Food Research International 102 (2017) 32–42

Contents lists available at ScienceDirect

Food Research International

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

Dehydration of jambolan [*Syzygium cumini* (L.)] juice during foam mat drying: Quantitative and qualitative changes of the phenolic compounds

Tavares Iasnaia Maria de Carvalho[a], Tuany Yuri Kuboyama Nogueira[a], Maria Aparecida Mauro[a], Sergio Gómez-Alonso[b], Eleni Gomes[a], Roberto Da-Silva[a], Isidro Hermosín-Gutiérrez[b,*], Ellen Silva Lago-Vanzela[a]

[a] *São Paulo State University (Unesp), Institute of Biosciences, Humanities and Exact Sciences (Ibilce), Cristovão Colombo, 2265, Jardim Nazareth, 15054-000, Campus São José do Rio Preto, São Paulo, Brazil*
[b] *Universidad de Castilla-La Mancha, Instituto Regional de Investigación Científica Aplicada, Avda. Camilo José Cela S/N, 13071 Ciudad Real, Spain*

A R T I C L E I N F O

Keywords:
Jambolan
Juice
Foam mat drying
Phenolic compounds
Anthocyanins
Flavonols
Hydrolysable tannins
Antioxidant activity

A B S T R A C T

Jambolan [*Syzygium cumini* (L.)] berries are a popular fruit in Brazil, renowned for their high phenolic compound (PC) content. These PCs have antioxidant, antibacterial, and other characteristics that may be beneficial to human health. The objective of the study was to evaluate the quantitative and qualitative changes of the main phenolic compounds (PCs) (anthocyanins, flavonols, and hydrolysable tannins) in the jambolan fruit, the produced fruit juice, and in the corresponding dehydrated powders obtained by foam mat drying (60, 70, and 80 °C) and lyophilization (control). The PCs were analyzed using high-performance liquid chromatography with a diode array detection coupled with an electrospray ionization mass spectrometry (HPLC-DAD-ESI-MS^n). Juice production resulted in a more pronounced degradation of anthocyanins than flavonols, and facilitated the extraction of hydrolysable tannins. Elevation of the dehydration temperature negatively impacted the anthocyanin content of the products; on the other hand, the flavonols and hydrolysable tannins were more sensitive to oxidation and heating time during dehydration, respectively, than dehydration temperature. In summary, it can be concluded that processing at 70 °C is most suitable, in light of the least loss of nutritional quality of the product with processing time. This study directly informs further investigations into preparation of high-quality jambolan fruit products.

Chemical compounds

Delphinidin 3,5-diglucoside (PubChem CID: 10100906)
Petunidin 3,5-diglucoside (PubChem CID: 10151874)
Malvidin 3,5-diglucoside (PubChem CID: 44256978)
Myricetin 3-glucoside (PubChem CID: 44259426)
Myricetin 3-rhamnoside (PubChem CID: 5281673)
Laricitrin 3-glucoside (PubChem CID: 44259475)
Syringetin 3-glucoside (PubChem CID: 44259492)
Gallic acid (PubChem CID: 370)
Ellagic acid (PubChem CID: 5281855)
Valoneic acid dilactone (PubChem CID: 10151874)

1. Introduction

Jambolan [*Syzygium cumini* (L.)] is a plant belonging to *Myrtaceae* family, originate in tropical Asia that covers 121 genuses and 3800 to 5800 species, and being widespread in all tropical and subtropical regions of the World. In Brazil, jabuticaba (*Myrciaria cauliflora* (Mart.) O. Berg) (Seraglio et al., 2017), cambuci (*Campomanesia phaea* (O. Berg.) Landrum), cagaita (*Eugenia dysenterica* DC), camu-camu (*Myrciaria dubia* Mc. Vaugh) (Balisteiro, de Araujo, Giacaglia, & Genovese, 2017)

Abbreviations: 3glc, 3-monoglucosylated; 35diglc, 3,5-diglucosylated; AA, antioxidant activity; ANOVA, analysis of variance; AOAC, association of official analytical chemists; cy, cyanidin; dp, delphinidin; DPPH, 2,2-diphenyl-1-picrylhydrazyl; FS, Fe_2SO_4 or ferric sulfate; FMD, foam mat drying; FRAP, ferric reducing antioxidant power; GA, gallic acid; GA-Me, methyl ester GA; HLPC-DAD-ESI-MS^n, high-performance liquid chromatography with diode array detection coupled with an electrospray ionization mass spectrometry; I, isorhamnetin; isoVA-Me, isomer of valoneic acid dilactone methyl ester; K, kaempferol; L, laricitrin; M, myricetin; M3glc, myricetin 3-glucoside; mv, malvidin; PC, phenolic compound; PCs, phenolic compounds; pn, peonidin; pt, petunidin; Q, quercetin; S, syringetin; TPC, total phenolic content; Trolox, 6-hydroxy-2,5,7,8-tetramethylchromane-2-carboxylic acid; TSS, total soluble solids; TA, titratable acidity; VA-Me, valoneic acid dilactone methyl ester; glcU, glucuronide; gal, galactoside; glc, glucoside; rhm, rhamnoside; pent, pentoside

* Corresponding author.
E-mail addresses: iasnaiamct@gmail.com (T. Iasnaia Maria de Carvalho), tuh.kuboyama@hotmail.com (T.Y.K. Nogueira), cidam@ibilce.unesp.br (M.A. Mauro), sergio.gomez@uclm.es (S. Gómez-Alonso), eleni@ibilce.unesp.br (E. Gomes), dasilva@ibilce.unesp.br (R. Da-Silva), isidro.hermosin@uclm.es (I. Hermosín-Gutiérrez), ellen@ibilce.unesp.br (E.S. Lago-Vanzela).

http://dx.doi.org/10.1016/j.foodres.2017.09.068
Received 15 June 2017; Received in revised form 10 September 2017; Accepted 24 September 2017
Available online 28 September 2017
0963-9969/

and pitanga (*Eugenia uniflora*) (Costa, Garcia-Diaz, Jimenez, & Silva, 2013) stand out among *Myrtaceae*. It bears fruit in the form of berries, 1.5 to 3.5 cm long. These berries are covered by a thin dark purple skin, have a colorless fleshy pulp, and a single seed (Singh et al., 2016). The fruit is edible and has a sweet but sharp taste (Jebitta & Allwin, 2016). The intense color of the skin is associated with a high anthocyanin content (Tavares et al., 2016), which is higher than that of other well-known Brazilian fruits, such as jaboticaba, camu-camu, and pitanga; its phenolic compound (PC) content is higher than in açaí (Costa et al., 2013).

Recent studies have highlighted the complex composition of PCs in jambolan; these include anthocyanins, flavonols, and hydrolysable and condensed tannins (Santhalakshmy, Don Bosco, Francis, & Sabeena, 2015; Tavares et al., 2016). According to Tavares et al. 2016, around 74 individual phenolic compounds, including 9 anthocyanins (mainly based on delphinidin, petunidin and malvidin), 9 flavonols (myricetin, laricitrin and syringetin glycosides), 19 flavanonols (dihexosides of dihydromyricetin and its methylated derivatives), 8 flavan-3-ol monomers (mainly gallocatechin), 13 gallotannins and 13 ellagitannins, together with some proanthocyanidins (highly galloylated prodelphinidins) and free gallic and ellagic acids were detected in the edible parts of jambolan. It has been suggested that these compounds possess various functional characteristics, i.e., antioxidant, antimutagenic, antimicrobial, antiglycemic, anticarcinogenic, and antiviral activities (Costa et al., 2013).

Given the possible health benefits associated with its PCs, jambolan has attracted considerable attention from the scientific community and industrialized food producers, as a potential raw material for the development of a variety of products. In the United States and European countries, jambolan is considered a delicacy, and is marketed in a dehydrated, seed-less form (Singh et al., 2016). It is also used for the preparation of pulp (Branco et al., 2016; Sheikh, Shahnawaz, Nizamani, Bhanger, & Ahmed, 2011), wine (Nuengchamnong & Ingkaninan, 2009), jelly (Lago-Vanzela, Santos, Lima, Gomes, & da Silva, 2011), and bread or “chapatti” (Kapoor, Ranote, & Sharma, 2015). Due to the seasonality and perishability of the fruit, various studies assessed the drying of jambolan fruit using different techniques, such as lyophilization (Sheikh et al., 2011), spray-drying (Santhalakshmy et al., 2015), warm air drying with a forced convection drier (Kapoor et al., 2015) and a spouted bed drier (Mussi, Guimarães, Ferreira, & Pereira, 2015; Sheikh et al., 2011).

Another promising technique for obtaining dehydrated fruit products aimed at retaining the bioactive compounds is foam mat drying (FMD). This technique involves mixing a pulp or juice of fruits and vegetables with stabilizing agent and/or foaming agent to produce stable foam spread on a tray, which undergoes air drying temperatures ranging from 50 to 80 °C, and then the dried product is further ground to produce a powdered product (Abbasi & Azizpour, 2016). Compared with more expensive techniques, such as spray-drying and freeze-drying, foam mat drying has the advantages of simplicity and low cost. In this technique, the drying rates during foam mat drying are quicker than during conventional drying with heated air circulation because of the greater exposed surface area; this contributes to reduce energy consumption and raises the quality of the product, which becomes more porous and with better rehydration capacity (Abbasi & Azizpour, 2016). However, the use of FMD poses a few disadvantages due to the surface area that is high due to incorporation of air to produce foam, which may require a larger surface area of drying. Moreover, because different countries take different approaches to ensuring food safety and health, the use of additives as foaming agents must to obey legislative aspects of the country or continent before to be used in this technology, i.e., each additive is assigned a unique number, termed as “E numbers”, which is used in Europe for all approved additives, similarly in the USA, the Food and Drug Administration (FDA) list these allowed items as “generally recognized as safe” (GRAS), and in Brazil, the allowed additives are listed by the Brazil National Health Surveillance Agency (ANVISA).

Despite the documented advantages of this technique, to the best of our knowledge, no studies on its employment for the production of jambolan powder have been published.

The objective of this study was to evaluate the quantitative and qualitative changes of jambolan fruit PCs (anthocyanins, flavonols, and hydrolysable tannins) in jambolan juice and in dehydrated products generated by foam mat drying at different temperatures (60, 70, and 80 °C), in comparison with lyophilization products (a control). The analysis was performed by high-performance liquid chromatography with a diode array detection coupled with an electrospray ionization mass spectrometry (HPLC-DAD-ESI-MS^n). The total content of PCs (TPC) and antioxidant activity (AA) of the products were also evaluated.

2. Materials and methods

2.1. Chemicals

All solvents were of chromatographic grade (> 99%); all chemical standards were of analytical grade (> 95%); ultrapure water (Milli-Q system) was used. Chemical standards malvidin (mv) 3-glucoside (3glc), mv 3,5-diglucoside (35diglc), peonidin (pn) 35diglc and quercetin (Q) 3-glucuronide were from Phytolab (Vestenbergsgreuth, Germany). The other chemical standards, cyanidin (cy) 3-glucoside, cy 35diglc, Q, kaempferol (K), isorhamnetin (I), myricetin (M), syringetin (S); the 3-glucosides of Q, K, I, and S; 3-galactosides of Q, K, and I; and ellagic and gallic acids, were from Extrasynthese (Genay, France). The commercially unavailable standard laricitrin (L) 3-glucoside was previously isolated from Petit Verdot grape skins (Castillo-Muñoz et al., 2009).

2.2. Jambolan fruit samples

Mature, healthy jambolan fruit [*S. cumini* (L.), vintage of 2014] was harvested in the city of São José do Rio Preto (São Paulo, Brazil), located at 20° 47′ 08″ S and 49° 21′ 36″ E, and 544 m above sea level (refer to WGS84 datum) (World Geodetic System, 1984). The species was identified by Dr. Regina Sampaio and a voucher specimen (number 32.214) was deposited in the herbarium SJRP in the IBILCE/UNESP, São José do Rio Preto. The pulp, skins and seeds yields of the fruit were determined and the results were expressed as a percentage (w/w). The physicochemical characteristics (moisture, pH, titratable acidity (TA), total soluble solids (TSS) and TSS/TA ratio) of the fruit were determined according to Association of Official Analytical Chemists (AOAC, 2005) in triplicate. The results were expressed in averages ± standard deviations.

2.3. Preparation of dehydrated jambolan products

All experiments were performed in triplicate. Fresh fruits (2 kg), hygienized and sanitized with chlorinated water, were used to prepare the juice by steam extraction in a stainless steel steamer pan (Suga Sucos, Bento Gonçalvez, Rio Grande do Sul, Brazil) at an average temperature of 85 °C, for 2.5 h. Immediately after extraction, the juice was packed in sterilized glass bottles with plastic screw lids. The bottled juice was cooled and stored (± 10 °C) until use, to ensure their quality in terms of microbial stability.

The percentage of juice yield (% w/w) was calculated as the difference between the initial mass of the fruit and the weight of the pellet after extraction of the juice divided by the initial mass of the fruit. The physicochemical characteristics (moisture, pH, TA, TSS and TSS/TA ratio) of the juice were determined according to AOAC (2005) in triplicate. The results were expressed in averages ± standard deviations.

To dehydrate the jambolan juice using the foam mat drying technique, the foams were first obtained as described by Tavares et al.