academicJournals

Vol. 10(46), pp. 995-1006, 15 December, 2016
DOI: 10.5897/AJPP2016.4686
Article Number: D3E4D5862109
ISSN 1996-0816

http://www.academicjournals.org/AJPP

African Journal of Pharmacy and Pharmacology

Full Length Research Paper

Euterpe oleracea Mart. (açai): an old known plant with a new perspective

Heitor Ribeiro da Silva[1,2], Daniele da Cruz de Assis[2], Ariadna Lafourcade Prada[1,2], Hady Keita[2], Jesus Rafael Rodríguez Amado[2] and José Carlos Tavares Carvalho[2]*

[1]Programa de Pós-graduação em Inovação Farmacêutica, Departamento de Ciências Biológicas e da Saúde, Universidade Federal do Amapá, Brazil.
[2]Laboratório de Pesquisa em Fármacos, Curso de Farmácia, Departamento de Ciências Biológicas e da Saúde, Universidade Federal do Amapá, Brazil.

Received 17 October 2016; Accepted 9 December, 2016

The açai (*Euterpe oleracea* Mart) fruit pulp is extensively used in Brazil as food among other uses. The health benefits of açai are largely reported by the Amazon inhabitants. Nonetheless, just a few pharmacological and toxicological studies were made to probe the innocuousness and the safety of the use of this product. The aims of this work were to update knowledge about the chemical composition, pharmacological and toxicological studies of the fruits and to identify possible vacuum of knowledge in the use, evaluation, and characterization of *E. oleracea* Mart (Açai) as a promising Amazon superfruit. It was made a draw out internet revision, especially in databases as NCBI, SCOPUS, PUBMED, SCIELO, and ELSEVIER by using the keywords *E. oleracea*, açai, nutraceuticals and food supplementations. Also, it was looked for each one of the ethnobotanical uses reported for this plant species combined with the first keywords. A complete record of the chemical composition of this species was achieved. Just two studies in humans were found in the literature using the açai fruit pulp. There is no sufficient systematic evidence to assure that all of the ethnobotanical uses of this species are true. A great emptiness of scientific knowledge related to the real benefits of this plant species exist. There exist neither pharmaceutical forms nor standardized product derived from the açai fruit. Until now, the number of scientific studies that allow the validaton of the ethnopharmacological practices, the innocuousness and the safety of the use of this plant fruit is insufficient.

Key words: *Euterpe oleracea*, açai, nutraceutical, food supplementation.

INTRODUCTION

Euterpe oleracea Mart (EOM), commonly known as acai, has long been used by the inhabitants of the Amazon. This is a plant with many beneficial health effects, which has been used in other countries of Europe, North America and Middle-Eastern (Menezes et al., 2011). The increase of the interest in the international community for the açai was clearly related by Heinrich et al. (2010). They demonstrated by using an overall search for açai

*Corresponding author. E-mail: farmacos@unifap.br

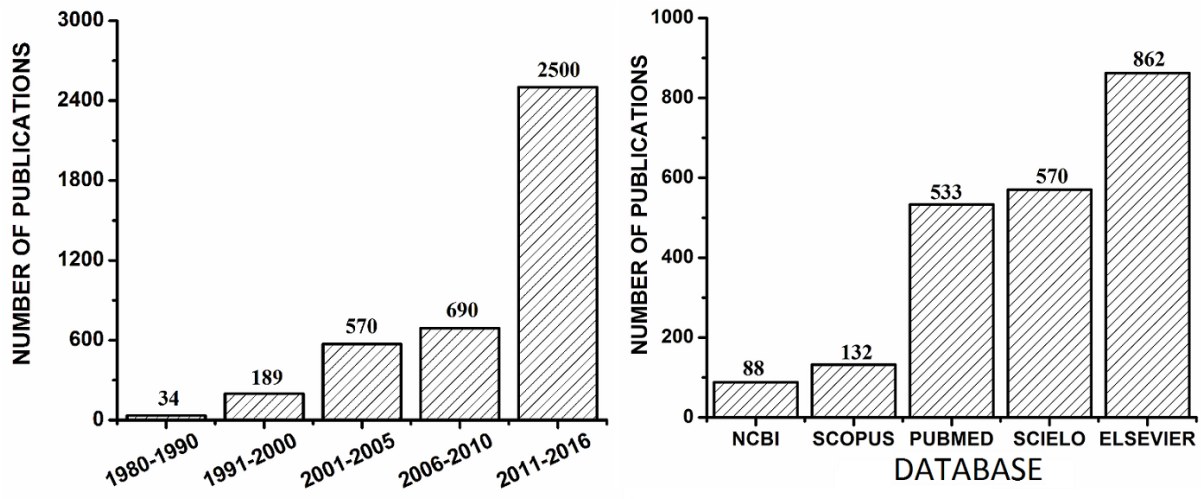

Figure 1. Publications including the term *Euterpe oleracea* Mart. (açai). (A) In international scientific database; (B) Represent reports for this species in Google (Period: 1980-2016).

from 2004 to 2010, that it was an increase in the searches about this plant all over the world and especially in USA, UK, Australia, New Zealand and Canada.The harvest period of this fruit is between August and December and approximately 1000 jobs are created every year for the local populations in the Northern Brazil. The northern states of Brazil produce 95% of all the country's açai (Heinrich et al., 2010). Just in 2015, 198.9 thousand ton of the acai were produced in Brasil; of it, 54% were produced in Para, 33.6% in Amazonas, 7% in Maranhão, 2% in Acre, and 1.1% in Amapá, Rondônia, and Roraima (0.9%).

The intake of açai fruit pulp with chicken meat, fish, and vegetals as tapioca or maize flour is a traditional practice of the Brazilian population. The açai fruit pulp is also used for the preparation of pies, jellies, creams, ice creams and liqueurs as run and wines (Rogez, 2000).

The interest for the use of this plant is continually increasing over the years (Schauss, 2016). To this regard, it was observed that there are a lot of publications (On the Internet) about the use of this species as nutraceutical and as a cosmetic ingredient. The majority of these publications lack the scientific perspectives with no serious data to support their characteristics.

Several ethnobotanical uses have been linked to the chemical composition of the açai fruits pulp (Portinho et al., 2012). Different parts of this plant have been used by Amazonian populations (Bourdy et al., 2000). Over the years, studies have been made to identify chemical characteristics of the fruits of EOM. The main secondary metabolites present in the fruits of açai are phenolics, principally flavonoids and anthocyanins (Costa et al., 2013). The dissimilar chemical composition of the açai fruit pulp allows their use in nutraceuticals, cosmetic and food industries (Schauss, 2015; Schauss, 2016). However, there are few scientific studies supporting the pharmacological and toxicological properties of the açai fruit pulp.

This paper aims to update knowledge about the chemical composition, pharmacological and toxicological studies related to the açai fruits and to identify possible vacuum of knowledge in the use, evaluation and characterization of *E. oleracea* Mart (Açai) as a promising Amazon superfruit.

MATERIAL

A draw out revision was made in databases as NCBI, SCOPUS, PUBMED, SCIELO, and ELSEVIER by using the keywords *E. oleracea*, açai, nutraceuticals and food supplements. Also, it each one of the ethnobotanical uses reported for this plant species (anti-inflammatory, anticancer, antioxidant, cardiovascular, dyslipidemic, neuroprotective, renal diseases, cosmetic, food, toxicity test, and pharmacological test) was looked for combined with the first keywords. The review was made from 1980 until 2016.

RESULTS AND DISCUSSION

The increase on the interest in this Amazonian fruit is noticeable. Figure 1 shows the increase of the research to prove the biological, nutraceutical and pharmaceutical activity of this species from 1980 to 2016. From 1980 up to 2016, 3983 publicatons were made about *E. oleracea* Mart. Nonetheless, just 2181 (54.75%) of these publications were found in the scientific database. In the last five years, it was an augment of 173% on the publications about this plant. Nonetheless, just 33% of these publications were publicized in scientific database. These are evidence of the increasing interest on this plant but just a few amounts of these are scientifically founded.

Figure 2. A plantation of *Euterpe oleracea* Mart (açai) palm tree in the Recanto Santa Clara, located at -0.96039 N; -51.268450 O, Mazagão, Amapá, Brazil.
Source: Authors.

Botanical aspects

The açai palm belongs to the Arecaceae family. This family has about 200 genera and about 2600 species distributed in tropical and subtropical areas (Jones, 1995). Of the native species from Brazil, the most important are *E. oleracea, Euterpe edulis,* and *Euterpe precatoria*. The first is popularly known as *Palmiteira*, *açai de Pará* and açai real. This species was the main source of raw material in the Palmito industry (Palm's heart pickled) (Choi et al., 1998). The botanical classification of this species, according to Cronquist is Kingdom Plantae; Division: Magnoliophyta; Class: Liliopsida; Order: Arecales, Family: Arecaceae; Genus: Euterpe; Species: *E. oleracea*. The binomial name of this species is *E. oleracea* Martius 1824 (Schauss, 2015, 2016). Figure 2 show the açai palm tree and the collected fruit ready to be commercialized.

Chemical composition

Species *E. oleracea* Mart has been extensively investigated for their chemical composition. Table 1 present all chemical compounds reported, until now, for the fruit of *E. oleracea* Mart.

The açai fruit pulp is rich in polyphenols like flavonoids and anthocyanins and content a diversity of fatty acids (Silva and Rogez, 2013). Anthocyanins are glycosidic derived from anthocyanidins. At low pH, they are predominantly present in the form of flavylium cation, giving a reddish color in aqueous solutions. At higher pH, the flavylium cation is converted into other species, some of them being uncolored (Cheminat and Brouillard, 1986).

Açai fruit pulp contains between 88.0 and 211.0 mg/L of total anthocyanins (Lichtenthaler et al., 2005) as cyanidin-3-glucoside, cyanidin-3-rutinosídeo, cyanidin-3-arabinoside (Bobbio et al., 2000) and cyanidin 3-acetyl

Table 1. Chemical compounds reported for the fruit of *Euterpe oleracea* Mart.

Groups	Compound	Reference
Anthocyanins	cyanidin-3-O-glucoside, cyanidin-3-O-rutinosídeo, cyanidin-3-arabinoside, cyanidin-3-arabinoside, cyanidin 3-acetyl hexose, peonidin 3-rutinoside, peonidin 3-glucoside, cyanidin 3-sambubioside	Del Pozo-Insfran et al. (2004), Gouvea et al. (2012), Muñiz-Miret et al. (1996), Schauss et al. (2006a)
Flavonoids	Quercetin, quercetin arabinopyranoside, orientin, isoorientina, isovitexin, rutin, epicatechin, catechin, taxifolin desoxihexose, apigenin, crisoeirol, 5,4'-dihydroxy-7, 3 ', 5'-trimethoxy flavone, luteoline diglicoside, astilbin, quercetin rhamnoside, protoanthocyanidin, procyanidin dimeric, quercetin rutinoside, scoparin, kaempferol rhamnoside, kaempferol rutinoside	Bobbio et al. (2000), Lichtenthaler et al. (2005), Del Pozo-Insfran et al. (2004), Del Pozo-Insfran et al. (2006), Dias et al. (2012), Gallori et al. (2004), Pacheco-Palencia et al. (2009), Schauss et al. (2006[a]), Vera de Rosso et al. (2008)
Phenolic	Ferulic acid, benzoic acid, p-hydroxybenzoic acid, gallic acid, pirocatéquic acid, ellagic acid, vanillic acid, p-coumarinic acid, glycoside ellagic acid, chlorogenic acid, escoparine, dihydrokaempferol, velutine, pinoresinol, syringaresinol, 3-hydroxy-1-(4-hydroxy-3,5-dimetoxyphenil)-1-propanona, dihydroconiferyl alcohol, lariciresinol	Gordon et al. (2012), Kang et al. (2010, 2011), Lichtenthaler et al. (2005), Pacheco-Palencia et al. (2009), Ribeiro et al. (2010), Rojano et al. (2011), Schauss et al. (2006b)
Fatty acids	Saturated: butyric, caproic, caprylic, capric, undecanoic, lauric, tridecanoic, myristic, pentadecanoic, margaric, stearic, nonadecanoic, eicosanoic, behenic, tricosanoic, lignoceric; Monounsaturated: tridecenoic, myristoleic, pentadecenoic, palmitoleic, margaroleic, oleic, elaidic, gadoleic, erucic, nervonic; Polyunsaturated: linoleic, linolenic, gamma linolenic, eicosadienoic, eicosatrienoic, homogamma linolenic, arachidonic, eicosapentaenoic, docosadienoic, docosahexaenoic	Nascimento et al. (2008), Schauss et al. (2006a)
Sterols	Campesterol, stigmasterol, b-sitosterol	Schauss et al. (2006a)
Aminoacids	Aspartic acid, threonine, serine, glutamic acid, glycine, alanine, valine, methionine, isoleucine, leucine, tyrosine, phenylalanine, lysine, histidine, arginine, proline, hydroxyproline, cysteine, tryptophan	Schauss et al. (2006a)
Sugars	Fructose, lactose, sucrose, glucose, maltose	(Schauss et al., 2006a)
Lignans	(+)-isolariciresinol, (+)-5-methoxy-isolariciresinol, (+)-lariciresinol (8), (+)-pinoresinol), (+)-syringaresinol	Chin et al. (2008), Da Costa et al. (2010), Ribeiro et al. (2010)
Carotenoids	α-carotene, β-caroten, lutein, tocopherols A, B, C, D, chlorophyll	Da Costa et al. (2010), Darnet et al. (2011), Schaus et al. (2006a)
Vitamins	Vitamin E, vitamin A, vitamin B1, vitamin B2, vitamin B3, vitamin B5, vitamin C, vitamin K	Rogez (2000)
Trace elements	Lead, cadmium,mercury, arsenic, potassium, magnesium, phosphorus, calcium, sodium, zinc, iron, copper	Pesce (2009); Schauss et al. (2006a)

Table 2. Pharmacological and toxicological studies using Euterpe oleracea Mart. and some extracts derived from.

Activity	Refference	*In vivo/ In vitro*	Biomodel/Assay
Antioxidant	Chin et al. (2008)	*in vitro*	DPPH
	Choi et al. (1998)	*in vitro*	DPPH and assay of superoxide anion
	De Bem et al. (2014)	*in vivo*	Rat model: first antioxidant defense system
	De Souza et al. (2010)	*in vivo*	Rat model: protein oxidation and first defense antioxidant system
	Gordon et al. (2012)	*in vitro*	TEAC AND TOSC
	Hogan et al. (2010)	*in vitro*	TEAC AND TOSC
	Kang et al. (2011)	*in vitro*	ORAC
	Lichtenthaler et al. (2005)	*in vitro*	TOSC
	Pacheco-Palencia et al. (2008)	*in vitro*	TEAC
	Rojano et al. (2011)	*in vitro*	ABTS, DPPH, FRAP AND ORAC
	Rufino et al. (2010)	*in vitro*	ABTS, DPPH, FRAP
	Santos et al. (2008)	*in vitro*	ABTS
	Schauss et al. (2006b)	*in vitro*	SOD, ORAC, NORAC, HORAC AND TAO
	Spada et al. (2009)	*in vitro*	SOD-TBARS
	Matheus et al. (2006)	*in vitro*	SNAP with cell culture. Nitric oxide-trapping capacity
	Rocha et al. (2007)	*in vivo*	Rat model: Determination of NO formation
Antineoplasic	Del Pozo-Insfran et al. (2006)	*in vitro*	Cellular proliferation and apoptosis
	Hogan et al. (2010)	*In vitro*	Rat, induction of apoptosis of C-6 brain glioma cells
	Silva et al. (2014)	*In vitro*	Human cell line, antitumorigenic potential in the MCF-7 cell line
Anti-inflammatory	Favacho et al. (2010)	*in vivo*	Rat model: edema
	Kang et al. (2011)	*in vivo*	Rat, SEAP
	Schauss et al. (2006b)	*in vivo*	Rat, cyclooxygenase (COX)-1 and COX-2 inhibition
	Matheus et al. (2006)	*In vitro*	Rat, production of NO in macrophage cell line
Genotoxicity	Ribeiro et al. (2010)	*in vivo*	Rat model: micronucleus test and comet assay
Cytoprotective	Chin et al. (2008)	*in vitro*	Cultured MCF-7 cells stressed by H_2O_2
Dislipidemic	De Souza et al. (2010)	*in vivo*	Rat model: Hypocholesterolemic
	De Souza et al. (2012)	*in vivo*	Rat model: Mediation of the Hypocholesterolemic activity
	Udani et al. (2011)	*in vivo*	Humans overwight, evaluation of lipid profile and metabolic parameter
	Xie et al. (2011)	*in vivo*	Rat model: Atherosclerosis

DPPH: 2,2-diphenyl-1-picrylhydrazyl; TEAC: trolox equivalent antioxidant capacity; TOSC: total oxidant scavenging capacity; ORAC: oxygen radical absorbance capacity; ABTS: 2,2′-azino-bis-3-ethylbenzthiazoline-6-sulphonic acid; FRAP: ferric reducing antioxidant power; SOD: superoxide dismutase; HORAC: hydroxyl radical antioxidan capacity; NORAC: peroxynitrite radical averting capacity; TAO: total antioxidant; TBARS: thiobarbituric acid reactive substances.

hexose (Dias et al., 2012). Cyanidin-3-glucoside and cyanidin-3-rutinoside are the anthocyanins with a higher presence in açai fruit pulp (Pacheco-Palencia et al., 2009; Vera de Rosso et al., 2008). To anthocyanins content, the antioxidant properties of the açai fruit pulp has been attributed (Del Pozo-Insfran et al., 2004; Muñiz-Miret et al., 1996).

The main phenolic and flavonoids reported for the acai fruit pulp were quercetin, orientin and its derivatives (Pacheco-Palencia et al., 2009; Schauss et al., 2006b). The phenolic profile of the açai fruit pulp was reported (Del Pozo-Insfran et al., 2004). Ferulic acid, p-hydroxybenzoic acid, gallic acid, pyrocatecolic acid, ellagic acid, vanillic acid, p-coumaric acid and glycoside

ellagic acid were the majorities. Other authors reported the presence of other phenolic compounds as epi-catechin, catechin, rutin, orientin, isoorientin, isovitexin, scoparone, taxifolin deoxihexose, apigenin, crisoeirol, dihydrokaempferol, velutine; 5,4'-dihydroxy-7, 3', 5'-trimethoxy flavone, luteolin diglycoside and procyanidin dimers (Gordon et al., 2012; Rojano et al., 2011).

The lipid fraction of the pulp contains between 68.0 and 71.0% of mono-unsaturated fatty acids and 7.8 and 10.6% of poly-unsaturated fatty acids, including linoleic acid, oleic acid and palmitic acid (Nascimento et al.,2008) in high concentrations. A large number of other minor fatty acids have been reported. Schauss et al. (2006a) reported the presence of nineteen amino acids in the lyophilized powder of açai fruit pulp, corresponding to 7.59% of the lyophilized fruit pulp. Furthermore, three sterols campesterol and stigmasterol were also reported (0.48 mg/g of dry weight) with 0.44 mg/g of dry weight of b-sitosterol.

A range of lignans has also been reported. Of the nine lignans isolated [including (+)-isolariciresinol, (+)-5-methoxy-isolariciresinol, (+)-lariciresinol (8), (+)-pinoresinol), (+)-syringaresinol], pinoresinol is well known as an antioxidant and monoterpenoids and norisoprenoids (Chin et al., 2008), α-carotene, β-carotene and lutein (Da Costa et al., 2010; Ribeiro et al., 2010), tocopherols A, B, C and D and vitamin E and chlorophyll 394 and 20.8 mg/100 g of dry pulp, respectively (Darnet et al., 2011). In the same way, Rogez (2000), reported (for each 100 g of the fruit pulp) the presence of vitamin A 146 IU, vitamin B1: 11.8 ug, vitamin B2: 0.32 ug, vitamin B3: 1738 µg, vitamin B5: 1389 µg, vitamin B6: 257 µg, vitamin C: 0.01 mg, vitamin E: 20 µg and vitamin K 2.07 µg. Pesce (2009) reported (in 100 g of dry pulp) the presence of trace elements as potassium 932 mg, magnesium 174 mg, phosphorus 124 mg, calcium 286 mg, sodium 56.4 mg, zinc 7 µg, iron 1.5 µg and copper 1.7 µg.

The açai fruit pulp content is a complete chemical composition that made them an excellent nutraceutical complement of vitamins, mineral, fatty acids and antioxidants compound like anthocyanins, polyphenols, and flavonoids.

These compounds can help to prevent several degenerative diseases. Besides this, the chemical composition of the açai fruit pulp can justify the fact that peoples living on the banks of the rivers having the açai fruit pulp as the basis of their diet as they lack other foods that will enable them to balance their nutrition. They are strong people and healthy from childhood. On the other hand a lot of ancient peoples in this region were observed just for intake of açai fruit pulp as a basis diet, just accomplished by some grains and cereals like maize, wheat, and oats.

Ethnobotanical and pharmacological uses of açai

Açai fruit pulp, the whole fruit, and the root of the açai palm tree have been used by Amazonian tribes as the remedy for treating diarrhea, parasitic infections, bleeding, and ulcer (Schauss, 2015, 2016). The decoction of the açai crushed seed has been used for the treatment of fever, menstrual pain, liver diseases, and malaria. The root mixed with other medicinal plants was used as antimalarial (Vigneron et al., 2005), for the treatment of the prostate cancer (Homma et al., 2006) and for the treatment of leishmaniasis (Odonne et al., 2011). Some of these ethnobotanical uses can be attributed to the presence of metabolites like phenolics, flavonoids, and anthocyanins. Nonetheless, there is a not reported study about these conditions.

Despite the great number of publications on the internet about the uses of EOM, just a few number of them are significantly and scientifically founded. Table 2 presents the most significant studies reported for this species in the scientific database. The fact that just one study in humans was made is interesting (Udani et al., 2011).

Is contradictory that the fact that the açai fruit pulp, probably the most consumed vegetal in the North and Northeast of Brazil, lack off the studies to probe the innocuousness, security and efficacy of their use by the population as food and as an ethnobotanical remedy. Still, more is curious that no work in humans was conducted to evaluate the real benefits of the majority of the popular uses of this product. Consequently, if this plant and especially the fruits have been used for centuries with certain “innocuousness”, is mandatory to confirm the ethnopharmacological use in order to validate, scientifically, the efficacy and safety of their use.

Antioxidant activity

Antioxidant activity is the most studied property of the *E. oleracea* Mart. Data about the açai fruit antioxidant potential are disagreeing. Del Pozo-Insfran et al. (2004) reported that anthocyanins are the predominant factor of the antioxidant capacity of açai pulp. Kang et al. (2010) concluded that the predominant factor in the açai antioxidant activity is the presence of seven flavonoids present on it (orientin, isoorientin, vitexin, luteolin, criseriol, quercetin, and dihydrokaempferol). Our judgment, both authors are on the right because the principal antioxidant effect of the natural extracts is the synergy among all of the compound present in the extracts, which are able to efficiently inactivate reactive nitrogen and oxygen species.

Spada et al. (2009) have shown an antioxidant activity of açai frozen fruit pulp in the cerebral cortex,

hippocampus, and cerebellum of rats treated with hydrogen peroxide (H_2O_2). Pretreatment of tissues with açai extract decreased the H_2O_2-induced damage of both lipids and proteins. The extract of the fruit was also able to reduce the activities of the antioxidant enzymes superoxide dismutase and catalase to basal levels. They observed a negative correlation between the polyphenol content of açai and the levels of lipid ($r=0.689$; $P<0.05$) and protein damage ($r=0.569$; $P<0.05$), suggesting the participation of polyphenols in the observed antioxidant activity.

Practically, all the compounds presents in açai fruits are recognized antioxidants. The synergistic antioxidant action of fatty acids, vitamins, sterols, flavonoids, anthocyanins and phenolics makes the pulp of this fruit a powerful antioxidant. The antioxidant activity of the majority of this compounds in others vegetal species were reported (Ismail et al., 2010; Lee et al., 2002; Liolios et al., 2009).

Some sickness like diabetes, hepatitis, and some degenerative diseases promote an imbalance in the body antioxidant defense. It could be interesting to test the preventive or regenerative activity of the differents açai fruit extracts as a way for the evaluation of the real benefit of these extracts in differents related pathologies. On the other side, there was no publishing article evaluating the benefits of the açai fruit pulp (or in derived extracts) in humans' model. Thus, a lack of these studies is a real necessity.

The use of this product must be cautiously in patients with diabetes or those using antidiabetic agents as, according to human research, açai may lower glucose and insulin (Udani et al., 2011).

Assays in cardiovascular diseases

The açai fruit pulp contains a large number of fatty acids, including linoleic acid, oleic acid, palmitic acid and other fatty acids (Schauss et al., 2006a). These substances showed a cardioprotective effect in rats improving the lipid profile (Bhattacharya et al., 2006). Another study reported a vasodilator effect on mesenteric vessels of rats related to a lipid profile improved by the açai fruit extract (Mantovani et al., 2003; Xie et al., 2011) reported the atheroprotective effects of açai fruit pulp in apolipoprotein E-deficient in mice, mediated by a reducing lipid peroxidation through boosting antioxidant enzymes and inhibiting pro-inflammatory cytokine production.

One study was conducted in overweight patients who consumed 100 g açai pulp twice daily for 1 month. There was a reduction in glucose levels from 98.0 ± 10.1 to 92.8 ± 10.9 mg/dl. There were also reductions in total cholesterol and triglycerides (Udani et al., 2011). Animals' feed with hypercholesterolemic diet, treated with açai pulp extract, showed an improvement in the lipid profile. These results suggest that açai pulp promotes a hypocholesterolemic effect in a rat model of dietary-induced hypercholesterolemia (De Souza et al., 2010). A diet rich in antioxidants can improve both the lipid metabolism and glucose homeostasis reducing complications in the two types of diabetes and in metabolic syndrome (Dembinska-Kiec et al., 2008).

In this sense, until we know, there is only one study in humans and the report is not enough to confirm the potential utility of the açai fruit to control dyslipidemic disorders and other imbalances of the lipidic profiles. Thus, the richness in chemical compounds of these products could be taken advantage for this kind of treatment, but other studies are needed.

Anti-inflammatory activity

The oily extract of the açai fruit reduced the number of neutrophils migrating in a carrageenan-induced peritonitis model in rats. These results suggested that the oil of açai fruit has anti-inflammatory and antinociceptive activity. It was attributed to the presence of flavonoids and a lot of unsaturated lipid present in the extract (Favacho et al., 2011). On the other side, açai fruit pulp showed potential cyclooxygenases COX-1 and COX-2 inhibitor activity (Schauss et al., 2006b).

The anti-inflammatory effects of the açai extract were screened by the secretion embryonic alkaline phosphatase (SEAP) assay. This assay is designed to measure NF-jB activation. It studied the capacity of activation of NF-jB of the açai extract by the secretion embryonic alkaline phosphatase (SEAP) assay in rats. A dose-dependent SEAP inhibitory activity in RAW-blue cells induced by lipopolysaccharides was observed. It was also observed an inhibition of SEAP induced by oxidized LDL, indicating a potential atheroprotective effect in rats (Kang et al., 2011).

Açai extracts inhibited lipopolysaccharide and interferon-gamma-induced nitric oxide (NO) production in a macrophage cell line. Overproduction of NO may lead to activation of NO synthase, leading to the generation of cells mediating inflammatory processes. The mechanism of action was associated with inhibition of NO synthase expression (Matheus et al., 2006).

The anti-inflammatory activity of açai fruit is still no conclusive, the studies made until now are none conclusive, in some of them was used the oily fraction of the açai fruit pulp, in others, they use the açai fruit pulp mixture with other species (Jensen et al., 2008; Schauss, 2016). There is not any report of the evaluation of any

formulation made by using and extract or the lyophilized fruit pulp. We do not find ethnopharmacological reports for the use as anti-inflammatory.

Neuroprotective activity

One study examined whether açai fruit extract afforded protection against β-amyloid (Aβ)-mediated loss of cell viability and oxidative stress associated with anti-fibrillar effects. PC12 cells were exposed to either Aβ1–42, Aβ25–35 or tertbutyl hydroperoxide (t-BHP), alone or in the presence of açai extract (0.5 to 50 µg/ml). The study shows that exposure to Aβ1–42, Aβ25–35 or t-BHP decreased PC12 cell viability. Pretreatment with açai extract significantly improved cell viability following Aβ1–42 exposure. Açai extract inhibited the thioflavin T fluorescence and disrupted Aβ1–42 fibril and aggregate morphology. In comparison with other phenolics, açai was most effective at inhibiting Aβ1–42 aggregations. Inhibition of β-amyloid aggregation may underlie a neuroprotective effect of açai (Wong et al., 2013).

The β-amyloid proteins are strongly implicated in Alzheimer's disease (Murphy and Levine, 2010; Schauss, 2016). A negative correlation was reported between the polyphenol content of açai and the levels of lipids and proteins damage. These data suggested that açai has a positive contribution to the prevention of the development of age-related neurodegenerative diseases. Nonetheless, further investigation is needed to evaluate the role of chemical compounds present in açai in these findings.

Anticancer effect

An anthocyanin-rich extract from açai fruit was used (AEA) to investigate the antioxidant properties and antiproliferative activity against C-6 rat brain glioma cells and MDA-468 human breast cancer cells. AEA remarkably suppresses proliferation of C-6 rat brain glioma cells, but has no effect on the growth of MDA-468 human breast cancer cells. Further experiments demonstrated that the AEA treatment dose-dependently inhibited the growth of C-6 rat glioma cells with an IC_{50} of 121 µg/ml. The DNA ladder fragmentation results indicated that AEA-induced apoptosis of C-6 rat brain glioma cells (Hogan et al., 2009).

Açai fractions containing polyphenolic compounds reduced the proliferation of HL-60 leukemia cells through caspase-3 activation in a dose- and time-dependent manner. The mechanism of action is associated with polyphenolic phytochemicals activating caspase-3, leading to cell death or apoptosis (Del Pozo-Insfran et al., 2006).

In another work, the anticancer activity in different human malignant cell lines derived from breast and colorectal adenocarcinomas was evaluated. Cell lines were treated with 10, 20, and 40 µg/mL of bark, seed, and total açai fruit hydroalcoholic extracts for 24 and 48 h. After treatment, cell viability was measured and cell morphological features were observed. The study demonstrated that açai possesses antitumorigenic potential in the MCF-7 cell line. This fact demonstrated the need to identify the compounds responsible for this activity and the molecular target in the cell (Silva et al., 2014). As observes, the real anticancer potential of the açai fruit pulp and the açai fruit extracts are still unexplored and just a few studies have been made to this regard, despite that the ethnopharmacological use in cancer is well reported for the population.

Use of açai extract in renal diseases

The use of açai extract in reduced acute renal failure (ARF) was reported. The study investigated the effect of açai fruit extract on glycerol-induced ARF in rats. Results showed for a different dose a significant decrease in serum urea, serum creatinine, and blood urea nitrogen. Moreover, there was significant amelioration in renal oxidative stress markers and renal histopathological changes. These results suggest that açai fruit extract has a potential effect in ameliorating renal damage involved in ARF (Unis, 2015).

Other study examined the effect of açai seed extract (ASE) on cardiovascular and renal alterations in adult offspring rats, whose mothers were fed with low-protein diet during pregnancy. It was observed that hypertension and the reduced acetylcholine-induced vasodilation in the low-protein group were prevented by ASE. This product improved nitrite levels and the superoxide dismutase and glutathione peroxidase activity in low-protein, with a decrease of malondialdehyde and in the protein carbonyl levels. Kidney volume and glomeruli number were reduced and glomerular volume was increased in low-protein group. These renal alterations were prevented by ASE (De bem et al., 2014).

A study to investigate the possible mechanisms of renal injury attenuation caused by açai extract in a rat renal (I/R) model was reported. Rats were administered with açai extract at 500 and 1000 mg/kg for 15 days, before bilateral renal I/R induction. Serum and kidneys were isolated and used for subsequent biochemical analysis. The açai extract significantly and dose-dependently attenuated I/R-induced renal damage. It suppressed the levels of blood urea nitrogen (BUN), serum creatinine, and renal tissue content of kidney injury molecule-1 (KIM-1). In addition, the serum lactate dehydrogenase (LDH) activity was inhibited. Moreover, renal contents of malondialdehyde (MDA), myeloperoxidase (MPO),

interferon-gamma (IFN-γ), caspase-3, collagen IV, and endothelin-1 were reduced, while renal interleukin-10 (IL-10) content was increased by açai extract administration (El Morsy et al., 2014).

The reported studies assuring the renal protective activity function did not specify the nature of the extract used. Finally, there is no study in humans, for the evaluation of the renal function or renal failure. Thus, this kind of studies is imperative.

Uses of açai in cosmetics

The high content of anthocyanins and phenolic compounds with important antioxidant activity was used in cosmetic preparation for the treatment and prevention of skin damages (Herculano, 2013). Among these products, both the extract and the pulp of açai fruits are used as moisture agents in creams, hair conditioner, and shampoo. The açai fruit pulp has properties of nutrition and capillary brightness. The oil extracted from the pulp is used in shampoos and body lotions (Hogan et al., 2009). The glycolic extract of açai was used to prepare a sunscreen emulsions (o/w). The resulted cream showed a good protection UV-A and UV-B factor (Daher et al., 2014).

In the face of all reports that can be found on the Internet promoting the use of cosmetics with açai fruit pulp or açai extracts as active principle, there are no reports of the studies evaluating the effectiveness and the security of all of these products. Thus, there are a lot of cosmetics and nutraceutical products using some product derived from açai as an active principle without scientific foundation. Nonetheless, this represents an excellent opportunity to do research in this area to justify scientifically the use of these products.

Pharmaceutical forms and foods based on açai

Due to the richness in phytochemical substances present in the açai fruit pulp, it is used in a variety of formulations. The freeze dried açai fruit pulp was used in a formulation for the erectile dysfunction. An increase in the time of shelf life of this product was observed (Clewell et al., 2010). Tablets and açai capsules can be found in the market. Everything is marketed as the nutritional supplement. In these formulations, the lyophilized açai fruit pulp was used (Empresa Saúdeja, 2015). In a general way, a lot of cosmetic and nutritional preparations containing açai fruit pulp including juices, powders, capsules, liquids, creams, and lotions can be found in the market. However, there is no product registered as a medicament (Medicament: A preparation containing a tested active drug used to diagnose, cure, treat, or prevent disease) (United States Pharmacopoeia, 2012). In all cases, there is no scientific evidence supporting the biological activities attributed to these preparations.

Toxicological studies involving açai fruit pulp

The toxicity of a mixture of the açai fruit pulp with a berry functional juice was studied. The mixture was neither cytotoxic nor genotoxic. The LD_{50} based on a 14-day acute oral toxicity study was greater than 2000 mg/kg body weight (Schauss et al., 2010). In another study, the genotoxicity of açai fruit pulp was investigated in Swiss albino mice by using a doxorubicin (DXR)-induced DNA damage model. The protective effect of açai fruit pulp was observed in both acute and subacute treatments when administered prior to DXR. The protective effects were associated with the phytocompound presents in the açai fruit pulp. Despite that the pulp of this fruit, it is used as food in Brazil and other parts of the world, and besides that, it is widely available in a variety of forms, including juices, powders, and capsules, etc., açai is not listed on the U.S. Food and Drug Administration (FDA) Generally Recognized As Safe (GRAS) list (Schauss, 2016).

Açai has been very well accepted by the population of big cities, attracted by the nutritional and medicinal properties of the fruit (Rogez, 2000). With the constant increase of açai consumption, a standardization of the quality of this product is required (Bhattacharya et al., 2006; Boghani et al., 2012; Nogueira et al., 2005).

Nonetheless, the evaluation of the safety of any pharmaceutical and food product is an imperious necessity. Thus, there is a lack of studies to demonstrate the safety in the use of the açai. Taking into account that the açai fruit is one of the most consumed vegetal product in the North and Northeast of Brazil, in some Asian country and in North America toxicological studies by means of the international standards are imperative to assure the innocuity of this product. On the other side, there is no published results talking about the safety and efficacy of any of the nutraceutical products that are sold in the market.

Nutritional composition

Each 100 g of the dry açai fruit pulp content has 533.9 calories, 32.5 g of total fats, 8.1 g of saturated fats, 13.5 mg of cholesterol, 52.2 g of carbohydrates, 44.2 g of dietary fiber, 1.3 g of sugar, and 8.1 g of proteins. Also, it contains vitamin A 1002 UI, vitamin C 0.1 mg, calcium260 mg, and sodium 30.4 mg (Costa et al., 2013; Schauss et al., 2006a).

For the diet, the great contribution of açai is their energetic value because of the high content of lipids (70

to 90% of the calories) (Crozier et al., 2011; Rufino et al., 2010). The high fiber content and a considerable amount of anthocyanins present in açai make this fruit a great help to prevent chronic degenerative diseases (Rufino et al., 2010). Açai is also an important source of trace elements such as calcium, phosphorus, sodium, zinc, iron, manganese, copper, boron, chromium, magnesium, potassium, and nickel (Crozier et al., 2011).

Conclusions

Despite the widespread use of açai by populations of Brazil and other countries, there are few scientifically based studies on nutrition and medicinal properties of the fruit pulp of this plant. The antioxidant activity has been the most investigated. No dosage forms using açai as the active ingredient were registered; until now, as a medicine to the health authorities of any country. Just two studies, in humans were found in the literature using the açai fruit pulp. There are no sufficient systematic evidence to assure that all of the ethnobotanical uses of this species could be scientifically founded. A great emptiness of scientific knowledge related to the real benefits of this plant species exists. There exist neither pharmaceutical forms nor standardized product derived from the açai fruit pulp. Until now, the number of scientific studies that allow the validation the ethnopharmacological practices, the innocuousness and the safety of the use of this plant fruit is insufficient.

ACKNOWLEDGEMENTS

This work was supported by the Conselho Nacional de Pesquisa e Desenvolvimento (CNPq), Brazil [grant number 402332/2013-0, 2013].

Conflict of interests

The authors have not declared any conflict of interests

REFERENCES

Bhattacharya A, Banu J, Rahman M, Causey J, Fernandes G (2006). Biological effects of conjugated linoleic acids in health and disease. J. Nutr. Biochem. 17(12):789-810.

Bobbio FO, Druzian JI, Abrao PA, Bobbio PA, Fadelli S (2000). Identification and quantification of anthocyanins from the açai fruit *(Euterpe oleracea)* Mart. Ciênc. Tecnol. Aliment. 20(3):388-390.

Boghani AH, Raheem A, Hashmi SI (2012). Development and storage studies of blended papaya–aloe vera ready to serve (RTS) beverage. J. Food Process. Technol. 3:185.

Bourdy G, Dewalt SJ, Michel LRC, Roca A, Deharo E, Muñoz V (2000). Medicinal plants uses of the Tacana, an Amazonian Bolivian ethnic group. J. Ethnopharmacol. 70(2):87-109.

Cheminat A, Brouillard R (1986). PMR investigation of 3-O-(â-Dglucosil)-malvidin structural transformations in aqueous solutions. Tetrahedron Lett. 27(37):4457-4460.

Chin YW, Chai HB, Keller WJ, Kinghorn AD (2008). Lignans and other constituents of the fruits of *Euterpe oleracea* (Açai) with antioxidant and cytoprotective activities. J. Agric. Food Chem. 56(17):7759-7764.

Choi WS, Lee SE, Lee HS, Lee YH, Park BS (1998). Antioxidative activities of methanol extracts of tropical and oriental medicinal plants. Hangug Nonghwahag Hoeji 41:556-559.

Clewell A, Qureshi I, Endres J, Horváth J, Financsek I, Neal-Kababick J, Jade K, Schauss AG (2010). Toxicological evaluation of a dietary supplement formulated for male sexual health prior to market release. Regul. Toxicol. Pharmacol. 57(1):55-61.

Costa AGV, Garcia-Diaz, DF, Jimenez P, Silva PI (2013). Bioactive compounds and health benefits of exotic tropical red-black berries. J. Funct. Foods 5(2):539-549.

Crozier SJ, Preston AG, Hurst JW, Payne, MJ, Mann J, Hainly L, Miller DL (2011). Cacao seeds are a ‘‘Super Fruit’’: A comparative analysis of various fruit powders and products. Chem. Cent. J. 7:5-5.

Da Costa PA, Ballus CA, Teixeira J, Godoy HT (2010). Phytosterols and tocopherols content of pulps and nuts of Brazilian fruits. Food Res. Int. 43(6):1603-1606.

Daher CC, Fontes IS, Rodrigues ROR, Damasceno GAB, Soares DS, Aragao CFS, Gomes APB, Ferrari M (2014). Development of O/W emulsions containing *Euterpe oleracea* extract and evaluation of photoprotective efficacy. Braz. J. Pharm. Sci. 50(3):639-652.

Darnet S, Serra JL, Rodrigues AMC, Silva LHM (2011). A high performance liquid chromatography method to measure tocopherols in assai pulp (*Euterpe oleracea*). Food Res. Int. 44(7):2107-2111.

De Bem GF, Da Costa CA, De Oliveira PR, Cordeiro VS, Santos IB, De Carvalho LC, Souza MA, Ognibene DT, Daleprane JB, Sousa PJ, Resende, AC, De Moura RS (2014). Protective effect of *Euterpe oleracea* Mart (açai) extract on programmed changes in the adult rat offspring caused by maternal protein restriction during pregnancy. J. Pharm. Pharmacol. 66(9):1328-1338.

De Souza MO, Silva LS, Magalhães CLB, Figueiredo BB, Costa DC, Silva ME, Pedrosa ML (2012). The hypocholesterolemic activity of açai (*Euterpe oleracea* Mart.) is mediated by the enhanced expression of the ATP-binding cassette, subfamily G transporters 5 and 8 and low-density lipoprotein receptor genes in the rat. Nutr. Res. 32(12):976-984.

De Souza MO, Silva M, Silva ME, Oliveira RP, Pedrosa ML (2010). Diet supplementation with açai (*Euterpe oleracea* Mart.) pulp improves biomarkers of oxidative stress and the serum lipid profile in rats. Nutrition 26(7-8):804-810.

Del Pozo-Insfran D, Brenes CH, Talcott, ST (2004). Phytochemical Composition and Pigment Stability of Açai (*Euterpe oleracea* Mart.). J. Agric. Food Chem. 52(6):1539-1545.

Del Pozo-Insfran D, Percival SS, Talcott ST (2006). Açai (*Euterpe oleracea* Mart.) polyphenolics in their glycoside and aglycone forms induce apoptosis of HL-60 leukemia cells. J. Agric. Food Chem. 54(4):1222-1229.

Dembinska-Kiec A, Mykkanen O, Kiec-Wilk B, Mykkanen H (2008). Antioxidant phytochemicals against type 2 diabetes. Br. J. Nutr. (99):109-117.

Dias ALS, Rozet E, ChataignéG, Oliveira AC, Rabelo CAS, Hubert P, Rogez H, Quetin-Leclercq J (2012). A rapid validated UHPLC-PDA method for anthocyanins quantification from *Euterpe oleracea* fruits. J. Chromatogr. AB 907:108-116.

El Morsy EM, Ahmed MA, Ahmed AA (2014). Attenuation of renal ischemia/reperfusion injury by açai extract preconditioning in a rat model. Life Sci. 123(2015):35-42.

Empresa Saúdeja (2015). Database for the example of nutritional suplement on the market. release 2.7. Available at: http://www.saudeja.com.br/açai-da-amazonia-90-comprimidos-stem-pharrmaceutical

Favacho HAS, Oliveira BR, Santos KC, Medeiros BJL, Souza PJC, Perazzo FF, Carvalho JCT (2011). Anti-inflammtory and

antinociceptive activities of *Euterpe oleracea* oil. Braz. J. Pharmacog. 21(1):105-114.
Gallori S, Bilia AR, Bergonzi MC, Barbosa WLR, Vincieri FF (2004). Polyphenolic constituents of fruit pulp of *Euterpe oleracea* Mart. (açai palm). Chromatography. 56(11):739-743.
Gordon A, Cruz APG, Cabral LMC, De Freitas SC, Taxi CMAD, Donangelo CM, Mattietto RA, Friedrich M, da Matta VM, Marx F (2012). Chemical characterisation and evaluation of antioxidant properties of Açai fruits (*Euterpe oleracea* Mart.) during ripening. Food Chem. 133:256-263.
Gouvea ACMS, Araujo MCP, Schulz DF, Pacheco S, Godoy RLO, Cabral LMC (2012). Anthocyanins standards (cyanidin-3-O-glucosideo and cyanidin-3-O-rutinoside) isolation from freeze-dried açai (*Euterpe oleracea* Mart.) by HPLC. Ciência Tecnol. Alime. 32(1):43-46.
Heinrich M, Dhanji T, Casselman I (2010). Açai (*Euterpe oleracea*) – A phytochemical and pharmacological assessment of the species health claims. Phytochem. Lett**.** 4(2011):10-21.
Herculano FEB (2013). Industrial production of cosmetics: the protagonism of the vegetal biodiversity of the Amazon. Manaus, Brazil: UFAM.
Antiproliferative and antioxidant properties of anthocyanin-rich extract from açai. Food Chem. 118(2010):208-214
Homma AKO, Nogueira OL, Menezes AJEA, de Carvalho JEU, de Nicoli CML, de Matos GB (2006). Açai: new challenges and trends (Açai: novos desafios e tendências). Amazônia Ciência & Desenvolvimento 1(2):7-23.
Ismail M, Mariod A, Bagalkotkar G, Ling HS (2010). Fatty acid composition and antioxidant activity of oils from two cultivars of Cantaloupe extracted by supercritical fluid extraction. Grasas Aceites 61(1):37-44.
Jensen GS, Wu X, Patterson KM, Carter SG, Wu X, Scherwitz L (2008). In vitro and in vivo antioxidant and anti-inflammatory capacities of an antioxidantrich fruit and berry juice blend. Results of a pilot and randomized, double-blinded, placebo-controlled crossover study. J. Agric. Food Chem. 56:8326-8333.
Jones DL (1995). Palms: throughout the world. Washington, United States: Smithsonian Institution.
Kang J, Li ZM, Wu T, Jensen GS, Schauss AG, Wu X (2010). Anti-oxidant capacities of flavonoid compounds isolated from açai pulp (*Euterpe oleracea* Mart.). Food Chem. 122:610-617.
Kang J, Xie C, Li Z, Nagarajan S, Schauss AG, Wu T, Wu X (2011). Flavonoids from açai (*Euterpe oleracea* Mart.) pulp and their antioxidant and antiinflammatory activities. Food Chem.128(1):152-157.
Lee SC, Tsai CC, Chen JC, Lin CC, Hu ML, Lu S (2002). The evaluation of reno- and hepato-protective effects of HuaiShan-Yao (*Rhizome dioscoreae*). Am. J. Chin. Med. 30(4):609-616.
Lichtenthaler R, Rodrigues RB, Maia JGS, Papgiannopoulos M, Fabricius H, Marx F (2005). Total oxidant scavenging capacity of the *Euterpe oleracea* Mart. (Açai) fruits. Int. J. Food Sci. Nutr. 56(1):56-64.
Liolios CC, Sotiroudis GT, Chinou I (2009). Fatty acids, sterols, phenols and antioxidant activity of Phoenix theophrasti fruits growing in Crete, Greece". Plant Foods Hum. Nutr. 64(1):52-61.
Mantovani, ISB, Fernandes, SBO, Menezes FS (2003). Apolar constituents of açai fruit (*Euterpe oleracea* M. – Arecaceae). Rev. Bras. Farmacongn. 13(1):41-42.
Matheus ME, de Oliveira Fernandes SB, Silveira CS, Rodrigues VP, de Sousa Menezes F, Fernandes PD (2006). Inhibitory effects of *Euterpe oleracea* Mart. on nitric oxide production and iNOS expression. J. Ethnopharmacol. 107(2):291-296.
Menezes E, Deliza R, Chan HL, Guinard JX (2011). Preferences and attitudes towards açai-based products among North American consumers. Food Res. Int. 44(7):1997-2008.
Muñiz-Miret N, Vamos R, Hiraoka M, Montagnini F, Mendelsohn RO (1996). The economic value of managing the açai palm (*Euterpe oleracea* Mart.) in the floodplains of the Amazon estuary, Para, Brazil. Forest Ecology and Management, 87(1-3):163-173.
Murphy MP, LeVine H (2010). Alzheimer's disease and the amyloid-beta peptide. J. Alzheimer´s Dis. 19(1):311-323.
Nascimento RJS, Couril S, Antoniassi R, Freitas SP (2008). Fatty acid composition of the oil of the açai pulp extracted with enzymes and with hexane. Rev. Bras. Frutic. 30(2):498-502.
Nogueira OL, Figueirêdo FJC, Muller AA (2005) Açai. (1th ed.). Belem, Brazil: Embrapa Amazônia Oriental.
Odonne G, Berger F, Stien D, Grenand P, Bourdy G (2011). Treatment of leishmaniasis in the Oyapock basin (French Guiana): A K.A.P. survey and analysis of the evolutionary of phytotherapy knowledge amongst Wayãpi Indians. J. Ethnopharmacol. 137(3):1228-1239.
Pacheco-Palencia LA, Duncan CE, Talcott ST (2009). Phytochemical composition and thermal stability of two commercial açai species, *Euterpe oleracea* and *Euterpe precatoria*. Food Chem. 115(4):1199-1205.
Pacheco-Palencia LA, Mertens-Talcott S, Talcott ST (2008). Chemical composition,antioxidant properties, and thermal stability of a phytochemical enriched oil from Açai (*Euterpe oleracea* Mart.). J. Agric. Food Chem. 56(12):4631-4636.
Pesce C (2009). Oilseeds of the Amazon (Oleaginosas da Amazonia). (2th ed.). Belem, Brazil: Paraense Emilio Goeldi Museum.
Portinho JA, Zimmermann LM, Bruck MR (2012). Beneficial Effects of Açai. Int. J. Nutrol. 5(1):15-20.
Ribeiro JC, Antunes LM, Aissa AF, Darin JD, De Rosso VV, Mercadante AZ, Bianchi MLP (2010). Evaluation of the genotoxic and antigenotoxic effects after acute and subacute treatments with açai pulp (*Euterpe oleracea* Mart.) on mice using the erythrocytes micronucleus test and the comet assay. Mutat. Res. 695(1):22-28.
Rocha AP, Carvalho LC, Sousa MA, Madeira SV, Sousa PJ, Tano T, Schini-Kerth VB, Resende AC, Soares De Moura R (2007). Endothelium-dependent vasodilator effect of *Euterpe oleracea* Mart. (açai) extracts in mesenteric vascular bed of the rat. Vascul. Pharmacol. 46(2):97-104.
Rogez H (2000). Açai: preparation, composition and improvement of conservation. (1th ed.). Belem, Brazil: UFPA.
Rojano BA, Vahos ICZ, Arbeláez AFA, Martínez AJM, Correa FBC, Carvajal LG (2011). Polyphenols and Antioxidant Activity of the Fruit Freeze-dried Palm Naidi (Colombian Açai) (*Euterpe oleracea* Mart.). Revista Facultad Nacional de Agronomía Medellín 64(2):6213-6220.
Rufino MSM, Alves RE, Brito ES, Pérez-Jiménez J, Saura-Calixto F, Mancini-Filho J (2010). Bioactive compounds and antioxidant capacities of 18 non-traditional tropical fruits from Brazil. Food Chem. 121(4):996-1002.
Santos GM, Maia GA, Sousa PHM, Costa JMC, Figueiredo RW, Prado GM (2008). Correlation between antioxidant activity and bioactive compounds of commercial açai pulps (*Euterpe oleracea* Mart). Arch. Latinoam. Nutr. 58(2):187-192.
Schauss AG (2015). The Effect of Acai (Euterpe spp.) Fruit Pulp on Brain Health and Performance. In R. R. Watson, & V. R. Preedy (Eds.) Bioactive Nutraceuticals and Dietary Supplements in Neurological and Brain Disease. Prevention and Therapy. London: Academic Press.
Schauss AG (2016). Advances in the study of the health benefits and mechanisms of action of the pulp and seed of the Amazonian palm fruit, Euterpe oleracea Mart., known as "Açai". In R. R. Watson, & V. R. Preedy (Eds.) Fruits, Vegetables, and Herbs (pp. 177-220). Oxford: Academic Press.
Schauss AG, Clewell A, Balogh L, Szakonyi IP, Financsek I, Horváth J, Thuroczy J, Béres E, Vértesi A, Hirka G (2010). Safety evaluation of an açai-fortified fruit and berry functional juice beverage (MonaVie Active®). Toxicology, 278(1):46-54.
Schauss AG, Wu X, Prior R, Ou B, Patel D, Huang D, Kababick J (2006a). Phytochemical and nutrient composition of the freezedried amazonian palm berry *Euterpe oleracea* Mart. (açai). J. Agric. Food Chem. 54(22):8598-8603.
Schauss AG, Wu X, Prior RL, Ou B, Huang D, Owens J, Agarwal A, Jensen GS, Hart AN, Shanbrom E (2006b). Antioxidant capacity and

other bioactivities of the freeze-dried Amazonian palm berry, *Euterpe oleracea* Mart. (açai). J. Agric. Food Chem. 54(22):8604-8610.
Silva DF, Vidal FC, Santos D, Costa MC, Morgado-Diaz JA, Do Desterro SBNM, De Moura RS (2014). Cytotoxic effects of *Euterpe oleracea* Mart. in malignant cell lines. BMC Complement. Altern. Med. 14:175.
Silva JJM, Rógez, H (2013). Evaluation of oxidative stability of açai crude oil (*Euterpe oleracea*) in the presence of pure phenolic compounds or of Amazonian plant extracts. Quim. Nova 36(3):400-406.
Spada PD, Dani C, Bortolini GV, Funchal C, Henriques JA, Salvador M (2009). Frozen fruit pulp of *Euterpe oleracea* Mart. (açai) prevents hydrogen peroxide-induced damage in the cerebral cortex, cerebellum, and hippocampus of rats. J. Med. Food 12(5):1084-1088.
Udani JK, Singh BB, Singh VJ, Barrett ML (2011). Effects of açai (*Euterpe oleracea* Mart.) berry preparation on metabolic parameters en a healthy overweight population: a pilot study. Nutr. J. 10:45.
Unis A (2015). Açai berry extract attenuates glycerol-induced acute
renal failure in rats. Ren. Fail. 37(2):310-317.
United States Pharmacopoeia (2012). The official compendia of standard. (30th Edn.). New York, United States: Arabswell.
Vera de Rosso V, Hillebrand S, Montilla EC, Bobbio FO, Winterhalter P, Mercadante AZ (2008). Determination of anthocyanins from acerola (*Malpighia emarginata* DC) and açai (*Euterpe oleracea* Mart.) by HPLC-PDA-MS/MS. J. Food Compos. Anal. 21(4):291-299.
Vigneron M, Deparis X, Deharo E, Bourdy G. (2005). Antimalarial remedies in French Guiana: A knowledge attitudes and practices study. J. Ethnopharmacol. 98(3):351-360.
Wong DYF, Musgrave IF, Scott HB, Darryl SS (2013). Açai (*Euterpe oleraceae* Mart.) berry extract exerts neuroprotective effects against-amyloid exposure *in vitro*. Neurosci. Lett. 556:221-226.
Xie C, Kang J, Burris R, Ferguson ME, Schauss AG, Nagarajan S, Wu X (2011). Açai juice attenuates atherosclerosis in ApoE deficient mice through antioxidant and anti-inflammatory activities. Atherosclerosis, 216(2):327-33.