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Physical, chemical and technological characteristics of *Solanum lycocarpum* A. St. - HILL (Solanaceae) fruit flour and starch

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ABSTRACT

Fruit of wolf (*Solanum lycocarpum* A. St. - HILL), found in Brazilian cerrado, has been used in the initial ripening stage as flour and/or starch in popular medicine due to its hypoglycemiant action. The aim of this work was to study the occurrence of phytochemical compounds, physical, chemical and technological characteristics of fruit of wolf flour and starch in the initial ripening stage. Flour and starch were extracted using known popularly and experimental methods (with sodium bisulfite) and chemical composition and technological characteristics were analyzed. The results were comparatively assessed by Tukey's test ($p<0.05$). The recommendation for use was the extraction of flour and starch products by previously removing peels and seeds of fruit of wolf. The most relevant finding in this study is the high content of fibers in flour (23 g/100 g) and high content of resistant starch (32 g/100 g) in the fraction of starch extracted from fruit of wolf, which can explain their use as hypoglycemic agent.

1. Introduction

The vegetable species *Solanum lycocarpum* A. St. Hill., belongs to the *Solanaceae* family, and it is popularly known in Brazil as fruit of wolf (*fruta do lobo, lobeira, capoeira-branca, berinjela-do-mato, jurubebão, baba-de-boi, loba* and *jurubeba-de-boi*), where it grows and develops under unfavorable environmental conditions, such as acid and nutrient-deficient soils, usual in Brazilian *cerrado*, being capable of supporting a dry weather and sustained periods of drought, also resisting to annual cycles of slash-and-burn (Campos 1994; Lorenzi & Matos 2002). Also, the fruit of wolf is spontaneously found in the Brazilian northeast and southeast highway margins (Caribé & Campos 1992).

The tree has specific characteristics, growing as big shrubs or little trees of 3–5 m high, with round and open crown, big thorns on the branches, simple, alternate, and coriaceous leaves, which are white-tomentose on the inner surface, with lobed margins, measuring 16–28 cm length. The fruits are smooth, green, and globular berries, with 8–13 cm of diameter, containing fleshy pulp with several seeds. When they are mature their peel becomes yellow and the pulp has also a yellow coloration, being soft, sweetish and extremely aromatic (Oliveira Filho & Oliveira 1988; Oliveira Junior, Santos, Abreu, Corrêa, & Santos 2003, 2004). Each plant may have 40–100 fruits, whose mass per fruit may vary from 400 to 900 g (Silva, Silva, Junqueira, & Andrade 1994). Blossom period comprises the whole year, however with higher intensity during the raining season and harvest from July to January (Oliveira Filho & Oliveira 1988; Silva et al. 1994).

The fruit comprises up to 50% of the diet from the Maned Wolf (*Chryssocyon brachyurus*) from *cerrado*, where it is believed to promote a therapeutic action against the giant kidney worm, frequently and usually fatal in this animal (Caribé & Campos 1992).

Due to the characteristics of the plant and fruit, they have gained place in household medicine from the countryside of Brazil, being used due to its diuretic, calmative, antispasmodic, antiophidic,

Abbreviations: C*, Chrome; h_{ab}, Hue; ICP OES, Inductively Coupled Plasma-Optical Emission Spectrometer; L*, Luminosity; LF2, Laboratory extraction flour extracted with peel and seeds and with addition of sodium bisulfite solution; LF3, Laboratory extraction flour extracted without peel and seeds and with addition of sodium bisulfite solution; LS2, Laboratory extraction starch extracted with peel and seeds and with addition of sodium bisulfite solution; LS3, Laboratory extraction starch extracted without peel and seeds and with addition of sodium bisulfite solution; PF1, Popular extraction flour of fruit of wolf; PS1, Popular extraction starch; SEM, Scanning electron microscopy; *UNIARARAS*, Centro Universitário Hermínio Ometto; WAI, Water Absorption Index; WSI, Water Solubility Index.

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antiepileptic and hypoglycemic action (Caribé & Campos 1992, Grasselli, Maia, Monteiro, & Costa 2001; Oliveira, Cavalcanti, Bezerra, & Pinto 1989). In food preparation, the mature fruit is mainly used for the preparation of domestic jelly and sweets (Caribé & Campos 1992).

Corrêa, Abreu, Santos, and Ribeiro (2000) developed a study on some chemical compounds of fruit of wolf during maturation, whereas in the final ripening stage the main characteristics of pulp concerned degradation of the high level of starch present in the green fruit. These observations about the amount of starch present in the fruit of wolf are in accordance with the studies made by Konishi, Kitazato, Asano, and Nakatani (1991).

Motta, Peters, Reis, and Guerra (2002) performed a study about the possibility of considering the fruit of wolf flour as a hypoglycemic agent, administering it to rats as a suspension for a 7-day period, and these authors concluded that when compared to the use of insulin and glibenclamide the results were not satisfactory. However, the methodology used, time and dose may have influenced the reported results.

This work aimed to extract flour and starch from wolf fruit in the initial ripening stage and assess the presence of toxic natural active ingredients, physical, chemical, and technological characteristics, including resistant starch and flour and starch contents.

2. Material and methods

2.1. Material

The fruits in the initial ripening stage used in this study were donated for the Forest Institute of the State of São Paulo *(Instituto Florestal do Estado de São Paulo)*, Campininha Farm *(Fazenda Campininha)*, located in Martinho Prado Jr. District, Mogi-Guaçu, São Paulo, Brazil.

2.2. Methods

2.2.1. Botanical characterization

This study focused the plant characteristics and preparation of the exsiccate, the analysis were perfomed in triplicate, and filed in the botanical collection of the Vegetal Biology Laboratory from UNIARARAS, Araras, SP, Brazil.

2.2.2. Extraction of flour and starch

Clean fruits without spots, rust and any other kind of lesion were washed, selected and kept under refrigeration (<24 h) until flour and starch extractions. *Known popularly* and laboratory extractions were performed.

2.2.2.1. Traditional popularly extraction. This process was based in the information provided by small agriculturists: fruits with peels and seeds were washed with water, cut in small pieces and put into a water container. Thereafter, they were grinded in a liquefier with water until homogeneous suspension was formed. Such suspension was sieved, separating portions of flour (PF1) (retained by the sieve) and starch (PS1), which was decanted in the container (12 h). Popular drying is usually conducted under the sun, but in order to prevent contaminations, it was made at 50 °C, 15 h, in convective hot-air dried (FANEM, São Paulo, Brazil).

2.2.2.2. Laboratory extraction. As the product of popular use showed great enzymatic browning during preparation, a second test was made using sodium bisulfite (200 mg/L) in the water solution so as to avoid this reaction. Two processes were made:

First: Flour and starch extracted with peel and seeds and with addition of sodium bisulfite solution.

Clean fruits were washed with chlorinated water then with distilled and deionized water, being cut in small pieces and put into a sodium bisulfite solution (200 mg/L). Subsequently, they were washed for removal of bisulfite excess and grinded in a liquefier with water until a homogeneous suspension was formed. The suspension was sieved, separating the portions of flour (retained in the sieve) (LF2) and starch was decanted and then centrifuged (LS2). The portions were dried at 50 °C for approximately 15 h in convective hot-air dried (FANEM, São Paulo, Brazil).

Second: Flour and starch extracted without peel and seeds and with addition of sodium bisulfite solution

Fruits were washed with chlorinated water then distilled and deionized water, being peeled and with the seeds removed, in order to undergo a process similar to the first one, until (LF3) and starch (LS3) were obtained.

2.2.3. Characterization of products

2.2.3.1. Yield. For calculation of yield of products, the relation between weight of the initial raw material (1 kg) and the weight of the final product was established, and the results were expressed in g/100 g.

2.2.3.2. Color. The color parameters were measured using a spectrophotometer following the CIELab system (Color Quest II Hunterlab, Reston, VA, EUA), with illuminant D and 10° angle, were expressed using coordinates L^* to represent luminosity (0 = black; 100 = white), a^* (+a = redness; −a = greenness), and b^* (+b = yellowness; −b = blueness) and obtained parameters Hue (h_{ab}) and Chrome (C^*). The parameter H is measured as an angle over a circle divided in 100 parts; while the C^* parameter is a measure of opacity (Giese 2000; Minolta 1994). With following equations:

$$C^* = \sqrt{(a^*)^2 + (b^*)^2}$$
$$hab = \tan^{-1}\{b^* / a^*\}$$

2.2.3.3. Specifications of minerals. Calcium, copper, iron, phosphorus, magnesium, manganese, potassium, sodium, and zinc were analyzed simultaneously in samples according to the method of Horwitz and Latimer (2006), in triplicate. All measurements of the mineral elements were carried out using a simultaneous radial view inductively coupled plasma-atomic emission spectrometer (ICP OES), model ICP 2000 (Baird, Bedford, MA, USA).

The optimal conditions for the multielement determination were established for the element manganese, according to manufacturer's recommendations. Instrumental parameters used are described in Table 1.

All solutions were prepared with distilled and deionized water (resistivity of 18.2 MW.cm). The analytical curve for the quantification

Table 1
Optimized operational conditions for inductively coupled plasma-optical emission spectrometer (ICP OES) determinations of mineral elements present in flour and starch samples.

Conditions	Values
RF incident power (W)	900
Plasma gas flow rate ($Lmin^{-1}$)	15
Auxiliary gas flow rate ($Lmin^{-1}$)	1.5
Nebulizer pressure (kPa)	200
Nebulizer	Concentric pneumatic
Spray chamber	Sturman-Master
Replicate read time (s)	3
Solution flow rate ($mL\ min^{-1}$)	1.5
Spectral lines (nm)	Ca (II) 317.93 Cu (I) 324.75 Fe (II) 259.94 P (I) 178.28 Mg (II) 279.08 Mn (II) 257.67 K (I) 766.49 Na (I) (589.59) Zn (I) 213.86

(I) Atomic emission line; (II) ionic emission line.

of mineral elements was prepared by diluting a standard solution (Tec-Lab for Phosphorus and Merck multielements containing Copper, Iron, Manganese, Zinc, Potassium, Magnesium, Sodium, and Calcium) of metals at 1000 mg/L in 5 g/100 g nitric acid solution (v/v) at the following concentrations range: Ca and Na 0.041 to 41 mg/L; P 0.06 to 60 mg/L; Mg 0.0145 to 14.5 mg/L; K 0.061 to 61 mg/L; Cr, Cu, Fe, Mn and Zn 0.001 to1 mg/L.

2.2.3.4. Phytochemical analysis. Cardioactive glycosides were determined in extracts and through reactions of characterization: Keller–Kiliani Reaction, Liebermann–Burchard Reaction, Kedde Reaction, Baljet Reaction (Costa 1994; Robbers, Speedie, & Tyler 1996). Alkaloids were determined in extracts and reactions of characterization, using Mayer's and Dragendorff's Reagents (Costa 1994; Robbers et al. 1996). Cyanogenic glycosides were determined using the technique of the picrate-impregnated paper according to Harborne (1972).

2.3. Characterization of flours and starches selected for use as food ingredients

After assessment of the results obtained in Section 2.2.3.4, extraction products considered appropriate for further use as food ingredients and characterization in this study were selected.

2.3.1. Physico-chemical characteristics

Moisture, AACC 44-15 (1995); protein, AACC 46-13 (1995); ash, AACC 08-01 (1995), fiber, AACC 32-30 (1995) and lipids, Bligh and Dyer (1959) were determined. Total carbohydrate was estimated by the difference between the whole mass and the sum of protein, fat, ash and moisture. The pH and acidity were determined according to the methodology of IAL (2005).

2.3.2. Technological characteristics of flour and starch

Water absorption index (WAI) and water solubility index (WSI) were determined following the procedures reported by Anderson, Conway, Pfeifer, and Griffin (1969). Density was determined according to the method of Voigt (1982).

2.4. Characterization of the fruit of wolf starch

The fruit containing wolf starch was analyzed and compared with the native corn starch, used as control, in relation to:

2.4.1. Amylose content

The amylose content was determined according to the methodology of Sowbhagya and Bhattacharya (1979).

2.4.2. Resistant starch

The resistant starch content was determined according to Goni, Garcia-Diaz, Mañas, and Saura-Calixto (1996).

2.4.3. Viscoamylographic profile

Characteristics of gelatinization and paste formation were determined according to the method no. 162 proposed by Cauvain and Young (2009) using the Rapid Visco-Amylograph (RVA, Rapid Visco Analyser, Newport Scientific, Australia). The parameters used for interpretation of results were:

Maximum viscosity: maximum viscosity developed during the heating cycle, expressed in centipoise (cP);

Pasting temperature or initial temperature of gelatinization: temperature in centigrade degrees that corresponds to the point where the curve starts to form in the graph;

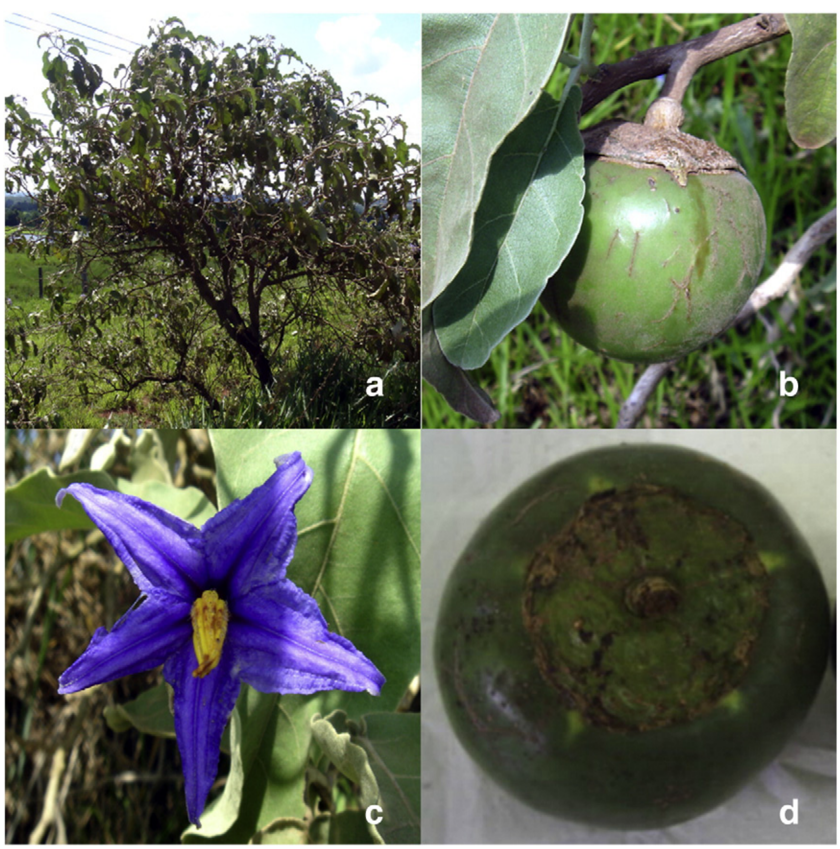

Fig. 1. Photograph of the *Solanum lycocarpum* A. St. HILL. A — Overview of a plant on its natural habitat in *Instituto Florestal do Estado de São Paulo*, *Fazenda Campininha*, located in Martinho Prado Jr. District, Mogi-Guaçu/SP. Where a) tree, b) green fruit on branch, c) flower, and d) fruit.

Table 2
Yield of extractions performed in laboratory (%) and color parameters, luminosity (L*) [1], Chrome (C*)[1] and Hue (h_{ab})[1].

Samples	Yield (g/100 g%)	L*	C*	h_{ab}
PF1	11.25 ± 1.25	66.61 ± 0.47^{e}	19.58 ± 0.50^{a}	$75{,}63° \pm 0.02^{a}$
PS1	5.01 ± 1.10	77.96 ± 0.19^{c}	10.04 ± 0.02^{c}	$76{,}78° \pm 0.02^{a}$
LF2	10.26 ± 2.00	88.28 ± 0.22^{b}	10.77 ± 1.48^{c}	$-82{,}51° \pm 0.03^{c}$
LS2	5.86 ± 0.5	72.06 ± 1.02^{d}	15.25 ± 0.02^{b}	$79{,}07° \pm 0.04^{a}$
LF3	7.42 ± 0.80	89.01 ± 0.09^{ba}	9.69 ± 0.01^{c}	$-77{,}92° \pm 0.02^{b}$
LS3	4.8 ± 0.65	93.59 ± 0.50^{a}	6.83 ± 0.06^{d}	$-74{,}48° \pm 0.03^{b}$

[1] Average value ± standard deviation (n = 3). Means followed by different small letters in a vertical line differ from each other according to Tukey's test ($p \leq 0.05$)

Time for maximum peak: heating time in which the maximum viscosity of paste occurred, expressed in minutes;
Breakdown (cP) maximum value of viscosity reached during or right after the heating phase minus the minimal viscosity at 95 °C;
Minimum viscosity at 95 °C (cP): it is the lowest value of viscosity after the constant temperature of 95 °C is reached;
Final viscosity at 50 °C (cP): viscosity value, obtained at the final point of the cooling-off cycle, at the temperature of 50 °C; and
Setback (cP), it is final viscosity at 50 °C minus the minimal viscosity at 95 °C.

2.4.4. Scanning electron microscopy (SEM)

Starch samples were coated with a gold layer in a high vacuum using Sputtering equipment (System Model LCV — 76 SEM) for 3 min. Samples were examined using the scanning electron microscope ESEM-EDAX, using a secondary electron detector with 15 kV of acceleration.

2.5. Statistical analysis

All reported values represent the average value for the analysis of at least three replicates. Statistical analysis of the results was performed using the program Statistica® (STATISTICA Software 2010) the analysis of variance (Anova) and the Tukey test were used to determine differences between treatments ($p < 0.05$).

3. Results and discussion

3.1. Botanical characterization

Fig. 1 shows the tree, flower and fruit of *wolf*. Exsiccates are stored in the botanical collection of Vegetal Biology Laboratory from *UNIARARAS*, Araras, São Paulo, Brazil.

3.2. Process yield

The green fruit peels and seeds comprise approximately 4 g/100 g of the fruit, which has moisture content around of 85 g/100 g. Flour and starch (Table 2) were approximately 10 and 5 g/100 g, respectively. These values indicate that the extraction of flour and starch from fruit of wolf can be performed in laboratories and agro industries with good results.

3.3. Color

Table 2 presents the results for the color parameters of flours and starches from fruit of wolf. Fig. 2 shows the fast enzymatic browning of the cut fruits, whereas, in 5 min of air exposure the fruit becomes dark and inappropriate for processing. The extractions of flour and starches occur with great consumption of water, because the fruits must be always conditioned in water. Fig. 3 shows that known popular extraction of flour resulted in a darkened product.

The enzymatic browning is one of the most important reactions in fruits, since it affects the coloration and final taste of fruit (Lee & Whitaker 1995). Aiming to enhance the color of the fruit of wolf final products, the enzymatic inhibitor sodium bisulfite was used, made in accordance with the FDA recommendations (FDA, 2009), obtaining products with better quality of coloration. The coloration of products obtained by popular extraction, FP1 and SP1, denotes L*, C*, and h_{ue} parameters that significantly indicate darker products and with yellow and yellow-green coloration, respectively, compared to other products. FL3 and SL3 considerably showed color parameters that indicate clearer products and with tonality closest to white. This fact suggests they may be appropriate for use in food ingredients, since when added to new products they will have a minor effect on product coloration and/or may be added with food colors.

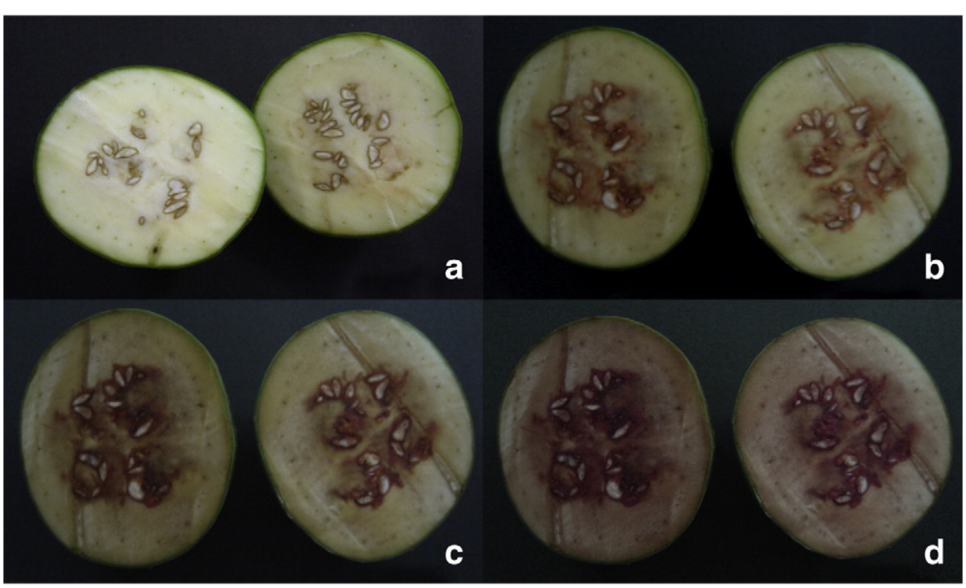

Fig. 2. Photograph of the enzymatic browning in *Solanum lycocarpum* A. St - HILL (fruit of wolf) green fruit, for a 0 to 5-minute period after transversal cut, where: a) after 0 min; b) after 1 min; c) after 2 min, and d) after 5 min.

Fig. 3. Photograph of the starch with peel and seeds extracted and popularly consumed for cholesterol and diabetes treatment.

In addition to the enzymatic inhibitor use, another fact that influenced the color of products obtained was the extraction with peels and seeds; therefore, it may be suggested that the extraction of flour or starch from fruit of wolf requires removal of peels and seeds and addition of an enzymatic browning inhibitor (Fig. 4).

3.4. Minerals

Table 3 shows the contents of minerals from *in natura* fruit (85 g/ 100 g of moisture content) and extracted flours and starches (10 g/ 100 g of moisture content). The flours extracted with peel and seed had the highest values of mineral salts, while the lowest contents were for FL3 and SL3, where starches showed the lowest values compared to the flours.

As the composition of minerals depends on plantation conditions, the results presented in this study revealed a composition of minerals, mostly, phosphorus, potassium and magnesium, higher than the contents found by Oliveira Junior et al. (2004), and lower contents of

Fig. 4. Photograph of the flours and starches extracted in laboratory, where: a) PF1, b) PS1, c) LF2, d) LS2, e) LF3, and e) LS3.

Table 3
Mean contents of minerals expressed in mg/100 g of flour and starch samples extracted from *Solanum lycocarpum* A. St. HILL fruits in the initial ripening stage[1].

Sample	Calcium	Copper	Potassium	Manganese	Phosphorus	Iron	Magnesium	Sodium	Zinc
Pulp fruit	14.7 ± 0.2	0.125 ± 0.004	248 ± 5	0.095 ± 0.002	21.5 ± 0.5	0.30 ± 0.01	8.1 ± 0.1	0.66 ± 0.04	0.179 ± 0.004
PF1	35.5 ± 0.6	0.47 ± 0.03	564 ± 3	1.21 ± 0.04	96.3 ± 0.6	1.21 ± 0.05	99 ± 6	5.6 ± 0.4	0.97 ± 0.02
PS1	18.5 ± 0.46	0.24 ± 0.02	109 ± 2	0.34 ± 0.01	19.1 ± 0.4	1.19 ± 0.06	12.5 ± 0.3	5.5 ± 0.2	0.34 ± 0.01
LF2	28.2 ± 0.4	0.480 ± 0.004	609 ± 7	0.97 ± 0.02	97 ± 5	1.09 ± 0.05	78 ± 1	181 ± 1	0.81 ± 0.01
LS2	6.2 ± 0.1	0.19 ± 0.02	93 ± 2	0.161 ± 0.002	10.8 ± 0.2	0.73 ± 0.05	6.2 ± 0.1	41.6 ± 0.4	0.19 ± 0.03
LF3	109 ± 4	0.41 ± 0.02	653 ± 12	0.84 ± 0.02	15.8 ± 0.2	1.31 ± 0.09	58 ± 1	137 ± 3	0.72 ± 0.04
LS3	13.7 ± 0.2	0.30 ± 0.01	193 ± 2	0.13 ± 0.01	13.1 ± 0.4	2.03 ± 0.07	8.06 ± 0.17	92.3 ± 0.4	0.215 ± 0.003

[1] Average value ± standard deviation (n = 3).

Table 4
Results of phytochemical screening through cardioactive and cyanogenic glycosides, alkaloids analyses[1].

Sample	Cardioactive glycosides				Alkaloids		Cyanogenic glycosides
	Keller–Kiliani Reaction	Liebermann–Burchard Reaction	Kedde Reaction	Baljet Reaction	Mayer Reagents	Dragendorff's Reagents	
PF1	−	−	−	−	+	−	−
PS1	−	−	−	−	+	−	−
LF2	−	−	−	−	+	−	−
LS2	−	−	−	−	+	−	−
LF3	−	−	−	−	−	−	−
LS3	−	−	−	−	−	−	−

(−) negative, (+) positive.

iron, copper and manganese. The fruits analyzed by Oliveira Junior et al. (2004) were from the state of Minas Gerais, Brazil.

The process of flour and starch extraction was conducted with a great amount of water, which may lead to a loss of soluble minerals. It is worth noting that the increased content of potassium in flours from fruit of wolf may become a good source of potassium. The increased sodium content in FL2 and FL3 and respective starches may be a result of the sodium bisulfite addition, which even with the washing process for removal of sodium may be retained in the product.

The results found in this work are similar to these reported by Silva et al. (1994) with relation to iron, calcium and zinc contents in *cerrado* fruits.

3.5. Phytochemical analysis

Table 4 shows phytochemical compounds in the products of extraction.

3.5.1. Cardioactive and cyanogenic glycosides

In both samples of flour and starch, the analysis of cardioactive heterosides presence resulted negative.

3.5.2. Alkaloids

Flours and starches extracted with peel and seeds resulted positive for the Mayer's Reagent, while in samples without peel and seeds the results were negative for the same reagent. For the Dragendorff's reagent, all results were negative.

These results confirm those from Motidome, Leeking, and Gotlieb (1970) and Silva et al. (1994), reporting presence of alkaloids in the fruit of wolf pulp.

Our results suggested that flours and starches of fruits must be performed with removal of peels and seeds, so as to ensure the safe use of these products as food ingredients, once FL3 and SL3 were the only ones with a negative test for the Mayer's reagent.

3.6. Physico-chemical characterization

Table 5 presents the chemical composition of flour (FL3) and starch (LS3) selected for physico-chemical and technological characterization. FL3 has the highest content of ash, proteins, lipids and fiber; and SL3 has the highest content of resistant starch. Such results may help to explain the popular use of fruit of wolf as a hypoglycemic agent, because the fiber and resistant starch, besides not being digested by the human digestive system, may delay starch digestion, providing a slow release of glucose (González-Soto, Mora-Escobedo, Hernández-Sánchez, Sánchez-Rivera, & Bello-Pérez 2007; Perera, Meda, & Tyler 2010). Thus, these products may also be evaluated for the decrease in the absorption of cholesterol and triglycerides.

Table 6 shows the results of the analyses of pH, acidity, WAI, WSI and density for FL3 and SL3.

There are no parameters of extracted flours from fruit of wolf, but Brazilian Law states the starch arising from cereal, roots and tubercles must have: 14 g/100 g of moisture (w/w), 80 g/100 g of starch (w/w), 0.5 g/100 g of ashes (w/w) and maximum acidity of 1.00 (v/w) expressed in mL of NaOH 1 N/100 g (Brasil 1978). Hence, fruit of wolf

Table 5
Physico-chemical composition of laboratory flour (FL3) and starch (LS3) of fruit of wolf [1].

Composition	LF3 (g/100 g)	LS3 (g/100 g)
Moisture	11.57 ± 0.03[b]	12.15 ± 0.07[a]
Protein	7.31 ± 0.37[a]	6.27 ± 0.16[b]
Lipids	1.04 ± 0.018[a]	0.18 ± 0.014[b]
Ash	3.81 ± 0.44[a]	0.38 ± 0.03[b]
Total carbohydrates	76.32 ± 0.83[a]	81.16 ± 0.21[a]
Resistant starch	17.11 ± 0.07[b]	32.32 ± 6.37[a]
Fiber	23.39 ± 0.24[a]	0.93 ± 0.11[b]

[1] Average value ± standard deviation (n = 3). Means followed by different small letters in a horizontal line differ from each other according to Tukey's test ($p \leq 0.05$).

Table 6
Physico-chemical and technological characteristics of flour and starch samples extracted from *Solanum lycocarpum* A. St. HILL fruits in the initial ripening stage[1].

Characteristics	LF3	LS3
Acidity (mL/100 g)	2.91 ± 0.06 [N.S.]	2.78 ± 0.16 [N.S.]
pH	4.57 ± 0.11[b]	5.15 ± 0.14[a]
WAI (%)	13.19 ± 0.39[a]	2.67 ± 0.08[b]
WSI (%)	29.58 ± 0.19[a]	3.53 ± 0.11[b]
Density (g/mL^{-1})	0.256 ± 0.00[b]	0.624 ± 0.01[a]

[1] Average value ± standard deviation (n = 3). Means followed by different small letters in a horizontal line differ from each other according to Tukey's test ($p \leq 0.05$), where N.S. = not significant.

Table 7
Viscoamylographic profile of the fruit of wolf and native corn starches (14% moisture content basis)[1].

Viscoamylographic characteristics	Fruit of wolf starch	Native cornstarch
Maximum viscosity (cP)	3479 ± 32.53	3590 ± 40.55
Pasting temperature (°C)	70.3 ± 1.13	74.2 ± 1.00
Time for maximum peak (min)	5.53 ± 0.19	5.28 ± 0.25
Breakdown (cP)	761 ± 72	1039 ± 105
Minimum viscosity at 95 °C (cP)	2717.5 ± 105	2551 ± 125
Final viscosity at 50°C (cP)	3440.5 ± 161	3761 ± 140
Setback (cP)	723 ± 56	1210 ± 45

[1] Average value ± standard deviation (n = 2).

flour SL3 is within the specifications for moisture, however acidity and ash are above the threshold for starches. Acidity may be due to the presence of fruit natural acids.

The pH values found in this study are in accordance with those found by Oliveira Junior et al. (2004), which also characterized the fruit of wolf.

Regarding WAI and WSI (Table 5), FL3 notably showed the highest values, suggesting presence of water-soluble compounds and high capacity of absorption of water compounds. This may help to explain the popular use of this flour as a hypoglycemic agent and for weight loss diets, because after being consumed it likely forms a tridimensional network with water, as occurs in compounds such as chitosan and gums (Angioloni & Collar 2008; Gallaher et al. 2002) that prolong the satiety sensation and delay nutrient absorption (Brennan, Blake, Ellis, & Schofield 1996; Ellis, Apling, Leeds, & Bolster 1981).

For SL3, WAI and WSI are close to the values found for another starches, such as corn starch that showed 1.81 and 1.46, respectively.

Density analysis (Table 6) shows that SL3 considerably has the highest value. Density of starches and flours is directly related to the use of products and standardization of measures for domestic or industrial preparations, e.g., in this case a tablespoon of FL3 will provide an amount lower than the SL3 one. In addition, 1 kg of FL3 will need a bigger package and will require more physical space than 1 kg of SL3, suggesting these two products have different transportation and storage conditions in relation to the space used.

The term resistant starch was created in 1983 by Hans Englyst, who described three types of RS: a) RS1: extracted from partially ground grains and seeds; b) RS2: banana and potato starch granules; c) RS3: resulting from the cooking process. Currently there is also RS4, which is chemically treated (Englyst & Hudson 1996; Englyst, Kingman, & Cummings 1992; Sajilata, Singhal, & Kulkarni 2006).

Fruits as banana (Vilas Boas 1995), mango (Lima 1997) and fruit of wolf have high contents of starch when they are green and which degrades during maturation in lower molecular weight sugars. Green banana flour has already been used as a resistant starch source in food preparations and has been considered as a functional ingredient (González-Soto et al. 2007). Thus, a study on the characteristics of fruit of wolf starch in unripe stage will be able to provide information for the technical feasibility of this starch as a food ingredient.

3.7. Characterization of the starch from fruit of wolf compared with native corn starch

In this study, native corn starch had 10.70 g/100 g ± 0.20 g/100 g moisture, 0.25 g/100 g ± 0.01 ash, 0.31 g/100 g ± 0.00 protein, 0.48 g/100 g ± 0.00 lipid and 86.8 g/100 g ± 0.05 carbohydrate, $L^* = 96.77$, $C^* = 4.85$, Hue = −83.84, WAI = 1.815 ± 0.008, WSI = 1.46 ± 0.03, resistant starch = 14.71 g/100 g ± 0.5, amylose = 31.6 g/100 g ± 0.9

Starch from fruit of wolf showed 25 g/100 g of amylose and 32 g/100 g of resistant starch.

Starch is formed by amylose and amylopectin, which have glucose as their structural unit. Amylose is a linear chain polymer, comprising of 500 and 2000 units of glucose bound by $\alpha - 1.4$ bounding and has low solubility in cold water (Lineback & Inglett 1982).

Amylose content in starch granules ranges according to the vegetal source of origin, and is generally found in 20–30 g/100 g ranges in normal starches of cereals. Corn starch has 25 to 28 g/100 g of amylose, while manioc starch has only 17 g/100 g (Lineback & Inglett 1982). Banana starch has 19 g/100 g of amylose (Teixeira, Ciacco, Tavares, & Bonezzi 1998).

Fruit of wolf and corn starch show similar contents of amylose, but have distinct paste properties.

In Table 7, the characteristics of the paste of starch from fruit of wolf and corn starch show distinct behavior.

The technological functionality of starches is related to their characteristics of gelatinization and paste formation and can be influenced for extraction procedure, where different results can be obtained with a given sample in a different method of extraction (Gidley et al. 2010). Starch gelatinization occurs when the granules are heated in water at the proper temperature for each starch source, which ranges from 60 to 70 °C. Under these conditions, granules irreversibly swell to a size many times its original size (Miles, Morris, Orford, & Ring 1985).

Starches with high viscosity of paste can be used in lower quantity as thickeners, providing an economic use of ingredients and reducing the energy value of foods.

After gelatinization, polymers present in starch tend to bind through hydrogen bondings, forming more organized areas. This reassociation of swollen granules, amylopectin and amylose, creates a tridimensional net comprised of more organized areas, often crystal, sometimes amorphous. This phenomenon is known as retrogradation, and it is based on, but is not limited to, texture, solubility, susceptibility and enzymes (Biliaderis 1992).

The characteristics of paste viscosity showed LS3 is distinct compared to corn starch.

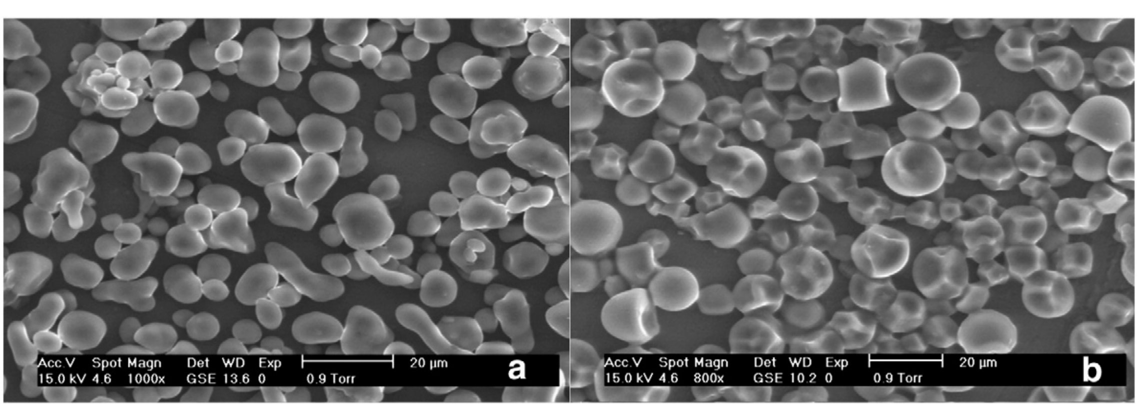

Fig. 5. SEM: a) native corn starch and b) starch of fruit of wolf.

Fig. 5 shows the SEM of native corn starch and fruit of wolf starch. The granules of native corn starch showed round and polygonal shape with a size varying from 4.68 to 15.90 μm (Fig. 5). The shape of starch granules varied with the botanical source of the starch. Starch from fruit of wolf presented oval, spherical and irregular shapes predominant among all granule shapes and with so different sizes as the corn starch.

4. Conclusion

Physico-chemical characterization of flours and starches of *S. lycocarpum* A. St. HILL revealed results suggesting they may be used as food ingredient, since, when extracted without peels and seeds and with sodium bisulfite addition, they showed results of adequate coloration for use in food preparations and absence of toxic natural compounds. Nutritionally, flour showed higher content of minerals, proteins, lipids and fibers; on the other hand, the starch showed a 32 g/100 g content of resistant starch, suggesting there is a great possibility of using it as a food ingredient. The technological characteristics indicated flours with high capacity of water absorption and starches with high viscosity during pastes formation and retrogradation. Considering this, it can be concluded the adjustment of the extraction methodology in addition to the nutritional quality of flour and starch of *S. lycocarpum* A. St. HILL fruit makes this species of fruit a feasible alternative of food ingredient or supplement for the treatment of dyslipidemia, diabetes and weight control, because of their fiber and resistant starch contents, respectively.

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