Journal of Food Science and Agricultural Technology

International peer-reviewed scientific online journal

Published online: http://rs.mfu.ac.th/ojs/index.php/jfat

Original Research Article

Effect of different drying processes on physical properties and carotenoid content of Gac fruit (*Momordica cochinchinensis Spreng*.)

Sirinthip Pinthong[1], Kunchit Judprasong[1]*, Nuttapol Tangsuphoom[1], Sitima Jittinandana[1], and Yupaporn Nakngamanong[1]

[1]Institute of Nutrition, Mahidol University (INMU), Phutthamonthon 4 Rd., Salaya, Phutthamonthon, Nakhon Pathom 73170, Thailand

ARTICLE INFO

Article history:

Received 31 July 2018

Received in revised form 31 December 2018

Accepted 08 January 2019

Keywords:

Carotenoids

Drying

Gac fruit

Powder

ABSTRACT

Gac fruit (*Momordica cochinchinensis* Spreng.) is an indigenous fruit of South and Southeast Asia. Pulp and aril of Gac fruit contain high levels of carotenoids and are known as strong antioxidants. However, the shelf life of fresh and ripened Gac fruit is limited (about 1 week). Gac powder is a good alternative source of raw material in food development. The aim of this study is to investigate the nutritional value of fresh Gac fruit and the effects of different drying processes on color characteristics, total carotenoid content, water solubility, and water holding capacity of Gac fruit powder. Fresh Gac fruit and its powders from different drying processes including freeze drying, spray drying and drum drying were analyzed to determine their physical and chemical properties. The results showed that fresh Gac fruits contained several nutrients, vitamins, minerals, and fatty acids. The moisture content of dried Gac powder was in the range of 2-8% and was found to be suitable for long-term storage and food development process. Spray drying (treated with pectinase) was found to be effective in retaining the carotenoids of Gac powders (b-carotene 57 mg/100g dried weight (DW), lycopene 139 mg/100g DW) and was similar to that of fresh Gac fruit (60.3 and 134.2 mg/100g DW respectively). In contrast, spray drying (not treated with pectinase) showed low amount of carotenoids (b-carotene 6.1 mg/100g DW and lycopene 12.5 mg/100g DW). Moreover, the drying processes significantly affected the color characteristics of Gac powder, including lightness (L*), redness (a*), yellowness (b*) and overall color difference (ΔE). Among the drying methods, the Gac fruit powder obtained from freeze drying (with ΔE 3.9) retained most of the color similar to the fresh Gac fruit. Gac powder obtained from spray drying (not treated with pectinase) provided the highest water solubility value whereas freeze drying showed the lowest water solubility value. Gac powder from freeze drying showed higher value of water holding capacity. Different drying processes provided different effects on both carotenoid content and physical properties of the product. In summary, spray drying process (treated with pectinase) retained more carotenoids and exhibited good characteristics when compared to other drying processes and can be added directly to several food products.

* *Corresponding author*: Tel.: +66-2800-2380 Ext. 324; Fax: +66-2441-9344

E-mail address: kunchit.jud@mahidol.ac.th

Published by School of Agro-Industry, Mae Fah Luang University

ISSN: 2408-1736

INTRODUCTION

Gac fruit (*Momordica Cochinchinensis* Spreng) also known as Baby Jackfruit, Spiny Bitter Gourd, Sweet Gourd, or Cochinchin Gourd, is a bright orange spiky fruit that can be easily grown in tropical regions such as Thailand, Vietnam, Laos and China. Primarily found in South East Asia, Gac fruit has been a well-kept secret for centuries and was used mainly as source of food and medicine in many countries such as Vietnam and Laos. For centuries, Vietnamese people considered Gac fruit as one of the best fruits to treat various ailments and have been used to improve eyesight, promote long life and increase physical energy. Similarly, in China, the seeds were used in traditional Chinese medicine and have been reported to contain multiple trypsin inhibitors (Wong et al., 2004). The young fruit has a green color and becomes dark orange or red when it ripens. The outer shell of the Gac fruit is not edible, but the pulp and the oily, red fleshy membrane surrounding the seed, known as aril are palatable. Pulp and aril are not sweet, but have a very mild taste and mushy texture. Gac fruits have been receiving considerable attention recently due to their antioxidant capacity which may provide protection against cancer and other degenerative diseases as revealed by epidemiological studies. The carotenoid content of the Gac fruit, especially β-carotene and lycopene were found to be much higher than other common carotenoid-rich fruits e.g., pumpkin and tomato (Mai et al., 2013). Lycopene is one of carotenoids recognized as a phytonutrient which can be found in red fruits and vegetables such as tomatoes, pink grapefruits, watermelons and papayas. It was reported to be associated with reduced risk of certain cancers such as prostate cancer, digestive–tract cancer and lung cancer (Kubula & Sirimornpun, 2011). Beta-carotene, one of carotenoids is also a type of pigment found in several plants. It can be converted to vitamin A in the human body, and is known as 'provitamin A carotenoid'. Beta-carotene can be found abundantly in food and has been associated with potential protective mechanisms against heart diseases and cancer. The oxidation of LDL-cholesterol is a crucial factor in the development of atherosclerosis and beta-carotene acts by inhibiting the lipoprotein oxidation (Mezzomo & Ferreira, 2016). Many studies have shown that Gac fruit is a rich source of bioactive compounds especially lycopene and beta-carotene. The content of lycopene and Beta-carotene in the aril was higher than any other part of the Gac fruit (Kubula & Sirimornpun, 2011). Similarly, Aoki et al. (2002) reported that Gac aril had substantial amounts of lycopene and beta-carotene (38,000 and 10,100 μg/100g of fresh sample, respectively) which was higher than other plants. In addition, the lycopene content of Gac fruits (53,000 μg/100g) was higher than that of tomatoes (700 μg/100g) (Vuong et al., 2006). Gac aril was found to be composed of 22% fatty acids by weight and contained 32% oleic, 29% palmitic, and 28% linoleic acids. Gac fruit is not only rich in beta-carotene, lycopene and essential fatty acids but also had significant levels of other carotenoids and bioactive compounds such as α-tocopherol (vitamin E), phenolic compounds and flavonoids (Kubola & Siriamornpun, 2011). Gac is a seasonal fruit with a short shelf-life and is not available all year round. It can be harvested annually in the months of December and January (Parks et al., 2013). Many studies have reported various methods of preservation to retain the nutrients of oil from Gac aril, which showed higher carotenoid content. For example, Kha et al. (2013) studied about the oil extraction from Gac aril by using microwave (630W, 65 min) and steam (20 min) prior to hydraulic pressing. Kubola et al. (2013) reported the extraction of Gac oil using different solvents and found that a mixture of chloroform, methanol, petroleum ether, and hexane improved lycopene and beta-carotene content in the extracted Gac oil. Besides Gac oil, many studies have also investigated methods to preserve the nutrients of Gac powder. For example, Tran et al. (2008) studied the effect of enzymatic pretreatment and different drying methods on Gac aril powder. Kha et al. (2010) reported that the inlet-air temperature of 120°C and 10% (w/v) maltodextrin was the most suitable condition for retaining the carotenoids and antioxidant activity of Gac powder. Since Gac powder occupied small space, it is more convenient for the storage and transportation of the final product. Moreover, Gac fruit in powder form can be used easily for food preparation. Thus, the objective of this study is to investigate the nutritive value of fresh Gac fruit and effects of different drying processes such as drum drying, spray drying (treated with and without enzyme) and freeze drying on color characteristics, total carotenoid content, water solubility and water holding capacity of Gac fruit powder.

MATERIALS AND METHODS

Sample preparation

Fresh Gac fruits were graded by local gardeners as fully matured by the dark red colour of the outer shell and by the size (about 9 am width and 11 cm length) of the fruit. About 100 kg of them were purchased from three Gac fruit gardens at Nakhon Pathom province, Thailand. The Gac fruits were cut open, inner parts were scooped out and the red aril were completely separated from the seeds. The pulp and aril were blended together, packed in aluminum plastic bags, and stored at -20°C for drying process and chemical analysis (within 1-2 weeks).

Drying process

Spray drying

- Not treated with enzyme

The blended Gac sample was mixed with deionized water (DI water) at a ratio of 1:5 (sample to DI water, w/w) in a food processor. The resulting juice was twice filtered using a filter screen of 100 μm so as to avoid clogging of the dryer atomizer. After that, 10% (w/v) of maltodextrin (10 DE) was added to the juice. The inlet temperature was set at 120°C and the measured outlet temperature was about 80°C respectively. The drying air flow rate, compressor air pressure, and feed rate were kept constant at 56±2 m3/h, 0.06 MPa gauge, and 12-14 mL/min, respectively (Kha et al., 2010). After the spraying drying, the Gac fruit powder was collected in aluminum plastic bags, packed under vacuum sealer and stored at -20ºC for further analysis (within 1-2 weeks).

- Treated with enzyme pectinase

The blended sample was treated with 0.1% pectinase enzyme at pH 3.3-4.0 (adjusted by 10% citric acid) and incubated at 20-25°C for 3.5 hrs. The resultant sample was spray dried using the conditions described in not treated with enzyme condition.

Freeze drying

The blended Gac sample was spread on trays of the freeze dryer with less than 1-cm thickness and kept in a freezer at -20°C for two hours. The frozen sample was dried in a freeze drying system using four major steps including freezing, primary drying, secondary drying, and final drying treatment, which took about 36 hrs for completion. The freeze dried sample was grinded into powder, filled in aluminum foil bags, and kept in -20°C for further use (within 1-2 weeks).

Drum drying

The blended Gac sample (2 kg) was filtered and then dried using a double drum dryer at 80°C, with drum speed of 9 rpm, and drum gap around 0.1 mm. The time for processing the sample was about 3 hrs. After the sample was dried, it was grinded into a powder, filled in aluminum foil bags and kept in -20°C for further use (within 1-2 weeks).

Analytical method

Nutrient determination

Nutrient analysis was conducted using standard AOAC methods (AOAC, 2016) which were well-validated. All samples were analyzed at the Institute of Nutrition laboratory, which conformed to ISO 17025:2005, the international standard for laboratory quality systems in terms of proximate compositions, minerals, and vitamins analysis.

- Proximate composition

Total nitrogen content was determined by Kjeldahl method (AOAC 2016; 981.10). The protein content was calculated from the nitrogen content as % nitrogen x 6.25. Moisture content was determined by drying the sample at 100 ± 2°C until a constant weight was obtained (AOAC 2016; 952.45). Crude fat content was analyzed by acid digestion prior to continuous extraction with petroleum ether in Soxtec system (AOAC 2016; 945.16). Ash content was determined by incinerating all organic matter at 550 ± 5°C (AOAC 2016; 945.46). Carbohydrate was calculated using the following formula: 100-(moisture+protein+fat+ash). Energy was calculated by Atwater factor (4 for protein and carbohydrate and 9 for total fat). Enzymatic gravimetric method was used for total dietary fiber analysis (AOAC 2016; 991.43).

- Minerals

Acid digestion of the samples was carried out in a closed Teflon vessel. The determination of magnesium, iron, copper, and zinc were carried out by using an inductively coupled plasma optical emission spectrophotometer (ICP-OES) according to AOAC 2016; 984.27. The ash residue which was obtained by incinerating the sample at 550°C for 2 h, was dissolved in acid and analyzed by flame atomic absorption spectrophotometer (AAS), according to AOAC 2016; 975.03 for the determination of calcium, sodium, and potassium. The acidic sample solution was also used for phosphorus analysis by the gravimetric method according to AOAC 2016; 962.02.

- Vitamins

Vitamins C and E were determined by HPLC method according to AOAC 992.03 (AOAC, 2016; Sanchez-Mata, Camara-Hurtado, Diez-Marques, & Torija-Isasa, 2000, respectively). For vitamin C, the sample was extracted with 3% metaphosphoric acid. The homogenate was filtered, and ascorbic acid was separated by reversed-phase HPLC with UV detection at 248 nm followed by quantification against an external ascorbic acid standard. For vitamin E, the sample was saponified with ethanolic potassium hydroxide solution and extracted with hexane. Tocopherol (vitamin E) was separated by reversed-phase HPLC with UV detection at 292 nm and quantified against an external tocopherol standard.

- Fatty acids

Fat and fatty acids were determined by hydrolysis method. Fat was extracted with petroleum ether and then methylated with boron trifluoride (BF_3) in methanol to form fatty acid methyl esters (FAMEs). Fatty acids were determined by capillary gas chromatography (GC) against C17:0 as an internal standard (AOAC 2016; 996.06).

Determination carotenoid content

- Extraction of carotenoids

The carotenoids in the samples were extracted using the method of Chitchumroonchokchai et al. (2017). A sample, 0.1 gram, was added to 1 mL of phosphate buffered saline (PBS) solution and homogenized three times. Then, the sample was mixed with 5 mL of Methanol: Tetrahydrofuran (1:1) and sonicated for 2 min. Hexane, 5 ml, was added into the mixture and centrifuged at 4600 rpm for 10 min. The supernatant was collected in a round-bottomed flask. The extraction step was repeated three times until the residue become colorless. Then, the sample extract was reconstituted with methyl tert-butyl ether (MtBE) (1500 µL) and methanol (500 µL). The final solution was filtered through 0.45 µm membrane filters and further injected (20 µL) into the HPLC.

- Carotenoids analysis by high performance liquid chromatography (HPLC)

Carotenoids analysis was performed using Agilent 1100 series pumps, a diode array detector, and YCM C30 column (4.6 x 250 mm, internal diameter 5 µm). The mobile phase consisted of 98% methanol+2% ammonium acetate (solvent A) and Methyl tert-butyl ether (MtBE) (solvent B) at a ratio of 80:20 with a flow rate of 0.6 mL/min. The column temperature was set at 25°C and the absorbance was read at 470 and 450 nm (Chitchumroonchokchai et al., 2017).

Particle size analysis

Sieve analysis was carried out by stacking and vibrating the sieve in ascending order of mesh size 40, 60, 80, 100, and 120 to obtain particle size of 425, 250, 180, 150, and 125 µm (American Society for Testing and Material, ASTM) respectively (Caparino et al., 2012). The major particle size in each drying method was analyzed and then used for water solubility and water holding capacity.

Water solubility (WS) and Water holding capacity (WHC)

Water solubility (WS) and water holding capacity (WHC) of Gac powder were determined according to Koksel et al. (2008). One gram of each sample powder was weighed into a pre-weighed centrifuge tube and added with 10 mL of DI water, and then vortexed for 15 s every 5 min. After 40 min, it was centrifuged (model Z 400K; HERMLE Labortechnik GmbH, Wehingen, Germany) at 6,500 rpm for 10 min at 25°C. The supernatant was dried at 105°C. The precipitate was weighed and then dried at 105°C. Water solubility (WS) and water holding capacity (WHC) were calculated as the following equations:

Water solubility (%)

$$WS = (\text{Weight of dried sample}/\text{Weight of sample}) \times 100$$

Water holding capacity (g/g)

$$WHC = \frac{(\text{Weight of wet precipitate} - \text{Weight of dried precipitate})}{\text{Weight of sample}}$$

Color measurement

The color value was measured using a Hunter Lab Digital Colorimeter (ColorFlex EZ, Hunter Associates Laboratory, Inc., Reston, Virginia) in a CIE-color system (L*, a*, b*). The result was expressed as L* (Lightness: 0 = black, 100 = white), a* (+ = redness, - = greenness) and b* (+ = yellowness, - = blueness) values. Total color difference was calculated by the formula as follows:

$$\Delta E^* = \sqrt{(L^* - L_0^*)^2 + (a^* - a_0^*)^2 + (b^* - b_0^*)^2}$$

Where L0, a0 and b0 are the values of the samples at zero time, and L, a, and b are the measured values of each sample after drying process. The total color difference can be estimated by the changes in color of the products during storage as compared to the fresh Gac fruit and was categorized as not noticeable (0–0.5), slightly noticeable (0.5–1.5), noticeable (1.5–3.0), well visible (3.0–6.0) and great (6.0–12.0)

Statistical analysis

All parameters were performed in three replications. The results were expressed as mean ± standard deviations. A one-way analysis of variance (ANOVA) with Duncan's multiple range test was used to indicate the significance of differences (p 0.05) among the mean values of each parameter. The statistical analysis was performed using SPSS software for Windows version 19.0 (SPSS Inc., lllinois, U.S.A.).

RESULTS AND DISCUSSION

Nutrients

Nutrient composition of fresh and fully ripened Gac fruit, composed of pulp and aril, is shown in Table 1. Moisture was the major component of the of fresh Gac fruit (89.76±0.40 g/100g fresh weight, FW). Fresh Gac fruit contained substantial amount of dietary fiber (3.54 g/100g FW) and small amount of protein and fat (0.62 and 0.37 g/100g FW, respectively). It also had small amount of carbohydrate (7.85 g/100g FW) and provided a total energy of 37 kcal/100g FW. Gac fruit is also a storehouse of several minerals such as potassium (487.40 g/100g FW), phosphorus (100.78 g/100g FW) and vitamins including vitamin C (3.79 g/100g FW) and vitamin E (3.15 g/100g FW). Since limited information is available on the nutrient composition of fresh Gac fruits, the present result is considered as the first report. However, Voung et al. (2006) reported that the vitamin E content in fresh Gac fruit was 7.6 mg/100g FW, which was two times higher than those found in the fresh sample in this study (3.15 g/100g FW).

Table 1. Nutrients of fresh Gac fruit (pulp and aril).

Nutrients		Amount (per 100 g)
Proximate composition:		
	Energy (kcal)	37
	Moisture (g)	89.76
	Protein (g)	0.62
	Total fat (g)	0.37
	Dietary fiber (g)	3.54
	Ash (g)	1.40
	Carbohydrate (g)	7.85
	Total sugar (g)	6.15
Minerals:		
	Calcium (mg)	20.72
	Magnesium (mg)	13.72
	Phosphorus (mg)	100.78
	Sodium (mg)	71.64
	Potassium (mg)	487.40
	Copper (mg)	0.04
	Iron (mg)	0.13
	Zinc (mg)	0.11
Vitamins:		
	Vitamin E (mg)	3.15
	Vitamin C (mg)	3.79

Fatty acid composition of fresh Gac fruit (pulp and aril) is presented in Table 2. Prominent fatty acids were oleic acid (C18:1, 64.55%), followed by palmitic acid (C16:0, 18.10%) and stearic acid (C18:0, 10.74%). Monounsaturated fatty acid was found as the major component (64.7%) and the saturated fatty acid present was about 29.5%. A previous study reported that oleic, palmitic and linoleic acids were the main fatty acids in Gac aril while stearic, linoleic, oleic and palmitic acids were the major fatty acids in Gac seed (Ishida et al., 2004). Oleic and linoleic acids present in Gac fruit benefit human health by reducing LDL-cholesterol and was reported to have anti-atherogenic effect (Pariza, 2004 & Lopez-Huertas, 2010). The difference in values of the nutrients in the Gac fruit may depend on several factors such as plant part, species and state of ripening.

Table 2. Fatty acid composition of fresh Gac fruit (pulp and aril).

Fatty acid	% Total fatty acid
Lauric acid (C12:0)	0.13
Myristic acid (C14:0)	0.53
Palmitic acid (C16:0)	18.10
Palmitoleic acid (C16:1)	0.18
Stearic acid (C18:0)	10.74
Oleic acid (C18:1)	64.55
Linoleic acid (C18:2, n-6)	4.78
Linolenic acid (C18:3, n-3)	0.98
Saturated fatty acid (SFA)	29.5
Monounsaturated fatty acid (MUFA)	64.7
Polyunsaturated fatty acid (PUFA)	5.8

Moisture contents in different types of Gac powder.

Table 3 presents moisture content of fresh Gac fruit and Gac powders from different drying processes. The moisture content of Gac powders from different drying methods ranged from 2 to 8% and was significantly different (p 0.05). Among the different drying processes, the spray drying (treated with pectinase) and drum drying showed highest and lowest moisture content (8.09±0.12 and 2.77±0.28 g/100g FW respectively) in Gac powders. The Gac powder that had undergone spray drying with or without pectinase showed difference in moisture content. This may be due to the addition of maltodextrin in the spray drying process (not treated with pectinase) that had caused a reduction in moisture content of the Gac powder. This result was supported by Quek et al. (2007) who observed that the moisture content of spray dried watermelon powder decreased with increase in the concentration of maltodextrin. In addition, the studies of Oberoi and Sogi (2015), Adhikari et al. (2004) and Ekpong et al. (2016) showed that the addition of maltodextrin can reduce the moisture content of the sample by increasing the total solid content of the feed prior to the spray drying and decreasing the water through evaporation. Spray drying (treated with pectinase) produced sticky Gac powder which easily absorbed moisture from the environment and produced higher moisture content as compared to other samples. On the other hand, Gac powder from drum drying had lower moisture content than the other samples due to the exposure of the sample to heat for a longer period. Hence, evaporation of water took place at a higher rate which affected the moisture content of the sample. Gac powder from freeze drying showed moisture content higher than spray drying (not treated with pectinase) and drum drying. This is due to the spongy structure of freeze dried sample that caused rapid moisture absorption during grinding, which lead to higher moisture content (Xu Si, et al. 2015). Overall, the moisture content of the Gac powders produced by different drying processes was considered suitable and safe for long term storage.

Carotenoid content of fresh Gac fruit and Gac powder.

The carotenoid contents of fresh Gac fruit and Gac powders from different drying processes are also showed in Table 3. The highest total carotenoids were found in fresh Gac fruit and Gac powder obtained from spray drying process (treated with pectinase) (194.50+8.99 and 195.93±11.43 mg/100g dried weight, DW), which indicated that spray drying with pectinase treatment did not affect to the carotenoid content. Two compounds namely, beta-carotene (29-34%) and lycopene (66-71%) were the major species of carotenoids found in Gac fruit. A ratio between beta-carotene and lycopene was found in both fresh and dried powder of Gac fruit. In general, plant cell walls are composed of cellulose, hemicellulose and pectin (Mai et al., 2013). The pectinase enzyme which was added before spray drying process could disrupt the cell wall releasing the intracellular carotenoids which are easily extracted during carotenoid extraction process. This may be the reason for the presence of high amount of carotenoids in the Gac powder obtained by spray drying (treated with pectinase). This study agreed well with the studies of Choudhari and Ananthanarayan (2007) and Strati et al. (2015) who observed that the enzymes (cellulase and pectinase) could increase the extraction of the lycopene from tomato fraction. In addition, pectinase was reported to be more effective than cellulase for the enzymatic treatment of tomatoes fraction (peel) and waste. Tomato peel is composed of cellulose, hemicellulose and pectin. The cellulase enzyme hydrolyzed the 1.4-β-D-glycosidic linkage in cellulose that are present in primary cell wall. However, pectinase had pectolytic and hemicellulose lytic activities that can break down pectin in the middle lamella and primary cell wall. In addition, Cinar (2004) reported the use of enzymes (cellulase and pectinase) for extraction of carotenoids from orange peel, sweet potatoes and carrot. On the other hand, Tran et al. (2008) and Kha et al. (2014) observed that the Gac sample treated with enzyme showed low carotenoid content when compared to the sample that was not treated with enzyme. The explanation was that the surface area of the enzyme-treated samples that is in contact with oxygen was larger than the surface of untreated sample. Hence, more cell walls were broken down during the enzymatic hydrolysis, releasing more carotenoids.These carotenoids undergo degradation when exposed to oxygen.

For spray drying process without pectinase treatment, Gac powder showed lowest total carotenoid content (18.65+2.11 mg/100g DW) due to the requirement of high concentration of maltodextrin (10%) for the adjustment of total solids before spray drying. Maltodextrin is commonly used as bulking agent for artificial sweetener, as a drying aid, as a carrier or an encapsulation agent (Diamante et al., 2012). Quek et al. (2007) reported that increased level of maltodextrin lowered the powder quality because the nutrients in sample were diluted. Dimante et al. (2012) reported that low level of maltodextrin would yield vacuum-fried product with higher beta-carotene content.

For freeze dried sample, it showed slightly lower total carotenoid content (173.31±11.27 mg/100g DW) compared to that of fresh Gac fruit (194.50±8.99 mg/100g DW). However, it was not significantly different ($p>0.05$). This is may be due to fact that the freeze drying process used very low temperature (-30°C) and high vacuum (10-3 mbar) that could reduce the oxidation causing the carotenoid degradation in Gac powder (Tran et al., 2008).

Drum drying process that was conducted at low temperature (80°C) showed lower total carotenoid content (95.28±3.45 mg/100g DW) which was about two times lower than fresh Gac fruit. This may be due to residence time of the product on drum surface which was longer (15-20 sec) as compared to spray drying method (5 sec). Likewise, Boonpoo et al. (2014) reported that drying time also affect the content of carotenoids in Gac powder. It was found out that shorter the time for drying, the higher will be the carotenoid concentration. Kha et al. (2011) reported that the optimal temperature for minimum loss of carotenoids in the aril was 60°C with shorter drying time (5 hrs) as compared to drying at 40°C and 50°C with longer time (10–12 hrs).

Although, powder sample came from the same raw material it showed different carotenoid contents. The spray drying process without pectinase treatment showed lower carotenoid content compared to other methods. This is due to the fact that powder contained maltodextrin during spray drying which diluted the carotenoid content. Maltodextrin was not used for other drying processes such as spray drying (treated with pectinase), freeze drying, and drum drying.

Factors affecting the total carotenoid content of Gac fruit were natural variation, variety, growth conditions, storage conditions and maturity of the investigated fruit (Ishida et al., 2004). Methods of analysis and variable production conditions were also found to be influencing the quality and carotenoid content of the Gac powder.

Table 3. Moisture, carotenoids content in fresh and powder of Gac fruit from different drying methods.

Sample	Moisture content (g/100 g wet weight)	Beta-carotene (mg/100g dry weight, DW)	Lycopene (mg/100g DW)	Total carotenoids (mg/100g DW)
Fresh Gac fruit	89.76±0.40^{a}	60.33±2.91^{a}	134.17±6.27^{a}	194.50±8.99^{a}
Freeze dried powder	5.39±0.18^{c}	54.53±3.65^{b}	118.78±7.64^{b}	173.31±11.27^{a}
Drum dried powder	2.77±0.28^{e}	32.12±1.02^{c}	63.16±7.64^{c}	95.28±3.45^{c}
Spray dried powder (untreated with pectinase)	3.31±0.35^{d}	6.12±0.69^{d}	12.53±1.53^{d}	18.65±2.11^{d}
Spray dried powder (treated with pectinase)	8.09±0.12^{b}	56.96±3.91^{b}	138.96±8.27^{a}	195.93±11.43^{a}

* Results are expressed as mean ± SD from three single sample analyses. The values in the same column with different superscripts (a-d) showed significant difference ($p\leq 0.05$).

Color measurement

Table 4 represented the results of color measurement, L*(lightness), a*(redness), and b*(yellowness), of fresh Gac fruit and Gac powders from different drying processes. Carotenoids are pigments which gave the characteristic color to the Gac fruit. Color is an important parameter to indicate the effectiveness of thermal dehydration of fruits and vegetables in term of color quality. The value of L*(lightness), a*(redness), b*(yellowness) and total color differences between the fresh Gac fruit and the Gac powders undergoing different drying processes were significantly different at $p \leq 0.05$ (Table 4). The Gac powders showed an increasing trend in the values L*, a* and b*when they were exposed to different drying processes. The increasing of a* and b* values may be due to the enzymatic and non-enzymatic browning reaction (caramelization). The phenolic compounds present in the Gac fruit undergoes oxidation when they are exposed to oxygen which is catalyzed by the presence of the enzyme polyphenol oxidase. Monophenol (no color) is oxidized to diphenol (no color) which in turn is oxidized to o-quinone. The reaction of o-quinone with an amino acid or protein results in the formation of a large molecule called melanin which is brown in color. Hence, the Gac powders were reddish and yellowish in color after drying. (Yuenyongputtakal et al., 2017).

For drum drying process, the Gac powder was reddish and yellowish in color with a caramel smell. This may be due to the fact that the sample was exposed to heat on drum surface for a long time. During the drying process, decomposition of sugar and polymerization of carbon compounds occurred which resulted in the unique of smell and taste of caramel. Tanongkankit et al (2016) also reported the increase of a*(redness) and b*(yellowness) values of Gac aril after drying. They explained that the increase in the values of a*(redness) and b*(yellowness) were due to the removal of water during the drying process. The increasing of L* in Gac powder sample may be due to color degradation of carotenoids as a result of high degree of structural unsaturation. This makes the compound sensitive to oxidative reaction and transforms the trans-carotenoids to less colored cis-carotenoids when they are exposed to heat (Yuenyongputtakal et al., 2017 and Rawsan et al., 2011).

Gac powder from spray drying process (without pectinate treatment) showed the highest L* value. This may be due to the addition of maltodextrin carrier (white powder) to the sample which was necessary to adjust the total solid content for effective spray drying (Caparino et al., 2012). Oberoi and Sogi (2015) also reported that the spray dried water melon powder become pale in color as the concentration of maltodextrin increased. This indicated that there was degradation of pigments in the sample which decreased the redness and yellowness but increased the lightness of the Gac powder.

The total color difference of Gac powders from different drying processes were compared to the fresh Gac fruit. It was evident that Gac powder from freeze drying process showed low value of total color difference (close to the fresh Gac fruit). Drum dried and spray dried powders (treated with pectinase) were found to be slightly different in total color as compared to the fresh one (6.36±0.06 and 6.08±0.04, respectively). On the other hand, Gac powder from spray drying process (not treated with pectinase) showed the highest total color difference value (17.07±0.05).

Water solubility

Solubility is a good criterion to evaluate the nature of powder sample in aqueous solution (Caparino et al., 2012). An ideal powder should disperse or dissolved in water quickly without the formation of lumps (Grabowski et al., 2006). Table 5 presented water solubility, water holding capacity, and particle size of Gac powder from different drying processes. Water solubility of Gac powders from different drying processes were significantly different ($p<0.05$). The Gac powder from spray drying (not treated with pectinase) showed the highest water solubility (96.23±1.03%) due to the addition of maltodextrin (DE=10) before spraying. This result agreed well with the study reported by Caparino et al. (2012) whereby maltodextrin enhanced the solubility of the mango powder during spray drying as compared to the other drying processes. Maltodextrin, an edible material is used to coat the surface of a particle during spray drying which resulted in the high solubility of the powder. Bopitsuwan and Rojanakorn (2017) also reported that the addition of maltodextrin increased the water solubility of the Gac powder as compared to the sample devoid of maltodextrin. This may be due to the fact that maltodextrin enhanced the porous nature of powder which in turn offered the powder more surface area to come in contact with water. On the other hand, Gac powder from spray drying process (treated with pectinase) showed lower water solubility when compared to those not treated with pectinase. This phenomenon can explained by the fact that the powder obtained from spray drying had spherical shape and wet surface, resulting in lump formation and eventually decreasing the water solubility of

Table 4. The color measurement of fresh Gac fruit and Gac powder from different drying process[1]

Sample	L*	a*	b*	Total color difference[2]
Fresh Gac fruit	29.40±0.03^{e}	20.33±0.05^{c}	16.18±0.07^{e}	-
Freeze dried powder	37.82±0.03^{c}	23.90±0.02^{a}	22.12±0.01^{c}	3.85±0.04^{d}
Drum dried powder	35.06±0.01^{d}	19.22±0.02^{d}	23.38±0.03^{b}	6.36±0.06^{b}
Spray dried powder (not treated with pectinase)	51.89±0.02^{a}	12.04±0.08^{e}	19.50±0.08^{d}	17.07±0.05^{a}
Spray dried powder (treated with pectinase)	37.76±0.02^{b}	21.67±0.08^{b}	24.77±0.05^{a}	6.08±0.04^{c}

[1] Results are expressed as mean ± SD from three single sample analyses. The values in the same column with different superscripts (a-e) showed significant difference ($p \leq 0.05$).

[2] The total color difference is calculated using fresh Gac fruit as reference.

the powder. This problem can be solved by increasing the inlet air temperature. High inlet air temperature remove the wet surface of spray dried sample and can result in less lump formation (Laokuldilok and Kanha, 2015). However, the high inlet air temperature can reduce the water solubility of sample by the formation of hard layer on the surface of the powder particle (Fazaeli et al., 2012).

Gac powder obtained from drum drying had water solubility of 48.81±0.60% which could be contributed by the disorganization of macromolecules that occurred during drying. The study of Avula and Singh (2009) demonstrated that degradation of starch during drum drying and macromolecular disorganization can increase the water solubility of the sample. The lowest water solubility was found in Gac powder from freeze drying (0.23±0.02%) which was due to the extremely low temperature used in the process that maintained the structure and preserved the pectin in the sample. Pectic substances are complex glycosidic molecules with high molecular mass found in the primary cell wall and are the major constituents of the middle lamella, a thin extracellular adhesive layer formed between the cell wall of adjoining young cells (Pedrolli et al., 2009). In unripe fruits, it is found as a precursor known as protopectin which is insoluble in water but in fully ripened fruits the protopectinase enzyme converts protopectin to water soluble pectin. (Waengkeaw, 2006). In this study, pectin content of fresh and fully ripened Gac fruit was estimated by the method of Kulkarni and Vijayanand (2010) and 10 % of the pectin was found in the samples. When pectin dissolves in water, it undergoes swelling and forms a gel which offers stability to the sample. This is the reason for the lowest water solubility of the Gac powder processed by freeze drying. Similarly, the study conducted by Que et al. (2008) showed that the pumpkin flour from freeze drying process had lower water solubility when compared to hot air drying process. This is due to the decomposition of starch during the drying process and water solubility indicated the extent of starch degradation. In addition, Caparino et al. (2012) reasoned that the cell structure of sample from freeze drying was not ruptured and the small quantities of solids were dissolved in the supernatant. Roongruangsri and Bronlund (2016) reported many factors affecting the water solubility of powder products including drying process, conditions for drying, composition of raw material, density, storage condition and particle size. This study also evaluated the particle size of Gac powder from different drying processes (Table 4). Gac powder from spray drying, both treated and untreated with pectinase showed the smallest particle size (125 μm) followed by Gac powder from drum drying (180 μm) and freeze drying (250 μm), respectively. Lee et al. (2012) reported that the small particles have larger surface area which makes water transfer easy. Hence, the water solubility of small sized particles was higher than that of large sized particles. Gac powder from spray drying process (not treated with pectinase) had small particle size and high water solubility whereas Gac powder from freeze drying that had large particle size and low water solubility. Gac powder from spray drying process (treated with pectinase) had small particle size and low water solubility. This could be due to its increased wetted surface which caused the formation of sticky powder, eventually affecting the water solubility of the powder sample (Laokuldilok and Kanha 2015). In addition, Gac powder had limited solubility due to the presence of high amount of liposoluble substances such as carotenoids and tocopherol in the pulp and the aril of Gac fruit (Kha et al., 2010).

Water holding capacity

Table 5 shows the water holding capacity of Gac powders from different drying processes and it showed significant difference ($p<0.05$). Freeze dried Gac powder exhibited the highest water holding capacity when compared to other methods. This result could be explained by the fact that Gac fruit contained high amount of pectin that influenced to water holding capacity of powder sample (Jongaroontaprangsee et al., 2007). Chantaro et al (2008) also reported that the presence of high amount of pectic substances increased the water holding capacity of carrot peel. The water holding capacity is influenced by the fiber structure of the sample as it plays an importance role in the kinetics of water uptake (Tawatsinlapasorn et al., 2017). Thus, freeze drying which is performed under controlled environment and very low temperature maintained the structure of sample which resulted in high value of water holding capacity of the Gac powder. On the other hand, Gac powder from spray drying process (not treated with pectinase) showed lowest water holding capacity. This might be due to the presence of maltodextrin. Maltodextrin can form an outer layer on the particle and reduce surface stickiness which would limit the particle-particle cohesion and particle-wall adhesion during spray drying process, resulting in less aggregate formation (Grabowski et al., 2006). Hence, the value of water holding capacity for the spray dried sample without pectinase treatment provided the lowest value compared to the other samples. Water holding capacity decreased when the sample was exposed to high drying temperature (Chantaro

Table 5. Water solubility, water holding capacity and major part of particle size of Gac powder from different drying processes*

Sample	Water solubility (%)	Water holding capacity (g/g)	Major part of particle size (μm)
Freeze dried powder	0.23±0.02^{d}	9.64±0.14^{a}	250
Drum dried powder	49.81±0.60^{b}	2.49±0.04^{c}	180
Spray dried powder (not treated with pectinase)	96.23±1.03^{a}	0.27±0.02^{d}	125
Spray dried powder (treated with pectinase)	22.01±1.20^{c}	6.74±0.29^{b}	125

*Results are expressed as mean ± SD from three single sample analyses. The values in the same column with different superscripts (a-d) showed significant difference ($p\leq 0.05$).

et al., 2008) because it caused the degradation of some soluble dietary fiber that lead to the reduction in the water retaining ability of the sample. In this study, Gac powder from drum drying showed low water holding capacity due to heat degradation of the sample structure. Tawatsinlapasorn et al. (2017) reported that the sample dried by hot air at 80°C lead to the decrease in the water holding capacity due to the collapse of the capillary porous structure that occurred during hot air drying process. Gac powder from spray drying process (treated with pectinase) showed higher water holding capacity than the drum drying process. Although this process used high temperature, it also used very short time for drying. Hence, the structure of sample was less degraded than that of the drum drying process. Particle size is one of factor that can affect the water holding capacity of the sample powders. This study demonstrated that the decrease in particle size caused reduction in water holding capacity. These results showed the occurrence of damage to the fiber matrix and the collapse of the pore during grinding (Jongaroontaprangsee et al., 2007).

CONCLUSION

The different drying processes including drum drying, spray drying (treated with and without pectinase enzyme), and freeze drying affected the physical properties and carotenoid content of Gac powder. For carotenoid content, spray dried method (treated with pectinase) retained maximum carotenoids in the Gac powder which was more or less similar to the fresh Gac fruit as compared to other methods. Spray dried and freeze dried powders showed highest value for water solubility and water holding capacity. The addition of Gac powder into food product depends on the characteristics of each drying process. Therefore, the powder obtained from spray drying process (treated with pectinase enzyme) would be recommended for further food development.

ACKNOWLEDGEMENTS

The research was supported by the Thailand Research Fund, National Science and Technology Development Agency (NSTDA), and Innovative House by TRF (RUG6050015). We would like to thank European Food Public Company Limited, Mr. Somsak Wachakorn and Ms. Surassawadee Poonnotok and their team for their contribution and coordination throughout this research project. We also thank Ms. Christine Stanly for editorial assistance.

REFERENCES

Adhikari, B., Howes, T., Bhandari, B. R., & Troung, V. (2004). Effect of addition of maltodextrin on drying kinetics and stickiness of sugar and acid-rich foods during convective drying: experiments and modelling. Journal of Food Engineering, 62(1), 53-68.

AOAC (2016). The Official Methods of Analysis of AOAC INTERNATIONAL (20th ed.). Washington, DC: Association of Officiating Analytical Chemists.

Aoki, H., Kieu, N. T., Kuze, N., Tomisaka, K., & Van Chuyen, N. (2002). Carotenoid pigments in GAC fruit (*Momordica cochinchinensis* SPRENG). Bioscience, Biotechnology, and Biochemistry*, 66*(11), 2479-2482.

Avula, Y. R., & Singh, K. R. (2009). Functional properties of potato flour and its role in product development. Food ©2009 Global Science Books, 3(3), 105-112.

Bopitsuwan, R., & Rojanakorn, T. (2017). Effects of maltodextrin on some physical characteristics of foam-mat dried Gac aril powder. The National and International Graduate Research Conference 2017, BMP6-7, 467-474.

Boonpoo, S., Sirisansaneeyaku, S., Jittanit, W., Parakulsuksatid, P., Songpim, M., Mongkolkarn, D., & Khuenpet, K. (2014). Development of processing of Gac fruit powder. Proceedings of 52nd Kasetsart University Annual Conference: Agro-Industry.

Caparino, O. A., Tang, J., Nindo, C. I., Sablani, S. S., Powers, J. R., & Fellman, J. K. (2012). Effect of drying methods on the physical properties and microstructures of mango (Philippine 'Carabao' var.) powder. Journal of Food Engineering, 111(1), 135-148.

Çinar, I. (2004). Carotenoid pigment loss of freeze-dried plant samples under different storage conditions. LWT - Food Science and Technology, 37(3), 363-367.

Chantaro, P., Devahastin, S., & Chiewchan, N. (2008). Production of antioxidant high dietary fiber powder from carrot peels. LWT - Food Science and Technology, 41(10), 1987-1994.

Chitchumroonchokchai, C., Diretto, G., Parisi, B., Giuliano, G., & Failla, M. L. (2017). Potential of golden potatoes to improve vitamin A and vitamin E status in developing countries. PLoS One, 12(11),1-13.

Choudhari, S. M., & Ananthanarayan, L. (2007). Enzyme aided extraction of lycopene from tomato tissues. Food Chemistry, 102(1), 77-81.

Chuyen, H. V., Nguyen, M. H., Roach, P. D., Golding, J. B., & Parks, S. E. (2015). Gac fruit (*Momordica cochinchinensis* Spreng.): a rich source of bioactive compounds and its potential health benefits. International Journal of Food Science & Technology, 50(3), 567-577.

Cserhalmi, Z., Sass-Kiss, Á., Tóth-Markus, M., & Lechner, N. (2006). Study of pulsed electric field treated citrus juices. Innovative Food Science & Emerging Technologies, 7(1), 49-54.

Diamante, L. M., Savage, G. P., Vanhanen, L., & Ihns, R. (2012). Effects of maltodextrin level, frying temperature and time on the moisture, oil and beta-carotene contents of vacuum-fried apricot slices. International Journal of Food Science & Technology, 47(2), 325-331.

Ekpong, A., Phomkong, W., & Onsaard, E. (2016). The effects of maltodextrin as a drying aid and drying temperature on production of tamarind powder and consumer acceptance of the powder. International Food Research Journal, 23(1), 300-308.

Fazaeli, M., Emam-Djomeh, Z., Kalbasi Ashtari, A., & Omid, M. (2012). Effect of spray drying conditions and feed composition on the physical properties of black mulberry juice powder. Food and Bioproducts Processing, 90(4), 667-675.

Grabowski, J. A., Truong, V. D., & Daubert, C. R. (2006). Spray-Drying of Amylase Hydrolyzed Sweetpotato Puree and Physicochemical Properties of Powder. Journal of Food Science, 71(5), E209-E217.

Ishida, K. B., Turner, C., Chapman, H. M., & Mckeon, A. T. (2004). Fatty Acid and Carotenoid Composition of Gac (*Momordica cochinchinensis* Spreng) Fruit. Journal of Agricultural and Food Chemistry, 52, 274–279.

Jongaroontaprangsee, S., Tritrong, W., Chokanaporn, W., Methacanon, P., Devahastin, S., & Chiewchan, N. (2007). Effects of Drying Temperature and Particle Size on Hydration Properties of Dietary Fiber Powder from Lime and Cabbage By-Products. International Journal of Food Properties, 10(4), 887-897.

Kha, T. C., Nguyen, M. H., & Roach, P. D. (2010). Effects of spray drying conditions on the physicochemical and antioxidant properties of the Gac (*Momordica cochinchinensis*) fruit aril powder. Journal of Food Engineering, 98(3), 385-392.

Kha, T. C., Nguyen, M. H., Roach, P. D., & Stathopoulos, C. E. (2013). Effects of Gac aril microwave processing conditions on oil extraction efficiency, and β-carotene and lycopene contents. Journal of Food Engineering.117(4), 486-491.

Kha, T. C., Phan-Tai, H., & Nguyen, M. H. (2014). Effects of pre-treatments on the yield and carotenoid content of Gac oil using supercritical carbon dioxide extraction. Journal of Food Engineering, 120, 44-49.

Koksel, H., Masatcioglu, T., Kahraman, K., Ozturk, S., & Basman, A. (2008). Improving effect of lyophilization on functional properties of resistant starch preparations formed by acid hydrolysis and heat treatment. Journal of Cereal Science, 47(2), 275-282.

Kubola, J., & Siriamornpun, S. (2011). Phytochemicals and antioxidant activity of different fruit fractions (peel, pulp, aril and seed) of Thai gac (*Momordica cochinchinensis* Spreng). Food Chemistry, 127(3), 1138-1145.

Kubola, J., Meeso, N., & Siriamornpun, S. (2013). Lycopene and beta carotene concentration in aril oil of gac (Momordica cochinchinensis Spreng) as influenced by aril-drying process and solvents extraction. Food Research International, 50(2), 664-669.

KulkarniS.G., and P. Vijayanand. 2010. Effect of extraction conditions on the quality characteristics of pectin from passion fruit peel (*Passiflora edulis* f. flavicarpa L.). LWT - Food Science and Technology 43. Elsevier Ltd: 1026–1031.

Laokuldilok, T., & Kanha, N. (2015). Effects of processing conditions on powder properties of black glutinous rice (*Oryza sativa* L.) bran anthocyanins produced by spray drying and freeze drying. LWT - Food Science and Technology, 64(1), 405-411.

Lee, C.W., Oh, H.J., Han, S.H., & Lim, S.B. (2012). Effects of hot air and freeze drying methods on physicochemical properties of citrus 'hallabong' powders. Food Science and Biotechnology, 21(6), 1633-1639.

Lopez-Huertas, E. (2010). Health effects of oleic acid and long chain omega-3 fatty acids (EPA and DHA) enriched milks. A review of intervention studies. Pharmacological Research, 61, 200–207.

Mai, C. H., Trunonng, V., & and Debaste, F. (2013). Optimisation of Enzyme-Assisted Extraction of Oil Rich in Carotenoids from Gac Fruit (*Momordica cochinchinensis* Spreng.). Food Technology and Biotechnology, 51(4), 488–499.

Mezzomo, N., & Ferreira, S. R. S. (2016). Carotenoids Functionality, Sources, and Processing by Supercritical Technology: A Review. Journal of Chemistry, 2016, 1-16.

Oberoi, D. P. S., & Sogi, D. S. (2015). Effect of drying methods and maltodextrin concentration on pigment content of watermelon juice powder. Journal of Food Engineering, 165, 172-178.

Parisa, M.W. (2014). Perspective on the safety and effectiveness of conjugated linoleic acid. American Journal of Clinical Nutrition, 79, 1132S-1136S.

Parks, S., Murray, C., Gale, D., Al-Khawaldeh, B., & Spohr, L. (2013). Propagation and Production of Gac (Momordica Cochinchinensis Spreng.), A Greenhouse Case Study. Experimental Agriculture, 49(2), 234-243.

Pedrolli, D. B., Monteiro, A. C., Gomes, E., & Carmona, E. C. (2009). Pectin and Pectinases: Production, Characterization and Industrial Application of Microbial Pectinolytic Enzymes. The Open Biotechnology Journal, 3(1), 9-18.

Que, F., Mao, L., Fang, X., & Wu, T. (2008). Comparison of hot air-drying and freeze-drying on the physicochemical properties and antioxidant activities of pumpkin (Cucurbita moschata Duch.) flours. International Journal of Food Science & Technology, 43(7), 1195-1201.

Quek, S. Y., Chok, N. K., & Swedlund, P. (2007). The physicochemical properties of spray-dried watermelon powders. Chemical Engineering and Processing: Process Intensification, 46(5), 386-392.

Rawson, A., Tiwari, B. K., Tuohy, M. G., O'Donnell, C. P., & Brunton, N. (2011). Effect of ultrasound and blanching pretreatments on polyacetylene and carotenoid content of hot air and freeze dried carrot discs. Ultrason Sonochem, 18(5), 1172-1179.

Roongruangsri, W., & Bronlund, J. E. (2016). Effect of air-drying temperature on physico-chemical, powder properties and sorption characteristics of pumpkin powders. International Food Research Journal, 23(3), 962-972.

Si, X., Chen, Q., Bi, J., Wu, X., Yi, J., Zhou, L., & Li, Z. (2016). Comparison of different drying methods on the physical properties, bioactive compounds and antioxidant activity of raspberry powders. Journal of the Science of Food and Agriculture. 96(6), 2055-2062

Strati, I. F., Gogou, E., & Oreopoulou, V. (2015). Enzyme and high pressure assisted extraction of carotenoids from tomato waste. Food and Bioproducts Processing, 94, 668-674.

Sanchez-Mata, M. C., Camara-Hurtado, M., Diez-Marques, C., & Torija-Isasa, E. (2000). Comparison of high-performance liquid chromatography and spectrflouorimetry for vitamin C analysis of green beans (Phaseolus vulgaris L.). European Food Research and Technology, 210, 220–225.

Tanongkankit, Y., Narkprasom, K., & Narkprasom, N. (2016). Effect of Processing on Physical Property and Carotenoid Content in Natural Food Colorant from Gac aril. Journal of Food Technology, Siam University, 11(1), 47-56.

Tawatsinlapasorn, N., Kuljarachanan, T., Chiewchan, N., & Devahastin, S. (2017). Effects of Drying Techniques on Selected Functional Properties and Bioactive Compounds of Dietary Fiber from the Outer Leaves of Cabbage. Chiang Mai University Journal of Natural Sciences, 16(1), 19-30.

Tran, T. H., Nguyen, M. H., Zabaras, D., & Vu, L. T. T. (2008). Process development of Gac powder by using different enzymes and drying techniques. Journal of Food Engineering, 85(3), 359-365.

Wengkeaw, W. (2006). Extraction of Pectin from Dried Pumelo Peel Using Steam Treatment. Thesis of Srinakharinwirot University.

Vuong, L. T., Franke, A. A., Custer, L. J., & Murphy, S. P. (2006). *Momordica cochinchinensis* Spreng. (gac) fruit carotenoids reevaluated. Journal of Food Composition and Analysis, 19(6), 664-668.

Yuenyongputtakal, W., Limroongreungrat, K., Chaipan, P., & Srimuang, T. (2017). Effect of Hot Air Drying Temperature and Time on Qualities of Enoki Mushroom (*Flammulina velutipes*) Powder Produced from Uncommonly Consumed Part. Research Article. Department of Food Science, Faculty of Science, Burapha University.