Fruits, 2015, vol. 70(6), p. 341-349
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DOI: 10.1051/fruits/2015035

FRUITS

Available online at:
www.fruits-journal.org

ORIGINAL ARTICLE

'Melão croá' (*Sicana sphaerica* Vell.) and 'maracujina' (*Sicana odorifera* Naud.): chemical composition, carotenoids, vitamins and minerals in native fruits from the Brazilian Atlantic forest

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Received 1 December 2014 – Accepted 10 July 2015

Abstract – Introduction. In the Brazilian Atlantic Forest, indigenous fruits are part of the eating habits of the population. Among these, 'melão croá' (*Sicana sphaerica* Vell.) and 'maracujina' *(S. odorifera* Naud) are rich in bioactive compounds such as carotenoids and antioxidant vitamins. The physical characteristics, physicochemical and proximate composition, concentration of carotenoids, vitamin C, vitamin E and minerals were investigated in both fruits found in Atlantic Forest of Minas Gerais, Brazil. **Materials and methods.** Titratable acidity was analyzed by volumetric neutralization; soluble solids (SS) by refractometry; pH by potentiometry; moisture and ash by gravimetry after drying in an oven and muffle furnace, respectively; proteins by the micro-Kjeldahl method; lipids by gravimetry using soxhlet; dietary fibers by non-enzymatic gravimetry; carotenoids and vitamin C by HPLC-DAD; vitamin E by HPLC-fluorescence; minerals by ICP-AES. **Results and discussion.** *S. sphaerica* presented the highest concentrations of SS (5.80 °Brix), TA (0.51 g of citric acid 100 g^{-1}), pH (6.95), moisture (83.4 g 100 g^{-1}), carbohydrate (13.38 g 100 g^{-1}), vitamin A (123.33 µg RAE 100 g^{-1}), vitamin C (4.97 mg 100 g^{-1}), vitamin E (334.66 µg 100 g^{-1}), K (28.79 mg 100 g^{-1}), Fe (1.92 mg 100 g^{-1}), and Zn (1.04 mg 100 g^{-1}); while *S. odorifera* had the highest concentrations of total dietary fibers (1.33 g 100 g^{-1}), lipids (1.00 g 100 g^{-1}), proteins (2.62 g 100 g^{-1}), ash (0.77 g 100 g^{-1}), P (1.26 mg 100 g^{-1}), and Ca (1.74 mg 100 g^{-1}). **Conclusion.** The analyzed fruit showed a potential source of nutrients that can contribute to reducing food and nutrition insecurity of rural people, especially in the American continent, occurrence region of these fruits.

Keywords: Brazil / *Sicana sphaerica* / *Sicana odorifera* / indigenous fruit / nutritional value / vitamins / carotenoids

Résumé – 'Melão Croa' (*Sphaerica sicana* Vell.) et 'maracujina' (*Sicana odorifera* Naud.) : composition chimique, en caroténoïdes, vitamines et minéraux de ces fruits natifs de la forêt atlantique brésilienne. Introduction. Les fruits natifs de la forêt atlantique brésilienne font partie des habitudes alimentaires de la population. Parmi ceux-ci, melão croa (*Sicana sphaerica* Vell.) et maracujina (*S. odorifera* Naud.) sont riches en composés bioactifs tels que les caroténoïdes et les vitamines antioxydantes. Les caractéristiques physiques, physico-chimiques et la composition globale en caroténoïdes, en vitamine C et vitamine E, et en éléments minéraux ont été étudiés dans les deux espèces de fruits collectés dans la forêt atlantique du Minas Gerais, au Brésil. **Matériels et méthodes.** L'acidité titrable a été analysée par neutralisation volumétrique ; les solides solubles (SS) par réfractométrie ; le pH par potentiométrie ; l'humidité et le taux de cendres par gravimétrie après séchage au four ; les protéines par la méthode de micro-Kjeldahl ; les lipides par gravimétrie au soxhlet ; les fibres alimentaires par gravimétrie non enzymatique ; les caroténoïdes et la vitamine C par HPLC-DAD ; la vitamine E par HPLC-fluorescence ; les minéraux par ICP-AES. **Résultats et discussion.** *S. sphaerica* a présenté les plus fortes concentrations en SS (5,80 °Brix), TA (0,51 g d'acide citrique 100 g^{-1}), le pH (6,95), l'humidité (83,4 g 100 g^{-1}), de glucides (13,38 g 100 g^{-1}), la vitamine A (123,33 µg RAE 100 g $^{-1}$), la vitamine C (100 mg 4,97 g^{-1}), la vitamine E (100 µg 334,66 g^{-1}), K (28,79 mg 100 g^{-1}), Fe (1,92 100 mg g^{-1}), et Zn (1,04 mg 100 g^{-1}) ; alors que *S. odorifera* avait les plus fortes concentrations de fibres alimentaires totales (1,33 g 100 g^{-1}), lipides (1,00 g 100 g^{-1}), protéines (2,62 g 100 g^{-1}), cendres (0,77 g 100 g^{-1}), P (1,26 mg 100 g^{-1}), et Ca (1,74 mg 100 g^{-1}).

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Conclusion. Les fruits analysés ont montré une source potentielle d'éléments nutritifs pouvant contribuer à réduire l'insécurité alimentaire et nutritionnelle des populations rurales, en particulier dans le sous-continent américain, région d'origine de ces fruits.

Mots clés : Brésil / *Sicana sphaerica* / *Sicana odorifera* / fruits indigènes / valeur nutritionelle / vitamines / caroténoïdes

1 Introduction

Brazil is home to a large number of indigenous fruit species of potential interest to the agricultural industry, which are sources of nutrients and income for the local population [1]. However, the nutritional value of these fruits is still little known among the population and in scientific literature, causing them to be little valued and used [2, 3].

The Brazilian Atlantic Forest presents environmental conditions that contribute to the diversity of food sources, including indigenous fruits [4]. These fruits contribute to feed the local population and may play an important role in food security and food sovereignty for many families, especially those living in rural areas of this biome [4]. Native fruits of the Atlantic Forest may contribute to increase the quality of life of the individuals who consume them, since they are rich in antioxidants which are associated with reduced risk of chronic diseases caused by oxidative stress [5]. The functional properties of these fruits have been widely attributed to their elevated levels of phenolic compounds, carotenoids and ascorbic acid, among others [5, 6].

The genus *Sicana* belongs to the botanical family Cucurbitaceae, comprising a group of Brazilian native plants found in the Northeast and Southeast regions, and spread through Central and South America. Among the species belonging to this genus that stand out are *S. sphaerica* and *S. odorifera*.

There are few studies on the nutritional value of fruit of the genus *Sicana* [7, 8]. Given the above, the present study investigated the physical characteristics, physicochemical and proximate composition, and concentration of carotenoids, vitamin C, vitamin E and minerals in fruit of *S. sphaerica* and *S. odorifera* found in the Brazilian Atlantic forest. The present study intends to describe the concentration of nutrients in both fruits, contributing to fill the gap in information on their nutritional composition.

2 Materials and methods

2.1 Collection and preparation of the samples

Fruits of the genus *Sicana* were collected in April 2013, in the municipality of Viçosa (20°45′14″ S latitude and 42°52′44″ W longitude), Minas Gerais, Brazil. Samples were collected in five different rural locations, which characterized the repetitions. In each repetition, approximately 1.5 kg fruit were obtained from at least three distinct plants.

Samples were transported from the collection site to the laboratory in polystyrene boxes within two hours after collection. The fruit were washed under tap water to remove dirt and then dried with paper towels. The pulp was manually separated from the skin and seeds with the aid of a stainless steel knife (Grindomix®, GM300, Brazil) and spatula. Next, the pulp was homogenized in a domestic food processor (Philips®, RI 7625, Brazil), packaged in polyethylene bags wrapped in aluminum foil and stored in a freezer (−18 ± 1 °C) until performing the analyzes, which occurred within 72 h.

2.2 Physical characterization

Measurements of length and diameter were obtained from 20 fruits of each species using a digital caliper (Mitutoyo®, M5, Brazil). Individual direct weighing of the total fruit mass (FM), edible portion (EM) and non-edible portion (peel mass – PM, seed mass – SM) was performed on a semi-analytical scale (Gehaka®, BG 2000, Brazil). Then the ratio of the edible part of each of the fruits was calculated using the following equation: (EM/FM) × 100.

2.3 Chemical analyses

The chemical analyses were performed, in three repetitions, at the Food Analysis and Vitamin Analysis Laboratories of the Department of Nutrition and Health, Federal University of Viçosa, Brazil. Titratable acidity (TA) was analyzed by volumetric neutralization and soluble solids (SS) by refractometry; pH by direct potentiometry according to analytical standard of the Instituto Adolfo Lutz [9]; moisture by gravimetric analysis after oven drying (SP Labor®, SP 200, Brazil) at 105 °C; ash by gravimetry after drying in a muffle furnace (Quimis, 318, Brazil) at 550 °C; proteins by the micro-Kjeldahl method; lipids by gravimetry after ethyl ether extraction using a soxhlet extractor and; total dietary fiber (TDF) by non-enzymatic gravimetry according to analytical methods of the Association of Official Analytical Chemists [10]. Carbohydrates were calculated as the difference using the equation:

$$[100 - \%\ \text{moisture} - \%\ \text{lipids} - \%\ \text{protein} - \%\ \text{TDF} - \%\ \text{ash}]$$

The total energetic value was estimated considering the conversion factors of 4 kcal g^{-1} protein or carbohydrate and 9 kcal g^{-1} lipid according to the methodology reported by Frary *et al*. [11].

2.4 Extraction and analysis of carotenoids and vitamins

Preparation and analysis of carotenoids and vitamins were performed in five repetitions using recently validated methods (limits of detection and quantification, tests of repeatability and recovery) in our laboratory for the analysis of fruit from the Brazilian Cerrado [12, 13].

During collection, extraction and analysis, fruit were protected from the light to avoid loss of vitamins. For the extraction of carotenoids and vitamins, the following reagents were used for analysis: acetone, petroleum ether and glacial acetic acid (Vetec, Brazil). For analysis of the compounds the following HPLC grade reagents were used: hexane, isopropanol, ethyl acetate, methanol and acetonitrile (Tedia, Brazil).

Analyses of carotenoids and vitamin C were carried out in a High Performance Liquid Chromatography system (HPLC) (Shimadzu, SCL 10AT VP, Japan) composed of a high-pressure pump (LC 10AT VP), autosampler with 500 µL loop (SIL-10AF), and diode array detector (DAD) (SPD-M10A). In the analysis of vitamin E, an HPLC system was used (Shimadzu, SCL 10AD VP, Japan) composed of a high-pressure pump with a valve for a low pressure quaternary gradient (LC 10AD VP), autosampler with 50 µL loop (SIL-10AF), and fluorescence detector (RF-10A XL).

Table I. Concentrations of the standard solutions for the identified compounds in fruit of the genus *Sicana* encountered in the Atlantic forest (Viçosa, Minas Gerais, Brazil).

Compounds	Concentration of the standard solutions
β−carotene	0.025 to 2.037 µg
β−cryptoxanthin	0.0045 to 4.58656 µg
lycopene	0.0003 to 0.0482 µg
ascorbic acid	0.0561 to 5.972 µg
α−tocopherol	1.06 to 106.47 ng
α−tocotrienol	2.01 to 201.37 ng
β−tocopherol	2.68 to 126.47 ng
γ−tocopherol	2.23 to 105.55 ng
γ−tocotrienol	3.34 to 157.55 ng
δ−tocopherol	2.79 to 131.75 ng
δ−tocotrienol	2.70 to 127.55 ng

2.4.1 Carotenoids

Carotenoids (α-carotene, β-carotene, β-cryptoxanthin and lycopene) were extracted in acetone and transferred to petroleum ether according to the methodology proposed by Rodriguez-Amaya *et al*. [14]. The chromatographic conditions developed by Pinheiro-Sant'Ana *et al*. [15] were used: HPLC system, DAD with detection at 450 nm, Phenomenex Gemini RP-18 chromatography column (250 mm × 4.6 mm, 5 µm i.d.), fitted with a Phenomenex ODS guard column (C18) (4 mm × 3 mm); mobile phase composed of methanol: ethyl acetate: acetonitrile (70:20:10, v/v/v) and mobile phase flow of 1.7 mL min^{-1}. The run time was 12 min and the chromatograms were obtained at 450 nm.

The quantity of vitamin A was estimated according to the recommendations of the US Institute of Medicine [16], wherein 1 Retinol Activity Equivalent (RAE) corresponds to 1 µg retinol, 12 µg β-carotene or 24 µg of other pro-vitamin carotenoids.

2.4.2 Vitamin C

Ascorbic acid (AA) and dehydroascorbic acid (DHA) were extracted in a buffer solution (3% metaphosphoric acid, 8% acetic acid, 0.3N sulfuric acid and 1 mM EDTA) [17]. Then DHA was converted to AA using dithiothreitol [15]. For analysis of AA the chromatographic conditions proposed by Campos *et al.* [17] were used, in the same HPLC system used for carotenoid quantification. The column used was RP-18 Lichrospher 100 (250 mm × 4 mm, 4 µm i.d.), equipped with a guard column (Phenomenex ODS, 4 mm × 3 mm), mobile phase composed of ultrapure water containing 1 mM NaH_2PO_4, 1 mM EDTA and pH adjusted to 3.0 with H_3PO_4, and flow rate of 1.0 mL min^{-1}. The run time was 8 min and the chromatograms were obtained at 245 nm. The DHA concentration was calculated by difference before and after reduction.

2.4.3 Vitamin E

The eight homologues of vitamin E (α-, β-, γ- and δ-tocopherols and tocotrienols) were investigated in the fruits, where extraction was performed with a solution of hexane: ethyl acetate (85:15, v/v), containing 0.05% butylated hydroxytoluene and anhydrous sodium sulfate [18]. The analysis was performed using the chromatographic conditions proposed by Pinheiro-Sant'Ana *et al*. [18], consisting of the HPLC system, fluorescence detector (290 nm for excitation and 330 nm for emission), LiChrosorb colum (Si60 Phenomenex 250 mm × 4 mm, 5 µm) fitted with a guard column (Phenomenex Si100, 4 mm × 3 mm), a mobile phase: hexane: isopropanol: glacial acetic acid (98.9: 0.6: 0.5, v/v/v); and flow rate of the mobile phase: 1.0 mL min^{-1}.

2.4.4 Identification and quantification

The vitamin E standards (α-, β-, γ- and δ-tocopherols and tocotrienols) were purchased from Calbiochem®, EMD Biosciences, Inc. (USA). L-Ascorbic acid was purchased from Sigma-Aldrich® (Germany). Standards of α-carotene and β-carotene were isolated from concentrated carrot extract; β-cryptoxanthin and lycopene were isolated from extracts of papaya (*Carica papaya* L.) and tomato (*Solanum lycopersicum* L.), respectively, by open column chromatography according to the methodology proposed by Rodriguez-Amaya [19].

Identification of the compounds was performed by comparing the retention times of the peaks obtained for the standards and for the samples under the same conditions. Furthermore, the ascorbic acid and carotenoids were identified by comparing the absorption spectra of the peaks of interest in the samples and standards using the DAD, and homologues of vitamin E identified by co-chromatography.

The compounds identified in fruit of the genus *Sicana* were quantified using analytical curves and regression equations constructed by means of injection, in duplicate, of six different

Table II. Concentrations of the multi-element standard solutions (MESS) prepared for analysis of minerals in fruit of *Sicana sphaerica* and *S. odorifera* encountered in the Atlantic forest (Viçosa, Minas Gerais, Brazil).

Minerals	MESS1 (ppm)	MESS2 (ppm)	Maximum concentration of the elements in the MESS (ppm)
P	–	98	39
K	–	250	100
Ca	–	200	80
Mg	–	200	80
Cu	25	–	1
Fe	50	–	2
Zn	25	–	1
Mn	50	–	2
Na	–	50	20
Cr	12.5	–	nd
Se	12.5	–	nd
Mo	12.5	–	0.5

nd: not detected.

concentrations of standard solutions (*table I*). A linear correlation was performed between peak areas and concentrations of each compound injected.

2.5 Determination of minerals

The minerals (P, K, Ca, Mg, Zn, Mn, Fe, Cu, Na, Cr, Se and Mo) were extracted according to Gomes and Oliveira [20], using a solution of nitric acid and perchloric acid (4:1, v/v). The sample suspension was heated to 80 °C followed by gradual increase up to 200 °C, until the extract reached crystalline coloration, and was then withdrawn to cool at room temperature. The crystalline extract was cooled and the volume completed to 25 mL with deionized water [20]. The obtained solution was used to read the concentration of minerals by inductively coupled plasma atomic emission spectrometry (ICP-AES) (Perkin Elmer, Optima 8300).

Two multi-element standard solutions (MESS) were prepared in 100 mL flasks, due to the different concentrations of minerals in the fruit (*table II*). MESS 1 was prepared for Cr, Se, Mo, Zn, Cu, Fe and Mn. MESS 2 was prepared for Na, P, Mg, Ca and K. After completing the mixture of standards in each MESS, the volume was completed to 50 mL with deionized water.

For quantification, standard curves were constructed using mineral standards purchased from Vetec® (Brazil) and Merck® (Brazil). For the construction of standard curves, increasing volumes were used of MESS 1 (0 to 2 mL) and MESS 2 (0 to 20 mL), supplemented to 50 mL with deionized water to construct the six points of the curve. Maximum concentration of the elements in the multi-element standard solutions is shown in (*table II*).

The samples were analyzed for concentrations of Ca, Fe, Mg, Mn, Cu, Zn, Se, Mo, Cr, P, K and Na by ICP-AES, using the respective wavelengths (in nm): 317.93, 259.94, 285.21, 259.37, 224.70, 213.86, 196.03, 202.03, 267.72, 213.62, 404.72 and 589.59. After reading, the concentrations found in ppm (mg L^{-1}) for the samples were converted into concentrations of minerals, considering the dilutions and the possible difference from the control.

2.6 Calculation of the potential of the fruit as a nutrient source

The potential nutritional contribution was based on the Recommended Dietary Allowance (RDA) for adult men between 19 and 30 years old, according to recommendations of the US Institute of Medicine [16]. The fruit portions were calculated according to the Food Guide for the Brazilian Population [21] considering the caloric density, where one fruit is equal to 70 kcal.

Fruit is classified as a "source" of nutrients when supplying 5 to 10% of the Dietary Reference Intake (DRI), as a "good source" when supplying 10 to 20% of the DRI and "excellent source" when supplying over 20% of the DRI [22].

2.7 Experimental design and statistical analysis of the data

A completely randomized design was used with five repetitions for analysis of carotenoids and vitamins, and three repetitions for physicochemical analysis and proximate composition. Descriptive statistics (mean, standard deviation and range of parameters) were used for presentation of the results. To evaluate the linearity range of the analytical standards, data obtained for the peak areas was used to calculate the coefficient of correlation (R^2). Statistical analysis was performed using the SAS software (Statistical Analysis System), version 9.2 (2008), licensed to the UFV.

3 Results and discussion

The present study assessed the nutritional value of *S. sphaerica* and *S. odorifera* collected in the wild environment. In order to simulate the conditions of ingestion, the fruits were collected from native plants so there was no control of environmental factors (soil, light, ventilation, water availability), which, according to Vallilo *et al.* [23], may interfere with nutrient concentrations.

3.1 Physical characterization

Fruit of the genus *Sicana* are classified as berries, have an oblong shape, consisting of a peel (exocarp) with color ranging from yellow to purple (*figure 1*). *S. sphaerica* has a hard, thick and compact peel, while *S. odorifera* has a fine and soft peel.

The edible part of the fruit, the mesocarp, is succulent and has a yellow color. The endocarp, the non-edible portion of the fruit, has a soft texture of dark yellow color in which small dark

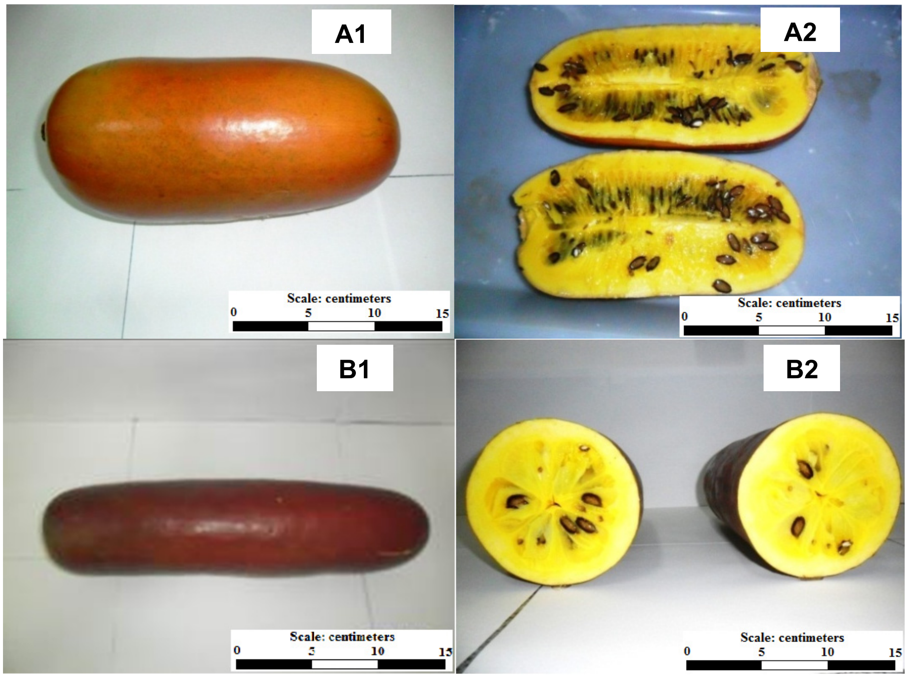

Figure 1. Anatomy and cross and longitudinal sections of fruits of *Sicana sphaerica* Vell. (A1 and A2) and *S. odorifera* Naud. (B1 and B2), found in the Atlantic Forest (Viçosa, Minas Gerais, Brazil).

Table III. Physical characteristics of fruit of *Sicana sphaerica* and *S. odorifera* encountered in the Atlantic forest (Viçosa, Minas Gerais, Brazil). Values are expressed in fresh mass (mean of 20 fruits ± standard deviation).

Variables	*S. sphaerica*	*S. odorifera*
Diameter (cm)	11.20 ± 0.45	9.72 ± 0.88
Height (cm)	23.70 ± 1.11	36.91 ± 1.96
Mass (g)		
Fruit	1,550 ± 71	2,510 ± 160
Seed	278 ± 14	768 ± 69
Peel	245 ± 10	319 ± 55
Pulp	1,026 ± 62	1,422 ± 164
Pulp yield (%)	66.00 ± 1.50	55.00 ± 3.76

colored seeds are located (*figure 1*). *S. odorifera* presented a total mass of 2,510 g, while *S. sphaerica* presented a total mass of 1,550 g. Furthermore, the mass observed for *S. odorifera* was 1.39 times greater than that observed in fruits of the same species grown in Peru (1.5 to 1.8 kg) [24].

Despite their lower mass, fruit of *S. sphaerica* presented a higher pulp yield (66.2%) due to a lower proportion of seeds (*table III*). This yield is high, especially when considering the native environment growing conditions, without the use of inputs that could improve their physical qualities. These results indicate the potential for cultivation of *S. sphaerica* with the ability to further improve its agronomic performances. This has been applied to few native fruits from the Amazon rainforest, targeting an increase in quantity and quality of production and opening new income opportunities for the native populations. Although these fruits are increasingly accepted in local, regional and international markets, due to their high nutrient concentration [25, 26], it is however observed that these ones still require wider disclosure. In the case of camu camu (*Myrciaria dubia*) and other native fruits from the Amazon and other Brazilian biomes, there is still much to investigate in genetics for crop enhancement, in plant physiology for setting up sustainable cropping techniques. Collecting data on these species and information on the associated traditional knowledge would contribute to address rural development policies for promoting family farming based on cultivation, marketing and consumption of these fruits.

3.2 Chemical characterization

The fruit presented high soluble solid concentrations (SS) and low titratable acidity (TA) (*table IV*). These features contribute to lower pH, requiring the addition of acid for correction and indicate the need for immediate consumption due to their high perishability. Additional factors are fragility of the peel and high moisture content, which make these fruit highly susceptible to rapid deterioration and requires immediate consumption or technological processing after maturation [27]. From an industrial point of view, foods with low TA increase the need for addition of acidifiers and results in lower microbiological safety and maintenance of sensory and nutritional quality [28].

The SS/TA ratio is one of the best ways to evaluate the flavor of a fruit. The fruit analyzed in this study showed a high SS/TA ratio and therefore they are indicated for the production of juices, nectars and frozen pulps.

The calorific values of the fruit (*table IV*) were higher than in orange (46 kcal 100 g^{-1}), watermelon (*Citrullus lanatus*

Table IV. Chemical and caloric density characteristics of fruits of *Sicana sphaerica* and *S. odorifera* encountered in the Atlantic forest (Viçosa, Minas Gerais, Brazil). Values expressed in fresh mass. Values are means of 3 repetitions ± standard deviation.

Variables	*S. sphaerica*	*S. odorifera*
Soluble solids (°Brix)	5.80 ± 0.01	4.15 ± 0.01
Titratable acidity (g of citric acid 100 g^{-1})	0.51 ± 0.17	0.33 ± 0.12
SS/TA ratio	11.4 ± 0.06	12.6 ± 0.08
pH	6.95 ± 0.03	6.61 ± 0.07
Moisture (g 100 g^{-1})	83.37 ± 0.83	82.46 ± 1.18
Total dietary fiber (g 100 g^{-1})	1.30 ± 0.10	1.33 ± 0.19
Lipids (g 100 g^{-1})	0.72 ± 0.31	1.00 ± 0.06
Proteins (g 100 g^{-1})	0.63 ± 0.26	2.62 ± 1.01
Ash (g 100 g^{-1})	0.60 ± 0.03	0.77 ± 0.08
Carbohydrates (g 100 g^{-1})	13.38 ± 0.23	11.81 ± 1.29
Caloric value (kcal 100 g^{-1})	62.50 ± 2.85	66.77 ± 2.34

(Thumb.)) (33 kcal 100 g^{-1}), papaya (40 cal 100 g^{-1}), tangerine (*Citrus reticulata* var. 'Ponkan') (38 kcal 100 g^{-1}) and pineapple (*Ananas comosus* L.) (48 kcal 100 g^{-1}), which are among the most consumed fruit in Brazil [29, 30].

Carbohydrate concentrations found in fruit of the genus *Sicana* (*table IV*) were similar to those found in pineapple (12.3 g 100 g^{-1}), abui (*Pouteria caimito* Ruiz & Pav.) (14.9 g 100 g^{-1}), hog plum (*Spondias lutea* L.) (11.4 g 100 g^{-1}), or cashew (*Anacardium occidentale* L.) (10.3 g 100 g^{-1}) [30]. These results show that the fruits evaluated in the present study represent a good option for daily intake of these nutrients, however, a study performed in the Amazon region [31] revealed that mostly of the native fruits have higher concentrations of soluble solids and lower acidity, which reduces their lifespan and accelerates its perishability, especially after harvest, than native fruits. Therefore, indigenous fruits require dedicated studies that help understand their physiology and nutraceutical changes. Development prospects would specially recommend efficient post-harvest practices, in order to target eager markets for these products, including functional foods, dietary supplements, cosmetics, pharmaceuticals and processing industry [31].

3.3 Carotenoids and vitamins in the Sicana fruit

3.3.1 Qualitative composition

The analytical methods used allowed for obtaining good chromatogram resolution, ensuring the identification and quantification of carotenoids and vitamins in the fruit (*figure 2*). Alpha-carotene and β-tocotrienol were not found in the fruits (*table V*). *S. sphaerica* showed a richer profile of carotenoids and vitamins than *S. odorifera*, which presented β-carotene, β-cryptoxanthin, AA, α-tocopherol, α-tocotrienol, β-tocopherol, δ-tocopherol and δ-tocotrienol. In *S. sphaerica* the following peaks were identified: β-carotene, β-cryptoxanthin, lycopene, AA, DHA, α-, γ- and δ-tocopherols and tocotrienols, and β-tocotrienol.

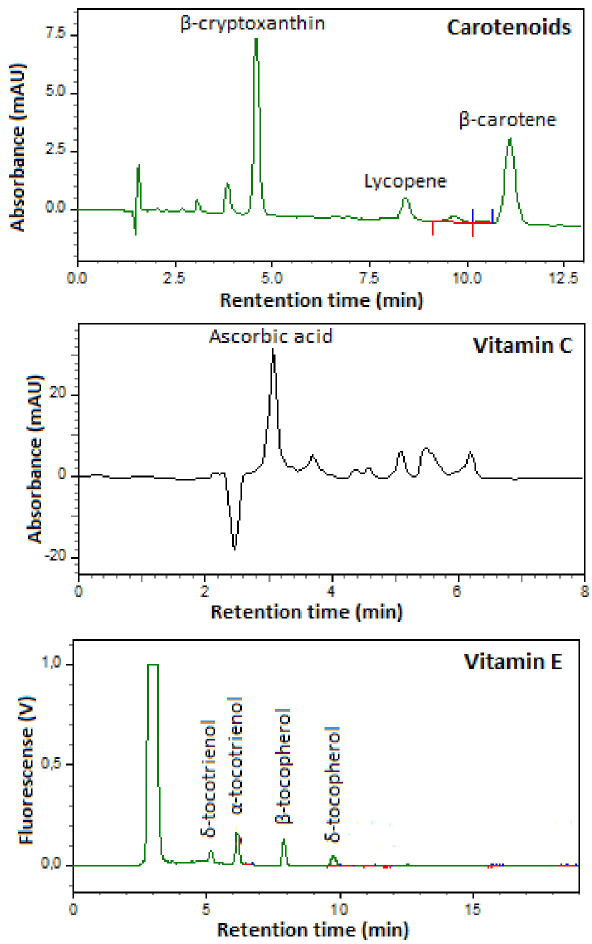

Figure 2. Analysis by HPLC of carotenoids, vitamin C and vitamin E in fruits of *Sicana sphaerica* Vell. and *S. odorifera* Naud. from the Brazilian Atlantic forest.

3.3.2 Quantitative composition

Sicana odorifera presented only β-carotene and β-cryptoxanthin with low concentration of provitamin A. In a study conducted in Panama [32], with a methodology similar

Table V. Concentration of carotenoids and vitamins in the fruits of *Sicana sphaerica* and *S. odorifera* found in the Atlantic forest (Viçosa, Minas Gerais, Brazil). Values are expressed in fresh mass (mean of 5 repetitions ± standard deviation).

Compounds	*S. sphaerica*	%	*S. odorifera*	%
Vitamin A (RAE µg 100 g^{-1})	123.33 ± 25.58	100	75.00 ± 27.91	100
Carotenoids (mg 100 g^{-1})	2.17 ± 0.37	100	1.29 ± 0.35	100
α-carotene	nd	–	nd	–
β-carotene	0.79 ± 0.26	36.40	0.51 ± 0.17	39.53
β-cryptoxanthin	1.03 ± 0.14	47.46	0.78 ± 0.23	60.47
Lycopene	0.35 ± 0.05	16.14	nd	–
Total vitamin C (mg 100 g^{-1})	4.97 ± 0.43	100	1.87 ± 0.08	100
ascorbic acid	3.21 ± 0.29	64.58	1.87 ± 0.08	100
dehydroascorbic acid	1.76 ± 0.17	35.42	nd	–
Total vitamin E (µg 100 g^{-1})	334.66 ± 39.55	100	12.35 ± 0.64	100
α-tocopherol	276.06 ± 36.98	82.49	4.11 ± 0.21	33.28
α-tocotrienol	28.58 ± 6.94	8.54	2.66 ± 0.19	21.54
β-tocopherol	14.64 ± 6.77	4.37	1.52 ± 0.11	12.30
β-tocotrienol	nd	–	nd	–
γ-tocopherol	3.63 ± 0.07	1.08	nd	–
γ-tocotrienol	2.30 ± 0.54	0.69	nd	–
δ-tocopherol	4.92 ± 0.11	1.47	2.09 ± 0.16	16.93
δ-tocotrienol	4.53 ± 0.63	1.36	1.97 ± 0.09	15.95

nd: not detected.

to that used in this study (although with one less sample), the concentration of total carotenoids in *S. odorifera* was reported equal to 28.9 mg 100 g^{-1}. The difference may be related to the fact that both studies deal with wild fruits, obtained from local uncontrolled environmental factors, known to influence its nutritional concentration. Possible explanations for differences between the chemical concentrations of the compared fruits may be related to the fact that some creole cucurbit varieties have higher genetic variability [33]. In this context, Antunes *et al.* [34] reported that distinct genetic materials, and also the environment weather conditions in which they were grown, significantly interfere in the chemical composition of some Cucurbitaceae. Another possible explanation may be the postharvest treatment of these fruits, since this procedure in regard to processing time and storage, among other parameters, is known to interfere with the chemical composition of vegetables [35,36]. Therefore, in order to elucidate the concentration variability, we would recommend to grow the species in a controlled environment.

Sicana sphaerica presented β-carotene, β-cryptoxanthin, lycopene, and retinol equivalent activity (123 µg 100 g^{-1}) higher than watermelon (31 µg 100 g^{-1}) or melon (1 µg 100 g^{-1}) [30], fruits of the same botanical family although of different genera (*table V*). The same species had the highest concentration of total vitamin C (4.97 mg 100 g^{-1}) (*table V*). However, this concentration was lower than those observed in watermelon (6.10 mg 100 g^{-1}) and melon (8.70 mg 100 g^{-1}) [30], which are two of the most consumed cucurbits in Brazil.

The highest concentration of vitamin E was observed in *S. sphaerica* (*table V*). Information on the vitamin E concentration in this fruit is not available in the literature, which does not allow for comparison of the data. The vitamin E concentration was 5 times higher than that found by Chun *et al.* in watermelon (50 µg 100 g^{-1}) [37], which belongs to the same botanical family of cucurbits as *S. sphaerica*.

3.4 Concentration of minerals

To date, there are no studies in literature on the concentration of minerals in the fruit analyzed in the present study. The highest concentrations of Ca, Mg and Mo occurred in *S. sphaerica*, while those of K, Cu, Fe and Zn occurred in *S. odorifera*. Concentrations of P and Na in the fruit were similar. Cr and Se were not found in any of the samples, while Mn was found only in *S. sphaerica* (*table VI*).

3.5 Potential contribution of the Sicanas to meet nutritional recommendations

The potential contribution of the fruit analyzed to supply the nutrient recommendations for adult men (aged 19 to 30) is shown in *table VII*. To provide 70 kcal, 112 g pulp from *S. sphaerica* and 105 g pulp from *S. odorifera* are necessary. Thus, the studied fruits were considered good source and source of carbohydrate, respectively.

Considering the vitamin A recommendation of the US Institute of Medicine for adult men [16], the fruits analyzed were considered good source of vitamin A, while *S. odorifera* was considered source this vitamin. *Sicana sphaerica* was considered source of vitamin C, but not source of vitamin E.

Table VI. Concentration of minerals in the fruits of *Sicana sphaerica* and *S. odorifera* encountered in the Atlantic forest (Viçosa, Minas Gerais, Brazil). Values expressed in fresh mass (mean of 3 repetitions ± standard deviation).

Minerals (mg 100 g^{-1})	*S. sphaerica*	*S. odorifera*
P	1.26 ± 0.12	1.25 ± 0.07
K	23.79 ± 1.27	28.79 ± 0.70
Ca	1.74 ± 0.23	1.50 ± 0.06
Mg	0.99 ± 0.14	0.66 ± 0.05
Cu	0.57 ± 0.04	0.69 ± 0.07
Fe	1.56 ± 0.14	1.92 ± 0.44
Zn	0.99 ± 0.05	1.04 ± 0.15
Mn	0.09 ± 0.06	nd
Na	0.12 ± 0.02	0.12 ± 0.01
Cr	nd	nd
Se	nd	nd
Mo	0.12 ± 0.05	0.05 ± 0.06

nd: not detected.

Both analyzed fruit species were considered excellent sources of Cu, Fe and Mo, while *S. sphaerica* and *S. odorifera* presented themselves as potential good source and source of Zn, respectively.

The interest in the consumption of indigenous fruits from the Brazilian forest, rich in natural biodiversity, has increased in the recent years, making these fruits an important business opportunity for native populations [38]. However, there is still a huge gap to be filled, especially about information on the chemical and nutritional value of these species, what is rather crucial for the inclusion of these fruits in new markets.

Table VII. Potential contribution of fruits of *Sicana sphaerica* and *S. odorifera* encountered in the Atlantic forest (Viçosa, Minas Gerais, Brazil), to provide the daily nutrient recommendations calculated from the Recommended Dietary Allowance of minerals for adult men between 19 and 30 years old [16], based on one portion of fruit which provides 70 kcal [21].

Nutrients	% Contribution	
	S. sphaerica (1 portion = 112 g)	*S. odorifera* (1 portion = 105 g)
Carbohydrates	11.52	9.52
Proteins	1.26	4.90
Fibers	3.83	3.67
Vitamin A	15.35	12.49
Vitamin C	6.21	2.18
Vitamin E (α-tocopherol)	2.06	0.02
P	0.20	0.19
K	0.69	0.53
Ca	0.17	0.18
Mg	0.18	0.26
Cu	85.9	66.5
Fe	26.9	20.5
Zn	10.6	9.45
Mn	nd	4.10
Na	0.006	0.005
Cr	nd	nd
Se	nd	nd
Mo	124.00	280.00

nd: not detected.

4 Conclusion

The fruit of genus *Sicana* showed elevated pulp yields. *Sicana sphaerica* was considered an excellent source of Cu, Fe and Mo, and good source of carbohydrates, vitamin A and zinc. *Sicana odorifera* was considered an excellent source of Cu, Fe and Mo and source of carbohydrates and Zn.

Good adaptation of the fruit to their native environment, and the availability of these fruits, their acceptance as a food resource and the nutritional value shown in the present study demonstrate the high potential of these fruits, which can be better utilized for meeting the daily nutrient recommendations. Thus, the fruit of the genus *Sicana* may contribute to reduce food and nutrition insecurity of the rural people, especially in the region of occurrence of these fruits.

Acknowledgements. The authors thank the FUNARBE, FAPEMIG, CNPq and CAPES for providing scholarships and financial support for performing this research.

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Cite this article as: Galdino Xavier de Paula Filho, Tibério Fontenelle Barreira, Soraia Silva Pinheiro, Leandro de Morais Cardoso, Hércia Stampini Duarte Martino, Helena Maria Pinheiro-Sant'Ana. 'Melão croá' (*Sicana sphaerica* Vell.) and 'maracujina' (*Sicana odorifera* Naud.): chemical composition, carotenoids, vitamins and minerals in native fruits from the Brazilian Atlantic forest. *Fruits* 70 (2015) 341–349.