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RESEARCH ARTICLE

Proximate analysis of the high phytochemical activity of encapsulated Mandai cempedak (*Artocarpus champeden*) vinegar prepared with maltodextrin and chitosan as wall materials [version 1; peer review: awaiting peer review]

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Abstract

Background: Mandai cempedak vinegar (MCV) is a fermented vinegar produced from the inner skin of cempedak (*Artocarpus champeden*), which contains antioxidants classified as flavonoids, phenols, and tannins. These bioactive compounds are sensitive to heat and prone to oxidative damage. Therefore, an encapsulation process is proposed to protect the bioactive compounds. This study aimed to design a potential scaling-up formulation of spray-dried encapsulated MCV based on Total Soluble Solid (TSS) with the addition of maltodextrin and chitosan, followed by determining the nutrition and phytochemical values of the formulation.

Methods: The formulation employed maltodextrin to achieve TSS of 15, 20, and 25 °Brix as the primary wall material treatment factor. The second factor was chitosan as auxiliary wall material at 1, 2, and 3% (w/w of maltodextrin). Products were spray-dried at 100 °C inlet temperature and 80 °C outlet temperature. Analyses of nutrition, flavonoid, phenol, and tannin were conducted in triplicate for each encapsulated product.

Results: The 15 °Brix of TSS from maltodextrin with 1% chitosan emerged as the best-encapsulating material, giving 7.54% moisture, 0.75% ash, 0.42% protein, 0.35% fat, and 90.94% carbohydrate content, resulting in a phytochemical activity equivalent to 9.13 mg Catechin Equivalent kg^{-1}, 69.61 mg Gallic Acid Equivalent kg^{-1}, and 25.04 mg Tannic Acid Equivalent kg^{-1}. Compared to maltodextrin, the chitosan generally contributed less to the proximate, flavonoid, phenol, and tannin content of the encapsulated MCV.

Conclusions: The best formulation contained maltodextrin at 15 °Brix

of TSS and 1% chitosan. Maintaining optimum TSS was a key to producing consistent encapsulated MCV with high phytochemical activity.

Keywords
chitosan, maltodextrin, mandai cempedak vinegar, spray drying, total soluble solids

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Introduction

Mandai cempedak is a traditional food fermented from the inner skin of cempedak (*Artocarpus champeden*), technologically processed with the addition of a bacterial starter containing Lactic Acid Bacteria (LAB).[1] The liquid separated from mandai cempedak solids is named mandai cempedak vinegar (MCV). MCV is produced twice as much as the weight of the solid part during fermentation. MCV developed in our design is a by-product of mandai cempedak fermentation with *Lactobacillus casei* as a starter.[1-3] Mariana *et al.*[4] show that MCV can reduce cholesterol levels in mice after 14 days of intervention. In addition, MCV contains bioactive, i.e., lactic acid, flavonoid compounds, and saponins. These substances may reduce cholesterol levels.[5,6]

MCV is easily degraded during storage because of its content. The changes include oxidation of phenol and evaporation of volatile compounds. In addition, the liquid form of MCV is affected by environmental factors, i.e., temperature, oxygen, humidity, light, and other unfavorable conditions during the storage process.[7,8] Therefore, the technology has been developed to protect the active compounds in MCV by converting MCV into encapsulated form. Encapsulation is the process of protecting, enclosing, or trapping the core material (liquid, gas, and solid particles) in a solid shell in the form of coating material for controlled release, immobilization, protection, or isolation of core material.[9]

The composition of coating materials can affect the characteristics of the resulting encapsulated product.[10] This study used maltodextrin and chitosan as wall and auxiliary coating materials in producing encapsulated MCV. It is essential to maintain the stability of the Total Soluble Solid (TSS) value in the encapsulation process.[11] As customarily observed from natural products,[12] MCV has a tiny but inconsistent amount of soluble solids. Hence, maltodextrin contributes to TSS as a primary controlling factor for wall material.[13] Maltodextrin is used because it has a high solubility in water, high viscosity, low price, and can maintain the stability of polyphenol compounds in a formulation.[14,15]

The auxiliary coating material used in this study is chitosan. Chitosan is non-toxic and biodegradable with some antimicrobial properties, benefiting product shelf life extension.[16,17] In addition, chitosan is a biocompatible amino polysaccharide capable of forming ionic or covalent bonds with crosslinking agents and forming networks where the active compounds can be retained.[18] These properties are helpful for encapsulation material of various active ingredients, enveloping bioactive compounds, and reducing oxidation.[17,19] As a result, chitosan is widely used as an encapsulation agent for sensitive core materials in the pharmaceutical industry, such as lipophilic drugs,[20] vitamin D2,[21] ampicillin,[22] and olive oil extract.[23] However, chitosan is expensive. Therefore, it is used as auxiliary material in this research.

Spray drying may be applied to encapsulate bioactive material from MCV because the short contact time with the medium and the high evaporation rate results in a high-quality product compared to conventional drying methods.[24] As a result, the spray drying technique is relatively easy to apply in the scaling-up process for volatile or non-volatile oils and flavor encapsulation. In addition, the production cost is relatively low compared to other available technologies.[25,26]

This research aims to design a potential scaling-up formulation of spray-dried encapsulated MCV based on maltodextrin equivalent to specified TSS with the addition of chitosan. The experimental parameters include proximate values (moisture, ash, protein, fat, and carbohydrate contents) and phytochemical characteristics (flavonoid, tannin, and phenol). The encapsulation of MCV is expected to be a new niche seasoning flavor with the additional advantage of high bioactive capacity.

Methods

Mandai Cempedak Vinegar (MCV)

The process of making MCV is described by Mariana *et al.*[4] The cempedak was obtained from the traditional markets in Samarinda, East Kalimantan, Indonesia. The inner cempedak skin was cut into small pieces, cleaned with running water, and then boiled with a ratio of 1:2 (w/v) cempedak and water at 100°C for five minutes to remove the sap. The cempedak skin was then cooled to achieve room temperature (28±3°C) in a closed jar. The boiling procedure was repeated twice. The boiled *cempedak* skin was then placed in a sterile container, and boiled potable water was added (2:1 v/w). LAB starter was added at 4% (v/v) and was aseptically stirred until evenly distributed. The mandai cempedak was fermented for 14 days at 5-8°C (stored in the refrigerator). Subsequently, the mandai cempedak was crushed with a blender and filtered with a clean cloth. The filtered MCV was then centrifuged at 3000 revolutions per minute (RPM) for 15 minutes. The supernatant was collected and stored at 5-8°C.

MCV encapsulation

MCV encapsulation was carried out using a spray dryer (locally built by Maxer Sterile - Malang, Indonesia, with a capacity of 0.5-5 liter/hour, electric heating of 13 kilowatts, automatic temperature control, a yield of 8-12%, and moisture content of 3-7%). Each batch consisted of 500 mL MCV. The treatment used in the encapsulation of MCV was maltodextrin equivalent to TSS 15, 20, 25 °Brix and chitosan (1, 2, 3% w/w of maltodextrin). About 500 mL MCV and a

specified maltodextrin content by TSS value were homogenized. The intended Brix value was achieved by adding maltodextrin in a stepwise manner. TSS was measured by a hand refractometer (Brix scale: 0 to 32% Brix, Automatic Temperature Compensation Range: 10-30°C) at room temperature of 28±3°C. The range of maltodextrin addition was 70-170 g, corresponding to 15 – 25 °Brix. Chitosan was added according to the treatment with concentrations of 1, 2, and 3% by weight of the maltodextrin used. The mixtures were spray-dried with the condition of 100°C inlet temperature and 80°C outlet temperature. The obtained encapsulated MCV was stored at -20±3°C for further analysis.

Moisture content analysis

The water content analysis was carried out by referring to the modified Lindani[27] method regarding the number of samples and the time of sample testing. A total of 0.5 grams of sample was put into the moisture analyzer (OHAUS MB 125), then the sample was flattened on a pan, and the instrument was closed again. The moisture was measured as per recommended method by the manufacturer. The results obtained were then recorded.

Ash content analysis

The measurement of ash content used the Andarwulan *et al.*[28] method. The inorganic residue formed by burning off the organic matter of the sample in a muffle furnace at 550±50°C for four hours was referred to as ash. A pre-heated crucible was filled with 2 g of the sample. The crucible was placed in a muffle furnace at 550±50°C for four hours or until whitish-grey ash was formed. After that, the crucible was placed in the desiccator and weighed.

Protein content analysis

Crude protein is calculated by multiplying the nitrogen content of the food by a factor of 6.25. This number is used because most protein contains 16% nitrogen. The Kjeldahl method is used to determine crude protein.[29] Digestion, distillation, and titration are all part of the process.[30] About 2 g of the material was weighed carefully in a Kjeldahl flask. About 25 ml of 97% sulfuric acid to the flask and 1 g of Kjeldahl tablet (containing Na_2SO_4 96.5%, $CuSO_4$ 1.5%, Se 2.0%) (Merck, USA) were added. Heat was slowly applied in a fume cupboard to avoid excessive frothing, then digestion continued for 45 minutes, or until the digesta became transparent pale green. The digesta was allowed to cool before adding 100 ml of distilled water. The digesta was rinsed 2-3 times before adding the digesting flask to the bulk. Distillation: Markham distillation device was used for distillation. The digesta was taken 10 ml of the digest to boil in the distillation equipment after heating it. About 10 ml sodium hydroxide (10 mol/l) (Merck, USA) was added to avoid ammonia loss. Five drops of methyl red indicator (0,1 % in ethanol) (Sigma-Aldrich, USA) were distill-filtered into 50 ml of 2% boric acid (Merck, USA). Titration: The alkaline ammonium borate was directly titrated with 0.1N HCl (Merck, USA). The volume of acid used was recorded as the titer value. The amount of acid used was factored into the formula, yielding %N.

$$Total - N = \frac{mL\,NaOH\,(sample\,titration - blank\,titration) \times N\,NaOH \times 14,008 \times 100}{sample\,weight\,(g) \times 100}$$

$$Percent\,protein = (Total - N) \times 6,25$$

Constant: Nitrogen molecular weight 14,008 g/mol; Conversion factor: 6,25

Fat content analysis

Crude lipid was determined using the Soxhlet extraction technique (Association of Official Analytical Chemists, 2005).[31] First, the lipid content of the sample (2 g) was extracted using 100 mL of petroleum ether. Then, the mixture was filtered, and its lipid content was collected in a pre-weighed (W_1) clean beaker. After that, exhaustive lipid extraction was done on the same sample with 100 mL of n-hexane (Fulltime, China) for 24 h. It was then filtered and decanted into a beaker (W_1). Next, the lipid content was concentrated to dryness in a steam bath and oven-dried at 40–60 °C, and the beaker was reweighed (W_2). Finally, the percentage of lipid was calculated.

$$Fat\,content\,(\%) = \frac{(W_3 - W_2)}{W_1} \times 100\%$$

Where:

W_1=Weight of sample (g)

W_2=Weight of fat flask without fat (g)

W_3=Weight of fat flask with fat (g)

Carbohydrate content by difference

The carbohydrate content was calculated by subtracting the total crude protein, ash, and crude fat from the total dry matter.[32]

$$\text{Carbohydrate}\,(\%) = 100\% - (\%\text{Moisture} + \%\text{Ash} + \%\text{crude fat} + \%\text{crude protein})$$

Total flavonoid

The total flavonoid content was determined.[33] Encapsulated MCV was weighed at 1 mg and then dissolved in 10 mL of 95% ethanol (SmartLab, Indonesia). A total of 0.7 mL of distilled water was added to the encapsulation and dissolved in ethanol. Then, about 0.1 mL of 5% $NaNO_2$ (Sigma-Aldrich, USA) was added to the mixture. After five minutes, 0.1 mL of 10% $AlCl_3$ (Sigma-Aldrich, USA) was added. After six minutes, 0.5 mL of 1 M NaOH (Merck, USA) was added. All ingredients were mixed with a vortex evenly, then incubated for 10 minutes. The absorbance value was detected at a wavelength of 510 nm (Biospectrometer, Eppendorf, Germany). The results obtained were plotted against the catechin (Sigma-Aldrich, USA) standard curve prepared similarly. Total flavonoid was expressed as milligrams of catechin equivalent per kilogram dry weight extract.

Total phenol

Measurement of total phenol was conducted.[34,35] About 0.3 g encapsulated MCV was carefully dissolved in 10 mL of ethanol and distilled water (1:1 ratio). About 0.2 mL of the extract solution was pipetted and added with 15.8 mL of distilled water and 1 mL of Folin-Ciocalteu 50% (v/v) reagent (Merck, USA). The solution was allowed to stand for eight minutes, and then 3 mL of 5% (w/v) Na_2CO_3 (Sigma-Aldrich, USA) was added. Then the solution was allowed to stand for two hours in the dark at room temperature (28±3°C). The absorbance value was detected at a wavelength of 725 nm (BioSpectrometer, Eppendorf, Germany). The absorbance value was plotted against a gallic acid (Sigma-Aldrich, USA) standard curve prepared similarly. Total phenol was expressed in milligrams of gallic acid equivalent per kilogram dry weight extract.

Total tannin

The total tannin was calculated.[36] A total of 0.5 g of encapsulated MCV was macerated in 10 mL of diethyl ether (Merck, USA) for 20 hours, then filtered, and the residue obtained was boiled with 100 mL of distilled water for two hours, then allowed to cool. About 0.1 mL of the cold sample was added with 0.1 mL of Folin-Ciocalteu reagent (Merck, USA) and vortexed, added with 2 mL of 2% Na_2CO_3 (Sigma-Aldrich, USA), and vortexed again. The absorbance value was detected at a wavelength of 760 nm (BioSpectrometer, Eppendorf, Germany) after being incubated for 30 minutes at room temperature (28±2°C). The results obtained were plotted against a tannic acid (Sigma-Aldrich, USA) standard curve prepared similarly. Thus, the total tannin content was expressed in milligrams tannic acid per kilogram extract.

Statistical analysis

The experimental design used in this study was a factorial, completely randomized design with nine treatments and two replications. This study consisted of two factors, namely maltodextrin equivalent to TSS (15, 20, 25 °Brix) and chitosan (1, 2, 3% w/w maltodextrin), as shown in Table 1.

Table 1. Mandai cempedak vinegar encapsulation treatment.

Sample code	Treatment
F1	TSS 15 °Brix, K 1%
F2	TSS 15 °Brix, K 2%
F3	TSS 15 °Brix, K 3%
F4	TSS 20 °Brix, K 1%
F5	TSS 20 °Brix, K 2%
F6	TSS 20 °Brix, K 3%
F7	TSS 25 °Brix, K 1%
F8	TSS 25 °Brix, K 2%
F9	TSS 25 °Brix, K 3%

TSS=Total Soluble Solid (15, 20, 25 °Brix), K=chitosan (1, 2, 3% w/w maltodextrin).

The data obtained from the chemical and phytochemical tests were analyzed using variance analysis at a 5% significance level using a GraphPad Prism (v9.2), but can also be analyzed using any open-source statistical software, including the freely available R. If the variance test shows a significant treatment effect, the variance analysis was continued with the Tukey test.

Result and discussion

Moisture content

Moisture content is an important parameter determining dry products' quality, such as dry encapsulation. The lower moisture content makes the product protected from bacterial and fungal spoilage.[37] The moisture content of the MCV encapsulated product in this study ranged from $5.31 \pm 1.00\%$ to $10.45 \pm 0.85\%$ (see Table 2 and *Underlying data*[67]). The TSS treatment and the interaction between the two factors had a significant effect (p<0.05) on the moisture content of the encapsulated MCV product. In contrast, the chitosan treatment showed no significant effect (p>0.05). However, TSS treatments showed a significantly different effect on moisture content. The 15 °Brix treatment group generally produced more moisture content than the 20 °Brix treatment group. The higher the TSS used in the encapsulation process, the lower the percentage of moisture content (Table 2).

According to Marte *et al.*,[38] the higher the total solids dried to a certain extent, the higher the evaporation rate, causing lesser moisture content. Hayati *et al.*[39] stated that maltodextrin used in quantities could reduce the moisture content of the encapsulated results.

At TSS 25 °Brix, the encapsulated MCV experienced an increase in moisture content. Different total solids influence the increase in moisture content. The high total solids are related to the drying rate during spray drying.[40] However, a high concentration of maltodextrin causes coagulation.[41] As a result, the water molecules that will diffuse are blocked by larger maltodextrin molecules and cause a decrease in the drying rate, thus causing the moisture content to increase.[41]

Chitosan has no significant effect on the moisture content of the encapsulated MCV product. However, chitosan has a humidifying effect, retaining moisture during the spray drying. Moreover, chitosan can slow down the crystallization process during spray drying.[42]

Ash content

The ash content of the MCV encapsulated product in this study ranged from $0.25 \pm 0.35\%$ to $1.25 \pm 0.35\%$ (see Table 2 and *Underlying data*[67]). The treatment and interaction of TSS and chitosan had no significant effect on the ash content of the encapsulated MCV product. The highest ash content value was obtained in the TSS 20 °Brix treatment with 1% chitosan, and the lowest ash content was found in the TSS 25 °Brix treatment with 2% chitosan.

Ash content is usually pointing to the total minerals in a material. The ash content of the MCV encapsulated product showed no significant difference. The non-significance values happened because the raw material in MCV was used in the same concentration. Siregar *et al.*[43] concluded ash content of the mandai cempedak product per 100 g of dry matter was 4.3%. The low ash content obtained is because MCV is a derivative product of the mandai. Caez and Jaraba[44] reported 0.43% ash content in mango juice microencapsulated with maltodextrin compared to other encapsulated

Table 2. Proximate values of encapsulated mandai cempedak vinegar product.

Sample	Moisture (%)	Ash (%)	Protein (%)	Fat (%)	Carbohydrate (%)
F1	7.54±0.25b	0.75±0.35	0.42±0.02a	0.35±0.00a	90.94±0.16
F2	10.45±0.85c	1±0.00	0.59±0.06bc	0.38±0.00b	87.59±0.23
F3	8.02±0.04b	1±0.00	0.69±0.01e	0.40±0.00c	89.89±0.01
F4	7.15±0.58b	1.25±0.35	0.63±0.02cd	0.69±0.00d	90.29±0.24
F5	5.31±1.00a	0.75±0.35	0.70±0.05d	0.69±0.00de	92.55±0.35
F6	7.43±0.28b	1±0.71	0.46±0.04a	0.69±0.00e	90.42±0.26
F7	7.45±0.16b	0.5±0.00	0.52±0.04ab	0.81±0.00f	90.73±0.05
F8	7.70±0.14b	0.25±0.35	0.57±0.06bc	0.85±0.00g	90.63±0.14
F9	8.47±1.12b	0.5±0.71	0.46±0.05a	0.85±0.00g	89.73±0.47

The same letter shows no significant difference at the 5% alpha level of the Tukey test.

products. Minerals are not significantly affected by chemical and physical treatments during processing.[45] For example, specific mineral ions can be oxidized in the presence of oxygen, but their final concentrations were not significantly affected.[46]

Protein content

The crude protein content in this study ranged from 0.42±0.02% to 0.70±0.05% (see Table 2 and *Underlying data*[67]). The treatment of TSS and chitosan and the interaction between the two factors significantly affected the protein content of the Encapsulated MCV. The TSS and chitosan treatments have significantly different effects. The highest protein content was obtained from the TSS 20 °Brix treatment with 2% chitosan, and the lowest protein content was obtained from the TSS 15 °Brix treatment with 1% chitosan. The TSS treatment of 15 and 20 °Brix showed no significant difference, but protein levels decreased in TSS 25 °Brix. The value explains that the higher the total solids used in the Encapsulated MCV, the lower the protein content of the powder produced.

Proteins consist of long chains of amino acids bound to each other by peptide bonds. Amino acids consist of carbon, oxygen, hydrogen, and nitrogen.[47] The decrease in protein content in the processing of MCV encapsulated products is also due to the spray drying method used, which causes the particles to come into direct contact with high temperatures, which allows the denaturation process to occur. For example, Anandharamakrishnan *et al*.[48] reported that protein denaturation by the spray drying method could occur even at an outlet temperature of 60°C.

The higher the chitosan concentration in the processing of the encapsulated MCV, the higher the protein content of the powder produced. Commercial chitosan contains 0.48% protein, so there may be an increase in protein due to the higher amount of chitosan added.[49] Conversely, a concentration of 3% chitosan showed a decrease in protein levels. This was because chitosan concentration was too high, making chitosan insoluble. This situation causes a crack in the encapsulation wall so that the compound can diffuse out through the gap formed.[50]

Fat content

Fats are compounds formed from the esterification reaction between fatty acids and glycerol. The use of high temperatures in fats will cause the double bonds in the fat to break, breaking the fat into glycerol and fatty acids.[51] The crude fat content value of the encapsulated MCV in this study ranged from 0.35% to 0.85% (see Table 2 and *Underlying data*[67]). The treatment of TSS and chitosan and the interaction between the two factors significantly affected the fat content of the encapsulated MCV. The highest fat content was obtained from the TSS 25 °Brix treatment with 3% chitosan, and the lowest fat content was obtained from the TSS 15 °Brix treatment with 1% chitosan. The fat content of the encapsulated MCV increased with the increasing amount of TSS and chitosan used.

The higher the maltodextrin and chitosan, the higher the fat content of the encapsulated MCV. Therefore, the rehydration of the sample may occur in a small amount. However, it affects the total weight of the fat tested. Maurer *et al*.[52] stated that rehydration might affect the fat content measurement. Since the fat content of encapsulated MCV is less than 1%, the minute increase in fat concentration affects the statistical calculation.

The fat content in cempedak fruit is less than 2%, so the fat content produced in encapsulated MCV is also insignificant.[53] On the other hand, the low-fat content provides advantages for the drying process and extends the shelf life.[54,55]

Carbohydrate content

In this study, the carbohydrate content of the encapsulated MCV was determined by the by-difference method. Major nutrients that affect carbohydrate levels include protein, fat, moisture, and ash content.[56] In this study, the carbohydrate content values ranged from 87.59±0.23% to 90.94±0.16% (see *Underlying data*[67]). The maltodextrin equivalent to TSS and chitosan treatments and their interactions had no significant effect on the carbohydrate content of the encapsulated MCV.

The carbohydrate content of cempedak fruit is 84-87%, so the carbohydrate content dominates the encapsulated MCV.[53] This is also possible because of maltodextrin and chitosan's combined carbohydrate content. Maltodextrin is a saccharide polymer generally obtained from the hydrolysis of corn starch with acids or enzymes.[55] Chitosan is a non-toxic amino polysaccharide obtained from chitin through a complete deacetylation process.[18] In this study, the carbohydrate content of the MCV encapsulated product was not significantly different, only slightly influenced by the increase in wall material concentration. In another report, the carbohydrate content in the encapsulated gac fruit did not change with the addition of auxiliary material.[57]

Table 3. Phytochemical values of encapsulated mandai cempedak vinegar.

Sample	Flavonoid (mg CE kg⁻¹)	Phenol (mg GAE kg⁻¹)	Tannin (mg TAE kg⁻¹)
F1	9.13±0.89	69.61±1.70bc	25.04±0.17f
F2	7.38±0.09	79.52±1.57d	26.67±0.64g
F3	8.23±0.94	83.13±0.92e	19.40±0.40d
F4	8.91±1.23	72.30±2.10c	13.12±0.89a
F5	8.96±0.48	56.93±0.52a	14.63±0.65b
F6	7.56±3.13	80.81±1.83de	15.42±0.07b
F7	6.99±1.08	68.41±1.05b	15.77±0.02b
F8	7.36±2.87	81.93±1.57de	22.00±0.45e
F9	8.18±2.40	70.81±0.52bc	17.12±0.69c

CE=Catechin Equivalent, GAE=Gallic Acid Equivalent, TAE=Tannic Acid Equivalent. The mean number followed by the same letter shows no significant difference at the 5% alpha level of the Tukey test.

Total flavonoid

Before the spray drying, the total flavonoid content in MCV was 11.4 mg Catechin Equivalent (CE) kg⁻¹. The flavonoid content of encapsulated MCV varies with maltodextrin and chitosan. The total flavonoid value of the MCV encapsulated product ranged from 6.99±1.08 mg CE (Catechin Equivalent) kg⁻¹ to 9.13±0.89 mg CE kg⁻¹ (see Table 3 and *Underlying data*[67]). The highest flavonoid content was found in encapsulated product with 15 °Brix TSS and 1% chitosan, the encapsulation with the lowest concentration of wall material. The encapsulation concentration influenced the flavonoid content in purple sweet potato in another research.[58] The binding of flavonoid by the encapsulated matrix caused the product with a higher encapsulated concentration to bind more flavonoid.[58] As a result, an increase in the concentration of the encapsulant causes a decrease in flavonoid levels.

The treatment of TSS and chitosan and their interactions had no significant effect on the total flavonoid of the Encapsulated MCV. The increase in maltodextrin and chitosan showed no significant difference in the total value of encapsulated flavonoid. The use of maltodextrin and chitosan can protect flavonoid compounds well because they have properties that can prevent oxidation.[41,59]

Total phenol

The initial total phenol content in MCV was 103.31 mg GAE (Gallic Acid Equivalent) kg⁻¹. The total phenol value of the MCV encapsulated product in this study ranged from 56.93±0.52 mg GAE kg⁻¹ to 83.13±0.92 mg GAE kg⁻¹ (see Table 3 and *Underlying data*[67]). The treatment of maltodextrin and chitosan and their interactions had a significant effect on the total value of the encapsulated product of MCV. Each treatment of TSS and chitosan and their interactions gave significantly different effects. The highest total phenol was obtained from 15 °Brix TSS treatment with 3% chitosan, and the lowest total phenol was obtained from 20 °Brix TSS treatment with 2% chitosan.

The highest total phenol was obtained from the 15 °Brix TSS treatment, and the lowest was accepted from the 20 °Brix TSS treatment. The higher the total solids, the total encapsulated phenol tends to decrease. Safithri *et al.*[60] stated that the more total solids used in functional drinks based on red betel leaf extract (*Piper crocatum*) in maltodextrin as coating material, the lower the total coated phenol. In addition, encapsulation materials such as maltodextrin and chitosan coat bioactive compounds in the form of phenol compounds.[61] When tested with phenol reagents, not all bioactive components can react, resulting in under-valued measurement.[62] The oxidation process causes this total degradation of phenol due to heat treatment during spray drying activities.[63] This can be related to changes in the molecular structure that cause a decrease in reactivity. In addition, the possibility of a reduction of total phenol levels is due to the formation of phenol-protein complexes or decomposition of phenol compounds and changes in chemical structure due to pressure and temperature.[63]

The highest total phenol was obtained from 3% chitosan treatment, and the lowest was accepted from 1% chitosan treatment. The use of higher concentrations of chitosan can encapsulate more phenolic compounds. The trend is also following the research of Kistriyani *et al.*,[59] which states that the higher the chitosan content, the higher the binding ability to protect phenolic compounds. Belscak-Cvitanovic *et al.*[64] showed that chitosan as an encapsulant was very effective in safeguarding bioactive compounds, slowing their release profile, and increasing encapsulation efficiency. Encapsulation efficiency is calculated based on the number of polyphenols encapsulated. Encapsulation efficiency is related to the

particles' morphological characteristics and heat resistance. Therefore, chitosan can protect the encapsulated active compounds.

Total tannin

The total tannin content in MCV was 33.63 mg TAE (Tannic Acid Equivalent) kg^{-1}. The total tannin value of the MCV encapsulated product in this study ranged from 13.12±0.89 mg TAE kg^{-1} to 26.67±0.64 mg TAE kg^{-1} (see Table 3 and *Underlying data*[67]). The highest total tannin was found in 15 °Brix TSS treatment with 2% chitosan. The treatment of maltodextrin and chitosan and their interactions significantly affected the total tannin of the encapsulated MCV.

The highest total tannin was found in the 15 °Brix TSS treatment, and the lowest was obtained from the 20 °Brix TSS treatment. The increase in TSS at various concentrations of maltodextrin and chitosan causes the total tannin content to be lower. The increasing TSS affects the movement of volatile components to the dried droplet surface.[50] According to Rosenberg *et al.*,[65] the concentration of total solids affects the viscosity and decreases the volatile components.

The more the addition of chitosan to various TSSs, the higher the total encapsulated tannin. Therefore, the ability of chitosan to protect the tannin compounds in the product to be dried by the spray drying process is more significant. Chitosan protects essential compounds contained in materials such as bioactive components, including tannin, because chitosan has a solid binding capacity to coated bioactive components.[66] The concentration of 3% chitosan showed a decrease, and this happened because chitosan was given in large quantities so that the chitosan became insoluble. Ali *et al.*[50] stated that increasing the higher chitosan concentration could cause chitosan to become insoluble. This condition results in cracks in the crust so that the bioactive components diffuse out through the gaps formed.

Conclusions

Maltodextrin and chitosan treatment significantly affected moisture, protein, and fat contents. Chitosan has a humidifying effect and can slow down the crystallization process during spray drying. In addition, a high concentration of maltodextrin causes coagulation; water molecules that will diffuse are blocked by larger maltodextrin molecules and cause a decrease in the drying rate, thus causing the moisture content to increase. The decreased protein content is due to the spray drying method used. However, the higher the chitosan concentration, the higher the protein content of the powder produced because commercial chitosan contains 0.48% protein, the more chitosan used, the higher the protein content. On the other hand, the higher the maltodextrin and chitosan, the higher the fat content, and the rehydration of the sample may occur in a small amount. Total flavonoid, phenol, and total tannin were related to maltodextrin equivalent to TSS and chitosan treatment. The best phytochemical concentrations of encapsulated MCV were produced from 15 °Brix TSS with 1% chitosan. Encapsulated MCV product with this treatment has 7.54% moisture, 0.75% ash, 0.42% protein, 0.35% fat, 90.94% carbohydrate contents, giving bioactive capacities equivalent to 9.13 mg CE kg^{-1}, 69.61 mg GAE kg^{-1}, and 25.04 mg TAE kg^{-1}.

Data availability

Underlying data

Open Science Framework: MCV encapsulation treatment. https://doi.org/10.17605/OSF.IO/3AQSW.[67]

This project contains the following underlying data:

- MCV encapsulation treatment.csv (sample code/key and treatment).

- Ash content.csv (replication and average ash on MCV encapsulation).

- Ash_data for graphs with GraphPad.csv (ash percentage data on MCV encapsulation for graphing with GraphPad Prism).

- Ash_Ordinary one-way ANOVA Results with GraphPad.csv (results of data analysis with ANOVA using GraphPad Prism).

- Ash_Multiple comparisons with GraphPad.csv (data analysis with Tukey's multiple comparisons test using Graphpad Prism).

- Carbohydrate Content.csv (replication and average carbohydrate on MCV encapsulation).

- Carbohydrate _data for graphs with GraphPad.csv (carbohydrate percentage data on MCV encapsulation for graphing with GraphPad Prism).

- Carbohydrate _Ordinary one-way ANOVA Results with GraphPad.csv (results of data analysis with ANOVA using GraphPad Prism).

- Carbohydrate _Multiple comparisons with GraphPad.csv (data analysis with Tukey's multiple comparisons test using Graphpad Prism).

- Fat content.csv (replication and average fat on MCV encapsulation).

- Fat_data for graphs with GraphPad.csv (fat percentage data on MCV encapsulation for graphing with GraphPad Prism).

- Fat_Ordinary one-way ANOVA Results with GraphPad.csv (results of data analysis with ANOVA using GraphPad Prism).

- Fat_Multiple comparisons with GraphPad.csv (data analysis with Tukey's multiple comparisons test using Graphpad Prism).

- Flavonoid content.csv (replication and average flavonoid on MCV encapsulation).

- Flavonoid_data for graphs with GraphPad.csv (flavonoid percentage data on MCV encapsulation for graphing with GraphPad Prism).

- Flavonoid_Ordinary one-way ANOVA Results with GraphPad.csv (results of data analysis with ANOVA using GraphPad Prism).

- Flavonoid_Multiple comparisons with GraphPad.csv (data analysis with Tukey's multiple comparisons test using Graphpad Prism).

- Moisture Content.csv (replication and average moisture on MCV encapsulation).

- Moisture_data for graphs with GraphPad.csv (moisture percentage data on MCV encapsulation for graphing with GraphPad Prism).

- Moisture_Ordinary one-way ANOVA Results with GraphPad.csv (results of data analysis with ANOVA using GraphPad Prism).

- Moisture_Multiple comparisons with GraphPad.csv (data analysis with Tukey's multiple comparisons test using Graphpad Prism).

- Phenols content.csv (replication and average phenols on MCV encapsulation).

- Phenols_data for graphs with GraphPad.csv (phenols percentage data on MCV encapsulation for graphing with GraphPad Prism).

- Phenols_Ordinary one-way ANOVA Results with GraphPad.csv (results of data analysis with ANOVA using GraphPad Prism).

- Phenols_Multiple comparisons with GraphPad.csv (data analysis with Tukey's multiple comparisons test using Graphpad Prism).

- Protein content.csv (replication and average protein on MCV encapsulation).

- Protein_data for graphs with GraphPad.csv (protein percentage data on MCV encapsulation for graphing with GraphPad Prism).

- Protein_Ordinary one-way ANOVA Results with GraphPad.csv (results of data analysis with ANOVA using GraphPad Prism).

- Protein_Multiple comparisons with GraphPad.csv (data analysis with Tukey's multiple comparisons test using Graphpad Prism).

- Tannin content.csv (replication and average tannin on MCV encapsulation).

- Tannin_data for graphs with GraphPad.csv (tannin percentage data on MCV encapsulation for graphing with GraphPad Prism).

- Tannin_Ordinary one-way ANOVA Results with GraphPad.csv (results of data analysis with ANOVA using GraphPad Prism).

- Tannin_Multiple comparisons with GraphPad.csv (data analysis with Tukey's multiple comparisons test using Graphpad Prism).

Data are available under the terms of the Creative Commons Zero "No rights reserved" data waiver (CC0 1.0 Public domain dedication).

References

1. Rahmadi A, Sari K, Khairiyah N, *et al.*: **Bacterial Population and Chemical Characteristics of Fermented** *Mandai cempedak* **with Starter Induction.** *Microbiol. Indonesia.* 2018; **12**(3): 83–91.
   Publisher Full Text

2. Rahmadi A, Sari K, Sitohang S, *et al.*: **Profil perubahan populasi BAL, pH, kadar flavonoid, dan Potensi aktivitas antioksidan dari fermentasi** *mandai cempedak* **higienis tanpa garam.** *Semin. Nas. PATPI.* 2017, October.

3. Rahmadi A, Sari K, Handayani F, *et al.*: **Modulation Of Phenolics Substances and Antioxidant Activity In** *Mandai cempedak* **By Unsalted Spontaneous and Lactobacillus casei Induced Fermentation.** *J. Teknol. dan Ind. Pangan.* 2019; **30**(1): 75–82.
   Publisher Full Text

4. Mariana RA, Syahrumsyah H: **Pengaruh Pemberian Cuka Mandai Terhadap Kadar Kolesterol Total, Lipoprotein dan Trigliserida Pada Mencit (Mus musculus) Dengan Induksi Kuning Telur.** *J. Trop. AgriFood.* 2020; **2**(1): 45–52.
   Publisher Full Text

5. Hasibuan R: **Efektifitas Pemberian Soyghurt Terhadap Penurunan Kadar Kolesterol Dalam Darah Mencit (Mus musculus) Dengan Jum;ah Bakteri Asam Laktat Dan Suhu Inkubasi Yang Optimum.** *J. Ilm. PANNMED (Pharmacist, Anal. Nurse, Nutr. Midwivery, Environ. Dent.).* 2019; **9**(2): 138–145.
   Publisher Full Text

6. Sutjiatmo AB, Sukandar EY, Sinaga R, *et al.*: **Efek Antiokolesterol Ekstrak Etanol Daun Creme (Phyllanthus acidus (L.) Skeels) Pada Tikus Wistar Betina.** *Kartika J. Ilm. Farm.* 2013; **1**(1): 1–7.

7. Khairullah Mohammed N, Tan C, Abd Manap Y, *et al.*: **Process conditions of spray drying microencapsulation of Nigella sativa oil.** *Powder Technol.* 2017; **315**: 1–14.
   Publisher Full Text

8. Deng M, Deng YY, Dong L, *et al.*: **Effect of Storage Conditions on Phenolic Profiles and Antioxidant Activity of Litchi Pericarp.** *Molecules.* 2018; **23**: 2276.
   PubMed Abstract | Publisher Full Text

9. Vladisavljević GT, Holdich RG: **Encapsulation.** *Encycl. Member.* 2016.
   Publisher Full Text

10. Siregar TM, Kristanti C: **Mikroenkapsulasi Senyawa Fenolik Ekstrak Daun Kenikir (***Cosmos caudatus* **K.).** *J. Apl. Teknol. Pangan.* 2019; **8**(1): 31–37.

11. Pantastico EB: **Fisiologi Pasca Panen.** *Universitas Gadjah Mada, Yogyakarta.* Yogyakarta: Universitas Gadjah Mada; 1986.

12. Khuenpet K, Charoenjarasrerrk N, Jaijit S, *et al.*: **Investigation of suitable spray drying conditions for sugarcane juice powder production with an energy consumption study.** *Agric. Nat. Resour.* 2016; **50**(2): 139–145.
    Publisher Full Text

13. Maherawati M, Hartanti L: **The Properties of Aloe Vera Powder using Cassava Maltodextrin as Carrier Agents.** *J. Ind. Has. Perkeb.* 2019; **14**(2): 44.
    Publisher Full Text

14. Kane SN, Mishra A, Dutta AK: **Preface: International Conference on Recent Trends in Physics (ICRTP 2016).** *J. Phys. Conf. Ser.* 2016; **755**(1): 011001.
    Publisher Full Text

15. Kha TC, Nguyen MH, Roach PD: **Effects of spray drying conditions on the physicochemical and antioxidant properties of the Gac (Momordica cochinchinensis) fruit aril powder.** *J. Food Eng.* 2010; **98**(3): 385–392.
    Publisher Full Text

16. Kurniasih RA, Darmadji P, Pranoto Y: **Pemanfaatan Asap Cair terenkapsulasi Maltodekstrin-Kitosan Sebagai Pengawet Ikan Cakalang (Katsuwonus pelamis).** *J. Teknol. Has. Pertan.* 2016; **9**(1): 9–16.
    Publisher Full Text

17. Raza ZA, Khalil S, Ayub A, *et al.*: **Recent developments in chitosan encapsulation of various active ingredients for multifunctional applications.** *Carbohydr. Res.* 2020; **492**(December): 108004.
    PubMed Abstract | Publisher Full Text

18. Estevinho BN, Rocha F, Santos L, *et al.*: **Microencapsulation with chitosan by spray drying for industry applications - A review.** *Trends Food Sci. Technol.* 2012; **31**(2): 138–155.

19. Bakry AM, Abbas S, Ali B, *et al.*: **Microencapsulation of Oils: A Comprehensive Review of Benefits, Techniques, and Applications.** *Compr. Rev. Food Sci. Food Saf.* 2016; **15**(1): 143–182.
    PubMed Abstract | Publisher Full Text

20. Ribeiro AJ, Neufeld RJ, Arnaud P, *et al.*: **Microencapsulation of Lipophilic Drugs in Chitosan-Coated Alginate Microspheres.** *Int. J. Pharm.* 1999; **187**(1): 115–123.
    PubMed Abstract | Publisher Full Text

21. Shi X, Tan T: **Preparation of Complex Chitosan Microcapsule and Its Application In Controlled Release of Vitamin D2.** *Biomaterials.* 2002; **23**(1): 4469–4473.
    PubMed Abstract | Publisher Full Text

22. Anal AK, Stevens WF, Remuñán-López C: **Ionotropic Cross-Linked Chitosan Microspheres For Controlled Release of Ampicillin.**

Int. J. Pharm. 2006; **312**(1–2): 166–173.
PubMed Abstract | **Publisher Full Text**

23. Kosaraju SL, D'ath L, Lawrence A: **Preparation and Characterisation of Chitosan Microspheres For Antioxidant Delivery.** *Carbohydr. Polym.* 2006; **64**(2): 163–167.
Publisher Full Text

24. Gong Z, Zhang M, Mujumdar A, *et al.*: **Spray drying and agglomeration of instant bayberry powder.** *Dry. Technol.* 2008; **26**(1): 116–121.

25. Reineccius GA: **The spray drying of food flavors.** *Dry. Technol.* 2004; **22**(6): 1289–1324.
Publisher Full Text

26. Jafari SM, Assadpoor E, He Y, *et al.*: **Encapsulation Efficiency of Food Flavours and Oils During Spray Drying.** *Dry. Technol.* 2008; **26**(7): 816–835.
Publisher Full Text

27. Lindani A: *Perbandingan Pengukuran Kadar Air Metode Moisture Analyzer Dengan Metode Oven Pada Produk Biskuit Sandwich Cookies Di PT. Mondelez Indonesia Manufacturing.* Skripsi: IPB University; 2016.

28. Andarwulan N, Kusnandar F, Herawati D: *Analisis Pangan.* Jakarta: Dian Rakyat; 2011.

29. Jiang B, Tsao R, Li Y, Miao M: **Food Safety: Food Analysis Technologies/Techniques.** Van Alfen NK, editor. *Encyclopedia of Agriculture and Food Systems.* Oxford: Academic Press; 2014; 273–288.
Publisher Full Text

30. Sudarmadji S, Haryono B, *et al.*: *Analisa Bahan Makanan dan Pertanian.* Yogyakarta: Liberty; 2010.

31. [AOAC] Association of Official Analytical Chemists: *Official Methods of Analysis of AOAC International.* 18th ed. Gaithersburg: AOAC International; 2005.

32. Winarno FG: *Kimia Pangan dan Gizi.* Jakarta: Gramedia Pustaka Utama; 1986.

33. Zou Y, Lu Y, We D: **Antioxidant activity of a flavonoid-rich extract of Hypericum perforatum L. in vitro.** *J. Agric. Food Chem.* 2004; **52**(16): 5032–5039.
PubMed Abstract | **Publisher Full Text**

34. Mu'nisa A, Wresdiyati T, Kusumorini N. , *et al*.: **Aktivitas Antioksidan Ekstrak Daun Cengkeh.** *J. Vet.* 2013; **13**(3): 272–277.

35. Nurhayati KS, Harjono: **Pengaruh Konsentrasi Natrium Benzoat dan Lama Penyimpanan Pada Kadar Fenolat Total Pasta Tomat.** *Indones. J. Chem. Sci.* 2012; **1**(2).

36. Malangngi L, Sangi M, Paendong J: **Penentuan Kandungan Tanin dan Uji Aktivitas Antioksidan Ekstrak Biji Buah Alpukat (Persea americana Mill.).** *J. MIPA.* 2012; **1**(1): 5.

37. Purnomo W, Khasanah LU, Anandito BK: **Pengaruh Ratio Kombinasi Maltodekstrin, Karagenan dan Whey Terhadap Karakteristik Mikroenkapsulan Pewarna Alami Daun Jati (Tectona Grandis L. F.).** *J. Apl. Teknol. Pangan.* 2014; **3**(3): 121–129.

38. Alcantara Marte Y, Alcantara Marte Y, Tejada AE, *et al.*: **Effect of different concentrations of pulverized mesocarp of Citrus paradisi Macf. on the bromatological characteristics of spray-dried lemon juice powder.** *Food Sci. Nutr.* 2018; **6**(5): 1261–1268.
PubMed Abstract | **Publisher Full Text**

39. Hayati FG, Dewi AK, Nugrahani RA, *et al.*: **Pengaruh Konsentrasi Maltodekstrin Terhadap Kadar Air Dan Waktu Melarutnya Santan Kelapa Bubuk (Coconut Milk Powder) Dalam Air.** *J. Teknol.* 2015; **7**(1): 55–60.

40. Djaafar TF, Santoso U, Ariestyanta A: **Pengaruh Penambahan Maltodekstrin dan Suhu Inlet Spray Dryer terhadap Karakteristik Fisiko-Kimia Bubuk Sari Kerandang (Canavalia virosa).** *Agritech.* 2018; **37**(3): 334.
Publisher Full Text

41. Santoso BD, Ananingsih VK, Soedarini B, *et al.*: **Pengaruh Variasi Maltodekstrin dan Kecepatan Homogenisasi Terhadap Karakteristik Fisikokimia Enkapsulat Butter Pala (Myristica fragrans Houtt) Dengan Metode Vacuum Drying.** *J. Teknol. Has. Pertan.* 2020; **13**(2): 94.
Publisher Full Text

42. Edrisi Sormoli M: **Imtiaz Ul Islam M, and Langrish TAG: The effect of chitosan hydrogen bonding on lactose crystallinity during spray drying.** *J. Food Eng.* 2012; **108**(4): 541–548.
Publisher Full Text

43. Siregar MTP, Kusdiyantini E, Rukmi MI: **Isolasi Dan Karakterisasi Bakteri Asam Laktat Pada Pangan Fermentasi Mandai.** *Biologi.* 2014; **3**(2): 40–48.

44. Fuentes KMC, Castro NJ: **Microencapsulación del Jugo de Mango (Mangifera indica L.) para la Obtención de un Concentrado con la Utilización de Maltodextrina como Material Pared. Thesis.** 2012; 1–85.

45. Ramadhia M, Kumalaningsih S, Santoso I: **The Making of Aloe vera Powder (Aloe vera L.) with Foam-mat Drying Method.** *J. Teknol. Pertan.* **13**(2): 125–137.

46. Lenaerts S, Van Der Borght M, Callens A, *et al.*: **Suitability of microwave drying for mealworms (Tenebrio molitor) as an alternative to freeze-drying: Impact on nutritional quality and color.** *Food Chem.* 2018; **254**(January): 129–136.
Publisher Full Text

47. Almatsier S: *Prinsip Dasar Ilmu Gizi. PT Gramedia Pustaka Utama. Jakarta.* Jakarta: Gramedia Pustaka Utama; 2009.

48. Anandharamakrishnan C, Rielly CD, Stapley AGF: **Effects of process variables on the denaturation of whey proteins during spray drying.** *Dry. Technol.* 2007; **25**(5): 799–807.
Publisher Full Text

49. Kaimudin M, Leonupun MF: **Characterization Chitosan From Waste Leather with Shrimp Process Using Different Bleaching and Deacetylation.** *Maj. BIAM.* 2016; **01**(12): 1–7.

50. Ali DY, Darmadji P, Pranoto Y: **Optimasi Nanoenkapsulasi Asap Cair Tempurung Kelapa Dengan Response Surface Methodology Dan Karakterisasi Nanokapsul.** *J. Teknol. dan Ind. Pangan.* 2014; **25**(1): 23–30.

51. Mamuaja CG: *Lipida.* Unsrat Press; 2017; 1–119.

52. Maurer AJ, Baker RC, Vadehra DV: **Factors Affecting the Drying, Stability, and Rehydration of Freeze-Dried Chicken Meat.** *Poult. Sci.* 1973; **52**(2): 784–792.
Publisher Full Text

53. Gopinathan M, Yusof YA, Pui LP: **Effects of Different Drying Methods on the Physicochemical and Antioxidant Content of "Cempedak" (Artocarpus Integer L.) Powder.** *J. Food Process. Preserv.* 2020; **44**.
Publisher Full Text

54. Hermanto S, Muawanah A, Wardhani P: **Analisis Tingkat Kerusakan Lemak Nabati dan Lemak Hewani Akibat Proses Pemanasan.** *J. Kim. Val.* 2012; **1**(6): 262–268.

55. Samantha SC, Bruna ASM, Adriana RM, *et al.*: **Drying by spray drying in the food industry: Micro-encapsulation, process parameters and main carriers used.** *Afr. J. Food Sci.* 2015; **9**(9): 462–470.
Publisher Full Text

56. wa ode Irmayanti H, Asyik N: **Analisis Organoleptik dan Proksimat Biskuit Berbahan Dasar Ubi Jalar (Ipomea batatas L) dan Kacang Hijau (Phaseolus radiatus L).** *J. Sains Dan Teknol. Pangan.* 2017; **2**(2): 413–424.

57. Angkananon W, Anantawat V: **Effects of Spray Drying Conditions on Characteristics, Nutritional Value and Antioxidant Activity of Gac Fruit Aril Powder.** *Rev. Integr. Bus. Econ.* 2015; **4**: 1–11.

58. Ahmed M, Akter MS, Lee JC, *et al.*: **Encapsulation by spray drying of bioactive components, physicochemical and morphological properties from purple sweet potato.** *LWT - Food Sci. Technol.* 2010; **43**(9): 1307–1312.
Publisher Full Text

59. Kistriyani L, Fauziyyah F, Rezeki S: **Profil Release Enkapsulasi Antosianin, Flavonoid dan Fenolik pada Kulit Semangka Menggunakan Metode Spray Drying.** *Eksergi.* 2020; **17**(2): 33.
Publisher Full Text

60. Safithri M, Indariani I, Yuliani R: **Effect of Microencapsulation Techniques on Physical and Chemical Characteristics of Functional Beverage Based on Red Betel Leaf Extract (Piper crocatum).** *J. Kim. Sains dan Apl.* 2020; **23**(8): 276–282.
Publisher Full Text

61. Afandi FA: **Pengaruh Nanoenkapsulasi terhadap Mutu Sensori, Fisikokimia, dan Fisiologiaktif Minuman Fungsional Berbasis Kumis Kucing (Orthosiphon aristatus BI. Miq), master thesis, Fakultas Teknologi Pertanian, Institut Pertanian Bogor, Bogor.** 2014.

62. Nallamuthu I, Devi A, Khanum F: **Chlorogenic acid-loaded chitosan nanoparticles with sustained release property, retained antioxidant activity and enhanced bioavailability.** *Asian J. Pharm. Sci.* 2015; **10**(3): 203–211.
Publisher Full Text

63. Yuliawaty ST, Susanto WH: **Pengaruh Lama Pengeringan dan Konsentrasi Maltodekstrin Terhadap Karakteristik Fisik Kimia dan Organoleptik Minuman Instan Daun Mengkudu (Morinda citrifolia L).** *J. Pangan dan Agroindustri.* 2015; **3**(1): 41–51.

64. Belšćak-Cvitanović A, Stojanovic R, Manojlovic, *et al.*: **Encapsulation of polyphenolic antioxidants from medicinal plant extracts in alginate-chitosan system enhanced with ascorbic acid by electrostatic extrusion.** *Food Res. Int.* 2011; **44**(4): 1094–1101.
Publisher Full Text

65. Rosenberg M, Kopelman IJ, Talmon Y: **Factors Affecting Retention in Spray-Drying Microencapsulation of Volatile Materials.**

J. Agric. Food Chem. 1990; **38**(5): 1288–1294.
Publisher Full Text

66. Saloko S, Sulastri Y, Kadir A: **Enkapsulasi Gula Semut Aren Menggunakan Kitosan dan Maltodekstrin.** *Pro Food (Jurnal Ilmu dan Teknol. Pangan).* 2021; **7**(1).

67. Rahmadi A, Banin MM, Rohmah M: **MCV encapsulation treatment.** *Data.* 2022, April 15.
Publisher Full Text

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