Effects of Spray Drying Conditions on Characteristics, Nutritional Value and Antioxidant Activity of Gac Fruit Aril Powder

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ABSTRACT

This research was aimed to develop suitable spray drying condition for Gac fruit aril powder. The aril was spray dried at the specified inlet/measured outlet temperatures of 120/66°C, 150/74°C and 170/88°C with/without maltodextrin addition as a drying carrier. The aril powders were analysed for physicochemical and microbial characteristics. The inlet spray drying temperature had significant effects on moisture content, colour, a_w, lycopene, β-carotene and antioxidant activity of Gac fruit aril powder. The lycopene, β-carotene, DPPH radical-scavenging activity and antioxidant activity of Gac fruit aril powder were in the range of 0.98 - 1.32 mg/g powder, 0.33 - 0.93 mg/g powder, 79.13 - 80.85% and 2758.33 – 2808.33µg Trolox equivalents/g powder, respectively. Spray drying at the inlet temperature of 170 ºC with 10% maltodextrin addition resulted in Gac fruit aril powder with higher lycopene (1.17 mg/g powder), β-carotene (0.79 mg/g powder), DPPH radical-scavenging activity (87.92%) and antioxidant activity (2998.33µg Trolox equivalents/g powder) compared to those of 20% and 30% maltodextrin addition. Therefore, the suitable condition for Gac fruit aril powder was spray drying at the specified inlet temperature of 170 ºC with 10% (w/w) maltodextrin addition.

Keywords: antioxidant, Gac, lycopene, spray drying

1. INTRODUCTION

Gac fruit (*Momordicacochinchinensis*Spreng) is a tropical plant grown in many Asian countries. It may be called by different name such as Gac (Vietnam), Fakkao (Thailand), Bhatkerala (India), MocNietTu (China), Makkao (Laos), Kushika (Japanese) and Spiny bitter gourd (England) (Vuong*et al*., 2006). Early recognition on the value of Gac fruit focused on β-carotene concentration (Ishida *et al*., 2004; Vuong, 2000). The fruit fresh contains red soft and oily arils, 1 – 3 mm thick, which accounting for 25% of the fruit weight. The aril contains antioxidants (lycopene and β-carotene) in extraordinary high amounts; approximately ten times higher than other fruits and vegetables. The aril can be cooked along with seeds to impart its red colour and flavour to a rice dish, xoigac, served at festive occasions in Vietnam. Several studies reported that Gac fruit red aril contains high levels of carotenoids, essential fatty acids, vitamin E, polyphenol compounds and flavonoids (Mai, Truong &Debasre, 2013; Vuong, 2000). The carotenoids are currently in special demand as

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they are natural antioxidant withpotential to prevent and treat cancers. Vuong (2000) reported that Gac fruit is a potential natural treatment of vitamin A deficiency for children in under-developed and developing countries. Lycopene is thought to has benefits in treating prostate cancer due to the strong antioxidant activity.

Gac fruit aril powder is more convenient to use as food colorants, nutrition supplementation and pharmaceutical ingredients than fresh Gac and the existing Gac products (Kha, Nguyen & Roach, 2010). The selection of a drying technique to process Gac fruit aril powder is crucial in order to maintain the good quality and high yield of a potential natural source of lycopene, β-carotene and colour for the food and pharmaceutical industries (Tran *et al.*, 2008).

Spray drying has been widely utilised for commercial production of dried fruits and vegetables. Spray-dried powders have good reconstitutional characteristics, low water activity (a_w) and are suitable for transport and storage. Furthermore, spray drying is a highly appropriate process for heat sensitive components such as carotenoids. This drying technique has been successfully applied for carotenoid stability in plant foods such as carrots, tomato pulp, sweet potato and sea buckthorn (Souza *et al*, 2009). However, spray drying is not very successful technique for enzyme-treated Gac fruit aril and therefore maltodextrin has been used as drying aids (Tran *et al.*, 2008). Maltodextrin can be used as a drying carrier or an encapsulating agent to increase the stability of carotenoids. It is reasonably cheap and commercially available. The addition of maltodextrin before spray drying has been reported to be effective in preserving carotenoids such as β-carotene (Kha, Nguyen & Roach, 2010; Leach, Oliveira &Morais, 1998; Souza *et al.*, 2009). In addition, colour of food is one of the most important sensory attribute which is affected by many factors during spray drying such as the inlet temperature and additives. The selection of drying technique to process and preserve Gac fruit aril powder is essential in order to maintain the good quality and high yield of a potential natural source of lycopene and β-carotene for food and pharmaceutical industries.

This research was proposed to study the impacts of spray drying conditions on the characteristics, nutritional value and antioxidant activity of Gac fruit aril powder. The investigation included physicochemical and microbial properties.

2. MATERIALS AND METHODS

Gac fruit aril preparation

The fully ripe Gac fruits, with more than 2/3 red colour on the skin were used in this study. The whole Gac fruit was scooped out and the red aril surrounding the seeds was completely separated. For each experimental run, the red aril (0.5 kg) was blended with distilled water (2.5 L) in a laboratory blender (Phillips, Taiwan) and filtered through a filter screen (100 μm mesh) to avoid blocking of the spray drier atomiser. In case of drying aid addition, the maltodextrin at the concentration of 10%, 20% and 30% (w/w) were added into the Gac fruit aril before spray drying.

Spray drying condition

The feed mixtures were spray dried in a Laboratory spray drier (Buchi, B-280, Japan). The inlet temperature/measured outlet temperature were 120 °C/66 °C, 150 °C/74 °C and 170 °C/88 °C. The spray drier was set at the 100% aspirator, 30 - 40% pump and 30 - 40 Q-flow. After the spraying process, the Gac fruit aril powder

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was collected in a glass collection vessel wrapped with aluminium foil. The spray drying processes were carried out in triplicate.

Colour characteristics

The colours of Gac fruit samples were determined using a Hunter Lab (Color Flex, USA). The results were expressed as Hunter colour values of *L**, *a**, and *b**, where *L** was used to denote lightness, *a** redness and greenness, and *b** yellowness and blueness.

Moisture content

The moisture content of Gac fruit samples were determined by drying at the temperature of 105 ºC in the oven until a constant weight was obtained (AOAC, 2005).

Water activity (a_w)

A water activity meter (Aqua Lab PawKit, Decagon Devices, USA) was used to measure a_w of the Gac fruit samples.

pH

The pH value of Gac fruit samples were determined by blending 5 g sample with 25 mL deionised water at 20 ºC, and investigate the pH using pH meter calibrated with standard buffers pH 4 and 7 before use.

Protein content

The protein content of Gac fruit sample was investigated using Kjeldahl method (Kjeltec TM 2200, Auto Distillation Unit, FOSS North America, Eden Prairie, MN).

Fat content

The fat content of Gac fruit sample was analysed using Soxtec method (Soxtec TM 2050, Auto Fat Extraction, Foss® Analytical, Hilleroed, Denmark).

Fiber

The finer content of Gac fruit samples were analysed using Extraction unit (Fibertec™1020 Hot Extraction Unit and Fibertec™1021 Cold Extraction Unit, FOSS Analytical, Denmark)

Ash

The ash of Gac fruit sample was investigated using Chamber Furnace wire spiral element model CWF.

Water solubility index (WSI)

The WSI of the Gac fruit aril powders was determined using the method described by Anderson *et al*. (1996). The powder (2.5 g) and distilled water (30 mL) were vigorously mixed in a 100 mL centrifuge tube, incubated in a 37 °C waterbath for 30 min and then centrifuged for 20 min at 10,000 rpm (11,410 g) in a J2-MC Centrifuge (Beckman, USA). The supernatant was carefully collected in a pre-weighed beaker and oven dried at a temperature of 103 ± 2 ºC. The WSI (%) was calculated as the

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percentage of dried supernatant with respect to the amount of the original 2.5 g powder.

Bulk density

Bulk density (g/mL) was determined by gently adding 2 g of Gac fruit aril powder into an empty 10 mL graduated cylinder and holding the cylinder on a vortex vibrator for 1 min. The ratio of mass of the powder and the volume occupied in the cylinder determines the bulk density value (Goula, Adamopoulos&Kazakis, 2004).

Determination of lycopene and β-carotene

Lycopene and β-Carotene contents were determined according to the Kimura method (Nagata &Yamashita, 1992). The Gac fruit sample (1 g) was vigorously shaken with 10 mL of acetone:hexane mixture (4:6) for 1 min, then immediately measured the optical density of the supernatant at 663, 645, 505 and 453 nm using spectrophotometer (Double beam, Perkin Elmer Instruments, Lambda 25 UV/VIS Spectrometer). The contents of lycopene and β-carotene were calculated according to equations (1) and (2), respectively.

$$\text{Lycopene (mg/g powder)} = -0.0458\,A_{663} + 0.204\,A_{645} + 0.372\,A_{505} - 0.0806\,A_{453} \quad (1)$$

$$\beta\text{-Carotene (mg/g powder)} = 0.216\,A_{663} - 1.22\,A_{645} - 0.304\,A_{505} + 0.452\,A_{453} \quad (2)$$

Where A_{663}, A_{645}, A_{505} *and* A_{453} are absorbance at 663, 645, 505 and 453 nm, respectively.

Gac fruit extraction

The Gac fruit samples were extracted using the method adapted from Cheok*et al*., (2011). Gac fruit samples (1 g) were vigorously mixed with 10 mL ethanol at room temperature. The resulted mixtures were centrifuged at 10000 rpm (11,410 g) for 30 min. The supernatants (Gac fruit extracts) were kept in the dark at approximately 4 °Cfor further analysis.

DPPH radical-scavenging assay

The antioxidant activity of the Gac fruit extracts, on the basis of the scavenging activity of the stable 1,1-diphenyl-2-picrylhydrazyl (DPPH) free redical, was determined by the method describe by Brace *et al*. (2001). Gac fruit extract (0.1 mL) was added to 3 mL of a 0.0001 M DPPH in methanol. The mixture was shaken vigorously and left to stand for 30 min in the dark. The reduction of the DPPH radical was determined by measuring the absorbance at 517 nm and the DPPH radical scavenging activity (RSA, %) was calculated using equation (3). The results were also expressed in µg Trolox equivalents (TE)/g sample using the standard curve of Trolox.

$$\text{DPPH radical scavenging activity (RSA, \%)} = [(A_{DPPH} - A_S)/A_{DPPH}] \times 100 \quad (3)$$

Where A_{DPPH} is absorbance without Gac fruit extract and and A_S absorbance with Gac fruit extract, respectively.

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Total microbial contents

The total microbial contents of Gac fruit aril samples were investigated by pour plate method using plate count agar (PCA) incubated at 35°C for 48 h. The total microbial content was reported as CFU/g.

Yeast and mold contents

The yeast and mold contents of Gac fruit samples were investigated by pour plate method using Potato Dextrose Agar (PDA) incubated at 30ºC for 48 h. The amount of yeast and mold were reported as CFU/g.

Statistical analysis

Experimental results are given as means plus the standard deviation of three parallel measurements. Analysis of variance (ANOVA) and Duncan’s Multiple Range Test were conducted to identify differences among means,*p* values of < 0.05 were regarded as significant.

3. RESULTS AND DISCUSSION

Gac fruit yielded 53% yellow pulp, 17% seed, 16% red aril and 14% skin. The red aril composed of approximately 85.57% moisture, 6.92% fat, 3.93% carbohydrate, 1.95% protein, 0.83% fiber, and 0.80% ash. The aril contained 8.47 mg lycopene/ 100 g fresh weight (FW) and 3.81 mg β-carotene/100 g FW. The aril had the DPPH radical-scavenging activity (RSA) of 89.09% and antioxidant activity of 3028.75 µg Trolox equivalents (TE)/100 g powder. The total bacteria count and yeast and mold count of the aril were 1.7 $\times 10^6$ CFU/g and 1.9 $\times 10^6$ CFU/g, respectively.

The characteristics of Gac fruit aril powder spray dried at the specified inlet/measured outlet temperatures of 120/66 ºC, 150/74 ºC and 170/88 ºC, and with different level of maltodextrin addition are shown in Tables 3.1 and 3.2, respectively. The moisture content of Gac fruit aril powder decreased as increased the inlet spray drying temperature. The higher drying temperature causes the water in the product to evaporate faster. The results were in accordance with previous researches on other fruits. The moisture content of tomato powder, orange juice powder, carrot powder, and pear powder decreases with increasing the inlet temperatures (Kha, Nguyen& Roach, 2010). The addition of maltodextrin at a higher ratio resulted in Gac fruit aril powder with lower moisture content (Table 3.2) as maltodextrin reduces moisture absorption properties. At the inlet spray drying temperature conditions of 170 °C and 10% - 30% maltodextrin concentration, the moisture content of resultant pineapple juice powder decreased as increased maltodextrin concentration (Abadio*et al*., 2004). A similar result was also reported by Grabowski, Truong and Daubert (2006) who carried out a research on sweet potato puree powder. These finding could be explained by the fact that addition of maltodextrin resulted in an increase in feed solid and a reduction in total moisture for evaporation. It was, also, found that when the inlet spray drying temperature and the amount of maltodextrin increased, the moisture content of Gac fruit aril powder decreased significantly (p< 0.05).

In this study, the pH values of the Gac fruit aril powders were not significantly affected by inlet spray drying temperature and maltodextrin addition (p >0.05). The finding was in agreement with the report of Gonzalez-Palomres*et al*. (2009) who found that pH of the Roselle extract powder did not change with different air drying temperatures.

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The $a_w$is one of the most important factors that significantly influence the shelf life of powder products. High a_w in product leads to shorter shelf life due to high free water for biochemical degradations. The deterioration of powder caused by microorganism and biochemical reactions can be prevented at a_w lower than 0.6 (Vuong, Dueker& Murphy, 2002). The a_w of Gac fruit aril powder were significantly different among the samples with different spray drying inlet temperature and maltodextrin addition ($p< 0.05$) as shown in Tables 3.1 and 3.2. Increased the spray drying temperature resulted in Gac fruit aril powder with decreased a_w. These results

Table 3.1 Characteristics of spray dried Gac fruit aril powders.

Characteristics	Drying temperature		
	120 °C	**150 °C**	**170 °C**
Physical properties			
Moisture content (%)	5.22 ±0.26[a]	4.72 ±0.17[b]	4.39 ±0.14[c]
Water activity (a_w)	0.588 ±0.01[a]	0.551 ±0.01[b]	0.424 ±0.01[c]
Bulk density (g/mL)	0.78 ±0.47[a]	0.75 ±0.51[a]	0.76 ±0.50[a]
Water solubility index (WSI, %)	37.50 ±0.47[a]	37.56 ±0.51[a]	37.60 ±0.50[a]
Colour value			
Lightness (*L**)	38.20 ±0.33[c]	48.40 ±0.11[b]	51.55 ±0.07[a]
Redness (*a**)	33.76 ±0.11[a]	32.71 ±0.14[b]	30.14 ±0.10[c]
Yellowness (*b**)	28.98 ±0.44[c]	40.20 ±0.29[b]	43.62 ±0.19[a]
Chemical properties			
Protein (%)	0.93 ±0.02[c]	1.03 ±0.10[b]	1.23 ±0.03[a]
Fat (%)	5.28 ±0.06[a]	5.27 ±0.05[a]	5.26 ±0.11[a]
Ash (%)	3.11 ±0.10[b]	3.51 ±0.06[b]	4.13 ±0.03[a]
Fiber (%)	14.65±0.03[a]	14.62±0.02[a]	14.57±0.02[b]
Carbohydrate (%)	70.81±0.16[a]	70.85±0.17[a]	70.42±0.09[b]
pH	4.70 ±0.06[a]	4.68 ±0.01[a]	4.70 ±0.03[a]
Lycopene (mg/g powder)	0.98 ±0.00[b]	0.98 ±0.01[b]	1.32 ±0.03[a]
β-carotene (mg/g powder)	0.34 ±0.01[b]	0.33 ±0.01[b]	0.93 ±0.01[a]
DPPH radical-scavenging activity (RSA, %)	79.13 ± 0.09[b]	80.51 ± 0.09[a]	80.85 ± 0.05[a]
Antioxidant activity (µg TE/g powder)	2758.33 ± 1.44[c]	2797.50 ± 2.50[b]	2808.33 ± 3.82[a]
Microbial properties			
Total plate count (CFU/g)	2.4×10^4	1.6×10^4	1.2×10^4

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Yeast and mold count (CFU/g)	2.6×10^4	1.7×10^4	1.9×10^4

Values in the same row followed by the different superscripts are significantly different ($p < 0.05$).

Table 3.2 Characteristics of spray dried Gac fruit aril powders withmaltodextrin addition.

Characteristics	Maltodextrin ratio (% w/w)		
	10	**20**	**30**
Physical properties			
Moisture content (%)	4.77 ±0.07[a]	4.47 ±0.36[ab]	4.25 ±0.05[b]
Water activity (a_w)	0.464 ±0.02[a]	0.437 ±0.05[b]	0.396 ±0.02[c]
Bulk density (g/mL)	0.70 ±0.02[a]	0.71±0.02[a]	0.74 ±0.03[a]
Water solubility index (WSI, %)	37.71 ±0.02[a]	37.78 ±0.02[a]	37.85 ±0.03[a]
Colour value			
Lightness (*L**)	76.79 ±0.24[c]	80.44 ±0.25[b]	82.58 ±0.01[a]
Redness (*a**)	17.34 ±0.38[a]	14.25 ±0.16[b]	11.54 ±0.10[c]
Yellowness (*b**)	27.49 ±0.52[a]	22.05 ±0.36[b]	19.57 ±0.34[c]
Chemical properties			
Protein (%)	0.31 ±0.04[a]	0.16 ±0.01[bc]	0.13 ±0.01[bc]
Fat (%)	5.93 ±0.02[a]	5.62 ±0.06[b]	5.17 ±0.02[c]
Ash (%)	0.58 ±0.06[a]	0.47 ±0.04[b]	0.38 ±0.02[c]
Fiber (%)	15.16±0.03[b]	15.30±0.07[a]	15.43±0.01[a]
Carbohydrate (%)	73.25±0.14[b]	73.98±0.32[a]	74.63±0.10[a]
pH	4.15±0.01[a]	4.14±0.02[a]	4.16±0.04[a]
Lycopene (mg/g powder)	1.17 ±0.03[a]	0.89 ±0.00[b]	0.48 ±0.01[c]
β-carotene (mg/g powder)	0.79 ±0.13[a]	0.47 ±0.01[b]	0.30 ±0.03[c]
DPPH radical-scavenging activity (RSA, %)	87.92 ± 0.11[a]	86.73 ± 0.05[b]	82.13 ± 0.05
Antioxidant activity (µg TE/g of powder)	2998.33 ± 1.44[a]	2970.00 ± 2.50[b]	2845.83 ± 2.89[c]

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Microbial quality			
Total plate count (CFU/g)	2.8×10^4	1.7×10^4	2.0×10^4
Yeast and mold count (CFU/g)	1.7×10^4	1.9×10^4	1.9×10^4

Values in the same row followed by the different superscripts are significantly different (p< 0.05).

were contradicted with the findings of Queek*et al*. (2010) who reported that the a_w of spray dried water melon powders was not significantly changed by inlet temperatures between 145 °C and 175 °C. Furthermore, higher maltodextrin concentration resulted in decreased in the $a_w$of the powders. The average a_w of Gac fruit aril powder in this study ranged from 0.396 to 0.588.

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The nutrition values of Gac fruit aril powder with different spray dried inlet temperature of 120 ºC, 150 ºC and 170 ºC are shown in Table 3.1. The percentage of protein increased as the spray drying temperature increased (p< 0.05), whereas the percentage of fat and ash were not significantly different (p> 0.05). Total plate count and yeast and mold count were decreased with increased spray dried inlet temperatures as drying with heat can affect the growth of microorganisms.

Spray drying inlet temperature (120 ºC, 150 ºC and 170 ºC) and maltodextrin addition at 10 - 30% did not affect the bulk density and water solubility index (WSI) of Gac fruit aril powder.

The colour of Gac fruit aril powder was investigated using colorimeter which reported the colour in *L**, *a**, and *b**. The *L** is represented of brightness values from 0 (black) to 100 (white). The *a** is represented of red (+) to green (-) and the *b** represented of yellow (+) to blue (-). The results showed that the *L**, *a** and *b** of Gac fruit aril powder spray dried at 120 ºC, 150ºC and 170 ºC were significantly difference (p< 0.05) as shown in Table 3.1.

Figure 3.1 also shows that when the spray drying inlet temperature increased, the redness of Gac fruit aril powder decreased, whereas the yellowness increased. Addition of maltodextrin as a drying carrier resulted in a significant change in *L**, *a**, and *b** values in Gac fruit aril powder (p< 0.05) as shown in Table 3.2 and Figure 3.2. Colour is an important sensory properties, which have been affected by drying process (Abadio*et al*., 2004).

120 ºC 150 ºC 170 ºC

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Figure 3.1 The colour characteristics of Gac fruit aril powders spray dried at different inlet temperatures.

10% 20% 30%

Figure 3.2 The colour characteristics of Gac fruit aril powders spray dried at 170 ºC with different concentration of maltodextrin addition.

The chemical analysis of the powders spray dried at various temperatures showed that the utilisation of high inlet spray drying temperature did not have a negative effect on the amount of lycopene and β-carotene in Gac fruit aril powder. The lycopene and β–carotene contents, DPPH radical-scavenging activity and antioxidant activity of the Gac fruit aril powder were in the range of 0.98 –1.32 mg/g powder, 0.33 –0.93 mg/g powder, 79.13 - 80.85% and 2758.33–2808.33 µg TE/g powder, respectively. The previous study reported that the body can increased the absorption of carotenoids from food products produced with high thermal process in the digestive system better than eating a fresh 2.5 folds. Increasing the concentration of maltodextrin addition before drying process of Gac fruit aril resulted in significantly decreased the lycopene and β-carotene contents and antioxidant activity as shown in Table 3.2 ($p < 0.05$). However, the addition of maltodextrin helps facilitating the spray dry process. It was found that at the spray drying inlet temperature of 170 °C, the Gac fruit aril powder contained high nutritional values. Addition of 10% (w/w) maltodextrin resulted in Gac fruit aril powder with similar nutritional values to those spray drying without maltodextrin addition.

4. CONCLUSION

Spray drying inlet temperature has significant effects on Gac fruit aril powder characteristics, nutrition value and antioxidant activity. Addition of maltodextrin improves spray drying efficiency. Gac fruit aril powder spray dried at 170 °C with 10% (w/w) maltodextrin addition contained high lycopene and β-carotene contents and antioxidant activity with acceptable colour attribute.

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