

Gac aril powder processing by using microwave drying and its incorporation into the rice porridge product

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Abstract

Gac (*Momordica cochinchinensis* Spreng) aril contains extraordinarily high contents of β -carotene and lycopene. These nutrients have proved to be beneficial to humans. Therefore, it is of interest to produce a stable and convenient Gac aril powder by using microwave drying technique that the powder can be used as a nutrient supplement and/or a natural red-orange colourant. Objective of this study was to investigate effects of pre-treatment and microwave power on the quality of Gac powder. A comparison of the quality of the microwave-dried, air-dried and freeze-dried aril powders was also made. Surface microstructures of these powders were also observed by scanning electron microscopy (SEM). The most suitable concentration of the powder incorporated into the rice porridge product was also determined. Results showed that significant effects of pre-treatments (concentration of ascorbic acid and soaking time) on the quality of the microwave-dried powder in terms of colour characteristics, β -carotene and lycopene contents were statistically found ($P < 0.001$). The best concentration of 0.1% (w/w) and the soaking time of 30 minutes were determined. The most suitable microwave power for drying the aril was significantly found to be 320 W. Positive effect of microwave power on microstructural changes of aril tissues were observed by using SEM. Results also indicated that the most suitable concentration of the powder incorporated into the rice porridge was 1% (w/w). Therefore, it can be concluded that the high quality of the microwave-dried powder in terms of colour characteristics, lycopene and β -carotene contents is most effectively preserved by applying the pre-treatments prior to microwave drying. It was also found that the Gac powder rich in β -carotene and lycopene contents could be incorporated satisfactorily into the porridge product.

Keywords: gac fruit, β -carotene, lycopene, microwave drying, rice porridge

1. Introduction

Gac fruit (*Momordica cochinchinensis* Spreng), also known as baby jackfruit or sweet gourd, is one of the traditional fruits in Viet Nam. Many studies have reported that Gac fruit aril contains high levels of carotenoids (β -carotene and lycopene), vitamin E, and unsaturated fatty acids (Aoki et al., 2002; Ishida et al., 2004; Kha et al., 2013; Vuong et al., 2006).

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It is well known that carotenoids in Gac aril play an important role in human health. For example, β -carotene is converted to vitamin A in the body (Strobel et al., 2007). Lycopene-rich diets are linked with a reduced risk of cardiovascular disease and cancers such as lung, breast, stomach and prostate (Agarwal and Rao, 2000; Lu et al., 2011). Interestingly, it has been reported that a significant improvement in the absorption of the carotenoids into human body occurs when they are digested with fat (Brown et al., 2004; Kuhnlein, 2004; Unlu et al., 2005). Moreover, in foods, as a natural antioxidant, vitamin E helps protect fatty acids and carotenoids in the arils from oxidation due to its high antioxidant activity.

Drying is the unique method for producing powder forms of fruits and vegetables. The main benefits of powder forms are the potential for long storage at ambient temperature, a significant reduction in the costs for transportation and storage, and very convenient food ingredients for use as flavour and colourings in food products (Tang and Yang, 2004). This is particularly important for seasonal fresh fruits such as Gac fruit.

Recently, microwave drying method has been used for production of dried fruits and vegetables. This is a novel method because it generally offers the advantages of being more environmentally friendly, solvent free, reduced processing time and uniform heating (Wang et al., 2013; Zhang et al., 2006). In addition to shortened drying time, the quality of microwave-dried food products is significantly improved compared with conventionally dried products (Zhang et al., 2006). Furthermore, pre-treatment prior to microwave drying is one of the most important factors that affect the quality of a final product. Several studies have showed that the colour and carotenoids of dried fruits and vegetables can be successfully preserved when pre-treatment such as soaking in ascorbic acid was applied before drying (Chen et al., 2007; Kha et al., 2011).

Objective of this study was to investigate effects of pre-treatment and microwave power on the quality of Gac powder in terms of colour characteristics, and content of β -carotene and lycopene. A comparison of the quality of the microwave-dried, air-dried and freeze-dried aril powders was made. Surface microstructures of these powders were also observed by scanning electron microscopy (SEM). Moreover, the use of carotenoid-based foods as natural colourants and nutrient supplements is currently receiving considerable attention from food manufacturers and consumers. Therefore, there is also a need to investigate whether the Gac aril powder can be incorporated into foods such as rice porridge product.

2. Materials and Methods

2.1 Chemicals

Solvents (analytical grade) and BHT (butylated hydroxytoluence) were obtained from Merck Pty. Ltd. β -carotene (C4582, type II synthetic, $\geq 95\%$) and lycopene (L9879, $\geq 90\%$, from tomato) standards were purchased from Sigma-Aldrich Pty. Ltd.

2.2 Gac fruits

Gac fruit, of uniform yellow-red skin and size, was purchased from a local market in Ho Chi Minh city, Viet Nam. The red arils without seeds were scooped out, vacuum-packed (200 g) and frozen at temperature of -18°C for further use.

2.3 Experiment

The frozen Gac arils were thawed at ambient temperature before pre-treatment and microwave drying. The arils were soaked in different concentrations of ascorbic acid solution (0.05, 0.1 and 0.15%, w/w) for different times (30, 60, 90, 120 min), and untreated as a control. After pre-treatment, the Gac arils were dehydrated by microwave drying. The microwave drying process was carried out in a household microwave oven (EM-G4755, Sanyo Co., Ltd., Viet Nam) and operating frequency at 2450 MHz. The arils (with initial moisture content of 80%) were spread (with a thickness of 1 cm) onto the turntable plate and subjected to heating at different power settings of 160, 320, 480, 640 and 800 W. The moisture content of the aril samples was measured every 2 or 5 min. The microwave drying process was terminated when the final moisture content of each sample was constant (approximately 6%). The microwave-dried samples were powdered using a laboratory blender and sealed in 5 g quantities into high barrier vacuum bags, using a vacuum sealer.

The two factors (ascorbic acid concentration and soaking time) were randomly designed to investigate the effect of pre-treatment prior to microwave drying at power of 320 W. The one factor was also randomly designed to investigate the effect of microwave power setting. Experiments were all carried out in triplicate. A total of 36 and 15 runs, respectively, was conducted.

For comparison, the air-drying and freeze-drying processes were employed. The arils (200 g) were air-dried at 40°C with the input air velocity of 1.1 ± 0.1 m/s until the final moisture content of the sample (6%) was reached. The loading material was 5 kg/m^2 . The freeze-drying

process was carried out at a condenser temperature of -46°C and pressure of 0.3 mbar absolute for 40 h in a freeze drier (EYELA 2100, Japan).

For incorporation study, the ingredients for the rice porridge product were glutinous rice (1%), rice (10%) and drinking water (89%) and the addition of the microwave-dried Gac aril powder (0.5, 1.0, 1.5, 2.0 and 2.5%, w/w). The ingredients were then mixed well, poured into a sterilisation bag (240 g) and sterilised at 121°C for 30 min.

2.4 Analytical methods

2.4.1 Moisture content determination

The moisture content of Gac samples was determined by drying at the temperature of 105°C in a laboratory air oven until a constant weight was obtained.

2.4.2 Colour characteristics

The colour of microwave-dried powder samples was determined using a Minolta Chroma Meter calibrated with a white standard tile. 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. Prior to measurement, the powder samples were packed into a clear polyethylene pouch and measured. Chroma, representing colour intensity was calculated by the formula $\sqrt{a^{*2} + b^{*2}}$. The hue angle (H°) was calculated by the formula $H^{\circ} = \arctan(b^*/a^*)$. The hue angle values vary from 0° (pure red colour), 90° (pure yellow colour), 180° (pure green colour) to 270° (pure blue colour) (Duangmal et al., 2008). The desirable hue angle of Gac aril powder is about 45° . Total colour difference between the two samples was calculated by the formula $\Delta E = \sqrt{(L_o^* - L^*)^2 + (a_o^* - a^*)^2 + (b_o^* - b^*)^2}$. Where L_o^* , a_o^* and b_o^* are the values of the pre-treated sample, and L^* , a^* and b^* are the values of the control sample.

2.4.3 Determination of β -carotene and lycopene

The procedure for the β -carotene and lycopene analyses was carried out according to the method of Englberger et al. (Englberger et al., 2006). The fresh Gac aril or the dried powder (1 g) was placed into 35 mL of a 4:3 (v/v) solution of ethanol and n-hexane, which contained BHT (0.1% in hexane) and the mixture was blended for 5 min at 5000 rpm. The residue was re-extracted with another 35 mL of the 4:3 (v/v) ethanol:n-hexane and then washed twice with

ethanol (12.5 mL) and once with hexane (12.5 mL). The combined extracts were washed with deionised water, dried in a rotary evaporator at 35°C and then diluted with the mobile phase solution. All operations were performed under subdued light to minimise oxidation of the carotenoids.

The HPLC analysis was performed with an Agilent 1,200 HPLC (Santa Clara, CA, USA) equipped with a diode array detector system and consisting of a Luna C18 (100 x 4.6 mm i. d.; 5 µm) direct-connect guard reverse phase column directly coupled to a Jupiter C18 (250 x 4.6 mm i.d.; 5 µm) reverse phase column (Phenomenex Australia Pty. Ltd., Lane Cove, NSW, Australia). The mobile phase consisted of acetonitrile, dichloromethane and methanol (ACN: DCM: MeOH) 50: 40: 10 v/v/v. The flow rate was 1.0 mL/min, detection was at 450 nm and the injection volume was 20 µL. The identification of β -carotene and lycopene was based solely on the retention time of the peaks compared with the authentic standards. The content of carotenoids in the fresh and dried powder samples were expressed as µg/g aril (dry basis, d.b.).

2.4.4 Scanning electron microscopy (SEM) analysis

In order to investigate the effects of the three drying methods (microwave, air and freeze drying) on the external structure of the Gac aril material, the dried Gac arils were analysed using a JSM-7401F SEM (Jeol Co. Ltd., Tokyo, Japan operating at a voltage of 5 kV). A small amount of Gac aril powder was fixed onto the surface of a double-coated metallic adhesive tape adhered to a metallic 320 stub. The stub was then coated with a fine layer of gold and argon in a MSP-1S magnetron sputter coater (Vacuum Device, Tokyo, Japan) under vacuum conditions to avoid charging under the electron beam.

2.4.5 Sensorial evaluation

The rice porridge product after incorporating Gac aril powder with different amounts was evaluated using acceptance test under laboratory conditions. The acceptance test with a 7-point hedonic scale (from 1 = disliked very much to 7 = liked very much) was carried out. Using this scale, panels were appointed to evaluate the sensorial attribute “global aspect” by filling out a card. This test, which was evaluated by 30 trained healthy students aged between 19 and 23, was conducted at the University of Food Industry, Ho Chi Minh City, Viet Nam.

2.5 Statistical analysis

The independent experiments and subsequent measurements were all performed in triplicate and results were presented as mean values with standard deviations. Different mean values were analysed by analysis of variance (ANOVA) and least significant difference (LSD) using SPSS-PASW GradPack 20 for Mac (IBM Corp., Armonk, NY, USA). The graphs of mean values and error bars were created using Excel for Mac 2011 (Microsoft, Seattle, WA, USA).

3. Results and Discussion

3.1 Effect of pre-treatments on the colour characteristics of the Gac aril powder

The colour characteristics of Gac powder samples from the fresh Gac aril at different ascorbic acid concentrations and soaking times before microwave drying at power of 320 W are presented in Table 1. Statistical analysis showed that the concentration of ascorbic acid significantly impacted the colour characteristics of the microwave-dried Gac aril powder including the lightness ($P < 0.01$), chroma ($P < 0.001$), hue angle ($P < 0.001$) and ΔE ($P < 0.001$). The colour characteristics of the microwave-dried powder were also significantly affected by the soaking time ($P < 0.01$). Furthermore, there was a significant interaction between the ascorbic acid concentration and the soaking time on the lightness ($P < 0.05$), chroma ($P < 0.001$), hue angle ($P < 0.001$) and ΔE ($P < 0.001$).

Generally, pre-treatment by soaking in ascorbic acid solution prior to microwave drying can improve the lightness and chroma of the dried samples in comparison with the control (untreated). This is because higher values of lightness and chroma of the pre-treated samples were obtained when the samples were pre-treated in ascorbic acid solutions at different concentrations for different times (Table 1). Similarly, the sample soaked in ascorbic acid solution prior to microwave drying had the lower value of hue angle, indicating redder colour. Therefore, pre-treatment in ascorbic acid solution prior to microwave drying is highly recommended in terms of colour retention for the dried Gac aril powder.

Table 1. Colour characteristics of Gac aril powder affected by different pre-treatments before microwave drying.

Ascorbic acid concentration (%, w/w) AAC	Soaking time (min) ST	Lightness L	Chroma C	Hue angle H°	ΔE
Control (untreated)		41.6 ± 0.2	8.1 ± 0.1	36.7 ± 0.4	
0.05	30	48.0 ± 0.8 ^a	11.2 ± 0.2 ^a	31.5 ± 1.1 ^a	7.1 ± 0.1 ^{ab}
	60	47.5 ± 0.8 ^a	12.1 ± 0.3 ^b	30.3 ± 2.0 ^a	7.1 ± 0.6 ^{ab}
	90	48.3 ± 0.2 ^a	11.8 ± 0.2 ^{bc}	31.4 ± 0.2 ^a	7.6 ± 0.2 ^a
	120	47.2 ± 0.6 ^a	11.0 ± 0.1 ^a	29.6 ± 0.4 ^a	6.4 ± 0.6 ^b
0.1	30	46.9 ± 0.6 ^{ab}	9.1 ± 0.4 ^a	40.9 ± 2.6 ^a	5.4 ± 0.6 ^a
	60	46.5 ± 0.5 ^a	10.2 ± 0.4 ^b	35.3 ± 2.1 ^b	5.3 ± 0.5 ^a
	90	47.6 ± 0.3 ^b	12.7 ± 0.1 ^c	31.6 ± 0.5 ^c	7.6 ± 0.3 ^b
	120	45.2 ± 0.2 ^c	6.8 ± 0.3 ^d	35.7 ± 1.3 ^b	3.8 ± 0.1 ^c
0.15	30	46.2 ± 0.2 ^{abc}	10.8 ± 0.3 ^a	33.3 ± 2.4 ^a	5.4 ± 0.1 ^a
	60	44.7 ± 1.0 ^b	7.5 ± 0.4 ^b	37.5 ± 1.5 ^b	3.1 ± 1.1 ^b
	90	47.3 ± 1.4 ^c	11.0 ± 0.9 ^a	33.1 ± 2.8 ^a	6.4 ± 1.0 ^a
	120	47.1 ± 1.5 ^c	11.4 ± 0.4 ^a	33.6 ± 1.9 ^{ab}	6.4 ± 1.0 ^a

Values are mean ± SD; Values in the same column followed by different superscripts (a-c) were significantly different ($P < 0.05$).

3.2 Effect of pre-treatments on the carotenoid content of the Gac aril powder

Results indicated that the content of lycopene and β -carotene was effectively preserved when the fresh Gac arils were soaked in ascorbic acid solution before microwave drying. According to statistical analysis, pre-treatments significantly affected the content of carotenoids ($P < 0.001$). Moreover, the interaction between ascorbic acid solution and soaking time on the lycopene and β -carotene contents was significantly established ($P < 0.001$).

Table 2. Carotenoid content of Gac aril powder affected by different pre-treatments before microwave drying.

Ascorbic acid concentration (% w/w) AAC	Soaking time (min) ST	Lycopene ($\mu\text{g/g}$, d.b.)	β -carotene ($\mu\text{g/g}$, d.b.)
Control (untreated)		7996.6 \pm 67.5	3994.8 \pm 88.5
0.05	30	5240.8 \pm 17.4 ^a	3271.6 \pm 229.9 ^a
	60	3296.3 \pm 4.8 ^b	2982.8 \pm 15.4 ^b
	90	3489.5 \pm 7.0 ^c	1479.5 \pm 20.7 ^c
	120	6699.6 \pm 64.7 ^d	1866.4 \pm 26.2 ^d
0.1	30	8563.0 \pm 66.7 ^a	4103.0 \pm 99.9 ^a
	60	5757.4 \pm 257.2 ^b	4010.1 \pm 162.5 ^a
	90	6004.8 \pm 4.3 ^b	2495.7 \pm 19.2 ^b
	120	7203.6 \pm 15.9 ^c	3309.1 \pm 23.9 ^c
0.15	30	7619.7 \pm 93.2 ^a	2674.9 \pm 35.7 ^a
	60	5593.7 \pm 4.0 ^b	2191.0 \pm 45.3 ^b
	90	6062.0 \pm 3.5 ^c	2589.1 \pm 16.6 ^c
	120	5444.6 \pm 20.0 ^d	3830.1 \pm 65.5 ^d

Values are mean \pm SD; Values in the same column followed by different superscripts (a-d) were significantly different ($P < 0.05$).

As can be seen in Table 2, generally an increase in the concentration of ascorbic acid and a decrease in the soaking time resulted in better retention of carotenoid content. The highest carotenoid content of the dried Gac aril powder was obtained when the sample was soaked in 0.1% ascorbic acid solution for 30 min. Positive effect of ascorbic acid on the retention of carotenoid is due to the beneficial role of antioxidant additive in preserving carotenoid in dried plant foods. This finding is consistent with a variety of studies which pre-treatment of antioxidant additive before drying has been employed to effectively maintain the carotenoid content in fruits and vegetables (Chen et al., 2007; Kha et al., 2011; Tai and Chen, 2000; Vibhakara et al., 2006).

3.3 Drying curve for microwave drying of fresh Gac aril

Samples of 200 g of the pre-treated fresh Gac aril in ascorbic acid solution for 30 min, in which the average initial moisture content was 79.5%, were dried at different microwave powers of 160, 320, 480, 640 and 800 W. The results for moisture content versus drying time are presented in Fig. 1. In general, the microwave power had a direct effect on the moisture content and drying time. The increase in microwave power led to a more rapid moisture drop to reach the moisture content of 6% or less. For instance, it took 73 min for microwave-dried sample at 160 W to attain moisture content of 6%, while the drying time at 800 W was 14 min.

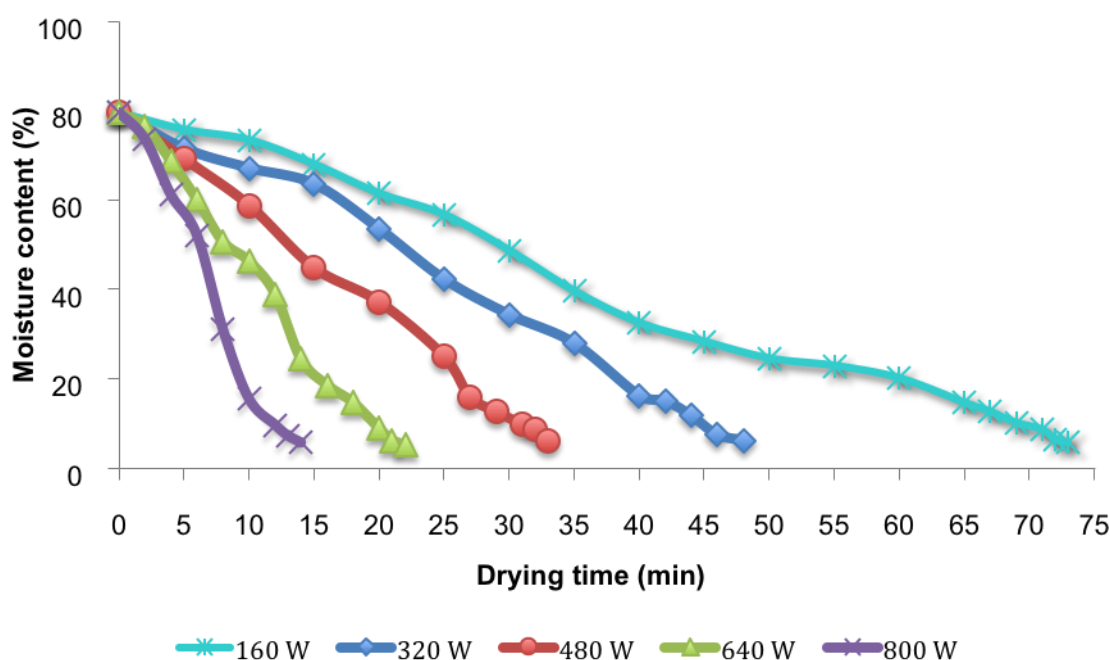


Figure 1. Drying curves for microwave drying of the fresh Gac aril.

3.4 Effect of microwave drying power on the colour characteristics of the Gac aril powder

Statistical results indicated that microwave power significantly affected chroma ($P < 0.001$) and hue angle ($P < 0.01$), but not lightness ($P > 0.05$). Generally, an increase in the microwave power resulted in increasing the hue angle and decreasing the chroma, indicating a loss of red colour (Fig 2). It could be explained by the fact that more heat generated during microwave drying at higher powers could destroy more carotenoids (refer to section 3.5), which are responsible for

the red colour of the Gac aril powder. Therefore, the significant degradation of colour in the powder was observed.

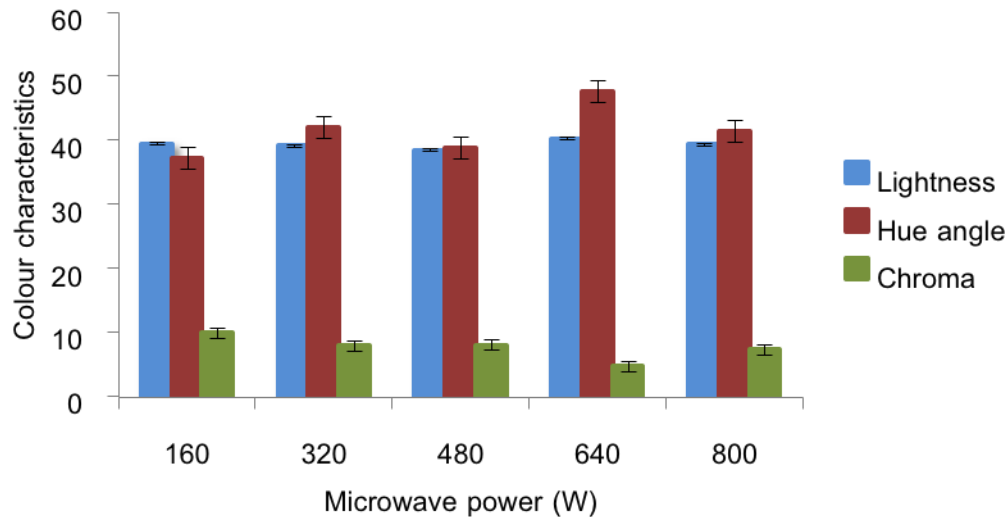


Figure 2. Colour characteristics of the Gac aril powder affected by different microwave powers.

3.5 Effect of microwave drying power on the carotenoid content of the Gac aril powder

Fig. 3 shows that the content of lycopene and β -carotene in the Gac aril powder is influenced by the different microwave powers. Statistical results showed that significant loss of carotenoids was found when increasing the microwave power from 160 to 800 W ($P < 0.001$). The highest content of lycopene and β -carotene in the dried Gac aril powder was obtained at microwave power of 320 W and 160 W, respectively. A significant loss of lycopene and β -carotene was found being 45 and 31% when the microwave power increased from 160 to 800 W. As a result, to effectively preserve the carotenoid content of the microwave-dried Gac aril powder, it is recommended to use a low microwave power to dry the Gac aril.

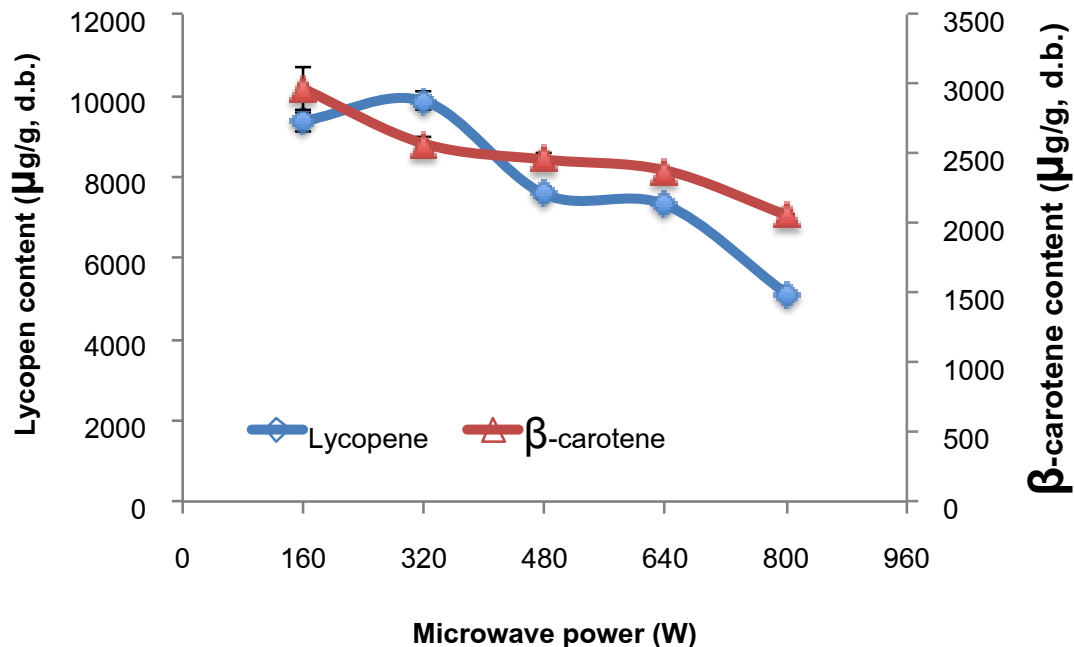


Figure 3. Carotenoid content of the Gac aril powder affected by different microwave power.

During the microwave drying process, thermal energy within the moist materials is converted from microwave energy, which is used for water evaporation. Local temperature may then increase above the boiling temperature of water (Zhang et al., 2006). Moreover, higher internal pressure is also generated, leading to an increase in the dried material's temperature. Higher microwave power results in higher temperature (Wojdyło et al., 2013). Therefore, the degradation of carotenoid could be explained by increasing in temperature due to applying high microwave power.

3.6 Comparison of different drying methods

It is desirable to investigate the effects of different drying methods on the quality of the dried Gac aril powder products. Table 3 shows the quality of the Gac aril powder produced from different drying methods, including air, freeze and microwave drying, in relation to colour and the content of lycopene and β-carotene. Statistical results showed that the colour and carotenoid content of the Gac aril powder were significantly affected by different drying methods ($P < 0.001$).

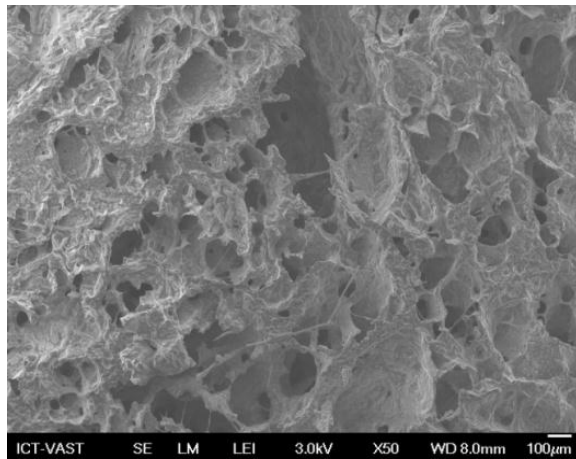
Table 3. Colour and carotenoid content of Gac aril powder produced by different drying methods.

Method	Lightness	Chroma	Hue angle	Lycopene	β -carotene
Air-drying	42.4 \pm 0.3 ^a	8.7 \pm 0.2 ^a	40.1 \pm 0.5 ^a	3653.3 \pm 351.3 ^a	4513.7 \pm 29.3 ^a
Freeze-drying	44.8 \pm 0.9 ^b	22.7 \pm 0.8 ^b	27.3 \pm 0.3 ^b	5341.5 \pm 377.7 ^b	5925.3 \pm 186.1 ^b
Microwave-drying	40.4 \pm 0.2 ^c	8.0 \pm 0.1 ^a	39.1 \pm 0.3 ^c	9350.1 \pm 252.0 ^c	5930.1 \pm 303.5 ^b

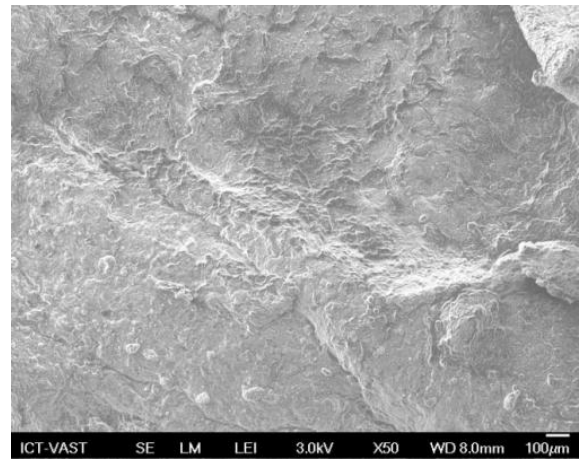
Values are mean \pm SD; Values in the same column followed by different superscripts (a-c) were significantly different ($P < 0.05$).

As can be seen in Table 3, the freeze-drying process was effectively preserved colour characteristics of the Gac aril powder, followed by microwave drying and air-drying. This is because the lower desirable value of hue angle indicates redder colour. However, it is interesting to note that the carotenoid content, especially lycopene, is much higher in the microwave-dried powder, followed by the freeze-dried and air-dried products. It is generally agreed that the quality of air-dried products is fairly poor, particularly as the resultant materials are sensitive to heat damage. In this study, although the β -carotene content in the microwave and freeze-dried products is quite similar, the lycopene content in microwave-dried powder is much higher. This phenomenon could possibly be explained that it took a very long time to freeze-dry the fresh Gac arils (more than 40 h) compared to microwave drying (48 min). As a result, a significant loss of lycopene in the freeze-dried Gac aril powder may occur due to oxidation.

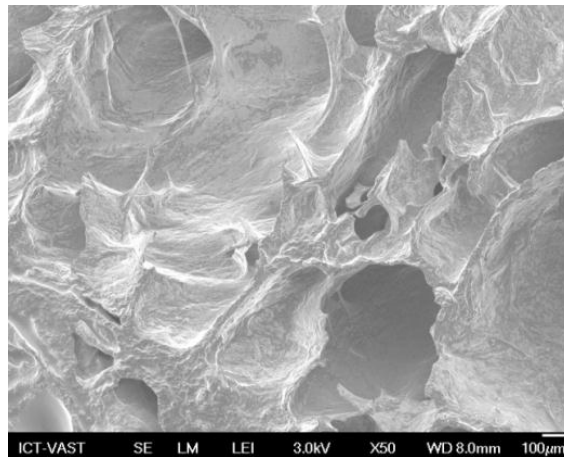
Furthermore, it is also necessary to investigate the microstructural changes of the dried Gac aril produced by different drying methods (Fig. 4). As can be seen in Fig. 4, the cell walls of the microwave-dried sample (Fig. 4C) appeared more ruptured than that of the air-dried arils (Fig. 4B), whereas a porous structure formed due to the removal of ice crystals was observed in the freeze-dried sample (Fig. 4A). Fig. 4B shows that a tough texture with the greater shrinkage and case hardening was observed in the air-dried Gac arils, resulting in a prolonged drying time (48 h). However, according to García-Martínez et al. (2013), the fast internal water evaporation that occurs when microwave energy is used may generate gas voids inside the cell walls, resulting in a more deformable and fragile structure and then open structures with a higher deformability (Fig. 4C). As a result, it took a very short time (less than 75 min) to microwave-dry sample as presented in Fig. 1.



(A) Freeze-dried Gac aril powder



(B) Air-dried Gac aril powder



(C) Microwave-dried Gac aril powder

Figure 4. Effect of different drying methods on the microstructural changes of Gac tissues.

3.7 Incorporation of microwave-dried Gac aril powder

The use of the natural dried materials rich in bioactive compounds as nutrient supplements and natural colourants is currently receiving considerable attention from food manufacturers and consumers. Therefore, investigation on the incorporation of microwave-dried Gac aril powder into foods such as the rice porridge needs to be carried out in this study.

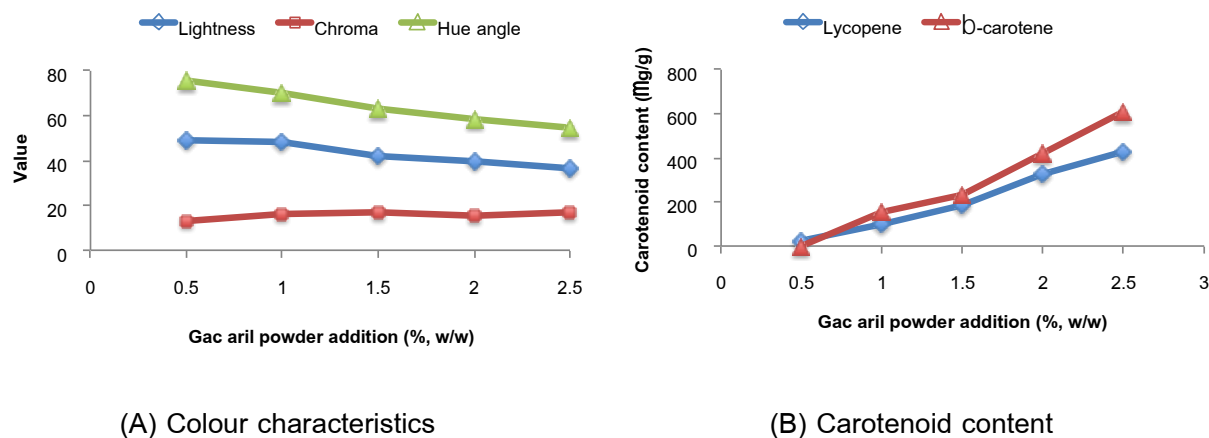


Figure. 5 Effects of different addition amounts of Gac aril powder into the rice porridge.

As can be seen in Fig. 5, an increase in addition of Gac aril powder into the rice porridge resulted in high values of colour characteristics and carotenoid content. The redder colour and the higher content of lycopene and β -carotene in the rice porridge were observed. It is also of interest to evaluate acceptance of the product in terms of colour and taste and results are presented in Fig. 6. High average score of the rice porridge product with the addition of 1.0 and 1.5% of Gac aril powder were obtained. It is indicated that the product was acceptable, demonstrating the feasibility of incorporation of Gac aril powder into the rice porridge product to improve nutritional quality by increasing lycopene and β -carotene and attractively natural colourant.

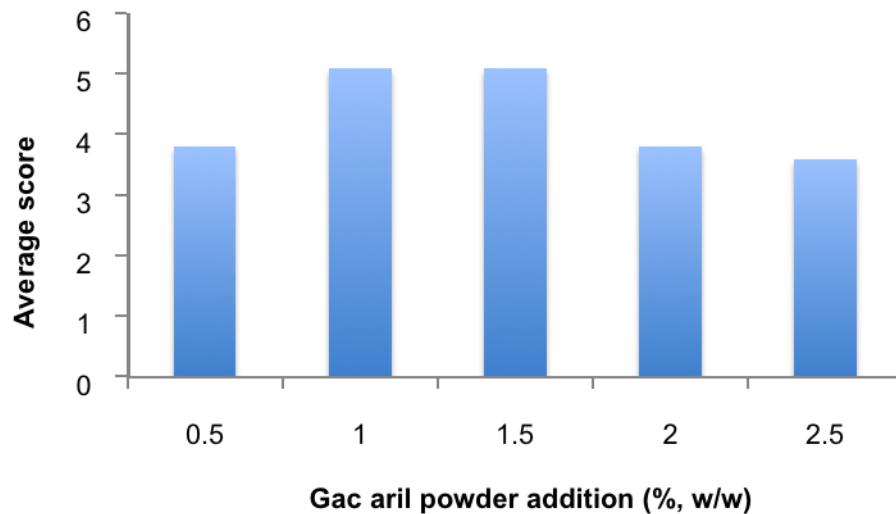


Figure 6. Sensorial evaluation of incorporated Gac aril powder rice porridge product.

4. Conclusions

It can be concluded that the high quality of the microwave-dried powder in terms of colour characteristics, lycopene and β -carotene contents is most effectively preserved by applying the pre-treatment in ascorbic acid (0.1%) for 30 min prior to microwave drying at 320 W. It was also found that the Gac powder rich in β -carotene and lycopene contents could be incorporated satisfactorily into the porridge product.

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