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Microencapsulation of *ciplukan* (*Physalis angulata* L.) extract as food ingredients: Effect of water ratio and maltodextrin concentration variables on product characteristics

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Abstract

The present work evaluated the characteristics of *ciplukan* (*Physalis angulata* L.) microcapsule extracts prepared by spray drying method. Different water ratios namely X_1 (1:2), X_2 (1:5), and X_3 (1:10), and maltodextrin concentrations namely Y_1 (5%) and Y_2 (10%) were applied in a spray drying system to produce microcapsule extracts. Investigations of physical properties (pH, moisture, water activity, total solid, solubility, and colour), as well as morphological characteristics by scanning electron microscopy (SEM) and functional properties (antioxidant, total phenolic, total flavonoid, and quercetin content) were carried out. Results showed that water ratio and maltodextrin gave a significant effect on the physical properties of microcapsule extract with X_1 (1:2) and Y_1 (5 %) having significant effect on total phenolic, flavonoid, and quercetin contents, and antioxidant properties of *ciplukan* extract microcapsule. Furthermore, the scanning electron microscopy (SEM) illustrated the morphological structure of microcapsule extract, which showed a spherical structure. All combinations of water ratios and maltodextrin concentrations showed agglomeration, except for X_1Y_2. In correlation analysis using partial least square, the antioxidant activity of microcapsule extract was proportional to physicochemical properties, total phenolic, total flavonoid, and quercetin contents of microcapsule extract. The present work revealed that water extraction ratios and maltodextrin concentrations affected microcapsule extract of *ciplukan*. The combination of X_1 (1:2) and Y_1 (5%) retained the functional properties of *ciplukan* microcapsule extract.

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Introduction

Physalis has 75 native species in the United States, and 65 species in Mexico (Martínez *et al*., 2017). The edible fruits of some *Physalis* species are nutritionally good (Zamora-Tavares *et al*., 2015; Saavedra *et al*., 2019). Sweet or sour, these fruits are consumed raw or made into jams, soups, and meals (Vargas-Ponce *et al*., 2016). *Physalis angulata* L. is a member of the Solanaceae family, and found throughout tropical and subtropical parts of the world (Ramakrishna Pillai *et al*., 2022). This plant is commonly referred to as "*camapu*" in Brazil and "*ciplukan*" in Indonesia. Its leaves have a variety of pharmacological properties, and its fruits could be consumed as food (Figueiredo *et al*., 2020). *Physalis angulata* flowers and fruits throughout their vegetative and reproductive cycles, with floral buds emitted shortly after plantlet emergence until senescence. Due to the overlapping timing of

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development and flowering, different stages of flower development have been observed in each plant throughout the cycle (Figueiredo *et al*., 2020).

Ciplukan is extremely nourishing and rich in important minerals with macronutrients such as potassium, phosphorous, and magnesium (Golubkina *et al*., 2018), as well as micronutrients and vitamin C (Iwansyah *et al*., 2022). Flavonoids, phenolics, and chlorogenic acid are among the secondary metabolites of plants which are essential phytochemicals (Moreira *et al*., 2020). *Ciplukan* has various bioactive compounds such as physalin (Moreira *et al*., 2020). Leaf and fruit extracts of *ciplukan* were found to have anti-inflammatory, antioxidant, cytotoxic, and antimicrobial effects (Farias *et al*., 2022). *Ciplukan* fruit juice is also known to have antidiabetic activity (Iwansyah *et al*., 2022). Therefore as a functional food, a method is needed to preserve the nutritional content of *ciplukan* to maintain the bioactivity of its compounds.

The nutritional content of *ciplukan* fruit is directly proportional to the speed of nutrient loss caused by external factors such as microorganisms, environmental temperature, and radiation (Rezende *et al*., 2018). Microencapsulation is a strategy for overcoming these limitations, and various techniques are used to prepare the microencapsulation. The microencapsulation process is divided into two stages, physical and chemical. Physical processes include spray drying, spray chilling, rotary disk atomisation, fluid bed coating, coextrusion, and pan coating. Meanwhile, chemical processes include brief and intricate coacervation, interfacial polymerisation, and phase separation. The food industry uses this technology to reliably protect sensitive and labile nutrients, including their controlled release (de Oliveira Ribeiro *et al*., 2021). Spray drying is one of the methods employed in pharmaceutical and food manufacturing to form dry powder from the liquid. The purpose of spray drying is to produce stable, high-quality particles with a particular size and water content (Rezende *et al*., 2018).

In the present work, the effect of water ratios and maltodextrin concentrations on the microcapsule of *ciplukan* extract characteristics was evaluated. Some product properties such as physico-chemical characteristics (pH, moisture, a_w, total solid, colour, titratable acidity, and solubility), and morphological and functional attributes (antioxidant and phytochemical contents) were determined to obtain the best combination in microcapsule preparation.

Materials and methods

Chemicals

Maltodextrins were obtained from Setia Guna Chemical Store, Bogor, Indonesia. Methanol, DPPH, ABTS, distilled water, quercetin, 10% $AlCl_3$, 1 M sodium acetate, gallic acid, Folin-Ciocalteu, 7.5% Na_2CO_3, and NaOH were procured from Sigma-Aldrich, Singapore.

Plant material and extraction

Fresh *ciplukan* samples were obtained from "Alenda Ciplukan Farm" at the village area in Bandung District, West Java Province, Indonesia. *Ciplukan* plants were gathered between February and March 2022. Botanical determination was performed at Herbarium Bogoriense, Center for Biological Research, National Research and Innovation Agency (BRIN), Indonesia.

Fresh *ciplukan* fruits were sorted, weighed, washed with tap water, and blanched at 70 - 80°C for 2 min. After that, the fruits were drained and homogenised with distilled water, at a ratio (X), using a blender (Philips HD 3115, China) at a speed of 21,080 - 28,520 rpm until homogeneous. Using filter paper, extract was filtered, and later pooled for subsequent analyses. For spray drying, *ciplukan* extracts were supplemented with maltodextrin (DE 10-12), at concentrations of 5 and 10%. The solutions were homogenised for 20 min at 2,500 rpm by a homogeniser (IKA Eurostar 20, USA). The spray drier (Buchi Mini B-290, Germany) conditions were: diameter spray nozzle, 0.7 mm; temperature inlet and outlet, 165°C and 80°C, respectively; drying chamber, 25°C; peristaltic pump, feed flow rate 2.0/Lh; and spray pressure, 0.7 - 1.4 kg cm^{-2}.

Experimental design

A completely randomised design (CRD) was adopted for the experimental design. Two factors namely water ratio (X) such as 1:2 (X_1), 1:5 (X_2), and 1:10 (X_3); and maltodextrin concentration (Y) such as 5% (Y_1) and 10% (Y_2) were selected, each with three triplicates, to a total of 18 trial units based on a preliminary study. In those water ratios and maltodextrin concentrations, *ciplukan* dried extract was in solid dried powder form. In addition, the use of maltodextrin with a concentration of > 10% decreased the orange colour of the *ciplukan* extract, which is its characteristic colour, thus not considered in the present work.

Physical characteristics

Solubility

The solubility of sample was measured by first determining its water content, and then dissolving 2 g of powdered material into 100 mL of distilled water filtered with Whatman filter paper no. 42. Before use, the filter paper was completely dried at 105°C for 3 h in an oven, then left to cool in a desiccator and weighed. The solubility value was expressed as the percentage of the residue's weight that could not pass through the filter paper, and measured using Eq. 1:

$$\text{Solubility (\%)} = 1 - \left(\frac{\text{Final dried weight of Whatman filter (g)} - \text{Initial dried weight of Whatman filter (g)}}{\left(\frac{100 - \%\text{Moisture}}{100}\right)\text{sample weight}}\right) \times 100 \quad \text{(Eq. 1)}$$

Total acidity

Phenolphthalein was utilised as an indicator in the total acidity determination. Briefly, 10 g of ground *ciplukan* extract powder was put in a beaker, and 80 mL of distilled water was poured in. The solution was then mixed, brought to a volume of 100 mL with distilled water, and the solution was filtered through filter paper. Using two drops of phenolphthalein (0.01 N) as an indicator, 20 mL of the filtered solution was titrated with 0.01 N sodium hydroxide to a pink colour. The amount (in mL) of 0.01 N NaOH used to neutralise the acids consisted in the samples was calculated for both methods based on the analytical guidelines of Lutz (2008), and the results were presented in g 100 g^{-1} of dry matter.

Colour

With a Hunter Laboratory Calorimeter (model SN 7877, Ultrascan, Hunter Associates Laboratory, Inc., Virginia), the colour of the clarified powder was determined, where +*L** indicated lightness and –*L** darkness, +*a** indicated red colour and -*a** green colour, and +*b** indicated yellow colour and -*b** blue colour (Iwansyah *et al*., 2020).

Total solid

The total soluble solids were determined using a digital refractometer (ATAGO-model Pal-1) on a scale of 0 - 10°Brix (Iwansyah *et al*., 2020).

pH value

A pH meter (ATAGO; model Pal-1) was used to determine the pH value of every sample. A total of 10 g of *ciplukan* powder sample was put into a beaker glass, mixed with distilled water (10 mL, pH 7.0), stirred until homogeneous, and kept at room temperature for 10 min. The homogeneous sample solution that has been separated was then measured for its pH by inserting the tip of pH meter electrode probe (Iwansyah *et al*., 2020).

Moisture content

The moisture content of *ciplukan* powder was determined using a moisture analyser (TOVATECH; model DSC 71P). Briefly, 5 g of sample was weighed and put in an aluminium pan. Following the standard of the manual, the heating temperature was standardised to 160°C. The moisture content of the samples was denoted in percentage (%), and the experiment was performed at room temperature (25°C) in triplicate.

Water activity

With a water activity meter (DECAGON; model Aqua Lab), the water activity (a_w) of the samples (1 g) was determined in triplicate.

SEM analysis

At the Research Centre for Food Technology and Processing, National Research and Innovation Agency (BRIN), Indonesia, an analysis was carried out on the structure of *ciplukan* extract powder. Samples were prepared by putting approximately 0.2 g of materials on the sticky part side of a tape.

Antioxidant properties

The total phenolic content, flavonoid content, and antioxidant capacity of *ciplukan* dried extract were determined using the 1,1-diphenyl-2-picrylhydrazyl (DPPH) assay. In every gram of the sample, the amount of phenol was determined in milligrams of gallic acid equivalents (GAE). The amount of flavonoid in each gram of the sample was measured in mg of quercetin equivalents (QE). Using a UV-vis spectrophotometer, antioxidant capacity was measured as the percentage of absorbance at 517 nm that was inhibited (Shimadzu UV-1900, Tokyo, Japan).

Quantification of quercetin

Quantification of quercetin was examined by liquid chromatography (Thermo Scientific) system consisting of a vacuum degasser, quaternary pump, auto-sampler, and diode array detector. Separation was conducted on a stationary phase, Octadecylsilyl silica gel for reversed (C_{18}), Zorbax column (250 mm

× 4.6 mm × 120 °A). Optimal separation efficiency was achieved with methanol:water (90:10, v/v) at a flow rate of 1.0 mL/min, a pressure of 400 bars, and a detection wavelength of 370 nm. The injection sample volume was 20 µL with the temperature of the column was ambient. Linear regression was used to correlate the peak area (Y) with quercetin concentration (X). The amount of quercetin in the extract was measured using the calibration curve. Standard quercetin in methanol was prepared at concentrations of 1.2, 2.4, 4.8, 9.6, and 19.2 µg/mL.

Statistical analysis

Data were recorded as mean ± standard deviation (S.D.) of triplicate. A normality test was performed on the data, and analysis of variance (ANOVA) was employed to identify the significant dissimilarities between treatments.

Simple linear regression was used to evaluate the relationship between the variable of *ciplukan* extract powder. Through the use of Microsoft Excel 365 and R-Statistic 4.03, a statistical analysis was conducted.

Results and discussion

Characteristics physics of ciplukan dried extract

The physical properties of *ciplukan* dried extract are shown in Table 1. Moisture content and water activity are strictly linked to microbial growth and countless degradative reactions which are able to unfavourably upset the solidity and storage of food ingredients (Bell, 2020).

Table 1 shows that the interaction between the water ratios and maltodextrin concentrations treatment on microcapsule of *ciplukan* significantly affected moisture content, total solids, and total acidity ($p < 0.05$), while the solubility did not significantly affect ($p > 0.05$). The a_w value of *ciplukan* dried extract ranged from 0.25 to 0.60; this was a low value range that would allow *ciplukan* extract to be preserved for a long time. The moisture content of *ciplukan* dried extract ranged from 3.77 to 7.31%. In foods, the effect of moisture and water activity on the proliferation of bacteria is critical. Majority of bacteria need water activity between 0.9 and 1.00 and good temperature for growth (Park, 2008). Although some halophilic bacteria can grow at 0.75 a_w, these microorganisms are not common food contaminants (Park, 2008). The pH factor, in addition to moisture and water activity, influences a variety of chemical and microbiological interactions. Furthermore, pH affects the taste and colour of food products (Andrés-Bello *et al*., 2013). *Ciplukan* dried extract has an acidic pH range of 3.65 - 3.83.

The quantities of sugars and organic acids were associated with the content of soluble solids, where a dry solid dissolved in a solution (g per 100 g of solution) calculated as sucrose was described as °Brix. In the present work, *ciplukan* dry extract had 7.50 - 9.00 °Brix. The components in the *ciplukan* dry extract had high solubility (97.89 - 99.56%) but

Table 1. Physical properties of *ciplukan* dried extract.

Constituent	Ratio 1:2 (X_1)		Ratio 1:5 (X_2)		Ratio 1:10 (X_3)	
	Conc. 5% (Y_1)	Conc. 10% (Y_2)	Conc. 5% (Y_1)	Conc. 10% (Y_2)	Conc. 5% (Y_1)	Conc. 10% (Y_2)
pH	3.65 ± 0.01^{Ca}	3.65 ± 0.03^{Ca}	3.70 ± 0.01^{Ba}	3.71 ± 0.03^{Ba}	3.78 ± 0.03^{Aa}	3.83 ± 0.03^{Aa}
Moisture (%)	5.11 ± 0.18^{Ca}	3.77 ± 0.08^{Cb}	7.31 ± 0.06^{Aa}	5.64 ± 0.30^{Ab}	6.27 ± 0.01^{Ba}	4.73 ± 0.10^{Bb}
Water activity (a_w)	0.33 ± 0.01^{Ca}	0.28 ± 0.01^{Cb}	0.46 ± 0.01^{Aa}	0.42 ± 0.01^{Ab}	0.46 ± 0.01^{Ba}	0.25 ± 0.01^{Bb}
Total solid (°Brix)	9.00 ± 0.00^{Ba}	7.50 ± 0.00^{Bb}	9.00 ± 0.00^{Aa}	8.67 ± 0.29^{Ab}	8.00 ± 0.00^{Ca}	7.50 ± 0.00^{Cb}
Total acidity (g/L)	0.67 ± 0.01^{Aa}	0.48 ± 0.01^{Ab}	0.44 ± 0.01^{Ba}	0.31 ± 0.01^{Bb}	0.32 ± 0.01^{Ca}	0.19 ± 0.00^{Cb}
Solubility (%)	98.72 ± 0.20^{Aa}	99.45 ± 0.09^{Aa}	99.56 ± 0.02^{Aa}	99.45 ± 0.12^{Aa}	97.89 ± 0.10^{Aa}	99.71 ± 0.14^{Aa}
Colour:						
*L**	92.23 ± 0.01^{Cb}	96.05 ± 0.00^{Ca}	96.42 ± 0.00^{Ab}	97.39 ± 0.01^{Aa}	95.73 ± 0.01^{Bb}	97.47 ± 0.41^{Ba}
*a**	3.61 ± 0.01^{Aa}	0.98 ± 0.01^{Ab}	0.54 ± 0.01^{Ba}	-0.01 ± 0.01^{Bb}	1.12 ± 0.02^{Ca}	-0.13 ± 0.01^{Cb}
*b**	21.16 ± 0.00^{Aa}	10.83 ± 0.01^{Ab}	9.02 ± 0.01^{Ba}	6.87 ± 0.01^{Bb}	9.65 ± 0.01^{Ca}	3.93 ± 0.01^{Cb}

Values are mean ± standard deviation (S.D.) of triplicate ($n = 3$). a > b > c, values in the same rows followed by different alphabets are significantly different by Duncan's test ($p < 0.05$). Uppercase superscripts represent ratio effect, and lowercase superscripts represent concentration effect.

low acid content (0.19 - 0.67%). Fruits with acidity between 0.08 and 1.95 g/L have a bland taste, and are typically eaten fresh (de Souza *et al*., 2012). Colour is another physical feature noted in *ciplukan*. *Ciplukan* dried extract had high brightness with L^* value ranging from 92.23 to 97.47, a^* value ranging from -0.01 to 3.61, while b^* value ranging from 3.93 to 21.16. The high value of L^* could have been due to the concentration of maltodextrin.

SEM analysis

The morphological structure of *ciplukan* dried extract microcapsules can be seen from the scanning electron microscopy (SEM) in Figure 1. The results of the SEM analysis showed that the morphological structure of the microcapsules produced by the spray drying technique had a spherical structure. The sample extract started to shrink due to the spray drying technique, whereby the temperature of the encapsulated emulsion solution in the spray dryer (at room temperature) differed from the operating temperature of the spray drying chamber (at temperatures above 100°C), thus causing water to evaporate quickly and wrinkled most of the surface. All combinations demonstrated agglomeration, except for X_1Y_2. This particle agglomeration could improve the stability of the microencapsulated substance by protecting the inner particles (Alves *et al*., 2017). The spherical conformation of all treatment microparticles could have been due to the spraying-induced production of droplets which are consequently converted into spherical particles by solvent evaporation (Rezende *et al*., 2018). The high degree of agglomeration in X_2Y_2 and X_3Y_1 could have been related to the water ratio of the treatment. The higher ratio of water as solvent causes the dispersion of compounds to occur in microencapsulation. However, the high concentration of maltodextrin affected the structure of X_3Y_2 even though the water ratio was sufficient. A similar structure was evident from the SEM observations of bioactive orange-peel extracts (Sormoli and Langrish, 2016). These particles were initially spherical, but they were inclined to create liquid bridges to link with one another by using humidity levels or absorbing moisture from the environment, henceforth their morphology transformed fast. After spray drying using maltodextrin, inulin, and gum Arabic, a microencapsulation structure of pineapple peel extract, as well as a violin structure with a high level of agglomeration could be seen (Lourenço *et al*., 2020).

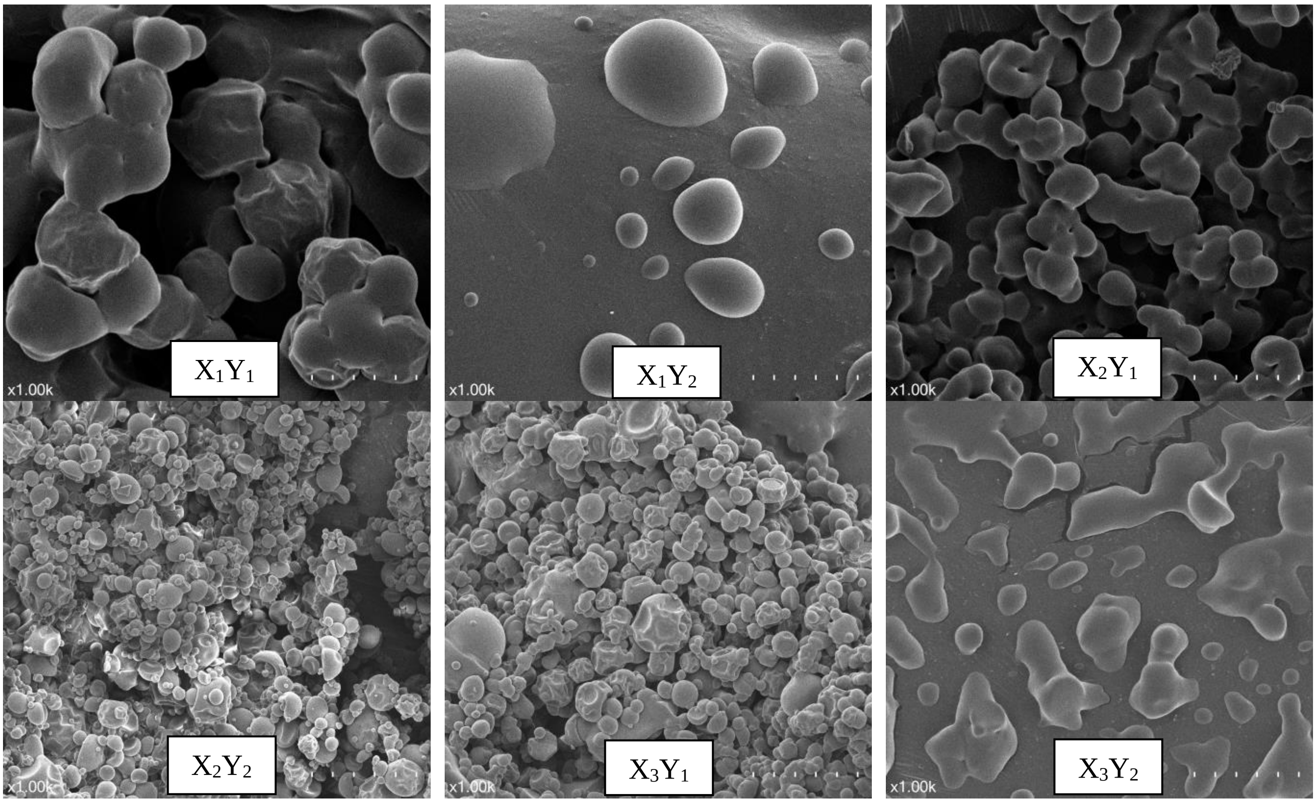

Figure 1. Scanning electron micrographs (SEM) of *ciplukan* dried extract microcapsules with different water ratios and maltodextrin concentrations (magnification: 1,000×).

Antioxidant properties

The antioxidant properties of microcapsule of *ciplukan* dried extract with water ratios and maltodextrin concentrations treatment are presented in Table 2.

Antioxidant activity is commonly measured using DPPH as a substrate. The DPPH radical scavenging assay is a straightforward, well-used method for determining the radical scavenging ability of plant extracts (Lourenço *et al*., 2020). At 517 nm, the absorption spectrum band is applied to count the colour change (purple colour) when the antioxidant receives an electron or a free radical species (Baliyan *et al*., 2022). Due to the lesser volume of hydrogen, a free-radical scavenger antioxidant combines with DPPH to produce DPPH-H, which absorbs less than DPPH. In comparison to the DPPH-H state, as the number of electrons gathered increases, this radical variant induces decolourisation (Baliyan *et al*., 2022). Table 2 shows that the antioxidant activity of *ciplukan* dried extract ranged from 5.66 to 21.03 mg AAE/mL. ANOVA analysis showed that the interaction between the water ratios and maltodextrin concentrations treatment on microcapsule of *ciplukan* significantly affected antioxidant activity ($p < 0.05$). X_1Y_1 had the greatest antioxidant activity (21.03 mg ascorbic acid equivalent per mL), followed by X_2Y_1, X_1Y_2, X_3Y_1, and X_3Y_2. All extracts showed activity in inhibiting free radicals DPPH.

Phenolic compounds are antioxidant-active components responsible for the antioxidant amount of various herbal plants. Phenolic compounds are secondary plant metabolites produced *via* the shikimate/phenylpropanoid pathway, which directly yields the phenylpropanoid, or the acetate/malonate "polyketide" process that is able to offer simple phenols, or both, thus resulting in monomers and polymers (Ramawat and Mérillon, 2013). Plants produce phenols and polyphenols for a variety of physiological functions. Using a gallic acid (0 - 200 g/mL) calibration curve ($y = 0.0005x + 0.0047$, $R^2 = 0.996$), the results were counted and expressed in gallic acid equivalents (GAE) per gram dry extract weight. Table 2 shows that the interaction between the water ratios and maltodextrin concentrations treatment on microcapsule of *ciplukan* significantly affected total phenolic contents ($p < 0.05$). The X_1Y_2 and X_2Y_1 had the greatest phenolic contents of 45.20 ± 1.20 and 43.00 ± 2.20 mg GAE/g, respectively, followed by X_1Y_1, X_2Y_2, X_3Y_2, and X_3Y_1.

One of phenolic compounds is flavonoids, which include polyphenolic phytochemicals found in a wide range of foods and beverages. They are divided into six classes based on their chemical structures and physiological effects (Mondal and Rahaman, 2020). Flavonoids are found in various natural sources such as roots, stems, leaves, and fruits of plants (Mondal and Rahaman, 2020). The highest flavonoid content of *ciplukan* extract powder was 10.75 ± 0.00 mg QE/g (X_1Y_1), and the lowest was X_3Y_2 (1.50 ± 0.00 mg QE/g). The flavonoid content was calculated and denoted in quercetin equivalents (QE) per gram dry extract weight. Quercetin (0 - 20 µg/mL) was used as standard.

Table 2. Antioxidant properties of *ciplukan* dried extract microcapsules with different water ratios and maltodextrin concentrations.

Constituent	**Ratio 1:2 (X_1)**		**Ratio 1:5 (X_2)**		**Ratio 1:10 (X_3)**	
	Conc. 5% (Y_1)	**Conc. 10% (Y_2)**	**Conc. 5% (Y_1)**	**Conc. 10% (Y_2)**	**Conc. 5% (Y_1)**	**Conc. 10% (Y_2)**
TP (mg GAE/g)	36.70 ± 2.10^{A}	45.20 ± 1.20^{A}	43.00 ± 2.20^{B}	26.50 ± 0.50^{B}	11.60 ± 0.69^{C}	18.40 ± 0.60^{C}
TF (mg QE/g)	10.75 ± 0.00^{Aa}	4.25 ± 0.00^{Ab}	4.25 ± 0.00^{Bb}	4.65 ± 0.00^{Ba}	4.50 ± 0.00^{Ca}	1.50 ± 0.00^{Cb}
TF/TP ratio	0.29	0.09	0.10	0.18	0.39	0.08
AOA (mg AAE/mL)	21.03 ± 1.21^{Aa}	19.01 ± 2.23^{Ab}	20.04 ± 3.87^{Ba}	17.05 ± 1.45^{Bb}	18.20 ± 2.12^{Ca}	5.66 ± 1.34^{Cb}
Quercetin (µg/mL)	964.57^{Aa}	407.20^{Ab}	324.59^{Ba}	110.78^{Bb}	210.83^{Ca}	N.A.^{Cb}

Values are mean ± standard deviation (S.D.) of triplicate ($n = 3$). TP: total phenolic contents; TF: total flavonoid contents; AOA: antioxidant activity; GAE: gallic acid equivalent; QE: quercetin equivalent; AAE: ascorbic acid equivalent). a > b > c, values in the same rows followed by different alphabets are significantly different by Duncan's test ($p < 0.05$). Uppercase superscripts represent ratio effect, and lowercase superscripts represent concentration effect. N.A. = not available.

These results were similar to the quercetin value of *ciplukan* dried extract in Table 2. The antioxidant activity of *ciplukan* extract could have been due to the presence of flavonoids and phenols.

Partial least square regression

The correlation of antioxidant activity with physicochemical composition, total phenolic contents, total flavonoid contents, and quercetin by using partial least squares (PLSR) is shown in Figure 2. PLSR describes the relationship or interaction between X and Y variables at the same time. This method has been applied to reveal the relationship or interaction between the volatile compound and sensory characteristics of many products, for example ginger flavour beverages and meatballs (Zhang *et al*., 2019; Pranata *et al*., 2021). Various *ciplukan* dried extract parameters including total solid, total acidity, colour, total flavonoid, antioxidant activity, and quercetin content were regressed by PLS to determine the correlation between its ratio extract and levels of filler. The results showed that all parameters were found to be correlated with a positive standardised coefficient (Figure 2). The standardised coefficient describes the strength of the effect of each independent variable (ratio of extract and level of filler) to the dependent variable (*ciplukan* dried extract parameters), where value of 1.0 shows strong correlation. The standardised coefficient was below 0.15, but still showed positive correlation; however, it was not significantly different. A low value indicates a weak correlation between variables. Positive values indicate a linear correlation, while negative values indicate a non-linear relationship between variables. The validation results showed that total acidity, colour, total flavonoid contents, antioxidant activity, and quercetin had good correlations with R^2_{TAT} = 0.975, R^2_{color} = 0.974, R^2_{TFc} = 0.957, R^2_{AOA} = 0.802, and $R^2_{\mathrm{quercetin}}$ = 0.971.

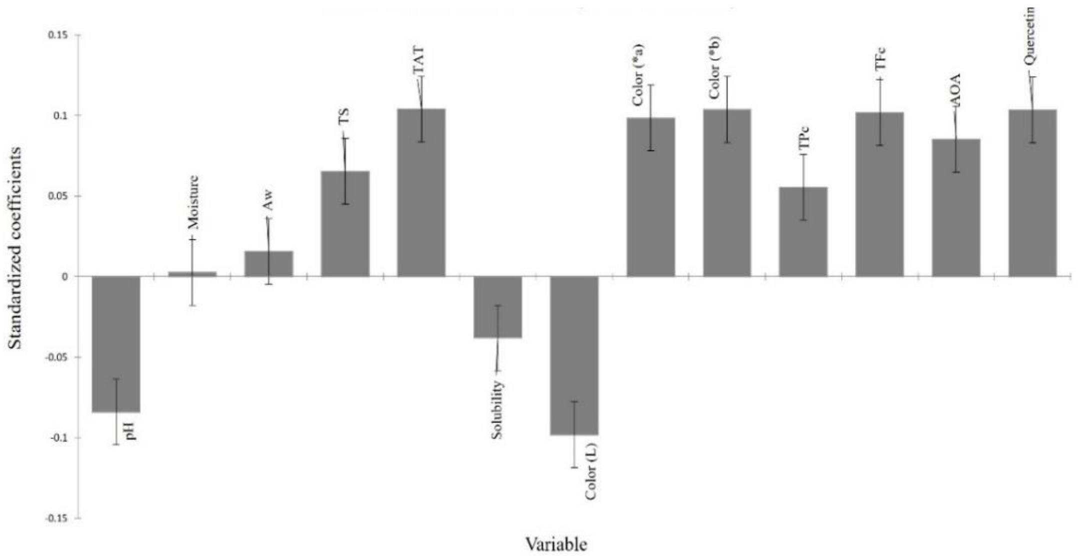

Figure 2. Standardised coefficient of quercetin with physicochemical and antioxidant properties.

Conclusion

In the present work, the effect of water ratios and maltodextrin concentrations on *ciplukan* (*P. angulata*) microcapsule characteristics was examined. We found that water ratios and maltodextrin concentration affected *ciplukan* microcapsule extract qualities. In physico-chemical properties, the combination of a water ratio of X_1 (1:2) and maltodextrin concentration (5%) gave a significant effect on the total solid and colour of the extract microcapsule. In the same condition in functional properties of *ciplukan* microcapsule extract, the combination of X_1 (1:2) and maltodextrin (5%) gave the most effective effect in maintaining antioxidant, total phenolic and flavonoid, and quercetin contents of the extract. However, for morphological features, all combinations gave no significant effect on the spherical structure of the powder. The present work suggested that extract microcapsules could be developed in maintaining an active compound contained in a plant extract to be used as a food ingredient.

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