บทความวิจัย

สมบัติทางเคมีกายภาพและสารออกฤทธิ์ทางชีวภาพของผงกะเพราที่ได้จากกระบวนการเอนแคปซูเลทกับมอลโทเดกซ์ทรินและกัมอารบิกด้วยเครื่องอบแห้งแบบพ่นฝอย

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บทคัดย่อ

ความชื้น แอคติวิตีของน้ำและความสามารถในการละลายของผงกะเพราลดลงอย่างมีนัยสำคัญทางสถิติเมื่อความเข้มข้นของสารห่อหุ้มเพิ่มขึ้นจากร้อยละ 10–30 ($p < 0.05$) อย่างไรก็ตามผงกะเพราที่ห่อหุ้มด้วยกัมอารบิกมีการละลายที่ดีกว่ามอลโตเดกซ์ทรินที่ความเข้มข้นเดียวกัน การศึกษาลักษณะทางสัณฐานวิทยาพบว่าเมื่อใช้ปริมาณสารห่อหุ้มเพิ่มขึ้นทำให้ผงกะเพรามีขนาดอนุภาคใหญ่ขึ้นแต่มีความหนาแน่นรวมลดลง นอกจากนี้การใช้ปริมาณสารห่อหุ้มเพิ่มขึ้นเป็นผลให้ปริมาณสารฟีนอลิกทั้งหมดและฤทธิ์ต้านอนุมูลอิสระ (DPPH) ของผงกะเพรามีค่าลดลงอย่างมีนัยสำคัญทางสถิติ ($p < 0.05$) ดังนั้นการห่อหุ้มผงกะเพราด้วยกัมอารบิกร้อยละ 10 จึงถูกเลือกใช้สำหรับการทดลองขั้นต่อไป การเพิ่มขึ้นของอุณหภูมิขาเข้าไม่มีผลต่อความสามารถในการละลายแต่มีผลต่อความชื้น แอคติวิตีของน้ำ ความหนาแน่นรวม ขนาดอนุภาค ค่าความสว่าง ปริมาณสารฟีนอลิกทั้งหมดและฤทธิ์ต้านอนุมูลอิสระ (DPPH) อย่างมีนัยสำคัญทางสถิติ ($p < 0.05$) การใช้อุณหภูมิขาเข้า 140 องศาเซลเซียส ทำให้ปริมาณสารฟีนอลิกทั้งหมดและฤทธิ์ต้านอนุมูลอิสระระหว่างการจำลองการย่อยในหลอดทดลองสูงกว่าการใช้อุณหภูมิอื่นอย่างมีนัยสำคัญทางสถิติ จากผลการทดลองสรุปว่าวิธีที่เหมาะสมที่สุดสำหรับการห่อหุ้มผงกะเพราคือการใช้กัมอารบิกเป็นสารห่อหุ้มร้อยละ 10 และใช้อุณหภูมิขาเข้าของเครื่องทำแห้งแบบพ่นฝอยที่ 140 องศาเซลเซียส

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Research Article

Physicochemical Properties and Bioactive Compound of Holy Basil Powder from Spray-dried Encapsulation with Maltodextrin and Gum Arabic

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Abstract

Moisture Content (MC), water activity (A_w) and solubility of the encapsulated powders significantly decreased when concentration of carrier increased from 10 to 30% ($p < 0.05$). However, the powders from GA gave better solubility than those of MD. Morphological study revealed that the powders had larger particle size and less in bulk density when concentration of carriers increased. In addition, Total Phenolic Content (TPC) and antioxidant activity (DPPH) significantly decreased when encapsulated holy basil in MD and GA ($p < 0.05$). Therefore, using 10% GA as a carrier was selected for second experiment. Increasing of inlet temperature did not affect solubility but significantly affected MC, Aw, bulk density, particle size, lightness, TPC and DPPH ($p < 0.05$). Using 140°C resulted in the highest TPC and DPPH activity compared to the other treatment during *in vitro* digestion. In conclusion, the suitable condition of holy basil powder by spray drying was using 10% GA at 140°C inlet temperature.

Keywords: Antioxidant Activity, Encapsulation, Holy Basil, Phenolic Compound, Spray Drying

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1. Introduction

Holy basil is an important traditional medical plant and its leave is used as an ingredient in Thai food. It contains vitamin C, ß-carotene, phenolic compounds including flavonoid, which act as an antioxidant, and also has specific aroma from ß-caryophyllene, ß-elemene, methyl eugenol, and methylchavicol [1], [2]. However, holy basil cannot storage for a long time, just 4-6 days at room temperature.

Spray drying is a method used to extend the shelf life of holy basil by converting characteristic from fresh leave to powders. It can reduce deterioration or loss of phenolic compounds in the fresh leave and it is alternative to reduce transport cost [3]. Encapsulation can enhance spray drying to keep bioactive compounds in the leave. The encapsulated sample can protect high diversity of polyphenolic compounds [3]. Daza *et al*. [4] reported the different concentrations of matrix carrier (10, 20, and 30%) and different inlet temperatures (140, 160 and 180°C) in Cagaita fruit. The results showed that loss of total phenolic content of Cagaita powder was around 30%. In addition, total phenolic content increased when using higher temperature (160°C) and lower concentration of gum arabic (10%).

The present study used maltodextrin (MD) and Gum Arabic (GA) as a matrix carrier in encapsulation process. Maltodextrin is a product from decomposing some part of corn flour by using acid or enzyme [5]. Dextrose Equivalent (DE) is a degree decomposition of starch polymer that indicates an ability to cause matrix which has an important part in making a wall coating [6]. Gum arabic is used as matrix carrier because it has a great solubility property, low viscosity, and acts as an emulsifier. The particles size of encapsulated powder is around 10–200 which depends on during spray-dried, inlet temperature, emulsion concentration, viscosity, and a ratio between gum arabic and maltodextrin [7].

Therefore, the objectives of this study were 1) to investigate effect of types and concentrations of matrix carrier on physicochemical, bioactive compounds, and *in vitro* digestion of holy basil powder and 2) to investigate effect of different inlet temperatures of spray drying on physicochemical, bioactive compounds, and *in vitro* digestion of holy basil powder. This study expected to get a spray-dried powder of holy basil leave which can retain the important bioactive compounds, antioxidant activity, increase usage facility, and also reduce cost of transportation and storage.

2. Materials and methods

2.1 Chemicals and reagents

Folin–Ciocalteu's phenol reagent, gallic acid, monosodium phosphate monohydrate, Trolox ((±)-6-Hydroxy-2,5,7,8-tetramethylchromane-2-carboxylic acid) and DPPH (2,2-diphenyl-1-picryhydrazyl), porcine pepsin, amyloglucosidase, pancreatin and invertase were purchased from Zigma, Germany. Maltodextrin 20DE (MD) was purchased from Baolingbao Biology Co., Ltd. (China) and gum arabic was purchased from Wendt Chemie Company GmbH (Germany). All other chemicals and reagents in this study were of analytical grade.

2.2 Sample preparation

The holy basil (*Ocimum Sanctum* L.) leave were wash, drained, cut into small pieces (1 × 1 cm^2), and

dried in tray dryer at 40°C until the final moisture content less than 7%. The dried holy basil leave were then extracted according to the methods of Arawwawala *et al*. [8]. Briefly, dried holy basil leaves were boiled with distilled water in 1 : 5 ratio for 4 h, and filtrated. Then, water in the extracted sample was collected. Extracted water was kept in a freezer at –40°C for spray drying.

2.3 Effect of types and concentrations of matrix carrier on physicochemical, bioactive compounds, and in vitro digestion

Extracted sample (100 g) was mixed with 10, 20, or 30 g of maltodextrin or gum arabic, and homogenized for 2 min at 20,000 rpm by using homogenizer. Then, the solution was fed into the spray dryer (JCM SDE10, Euro Best Co. Ltd., Thailand) with a flow rate of 0.6 m^3/min, inlet temperature 140°C, and outlet temperature 80°C [3], [8]. The powder samples were collected and stored in vacuum aluminium foil bag at 4°C for further analysis. The best treatment was selected for the next step.

2.4 Effect of inlet temperature on physicochemical, bioactive compounds, and *in vitro* digestion

Extracted sample (100 g) was mixed with MD or GA according to the selected treatment from section 2.3 and homogenized for 2 min at 20,000 rpm by homogenizer. The solution was then fed into the spray dryer with a flow rate 0.6 m^3/min, at three different inlet temperatures (120, 140, and 160°C) and outlet temperature at 80°C. The powder samples were collected and stored in vacuum aluminium foil bag at 4°C for further analysis.

2.5 Determination of physicochemical properties

2.5.1 Moisture Content (MC)

The moisture content of sample was determined by weigh the powder (2 g) into a moisture can, and put in the oven overnight. The moisture content (g/100 g) and dry matter (g/100 g) in the samples were then calculated from the weight differences.

2.5.2 Water activity (A_w)

The water activity was determined by using a water activity analyzer.

2.5.3 Color

The color was measured by photocolorimetry using a reflectance spectrophotometer and observed the results in the CIELAB color system. L*, a*, and b* values were obtained [3].

2.5.4 Bulk density

The holy basil powder (2 g) was added in 10 mL of graduated measuring cylinder and vortex for 1 min. Bulk density of the powder was calculated by measuring the ratio of mass of powder to the volume occupied by the powder [9].

2.5.5 Solubility

The solubility of powder was determined by adding 0.5 g of sample with 50 mL of distilled water, stirred at 110 rpm for 30 minutes according to the methods of Daza *et al*. [4].

2.5.6 Particles morphology

The holy basil powder was observed the size and shape under a Scanning Electron Microscope (SEM). The images were captured with a voltage acceleration of 5 kV and a current of 1750 mA by following the methods of Daza *et al*. [4].

2.6 Determination of bioactive compound properties

2.6.1 Total Phenolic Content (TPC)

The total phenolic content was determined spectrophotometrically by using Folin-ciocalteu method. The sample (1 mL) was mixed with 5 mL of freshly prepared 10%v/v Folin reagent. Then 4 mL of 7.5% w/v sodium bicarbonate solution was added to the mixture. The mixture was leaved for 60 min at room temperature and the absorbance was measured at 725 nm using a UV-vis spectrophotometer. Gallic acid (0–100 mg/mL) was used to prepare the standard curve [9].

2.6.2 Antioxidant activity by DPPH scavenging activity

The DPPH free radical was determined by using the stable 2, 2-diphenyl-1-picrylhydrazyl radical (DPPH) [10]. A solution of 50 µl of sample (of varying concentrations) was mixed with 1950 µl of 60 mM DPPH dissolved in methanol and allowed to react at room temperature in the dark for 30 min, then recorded absorbance at 517 nm. The DPPH radical scavenging activity was calculated with the calibration curve through the following equation [9].

$$\% \text{ inhibition} = ((abs1 - abs2)/abs1) \times 100$$

When abs1 was absorbance of control, abs2 was absorbance of sample

2.7 Determination of *in vitro* digestion

The analysis of *in vitro* digestion was performed following Dartois *et al*. [11] Pepsin buffer was prepared by mixing 2 g of NaCl with 14 mL of 6 M HCl, and 900 mL distilled water. pH was adjusted to 1.2 with 3 M HCl and adjusted volume to 1 L. Pepsin enzyme solution was prepared by mixing 0.12 g of pepsin (≥ 250 units/mg solid) with 25 mL pepsin buffer. Intestinal buffer was prepared by mixing 6.8 g of KH2PO4 with 250 mL water, added 77 mL of 0.2 M NaOH and 500 mL distilled water. pH was adjusted to 6.8 then adjusted the volume to 1 L. Intestinal enzyme solution was prepared by mixing 0.1 g of pancreatin (4×USP), 0.0075 g of invertase (≥ 300 units/mg solid), 2 mL of amyloglucosidase (3.260 U/mL), and 23 mL of intestinal fluid buffer.

The assay was performed according to the procedure described by Dartois *et al*. [11] for effect of different types and concentrations of matrix carrier. 170 mL of holy basil solution (2 g of holy basil powder mixed with 150 mL of water) was added to a jacketed glass reactor (500 mL capacity) and stirred at 300 rpm. The reactor jacket was connected with 37°C of water bath. The pH was adjusted to 1.2 and mixed with 19 mL of pepsin solution. After 30 min of gastric digestion, intestinal digestion was stimulated. pH was adjusted to 6.8 using 1 M NaOH then mixed with 23 mL of intestinal enzyme solution. The mixtures then were incubated at 37°C for 2 h. Aliquots (0.5 mL) was taken into 2 mL ethanol after 0 (control), 15, 30, 31, 35, 40, 45, 60, 75, 90, 105, 120, 135, and 150 min of digestion and then immediately analyzed.

For study of effect of different drying temperature, *in vitro* gastrointestinal digestion was slightly modified according to the method described by Benziea and Strain [12]. Briefly, 1 mL of each extract was mixed with saline (140 mM NaCl and 5 mM KCl containing 150 µM BHT) to create a final volume of 4.5 mL. The mixtures were mixed well and acidified with 0.1 M/1 M HCl until it reached pH 2. Then, gastric digestion was performed with the addition of 125 µL of pepsin solution (40 mg/mL of

Table 1 Effect of types and concentrations of matrix carriers on physicochemical, water activity (A_w), moisture content (MC), solubility (S), bulk density (B), particle size, and color values of holy basil powder

Treatment	A_w	MC	S	B	Particle Size	Color		
						L*	a*	b*
Control	0.216±0.001^{c}	13.52±0.05^{a}	99.02±0.01^{ab}	0.60±0.02^{a}	15.37±4.95^{c}	49.50±0.01^{g}	6.54±0.01^{a}	13.06±0.02^{g}
MD10%	0.255±0.002^{a}	5.96±0.34^{c}	99.01±0.01^{b}	0.46±0.01^{b}	17.05±7.79^{c}	62.42±0.00^{e}	5.22±0.01^{b}	17.48±0.01^{b}
MD20%	0.218±0.002^{c}	4.91±0.07^{e}	98.96±0.03^{c}	0.42±0.02^{c}	17.77±9.56^{c}	65.23±0.01^{d}	4.83±0.01^{c}	18.24±0.01^{a}
MD30%	0.174±0.001^{e}	3.75±0.02^{f}	98.97±0.02^{c}	0.41±0.01^{c}	21.52±11.74^{ab}	68.30±0.00^{a}	5.00±0.01^{d}	17.33±0.01^{c}
GA10%	0.233±0.002^{b}	5.72±0.32^{cd}	99.04±0.00^{a}	0.47±0.01^{b}	17.01±8.61^{c}	61.92±0.01^{f}	5.50±0.01^{b}	16.44±0.01^{d}
GA20%	0.210±0.006^{d}	5.17±0.11^{de}	99.03±0.02^{ab}	0.45±0.00^{b}	18.42±9.19^{bc}	65.43±0.01^{c}	4.73±0.00^{g}	14.68±0.01^{f}
GA30%	0.142±0.004^{f}	7.63±0.80^{b}	99.00±0.01^{b}	0.47±0.01^{b}	22.78±11.84^{a}	66.02±0.01^{b}	4.84±0.01^{e}	15.61±0.01^{e}

MD, Maltodextrin; GA, Gum Arabic; 10%, 20%, and 30% are concentration of matrix carrier; A_w, water activity; MC, moisture content (%dry basis); S, solubility (%); B, bulk density (g/mL); L, lightness; a and b, color-opponent dimensions. Values are expressed as means ± SD (n=3). Size, Particle size (μm). Values are expressed as means ± SD (n=60). Different superscripts letters in the same column mean significantly differences ($p < 0.05$)

0.1 M HCl) and the mixtures were placed in a shaker at 37°C for 1 h. Thereafter, the pH of the solution was adjusted to 6.9 with the addition of 0.1 M/1 M $NaHCO_3$. Further intestinal digestion was performed with the addition of 625 μL of pancreatin solution (2 mg/mL of 0.1 M $NaHCO_3$) and incubated in a shaker at 37°C for 2 h. The digesta volume was adjusted to 4 mL with saline and then immediately analyzed.

2.8 Statistical analysis

Data were expressed as means ± standard deviation. The data were also subjected to analysis of variance (ANOVA) and Duncan's multiple range tests using SPSS 16.0 for Windows. The significance level of $P < 0.05$ was considered significantly different.

3. Results and Discussion

3.1 Effect of types and concentrations of matrix carrier of holy basil powder

3.1.1 Determination of physicochemical properties

1) Moisture content and water activity

Water activity (A_w) is an important value for spray-dried powder because it affects the shelf-life of the powder product. It measures the availability of free water in a food system that is response for any biochemical reactions. All spray-dried treatments presented values of water activity lower than 0.3, indicating that they are microbiological stable or these is no microbial growth below this values [13]. From Table 1, different matrix carrier concentration at the same inlet temperature significantly affected to water activity ($p < 0.05$). Increasing of matrix carrier (MD and GA) concentration significant decreased A_w ($p < 0.05$). Daza *et al*. [4] reported matrix carrier concentration had a negative effect on water activity of powders obtained with MD and GA which are higher concentration, lower the water activity.

Moisture content represents the water composition in food system. Low moisture content prevents the agglomeration of particles avoiding the caking of powder which is reduce retention of

active component and other properties example for flow and dispersion of powders [14]. The results showed that increasing of MD or GA concentration significantly decreased moisture content compared to the control ($p < 0.05$) because the addition of MD or GA to the feed increased the total solid content and reduces amount of water of evaporation [14].

2) Solubility

Solubility refers to the ability of powders to form solution in water which effect on powder's functional properties in food system [15]. As presented in Table 1, solubility values ranged from 98.96 to 99.01% in the extracts obtained from MD, and 99.00 to 99.04% in those obtained from GA due to both carrier agents are highly soluble in water [15]. Although, the higher concentration of matrix carriers significant decreased solubility, but all values of solubility still showed in great ability. However, Grabowski *et al*. [16] reported that addition of matrix carrier to sage extracts and increasing concentrations of matrix carriers increase solubility.

3) Bulk density

Bulk density is important in term of functional and economic. The effect of the different carriers on the bulk density of the holy basil was shown in Table 1. Control samples showed the highest bulk density compared to the other treatments. There was significantly decreased when increase concentration of MD ($p < 0.05$), while GA level did not show significant effect on bulk density of holy basil powder (≥ 0.05). Moreover, average particle size of control treatment had lowest, followed by concentration 10%, 20%, and 30% of both matrix carriers. Jinapong *et al*. [17] revealed that size of particle will be increased when amount of total solid content increased. Similar result was studied by Goula *et al*. [18], tomato and pineapple pulp were spray-dried by using maltodextrin as matrix carrier. They stated that increasing of the particle size when the concentration increased. The lowest bulk density was observed with GA which may relate to the structure on the powder.

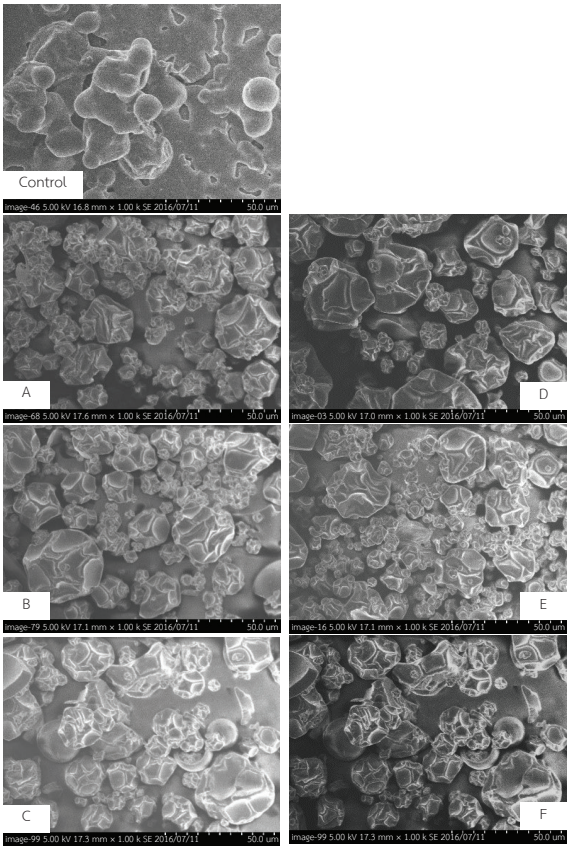

Figure 1 Scanning electron microscopy images (×1000) of spray-died holy basil powders at 140°C (Control; A, 10%MD; B, 20%MD; C, 30%MD; D, 10%GA; E, 20%GA; F, 30%GA).

4) Particle size

The morphology of control sample was a spherical shape (Figure 1), but it was quite packed together because it has high moisture content. The

powder coated with MD and GA was not spherical, but crumbly due to the matrix carrier. At higher concentration of each matrix carrier, the powder had larger particles size that it was less densely packed. Rajabi *et al*. [19] reported increasing of matrix carriers resulted in larger particle sizes so the viscosity of feed increased with total solid concentration.

5) Color

Table 1 showed lightness (L*) of samples was influenced by concentration of matrix carrier agents ($p < 0.05$). Increasing of carrier concentration increased L* value compared to the control ($p < 0.05$) because of the dilution effect [20]. Using GA as matrix carrier gave the lower lightness compared to MD because original color of GA was cream not white color as MD due to GA includes different sugars along with arabinogalacto-protein complex [21]. Increasing of carrier concentration decreased a* value of the powder ($p < 0.05$). In general, the lower values of parameter a* were found at higher concentrations of carrier agent, because an increase in the ratio carrier-sample led to a dilution of material. Also extract water was a deep dark purple brown, it might cause decreasing of a* value [3].

3.1.2 Determination of bioactive compounds

Figure 2 and Figure 3 expressed that total phenolic content and DPPH radical scavenging activity of holy basil powder significant decreased when encapsulated with MD and GA compared to the control ($p < 0.05$) because the amount of bioactive compounds affected by concentration of matrix carrier. The holy basil powder encapsulated with 10% concentration had significant higher amount of retention than 20 and 30% concentration ($p < 0.05$).

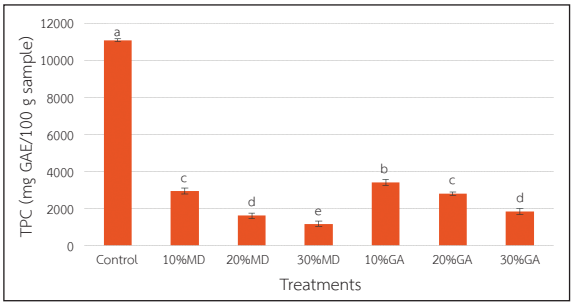

Figure 2 Total phenolic content of holy basil powder from different types and concentrations of matrix carrier. Values are expressed as means ± SD (n=3). Different superscripts letters mean significantly differences ($p < 0.05$).

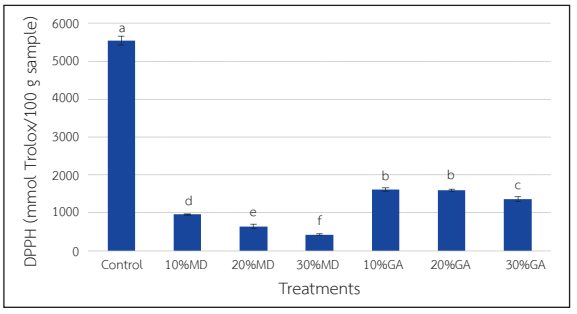

Figure 3 DPPH of holy basil powder from different types and concentrations of matrix carrier. Values are expressed as means ± SD (n=3). Different superscripts letters mean significantly differences ($p < 0.05$).

In addition, powder encapsulated with GA had higher retention than MD. The powders with high concentration of matrix carrier (both MD and GA) decreased retention of bioactive compounds may be from the dilution effect of carrier. According to study of Mishra *et al*. [9], powders with 5% concentration of carrier had higher antioxidant activity than powders with 7 and 9% of carrier. When comparing

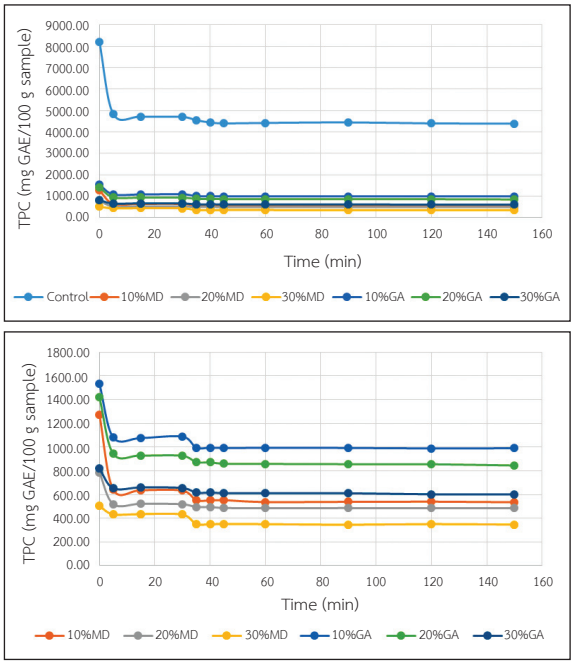

Figure 4 The change of total phenolic content during *in vitro* digestion.

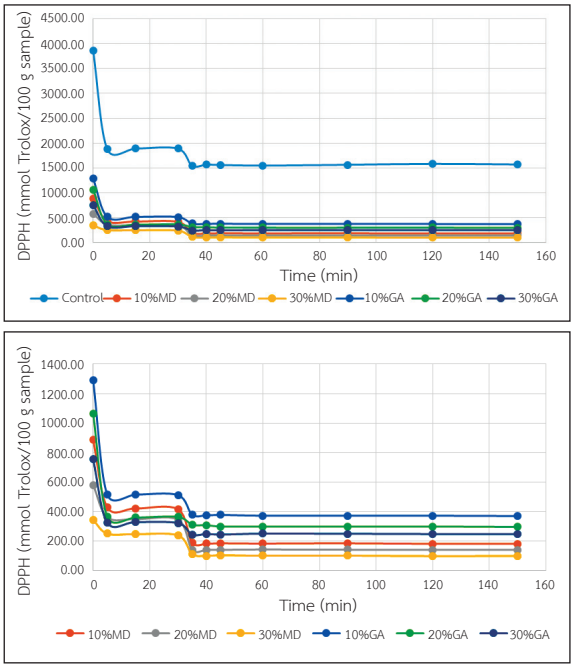

Figure 5 The change of DPPH radical scavenging activity during *in vitro* digestion.

between two types of matrix carriers at same concentration, MD retained bioactive compounds less than GA significantly ($p < 0.05$).

3.1.3 Determination of *in vitro* digestion

Figure 4 showed total phenolic content of all samples during gastric digestion (0–30 min) higher than intestinal digestion. This finding was similar to study of Kamiloglu *et al*. [22] who reported the phenolic content of black carrot jams and marmalades with different storage conditions and processing after *in vitro* digestion in gastric digestion has significantly higher than intestinal digestion. It could be explained that acidic condition can effect to the enzyme activity which extracted the phenolic compounds in holy basil powder from the matrix carrier. In gastric condition, the phenolic compounds may be altered the activity or reaction with other compounds that may occurred, and changed in chemical structure, composition, and concentration of water-soluble compounds such as increased or reduced their solubility [23]. Decreasing of bioactive compounds in small intestinal phase may be from instability of some phenolic compounds in alkaline condition and related to the complex formation between phenolic compounds and dietary constituents [24].

Figure 5 showed DPPH value of all samples higher in gastric phase and decreased in intestinal digestion similar to total phenolic content. Due to main phenolic substance in holy basil is flavonoids (orientin, vicenin, and luteolin) which has an antioxidant property, so the free radical scavenging activity will follow the total phenolic content. In addition, the antioxidant activity was depended on

Table 2 Effect of inlet temperature on physicochemical of spray-dryer on physicochemical, water activity (A_w), moisture content (MC), solubility (S), bulk density (B), particle size, and color values of holy basil powder

Temperature (°C)	A_w	MC	S	B	Particle Size	Color		
						L*	a*	b*
140	0.152±0.01^{a}	3.24±0.16^{a}	98.98±0.07^{a}	0.47±0.01^{ab}	19.32±8.20^{a}	55.49±0.02^{a}	7.05±0.01^{c}	9.33±0.02^{a}
160	0.156±0.00^{a}	3.07±0.13^{a}	98.99±0.00^{a}	0.49±0.01^{a}	17.81±6.07^{b}	51.84±0.26^{b}	8.27±0.07^{b}	8.69±0.02^{b}
180	0.110±0.03^{b}	2.56±0.18^{b}	99.00±0.01^{a}	0.46±0.01^{b}	12.45±6.09^{c}	49.69±0.01^{c}	8.69±0.02^{a}	8.64±0.02^{c}

A_w, water activity; MC, moisture content (%dry basis); S, solubility (%); B, bulk density (g/mL); L, lightness; a and b, color-opponent dimensions. Values are expressed as means ± SD (n=3). Size, Particle size (μm). Values are expressed as means ± SD (n=60). Different superscripts letters in the same column mean significantly differences ($p < 0.05$)

composition and concentration of its antioxidants, mainly is phenolic compounds [24]. Antioxidants probably modified their reaction during the digestion process due to the change of pH.

Therefore, holy basil powder encapsulated with 10% GA was the best treatment and was selected for the next experiment.

3.2 Effect of inlet temperature of holy basil powder

3.2.1 Determination of physicochemical properties

1) Moisture content and water activity

Table 2 showed that inlet temperature at 180°C significant effect on water activity and moisture content of holy basil powder compared to the other treatments ($p < 0.05$). At higher inlet temperature cause decreasing of moisture content; higher heat transfer to particle, then showed the greater driving force for water evaporation. Daza *et al*. [4] reported decreasing in moisture content and water activity were cause from higher inlet temperature in spray-drying process.

2) Solubility

Table 2 showed that increasing of inlet temperature did not affect to solubility of holy basil powder compared to each treatments ($p \geq 0.05$). Effect of inlet temperature on solubility depends on its moisture content which low moisture content was made faster dissolution [18].

3) Bulk density

Table 2 showed that at 180°C significantly effect on bulk density of holy basil powder compared to the other treatments ($p < 0.05$). Lower bulk density (at 180°C) cause from higher inlet temperature remove water out rapidly, then given very fine droplet and shrinkage of powder [9].

4) Particle size

Particle size of holy basil powders in Table 2 and Figure 6 showed that higher inlet temperature significantly decreased particle size of powder ($p < 0.05$). Similar resulted of Rajabi *et al*. [19] reported higher temperature in the process was made droplets very fine leads to rapid remove water out from its particle, which cause wrinkles and shrinkage on surfaces.

5) Color

Increasing of inlet temperature significantly decreased lightness and yellowness of holy basil powder compared to the control, however a redness;

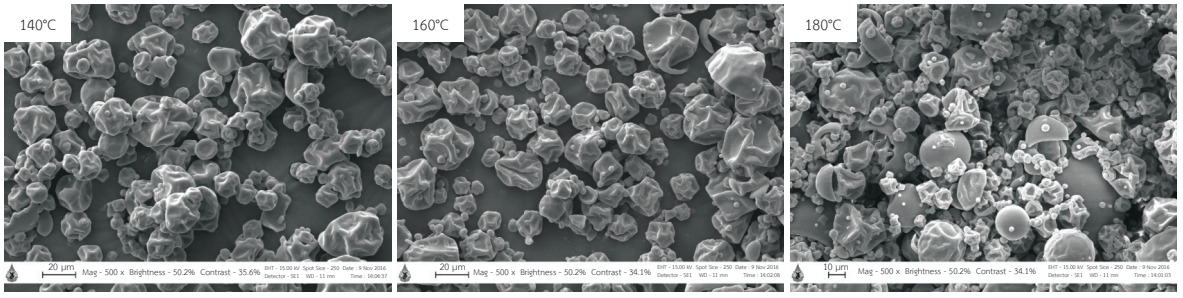

Figure 6 Scanning electron microscopy images (×500) of spray-died holy basil powders at 140, 160, and 180°C, respectively.

a*, of the powders increased when temperature increased ($p < 0.05$). According to Sahin-Nadeem *et al*. [15] reported redness of sage increased when increase inlet temperature due to its lightness was decreased which they explained water soluble melanoidins as non-enzymatic browning reaction occurred during spray drying process.

3.2.2 Determination of bioactive compounds

Figure 7 and 8 showed TPC and DPPH of powders at different inlet temperatures. At 180°C of inlet temperature significantly decreased phenolic content and antioxidant activity than at 160°C and 140°C, respectively ($p < 0.05$) due to phenolic compounds and antioxidants are unstable at high temperature, and it may loss during spray-dried process. Similar to Mishra *et al*. [9] reported that antioxidant activity decreased while inlet temperature increased due to the bioactive compounds which exposure to high temperature were break down or synthesis to other forms.

3.2.3 Determination of *in vitro* digestion

The sample from 140°C inlet temperature showed highest retention of total phenolic compounds and antioxidants activity when compared with higher inlet temperature at 160°C and 180°C ($p < 0.05$) (Figure 9 and 10). The study of heat treatment

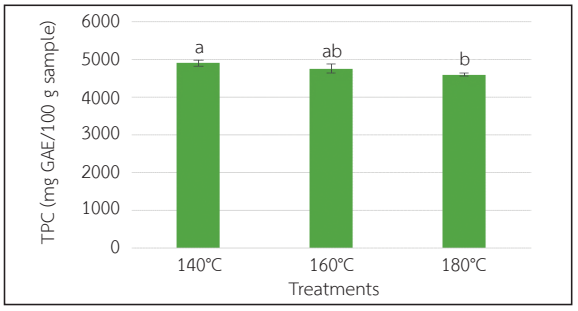

Figure 7 Total phenolic content of holy basil powder from different types and concentrations of matrix carrier. Values are expressed as means ± SD (n=3). Different superscripts letters mean significantly differences ($p < 0.05$).

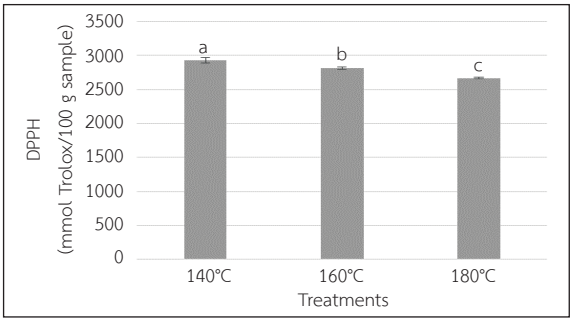

Figure 8 DPPH of holy basil powder from different types and concentrations of matrix carrier. Values are expressed as means ± SD (n=3). Different superscripts letters mean significantly differences ($p < 0.05$).

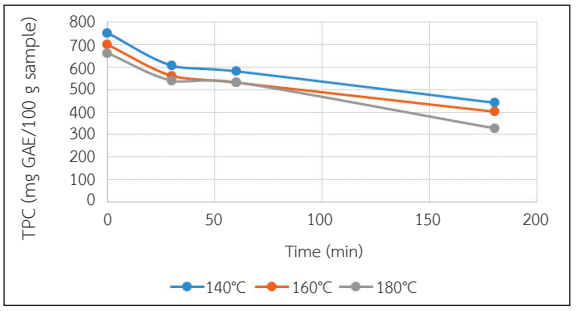

Figure 9 The change of total phenolic content during *in vitro* digestion.

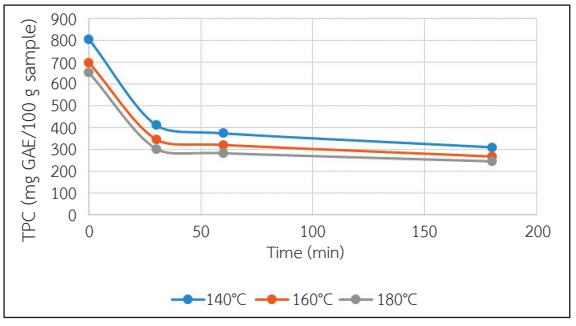

Figure 10 The change of DPPH radical scavenging activity during *in vitro* digestion.

affected to the bioavailability that it may break down the carrier in gastric phase, however phenolic compounds and antioxidants are highly sensitive to alkaline condition caused the decreasing of TPC and DPPH in intestinal phase [25].

4. Conclusion

The study showed that the best condition of encapsulated holy basil powder by spray drying was using 10% gum arabic at 140°C inlet temperature.

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References

[1] M. Baseer and K. Jain, "Review of botany, phytochemistry, pharmacology, contemporary applications and toxicology of *ocimum sanctum*," *International Journal of Pharmacy & Life Sciences*, vol. 7, no. 2, pp. 4918–4929, 2016.

[2] F. Aqil, L. Ahmad, and Z. Mehmood, "Antioxidant and free radical scavenging properties of twelve traditionally used Indian medicinal plants," *Turkish Journal of Biology*, vol. 30, pp. 177–183, 2006.

[3] A. Wilkowska, W. Ambroziak, J. Adamiec, and A. Czyzowska, "Preservation of antioxidant activity and polyphenols in chokeberry juice and wine with the use of microencapsulation," *Journal of Food Processing and Preservation*, vol. 41, no.3, 2016.

[4] L. D. Daza, A. Fujita, C. S. F. Trindade, J. N. R. Ract, D. Granatod, and M. I. Genovesea, "Effect of spray drying conditions on the physical properties of Cagaita (Eugenia dysenterica DC.) fruit extracts," *Food and Bioproducts Processing*, vol. 97, pp. 20–29, 2016.

[5] M. M. Kenyon and R. J. Anderson, " Maltodextrins and low-dextrose-equivalence corn syrup solids," *ACS Symposium Series*, vol. 370, no. 2, pp. 7–11, 1988.

[6] F. Shihidi and X. Q. Han, "Encapsulation of food ingredients," *Food Science and Nutrition*, vol. 33, pp. 501–542, 1993.

[7] P. A. Williams and G. O. Phillips. in *Handbook of Hydrocolloids*, CRC Press: Cambridge, 2000, pp. 155–168.

[8] L. D. A. M. Arawwawala, H. G. S. P. Hewageegana, L. S. R. Arambewela, and H. S. Ariyawansa,

"Standardization of spray-dried powder of Piper betle hot water extract," *Pharmacognosy Magazine*, vol. 7, no. 26, pp. 157–160, 2010.

[9] P. Mishra, S. Mishra, and C. L. Mahanta, "Effect of maltodextrin concentration and inlet temperature during spray drying on physicochemical and antioxidant properties of amla (Emblica officinalis) juice powder," *Food and Bioproducts Processing*, vol. 92, pp. 252–258, 2014.

[10] G. Singh, A. K. Passsari, V. V. Leo, V. K. Mishra, S. Subbarayan, B. P. Singh, B. Kumar, and S. Kumar, "Evaluation of phenolic contentvariability along with antioxidant, antimicrobial, and cytotoxicpotential of selected traditional medicinal plants from india," *Frontiers in Plant Science*, vol. 7, pp. 1–12, 2016.

[11] A. Dartois, J. Singh, L. Kaur, and H. Singh, "Influence of guar gum on the in vitro starch digestibility—rheological and microstructural characteristics," *Food Biophysics*, vol. 10, pp. 149–160, 2010.

[12] F. F. Benziea and J. J. Strain, "The ferric reducing ability of plasma (FRAP) as a measure of Antioxidant power: The FRAP assay," *Analytical biochemistry*, vol. 239, no. 1, pp. 70–76, 1996.

[13] D. S. Reid, K. L. Parkin, and O. R. Fennema, *Química de Alimentos de FENNEMA*. Artmed, Porto Alegre, pp. 25–74, 2010.

[14] F. C. da Silva, C. R. da Fonseca, S. M. de Alencar, M. Thomazini, J. C. Balieiro, P. Pittia, and C. S. Favaro-Trindade, "Assessment of production efficiency, physicochemical properties and storage stability of spray-dried propolis, a natural food additive, using gum Arabic and OSA starch-based carrier systems," *Food and Bioproducts Processing*, vol. 91, no. 1, pp. 28–36, 2013.

[15] H. Sahin-Nadeem, C. Dinçer, M. Torun, A. Topuz, and F. Özdemir, "Influence of inlet air temperature and cerrier material on the production of instant soluble sage (Salvia fruticosa Miller) by spray drying," *LWT - Food Science and Technology*, vol. 52, no.1, pp. 31–38, 2013.

[16] J. A. Grabowski, V. D. Truong, and C. R. Daubert, "Nutritional and rheological characterization of spray dried sweet potato powder," *LWT - Food Science and Technology*, vol. 41, pp. 206–216, 2008.

[17] N. Jinapong, M. Suphantharika, and P. Jamnong, "Production of instant soymilk powders by ultrafiltration, spray drying and fluidized bed agglomeration," *Journal of Food Engineering*, vol. 84, no. 2, pp. 194–205, 2008.

[18] A. M. Goula, K. G. Adamopoulous, and N. A. Kazakis, "Influence of spray drying conditions on tomato powder properties," *Drying Technology*, vol. 22, no. 5, pp. 1129–1151, 2004.

[19] H. Rajabi, M. Ghorbani, S. M. Jafari, A. S. Mahoonak, and G. Rajabzadeh, "Retention of saffron bioactive components by spray drying encapsulation using maltodextrin, gum Arabic and gelatin as wall materials," *Food Hydrocolloids*, vol. 51, pp. 327–337, 2015.

[20] T. A. Comunian, E. S. Monterrey-Quintero, M. Thomazini, J. C. Balieiro, P. Piccone, P. Pittia, and C. S. avaro-Trindade, "Assessment of production efficiency, physicochemical properties and storage stability of spray-dried chlorophyllide, a natural food colourant, using gum Arabic, Maltodextrin and soy protein isolated-based

carrier systems," *Food Science and Technology*, vol. 46, no. 6, pp. 1259–1265, 2011.

[21] T. Mahengdran, P. A. Williams, G. O. Philips, S. Al-Assaf, and T. C. Baldwin, "New insights into the structural characteristics of the arabinogalactan - protein (AGP) fraction of gum Arabic," *Agricultural and Food Chemistry*, vol. 56, no. 19, pp. 9269–9276, 2008.

[22] S. Kamiloglu, A. A. Pasli, B. Ozcelik, J. V. Camp, and E. Capanpglu, "Colour retention, anthocyanin stability and antioxidant capacity in black carrot (Daucus carota) jams and marmalades: Effect of processing, storage conditions and in vitro gastrointestinal digestion," *Functional foods*, vol. 13, pp. 1–10, 2015.

[23] R. L. Gonzalez, S. N. Coves, J. A. P. Alvarez, J. F. Lopez, L. V. Munoz, and M. V. Martos, "Assessment of polyphenolic profile stability and changes in the antioxidant potential of maqui berry (*Aristotelia chilensis* (Molina) Stuntz) during in vitro gastrointestinal digestion," *Industrial Crops and Products*, vol. 94, pp. 774–782, 2016.

[24] B. Gullon, M. E. Pintado, J. F. Lopez, J. A. P. Alvarez, and M. V. Martos, "In vitro gastrointestinal digestion of pomegranate (*punica granantum*) flour obtained from co-products: Change in the antioxidant potential and bioactive compounds stability," *Journal of Functional Foods*, vol. 19, pp. 617–628, 2015.

[25] M. G. Ozgüven I. Berktas, and B. Ozcelik, "Change in stability of procyanidins, antioxidant capacity and in-vitro bioaccessibility during processing of cocoa powder from cocoa beans," *Food Science and Technology*, vol. 72, pp. 559–565, 2016.