Effect of Vacuum Drying Temperatures and Times on Color and Lycopene Content of Dried Gac Fruit (*Momordica cochinchinensis* Spreng.) Aril

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Abstract

Lycopene is the significant and the most abundant carotenoid in gac fruit aril. However, degradation of lycopene can occur during drying and storage and is influenced by factors such as heat, oxygen, and light. This research aimed to determine the optimal condition for drying of aril using vacuum drier that limits aril exposure to oxygen. Aril was dried at 50, 70 and 90°C under 10 kPa vacuum, samples were collected every 2 h until their moisture content was less than 12% (wet basis) specified in the dried fruit standard. Properties of the dried aril were examined including moisture content, water activity, instrumental color, and percentage of lycopene retention. The time needed to achieve the required final moisture content when fresh aril was dried at 50, 70 and 90°C were 18, 10 and 8 h, respectively. Properties of the dried aril were found to be depended on the drying conditions. It was found that the optimum temperature and time for drying of gac fruit aril were 90°C and 8 h. The attained moisture content was 7.46% (wet basis) and water activity was 0.449 respectively. The dried aril exhibited the highest redness (a*) and yellowness (b*) values compared to other conditions. The retention of lycopene was 27.18%, almost similar to other conditions. The results also revealed the possibility of using vacuum sealed laminated aluminum foil bag stored at ambient temperature as an option for storage of the dried aril resulting in the lycopene retention of 92.14% after 4 weeks.

Keywords: *Gac fruit, Gac fruit aril, Vacuum drying, Lycopene*

1. Introduction

Gac (*Momordica cochinchinensis* Spreng.) is the tropical plant, belongs to the melon family (Cucurbitaceae) (Vuong et al, 2006) and has been used as a food in Thailand and some others Southeast Asian countries (Auisakchaiyoung and Rojanakorn, 2015). Gac fruit aril is an abundant source of yellow, orange, and red-orange color carotenoids, especially lycopene and to the lesser extent β-carotene (Aoki et al, 2002; Vuong, 2006). The substantial problem of gac fruit aril is its fairly short shelf-life. Therefore, various drying methods have been used to extend its shelf-life, however these techniques had a negative effect on lycopene content (Collins et al, 2006; Tran et al, 2008; Auisakchaiyoung and Rojanakorn, 2015; Pinthong et al, 2019). There are many factors that lead to the degradation of lycopene such as temperature, light, oxygen, processing time through isomerization and oxidation (Giovanelli and Paradiso, 2002; Mayeaux et al, 2006; Vongsawasdi et al, 2007).

Hence, in this research vacuum drying which reduces the oxygen exposure of the drying material was selected as a technique that helped overcome the oxidation of lycopene during drying. Effect of temperature and time during drying were also studied. As reported by previous studies, lycopene and also β-carotene are strong antioxidant (Kha et al, 2011) and capable of reducing the risk of various diseases including prostate and lung cancers, promoting healthy vision, and increasing blood plasma level (Vuong et al, 2006; Tran et al, 2008; Auisakchaiyoung and Rojanakorn, 2015; Bhumsaidon and Chamchong, 2016). The vacuum dried gac fruit aril might see greater benefit from these functional properties comparing to the arils that are dried by other hot air drying methods especially spray drying.

2. Objectives

1. To study the effect of vacuum drying at various temperatures and times on the significant physico-chemical properties of gac fruit aril.
3. To determine the optimal condition for vacuum drying of gac fruit aril.
2. To study the effect of storage time on the lycopene content of vacuum dried gac fruit aril.

3. Materials and Methods

3.1 Preparation of gac fruit aril

Fully ripe fresh gac fruits identified by dark red outer shell were obtained from local gardeners of Plakmailai community located in Thung Khwang sub-district, Kamphaeng Saen district, Nakhon Pathom province, central Thailand. The fruits were washed with tap water, left to dry and cut into 2 halves. The whole seed including aril was separated from yellow pulp and the orange-red aril manually separated from the seed. All of the aril was thoroughly mixed by a blender (Philips HR2021, Koninklijke Philips N.V., Netherlands) for 3 min at low speed to obtain a uniform sample (control sample). The fresh aril was then packed in laminated aluminum foil bag and stored at 4°C for drying experiment and further analysis.

3.2 Drying experiment

Gac fruit aril was dried in a vacuum drier (Binder VD 23, Binder GmbH, Germany) at 3 different temperatures of 50, 70 and 90°C under constant vacuum maintained at 10 kPa. The drying processes was performed until final moisture content (MC) of dried aril was less than 12% wet basis (wb) as required by Thailand Community Product Standard for dried fruits and vegetables (TCPS 136-2558) (Thai Industrial Standard Institute, 2015). Aril samples were randomly collected every 2 h. The samples was ground and packed in laminated aluminum foil bag and stored at 4°C for further analysis. Drying at elevated temperatures of 70 and 90°C were included in this study to see the possibility of maximizing evaporation and drying rates and minimizing drying time, since lessening production time while increasing production rate is significant in scaling up a process for commercialization. If the qualities of aril dried at higher temperature especially its lycopene content are acceptable comparing to the one dried at lower temperature, this will be a decent production choice for manufacturer.

3.3 Storage test

Appropriate condition for vacuum drying of gac fruit aril was selected from the drying experiment and used to prepare another set of dried aril samples for storage study. Dried aril samples were packed in 5x7 cm laminated aluminum foil bag (PET/AL/PE, AL layer thickness is 10 μm) (Huayi World Trade Co. Ltd., Thailand), vacuum sealed under 15 mmHg pressure, and then kept at ambient temperature for 4 weeks. Samples were analyzed before storage and again after 4 weeks. Storage test was performed only for a limited time to initially evaluate the possibility of using a combination of this container option and storage condition for storage of a vacuum dried aril.

3.4 Moisture content and water activity

MC of fresh aril and dried arils from drying experiment was determined according to AOAC method (AOAC, 2012), while their water activity (a_w) was measured using a water activity meter (AquaLab Series 3TE, Decagon Devices Inc., USA) at 25°C.

3.5 Instrumental color

The color of fresh aril and dried arils from drying experiment was measured using a Tristimulus colorimeter (Minolta CR-10, Konica Minolta Inc., Japan), the results were expressed in CIE Lab color space as L* (lightness), a* (redness) and b* (yellowness).

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3.6 Lycopene content

Fresh aril and dried arils from both drying experiment and storage test was analyzed for lycopene content according to Kimura's method as described by (Nagata and Yamashita, 1992; Bhumsaidon and Chamchong, 2016). One g of aril samples (before and after dried) was extracted by 10 mL of mixed solvent of acetone and hexane (4:6 by volume). Aril extract was homogenized at 16,000 rpm for 1 min using a homogenizer (Ystral X 10/25, Ystral GmbH, Germany), let the sediment settled then collected a supernatant layer. The light absorption values (A) at 453, 505, 663 and 645 nm wavelength were recorded using a UV-visible spectrophotometer (GENESYS 20, Thermo Fisher Scientific Inc., USA). If the absorbance of any sample was off the measurement limit of the instrument, sample dilution (as high as 30-40 folds) was necessary. The recorded values were used to calculate lycopene content in mg per 100 mL of mixed solvent from Eq.1. The obtained value was further calculated to be expressed in mg per 100 g of dry solid by Eq.2 and Eq.3. Percentage of lycopene retention during vacuum drying and storage was calculated based on initial lycopene content at the beginning of experiments as shown in Eq.4.

$$\text{Lycopene (mg/100 mL)} = -0.0458A_{663} + 0.204A_{645} + 0.372A_{505} - 0.0806A_{453} \quad (1)$$

$$\text{Lycopene (mg/mL)} = \text{Lycopene (mg/100 mL)} \times \text{Mixed solvent volume (mL)} / 100 \quad (2)$$

$$\text{Lycopene (mg/100 g dry solid)} = \text{Lycopene (mg/mL)} / \text{Sample weight (g)} \times (100 - \text{MC of sample}/100) \quad (3)$$

$$\text{Lycopene retention (\%)} = (\text{Lycopene content} / \text{Initial lycopene content}) \times 100 \quad (4)$$

3.7 Statistical analysis

Analysis of variance (ANOVA) and Duncan's new multiple range test (DMRT) at 95% confident level using SPSS program version 16 (SPSS Inc., USA) were conducted to investigate the statistical significance of the effect of different drying times and temperatures on MC, a_w, L*, a*, b*, and lycopene retention of the dried arils. T-test at 95% confident level (also using SPSS) was used to investigate the effect on storage time on lycopene content of the dried arils. All experiments were performed in triplicate.

4. Results and Discussion

4.1 Moisture content and water activity

The MC and a_w of the gac fruit aril samples measured at 2-h intervals during vacuum drying at temperatures of 50, 70 and 90°C under similar pressure maintained at 10 kPa were shown in Table 1. It was found that initial MC and a_w of the fresh gac fruit aril (control samples) before drying were almost identical ranging from 78.94 to 79.63% (wb) and from 0.988 to 0.995. The results revealed that MC and a_w showed a tendency to reduce from the beginning of the process and continued to reduce throughout the process. The reduction rates of MC and a_w for each process were clearly seen to be depended upon the drying temperature, the higher the temperature, the faster the decrease in MC and a_w. For example, at 90°C the MC exhibited the significance declining ($p < 0.05$) just 4 h after the drying commenced, while it required as long as 10 h of drying for the process at 50°C to exhibit the similar effect. Water activity data also showed the same behavior (Table 1). This can be explained by the fact that higher drying temperature and lower drying pressure increased the water evaporation and drying rate resulting in shorter drying time. Similar behavior occurred during vacuum drying of carrot, banana, and galangal as reported by Luampon et al (2016). Tanongkankit et al (2016) found the similar results during hot air drying of gac fruit aril. This also happened in the drying of fresh eggplant and pumpkin (Ertekin and Yaldiz, 2007; Doymaz, 2004).

Therefore, the end point of drying process at each temperature (50, 70 and 90°C) as determined from the dried sample final MC of 12% (wb) or below (according to TCPS 136/2558) were different. Hence, the total time necessitated for the vacuum drying of gac fruit aril at 50, 70 and 90°C were 18, 10 and 8 h

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respectively. From Table 1, the attained final MCs of the samples for each drying temperature were 10.42, 10.71 and 7.46% (wb).

However MC alone is unable to ascertain the prevention of the processed food spoilage, the storage stability concept based on aw is proved to be more suitable. It is also generally accepted that aw of the dried food should be lower than 0.6 to assure its storage stability (Barbosa-Canovas et al, 2007). From Table 1, the final aw of the samples dried at 50, 70 and 90°C were 0.572, 0.611 and 0.449 respectively. As the data showed, the final aw of the sample dried at 70°C for 10 h was still higher than 0.6 even though its MC (10.71%) was lower than 12% (wb), while other 2 samples was able to achieved aw below 0.6. Thus, it will need somewhat longer drying time than 10 h to gain the acceptable storage stability if the sample is dried at 70°C. It is also important to note that final MC of the sample dried at 90°C was actually 4.54% (wb) lower than as required by the standard and its aw was also approximately 0.15 less than the accepted level. Therefore, the drying time at 90°C needed to achieve final MC specified by the standard might be shorter than 8 h nonetheless longer than 6 h. This could possibly yield positive impact on the economical aspect of the process in larger scale by partially lessening the production cost. When taking into account the final MC and aw, it can be presumed that the appropriate drying condition for manufacturing the vacuum dried gac fruit aril was 90°C, 10 kPa and 8 h.

Table 1 Moisture contents and water activities of gac fruit aril during vacuum drying at different temperatures

Time	Moisture content (% wb)			Water activity		
(h)	50°C	70°C	90°C	50°C	70°C	90°C
0	78.94 ± 0.121^{a}	79.63 ± 2.125^{a}	79.44 ± 1.750^{a}	0.995 ± 0.006^{a}	0.987 ± 0.002^{a}	0.988 ± 0.006^{a}
2	77.26 ± 0.130^{a}	76.94 ± 1.572^{ab}	72.42 ± 5.054^{ab}	0.991 ± 0.005^{a}	0.982 ± 0.004^{a}	0.986 ± 0.007^{a}
4	75.53 ± 0.828^{ab}	67.75 ± 5.316^{b}	63.65 ± 1.997^{b}	0.987 ± 0.002^{ab}	0.980 ± 0.004^{a}	0.974 ± 0.006^{a}
6	73.66 ± 0.355^{ab}	50.93 ± 0.148^{c}	30.67 ± 2.413^{c}	0.981 ± 0.004^{a}	0.971 ± 0.004^{a}	0.866 ± 0.071^{b}
8	70.31 ± 0.276^{ab}	24.26 ± 2.367^{d}	7.46 ± 2.162^{d}	0.977 ± 0.009^{a}	0.939 ± 0.004^{a}	0.449 ± 0.078^{c}
10	64.18 ± 0.565^{b}	10.71 ± 0.530^{e}	-	0.972 ± 0.008^{a}	0.611 ± 0.149^{b}	-
12	38.12 ± 6.719^{c}	-	-	0.977 ± 0.009^{a}	-	-
14	25.83 ± 5.331^{d}	-	-	0.952 ± 0.171^{a}	-	-
16	14.30 ± 4.002^{e}	-	-	0.827 ± 0.989^{a}	-	-
18	10.42 ± 0.772^{e}	-	-	0.572 ± 0.202^{b}	-	-

Remark: Different letters in the same column indicate significant differences ($p < 0.05$)

4.2 Instrumental color

The changes in L^*, a^*, and b^* of gac fruit aril samples subjected to vacuum drying were monitored every 2 h until the end point of the process as shown in Table 2, 3, and 4 respectively. From Table 2, it was found that L^* values among the control samples were not significantly different ($p > 0.05$) and the values started to decrease immediately after the drying processes began. At the end of the process when heating was terminated, L^* of all samples were significantly lower than control samples ($p < 0.05$). This result was consistent with those reported by Tanongkankit et al (2016). The rate of declining for L^* was increased when drying temperature increased. As can be seen from Table 1, L^* of the sample dried at 90°C was significantly lower than those dried at 50 and 70°C ($p < 0.05$) just 2 h after the process began. However, it took 6 h for L^* of the sample dried at 70°C to be significantly lower than the one dried at 50°C ($p < 0.05$). Therefore, differences in L^* (ΔL) between control samples and final dried sample for all drying processes were clearly increased when drying temperature increased. The ΔL of the samples dried at 50, 70 and 90°C were 5.85, 6.47, and 8.55 respectively.

These observations pointed out that even though the surrounding atmosphere in a vacuum drier was low in oxygen (10 kPa pressure) which may limit the likelihood of enzymatic browning reaction (Damodaran et al, 2008), all samples were getting darker when exposed to the heat. This biochemical reaction was said to involve in the change of the color of dried gac fruit pulp and aril as reported by Pinthong et al (2019). However non-enzymatic browning (Maillard) reaction which was accelerated by higher temperature and longer drying

time may be responsible for the above mentioned phenomena as explained in the research entailing drying of gac fruit aril (Auisakchaiyoung and Rojanakorn, 2015).

Table 2 Lightness values of gac fruit aril during vacuum drying at different temperatures

Time (h)	Lightness value (L^*)		
	50°C	70°C	90°C
0	$41.00 \pm 1.47^{a(a)}$	$40.10 \pm 1.37^{a(a)}$	$41.21 \pm 0.24^{a(a)}$
2	$39.80 \pm 1.02^{ab(a)}$	$39.78 \pm 1.07^{a(a)}$	$38.81 \pm 0.55^{b(b)}$
4	$39.08 \pm 1.30^{abc(a)}$	$38.76 \pm 1.17^{ab(a)}$	$36.69 \pm 0.41^{c(b)}$
6	$38.68 \pm 1.20^{abc(a)}$	$36.50 \pm 0.64^{b(b)}$	$32.06 \pm 1.11^{e(c)}$
8	$37.79 \pm 0.80^{bcd(a)}$	$33.23 \pm 1.69^{c(b)}$	$32.66 \pm 0.28^{d(b)}$
10	$37.16 \pm 1.46^{cd(a)}$	$33.63 \pm 2.64^{b(b)}$	-
12	35.76 ± 1.35^{de}	-	-
14	34.06 ± 1.87^{ef}	-	-
16	32.28 ± 1.67^{f}	-	-
18	35.15 ± 4.42^{e}	-	-

Remark: Different letters in the same column and different letters in brackets in the same row indicate significant differences ($p < 0.05$)

In this research it can be implied that the a^* value is the parameter representing in large part the color intensity of lycopene, the predominant deep red color pigment found in gac fruit aril (Shi and Le Maguer, 2000; Aoki et al, 2002; Ishida et al, 2004; Vuong et al, 2006). While the combination of a^* and b^* values can be assumed to reflect the color intensity of other carotenoids, the group of yellow-orange to orange-red color pigments (Khoo et al, 2011). This group of pigments included β-carotene another significance compound in gac fruit aril, although about 5 times less in quantity than lycopene (Aoki et al, 2002; Ishida et al, 2004; Vuong et al, 2006). Literally previous researches revealed that the changes in b^* and also L^* values were correlated well with degradation of carotenoids or β-carotene in some dried fruits (Saxena et al, 2012; Song et al, 2017).

Lycopene and β-carotene can suffer the color change cause by oxidation when exposed to oxygen (Collins et al, 2006; Damodaran et al, 2008). Since oxygen supply is limited during vacuum drying, oxidation of these pigments is unlikely to occur. However, a^* and b^* values showed the decreasing trends after the samples were heated in the drier at all experimented temperatures similar to L^*. The downward trends were considerably immense leading to significant reduction in a^* and b^* of final dried samples when compared to control samples ($p < 0.05$). Thus, this may be originated from the color degradation of lycopene and to some extent β-carotene by heat. Both pigments when exposed to heat can undergo an isomerization, a chemical reaction that alters their molecular configuration from all-*trans* isomer to *cis*-isomer, which have a negative influence on their visual color (Collins et al, 2006; Khoo et al, 2011; Pinthong et al, 2019). Moreover, these results also highlighted that enzymatic browning reaction which was described by Pinthong et al (2019) as one of the factor that help increased a^* and b^* values of the dried gac fruit aril may not show much effect in this research (limited oxygen during vacuum drying), instead Maillard reaction might play bigger role in retarding the color loss. The declining of both a^* and b^* were depend on the drying temperature, however differences in a^* (Δa) and b^* (Δb) were decreased when temperature increased. At 50, 70 and 90°C, Δa of the samples were 21.10, 17.45, and 15.45 respectively, and Δb were 16.20, 15.89, and 13.27 respectively. This may be related to the effect of longer drying time when lower temperature was used.

From the all instrumental color data, it can be concluded that the preferable temperature for vacuum drying of gac fruit aril was 90°C. At this temperature, the highest a^* and b^* can be obtained and L^* was slightly lower than at 70 and 50°C (ΔL was only 0.97 and 2.49).

Table 3 Redness values of gac fruit aril during vacuum drying at different temperatures

Time (h)	Redness value (a^*)		
	50°C	70°C	90°C
0	$49.17 \pm 0.29^{ab(a)}$	$49.24 \pm 0.69^{a(a)}$	$49.71 \pm 0.97^{a(a)}$
2	$49.92 \pm 1.26^{a(a)}$	$49.38 \pm 0.67^{a(a)}$	$48.02 \pm 1.10^{b(b)}$
4	$49.52 \pm 0.95^{ab(a)}$	$48.42 \pm 0.63^{a(b)}$	$46.10 \pm 0.91^{c(c)}$
6	$49.22 \pm 0.49^{ab(a)}$	$45.29 \pm 0.77^{b(b)}$	$36.74 \pm 2.67^{d(c)}$
8	$48.56 \pm 1.93^{ab(a)}$	$39.40 \pm 1.86^{c(b)}$	$34.26 \pm 1.99^{e(c)}$
10	$47.59 \pm 0.60^{bc(a)}$	$31.79 \pm 2.59^{d(c)}$	-
12	46.10 ± 1.53^{c}	-	-
14	41.96 ± 2.39^{d}	-	-
16	33.10 ± 3.61^{e}	-	-
18	28.07 ± 3.93^{f}	-	-

Remark: Different letters in the same column and different letters in brackets in the same row indicate significant differences ($p < 0.05$)

Table 4 Yellowness values of gac fruit aril during vacuum drying at different temperatures

Time (h)	Yellowness value (b^*)		
	50°C	70°C	90°C
0	$26.88 \pm 1.52^{a(a)}$	$26.47 \pm 2.23^{a(a)}$	$27.50 \pm 0.49^{a(a)}$
2	$25.98 \pm 1.56^{ab(ab)}$	$26.28 \pm 1.50^{a(a)}$	$24.63 \pm 0.52^{b(b)}$
4	$24.99 \pm 1.75^{bc(a)}$	$24.87 \pm 1.71^{a(a)}$	$21.97 \pm 0.59^{c(b)}$
6	$24.28 \pm 1.53^{cd(a)}$	$21.61 \pm 1.03^{b(b)}$	$14.92 \pm 0.96^{de(c)}$
8	$23.00 \pm 1.88^{de(a)}$	$17.26 \pm 1.03^{c(b)}$	$14.23 \pm 0.66^{e(c)}$
10	$22.19 \pm 1.13^{e(a)}$	$10.58 \pm 1.74^{d(c)}$	-
12	19.79 ± 1.42^{f}	-	-
14	16.92 ± 2.04^{g}	-	-
16	12.69 ± 1.62^{h}	-	-
18	10.68 ± 1.31^{i}	-	-

Remark: Different letters in the same column and different letters in brackets in the same row indicate significant differences ($p < 0.05$)

4.3 Lycopene retention

Final lycopene retention of the sample dried at 50°C was 29.49% (Table 5), the highest among others, albeit it took much longer time (about 2 folds) to accomplish the drying process at this temperature. Whereas slightly lower retentions of 27.06 and 27.18% were observed for the samples dried at 70 and 90°C (Table 5). Therefore, if the combination of storage stability, product color, lycopene content and economic aspects were taken into consideration, it can be concluded that vacuum drying of gac fruit aril at 90°C was justifiable despite the fact that lycopene retention was lower than the one dried at 50°C.

Due to variation in the initial lycopene content among the fresh gac fruit aril samples, percentage of lycopene retention (% retention) was used to fairly track the change in lycopene level of the sample during drying instead of actual lycopene content (mg/100 g of sample). From Table 5, Percentages of lycopene retention of all dried samples at the end of drying process were significantly lower than control samples ($p < 0.05$). The results also revealed that as drying time or temperature increased, lycopene retention decreased. Lycopene loss might cause by isomerization when it was exposed to heat as described earlier. The results (Table 5) also highlighted the effect of browning reaction (as also mentioned earlier) that possibly made the dried samples became more reddish and yellowish at higher drying temperature (Table 3 and 4) even though these samples had lower lycopene retention. Tanongkankit et al (2016) also reported the accelerated loss of lycopene in dried gac fruit aril as temperature of hot air increased from 60 to 70 and 80°C. Lycopene in

tomato slurry also decreased as hot air temperature and time increased from 177 to 218°C and 15 to 45 min in baking process (Mayeaux et al, 2006).

Spray drying, drum drying and freeze drying methods had been shown recently to have negative effect on lycopene content of gac fruit pulp and aril mixture as well (Pinthong et al, 2019). They reported that lycopene retention was only 9.34% after spray drying at 120°C. In drum drying at 80°C which uses a heated surface drier unlike other hot air driers, 47.07% lycopene retained but its redness value was about 1.8 times lower than that obtained in this research. Freeze drying, although performed at very low temperature resulting in lycopene retention of 88.53%, took 36 h to complete which was almost 5 times longer than vacuum drying done in this research. However, the performance of a drier was also the significant factor influencing lycopene retention of dried food. Lower performance model required longer drying time leading to longer exposure time between foods and hot surrounding.

Table 5 Percentages of lycopene retention of gac fruit aril during vacuum drying at different temperatures

Time (h)	Lycopene retention (%)		
	50°C	70°C	90°C
0	$100.00 \pm 0.00^{a(a)}$	$100.00 \pm 0.00^{a(a)}$	$100.00 \pm 0.00^{a(a)}$
2	$93.64 \pm 0.40^{ab(a)}$	$91.04 \pm 0.76^{b(b)}$	$79.29 \pm 1.41^{b(c)}$
4	$89.40 \pm 0.05^{bc(a)}$	$75.66 \pm 1.10^{c(b)}$	$60.08 \pm 1.22^{c(c)}$
6	$81.89 \pm 0.86^{cd(a)}$	$48.85 \pm 7.70^{d(b)}$	$40.57 \pm 0.60^{d(b)}$
8	$73.24 \pm 0.09^{d(a)}$	$32.10 \pm 2.92^{e(b)}$	$27.18 \pm 2.18^{e(c)}$
10	$61.18 \pm 0.00^{e(a)}$	$27.06 \pm 2.55^{e(b)}$	-
12	40.39 ± 1.02^{f}	-	-
14	34.01 ± 5.58^{fg}	-	-
16	31.26 ± 7.49^{fg}	-	-
18	29.49 ± 1.51^{g}	-	-

Remark: Different letters in the same column and different letters in brackets in the same row indicate significant differences ($p < 0.05$)

4.4 Lycopene stability

Storage stability of gac fruit aril sample vacuum dried at 90°C was conducted by monitoring its lycopene content as shown in Table 6. It can be seen that lycopene content of the sample significantly decreased after 4 weeks ($p < 0.05$), although percentage of lycopene retention during storage was still high at 92.14. This might be explained by very unstable characteristics of dried lycopene which will easily undergo isomerization as described by Giovanelli and Paradiso (2002). This result was in agreement to the study by Tran et al (2008) in which the amount of carotenoids of gac fruit aril powder decreased as storage time and temperature increased. Oxygen and light are the factors that accelerated the degradation of dried lycopene (Giovanelli and Paradiso, 2002). However, lycopene content of the sample still decreased during 4 weeks storage despite the fact that it was vacuum packed in aluminum foil bag which protected it from oxygen and light. Vongsawasdi et al (2007) also reported 60-64% retention of lycopene in dried tomato pomace during 8 weeks storage at 25-29°C under vacuum without light exposure.

Table 6 Lycopene content of vacuum dried gac fruit aril during storage

Storage time (weeks)	Lycopene content (mg/100 g dry solid)
0	32.31 ± 0.000^{a}
4	29.77 ± 0.400^{b}

Remark: Different letters in the same column indicate significant differences ($p < 0.05$)

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5. Conclusion

Since there was no known previous research that studied the effect of vacuum drying at various temperatures and times on lycopene content or visual color of gac fruit aril, hence an effort was made in this research in order to determine what was going to happen during the drying process under limit oxygen supply and how to minimize the drying time by increasing the temperature while keeping the qualities of the product under acceptable level. Thus, effect of vacuum drying process at 50, 70 and 90°C on the qualities of gac fruit aril including MC, a_w, color, and lycopene retention were studied. Also effect of packaging and storage time on the lycopene content of vacuum dried gac fruit aril was also studied. The results indicated that MC, a_w, instrumental color values and lycopene retention decreased as drying time and temperature increased. It was found that the preferable condition for vacuum drying process was 8 h at 90°C under pressure maintained at 10 kPa. The attained MC and a_w were 7.46% (wb) and 0.449. Highest redness and yellowness values were achieved under this condition. Moreover, lycopene retention was only 2% less than the retention gained when dried at 50°C. The results also revealed that after 4 weeks storage at ambient temperature in vacuum sealed aluminum foil bag, lycopene retention were still high at 92.14%. The data from this research can be used as a basis for setting up and scaling up a process for commercial production of vacuum dried gac fruit aril. Further studies on the content of other carotenoids especially β-carotene and on the antioxidant capacity will give more valuable knowledge about the benefits of vacuum dried gac fruit aril. Deeper studies on the chemical reaction responsible for lycopene degradation may give a way to prevent lycopene loss during processing. Longer storage study should be conducted to further reveal the lycopene stability of vacuum dried aril under vacuum storage.

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7. References

AOAC. (2012). *Official methods of analysis of AOAC international*. 19th edition. Virginia: The Association of Official Analytical Chemists.

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

Auisakchaiyoung, T., & Rojanakorn, T. (2015). Effect of foam-mat drying conditions on quality of dried gac fruit (*Momordica cochinchinensis*) aril. *International Food Research Journal*, *22*(5), 2025-2031.

Barbosa-Canovas, G. V., Fontana Jr., A. J., Schmidt, S. J., & Labuza, T. P. (2007). *Water activity in foods: Fundamentals and Applications*. Iowa: Blackwell Publishing Professional.

Bhumsaidon, A., & Chamchong, M. (2016). Variation of lycopene and beta-carotene contents after harvesting of gac fruit and its prediction. *Agriculture and Natural Resources*, *50*, 257-263.

Collins, J. K., Perkins-Veazie, P., & Roberts, W. (2006). Lycopene: from plants to humans. *HortScience*, *41*(5), 1135-1144.

Damodaran, S., Parkin, K. L., & Fennema, O. R. (2008). *Fennema's food chemistry*. 4th edition. New York: CRC Press.

Doymaz, I. (2007). The kinetics of forced convective air-drying of pumpkin slices. *Journal of Food Engineering*, *79*(1), 243-248.

Ertekin, C., & Yaldiz, O. (2004). Drying of eggplant and selection of a suitable thin layer model. *Journal of Food Engineering*, *63*(3), 349-359.

Giovanelli, G., & Paradiso, A. (2002). Stability of dried and intermediate moisture tomato pulp during storage. *Journal of Agricultural Food Chemistry*, *50*, 7277-7281.

Kha, T. C., Tuyen, C., Nguyen, M. H., & Roach, P. D. (2011). Effects of pre-treatments and air drying temperature on color and antioxidant properties of gac fruit powder. *International Journal of Food Engineering*, *7*(3): 1556-3758.

Khoo, H., Prasad, K. N., Kong, K., Jiang, Y., & Ismail, A. (2011). Carotenoids and their isomers: color pigments in fruits and vegetables. *Molecules*, *16*(2), 1710-1738.

Ishida, B. K., Turner, C., Chapman, M. H., & McKeon, T. A. (2004). Fatty acid and carotenoid composition of gac (*Momordica cochinchinensis* Spreng.) fruit. *Journal of Agricultural and Food Chemistry*, *52*(2), 274-279.

Luampon, R., Supakarn, S., Theerakulpisut, S., & Artnaseaw, A. (2016). Heat and moisture transfer equations for a vacuum drying. *KKU Research Journal (Graduate Studies)*, *16*(2), 1-14.

Mayeaux, M., Xu, Z., King, J. M., & Prinyawiwatkul, W. (2006). Effects of cooking conditions on the lycopene content in tomatoes. *Journal of Food Science*, *71*(8), C461-C464.

Nagata, M., & Yamashita, I. (1992). Simple method for simultaneous determination of chlorophyll and carotenoids in tomato fruit. *Nippon Shokuhin Kogyo Gakkaish*, *39*, 925-928.

Pinthong, S., Judprasong, K., Tangsuphoom, N., Jittinandana, S., & Nakngamanong, Y. (2019). Effect of different drying processes on physical properties and carotenoid content of Gac fruit (*Momordica cochinchinensis* Spreng.). *Journal of Food Science and Agricultural Technology*, *5*, 61-70.

Saxena, A., Maity, T., Raju, P. S., & Bawa, A. S. (2012). Degradation kinetics of color and total carotenoids in jackfruit (*Artocarpus heterophyllus*) bulb slices during hot air drying. *Food and Bioprocess Technology*, *5*, 672-679.

Shi, J., & Le Maguer, M. (2000). Lycopene in tomatoes: chemical and physical properties affected by food processing. *Critical Reviews in Biotechnology*, *20*(4), 293-334.

Song, J., Wang, X., Li, D., & Liu, C. (2017). Degradation kinetics of carotenoids and visual color in pumpkin (*Cucurbita maxima* L.) slices during microwave-vacuum drying. *International Journal of Food Properties*, *20*(S1), S632-S643.

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), 47-57.

Thai Industrial Standard Institute. (2015). *Thailand community product standard for dried fruits and vegetables (TCPS 136-2558)*. Bangkok: Ministry of Industry.

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*, 359-365.

Vongsawasdi, P., Nopharatana, M., Soomim, P., & Arunrodjanavut, S. (2007). Effect of storage temperature on lycopene degradation in tomato pomace. *Proceedings of 45th Kasetsart University Annual Conference: Agricultural Extension and Home Economics, Agro-Industry, p. 316-323, Bangkok, Thailand*.

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*(6-7), 664-668.