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Evolutions of β-carotene and Lycopene in a Natural Food Colorant from Gac (*Momordica cochinchinensis* Spreng) Arils during Drying

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Abstract. The use of a natural food colorant is recently of interest from the health benefit viewpoint. Gac aril has been reported to be a potential raw material for production of food colorant since it contains significant amounts of β-carotene and lycopene that are responsible for a yellow red color. However, drying which is an important step for a food colorant production may cause losses of those compounds in Gac aril. This study was aimed to investigate the effect of hot air drying temperature (60-80 ℃) on the evolutions and retention of β-carotene and lycopene in Gac aril. Color of the dried Gac aril was also determined. The results illustrated that both β-carotene and lycopene significantly degraded during drying. Higher drying temperature made higher degradation rate of β-carotene and lycopene. However, the drying temperature did not significantly affect the color of dried samples. Hot air drying at 60 ℃ of Gac aril was recommended for producing natural food colorant by providing the highest retention of β-carotene and lycopene.

Keywords: β-carotene, color, drying, lycopene

1. Introduction

Gac (*Momordica cochinchinensis* Spreng) is a tropical fruit widely found in many countries including China, India, Veitnam, Laos and Thailand [1]. It is classified in the *Cucurbitaceae* family, round or oblong in shape and full of spines. The fruit consits of a thick yellow mesocarp and red soft and sticky aril covering black seed [2]. The Gac aril contains high amount of β-carotene and lycopene which are claimed to possess antioxidant activity [3], [4]. Kubola et al. [5] reported the levels of β-carotene and lycopene in the Gac aril were approximately 1.18 and 0.49 mg/g fresh, respectively. Recently, several works reported that the Gac aril has a potential to be a starting raw material for production of a food colorant. Hoang [1], for example, showed the Gac aril powder could be mixed into steamed glutinous rice, yogurt, cheese sauce and fettuccine pasta for enhancing a yellow red color of the food.

The production steps of the food colorant from Gac aril have been reported [1]. The steps start from washing, cutting the fruit, scooping the arils and removing the seeds from the arils. The seedless arils are then dried before being ground into powder. As the production steps involve a thermal process (e.g., drying), the changes of some physical properties and bioactive compounds may occur. Tran et al. [2] reported that 35% of carotenoids in Gac aril degraded after hot air drying at 60 ℃. Their results also showed that the intensity and color brightness of the Gac powder were lower when compared with the fresh aril. Moreover, Dermiray et al. [6] studied the degradation of β-carotene and lycopene in tomatoes while drying between 50-80°C. Their study revealed that drying at 70°C was the recommended condition to minimize β-carotene and lycopene degradation.

To obtain the high quality of the food colorant from Gac aril, it is necessary to determine how the drying temperature affects the changes of bioactive compounds and color in dried Gac aril. Therefore, this work was

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aimed at investigating the evolutions of β-carotene and lycopene content during hot air drying at 60-80 ℃ as well as the change of color in dried Gac aril.

2. Materials and Methods

2.1. Sample Preparation

Gac fruits (*Momordica cochinchinensis* Spreng) were obtained from a local market. Prior to each experiment the samples were gently washed with tap water and the surface was dried with a cloth. The Gac fruits were cut into halves before scooping out the arils and removing the seeds from the arils; only the arils were used as a raw material.

2.2. Drying Experiments

In each drying experiment approximately 100 g of the aril was spread on a tray in a thin layer. The sample was dried using a hot air oven (Memmert, 500/108I, Germany) at temperatures ranging from 60-80 ℃ until a final moisture content of less than 10% (db) was reached. During each experiment 3-5 g of the sample was taken out at various time intervals to determine its moisture content. The moisture content of the sample was determined by using a gravimetric method at 105 ℃ (AOAC Method 984.25; AOAC, 2000).

2.3. Determination of β-carotene

Analysis of the total amount of β-carotene was performed following a modification of the method described by Britton, G. 2005. Fresh Gac (5 g) or dried Gac (3 g) was placed in a test tube filled with 10 mL of acetone. The tube was vortexed for 30 s and centrifuged at 2100 rpm for 5 min. The acetone extract was then filtered through Whatman No. 1 filter paper. The sample was re-extracted twice and combined with the first extract. Aliquot of the extract was concentrated using a rotary evaporator (Büchi Labortechnik AG, R125, Flawil, Switzerland) at 50 ℃ and subsequently reconstituted with 1 mL of acetonitrile. The extract was filtered through a 0.45 μm filter before being injected into Zorbax Eclipse C_{18} 5 μL (4.6 ×150 mm) HPLC column (Agilent, 1100 series, Waldbronn, Germany). The mobile phase was ethanol and acetonitrile (60:40) and its flow rate was set at 1.0 mL/min. A UV spectrophotometer detector, operated at a wavelength of 456 nm, was used for detecting β-carotene. Quantification of β-carotene was carried out based on a β-carotene standard curve.

2.4. Determination of Lycopene

A sample was extracted and analyzed following the same procedure as that for β-carotene (Britton, G. 2005). A UV detector at a wavelength of 280 nm was used for quantification of the lycopene content. Quantification of the lycopene was carried out based on a lycopene standard curve.

2.5. Color Measurements

Color of a sample was measured in the CIELAB color system using spectrophotometer (HunterLab ColorFlex Version 1.72, USA). Three Hunter parameters, i.e., L^* (lightness), a^* (redness and greenness) and b^* (yellowness and blueness), were measured and the total color difference (ΔE) was calculated as follows:

$$\Delta E = \sqrt{\left(\Delta L^*\right)^2 + \left(\Delta a^*\right)^2 + \left(\Delta b^*\right)^2}$$

$$\Delta L = L^* - L^*_0,\ \Delta a = a^* - a^*_0 \text{ and } \Delta b = b^* - b^*_0$$

where L_0, a_0, b_0 are the color values of the fresh sample. All measurements were performed in triplicate and the data were reported as average values of the three measurements.

2.6. Statistical Analysis

The experiments were designed to be completely random. The data were subjected to an analysis of variance (ANOVA) and are presented as mean values with standard deviations. Differences between mean values were established using Duncan's multiple range tests. Values were considered at a confidence level of 95%. All experiments were performed in triplicate unless specified otherwise.

3. Results and Discussion

3.1. Drying kinetic of Gac Arils

The moisture content of a fresh sample was approximately 4.85 ± 0.72 g/g dry basis. Figure 1 shows the drying curves of the samples undergoing hot air drying at various temperatures. As expected, the drying rate at higher temperatures was faster than that at lower temperatures. This was due to drying at higher temperatures results in a larger driving force for heat and mass transfer leading to higher moisture diffusivity values than that at lower temperatures. The equilibrium moisture content (EMC) and time needed to dry a sample to the desired moisture content of less than 0.1 g/g dry basis are listed in Table I. EMC of the samples was in the range of 0.050-0.065 g/g dry basis. The results showed that higher drying temperatures required shorter drying time to reach the desired moisture content.

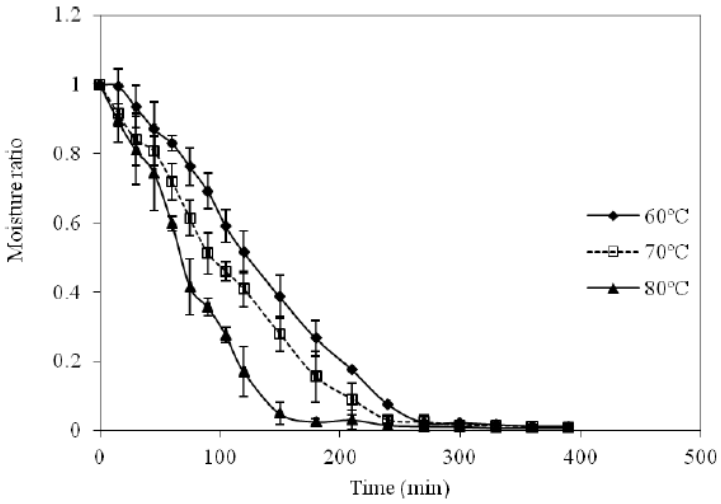

Fig. 1: Drying curve of Gag arils at different temperatures.

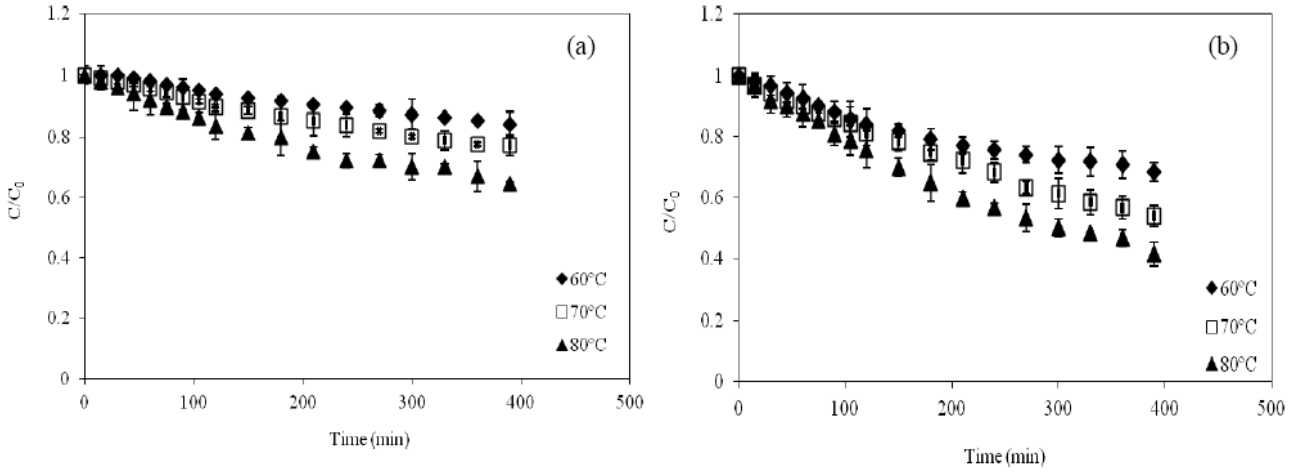

Fig. 2: Evolutions of (a) β-carotene and (b) lycopene during drying at different drying temperatures.

Table I: Drying time of cabbage outer leaves with the final moisture content (less than 0.1 g/g dry basis) and equilibrium moisture content (g/g dry basis).

Temperature (℃)	Drying time (min)	Equilibrium moisture content (g/g dry basis)
60	330	0.060 ± 0.010
70	300	0.065 ± 0.009
80	270	0.050 ± 0.004

3.2. Evolutions of β-carotene and Lycopene during Drying

The evolutions of β-carotene and lycopene during drying are shown in Figure 2. The results showed that both β-carotene and lycopene decreased gradually during drying. It was also observed that higher

temperatures resulted in larger reduction of β-carotene and lycopene. This was probably due to the degradation of β-carotene and lycopene might be caused by both enzymatic reaction and thermal destruction. Lipoxygenase, an enzyme found in fresh fruits and vegetables, was responsible for the oxidative degradation of β-carotene and lycopene [7]. Increase in drying temperatures would accelerate lipoxygenase activity leading to higher losses of the compounds. At higher temperatures heat also could more penetrate into the plant cells resulting in more degradation of the compounds [8]. In addition, it can be seen that the reduction rate of lycopene was faster than that of β-carotene. The results were consistent with those of Anguelova and Warthesem [9] who reported that the degradation rate of lycopene was more extensive than that of β-carotene at a temperature of 60 ℃.

Table II presents the β-carotene content and retention of β-carotene in the final dried Gac; a comparison was made with the content of β-carotene in the fresh Gac aril. It can be seen that drying at 60 ℃ exhibited the highest retention of β-carotene (85.63%); this was followed by drying at 70 ℃ (78.45%) and drying at 80 ℃ (63.62%). Similar results with the highest retention of lycopene at 60 ℃ (71.80%), followed by 70 ℃ (61.38%) and 80 ℃ (53.23%) were noted (Table III).

Table II: β-carotene content and retention in dried Gac as compared with fresh Gac aril.

Temperature (℃)	β-carotene content (mg/g dry weight)	Retention (%)
Fresh	197.75 ±19.64^{a}	-
60	170.52 ±14.75^{ab}	85.63 ±4.25^{a}
70	158.21 ±15.90^{b}	78.45 ± 2.49^{b}
80	126.77 ±11.00^{c}	63.62 ±3.99^{c}

Same letters in the same column indicate that values are not significantly different (p>0.05).

Table III: Lycopene content and retention in dried Gac as compared with fresh Gac aril.

Temperature (℃)	Lycopene (mg/g dry weight)	Retention (%)
Fresh	270.19 ±15.75^{a}	-
60	193.80 ±15.23^{b}	71.80 ±3.26^{a}
70	168.33 ±14.55^{b}	61.38 ± 2.02^{b}
80	134.50 ±14.61^{c}	53.23 ±2.19^{c}

Same letters in the same column indicate that values are not significantly different (p>0.05).

Table IV: Color of fresh and dried Gac at different drying temperatures.

Drying temperature (℃)	L^*	a^*	b^*	$\triangle E$
Fresh	43.51 ±2.43^{a}	26.56 ±1.29^{a}	18.15 ±3.05^{a}	-
60	22.18 ±3.91^{b}	27.73 ±1.23^{a}	20.84 ±1.06^{a}	21.59 ±3.67^{a}
70	25.77± 2.53^{b}	29.94 ±0.85^{a}	22.16 ±3.23^{a}	18.76 ±1.76^{a}
80	29.07 ±0.82^{b}	31.13±2.45^{a}	24.20 ±2.82^{a}	18.41 ±0.85^{a}

Same letters in the same column indicate that values are not significantly different (p>0.05).

3.3. Color Measurements

Table IV presents the color parameters of the Gac aril, in the fresh form and after drying at different temperatures. The lightness of the dried Gac aril was lower, while the redness and yellowness were not significantly different as compared with the values of the fresh sample. It was also observed that drying temperature did not significantly affect the color of the dried Gac aril. Although degradation of β-carotene and lycopene in the Gac aril occurred during drying, lower moisture content might result in enhancing color concentration of the dried Gac. Similar results have previously been reported. Guinéa and Barrocab [10], for example, found that the redness and yellowness of pumpkin were more intense after drying at 30 and 70 ℃.

4. Conclusions

The experiments were performed to determine the effects of different drying temperatures on the evolutions of β-carotene and lycopene in the Gac aril. It was evidenced that the drying temperature had a significant influence on the losses of β-carotene and lycopene in Gac aril. No significant differences in redness and yellowness values of the fresh and dried Gac aril were observed. Overall, drying at 60 ℃ is a recommended process for production of natural food colorant as it provided the highest retention of β-carotene and lycopene.

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