A method of preserving and testing the acceptability of gac fruit oil, a good source of β-carotene and essential fatty acids

L. T. Vuong and J. C. King

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 provitamin A, β-carotene. In northern Vietnam, gac fruits are seasonal and are mainly used in making a rice dish called xoi gac. The purpose of this study was to develop a method to collect and preserve gac fruit oil, to evaluate the nutritional composition of the oil, and to assess the acceptability of the gac oil by typical Vietnamese homemakers. One hundred women participated in training to learn how to prepare the fruits and operate the oil press. The women also participated in a survey of gac fruit use and their habitual use of animal fat and vegetable oil. Among all the participants in the training and surveys, 35 women actually produced oil from gac fruits grown in the village, using manual oil presses and locally available materials. The total carotene concentration in gac fruit oil was 5,700 µg/ml. The concentration of β-carotene was 2,710 µg/ml. Sixty-nine percent of total fat was unsaturated, and 35% of that was polyunsaturated. The average daily consumption of gac fruit oil was estimated at 2 ml per person. The daily β-carotene intake (from gac fruit oil) averaged approximately 5 mg per person. It was found that gac oil can be produced locally by village women using manual presses and locally available materials. The oil is a rich source of β-carotene, vitamin E, and essential fatty acids. Although the β-carotene concentration declines with time without a preservative or proper storage, it was still high after three months. The oil was readily accepted by the women and their children, and consumption of the oil increased the intake of β-carotene and reduced the intake of lard.

Key words: β-Carotene, essential fatty acids, gac fruit, oil production, Vietnam

Introduction

In rural Vietnam, where animal foods are not economically available, adequate intake of food rich in β-carotene might alleviate vitamin A deficiency. Among all the fruits and vegetables available in Vietnam, ripe gac fruit pulp contains the highest β-carotene concentration (17,000-35,000 µg/100 g of edible portion) [1, 2]. In addition to β-carotene, gac fruit pulp contains a significant amount of oil, 69% of which is unsaturated fatty acids [3]. Descriptions of gac fruit (Momordica cochinchinensis Spreng), its traditional use in Vietnam, and the bioavailability and efficacy of xoi gac (a rice preparation with gac fruit pulp) in improving plasma retinol and β-carotene levels have been published elsewhere [3–5]. Gac fruit, a rich source of β-carotene, is indigenous to Vietnam and easy to cultivate. Growing the gac vine does not require significant land or cash investment. In most communes in northern Vietnam, 30% to 35% of households grow the gac vine.*

Despite its nutritional value, the fruit has been underutilized because of seasonality and lack of postharvest processing. Ripe gac fruits are available for only about three months each year. Gac fruit oil is available all year, although the fruit itself is available only from October to February. During the months gac fruit is available, the local people make xoi gac, a rice dish reddened by the juice of gac pulp. This rice dish is commonly eaten for breakfast and is traditionally served on special occasions such as weddings or New Year celebrations. Because β-carotene is best preserved and delivered into the body in oil, a process to extract oil from the gac pulp was devised and carried out on

L. T. Vuong is affiliated with the Cancer Research Center of Hawaii, University of Hawaii, Honolulu, Hawaii, USA. J.C. King is affiliated with Children’s Hospital Oakland Research Institute, Oakland, Calif., USA.

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* Personal communication, Mr. Bach Trung Hung, Vietnam Agricultural Science Institute (VASI), Hanoi, September 1999.
Preserving and testing the acceptability of gac fruit oil

Materials and methods

Location

The production was carried out at the health post of Tan-Minh village of Soc-Son District, a group of seven villages with approximately 2,200 households each, about 35 km from Hanoi City. Two villages, Tan-Minh and Bac-Son, were selected as the study sites. The two villages were not adjacent to each other but were comparable in terms of demography, geography, and socioeconomic status (table 1). The Soc-Son District was selected because it is a poor district with a high percentage of undernourished children and low-income households; the majority of the households had no income-generating activities other than rice farming. In the past five years, there has been no nutrition intervention project in the two villages. Because workers at the health post in the villages follow the directive of the district health center, it was essential to have the full cooperation of administrators and health officials at the district level. Selection of the two communes (Tan-Minh and Bac-Son) was approved by local administrators at the district and commune levels.

Selection of participants

Health workers at each commune assisted in identifying households growing the gac vine and having at least one child under five years of age at home. Women of those households were invited to learn about gac fruit oil production and participate in the study. The selection criteria were willingness to participate in the production of gac oil and the gac oil consumption survey, the presence of at least one child of preschool age in the household, ability to provide at least 100 kg of gac (80 to 90 fruits) from a household garden, and the presence of one adult in the household willing and capable of operating the oil press. Since women in these villages have the main responsibility for cooking and food selection in the households, all of the participants were women. Husbands were encouraged to participate in the production of the oil.

Fifty-two women from Tan-Minh and 48 women from Bac-Son who met the selection criteria participated in the introductory training meeting on producing gac oil and participated in the survey of gac fruit and oil use. Thirty-five women from Tan-Minh were randomly selected to participate in the oil production. Thus, all 100 participants received instructions on how to produce gac fruit oil, from preparing the fruit to operating the oil press. However, only 35 women actually produced the oil from fruit gathered in their gardens. All women participating in the oil production signed an agreement form after the details of the study were explained. Each produced approximately 1 L of oil.

Nutritional analysis

Sample collections

Over three days, a 50-ml sample was taken from each day’s yield of gac oil. The samples were packed in 10-ml vials and sent to the University of California, Davis, California, USA for analysis. A second set of 10-ml samples was collected and stored at the houses of participants under the same conditions as other cooking oils for three months. The purpose of collecting the second set was to determine the stability of carotenoids and other nutrients in the oil after three months under the storage conditions typically used in households.

Acceptability survey

Gac production and use survey

Before production, a survey of gac fruit planting and use of gac fruits, fat, and oils was conducted among all participants, including those not involved in the oil production.

Gac fruit oil use and acceptability survey

One hundred women from Tan-Minh and Bac-Son villages participated in personal interviews by the primary investigator and two local research assistants. Survey forms, in Vietnamese, contained mostly open-ended questions about the use of gac fruits, oil, and lard. Each participant who received 1 L of gac fruit oil for home use was instructed to record in detail the

<table>
<thead>
<tr>
<th>Feature</th>
<th>Tan-Minh</th>
<th>Bac-Son</th>
</tr>
</thead>
<tbody>
<tr>
<td>Population</td>
<td>11,836</td>
<td>12,000</td>
</tr>
<tr>
<td>Area (km²)</td>
<td>33</td>
<td>34</td>
</tr>
<tr>
<td>No. of households</td>
<td>2,416</td>
<td>2,400</td>
</tr>
<tr>
<td>No. of women 15–49 yr old</td>
<td>3,084</td>
<td>3,038</td>
</tr>
<tr>
<td>No. of children &lt; 5 yr old</td>
<td>1,150</td>
<td>1,161</td>
</tr>
<tr>
<td>% of children &lt; 5 yr old who were malnourished</td>
<td>36.5</td>
<td>37.01</td>
</tr>
</tbody>
</table>
amount and the way the oil was used each time on a preprinted form. The form was collected at a follow-up interview three months later. During the interview, the participants were asked whether they liked gac fruit oil, about the ways the oil was used, and any changes in the amount of oil and lard used during the study period. To quantify the amount of gac oil used, the remaining oil in each bottle was weighed.

Results

Oil preservation

Gac oil production

Production was carried out in early December when gac fruits were in season. Rice harvesting had been completed, and there was no other economic activity during this time in these villages; hence the production of gac oil did not interfere with the regular income-generating activities of the local women. The total amount of oil needed for oil production was two days for each group of 10 women. It takes approximately 100 kg of whole fresh gac fruits (approximately 80 to 90 fruits) to produce 1 liter of gac oil. Thirty-five women were selected from Tấn-Minh village to produce the oil. Two oil presses were shared among the participants. The gac fruits used to produce the oil were purchased from the participants. The purchase price was agreed between the project and a farmers’ cooperative that represented the growers in the community. About 36 L of gac oil were produced. Of this, 600 ml was set aside for chemical analysis, and the rest was divided among the participants.

The processing method for gac oil, which included seeding, drying, pressing, separation of water, and packaging, was devised and tested by the primary investigator prior to oil production. The technique was designed to retain the maximum amount of β-carotene with a minimum amount of water activity and a low rancidity value in the oil.

The cost of production, including fixed costs (oil press, dryer, filter, facility, and storage) and variable costs (fruit, labor, containers, coal, electricity, and water) was between US$20 and $30 per liter.

Seeding and drying

Although gac seeds also contain oil, for this project only gac pulp oil was extracted. The 35 participants were divided into three groups, and preparation of the fruit for oil production was scheduled for three consecutive days. All fruits were weighed, washed, and split in half. All seed pulp (covering seeds) was then removed and dried. The pulp dried quickly (one hour at 60°C) in a drying oven until the surface was no longer sticky. After the pulp was dried, seeds were removed from the pulp. The pulp can also be covered by clean cloth and sun-dried for four to five hours, or in a pan over low flame for about one hour. However, those techniques are expected to incur higher losses of light- and heat-sensitive carotenoids. Drying seed pulp before seeding has been proved to speed up the seeding process and reduce water, which is necessary for oil production. After it was seeded, the pulp was dried again in a drying oven at 60°C until the volume of water was reduced to about 12% to 15%.

Pressing and oil separation

Just before pressing, the gac pulp was smashed and heated slightly by hot steam for five minutes, since heating increases the yield of the seed oils [6]. The pulp was pressed by a manual single press, powered by a four-ton hydraulic jack (Bottle Jack, Napa Lifting Equipment, made in China for Bakkamp). The press prototype was provided by the Pilot Plant of the Department of Food Science and Technology at the University of California Davis and brought to Hanoi. Using the prototype as an example, a second press was constructed locally in Vietnam. Each press weighed about 35 kg and could process 1 kg of gac pulp per batch. The pressing time, including loading and cleaning, was 10 to 20 minutes per batch. The oil produced was allowed to settle in a large container and filtered through a cloth into individual 1-L amber Boston round bottles. At the end of production, each participant received a labeled bottle of oil, along with an oil-use record form.

Workshop

Detailed written instructions of the production process in Vietnamese were developed and distributed to all participants in a workshop before production started. The workshop allowed participants to review the procedure, ask questions, and provide feedback prior to the start of production. During the workshop, use of the oil presses and basic food hygiene were demonstrated to all participants. Although 95% of the villagers could read and write, the procedure of oil production was also explained to all participants orally by field workers.

Nutritional composition of the oil and stability of the nutrients

Chemical analysis of gac fruit oil was performed at the laboratory of the Department of Nutrition, University of California Davis, and by Analytical Services VFHA (Vitamins and Fine Chemicals Division) of Hoffman-La Roche. Identification and quantification of carotenoids and vitamin E in gac fruit oil were performed by reversed-phase high performance liquid chromatog-
raphy (RP-HPLC) using published methods [7,8]. The results listed in table 2 are the means of triplicate assays. β-Carotene and lycopene are the major carotenoids in gac fruit oil.

Gac fruit oil distributed to participants of the study was kept in sealed amber bottles at room temperature, which in the study area during the season was between 25° and 27°C. Since the oil did not contain preservatives or antioxidants, and refrigeration is not available in rural areas, loss of β-carotene by oxidation was the major concern. A sample was collected after three months in clear 10-ml scintillation vials and sent to the University of California at Davis and Hoffman-La Roche in Basel, Switzerland, for analysis. The oil samples were kept at 0°C until analyzed by RP-HPLC. There was a 47% reduction of β-carotene in the oil compared with the first analysis. The concentration of β-carotene in this sample was 1,622 parts per million (ppm). There was no deterioration of vitamin E in the oil after six months.

Results of surveys of acceptability by the women and use of gac fruits and gac oil

Acceptability

Ninety-four percent of all participants in the gac fruit oil survey used gac fruit oil daily. The reasons given for using it included the following: it was convenient to use in making xoi gac or in rice (100%); it was flavorful (82%); it was healthful (47%); it was good for the skin (29%); children preferred rice mixed with gac fruit oil (24%); and it was cheaper than lard (17%). Some respondents liked to mix gac fruit oil with other food because of the color (12%).

Use of gac fruits

Less than 50% of the total number of gac fruits harvested was consumed. The rest was given away, sold, or, in few cases, used as pig feed. Growers with large yields (100 kg or more) sold the fruits at local markets or to vendors who supplied gac fruits to markets in Hanoi. Only 10% of the growers could quantify the income received from selling gac fruits. Some answered that the amount was too insignificant to remember. All respondents used gac pulp in preparing xoi gac. In addition to making xoi gac, 25% of respondents cooked gac seed kernels with eggs for children, 21% mixed gac pulp with other vegetables in stir-fried dishes, and one respondent used the mesocarp (peel) of the fruit as a vegetable. Few women (5%) preserved gac pulp with sugar or alcohol, and 4% of them fed raw gac pulp to their children. None of the respondents had previously heard of gac fruit oil (table 3).

All respondents stated that gac fruit was healthful; 35% stated that gac fruit was good for the eyes, and some believed that gac seed kernel contained vitamin A. Many respondents (18%) thought that gac fruit was good for the blood, perhaps because of the red color of the pulp. Some women said that gac pulp added color to skin (4%). Some respondents also believed that gac fruits could be used to relieve headache (2%), lower blood pressure (1%), treat diarrhea in children (4%), and relieve dizziness (2%). Eight percent of the respondents thought that gac fruit maintained a healthy body, and one said that eating xoi gac made her feel good.

Use of gac fruit oil

Table 4 contains information from the follow-up interviews of the 35 participants who produced the oil. The survey was conducted three months after the oil production. The interviews were performed by the primary investigator and field assistants at the Tan-Minh health post. At this time, the amount of leftover oil in the bottles distributed to the participants was recorded. Samples of the oil were also collected to determine the loss of β-carotene and other nutrients after three months of storage under typical local conditions.

All of the 35 participants said they used gac fruit

| TABLE 2. β-Carotene, lycopene, and α-tocopherol concentrations (μg/ml) in gac fruit oil |
|--------------------------------------|---|---|
| Carotenoid                           | 1st analysis (March 2001) | 2nd analysis (June 2001) |
| Total carotenoids                    | 5,770 | 3,190 |
| β-Carotene and isomers               | 2,710 | 1,622 |
| Lycopene                             | 3,020 | 1,186 |
| α-Tocopherol                         | 334  | 380  |

| TABLE 3. Uses of gac fruits in food by growers and participants in the study |
|-------------------------------------------------|-----|
| Use of fruit                                     | % (n = 100) |
| Making xoi gac                                  | 100 |
| Pulp cooked with other vegetables               | 21  |
| Pulp preserved in alcohol or sugar              | 5   |
| Mesocarp stir-fried with other vegetables        | 1   |
| Pulp eaten raw                                  | 4   |
| Seed kernels stir-fried with egg                 | 25  |

| TABLE 4. Uses of gac fruit oil by participants in oil production |
|---------------------------------------------------------------|-----|
| Use of oil                                                    | % (n = 35) |
| Making xoi gac                                                | 100 |
| Mixed with a vegetable dish                                   | 100 |
| Mixed with cooked rice                                        | 100 |
| Mixed with soup                                               | 100 |
| Vitamin supplement for children                               | 12  |
| On skin                                                      | 40  |
oil daily. Most of these respondents perceived that gac fruit oil had benefits for the health of their children. All mothers gave gac fruit oil to their children every day with rice and other dishes, and 12% also gave it directly to their children as a supplement. After the study, 82% of the women requested assistance in planting techniques and materials in order to produce more gac fruits. Sixty-five percent wanted to produce gac fruit oil for home use, and 18% wanted to make gac fruit oil to sell for extra income. Fifty-three percent of the participants wanted to have a larger-scale production of the oil so that everyone in the community could have gac fruit oil. Six percent complained that the production was time-consuming and the press was too hard to operate.

Impact of gac oil use on diet quality

Daily β-carotene consumption

Although gac fruit oil was a new food to the participants, it was well accepted because it was convenient to use, had the familiar gac flavor, and was perceived to have heath benefits. According to data from the gac oil use form and the amount left over in the bottles after three months, a household of five people consumed an average of 840 ml of gac oil over three months. The daily consumption per person was estimated as 1.9 ml, which would provide about 5 mg of β-carotene daily.

Daily lard and oil use

In these villages, peanut oil was the only type of vegetable oil available. Fifty-six percent of all respondents did not use oil at all, and 90% stated that they used oil only for deep frying. On the average, oil consumption per household of five people was one half-liter per month. All respondents preferred pork fat to vegetable oil. The reasons given were its taste, convenience, availability, and cost. In these villages, lard is sold in the market in the form of raw fat, which is cut into small pieces and fried. Both the liquid and the fried fat are used. The liquid fat (lard) is used in the same way as vegetable oil: drizzled directly onto rice when other oils are not available. Fried pork fat may be eaten with rice instead of meat or mixed with vegetables. Pork fat is meat to poor families. Thirty-five percent of the women said that they did not use vegetable oil because their children ate more rice with fried pork fat. Most respondents (67%) believed that lard was more healthful than vegetable oil.

Discussion

This study demonstrated that it is feasible to preserve gac oil for year-round use. The preservation process is low in cost and can be performed with the use of local resources.

Drying box

It was critical to dry the pulp before pressing to remove water, which reduces the oil's shelf-life. The drying box used in this study is simple to construct and very cost effective. The temperature is controlled by attaching a thermometer inside the oven wall and adjusting the heat by removing or adding more coal to the burners periodically. This kind of drying box can also be used on a large scale and is more effective and cost efficient than electrically powered heating chambers.

Oil press

The oil press was a modified hand-operated screw-press. The power for the pressing was provided by a removable 4-ton hydraulic jack. The press can easily be disassembled, making it convenient to transport and store, while the steel frame provides sufficient weight and stability for the pressing. This manual press can be used in small household production. However, for a larger-scale application, or at a community level, a small, electrically powered, continuous oil expeller is recommended. The oil yield from the manual press is about 50% of that from a mechanical press, but the latter requires more time for loading the press with fruit and for cleaning between batches.

Local acceptability

Gac oil has a very mild nutty taste, comparable to that of sesame or peanut oil. The oil has a viscosity similar to that of red palm oil and an intense red color. The field setting and budget limitations did not allow a complete sensory evaluation; however, personal in-depth interviews in combination with investigators’ observations revealed a high degree of acceptability among the participants as well as the fieldworkers.

The uses of gac oil were expanded beyond the traditional uses of gac fruit. Gac fruits have been used mainly to make xoi gac for special occasions, such as weddings or Tet. With the availability of gac oil, the participants used it daily in cooked rice and mixed with stir-fried vegetables, meat dishes, tomato-based dishes, or soup. Some participants (12%) gave gac oil to their children every day as a vitamin supplement.

Nutritional quality of gac fruit oil

The total carotenoid concentration of gac fruit oil is 5,770 ppm, consisting mainly of two carotenenes, β-carotene and lycopene. The concentration of the most efficient provitamin A carotene, trans-β-carotene, is more than five times that in red palm oil [9]. There is a quantifiable amount of α-carotene in gac oil and a small amount of canthaxanthine. The distribution of carotenones in gac oil is closer to that in tomatoes. The
concentration of vitamin E, expressed as the concentration of α-tocopherol, is 330 ppm. As a natural antioxidant, vitamin E helps protect gac oil from oxidation. The percentage of loss of β-carotene after three months without a preservative or proper storage was 47%. However, gac fruit oil kept at room temperature for three months still provided 1,622 ppm of β-carotene and 330 ppm of α-tocopherol.

The concentration of saturated fatty acids in gac fruit oil is lower than that in animal fats and coconut oil, and the concentration of polyunsaturated fatty acids is higher (table 5). Because saturated fatty acids are associated with an increased risk of cardiovascular disease [10] and polyunsaturated fatty acids may be protective for normal development [11,12], gac fruit oil may have a health advantage over coconut oil and fat of animal origin.

### Impact of gac fruit oil on the health of children

Eighty-eight percent of the participants reported that they had reduced the amount of animal fats and vegetable oils they used and replaced them by gac fruit oil. Vegetable oil consumption was reduced in 29% of the households. Replacement of pork fat with gac fruit oil increased the intake of β-carotene and essential fatty acids and lowered the intake of saturated fatty acids. Studies of children and adolescents in developed countries and countries in transition show a correlation between high intakes of foods rich in saturated fatty acids and cholesterol with an increasing prevalence of obesity, cardiovascular disease, and other degenerative diseases [13,14]. Although the problems of obesity and cardiovascular disease are not prevalent in the population studied here, reduction in the daily intake of animal fat will probably have a positive long-term effect on health.

### Conclusions

This study shows that gac fruit oil can be produced at the household or community level with the use of a hand press and locally available materials. The oil has a high concentration of β-carotene and is well accepted by local people in their daily diet and in cooking. The production of gac fruit oil increased the intake of β-carotene and extended the use of gac fruits beyond the season when gac fruits are available. In addition to provitamin A carotenoids, gac fruit oil provided essential fatty acids that are important for proper growth and development in children. Household consumption of animal fat was lower when gac fruit oil was available. Future work is needed to achieve the commercial production of gac oil as a food source for Southeast Asia.

### Acknowledgments

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### TABLE 5. Nutritional quality of gac fruit oil and of other fat and oil sources (per 100 g of edible portion) 

<table>
<thead>
<tr>
<th>Oil</th>
<th>Carotene (µg)</th>
<th>Vitamin E (mg)</th>
<th>Vitamin A[b] (µg RE)</th>
<th>Saturated fat (g)</th>
<th>MUFA (g)</th>
<th>PUFA (g)</th>
<th>Cholesterol (mg)</th>
<th>Energy (kcal)</th>
<th>Phytosterol</th>
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<tbody>
<tr>
<td>Coconut</td>
<td>0.280</td>
<td>21.1</td>
<td>0</td>
<td>87</td>
<td>6</td>
<td>2</td>
<td>0</td>
<td>862</td>
<td>86</td>
</tr>
<tr>
<td>Corn</td>
<td>33</td>
<td>40</td>
<td>31</td>
<td>13</td>
<td>25</td>
<td>62</td>
<td>0</td>
<td>884</td>
<td>968</td>
</tr>
<tr>
<td>Gac[c]</td>
<td>577</td>
<td>12.4</td>
<td>0.1</td>
<td>14</td>
<td>77</td>
<td>9</td>
<td>0</td>
<td>884</td>
<td>221</td>
</tr>
<tr>
<td>Lard</td>
<td>0.12</td>
<td>—</td>
<td>18</td>
<td>18</td>
<td>49</td>
<td>33</td>
<td>0</td>
<td>884</td>
<td>207</td>
</tr>
<tr>
<td>Olive</td>
<td>50</td>
<td>21.7</td>
<td>8</td>
<td>48</td>
<td>37</td>
<td>10</td>
<td>0</td>
<td>n/a</td>
<td>n/a</td>
</tr>
<tr>
<td>Peanut</td>
<td>1.68</td>
<td>11.2</td>
<td>15</td>
<td>15</td>
<td>24</td>
<td>61</td>
<td>0</td>
<td>884</td>
<td>250</td>
</tr>
</tbody>
</table>

RE, Retinol equivalents; MUFA, monounsaturated fatty acids; PUFA, polyunsaturated fatty acids.

b. Based on a conversion ratio of 6 to 1 for β-carotene to retinol.
c. Data from this paper.
d. From Nagendran et al. [9].
References