 ± 0.01. A negative a* value indicates a green colour. The highest b* value for colour intensity was found in the MG_1 sample at 36.04 ± 0.01, while the lowest value was found in the MG_3 sample at 35.31 ± 0.05. A positive b* value indicates a yellow colour.

Based on the a* and b* values, the encapsulated piperine sample exhibits a yellowish-green colour, as shown in the image above. It is worth noting that black pepper oleoresin, according to SNI 01-0025-1987, has a brown or greenish-brown colour, while black pepper essential oil, according to ISO 3061:2008, has a greenish-yellow colour [19]. The obtained results show that the brightness level of the sample is influenced by the oleoresin and essential oils present in it. This is because the yellow colour of the essential oil increases the L* value in the test, resulting in a yellowish-green colour in the sample.

3.2 Encapsulated Piperine Water Content

Water content is a crucial parameter as it affects product stability during storage. A low water content in powder products makes them resistant to damage by microorganisms. The Indonesian Minister of Health [20] mandates that traditional medicine powders have a water content of less than 10 %.

The gravimetric method is used to test water content. This method involves heating the material to evaporate the water and then weighing it until a constant weight is achieved. The results show a significant difference in water content of the materials, which is caused by the varying concentration of the coating material used. Table 3 displays the water content of encapsulated piperine. It shows that the water content parameters of encapsulated piperine are significantly affected at the 95 % confidence level by the addition of maltodextrin and gum arabic as coating materials with different concentration ratios. The water content ranges from 6.60 to 7.74 % for samples MG_1 (75:25), MG_2

(25:75) and MG_3 (0:100). Sample MG_1 has the lowest water content at 6.60 %, while sample MG3 has the highest water content at 7.74 %.

Table 3
Encapsulated Piperine water content

Sample	Water Content (%)
MG_1	6.60 ± 0.06^a
MG_2	6.99 ± 0.03^b
MG_3	7.74 ± 0.16^c

Gardjito *et al*., [21] found that the water content of microcapsules is affected by the encapsulant used. MG_1 has the lowest water content value due to its high maltodextrin content compared to MG_2 and MG_3. This is because maltodextrin has a lower molecular weight and simpler molecular structure, allowing for easier evaporation of water during the drying process. Meanwhile, MG_3 has the highest water content value because it uses the highest concentration of gum Arabic compared to MG_1 and MG_2. Gum Arabic has a larger molecular weight and a more complex molecular structure, resulting in stronger bonds with water molecules. As a result, during the drying process, the water molecules are more difficult to evaporate and require greater evaporation energy.

Widarta *et al*., [22] found that increasing the concentration of maltodextrin as an encapsulant reduces the available water for evaporation, resulting in lower water content. However, the high water content in samples with gum arabic encapsulant may be due to the high viscosity of gum arabic.

3.3 Encapsulated Piperine Particle Size and Zeta Potential

Particle size analysis (PSA) was used to measure the particle size of the piperine-encapsulated powder. The particles were classified into two categories: microparticles, which have a diameter between 1-1000 µm, and nanoparticles, which are defined as dispersed particulates or solid particles with a size ranging from 10-100 nm [23].

Zeta potential is commonly utilized to characterize the surface charge properties of nanoparticles or colloidal systems. This is crucial in evaluating physical stability and determining the effectiveness of surface coatings [24]. A higher zeta potential indicates a smaller interaction between particles or the merging of particles from small to large (flocculation) [25].

According to Figure 1, the sample's particle size ranges from 118 to 439.6 nm. This indicates that piperine encapsulation is present in the form of nanoparticles with a polymer size of 10-1000 nm [26]. The particle size increases with higher concentrations of gum arabic coating material used. According to Estupiñan-Amaya *et al*., [27], increasing the concentration of gum arabic leads to higher viscosity, resulting in less deformed droplets. Additionally, Ho *et al*., [28] found that high water content in a sample can cause particle clumping or agglomeration, resulting in larger particle sizes.

The sample's zeta potential value ranges from (-50.5) – (-60.3) mV, indicating a negative surface charge for piperine encapsulation. A higher zeta potential value can reduce particle flocculation, as noted by [25]. Alwin Azhari *et al*., [29] suggest that a desirable zeta potential value falls within the range of +30 to +100 or -100 to -30 mV. Based on Figure 3, the obtained values fall within a good range for zeta potential. Therefore, it can be concluded that the encapsulation of piperine is relatively stable.

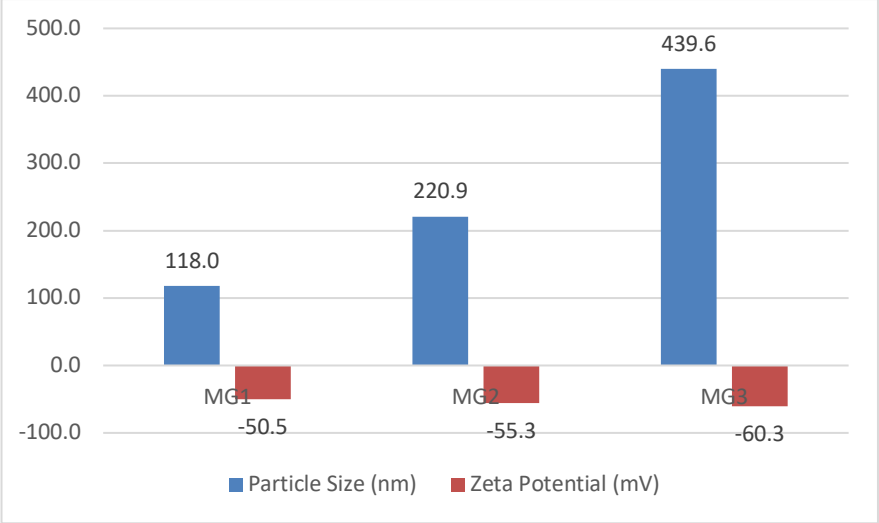

Fig. 1. Bar chart of encapsulated piperine particle size and zeta potential

3.4 Encapsulated Piperine Water Solubility

The solubility of a product in water is related to the release of the active ingredient upon encapsulation application. A good encapsulated powder is expected to have a high solubility value in water. The solvent commonly used to test the solubility of an encapsulated powder product is water [30].

Table 4 shows that the solubility value of encapsulated piperine in sample MG_1 differs significantly from that in samples MG_2 and MG_3. Additionally, there is no significant difference between the solubility values of samples MG_2 and MG_3. The treatment with the concentration of maltodextrin and gum arabic MG_1 had the highest average value of piperine encapsulant solubility at 86.26 ± 0.49 percent. On the other hand, the treatment with the concentration of coating material using only gum arabic, MG_3 had the lowest solubility at 71.26 ± 0.91 percent. The solubility of the treatment with the concentration of maltodextrin and gum arabic MG_2 was 71.86 ± 0.00 percent, which was not significantly different from the treatment with only gum arabic.

According to the results obtained, the solubility percentage increases with the amount of maltodextrin used. This correlation is due to the higher concentration of maltodextrin resulting in a higher solubility value. Umi Khasanah *et al*., [30] attribute the high solubility to the presence of maltodextrin. Maltodextrin has the ability to bind hydrophobic substances due to its properties. It is a polysaccharide that is highly soluble in water, allowing it to form a uniformly dispersed solution system [31]. The hydroxyl groups in maltodextrin interact with water when the material is dissolved. The greater the number of free hydroxyl groups in the coating material, the higher the level of solubility [32].

Table 4
Encapsulated Piperine water solubility

Sample	Water Solubility (%)
MG_1	86.26 ± 0.49^{b}
MG_2	71.86 ± 0.00^{a}
MG_3	71.26 ± 0.91^{a}

Table 4 shows a decrease in the solubility of encapsulated powder as the concentration of maltodextrin decreases. The solubility value is related to the water content of the material, with higher water content resulting in lower solubility. The solubility value is related to the water content

of the material, with higher water content resulting in lower solubility. As noted by Gardjito *et al*., [21], a material's solubility in water is influenced by its water content. The material's high water content hinders its ability to spread in water and form pores, preventing it from absorbing large amounts of water. Additionally, materials with high water content have a limited surface area available for wetting due to the large granule size and tendency to stick together.

3.5 Encapsulated Piperine Solubility Time

Dissolution time testing was conducted to determine the time required for the piperine encapsulated powder to dissolve. The dissolution time of the piperine encapsulated powder is affected by the coating material used.

As shown in Table 5, the addition of maltodextrin and gum arabic as coating materials with different concentration ratios has a significant effect at the 95 % confidence level on the dissolution time parameters of encapsulated piperine. The addition of maltodextrin and gum arabic in MG_1 (75:25), MG_2 (25:75) and MG_3 (0:100) resulted in dissolution times ranging from 47.94 seconds to 58.33 seconds. The MG_1 treatment had the fastest dissolving time at 47.94 ± 0.04 seconds, while the MG3 treatment had the longest dissolving time at 58.33 ± 0.04 seconds.

Table 5
Encapsulated Piperine solubility time

Sample	Solubility Time (s)
MG_1	47.94 ± 0.04^a
MG_2	53.86 ± 0.01^b
MG_3	58.33 ± 0.04^c

The treatment of maltodextrin concentration accelerated the solubility time of the piperine encapsulated powder. This is due to the interaction between the hydroxyl groups present in the maltodextrin and water, which increases the solubility of the powder. The level of solubility is directly proportional to the number of free hydroxyl groups in the filler. If the obtained solubility value is higher, it indicates faster solubility and better product quality. This is because the presentation process becomes easier. This finding is consistent with the research conducted by [32] which showed that increasing maltodextrin improves solubility and reduces solubility time.

Ramadhani [33] research found that adding 20 % maltodextrin resulted in a faster dissolution time for dragon fruit peel powder drinks compared to adding 10 % maltodextrin. Specifically, the addition of 20 % maltodextrin reduced the solubility time of the dragon fruit peel drink to 12.11 seconds, while the addition of 10 % maltodextrin resulted in a solubility time of 16.56 seconds. Specifically, the addition of 20 % maltodextrin reduced the solubility time of the dragon fruit peel drink to 12.11 seconds, while the addition of 10% maltodextrin resulted in a solubility time of 16.56 seconds. This is because the increased surface area of the powder can cause it to dissolve more quickly when in direct contact with water.

3.6 Encapsulation Efficiency of Piperine Extract

Encapsulation efficiency is determined by comparing the total active compounds in nanocapsules to the active compounds on the surface of the capsule. The piperine calculation was performed using a regression equation obtained from a standard curve ($y = 0.0511x – 0.0213$, $R^2 = 0.9967$).

Table 6 shows that the encapsulation efficiency parameters of piperine are significantly affected at the 95 % confidence level by the addition of coating materials maltodextrin and gum arabic in

different concentration ratios. The addition of maltodextrin and gum arabic in ratios of MG_1 (75:25), MG_2 (25:75) and MG_3 (0:100) resulted in encapsulation efficiency ranging from 21 - 78 %. Sample MG_1 had the highest piperine encapsulation efficiency value at 78.00 ± 0.00 percent, while sample MG_3 had the lowest value at 21.00 ± 0.00 percent.

Table 6
Encapsulation efficiency of Piperine extract

Sample	Encapsulation Efficiency (%)
MG_1	78.00 ± 0.00^{c}
MG_2	48.50 ± 0.71^{b}
MG_3	21.00 ± 0.00^{a}

The encapsulation efficiency value decreased as the concentration of gum arabic coating material increased. Raising the concentration of gum arabic to 60 % may lead to a decrease in encapsulation efficiency due to increased emulsion viscosity, which in turn reduces water diffusivity [34]. The International Oenological Codex [35] states that gum arabic will precipitate when dissolved in an equal volume of ethanol, likely due to its low solubility in ethanol resulting from its composition and chemical structure.

Gum arabic is a polysaccharide obtained from the sap of the Acasia *sp.* tree through an exudation process. It is then converted into a powder [36]. Polysaccharides are generally insoluble in hydrophilic solvents such as ethanol. Gum arabic, however, can dissolve in cold water, glycerol and propylene glycol, but not in ethanol [37].

3.7 Encapsulated Piperine Content

Piperine is the primary alkaloid compound present in black pepper (*Piper nigrum* L.). Its levels were measured using a UV-Vis spectrophotometer, which is a relatively inexpensive and highly selective method. The standard technique for analyzing piperine levels in black pepper is SNI 005:2013 Black Pepper. This method involves thermal extraction with ethanol solvent, followed by absorbance reading using a UV-Vis spectrophotometer. The maximum wavelength in the standard piperine solution was determined within the wavelength range of 340-350 nm, resulting in a maximum wavelength of 341.5 nm.

Table 7 shows that the addition of maltodextrin and gum arabic as coating materials with different concentration ratios does not significantly affect the parameters of encapsulated piperine content during storage with the addition of maltodextrin and gum arabic MG_1 (75:25), MG_2 (25:75) and MG_3 (0:100) at a 95 % confidence level. Sample MG_3, with a coating of 0:100 maltodextrin and gum arabic, had the lowest piperine content value of 7.08 ± 0.42 percent. In contrast, sample MG_1, with a coating of 75:25 maltodextrin and gum arabic, had the highest piperine content of 7.31 ± 0.01 percent. The difference between the two values was not significant.

Table 7
Encapsulated Piperine content

Sample	Piperine content (%)			
	D0	D7	D14	D21
MG_1	7.31 ± 0.01^{aB}	6.65 ± 0.03^{aA}	7.49 ± 0.02^{aC}	7.45 ± 0.01^{aC}
MG_2	7.27 ± 0.03^{aB}	6.75 ± 0.03^{aA}	7.34 ± 0.04^{aB}	7.30 ± 0.03^{aB}
MG_3	7.08 ± 0.42^{aA}	6.59 ± 0.39^{aA}	7.31 ± 0.42^{aA}	7.25 ± 0.40^{aA}

Table 7 shows that storage time significantly affects the levels of encapsulated piperine during storage at a 95 % confidence level, compared to the concentration ratio of maltodextrin and gum arabic MG_1 (75:25), MG_2 (25:75) and MG_3 (0:100). The levels of piperine (MG_1, MG_2 and MG_3) were lowest after 7 days of storage, with values of 6.65 ± 0.03 %, 6.75 ± 0.03 % and 6.59 ± 0.39 %, respectively. Conversely, the highest values were observed after 14 days of storage, with values of 7.49 ± 0.02 %, 7.34 ± 0.04 % and 7.31 ± 0.42 %, respectively.

These differences in piperine content are attributed to the encapsulation efficiency of the samples, with sample MG_1 having the highest encapsulation efficiency value of 78 %. According to Gorgani *et al*., [3], MG_1 appears to have a good ability to protect against damage to piperine. The levels of piperine in black pepper, as reported by the same authors, vary from 2 - 7.4 %.

3.7.1 Stability of encapsulated Piperine during storage

To test the stability of piperine, its levels were measured once a week for 21 days. Periodic tests were conducted to determine the stability of the piperine in the encapsulated samples.

Based on the results presented in Table 7. It can be concluded that the storage time did not have a significant effect on the stability of piperine levels for all samples, regardless of the concentration of the coating material in the form of maltodextrin and gum arabic. It is worth noting that all samples experienced a decrease in piperine levels during the 7-day storage period. During storage for 7 to 14 days, all samples showed an increase in piperine levels. During storage for 7 to 14 days, all samples showed an increase in piperine levels. From 14 to 21 days, the piperine levels remained approximately the same as those at 14 days.

During storage for 7 to 14 days, all samples showed an increase in piperine levels. This increase is likely due to oxidation reactions. Piperine oxidation can lead to the formation of various compounds. Piperic acid, a derivative of piperine, can undergo oxidative cleavage when exposed to strong oxidants, resulting in the formation of piperonal and piperonylic acids [38]. These reactions demonstrate the potential for the production of various compounds through the oxidation of piperine and its derivatives.

4. Conclusions

The physicochemical characteristics of black pepper extract encapsulation are influenced by the concentration of coating materials, specifically maltodextrin and gum arabic. The best results were obtained with a ratio of 75:25 of maltodextrin and gum arabic concentrations in sample MG_1, which showed a water solubility level of 86.26 %, an encapsulation efficiency value of 78 % and a piperine content value of 7.08 – 7.49 % during storage.

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