

## Optimum Condition of Beta-Cyanin Colorant Production from Red Dragon Fruit (*Hylocercus polyrhizus*) Peels using Response Surface Methodology

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### ABSTRACT

*The extraction and drying processes used to produce red colorant from red dragon fruit peels were optimized to yield the highest beta-cyanin content. The types of solvents (deionized water and 80% ethanol), pH, extraction time and temperature were the independent variables in the extraction process. The amount of binding medium (acetylated oxidized starch and maltodextrin) and extract, inlet temperature and feed rate were the independent variables in the spray-drying process. Based on response surface methodology, Box-Behnken and full factorial designs were used for the experiment, while beta-cyanin was determined as the response. Antioxidant activity of the colorant powder was also tested. The optimum extraction condition giving the highest beta-cyanin content was a pH of 5.5 at 40°C for 20 min extracted by deionized water. The optimum drying condition for the production of red colorant powder was 6% binding medium at a feed rate of 6 ml/min and an inlet temperature of 140 and 160°C for acetylated oxidized starch and maltodextrin, respectively. The experimental results following the response surface methodology corresponded well to the predicted values. The optimum drying conditions yielded a red colorant powder with antioxidant properties that could be used in food products.*

**Keywords:** Beta-cyanin, Spray drying, Extraction, Red dragon fruit, Optimum condition

### INTRODUCTION

Peels from red flesh dragon fruit (*Hylocereus polyrhizus*), a byproduct of consumption, are potentially useful to the food colorant industry because of an abundance of betalains, with their red shades of color. Betalains are composed of beta-cyanins and betaxanthins compounds, which have red and yellow color, respectively. The beta-cyanins are more abundant than the betaxanthins in betalains (Harivaindaran et al., 2008). Betalains are an antioxidant, like anthocyanins, that can dissolve in water, but are very sensitive to pH and heat (Wybraniec and Mizrahi, 2002; Wu et al., 2006). Thus, the extraction process of betalains is important to maintaining the stability of sensitive pigments, such as beta-cyanins.

Encapsulation of these pigments by spray drying has been used to produce and stabilize the colorants, because of its ability to yield a powder that preserves the pigments. The colorants obtained from spray drying are of good quality – low water activity, color stability, high antioxidant activity and lower cost (Cai and Corke, 2000; Gharsallaoui et al., 2007). However, a ratio of binding medium such as maltodextrin (MD) to beta-cyanin extract in spray drying had the largest effect on the yield of beta-cyanin colorants from beet roots. The more maltodextrin added, the less beta-cyanin content in the powder (Azeredo et al., 2007). In addition, the interaction between lower and higher dextrose equivalent maltodextrins as binding medium seemed to retard the degradation of beta-cyanin color (Cai and Corke, 2000).

Acetylated oxidized starch (AOS) is the other high potential binding medium used in spray-drying encapsulation. Acetylated oxidized starch is a chemically modified starch preventing an association of amylopectin and amylose, resulting in less retrogradation when it is cooled or stored (Apeldoorn et al., 2001). These attributes of acetylated oxidized starch are suitable for food or flavor microencapsulation in order to prevent oxidation. However, no one has reported using acetylated oxidized starch as a binding medium in spray-dry encapsulation.

Response surface methodology has been demonstrated to be a useful tool for optimization in food innovation production. However, to our knowledge, there is no information about the optimum condition of beta-cyanin colorant production from peels of red dragon fruit, a waste product of fresh consumption. The main objective of this study was to optimize the extraction and drying parameters for yielding beta-cyanin from red dragon fruit peels and to determine the antioxidant activity of the resultant natural red. The results of this study would be useful in developing a novel and natural colorant powder as a functional food colorant that could potentially replace synthetic food colorants.

## MATERIALS AND METHODS

### Materials

Fresh red dragon fruits were purchased from farms in Nakhon Ratchasima Province in northeastern Thailand. Acetylated oxidized starch and maltodextrin were obtained from Siam Modified Starch Inc., Thailand. All chemicals used were of analytical grade.

### Preparation of dragon fruit peels

The peels of fresh dragon fruits were washed and used as materials to produce the beta-cyanin extract. The peels were cut into 3x3 cm<sup>2</sup> and then dried in a tray dryer (tray dryer, TD372, New Way Manufacturing Co., Ltd., Thailand) at 55°C for 24 hr. The dried peels were ground and stored in sealed laminated plastic bags at -20°C before use.

### **Optimization condition of beta-cyanin extraction in dragon fruit peels**

Dragon fruit peels were extracted in deionized water (DI water) or 80% ethanol (EtOH) by varying the extract pH (X1) adjusted by 1M citric acid and 2M NaOH(aq), extraction temperature (X2) and duration of extraction (X3). The ratio of peels to extraction solvent was fixed at 6 g to 200 ml, respectively. The mixes were made homogeneous by Vertex (Vortex-Genic1 Touch Mixer, Scientific Industries, Inc., USA) and centrifuged (Legand Mach 1.6R, Sorvall, Germany) at 10000xg, 4°C for 20 min. The supernatant after extraction was volumetrically adjusted to 200 ml with solvents before analyzing the beta-cyanin content. The experimental design was Box-Behnken with 15 treatments (Table 1). The extract condition with the highest beta-cyanin content was selected to be the optimum condition for extraction calculated and analyzed by response surface methodology.

### **Optimization condition of beta-cyanin colorant powder production**

The extract that provided the highest beta-cyanin content from the extraction process was mixed with acetylated oxidized starch or maltodextrin as a binding medium in different ratios (Y1). The mixes were homogenized at 5,000 rpm for 10 min by single stage homogenizer (Homogenizer T50L, Sciencelab.com, Inc., USA). For spray drying, inlet temperature (Y2) and feed flow rate (Y3) were also varied following 23 Factorial designs (Table 2). The optimum condition of spray drying that provided the highest beta-cyanin content in the colorant powders was determined and analyzed by response surface methodology.

### **Analysis of beta-cyanin content**

Beta-cyanin content in the extract and in the colorant powders were analyzed following methods of Wu et al. (2006) and Cai and Corke (2000), respectively. The absorbance expressed at 537 nm was measured by spectrophotometer (Spectrophotometer UV-vis, Libra S22, Biochrom, UK).

### **Determination of total phenolic content**

The total phenolic content in the extract and colorant powders was determined using the Folin-Ciocalteu method following Bae and Suh (2007). The absorbance was measured at 750 nm. Gallic acid was used as a reference standard and the results were expressed as milligram gallic acid equivalent (mg GAE)/L of extract and (mg/100 dry basis) of powder.

### **Antioxidant activity and reducing power of dragon fruit peel extract DPPH• radical scavenging activity**

The 1,1-diphenyl-2-picrylhydrazyl radical scavenging activity (DPPH•) of the colorant powders was analyzed following Wu et al. (2006). McIlvaine buffer (pH 5.6) and DPPH solution were used in this study. The absorbance was measured at 515 nm using UV-Vis spectrophotometer. Ethanol (80%) was used as a blank solution and DPPH solution without test samples (3.9 ml of DPPH with 0.1 ml of 80% ethanol) accounted as the control.

**Table 1.** Beta-cyanin content and total phenolic compounds in the extract of red dragon fruit peels in different extraction conditions.

Treatment	pH	Temp (°C)	Time (min)	Beta-cyanin (mg/g dry sample)		Total polyphenols (mg/100 gdry sample)	
				80%EtOH	DI water	80%EtOH	DI water
1	5.0 (0)	40 (-1)	20 (-1)	11.83 ± 1.05 <sup>B, f</sup>	143.66 ± 5.95 <sup>A, abc</sup>	434.53 ± 8.45 <sup>A, g</sup>	358.73 ± 3.68 <sup>B, c</sup>
2	5.0 (0)	85 (+1)	20 (-1)	42.62 ± 1.87 <sup>B, c</sup>	131.98 ± 12.30 <sup>A, de</sup>	517.74 ± 17.78 <sup>A, bc</sup>	388.46 ± 5.70 <sup>B, ab</sup>
3	5.0 (0)	40 (-1)	60 (+1)	8.73 ± 0.26 <sup>B, h</sup>	147.14 ± 2.96 <sup>A, ab</sup>	431.02 ± 15.61 <sup>A, g</sup>	337.84 ± 5.83 <sup>B, e</sup>
4	5.0 (0)	85 (+1)	60 (+1)	33.92 ± 1.30 <sup>B, d</sup>	126.78 ± 3.05 <sup>A, e</sup>	556.95 ± 7.31 <sup>A, a</sup>	390.85 ± 14.72 <sup>B, ab</sup>
5	4.5 (-1)	40 (-1)	40 (0)	10.26 ± 0.57 <sup>B, g</sup>	147.81 ± 2.00 <sup>A, ab</sup>	462.05 ± 22.91 <sup>A, ef</sup>	353.41 ± 10.68 <sup>B, cd</sup>
6	4.5 (-1)	85 (+1)	40 (0)	55.48 ± 0.89 <sup>B, b</sup>	131.78 ± 2.91 <sup>A, de</sup>	512.47 ± 15.23 <sup>B, c</sup>	400.06 ± 23.17 <sup>B, a</sup>
7	5.5 (+1)	40 (-1)	40 (0)	9.73 ± 0.22 <sup>B, gh</sup>	149.11 ± 1.59 <sup>A, a</sup>	434.60 ± 11.03 <sup>A, g</sup>	360.82 ± 19.93 <sup>B, c</sup>
8	5.5 (+1)	85 (+1)	40 (0)	60.47 ± 1.62 <sup>B, a</sup>	118.79 ± 14.55 <sup>A, f</sup>	535.02 ± 29.71 <sup>A, b</sup>	357.84 ± 5.06 <sup>B, c</sup>
9	4.5 (-1)	60 (0)	20 (-1)	12.67 ± 2.17 <sup>B, f</sup>	141.55 ± 2.02 <sup>A, abc</sup>	444.28 ± 31.49 <sup>A, fg</sup>	381.09 ± 4.46 <sup>B, b</sup>
10	4.5 (-1)	60 (0)	60 (+1)	15.80 ± 0.54 <sup>B, e</sup>	140.43 ± 2.92 <sup>A, bc</sup>	442.61 ± 12.12 <sup>A, fg</sup>	392.31 ± 3.72 <sup>B, ab</sup>
11	5.5 (+1)	60 (0)	20 (-1)	9.21 ± 0.33 <sup>B, gh</sup>	147.18 ± 3.97 <sup>A, ab</sup>	436.06 ± 9.97 <sup>A, g</sup>	348.82 ± 20.86 <sup>B, cde</sup>
12	5.5 (+1)	60 (0)	60 (+1)	16.13 ± 1.42 <sup>B, e</sup>	137.94 ± 2.28 <sup>A, cd</sup>	430.39 ± 8.09 <sup>A, g</sup>	341.75 ± 4.63 <sup>B, de</sup>
13	5.0 (0)	60 (0)	40 (0)	15.95 ± 0.47 <sup>B, e</sup>	146.18 ± 1.41 <sup>A, ab</sup>	482.01 ± 7.86 <sup>A, de</sup>	353.75 ± 10.02 <sup>B, cd</sup>
14	5.0 (0)	60 (0)	40 (0)	16.01 ± 0.56 <sup>B, e</sup>	141.59 ± 4.51 <sup>A, abc</sup>	483.88 ± 10.60 <sup>A, d</sup>	350.30 ± 6.79 <sup>B, cde</sup>
15	5.0 (0)	60 (0)	40 (0)	16.03 ± 0.28 <sup>B, e</sup>	143.70 ± 1.83 <sup>A, abc</sup>	434.75 ± 29.28 <sup>A, g</sup>	342.10 ± 7.58 <sup>B, de</sup>

Note: Least significant difference with capital letter for comparison of means in the same row. Least significant difference with small letter for comparison of means in the same column.

**Table2.** Beta-cyanin content and total phenols of colorant powders with different spray-drying conditions.

Treatment	MS:Extract (%w/w)	Inlet Temp (C)	Feed flow rate (ml/min)	Beta-cyanin (mg/g dry sample)		Total polyphenols (mg/100g dry sample)	
				MD	AOS	MD	AOS
1	8 (+1)	160 (+1)	6 (-1)	52.53 ± 1.55 <sup>ns, c</sup>	51.63 ± 0.95 <sup>ns, d</sup>	545.82 ± 23.11 <sup>ns, f</sup>	529.62 ± 41.95 <sup>ns, d</sup>
2	8 (+1)	140 (-1)	6 (-1)	53.59 ± 1.08 <sup>B, c</sup>	54.91 ± 0.63 <sup>A, c</sup>	552.68 ± 24.20 <sup>ns, ef</sup>	545.86 ± 37.34 <sup>ns, cd</sup>
3	6 (-1)	160 (+1)	6 (-1)	69.12 ± 0.44 <sup>A, a</sup>	66.28 ± 1.58 <sup>B, b</sup>	742.90 ± 23.41 <sup>A, a</sup>	658.75 ± 24.31 <sup>B, a</sup>
4	8 (+1)	160 (+1)	12 (+1)	54.47 ± 1.18 <sup>ns, c</sup>	54.49 ± 0.83 <sup>ns, c</sup>	594.58 ± 22.82 <sup>ns, d</sup>	572.09 ± 50.71 <sup>ns, bc</sup>
5	6 (-1)	140 (-1)	12 (+1)	64.65 ± 2.17 <sup>B, b</sup>	66.90 ± 0.18 <sup>A, ab</sup>	712.26 ± 30.29 <sup>A, b</sup>	673.30 ± 18.02 <sup>B, a</sup>
6	8 (+1)	140 (-1)	12 (+1)	54.22 ± 1.72 <sup>A, c</sup>	50.72 ± 0.99 <sup>B, d</sup>	572.41 ± 16.90 <sup>ns, e</sup>	585.70 ± 37.53 <sup>ns, b</sup>
7	6 (-1)	160 (+1)	12 (+1)	68.23 ± 2.72 <sup>ns, a</sup>	66.88 ± 1.63 <sup>ns, ab</sup>	683.62 ± 21.18 <sup>ns, c</sup>	696.91 ± 60.47 <sup>ns, a</sup>
8	6 (-1)	140 (-1)	6 (-1)	64.85 ± 0.30 <sup>B, b</sup>	68.31 ± 1.72 <sup>A, a</sup>	715.22 ± 29.41 <sup>ns, b</sup>	686.98 ± 49.05 <sup>ns, a</sup>

Note: Least significant difference with capital letter for comparison of means in the same row. Least significant difference with small letter for comparison of means in the same column. ns means not significant.

**Table 3.** Antioxidant activity of colorant powders.

Samples/standard	ABTS.+ (IC50)	DPPH. (IC50)	FRAP (mmol Fe2+/100 g)
Dragon fruit peel extract with AOS	6.20 ± 0.87 <sup>a</sup> (mg GAE/100 ml)	11.52 ± 0.46 <sup>a</sup> (mg GAE/100 ml)	1.26 ± 0.32 <sup>b</sup>
Dragon fruit peel extract with MD	5.63 ± 0.94 <sup>a</sup> (mg GAE/100 ml)	11.24 ± 1.57 <sup>a</sup> (mg GAE/100 ml)	1.31 ± 0.41 <sup>b</sup>
Ascorbic acid	4.44 ± 0.24 <sup>b</sup> (mg/100 ml)	4.94 ± 0.45 <sup>b</sup> (mg/100 ml)	1,280.93 ± 15.84 <sup>a</sup>

Note: Least significant difference with capital letter for comparison of means in the same row. Least significant difference with small letter for comparison of means in the same column.

### ABTS•+ assay

The 2,2'-azino-bis (3-ethylbenzothiazoline-6-sulphonic acid) assay (ABTS•+) was modified from Wu et al. (2006). Concisely, a colorant powder (in grams) was diluted 100 X with the ABTS•+ solution to a total volume of 1 ml and allowed to react for 6 min. Five different concentrations at 5 to 40 mg/ml were determined. Absorbance was measured at 734 nm with different time intervals by UV-Vis spectrophotometer. The percentage inhibition was calculated against a control used as blank and 990 µl of PBS were added to these control samples instead.

### Ferric-ion reducing antioxidant power (FRAP)

The analytical measurement of FRAP was determined using a modified method of Wootton-Beard et al. (2010). FRAP reagent was prepared from 300 mM acetate and glacial acetic acid buffer (pH 3.6), 20 mM ferric chloride and 10 mM 4,6-tripyridyls-triazine (TPTZ) in 40 mM HCl. These solutions were mixed together in the ratio of 10:1:1. The FRAP assay was completed by warming 1 ml of deionized water to 37°C before adding 25 µl of sample solution and 1 ml of reagent and then incubating at 37°C for 4 min. The sample solution was prepared by dissolving 1.0 g of colorant powder with McIlvaine buffer (pH 5.6). The determination was expressed as the absorbance at 593 nm. The total antioxidant capacity of samples was determined against a standard (1000 µM ferrous sulphate) of known FRAP value.

### Statistical analysis

Analysis of variance and mean difference test were performed using Duncan's New Multiple Range Test (DMRT) (SPSS version 12.0, SPSS Inc., Illinois, USA). Response surface methodology was performed using Design-Expert version 8 (Stat-Ease Inc., Minneapolis, USA). Each experiment was run in three replicates of each sample. A probability of 5% or less was accepted as statistically significant.

## RESULTS

### Optimum extracting condition of red dragon fruit peel extract

Extraction conditions of red dragon fruit peels for beta-cyanins and total phenols are shown in Table 1. Beta-cyanin content in the peel extract with deionized water was significantly higher than that extracted by EtOH ( $p < 0.05$ ).

However, from using response surface methodology with stepwise regression analysis, we found that the condition of beta-cyanin extract followed equation 1 ( $R^2 = 0.6856$ ):

$$\begin{aligned} \text{Beta-cyanin content (mg/g dry sample)} = & \\ & -6.09015 + 26.44521X_1 + 2.52394X_2 + 1.21725X_3 \\ & - 0.33408X_1X_2 - 0.20307X_1X_3 - 4.52680 \times 10^{-3}X_2X_3 - 8.86370 \times 10^{-3}X_2^2 \dots \dots \dots \end{aligned} \tag{1}$$

Equation 1 was differentiated to obtain the optimum condition of beta-cyanin extraction. From the results, extraction with deionized water at pH 5.5 and 40°C for 20 min yielded the most beta-cyanin (150.41 mg/g of dried peels) (Figure 1a-c).

### Optimization condition of red colorant powder production from red dragon fruit peel extracts

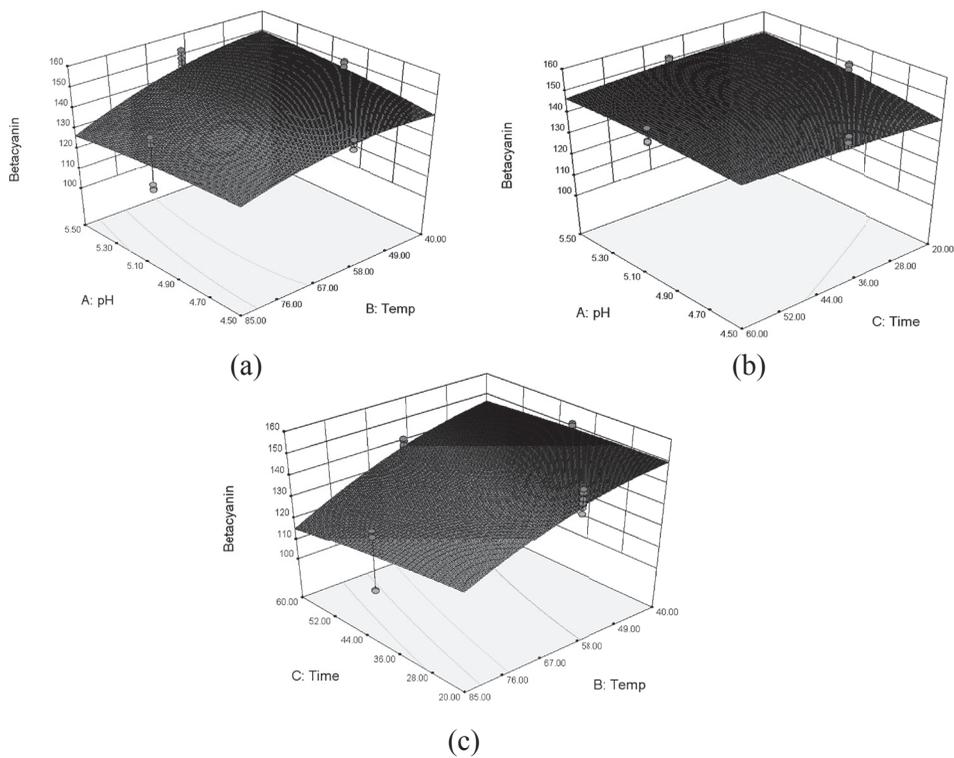
The extracts from the optimal condition were then mixed with acetylated oxidized starch or maltodextrin following the ratio shown in Table 2. Both acetylated oxidized starch and maltodextrin could be used as binding medium or drying carrier, since they were both perfectly compatible with the dragon fruit peel extracts. The mixtures were sprayed and dried in a spray dryer. Beta-cyanins, total phenols and antioxidant activity of the powder from the drying condition were determined. The results are shown in Table 2.

The results revealed that the different binding mediums significantly affected beta-cyanin content and total phenols (Table 2). However, beta-cyanin content in the colorant powder was lower than in the extract, in contrast with total phenols. In order to obtain the optimum condition of colorant powder production using spray drying, beta-cyanin content was chosen as the response of response surface methodology analysis. The independent variables were the ratio of binding medium to the extracts ( $Y_1$ ), inlet temperature of spray dryer ( $Y_2$ ) and feed flow rate ( $Y_3$ ). Stepwise regression analysis was used to determine the equation of conditions for colorant powders made from acetylated oxidized starch and maltodextrin according to equation 2 ( $R^2 = 0.9782$ ) and 3 ( $R^2 = 0.8259$ ), respectively.

$$\begin{aligned} \text{Beta-cyanin content-AOS (mg/g dry sample)} = & \\ & -1.945 + 33.34833333Y_1 + 0.7395833333Y_2 \\ & + 16.41472222Y_3 - 0.3140833333Y_1Y_2 - 6.335Y_1Y_3 - 0.109013889Y_2Y_3 \\ & + 0.041944444Y_1Y_2Y_3 \dots \dots \dots \end{aligned} \tag{2}$$

$$\begin{aligned}
 \text{Beta-cyanin content-MD (mg/g dry sample)} = & \\
 & 303.4116667-72.41Y_1-1.094583333Y_2 \\
 & -57.8Y_3+0.331166667Y_1Y_2+16.42027778Y_1Y_3 \\
 & +0.351486111Y_2Y_3-0.099680556Y_1Y_2Y_3 \dots\dots\dots (3)
 \end{aligned}$$

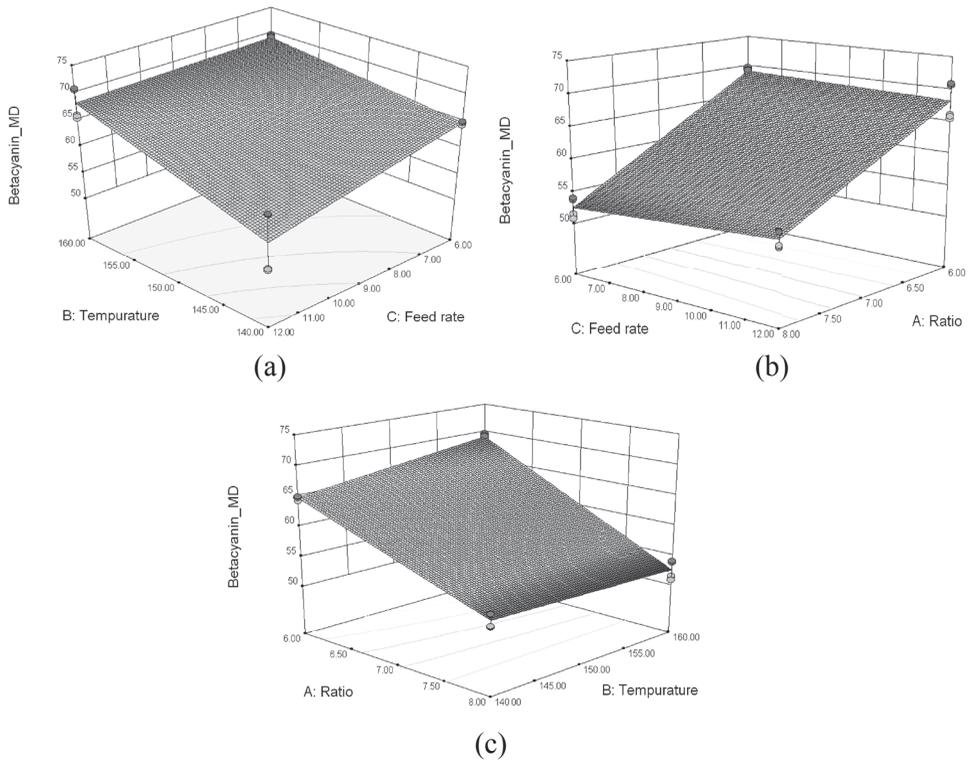
To obtain the optimum condition of spray drying of colorant powder, equations 2 and 3 were differentiated. The results showed that the optimum condition of colorants containing acetylated oxidized starch was using acetylated oxidized starch at 6% (w/w) at a feed rate of 6 ml/min and inlet temperature of 140°C. For maltodextrin, the optimum condition was similar, except the inlet temperature was 160°C. From these conditions, we found that the beta-cyanin contents were 68.3 and 69.1 mg/g of dry peels for acetylated oxidized starch and maltodextrin, respectively (Figure 2 and 3, respectively).



**Figure 1.** The effects of pH and Temperature at extraction time of 20 min (a), pH and extraction time at temperature of 40°C (b), and extraction time and temperature at pH of 5.5 (c) on beta-cyanin content in the extract.

### Antioxidant activity of colorant powders

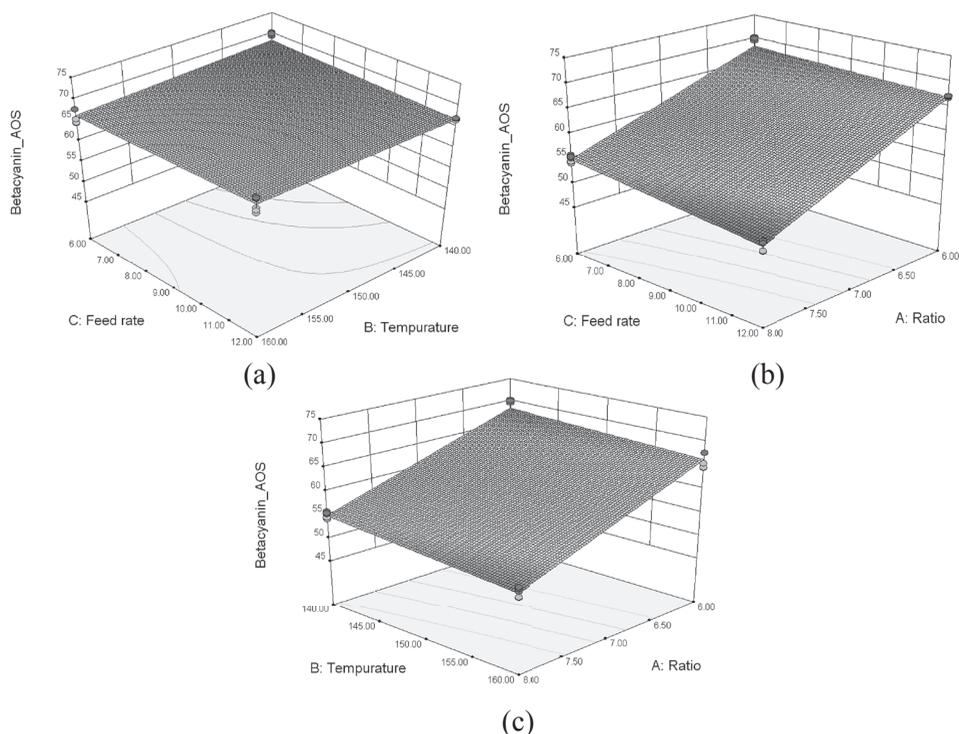
DPPH• radical scavenging activity, ABTS•+ assay and Ferric-ion reducing antioxidant power (FRAP) were used to analyze the antioxidant activity of the colorant powders that were produced according to the optimum spray-drying conditions mentioned previously. All antioxidant activity values of colorants from acetylated oxidized starch and maltodextrin were not significantly different ( $p < 0.05$ ) (Table 3). However, ABTS•+ and DPPH• of both colorants were less than those of the standard sample (ascorbic acid) ( $p > 0.05$ ).



**Figure 2.** The effects of the ratio of extract to acetylated oxidized starch and inlet temperature at feed flow rate of 6 ml/min (a), the ratio of extract to acetylated oxidized starch and feed flow rate at inlet temperature of 140°C (b), and inlet temperature and feed flow rate at ratio of extract to acetylated oxidized starch of 6%(w/w) ((c) on beta-cyanin content in colorant powders.

## DISCUSSION

Our results showed that beta-cyanins dissolved better in water than in EtOH, as explained by Casteller et al. (2003); given their high polarity, they prefer to dissolve in a more polar solvent such as water, than in a less polar solvent such as EtOH. The other factor that affected beta-cyanins was the pH. Herbach et al. (2006a) suggested that a pH of 4-6 least affected beta-cyanin stability. This might be due to the isomerization of C-15 of betanin and betanidin, found as compounds in beta-cyanins, in a high acidic condition (low pH) that could change betanin and betanidin to isobetanin and isobetanidin, respectively. Both pigments have a red-purple color. However, the color might be changed further from red-purple to yellow of 14,15-dehydrobetanin or neobetanin under very high acidic conditions or when hydrolysis occurred, converting betanin and betanidin to betalamic acid, which also presented a yellow color (Strack, Vogt, and Schliemann, 2003; Herbach et al., 2006a; Stintzing and Carle, 2007; Tsai, et al., 2010). Moreover, temperature and extraction time also affected the beta-cyanin content (Wybraniec and Mizrahi, 2002; Castellar, et al., 2003; Wu et al., 2006; Harivaindaran et al., 2008; Meoreno et al., 2008).



**Figure 3.** The effects of the ratio of extract to maltodextrin and inlet temperature at feed flow rate of 6 ml/min (a), the ratio of extract to maltodextrin and feed flow rate at inlet temperature of 160°C (b), and inlet temperature and feed flow rate at ratio of extract to maltodextrin of 6%(w/w) (c) on beta-cyanin content in colorant powders.

However, from our results, a higher temperature and lower pH lowered beta-cyanin content. This might be due to the degradation of beta-cyanins to yellowish betalamic acid, colorless cyclo-dopa 5-O- $\beta$ -glucoside, or reddish 12, 15-decarboxybetaninas mentioned previously (Strack, Vogt and Schliemann, 2003; Herbach et al., 2006a; 2006b; Stintzing and Carle, 2007), resulting in less beta-cyanin content in this studied extract. Moreover, Stintzing and Carle (2004) and Meoreno et al. (2008) reported that initial pigment content, oxygen and aw also affected the content of beta-cyanins.

Nevertheless, the results revealed that the optimum condition of beta-cyanin extraction from red dragon peels did not give the highest total phenol content, and the total phenol content inversely varied with beta-cyanin content. Phenolic compounds found in red dragon fruit peels were not only beta-cyanins, but also betaxanthins, ascorbic acid and beta-cyanins' derivatives, such as betalamic acid, cyclo-dopa 5-O-glycoside, neobetanin and betanidin (Stintzing and Carle, 2004; Bellec et al., 2006; Herbach et al., 2006a). These might interfere with the results of beta-cyanin content when reacted with gallic acid in Folin-Ciocalteu's method (Naczki and Shahidi, 2004; Prior et al., 2005; Rebecca et al., 2010). Wu et al. (2006) explained this might be due to the unspecific site reaction of gallic acid with such compounds. Thus, from our study, the optimum condition that gave the highest beta-cyanin content was not the suitable condition that provided the highest total phenols. Moreover, phenolic compounds dissolved in EtOH better than in deionized water, due to their ability to dissolve in polar alcoholic solvents (Harjo, Wibowo and NG, 2004; Naczki and Shahidi, 2004; Stalikas, 2007;).

Modified starches (acetylated oxidized starch and maltodextrin) were selected as the binding medium in this study in order to increase the extract soluble solid, reduce the effect of the browning reaction and neutralize the acidity of the extracts (Cai and Corke, 2000; Saénz et al., 2009; Chik et al., 2011). In addition, the powder from these binding media might entrap some functional ingredients and antioxidant agents in a severe condition like spray drying. However, in this study, beta-cyanins could not be completely shielded from degradation during spray drying, especially from heat, which contributed to the change of beta-cyanins to betalamic acid and cyclo-dopa 5-O- $\beta$ -glucoside (Stintzing and Carle, 2004; Bellec et al., 2006; Herbach et al., 2006a), resulting in less beta-cyanin in the powder than before spray drying.

The antioxidant activity of the colorant powders also decreased as a result of spray drying. This result agreed with the studies of Kim et al. (2002), Wetwityaklung et al. (2005), and Stratil et al. (2006). The decreased antioxidant activity of the colorant powders might be due to the effect of the high temperature of spray drying, which could change the chemical structures of beta-cyanins into their derivatives, such as betanins (Pedreño and Escribano, 2001; Herbach et al., 2006a) that are composed of imino and hydroxyl groups, with consequently less antioxidant capacity (Wu et al., 2006). In addition, mixing binding mediums (acetylated oxidized starch and maltodextrin) might influence the antioxidant activity by decreasing beta-cyanin content compared to the same weight of standard samples used for this analysis.

## CONCLUSION

The optimum extraction conditions for high beta-cyanin content from dragon fruit peel were mixing deionized water at pH 5.5 and extracting at 40°C for 20 min. The optimum conditions of spray drying to produce red colorant powder were mixing 6% (w/w) dragon fruit peel extract with acetylated oxidized starch or maltodextrin, feeding the mix into a spray dryer at 6 ml/min and controlling the inlet temperature at 140 and 160°C for acetylated oxidized starch and maltodextrin, respectively. The red colorant powder provided the highest beta-cyanin content and showed the highest potential as an antioxidant-food colorant in the food industry. Thus, red dragon fruit peels, typically considered a waste product of fresh fruit consumption, offer potential as an economic, value-added, raw material for food colorant production.

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