International Journal of Multidisciplinary Research and Development

IJMRD 2014; 1(2): 66-70
www.allsubjectjournal.com
Received: 27-07-2014
Accepted: 29-07-2014
e-ISSN: 2349-4182
p-ISSN: 2349-5979

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The changes of total Carotenoid content of GAC (*Momordica cochinchinensis* Spreng) powder product in accelerated temperature to the appropriate temperature and shelf-life of product storage

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Abstract
Gac fruit (*Momordica cochinchinensis* Spreng) is indigenous to Vietnam and other countries in Southeast Asia. Its seed pulp contains high concentrations of carotenoids, especially the pro-vitamin A, beta-carotene. Due to regulatory issues and consumer demands, industrialized food products need to clearly state their shelf-lives, that is the time within their characteristics are kept at acceptable levels, in their packages. Nowadays consumers demand products with superior appearance, texture, taste and flavor whilst keeping their nutritional value. Thus, food companies need to carry out kinetic studies whenever a new or modified product is to be launched onto the market. The purpose of this study was to develop a method to investigate the changes of total carotenoids content of Gac powder product in accelerated temperature to find out the appropriate temperature and shelf-life of product storage. The result shows that total carotenoid content maintains at 70% in comparing with the beginning content in three months at 10 ^{0}C or five months at 5 ^{0}C in condition of absent oxygen and light.

Keywords: *Momordica cochinchinensis Spreng, carotene, accelerated temperature, shelf-life*

1. Introduction

1.1 Gac fruit

The Vietnamese name of *Momordica cochinchinensis* Spreng is Day Gac. The plant can be cultivated either from seeds or root tubers. Leaves are alternate and deeply 3-5 lobed with toothed margins. The leaf stalk is glandular. The gac plant is dioecious, that is the male and female pants are separate. Flowers are pale-yellow and solitary in the axil of the leaves. The production of parthenocarpic fruits, which is of economic importance, can be accomplished using growth regulators in the female plant in the absence of male plants. However induced parthenocarpic fruits have no seed, whereas hand pollinated fruits contain 18 seeds per fruit on average.

The plant starts flowering about 2 months after planting root tubers. This flowering usually occurs in April and continues to July/ August and sometimes until September. On average, it takes about 18-20 days for a fruit to mature from emergence of the bud of the female flower. A plant produces 30 to 60 fruits on average in one season. The ripe fruit is picked from August to February.

Fruits of *Momordica cochinchinensis* are big, denselyaculaeate, green in color and when ripe, become dark orange or red. Unlike the bitter gourd (Momordica Charantia), the exocarp (rind) of the gac fruit is hard, and covered with conical points one eighth inch high. There are two shapes of gac fruit available in Vietnam, oblong and almost round, however there are no differences in the ways the fruits are used or consumed. There are also variations among different fruits with respectto their spine and fruit tips. In some fruits, the spines are smooth and dense, whereas insome, they are hard and thinly arranged. The oblong types are 6-10 cm in length and round types are 4-6 cm in length. In Vietnam, the oblong fruit weighs between 500 g and 1600 g and can be 10 to 13 cm long. Unlike bitter gourd, which is mostly harvested in the developmental stages, gacfruits in Vietnam are only picked at maturity when the fruit is bright red and seeds are hardened.

The mesocarp of the *Momordica cochinchinensis* (gac) fruit is 1/2" thick, spongy and orange in color. The core is divided into cartilaginous chambers containing bright red fleshy seed

pods. Each fruit has on average between 15 to 20 seeds. Seed are round, compressed and sculptured.

Seed membrane and kernels contain oil and are used in traditional medicine. There is no record of any use of the mesocarp. The average weight of the pulp is about 19% of the total fruit weight. An average gacfruit weighing 1kg yields approximately 190 g of fruit pulp and 130 g of seeds. The seed pulp of a ripe *Momordica cochinchinensis* fruit is bright red in color and has a palatable bland to nutty taste.

Fig 1: Ripen Gac

Fig 2: Fresh Gac fruit component

1.2 Many studies have reported about Gac

- Hiromitsu Aoki *et al*. (2002) determined carotene in Gac and concluded lycopene in Gac seed membrane with carotenoid concentrations to 380µg/g, 10 fold higher than those in any of the plant sources [5]
- L.T.Vuong *et al*. (2005) determined the acceptance of Gac supllementation to Vietnamese children. Results showed that vitamin A in Vietnamese children body was higher in Gac consumption than using β-carotene synthetic. They Vuong also reevaluated β-carotene content in fresh Gac fruit 408µg/g [4]
- Tran Hoang Thao *et al*. (2007) produced Gac powder by different drying methods. They proved that freeze drying method retained the highest β-carotene content. They also researched pretreatment methods to detach Gac seed membrane more easily, including thermal and enzyme. Loss of carotene by these pretreatment methods was 35%. If these products kept in vacuum below 25 ^{0}C would maintain red color and carotene to 70% in 4 month [7]
- Nguyen Minh Thuy *et al.* (2009) manufactured variety of Gac products such as: dried Gac seed membrane, jelly, gum, paste, oil and juice. They also proved the change of carotene in Gac seed membrane after 6 days harvested [1]
- Dang Thi Tuyet Nhung *et al*. (2009) evaluated the change of lycopene and β-carotene in Gac seed membrane and Gac oil during preservation. Gac seed membrane primarily contained lycopene 2.378 – 3.728 mg/g (raw material), β-carotene 0, 257 – 0,379 mg/g (raw material), carotene stabilized within the first one week by strongly decomposed in the second week of preservation. Gac oil extracted from seed membrane with addition of 0.02% BHT, it could be preserved 15 to 19 weeks at 5 ^{0}C, 40 ^{0}C, 60 ^{0}C; lycopene and β-carotene also reduced dramatically [3]
- Tuyen Chan Kha *et al*. (2010) produced Gac powder by using spray drying method with maltodextrin supplementation. They concluded that the appropriate drying process to keep red color was in temperature 1200 C, 10% maltodextrin as carrier material (w/v) [8]

1.3 Food Product Shelf Life

In order to meet consumers' expectations for high-quality products, food industries must conduct shelf-life studies that many times include the assessment of several analytical and sensory properties. However, whenever a new product is to be launched onto the market, defining which are the most relevant properties to monitor, as well as their cut-off criterion, is the subject of strong debate. Besides, for products with long estimated shelf-lives, accelerated studies have to be conducted and a third parameter has to be estimated: the acceleration factor which defines the correlation between the different storage conditions [2, 6]

The principal mechanisms involved in the deterioration of processed foods are as follows:

1. Microbiological spoilage sometimes accompanied by pathogen development.

2. Chemical and enzymatic activity causing lipid breakdown, color, odor, flavor, and texture changes.

3. Moisture and/or other vapor migration producing changes in texture, water activity and flavor.

Formulation and processing variables which affect these mechanisms and which can be used to control deterioration include: (1) moisture and water activity; (2) pH; (3) heat treatments; (4) emulsifier systems; (5) preservatives and additives; and (6) packaging [6].

1.4 The kinetics of shelf-life testing

The prediction of shelf life for food products is based on the application of the principles of temperature dependent chemical reaction kinetics. These reaction rates, as Figure 1 depicts, depend on product composition as well as environmental factors, i.e., temperature, humidity, atmosphere, etc. Basic to any predictive use of reaction kinetics is that the relationship between the measurable changing reaction parameter and time be linear. Quality loss follows the equation:

$$dQ/dt = k(QA)n$$ [6]

Where, dQ/dt is the change in the measurable quality factor A, with time, k is the rate constant in appropriate units, and n is the order of the chemical reaction of the quality factor. The order of reaction for most quality attributes in food products is either zero, first or second. In zero order reactions, the rate of loss of the quality factor is constant or linear and the resulting curve will be linear on a linear plot. First order reactions are not linear but are dependent on the amount of the quality factor that remains in the sample at the time. In these types of reactions, a linear prediction curve is constructed using semi-logarithmic coordinates. Typical first order reactions are: (1) rancidity, (2) microbial growth and death, (3) microbial production products, (4) vitamin losses in dried foods, and (5) loss of protein quality.

1.5 The Concept of Q10

One of the most frequently asked questions regarding shelf-life studies have to be: "One week at 100 °F equal how many weeks at room temperature?" The answer depends on the type of product and the mode of degradation involved. Each of the chemical deterioration reactions requires a certain amount of energy to get started. This is called activation energy, measured in kcal/mol. The higher the activation energy is for a reaction, the greater the acceleration with increases in temperature. A simple way to express this acceleration is to use the Q10 concept. Q10 is the increase in the rate of the reaction when the temperature is increased by 10 degrees centigrade (18 °F). For example, if a food has a stability of 20 weeks at 20 °C and 10 weeks at 30 °C, then the Q10 will be 20/10 or 2. The rate of reaction being followed is doubled for the 10 °C temperature rise. This value can be calculated from the data of most storage tests where the product has been stored at two or more temperatures regardless of whether or not they are 10 °C apart [2, 6].

1.6 Typical shelf-life study design

The first step in setting up a shelf-life study is to select one of the degradation reactions which are expected to occur in the product at typical storage temperatures, can be measured, and can be used as an index of quality loss. As discussed, these could include lipid oxidation, vitamin loss, gain or loss of moisture, etc. means the more accurate the analysis, the more precise the shelf-life prediction [2, 6]

Next, select the package that you want to protect the product in the distribution channels. This will enable you to generate data more pertinent to the product's actual shelf life. Storage temperature conditions should then be chosen which fit the product and give reliable results in a reasonable amount of time. Common temperatures used would be 20, 30, 40, and 55 °C (68, 86, 104, and 131 °F). At least two temperatures are required with three or four preferred for more accurate predictions. A control, stored at 0 °F, can also be used. The frequency of the analytical testing is the next important decision. The higher the storage temperature, the more frequent should be the testing [6]

Labuza has developed the following equation for testing frequency:

$$F_2 = f_1 \times Q_{10}^{\Delta/10}$$

Where,

f_1 is the time between tests at the higher temperature, f2 at the lower temperature, and "delta" is the difference in degrees centigrade between the two. For a product with a Q10 of 2, tested each week at 30°C, the frequency at 20 °C would be: $f_2 = 1 \times 2^{10/10}$ or $f_2 = 2$ weeks

2. Material and methods

2.1 Raw Gac fruit source

Gac fruits *(Momordica cochinchinensis* Spreng*)* are originally collected from Trang Bang, Tay Ninh province, Vietnam when they are in half ripen stage. They are kept 6 days and then experimented.

Fig 1: Gac tree

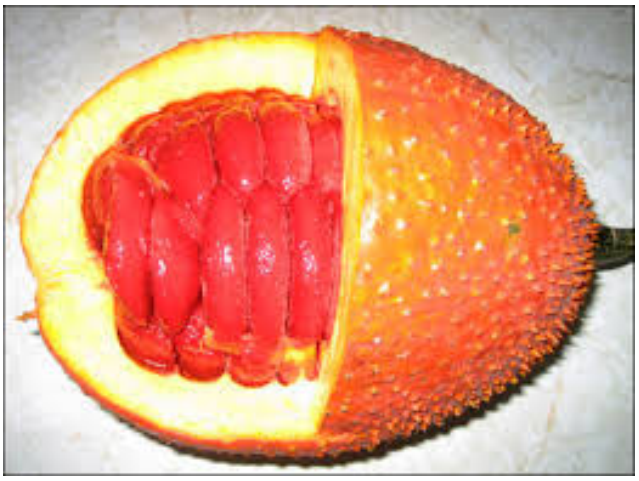

Fig 2: Overal ripen Gac

2.2 Raw material preparation

Gac fruits are choped into two parts, collect seed membrane, discard seed. In our experiments, we only use seed membranes without seed, pulp and skin.

2.3 Storage of Gac powder in accelarated temperature

Experimental parameter:

- Total carotene at begining, after 1 days, 2 days etc until carotene reduction > 80% compared to begining at 45 ^{0}C, 55 ^{0}C to calculte the real time of preservation.

Fixed parameter:

- Temperature storage: 55 ^{0}C, 45 ^{0}C.
- Packing: sample be packed in vaccum in two layes PA/PE with alluminum carton layer outside.

Target parameter:

- Total carotenoid µg/g Gac seed membrane (dry matter).

3. Results and Discussion

3.1 Effect of temperature in Gac powder storage at temperature 55 ^{0}C

In our experiments, we regconize quite clearly that total carotene decrease day by days when preserving Gac powder at 55 ^{0}C. Although all samples are kept in vaccum and packed by two layers PA/PE, outer covered by alluminum paper; caroten is also decomposed owing to high temperature, carotene change from basic energy to exciting energy so molecue breakdown. Carotenase remained in powder or microorganism contaminated during processing will hydrolise carotene. Free peroxy, unsaturated fatty acid, O_2 available in Gac powder will react with carotene, change carotene structure and lose anti-oxidise activity, light absorbability. Moreover, oxygen permeated through bag or existed in packing environment will react with caroten after 6.5 days, total carotene decreases to 98%.

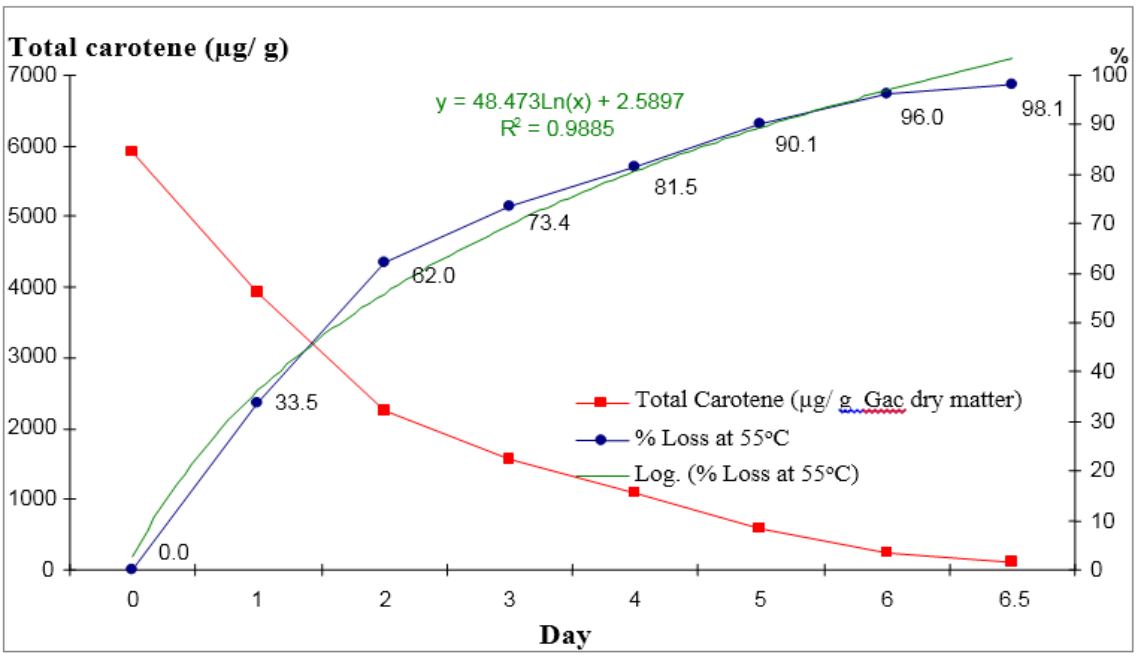

Fig 3: Effect of temperature 55 ^{0}C to total carotene in Gac powder (µg/g Gac seed membrane) (dry matter).

At temperature 45 ^{0}C

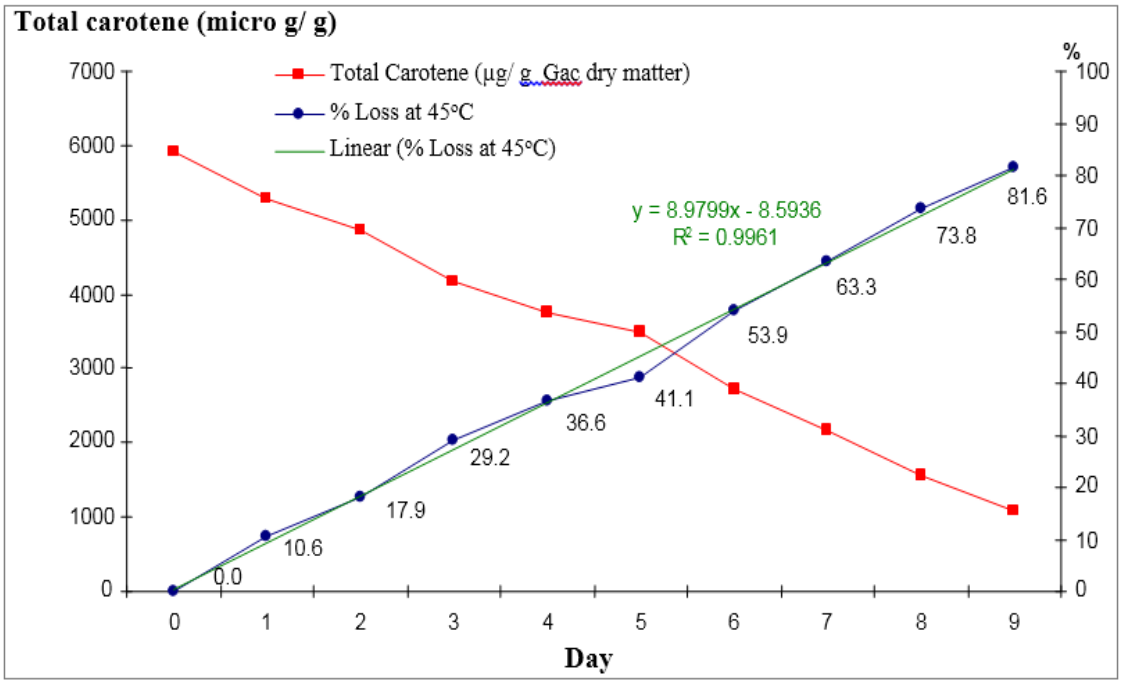

Fig 4: Effect of temperature 45 ^{0}C to total carotene in Gac powder (µg/g Gac seed membrane) (dry matter)

At temperature 45 ^{0}C in PA/PE bag, carotene declines slowly 2 - 3 times compared to 55 ^{0}C. According to Arrhenius, effect of temperature to reacting velocity can be expressed by the exciting molecules at high temperature.

4. Determine the shelf-life of carotene in Gac powder

Calculating from figure 3, in order to get carotene 30% it should be keep within 1.76 days (55 ^{o}C), 4.29 days (45 ^{o}C).

Value of Q_{10}:

$$Q_{10} = \frac{4.2978}{1.7603} = 2.44$$

Storage duration at of Gac powder at 10^0C (carotene 30% reduction) will be:

$$F_2 = f_1 \times Q^{\frac{\Delta}{10}}{}_{10} = 1.76 \times (2.44)^{\frac{(55-10)}{10}} = 97.8 days \approx 3 months$$

Storage duration at of Gac powder at 5^0C (carotene 30% reduction) will be:

$$F_2 = f_1 \times Q^{\frac{\Delta}{10}}{}_{10} = 1.76 \times (2.44)^{\frac{(55-5)}{10}} = 152.8 days \approx 5 months$$

So we should keep Gac powder within 3 months at 10 ^{0}C or 5 months at 5 ^{0}C to maintain 70% carotene.

5. Conclusion

Gac powder should be stored in sealed bags (PA/PE, aluminum foil) to strictly restrict oxygen and light. Preserving at 10 ^{0}C in 3 months or 5 ^{0}C in 5 months can maintain carotene 70%. We recommend further studies: compare different preserving methods such as vacuuming, inert gas to protect carotene, survey other packing materials to protect carotene during preservation, survey self-life of Gac powder at normal temperature.

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