Journal of Food Engineering 118 (2013) 358–364

Contents lists available at SciVerse ScienceDirect

Journal of Food Engineering

journal homepage: www.elsevier.com/locate/jfoodeng

Impact of limited drying on *Momordica cochinchinensis Spreng.* aril carotenoids content and antioxidant activity

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ARTICLE INFO

Article history:
Received 31 October 2012
Received in revised form 7 April 2013
Accepted 13 April 2013
Available online 7 May 2013

Keywords:
Momordica cochinchinensis Spreng.
Drying
Carotenoids
Antioxidant activity

ABSTRACT

Food product based on gac fruit (*Momordica cochinchinensis Spreng.*) arils have a high potential due to the high carotenoids content of this fruit. Drying is a key preparation step for carotenoids extraction from gac fruit in a economically viable process. The impact of different drying technics, temperature, final product moisture content on the carotenoid content, hydrophilic and lipophilic antioxidant activity (evaluated with three methods) and color of the gac arils is discussed based on laboratory scale experimental tests. The results highlight an optimal temperature between 50 °C and 60 °C to conserve the color, the carotenoid content and the antioxidant activity. Also, these properties are better preserved by limiting the drying to dry based moisture content between 15% and 18% while the advantages of drying for further processing and for refrigerated conservation for a few months are achieved.

1. Introduction

Momordica cochinchinensis Spreng., known in Vietnam as gac fruit (Bailey, 1937), is common to many countries of eastern Asia (China, Japan, India, Thailand, Laos, Cambodia, the Philippines, Malaysia and Bangladesh) (Nguyen, 1998; Perry, 1980).

The fruit is mainly composed of two parts: a mesocarp and an endocarp. The mesocarp, which occupies nearly 50% of the weight of a fruit, is thick, spongy, and orange. The endocarp, is composed of red soft and sticky arils, 1–3 mm thick, covering black seeds, accounting for around 25% of the fruit weight (Vuong, 2000).

Gac fruit aril membrane is a potentially highly valuable source of carotenoids. Indeed, the total concentration of lycopene, a powerful set of antioxidant, in the ripest samples is about 3 mg/g fresh weight (fw), compared to 40–50 μg/g fw in commercially available tomatoes (Ishida et al., 2004). β-Carotene in the gac aril is also 10 times more concentrated than in carrots (Vuong, 2000). High concentrations of other carotenoids have also been reported (Vuong and King, 2003; Vuong et al., 2006; Ishida et al., 2004).

Therefore, getting a carotenoid rich extract from gac fruit might be of interest for various application, such as:

1. Supplementing diets for eastern Asia populations facing deficiency in vitamin A and other antioxidants.
2. Coloring food or other products.
3. Achieving affordable high purity lycopene from natural source for the food, cosmetic and pharmaceutical industries.

To achieve this extraction in an economically viable process, a preparation operation is needed to allow:

1. The storage of the arils in order to make the extraction outside of the harvesting season which is only 3 month a year.
2. Easy removal of the seeds from the arils, which is needed for further processing (oil extraction, inclusing in rice cooking, carotenoids extraction, and freezing). Because of stickiness, this operation is labor consuming on the fresh fruit.

Two operations can be considered for this: freezing and drying. Freezing however requires low temperature conservation, which makes it expensive. Compared to that, dried aril can be stored in sealed, dark container for up to one year without significant degradation of carotenoids (Vuong et al., 2003; Vuong, 2004).

Carotenoids being sensitive to heat, the selection of the drying techniques and the processing parameters seems to be essential in order to preserve high carotenoids concentrations. Freeze-drying is therefore the leading candidates for this operation as it allows

Abbreviations: BHT, butylated hydroxytoluene; db, dry based water content; DMPD, N,N-Dimethyl-p-phenylenediamine; DPPH, 2,2-diphenyl-1-picrylhydrazyl; FRAP, ferric reducing antioxidant power test; fw, fresh weight; HAA, hydrophilic antioxidant activity; LAA, lipophilic antioxidant activity; LSD, Least Significant Difference; MTBE, Methyl-tert-butylether; TCC, total carotenoid content; TE, Trolox equivalents; TPTZ, 2,4,6-tripyridyl-s-triazine.

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http://dx.doi.org/10.1016/j.jfoodeng.2013.04.004

retaining 100% of carotenoids in the dried samples (Tran et al., 2008).

However, the link between heat and carotenoid content and antioxidant activity is not straightforward. Indeed, heat processing can lead to the solubilization of lycopene bounded to insoluble fiber portion (Toor and Savage, 2005) or freed by cell-wall breaking (Rao, 2004; Omoni and Aluko, 2005). These phenomena have been described for tomato fruit, for which at 32 °C, drying leads to an apparent increase of lycopene concentration of 55% (Dewanto et al., 2002; Tonucci et al., 1995), while at higher temperature drying, reduced concentration was reported (Zanoni et al., 1998; Shi et al., 1999; Lavelli et al., 1999). In parallel, it can lead to the isomerization lycopene and β-carotene and its change from all-*trans* to *cis* conformations. The quantity of *cis* isomers grows with the increase in temperature and duration of heat treatment (Shi et al., 1999).

This complex impact of the temperature, coupled with the high cost of freeze drying, opens interesting prospects for the air drying or vacuum drying techniques. Existing studies for drying of gac arils (Vuong, 2004; Tran et al., 2008; Kha et al., 2010, Kha et al., 2011) focused on drying to dry-based moisture content of 6%. However, the removal of the last fraction of water is the most time consuming and the most critical when considering oxidation. Stopping the drying at higher humidity might lead to a product that would be easy to process and retaining a larger part of the carotenoids.

The goal of this work is to evaluate quantitatively the interest of limited drying of gac arils.

To meet this goal, drying limited to a dry based water content (db) of 15–18% was tested and compared to the classical final 6% db. Different drying techniques (air drying, vacuum drying, and freeze drying) were tested for their impact on product color, total carotenoid content and total antioxidant activity. For the total antioxidant activity evaluation, three different analytical methods were tested and compared to each others. The results were compared to studies from the literature, mainly Tran et al. (2008) and Kha et al. (2011). The long term conservation of the sample was also evaluated to ensure the conservation despite the higher moisture content of the dried fruit.

2. Materials and methods

All the presented results were analyzed using standard linear regression algorithm, one way or two way ANOVA tests using Excel 2003 (Microsoft, USA) and Statgraphic 6.0 (Statpoint technologies, USA). Significance analyze were based on a confidence of 95% ($p < 0.05$).

2.1. Materials and storage

The fresh gac fruits were purchased from market Pham Van Hai in Ho Chi Minh, Vietnam. To identify rip gac fruit the criterion had to have a red skin (at least 50% of its surface), slightly soft at touch, the seeds had to be hardened and the fruit had to weight minimum 0.8 kg. Fruit were collected only during at maturity season (August to February) (Nguyen, 1998). All the fresh gac fruits were stored in fridge from 3 to 5 days. Dried gac arils samples were stored in sealed aluminum packages.

The following chemicals, used for the different standard tests, came from Sigma–Aldrich Belgium: acetone, ascorbic acid, acetic acid, N,N-Dimethyl-p-phenylenediamine (DMPD), 2,2-diphenyl-1-picrylhydrazyl (DPPH), ferric chloride, Methanol, Methyl-tert-butylether (MTBE), *n*-hexane, (S)-(-)6-hydroxy-2,5,7,8-tetramethylchroman-2-carboxylic acid (Trolox), potassium persulfate solution 2.6 mM, sodium acetate tryhydrate, 2,4,6-tripyridyl-s-triazine (TPTZ) and butylated hydroxytoluene (BHT).

2.2. Drying methods and moisture content measurement

The gac arils were dried under vacuum drying and air drying at a constant temperature in the 40–80 °C range until a moisture of 15–18% db was obtained. Experiments leading to similar moisture content were also realized using freeze drying.

The samples are approximately hexahedron of thickness varying from 5 mm to 1 cm and presenting a square surface of 3 cm of side length. The samples are disposed in the dried avoiding any superposition and separated from each others by about 2 cm.

All the weighing measurement were realized using a Sartosius GD503 balance (Sartorius, Germany). The dry weight was evaluated by drying samples in a Memmert Beschickung UNB 400 (Memmert Co., Germany) with dry air at 70 °C until no further mass change was observed (Ranganna, 1986).

The drying kinetic of gac arils was recorded by weighing periodically (every hour for air drying and every 2 h for vacuum drying) three sample sets in the dryer. Each sample initial mass was about 3 g. By careful removal of the sample for the weighing, it was possible to eliminate any eye-detectable mass loss that might have appeared due to the initial stickiness of the sample. For the drying kinetic measurement, experiments were 15 h long. For other tests, the drying was stopped when a db between 15% and 18% was achieved. A few tests, realized for comparison purpose, were continued until a 6% db were achieved. Every test were realized three times. Presented results are the average of the three experiments measurements. Error crosses show the standard deviations.

The hot air dryer was a Memmert UFB 400 (Memmert Co., Germany). The dryer comprises perforated mesh trays fitted in an insulated cabinet. Air can be directly heated by an electric heater and was then circulated (at a velocity around 0.2 m/s) between the trays. The vacuum dryer was a JISICO, model J-DV01 (South Korea). During the vacuum drying experiments, pressure was reduced to values around 9000 Pa. The freeze dryer was a GPFD 24DX48 (VirTis, USA). The freeze drying experiments are conducted at −20 °C and 250 Pa.

2.3. Aril color measurement

The color of gac aril samples was determined using a Minolta Chroma Meter calibrated with a white standard tile. The results is expressed as CIE values of L^*, a^*, and b^* (Sahin and Sumnu, 2006). Chroma $\left(c = \sqrt{a^{*2} + b^{*2}}\right)$, hue angle ($H^\circ = arctan(b^*/a^*)$), and total color changes (Sahin and Sumnu, 2006) were tested. The total color change or difference between a fresh and a dry sample (with subscripts $_0$ and $_1$ respectively) was calculated as follows:

$$\Delta E = \sqrt{\left(L_0^* - L_1^*\right)^2 + \left(a_0^* - a_1^*\right)^2 + \left(b_0^* - b_1^*\right)^2}. \quad (1)$$

All the color measurement were realized on three samples for every drying condition. Presented results are average of the three samples. Except for the total color change, the results are expressed as a ratio between the measured value and a reference value for a fresh fruit.

All the color data are analyzed with analysis of variance and regression models using a commercial statistical package STATGRAPHIC version 6.0. Multiple ranges test LSD (Least Significant Differences) was used.

2.4. Extraction method

A modified version of the method by Tran et al. (2008) and Gross (1991) was employed to determine to the total carotenoid content. Approximately 0.3 g of fresh gac aril was weighed in beaker. Extraction was achieved by putting in contact the sample with 10 mL of a mixture of *n*-hexane:acetone (v/v 3:2) with 0.1% BHT in