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SAPOTA-DO-SOLIMÕES (*Quararibea cordata*): CARACTERIZAÇÃO FÍSICO-QUÍMICA, ESTABILIDADE, COMPOSTOS BIOATIVOS E VOLÁTEIS

Santa Maria, RS
2017

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Tese apresentada ao Curso de Pós-Graduação em Ciência e Tecnologia dos Alimentos, da Universidade Federal de Santa Maria (UFSM, RS), como requisito parcial para obtenção do título de **Doutora em Ciência e Tecnologia dos Alimentos**.

Orientadora: Profa. Dra. Claudia Severo da Rosa

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RESUMO

SAPOTA-DO-SOLIMÕES (*Quararibea cordata*): CARACTERIZAÇÃO FÍSICO-QUÍMICA, ESTABILIDADE, COMPOSTOS BIOATIVOS E VOLÁTEIS

AUTORA: Sabrina Sauthier Monteiro
ORIENTADORA: Profa. Dra. Claudia Severo da Rosa

A sapota-do-Solimões (*Quararibea cordata*) é uma fruta encontrada na região Amazônica do Brasil consumida apenas pela população local. A produção de polpa vegetal é uma operação viável em período de safra e capaz de atender o consumidor em qualquer época do ano, mesmo em locais distantes de sua origem. É uma fruta ainda pouco conhecida mundialmente e apresenta um elevado potencial agroindustrial. Assim, o presente trabalho teve por objetivo caracterizar as partes (casca, polpa e sementes) da sapota-do-Solimões, a estabilidade de polpas elaboradas e os compostos bioativos e voláteis da polpa em diferentes estádios de maturação. As amostras foram coletadas na cidade de Tefé-AM em três estádios de maturação distintos: verde (V), maduro coletado da árvore (M) e maduro coletado do chão (MC), quando se desprende naturalmente da planta, e transportados para Santa Maria-RS. No primeiro estudo foram utilizados os frutos M e caracterizados os parâmetros biométricos, a composição química e o conteúdo mineral. No segundo, os frutos M foram despolpados e submetidos aos tratamentos: congelamento, pasteurização + congelamento, refrigeração e pasteurização + refrigeração. As características físico-químicas e microbiológicas e os compostos bioativos foram analisados em sete diferentes tempos de armazenamento durante 180 dias. O terceiro estudo compreendeu as análises da polpa (V, M e MC) de parâmetros biométricos, de qualidade, compostos bioativos, composição química, perfil de ácidos graxos e de voláteis. As porcentagens de casca, polpa e sementes foram, respectivamente, de 53,2%, 39,6% e 7,2%. A composição química em 100 g de polpa de sapota-do-Solimões foi de 85,01% de umidade; 0,79% de cinzas; 0,67% de proteína; 0,10% de lípidos, 4,10% de fibra alimentar; 9,34% de carboidratos e 40,94 Kcal. O magnésio foi o mineral de maior relevância na polpa. Nas polpas elaboradas, os tratamentos afetaram os parâmetros físico-químicos durante o armazenamento. O ácido ascórbico permaneceu estável durante o congelamento e os níveis de carotenóides totais foram mantidos na pasteurização+congelamento. Os fenóis totais permaneceram estáveis até 150 dias e a atividade antioxidante diminuiu durante o armazenamento para todos os tratamentos. Os tratamentos de pasteurização+congelamento, bem como o tratamento de congelamento, mantiveram a qualidade da polpa durante 180 dias de armazenamento. Com o amadurecimento da sapota-do-Solimões houve um aumento na atividade de água (0,977-0,996), pH (6,53-7,04), sólidos solúveis (8,53-12,65%), açúcares totais (4,26-7,98%), açúcares redutores (0,99-3,14%), açúcares não redutores (3,11-4,60%), carotenoides totais (0,67-1,24 μg/g de polpa). Os lipídios aumentaram em relação ao estádio de maturação V (0,16%) e MC (0,30%). Onze ácidos graxos foram detectados nas polpas. Foram identificados 86 compostos voláteis, sendo 57 componentes nos frutos V, 54 nos frutos M e 68 nos frutos MC. Os ésteres benzoato de metila e etila foram encontrados nos frutos MC. Houve um aumento de compostos terpênicos, 0,4% do V para 5,6% do MC. Os dados mostraram que a composição dos frutos foi influenciada pelo estádio de maturação das polpas.

Palavras-chave: *Matisia cordata*. Fruta amazônica. Processamento de polpa de fruta. Estágios de amadurecimento. Compostos voláteis.

ABSTRACT

SAPOTA-DO-SOLIMÕES (*Quararibea cordata*): PHYSICOCHEMICAL CHARACTERIZATION, STABILITY, BIOACTIVE AND VOLATILE COMPOUNDS

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Sapota-do-Solimões (*Quararibea cordata*) is a fruit found in the Amazon region of Brazil consumed only by the local population. The production of vegetable pulp is a viable operation in harvest period and able to serve the consumer at any time of year, even in distant places of origin. It is a fruit still little known worldwide and presents a high agroindustrial potential. Thus, the present work aims to analyze the parts of sapota-do-Solimões (peel, pulp and seeds), the stability of elaborated pulps and the bioactive and volatile compounds of the pulp in different ripening stages. The samples were collected from the city of Tefé-AM in three distinct ripening stages: unripe (U), ripe and collected from the tree (R); and ripe and collected from the ground, i.e. when the fruit fell naturally to the ground from the tree (RG), and transported to Santa Maria-RS. In the first study, the fruits R were used and the biometric parameters, the chemical composition and the mineral content were characterized. In the second, fruits R were pulped and submitted to the treatments: freezing, pasteurization + freezing, refrigeration and pasteurization + refrigeration, physicochemical and microbiological characteristics and bioactive compounds were analyzed in seven different storage times during 180 days. The third study, one comprised pulp analysis (U, R and RG) of biometric parameters, of quality, bioactive compounds, chemical composition, fatty acids and volatile profile. The percentages of peel, pulp and seeds were, respectively, 53.2%, 39.6% and 7.2%. The chemical composition in 100 g of sapota-do-Solimões was 85.01% moisture; 0.79% ash; 0.67% protein; 0.10% lipids, 4.10% dietary fiber; 9.34% carbohydrate and 40.94 calories. Magnesium was the most important mineral in the pulp. In the elaborated pulps, the treatments affected the physical-chemical parameters during the storage. Ascorbic acid remained stable during freezing and total carotenoid levels were maintained in pasteurization + freezing. Total phenols remained stable for up to 150 days and antioxidant activity decreased during storage for all treatments. The pasteurization + freezing treatment, as well as the freezing treatment, maintained pulp quality for 180 days of storage. With the ripening of the sapota-do-Solimões, there was an increase in water activity (0.977-0.996), pH (6.53-7.04), soluble solids (8.53-12.65%), total sugars (4.26-7.98%), reducing sugars (0.99-3.14%), non-reducing sugars (3.11-4.60%), total carotenoids (0.67-1.24 µg/g of pulp). The lipids increased with respect to ripening stage U (0.16%) and RG (0.30%). Eleven fatty acids were detected in the pulps. A total of 86 volatile compounds were identified, of which 57 were found in U fruits, 54 in R fruits and 68 in RG fruits. Methyl and ethyl benzoate esters were found in the RG fruits. There was an increase in terpene compounds; from 0.4% for U fruit to 5.6% for RG fruit. The data showed that the composition of the fruit was influenced by the ripening stage of the pulp.

Keywords: *Matisia cordata*. Amazon fruit. Processing of fruit pulp. Ripening stages. Volatile compounds.

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LISTA DE ABREVIATURAS E SIGLAS

a*	Variação entre a cor vermelha (+a^*) e a verde (-a^*)
ANOVA	Análise de variância
ANVISA	Agência Nacional de Vigilância Sanitária
AOAC	Association of Official Analytical Chemists
b*	Variação entre a cor amarela (+b^*) e o azul (-b^*)
c	Chroma
Car	Carboxen
DBV	Divinilbenzeno
DP	Desvio padrão
DPPH	1,1-difenil-2-picrilhidrazil ou 2,2-difenil-1-picrilhidrazil
EAG ou GAE	Equivalente Ácido Gálico
EMBRAPA	Empresa Brasileira de Pesquisa Agropecuária
FAO	Food and Agriculture Organization
g	gramas
GC/MS	Gas Chromatograph equipped with a Mass Spectometry
h	Ângulo hue
HS-SPME	Headspace of the Solid Phase Microextraction
IC_{50}	Quantidade de antioxidante requerida para obter-se 50% de inibição do radical DPPH
Kcal	Calorias
L*	Luminosidade, variando de 0 (preto) até 100 (branco)
Log	Logaritmo
M	Molar
mg	Miligrama
mL	Mililitro
pH	Potencial hidrogeniônico
rpm	Rotações por minuto
TE	Trolox Equivalente
UI	Unidades Internacionais
µg	Micrograma
µL	Microlitro
µmol	Micromolar
°Brix	Graus Brix
°C	Graus Celsius
%	Porcentagem

SUMÁRIO

1 INTRODUÇÃO

A sapota-do-Solimões é uma fruta originária na Amazônia brasileira, possui forma ligeiramente ovoide ou, às vezes, arredondada. Sua casca é espessa, resistente, de coloração marrom-esverdeada e pulverulenta. A polpa é amarela alaranjada com finas fibras que envolvem sementes cuneiformes verde-castanhas, duras e espessas (CLEMENT, 1989; CAVALCANTE, 1991; PAOLI; NASCIMENTO, 2004). É um fruto consumido *in natura* ou na forma de suco (BRAGA et al., 2003), contudo, a polpa apresenta grande potencial industrial e vem despertando acentuado interesse pelas suas qualidades como fruto delicioso, sabor exótico e potencial para a exportação pela resistência ao transporte devido à espessura da casca e presença de compostos bioativos como fenólicos e carotenoides com poder antioxidante, características que sugerem que a sapota possui compostos que protegem a fração lipídica da oxidação (SOUSA; BRAGA, 1994; BRAGA et al., 2003).

É uma fruta que apresenta condições de transporte, porém a elaboração de polpas pode melhorar a qualidade, facilitar o preparo e a distribuição, agregando valor econômico, social e ambiental a fruta, evitando desperdícios e minimizando perdas que podem ocorrer durante sua comercialização na forma *in natura*. Com base no exposto, esse trabalho justifica-se pela necessidade de conhecer melhor a sapota-do-Solimões em relação às suas características físico-química, estabilidade, compostos bioativos e compostos voláteis, além de verificar a viabilidade da utilização da mesma para processamento na forma de polpas para que possa contribuir para a expansão de novos mercados consumidores, possibilitando uma larga aplicação tanto para uso industrial, institucional ou mesmo doméstica, além de estimular e desenvolver o comércio local da região onde há produção da fruta.

A produção de polpas de fruta no geral é uma alternativa para o aproveitamento integral do vegetal e uma operação viável tecnicamente para época de safra, evitando-se inconvenientes ligados às produções sazonais. O processamento de polpas de frutas aumenta a vida útil, reduz perdas e possibilita a disponibilidade, pois os indivíduos que buscam alimentação saudável podem ser atendidos em qualquer época do ano, mesmo em locais distantes de sua origem (BASTOS et al., 1999; MATTA et al., 2005), como no caso da sapota-do-Solimões que está presente no norte do País, mas que por meio de processos agroindustriais, poderia atender aos consumidores de outras regiões e o mercado externo.

2 REVISÃO DE LITERATURA

2.1 SAPOTA-DO-SOLIMÕES

A sapota (*Quararibea cordata*) é uma espécie pertencente à família Bombacaceae, sendo considerada como nativa da floresta Amazônica (HODGE, 1960; ROBYNS, 1964) e encontrada na Amazônia brasileira na parte ocidental, a partir de Tefé, no rio Solimões (DUCKE, 1946; CAVALCANTE, 1991). É cultivada no médio e alto Solimões (CAVALCANTE, 1991; VAN LEEUWEN; GOMES; BARON, 2009), nos últimos 4 mil anos pelos índios Ticunas (KERR; CLEMENT, 1980). Planta tipicamente amazônica, a sapota é um dos recursos genéticos nativos da região. É encontrada com muita frequência no estado silvestre na mata primária em terra firme e precisa de boa fertilidade e proteção contra a competição de outras plantas (VAN LEEUWEN; GOMES; BARON, 2009).

Tem como sinônimo o nome científico *Matisia cordata* e vários nomes populares no Brasil como sapota-do-Solimões, sapota, sapotinha, sapota-do-peru, pau-de-mucura, entre outros. Em outros países é chamada também de sapotillo, zapote chupa, zapote chupachupa (Colômbia e Peru); chupa-chupa, zapote, zapote amarillo (Colômbia); sapote (Peru); mame colorado, mamey colorado (Venezuela); balso de montaña, manguito, zapote amarillho e zapote colombiana (Costa Rica) (CASCANTE-MARÍN, 1997; RESQUE, 2007; RIOS; JÚNIOR, 2011).

Para introduzir essa revisão de literatura, foi realizada uma busca pelos nomes *Quararibea cordata* e *Matisia cordata* nos sites de busca. Foram observados que ainda são poucos os trabalhos realizados com a sapota-do-Solimões, mas a mesma vem despertando interesse da comunidade científica devido seu sabor agradável, características físicas e propriedades funcionais e nutricionais. Publicações relevantes que utilizaram a sapota como amostra em diversas pesquisas estão listadas na Tabela 1. Esses trabalhos foram utilizados no levantamento bibliográfico e contribuíram para saber o que já havia sido realizado com a sapota, assim como, o que ainda poderia ser estudado. De acordo com essa pesquisa bibliográfica realizada, existe uma carência de estudos publicados sobre essa fruta e isso demonstra que a sapota é pouco explorada cientificamente, assim como muitas outras frutas da região Amazônica. Além dessas publicações, outras também foram utilizadas como relatórios de pesquisa, trabalhos finais de graduação, dissertações, livros, manuais e resumos publicados em eventos, entre outros.

Tabela 1 – Relação dos estudos sobre sapota-do-Solimões (*Quararibea cordata e Matisia cordata)* conforme autoria e ano de publicação, periódico, local de realização da pesquisa, título e informações da amostra.

Autor e ano de publicação	Periódico	Local de realização da pesquisa	Título	Informações da amostra
Braga et al., 2003	Revista do Programa de Ciências Agro-Ambientais	Instituto Nacional de Pesquisas Amazônicas e Universidade Estadual Paulista	Caracterização físico-química da sapota-do-solimões (*Quararibea cordata* (Humb. & Bonpl.) Vischer, Bombacaceae)	Somente sapota (Brasil)
Alegría; Hoyos; Prado, 2005	Facultad de Ciencias Agropecuarias	Universidad del Cauca	Evaluación del comportamiento de la pulpa del fruto del zapote (*Matisia cordata*) frente a procesos de trasformación agroindustrial	Somente sapota (Colômbia)
Leterme et al., 2006	Food Chemistry	Universidad Nacional de Colombia	Mineral content of tropical fruits and unconventional foods of the Andes and the rain forest of Colombia	68 espécies, entre elas sapota (Colômbia)
Alegría; Hoyos; Prado, 2007	Facultad de Ciencias Agropecuarias	Universidad del Cauca	Características físicoquímicas de dos variedades del fruto del zapote (*Matisia cordata*) comercializadas en el departamento del Cauca	Somente sapota (Colômbia)
Murillo; Meléndez-Martínez; Portugal, 2010	Food Chemistry	Universidad de Panama	Screening of vegetables and fruits from Panama for rich sources of lutein and zeaxanthin	74 frutas e legumes, entre elas sapota (Panamá)
Carvalho et al., 2012	Ciência e Agrotecnologia	Universidade Federal de Goiás	Development and antioxidant capacity of sapota pulp jelly (*Quararibea cordata* Vischer)	Somente sapota (Brasil)
Murillo et al., 2013	Food Chemistry	Universidad de Panama	Native carotenoids composition of some tropical fruits	6 frutas tropicais, entre elas sapota (Panamá)
Carvalho; Damiani; Asquieri, 2014	Revista Verde de Agroecologia e Desenvolvimento Sustentável	Universidade Federal de Goiás	Evaluation of physical and chemical parameters of the Sapota (*Quararibea cordata* Vischer): A fruit of the Amazon Brazilian	Somente sapota (Brasil)
Céron et al., 2014	Journal of Food Engineering	Universidad Nacional de Colombia	Process synthesis for antioxidant polyphenolic compounds production from *Matisia cordata* Bonpl. (zapote) pulp	Somente sapota (Colômbia)
Berto et al., 2015	Food Research International	Univercity of Porto	Bioactive compounds and scavenging capacity of pulp, peel and seed extracts of the Amazonian fruit *Quararibea cordata* against ROS and RNS	Somente sapota (Brasil)
Castilho; Moreno; Ramírez, 2016	Solidary Engineering	Universidad Santiago de Cali	Evaluation of Cu, Mg, Fe and Na metal contents in the sapote (*Quararibea cordata*) from Valle del Cauca, Colombia.	Somente sapota (Colômbia)

Fonte: (AUTOR, 2017).

2.1.1 Apresentação e utilização da fruta

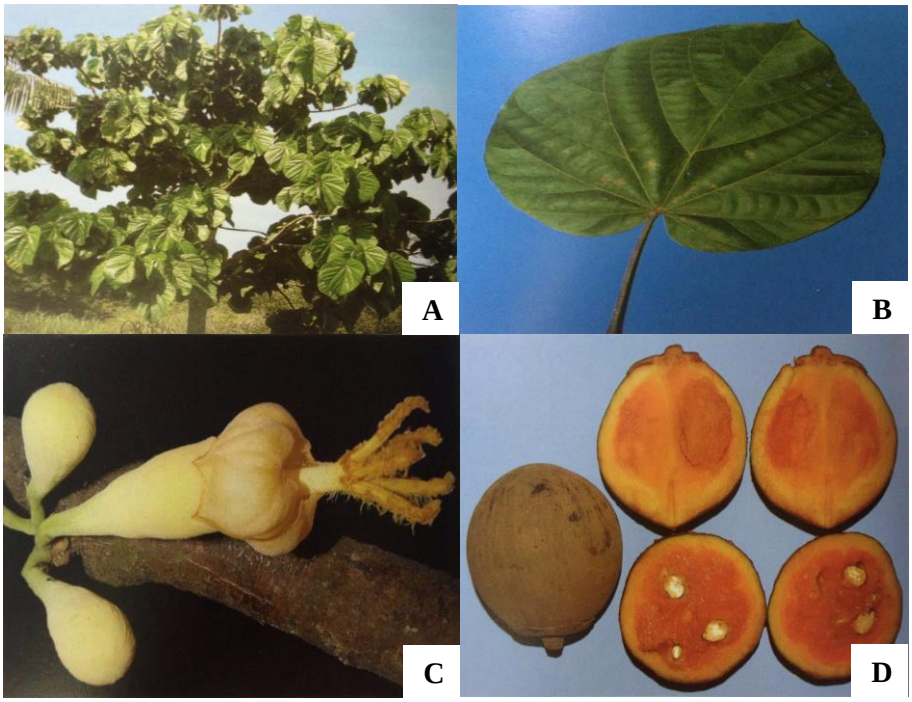
É uma árvore de grande porte podendo crescer até a altura de aproximadamente 40 a 45 m e sua frutificação inicia com 6 a 8 anos após o plantio (FAO, 1986). Possui folhas grandes, de até 50 cm de comprimento, e flores de coloração branco-rosada que surgem de agosto a novembro. O fruto possui forma ligeiramente ovoide ou, às vezes, globoso, com 7 a 15 cm de diâmetro longitudinal (comprimento) por 5 a 15 cm de diâmetro transversal (largura). Sua casca é espessa, resistente, marrom-esverdeada e pulverulenta. A polpa é amarela alaranjada, suculenta e abundante, com finas fibras e envolve de 2 a 5 sementes de formato cuneiformes, verde-castanhas, duras e espessas. É bastante apreciada por seus frutos de grande tamanho, se comparado às demais frutas da região (CLEMENT, 1989; CAVALCANTE, 1991; BRASIL, 2002; PAOLI; NASCIMENTO, 2004).

A polpa é a parte comestível utilizada para consumo *in natura* ou na forma de sucos, entretanto, é possível a preparação de doces em calda com a parte interna da casca (BRAGA et al., 2003). Sensorialmente o fruto possui aroma adocicado e suave, além de, agradável sabor próprio, e quando consumida pela primeira vez, lembra o sabor de frutas como manga e mamão, relatado por Cavalcante (1991), coco e abacate, observado por Sousa e Braga (1994) e Braga et al. (2003).

Alegría, Hoyos e Prado (2005) relataram a utilização da sapota, na Colômbia, na elaboração de sucos, refrescos, saladas, doces, compotas e como saborizante em bebidas. A polpa apresenta grande potencial industrial e já foram estudados, no Brasil, a produção de geleia e sorvete (CARVALHO et al., 2012; MAGALHÃES, 2012), iogurte, no Peru (DEL AGUILA VALERA, 1990).

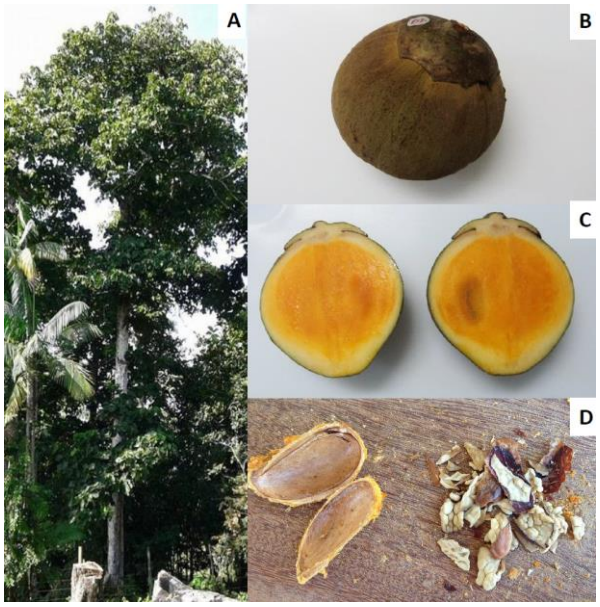
A Figura 1 mostra imagens fotográficas da árvore sapotazeira, folha, flor e fruto publicados em um livro sobre “Frutos nativos da Amazônia: comercializados nas feiras de Manaus – AM”, que dedica um capítulo para a sapota-do-Solimões (RABELO, 2012). E a Figura 2 apresenta imagens de uma sapotazeira de Tefé, Amazonas, Brasil, local da coleta dos frutos, a sapota-do-Solimões inteira e cortada na direção longitudinal e do tegumento e semente.

Figura 1 – Sapota-do-Solimões (*Quararibea cordata*). A: Sapotazeira; B: Folha da sapotazeira; C: Flor da sapotazeira; D: Fruto da sapotazeira.



Fonte: (RABELO, 2012).

Figura 2 – Sapota-do-Solimões (*Quararibea cordata*). A: Sapotazeira, Tefé, Amazonas, Brasil; B: Sapota-do-Solimões inteira; C: Sapota-do-Solimões corte na direção longitudinal; D: Tegumento e semente.



Fonte: (AUTOR, 2015).

2.1.2 Característica física e rendimento percentual de partes do fruto

Um estudo realizado com frutos maduros coletados em Goiânia, Goiás, realizou a avaliação visual e descreveu que a fruta possui casca grossa e resistente, de cor marrom-esverdeada, a polpa é alaranjada, fibrosa e suculenta, contendo 4-5 sementes cuneiformes (CARVALHO; DAMIANI; ASQUIERI, 2014), o que é consistente com os achados de Shanley e Medina (2005), ao observarem sapotas provenientes da região Amazônica.

Frutas inteiras apresentaram massa média de 595,23 g (CARVALHO; DAMIANI; ASQUIERI, 2014) equivalente à encontrada por Braga et al. (2003), que obtiveram dados que variaram de 373 g a 1088 g, estudando sapota da região de Tefé, Amazonas. A Empresa Brasileira de Agropecuária (CARVALHO; MÜLLER, 2005), encontrou em frutos coletados em Belém, Pará, peso médio de 882,4 g. É possível que na bacia Amazônica a sapota apresente maior tamanho do fruto do que em outras áreas (WHITMAN, 1976). Portanto, é provável que o melhor desenvolvimento do fruto esteja na região de ocorrência natural, pois as condições climáticas e de solo são fundamentais para tais características.

Carvalho e Müller (2005) encontraram um rendimento de 25,4% para casca, 72,3% para polpa e 2,3% para sementes. Os diâmetros longitudinal e transversal médio encontrados por Braga et al. (2003) foram de 10,95 cm e 10,85 cm, respectivamente. Carvalho e Müller (2005) encontraram valores médios de 12,9 cm e 11,8 cm, respectivamente.

2.1.3 Característica físico-química

Análises físico-químicas da polpa revelaram que a sapota apresenta, em média, 7,06% de açúcares totais, 2,88% de açúcares redutores, 4,18% de sacarose, pH de 6,83, 0,11% de acidez titulável total, 0,0013 mg/g de ácido málico, 0,009 mg/g eq. de ácido cítrico e 12,20% de sólidos solúveis (CARVALHO; DAMIANI; ASQUIERI, 2014).

Céron et al. (2014), encontraram pH de 7,5 na polpa de sapotas colombianas e 15,9 ºBrix, enquanto Alegría, Hoyos e Prado (2007), relataram pH de 6,8 e 6,5 para sapotas Caucanas e Equatorianas, respectivamente, assim como 10,9% e 9,0% para sólidos solúveis. De forma geral, a sapota pode ser considerada boa fonte de sólidos solúveis, com baixa acidez e elevada relação sólidos solúveis totais e acidez total titulável que a caracterizam como fruto de sabor doce e suave (BRAGA et al., 2003).

A polpa da sapota apresenta um bom potencial para processamento agroindustrial devido suas propriedades físico-químicas, pois é abundante em água e açúcares e apresenta baixa acidez (CARVALHO; DAMIANI; ASQUIERI, 2014).

Quanto à composição química, a sapota é bastante diversificada. Um estudo mostrou teor de umidade de 90,75% (CARVALHO; DAMIANI; ASQUIERI, 2014), valor próximo ao encontrado por Alegría, Hoyos e Prado (2007), que estudaram frutos de procedência Caucana (87,15%) e Equatoriana (87,44%), ambas da Amazônia colombiana. Aguiar (1996) encontrou um valor de 82,5% para o teor de umidade nas frutas da Amazônia brasileira.

Carvalho, Daminani e Asquieri (2014) observaram que sapota é um fruto com umidade elevada o que promove a rápida deterioração sugerindo um potencial das frutas para a industrialização, já que a sua perecibilidade é alta. Assim, o processamento de frutas na preparação de doces, sucos e néctares é essencial para a sua conservação e disponibilidade para os mercados nacional e internacional.

Resultados obtidos por Carvalho, Damiani e Asquieri (2014) mostram que a sapota possui 36,74 Kcal em 100 g de fruta. Já trabalhos realizados com sapotas da região Amazônica trazem valores maiores, como o encontrado na tabela de composição de alimentos da Amazônia (AGUIAR, 1996) que apontam 68,8 Kcal em 100 g, sendo 15,3 g de carboidratos, 0,4 g de lipídios e 1,0 g de proteína.

De acordo com Luzia e Jorge (2011), a composição química dos frutos pode ser influenciada por vários fatores, incluindo a variedade, cultivar, maturidade, condições climáticas e geográficas de produção, manipulação, durante e pós-colheita, processamento e armazenamento. Além disso, o genótipo de espécies, das condições de crescimento e a interação entre as características genotípicas e ambientais podem também influenciar diretamente a composição dos frutos.

Braga et al. (2003) verificaram 1612,53 UI de vitamina A, outras vitaminas quantificadas no fruto foram tiamina 0,02 mg, riboflavina 0,09 mg, niacina 0,62 mg e ácido ascórbico 8,90 mg (VILLACHICA, 1996).

O conteúdo de mineral da sapota-do-Solimões encontrado em um estudo sobre frutas tropicais e alimentos não convencionais da Colômbia, mostra que a sapota é rica em cálcio, 50 mg/100 g de porção comestível. Os demais minerais quantificados e expressos em mg/100 g de porção foram fósforo (14-20), potássio (368-371), magnésio (15-16), sódio (3-4), cloro (44-46), enxofre (8-10), manganês (0,12-0,25), zinco (0,15-0,24), ferro (0,30-0,59), cobre (0,11-0,19) e níquel (0,02-0,03) (LETERME et al., 2006).

O total de fibras alimentares na sapota da região de Goiânia foi de 11,94%, sendo 7,16% de fibras solúveis e 4,77% de fibras insolúveis (CARVALHO; DAMIANI; ASQUIERI, 2014). Observa-se que mais de 50% das fibras totais encontradas são solúveis e estas apresentam propriedades de diminuição da absorção de ácidos biliares, têm atividade hipocolesterolêmica e de redução da insulinemia (GONÇALVES et al., 2007). As fibras solúveis possuem a capacidade de reter água e formar géis e servem de substrato para a fermentação de bactérias colônicas (QUINATO; DEGÁSPARI; VILELA, 2007).

2.1.4 Compostos bioativos

A importância nutricional da sapota deve-se à presença de grandes quantidades de carotenoides, especialmente porque alguns deles são precursores de vitamina A (CARVALHO; DAMIANI; ASQUIERI, 2014). O altíssimo conteúdo de zeaxantina na sapota foi notável em um trabalho realizado no Panamá sendo o conteúdo total de carotenoides de 95,4 μg/g, desses 46,2 μg/g era zeaxantina, também foi encontrado 2,2 μg/g de luteína (MURILLO; MELÉNDEZ-MARTINEZ; PORTUGAL, 2010).

Murillo et al. (2013) estudaram a composição de carotenoides de frutas tropicais nativas do Panamá e verificaram a presença de 22 carotenoides na sapota, incluindo β-caroteno (23,3%), α-criptoxantina (2,6%), e β-caroteno-5,6-epóxido (4,1%); além disso, revelou a presença de 10 di-ésteres diferentes de zeaxantina (42,9%), incluindo seus ésteres com ácidos graxos insaturados. Levando-se em conta a grande quantidade de β-caroteno detectado nesta fruta, ela apresenta potencial de pró-vitamina A e pode, por conseguinte, ser considerado uma importante fonte de vitamina A na dieta. Este estudo é útil para fornecer informações sobre os frutos estudados, para atualizar as tabelas de composição de carotenoides de frutas tropicais e promover o consumo desses frutos localmente e no exterior.

Em um estudo mais recente, Berto et al. (2015), identificaram e quantificaram 5 carotenoides em extratos alcoólicos obtidos de polpa de sapota-do-Solimões adquiridas em Manaus, Amazonas, sendo encontrado para polpa um total de 6 μg/g de extrato em base seca, sendo os principais equivalentes de zeaxantina e β-caroteno, respectivamente, 2,5 e 2,2 μg/g de extrato em base seca, perfazendo aproximadamente 80% do total dos carotenoides identificados e quantificados.

O interesse em compostos fenólicos tem aumentado e estão sendo utilizados com propriedades antioxidantes e anti-inflamatórias. Céron et al. (2014) fizeram uma abordagem sistemática para a síntese de processo de produção de compostos fenólicos de polpa de

Matisia cordata. Primeiramente, foi realizado a quantificação de compostos fenólicos totais e atividade antioxidante total na polpa do fruto *in natura* que foram de 358,12 mg EAG.100 g^{-1} peso fresco e 8,9 μmol TE mL^{-1}, respectivamente. Após a utilização de alternativas de processo de pré-tratamento (secagem em bandeja e liofilização), extração (convencional por solvente e extração com fluido supercrítico) e concentração (destilação a vácuo e ultrafiltração com nanofiltração), concluiu-se que a via ótima para obter alta produção e baixos custos operacionais foi: secagem em bandeja, extração com fluido supercrítico e ultrafiltração com nanofiltração, que apresentou 244,17 mg EAG.100 g^{-1} peso fresco para compostos fenólicos totais e atividade antioxidante total de 14,34 μmol TE mL^{-1}.

Carvalho, Damiani e Asquieri (2014) quantificaram o teor de fenólicos na polpa da sapota e encontraram valores de 6,31 mg EAG.100 g^{-1} em extrato alcoólico e 15,06 mg EAG.100 g^{-1} em extrato aquoso. O potencial antioxidante, expresso em % de descoloração do radical DPPH, total foi 27,85, para o extrato alcoólico 10,65 e para o extrato aquoso 16,27 (MAGALHÃES, 2012).

3 OBJETIVOS

3.1 OBJETIVO GERAL

Caracterizar física e quimicamente as partes da fruta sapota-do-Solimões (casca, polpa e sementes), a estabilidade após processamento da polpa de fruta e os compostos bioativos e voláteis da polpa obtida da fruta em diferentes estádios de maturação.

3.2 OBJETIVOS ESPECÍFICOS

Caracterizar a casca, a polpa e as sementes da fruta sapota-do-Solimões quanto a parâmetros físicos, composição química e conteúdo mineral.

Acompanhar a estabilidade física, química e microbiológica de polpas pasteurizadas e não pasteurizadas de sapota-do-Solimões preservadas pelo frio (congelamento e refrigeração) durante o armazenamento por 180 dias.

Avaliar os parâmetros físicos, de qualidade, composição química, perfil lipídico, compostos bioativos e voláteis da polpa de sapota-do-Solimões em diferentes estádios de maturação e relacionar com a aceitação sensorial das polpas.

4 ARTIGOS CIENTÍFICOS INTEGRADOS

ARTIGO 1 – PHYSICAL QUALITY, CHEMICAL COMPOSITION AND MINERAL CONTENT OF PEEL, PULP AND SEEDS OF SAPOTA-DO-SOLIMÕES

Esse artigo foi submetido ao periódico International Food Research Journal, ISSN 1985-4668, Área de avaliação em Ciência de Alimentos, Classificação B1 e encontra-se "sob revisão".

ARTIGO 2 – INFLUENCE OF PRESERVATION BY HEAT AND COLD ON THE PHYSICOCHEMICAL AND MICROBIOLOGICAL CHARACTERISTICS, BIOACTIVE COMPOUNDS OF PULP FROM SAPOTA-DO-SOLIMÕES (*Quararibea cordata*)

Esse artigo foi publicado no periódico CyTA: Journal of Food (online), ISSN 1947-6345, Área de avaliação em Ciência de Alimentos, Classificação B1. (http://dx.doi.org/10.1080/19476337.2017.1340342).

ARTIGO 3 – EVALUATION OF THE CHEMICAL AND VOLATILE COMPOSITION OF SAPOTA-DO-SOLIMÕES (*Quararibea cordata*) PULP AT DIFFERENT RIPENING STAGES

Pretende-se submeter esse artigo no periódico Food Research International, ISSN 0963-9969, Área de avaliação em Ciência de Alimentos, Classificação A1.

4.1 ARTIGO 1

Physical quality, chemical composition and mineral content of peel, pulp and seeds of sapota-do-Solimões

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Abstract

The sapota-do-Solimões is a fruit found in the Amazon region; it has attracted interest for exportation because of its taste and thick peel, which means it is easier to transport. The aim of this study was to perform the biometry of sapota-do-Solimões and to chemically characterise the different parts of the fruit. The sapotas-do-Solimões were acquired in the city of Tefé, Brazil. They were harvested at a ripe stage and evaluated: diameters, mass of the whole fruit, peel, pulp and seeds, and number of seeds. The percentage yields were calculated. The chemical composition and the mineral content of the following parts of the sapota-do-Solimões were analised. The percentages of peel, pulp and seeds were respectively 53.2%, 39.6% and 7.2%. The transverse diameters of the fruits were positively correlated with the mass of the whole fruit. The chemical composition of 100 g of pulp of sapota-do-Solimões was: 85.01% moisture; 0.79% ash; 0.67% protein; 0.10% lipids, 4.10% dietary fibre; 9.34% carbohydrate and 40.94 Kcal. The mineral magnesium in the pulp showed the greatest relevance. The sapota-do-Solimões showed a high percentage of peel. In all the fruit parts, it was observed a high content of dietary fibre. The seeds contained the highest mineral content.

Keywords: *Quararibea cordata*, amazonian fruit, edible and inedible parts, dietary recommendations

Introduction

The sapota-do-Solimões, Q*uararibea cordata* (Humb. and Bonpl.) Vischer, is a species that belongs to the Bombacaceae family. It is native to the Peruvian and Colombian Amazonian

regions (Hodge, 1960; Robyns, 1964) and also the western part of the Brazilian Amazon near the city of Tefé on the River Solimões (Cavalcante, 1991). It is grown in the mid to upper regions of the river Solimões (Van Leeuwen *et al.*, 2009) and has been cultivated by the Ticuna indigenous people over the last 4,000 years (Kerr and Clement, 1980).

The sapota is a typically Amazonian plant and is one of the native genetic resources in the region, which is an important centre for the domestication of plants by the Ticuna people. The Ticuna reinforce plant selection, i.e. all fruit or other edible products that are particularly large or tasty are divided between the tribe and the seeds are planted. Given this positive selection, which depends on the size of the fruit, the above definition, although simple, is useful (Kerr and Clement, 1980).

The sapota is frequently found in the wild state in primary forest on land and it requires good fertility and protection against competition from other plants (Van Leeuwen *et al.*, 2009). It is a large tree that can grow to a height of about 40-45 m; fruiting starts 6-8 years after planting (FAO, 1986).

The tree has large leaves, up to 50 cm long, and white-pinkish flowers that emerge from August to November. The fruit is slightly ovoid in form or sometimes globose and is 7-15 cm long and 5-15 cm in diameter. Its peel is thick, tough, greenish-brown in colour and powdery. The pulp, which is orange-yellow in colour, juicy and plentiful, is full of fine fibres and contains 2-5 cuneiform-shaped seeds which are green-brown in colour, hard and thick (Clement, 1989; Brasil, 2002).

A combination of *in situ* and *ex situ* conservation makes it possible to study the conservation of this fruit species. The sapota tree presents fruits that range from 150 to 1000 g in weight; when mature trees are grown in fertile soil they can withstand an average of 1000 fruit that weigh from 300 to 400 g (Kerr and Clement, 1980). The tree bears fruit from January to May and the fruits are generally sold for high prices in the city of Manaus, Amazonas, Brazil. This species is of interest to farmers in the region because it has the potential to be grown in farms and agroecological systems; however, the tree needs careful management (Rabelo, 2012).

Sapotas have been attracting increasing interest for exportation because of their excellent taste and the fact that their fairly thick peel aids transport (Sousa and Braga, 1994; Braga *et al.*, 2003). The quality characteristics for this fruit are due to its appearance, its flavour and aroma, but the quality of the fruit can be prejudiced by pests, wind and poorly performed harvesting. In terms of the food industry, the advantages of this fruit are not restricted to its chemical characteristics but also include its physical characteristics (Nascimento, 2008). There are no data on the mineral content the inedible parts of sapota-do-Solimões as peel and

seeds. The aim of this study was to perform the biometry of sapota-do-Solimões and to chemically characterise the different parts of the fruit (peel, pulp and seeds).

Materials and Methods

Raw materials

The collection was carried out in a private area in the community of Vila Vale, located near the experimental area of the Mamirauá Sustainable Development Institute. The geographical coordinates of the city of Tefé, Amazonas, Brazil, where the sample was collected, are latitude 3º 21'15" S and longitude 64º42'41" W, with an altitude of approximately 75 m. According to the Köppen-Geiger classification, the climate is Af type, i.e. equatorial, tropical and humid, with an annual average temperature of 26.85°C and average rainfall of 211.54 mm. The soil is classified as Plinthosol, with reddish colours.

The fruits were collected the tree in an area that has 15 plants (individuals) of about 30 m in height and approximately 50 years old, and evaluated when they were fit for consumption, i.e. at the ripe stage in March 2015. One hundred and five fruits were collected and transported in thermal boxes to the Department of Technology and Food Science at the Federal University of Santa Maria (UFSM), where the experiment was conducted.

The fruits were selected for the absence of defects, pests and diseases, had their surfaces washed with mild detergent to remove dirt, and were rinsed under running water. Sanitisation was subsequently performed with 50 mg/Kg chlorine and an immersion time of 30 minutes.

Biometry

Seventy-five *in natura* fruits were analysed individually in terms of the following features: longitudinal and transverse diameters (cm) using Eccofer® digital calipers; the mass of the whole fruit (g), the mass of the peel (g), the mass of the pulp (g), the mass of the seeds (g) using a digital scale; and the number of seeds. The percentages of yield from the peel, pulp and seeds were calculated according to the technical statement of EMBRAPA (Carvalho and Müller, 2005).

Chemical composition

The fruits were dried in an oven with forced air circulation at a temperature of 60°C for 36 hours. The pre-dried samples were crushed in a micro mill that was cooled to 4°C (Quimis, model Q 298A21, Brazil). The chemical composition was subsequently determined from the following parts of the sapota-do-Solimões: peel, pulp and seeds (seeds with integument - SWI

and seeds without integument - SWOI), were used methodologies of the AOAC (1998). The moisture determination was performed by drying in an oven at 105°C to constant weight. The ash was assessed by incineration in a muffle furnace at 550°C. The protein content was determined by the Kjeldahl method. The total lipids were obtained by extraction of the ethereal fraction using Soxhlet apparatus. The fraction of total dietary fibre was determined by the enzymatic gravimetric method. Carbohydrates were obtained by difference. Total metabolizable energy, expressed in kilocalories (kcal), was calculated considering Atwater conversion factors

Mineral content

The total content of the macro minerals, P (phosphorus), K (potassium), Ca (calcium), Mg (magnesium) and S (sulphur), and the micro minerals B (boron), Cu (copper), Fe (iron), Mn (manganese) and Zn (zinc) were determined. The measurements of calcium, magnesium, copper, iron, manganese, zinc and potassium were performed by atomic absorption spectrophotometry. Those for phosphorus and boron were performed by visible spectrometry and that of sulphur was performed by turbidimetry. The digestions that were used were nitric perchloric acid (HNO_3 + $HClO_4$) [3:1], except for boron, which was dry digestion. The wavelengths used for the minerals were as follows: P (660.0 nm), K (466.49 nm), Ca (422.67 nm), Mg (285.21 nm), S (420.00 nm), B (460.00 nm), Cu (324.75 nm), Fe (248.33 nm), Mn (279.48 nm) and Zn (213.86 nm) (Tedesco *et al.*, 1995; Miyazawa *et al.*, 1999).

Dietary recommendations

The percentage contribution of some nutrients in the samples of parts of sapota-do-Solimões in relation to the recommended daily intake (RDI) was calculated for an adult, using the values set by the Technical Regulation on the Recommended Daily Intake (RDI) of protein, vitamins and minerals, of the National Health Surveillance Agency - ANVISA, Brazil, for healthy population (Brasil, 2005).

Statistical analysis

The results were expressed as mean ± standard deviation. ANOVA was performed for the biometric variables. The Pearson correlation coefficient was calculated because the variables had a normal distribution according to the Kolmogorov-Smirnov and Lilliefors tests. The classification of the intensity of the correlation for $p < 0.01$ is considered as either very strong ($r \pm 0.91$ to ± 1.00), strong ($r \pm 0.71$ to ± 0.90), average ($r \pm 0.51$ to ± 0.70) or weak ($r \pm 0.31$

to ± 0.50) (Guerra and Oliveira, 1999). In the assessment of chemical composition the t-test was used to examine whether there was a significant difference on the part of the seeds of the sapota-do-Solimões in relation to the seeds with integument and the seeds without integument. All the statistical analyses were performed using version 7.0 of the Statistica software programme.

Results and Discussion

Morphological characteristics

The general descriptive analysis of the variables analysed in relation to the sapota-do-Solimões are presented in Table 1.

Table 1. Biometric characteristics, number of seeds, percentage yields of peel, pulp and seeds of sapota-do-Solimões (*Quararibea cordata*).

Measurements	Sapota-do-Solimões
Mean of longitudinal diameter (LD)* (cm)	10.75 ± 7.73
Mean of transversal diameter (TD)** (cm)	9.57 ± 4.81
Mean of mass of whole fruit (MWF) (g)	511.00 ± 63.88
Mean of mass of peel (MPE) (g)	263.00 ± 44.56
Mean of mass of pulp (MPU) (g)	197.00 ± 50.97
Mean of mass of seeds (MS) (g)	35.00 ± 7.67
Mean of number of seeds (No.)	5.00 ± 0.00
Sum of the means of the masses of the parts (g)	495.00 ± 62.73
Percentage of peel (%)	53.20 ± 7.30
Percentage of pulp (%)	39.60 ± 7.60
Percentage of seeds (%)	7.20 ± 1.69

*Longitudinal diameter (LD) = length; **Transverse diameter (TD) = width. Values expressed as mean ± standard deviation.

The averages for the longitudinal and transverse diameters were 10.75 cm and 9.57 cm, respectively. These values were similar to those found in another study, which were 10.95 cm and 10.85 cm, respectively (Braga *et al.*, 2003). Another study found respective average values of 12.9 cm and 11.8 cm in sapotas-do-Solimões from the city of Belém in the Brazilian state of Pará (Carvalho and Müller, 2005). These results demonstrate that there is uniformity between fruit from both regions.

In the present study the whole fruits had an average weight of 511 g, which was similar than the value of 595.23 g that was found in another study (Carvalho *et al.*, 2014). Other studies obtained values that ranged from 373 g (minimum) to 1088 g (maximum), for sapota from the Tefé region in Amazonas state (Braga *et al.*, 2003) and an average weight of 882.4 g was

found for fruits collected in Belém, Pará (Carvalho and Müller, 2005). It is possible that in the Amazon Basin sapotas-do-Solimões are larger than in other areas (Whitman, 1976) because the climate and soil conditions are fundamental for the development of this fruit. However, the sapotas-do-Solimões used in the present study showed a lower than average mass for the whole fruit, which reduced the yield when processing the fruit.

The mean weights for the peel (263 g), pulp (197 g) and seeds (35 g) were in accordance with other studies (Sousa and Braga, 1994; Braga *et al.*, 2003; Carvalho *et al.*, 2014). The percentages found in the present study for peel, pulp and seeds (53.2%, 39.6% and 7.2% respectively) were different from those found in another study (Carvalho and Müller, 2005), which found a yield of 25.4% for peel, 72.3% for pulp and 2.3% for seeds. This demonstrates that the sapotas-do-Solimões in the Tefé region have less pulp and more peel, thus requiring more fruits to achieve a similar yield when processing. Furthermore, the removal of the pulp can influence the yield can take as part of the peel together.

The estimates of the Pearson correlation coefficients between the variables for the biometric features of sapotas-do-Solimões are shown in Table 2.

Table 2. Pearson's correlation for the biometric variables of longitudinal diameter (LD), transverse diameter (TD), mass of the whole fruit (MWF), mass of the peel (MPE), mass of the pulp (MPU) and mass of the seeds (MS) of sapota-do-Solimões (Q*uararibea cordata*).

Variables	LD (mm)	TD (mm)	MWF (g)	MPE (g)	MPU (g)	MS (g)
LD (mm)	1					
TD (mm)	0.124^{ns}	1				
MWF (g)	0.481^{**}	0.768^{**}	1			
MPE (g)	0.027^{ns}	0.625^{**}	0.577^{**}	1		
MPU (g)	0.518^{**}	0.389^{**}	0.695^{**}	-0.164^{*}	1	
MS (g)	0.27^{**}	0.008^{ns}	0.165^{*}	0.114^{ns}	-0.054^{ns}	1

*5% level of significance; **1% level of significance; ns: not significant.

The correlations between the longitudinal diameter (LD) of the fruit and the mass of the whole fruit (MWF) and the mass of the seeds (MS) were positive although weak. The correlation between the longitudinal diameter (LD) of the fruit and the mass of the pulp (MPU) was positive and average; thus, it can be said that the larger the longitudinal diameter of the largest the greater the mass of the pulp. The transverse diameter (TD) of the fruits was positively correlated with the mass of the whole fruit (MWF), the mass of the peel (MPE) and the mass of the pulp (MPU). These correlations were respectively strong, medium and weak, indicating that the greater the transverse diameter of the fruit the greater the mass of the whole

fruit and the mass of the peel. The mass of the whole fruit (MWF) was positively correlated with all the other variables and it was possible to verify that the greater the mass of the whole fruit the greater the mass of the pulp. The choice of heavier fruits to harvest by rural populations allows the fruits to obtain more pulp and so consumers should choose fruits with a larger longitudinal diameter. Such fruits will consequently have a higher pulp yield as this feature cannot be measured at the time of purchase.

Another study (Sousa and Braga, 1994) that analysed the biometric parameters of sapota-do-Solimões from the Tefé region of Amazonas found a strong positive correlation between the variables of the mass of whole fruit (MWF) and transverse diameter (TD). When the mass of the peel (MPE) was correlated with mass of the pulp (MPU), a positive correlation was found, which was contrary to the finding in the present study; however, both correlations were weak. In the present study, the negative correlation between the mass of the peel and the mass of the pulp indicated that these variables were reversed, i.e. a reduction in the mass of the peel increased the mass of the pulp and vice versa.

Chemical composition

Table 3 shows the results of the chemical composition for the fruits of sapota-do-Solimões separated into the following four fractions: peel (PE), pulp (PU) and seeds (seeds with integument - SWI and seeds without integument - SWOI).

Table 3. Chemical composition of the parts of sapota-do-Solimões (*Quararibea cordata*) in 100 g of *in natura* sample.

Constituents g%	Peel	Pulp	Seeds	
			SWI	SWOI
Moisture	85.26 ± 0.14	85.01 ± 0.21	56.41^{a} ± 0.13	52.25^{b} ± 0.09
Ash	1.16 ± 0.09	0.79 ± 0.13	1.36^{b} ± 0.08	2.06^{a} ± 0.07
Protein	0.81 ± 0.09	0.67 ± 0.11	2.85^{b} ± 0.50	4.97^{a} ± 0.27
Lipids	0.07 ± 0.01	0.10 ± 0.05	1.19^{b} ± 0.49	2.67^{a} ± 0.12
Dietary fibre	10.36 ± 0.01	4.10 ± 1.14	28.75^{a} ± 0.28	18.98^{b} ± 0.92
Soluble fibre	1.06 ± 0.01	0.44 ± 1.32	1.80^{a} ± 0.28	1.68^{a} ± 0.08
Insoluble fibre	9.30 ± 0.49	3.66 ± 0.18	26.95^{a} ± 0.76	17.30^{b} ± 0.83
Carbohydrates	2.34 ± 0.34	9.34 ± 1.18	9.44^{b} ± 0.76	19.06^{a} ± 0.68
Calories (Kcal)	13.23 ± 1.48	40.94 ± 4.20	59.83^{b} ± 3.53	120.21^{a} ± 2.96

SWI: seeds with integument; SWOI: seeds without integument. Values expressed as mean ± standard deviation. Different letters in the same line indicate significant at 1% level of significance by T-test for seeds SWI and SWOI.

Table 3 shows that moisture was the major component of the fruit and the largest concentration of water was in the peel, similar by the pulp. Another study (Carvalho *et al.*,

2014) found moisture levels of 90.75%, a value close to that found in caucana fruit (87.15%) and Ecuadoria fruit (87.44%) both of which are found in the Colombian Amazon (ALEGRÍA *et al.*, 2007). Another study found moisture content of 82.5% in fruit from the Brazilian Amazon (Aguiar, 1996). This suggests a potential for the processing of such fruits because their level of perishability is high. Consequently, the processing of these types of fruits in the preparation of sweets, juices and nectars is essential for their conservation and also to make them available nationally and internationally (Carvalho *et al.*, 2014).

The ash content varied from 0.79% for the pulp to 2.06% for the seeds without integument (Table 3). These values were higher than those found in another study, both for the peel and the pulp (0.79% and 0.32% for the peel and 0.49% and 0.56%. for the pulp) (Alegría *et al.*, 2007). In terms of pulp, fruits from the Amazonian region of Manaus, Brazil, showed 0.80% ash content, a value that was close to that found in the present study (Aguiar *et al.*, 1980; Luzia and Jorge, 2014). Other research found 0.29% ash in the pulp (Carvalho *et al.*, 2014).

The protein content in the peel (0.81%) and pulp (0.67%) were lower than in other studies for sapota-do-Solimões from the Brazilian Amazon region (1.0% in the pulp) (Aguiar, 1996) and in Colombian fruits (1.52% in the peel of Caucana and 1.33% in the peel of Ecuadoria) (Alegría *et al.*, 2007). When compared with fruits from the region of Goiânia, Goiás, Brazil (0.54% in the pulp) (Carvalho *et al.*, 2014) the results of the present study were higher.

The level of lipids in the peel (0.07%) was similar to the level found by other authors, which was 0.08% and 0.09% (Alegría *et al.*, 2007). In terms of pulp, fruits from Goiânia, Goiás, Brazil contained higher amounts (0.18%) of lipids (Carvalho *et al.*, 2014).

The total dietary fibre, soluble fibre and insoluble fibre was higher in the peel than in the pulp (Table 3). The total fibre found in the pulp of sapota from the Goiânia region of Brazil was 11.94%, of which 7.16% was soluble fibre and 4.77% was insoluble fibre (Carvalho *et al.*, 2014).

The edible part of the sapota-do-Solimões (pulp) contained 9.34% carbohydrates and 40.94 Kcal per 100 g of fruit, similar to the results obtained in another study of sapota, which found 8.24% and 36.74 Kcal per 100 g of fruit (Carvalho *et al.*, 2014).

Regarding the seeds (Table 3), for the fractions of moisture, ash, protein, lipids, dietary fibre, insoluble fibre, carbohydrates and calories, the difference was significant by t-test at a 1% level of significance. In terms of soluble fibre the difference between the seeds with integument and the seeds without integument was not significant.

The chemical composition of fruits can be influenced by several factors including the variety, cultivar, maturity, climate and geographical conditions, handling, during harvest and post-

harvest, as well as processing and storage. In addition, the genotype of the species, growing conditions and the interaction between the genotype and environmental characteristics may also directly influence the composition of fruit (Luzia and Jorge, 2014).

Mineral composition

Table 4 shows the macro and micro levels of the mineral parts of the sapota-do-Solimões. It can be seen that the inedible parts of the sapota-do-Solimões, such as the peel and the seeds, had higher values than the pulp.

Table 4. Mineral content of the parts of sapota-do-Solimões (*Quararibea cordata*) in 100 g of *in natura* sample.

Minerals	Peel	Pulp	Seeds	
			SWI*	SWOI**
Phosphorus (mg)	49.53	37.34	92.84	173.32
Potassium (mg)	322.82	273.80	495.14	572.48
Calcium (mg)	99.20	23.54	61.46	73.53
Magnesium (mg)	29.63	23.69	91.10	159.00
Sulphur (mg)	14.15	10.20	56.66	102.65
Boron (mg)	0.01	0.00	0.04	0.10
Copper (µg)	12.50	8.76	41.84	66.84
Iron (mg)	0.04	0.02	0.08	0.12
Manganese (mg)	0.02	0.01	0.04	0.05
Zinc (mg)	0.01	0.01	0.03	0.07

*SWI: seeds with integument; **SWOI: seeds without integument.

The edible part of the fruit (pulp) contained calcium and magnesium, which are important minerals in nutritional terms in relation to bones and teeth, blood clotting, secretion of hormones, neurotransmitters, as well as being the cofactors of several enzymes (Damodaran *et al.*, 2010). Because the pulp of sapota fruit is a source of minerals it can be consumed in the form of juices, soft drinks, salads, jams, compotes and also as a flavouring in drinks (Alegría *et al.*, 2005). The pulp has a great industrial potential for use in the production of jelly and ice cream (Carvalho *et al.*, 2012; Magalhães, 2012), processed pulp (Monteiro *et al.*, 2017), yoghurt (Del Aguila, 1990) and fermented beverages (Alegría *et al.*, 2005). Consequently, the edible part of the fruit can be used as an ingredient to formulate other products and improve the nutritional composition of those products.

The mineral content depends on the area where the culture, time year in which it was harvested and the degree of maturity fruits (Álvarez-Loayza and Terborgh, 2011). Other authors obtained composition of minerals in the pulp of *Quararibea cordata* was of 0.0034

mg Mg/100g and 0.26 mg Fe/100g, in dry basis. The report includes low content of Mg and higher amounts of Fe (Castilho, Moreno and Ramírez, 2016).

Dietary recommendations

Using the results of this study it was possible to calculate the percentage contributions of some nutrients in the samples of parts of the sapota-do-Solimões in relation to the recommended daily intake (RDI) for an adult (Brasil, 2005), as shown in Table 5. The RDI values were as follows: protein 75 g; lipids 55 g; dietary fibre 25 g; carbohydrates 300 g; calories 2000 Kcal; phosphorus 700 mg; calcium 1000 mg; magnesium 260 mg; copper 900 μg; iron 14 mg; manganese 2.3 mg and zinc 7 mg.

Table 5. Percentage of recommended daily intake (RDI) for an adult in relation to 100 g of *in natura* sample of parts of sapota-do-Solimões (Q*uararibea cordata*).

Nutrients	Peel	Pulp	Seeds	
			SWI*	SWOI**
Protein	1	1	4	7
Lipids	0	0	2	5
Dietary fibre	41	16	115	76
Carbohydrates	1	3	3	6
Calories	1	2	3	6
Phosphorus	7	5	13	25
Calcium	10	2	6	7
Magnesium	11	9	35	61
Copper	1	1	5	7
Iron	0	0	1	1
Manganese	1	0	2	2
Zinc	0	0	0	1

*SWI: seeds with integument; **SWOI: seeds without integument.

The contribution of dietary fibre for the inedible parts was notable, although the contribution of the pulp was also important as it reached 16% of RDI. The level of magnesium in the pulp reached almost 10% of RDI and was the most important mineral for this part of the sapota-do-Solimões.

A prospective solution might be to find ways to transform inedible portions of this fruit, such as the peel, into ingredients to be used in formulations in other foods to add nutritional value, particularly in terms of dietary fibre minerals such as calcium and magnesium.

Conclusion

This study verified that there was little variation in the biometric characteristics of the fruits of sapota-dos-Solimões. The cultivated trees produce homogeneous fruits that make it possible to secure a standard of quality to enable these fruits to be presented to other consumer markets. The sapota-do-Solimões contained more peel than pulp and seeds. The high content of dietary fibre was notable in all parts of the fruit. The level of magnesium in the pulp reached a good percentage of the recommended daily intake and was the most important mineral in relation to this part of the fruit. The seeds contained the highest levels of mineral content, with the exception of calcium, which was found in the peel. Moreover, this is the first report on the mineral content of peel and seeds of sapota-do-Solimões.

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4.2 ARTIGO 2

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Influence of preservation by heat and cold on the physicochemical and microbiological characteristics, bioactive compounds of pulp from sapota-do-Solimões (*Quararibea cordata*)

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ABSTRACT

The aim was to evaluate the influence of preservation by heat and cold on the physicochemical and microbiological characteristics and bioactive compounds of pulp from sapota-do-Solimões (*Quararibea cordata*) for 180 days of storage. The pulps were submitted to the following treatments: freezing; pasteurization + freezing; refrigeration; and pasteurization + refrigeration. The treatments affected the physicochemical parameters during storage. Of particular note was the reduction in water activity, the reduction in pH in the pulps stored under refrigeration, and the lightening in color of the pulps. Ascorbic acid remained stable during freezing, and the levels of total carotenoids were maintained in the pasteurization + freezing treatment. The total phenolics remained stable up to 150 days, and the antioxidant activity decreased during storage for all the treatments. The coliforms were less than 1 log CFU.g^{-1} and *Salmonella ssp.* was absent. The pasteurization + freezing treatment, as well as the freezing treatment, maintained the quality of the pulp for 180 days of storage.

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PALABRAS CLAVE
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Influencia de la preservación térmica sobre las características físico-químicas, microbiológicas y compuestos bioactivos de la pulpa de sapota-do-Solimões (*Quararibea cordata*)

RESUMEN

El objetivo fue evaluar la influencia de la preservación por calor y frío sobre las características físico-químicas y microbiológicas y los compuestos bioactivos de la pulpa de sapota-do-Solimões (*Quararibea cordata*) durante 180 días de almacenamiento. Los frutos fueron despulpados y sometidos a los tratamientos: congelación; pasteurización + congelación; refrigeración; y pasteurización + refrigeración. Los tratamientos afectaron los parámetros fisicoquímicos durante el almacenamiento. Destacan la reducción de la actividad de agua, la reducción del pH en las pulpas almacenadas bajo refrigeración y el aclaramiento en color de las pulpas. El ácido ascórbico se mantuvo estable durante la congelación y los niveles de carotenoides totales se mantuvieron en la pasteurización + congelación. Los fenoles totales permanecieron estables hasta 150 días y la actividad antioxidante disminuyó durante el almacenamiento para todos los tratamientos. Los coliformes fueron menores que 1 log CFU.g^{-1} y *Salmonella ssp.* estuvo ausente. El tratamiento de pasteurización + congelación, así como el tratamiento de congelación, mantuvieron la calidad de la pulpa durante 180 días de almacenamiento.

Introduction

The northern region of Brazil is rich in fruit species which, although they are still not commercially exploited, are of great agro-industrial potential and may represent an important source of employment and income for the local population. The fruits of the sapota tree are globular and have sub-globular berries with a persistent calyx at the upper extremity. The epicarp is fleshy, with a thick consistency and a powdery surface that is brown in color. The flesh is juicy, orange in color, slightly fibrous, with low acidity, a pleasant taste, and considerable amounts of proteins, carotenoids, and minerals (Rabelo, 2012).

In recent decades, the demand for functional foods has led to increased interest in the properties of Amazonian fruits. Thus, the studies of these fruits, as well as the characterization of their bioactive compounds, are challenges that need to be overcome in order to ensure their effective use in agribusiness and the possibility of generating high-quality raw material. The major phenolic in the pulp extract was epicatechin (Berto, Ribeiro, de Souza, Fernandes, & Chisté, 2015).

Products derived from sapota-do-Solimões (*Quararibea cordata*) represent a great opportunity to reach niche markets for exotic products that are nutritious and rich in sources of substances that can maintain good health, as well properties that can prevent disease. Recent studies have demonstrated the antioxidant potential and bioactive compounds present in sapota-do-Solimões (Berto et al., 2015; Céron, Ng, El-Halwagi, & Cardona, 2014; Murillo et al., 2013; Murillo, Meléndez-Martinez, & Portugal, 2010).

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The Brazilian Ministry of Agriculture, Livestock and Supply (MAPA) (Brasil, 2000) defines fruit pulp as an unfermented, non-concentrated, undiluted product that is obtained by crushing fleshy fruits using an appropriate technical process with a minimum content of total solids from the edible part of the fruit, which is specific for each fruit pulp. Brazilian legislation sets out minimum microbiological standards regarding identity and physicochemical characteristics for some types of pulp; however, there are no defined parameters for sapota-do-Solimões pulp.

Several methods can be used to preserve fruit pulp, including those which apply or remove heat (pasteurization and freezing). These methods inhibit microbial growth and enzymatic activity and thereby increase shelf life and microbiological safety (Santos, Salles, Chagas Filho, & Rabelo, 2004). However, they can modify the content of some nutrients such as vitamins and carotenoids.

The preparation of sapota-do-Solimões pulp can improve quality, as well as facilitating distribution and adding value. Consumers are increasingly demanding and have opted for products with a longer shelf life that maintain their sensory and nutritional characteristics during storage (Pinheiro, Cardoso, Chaves, Oliveira, & Rios, 2011). Thus, the aim of this study was to evaluate the influence of preservation using heat and cold on the physicochemical and microbiological characteristics, as well as the bioactive compounds of pulp from sapota-do-Solimões storage for 180 days.

Materials and methods

Raw materials

The fruits were collected from a private area in the community of Vila Vale, which is located near the experimental area of the Mamirauá Sustainable Development Institute. The geographical coordinates of the city of Tefé, Amazonas, Brazil, where the samples were collected, are latitude 03°21'15"S and longitude 64°42'41"W, with an altitude of approximately 75 m. According to the Köppen–Geiger classification, the climate is type Af, i.e. humid and equatorial tropical with an annual average temperature of 26.85°C and an average rainfall of 211.54 mm. The soil is classified as Plinthosol with reddish colors. The fruits were collected in an area that had 15 plants (individuals) of about 30 m in height which were approximately 50 years old. The fruits were evaluated in the mature stage in March 2015. A total of 105 fruits were collected and were initially transported via river and then air, totaling 36 h of travel, to the Federal University of Santa Maria and the Department of Technology and Food Science, where the experiments were conducted. Upon receipt, the fruits were selected for the absence of defects, pests, and diseases and then had their surfaces washed with mild detergent to remove dirt. They were then rinsed in running water.

Obtaining the pulp and processing

The following stages were performed to obtain the pulp and to process it (Figure 1).

The fruits were received, prewashed, washed, and then sanitized by immersion in chlorinated drinking water with a chlorine concentration of 50 mg.kg^{-1} and immersion time of 30 min. The fruits were subsequently rinsed, selected, cut, and pulped. The seeds were removed, and the fruit was processed in a blender used to homogenize pulp. After processing, the pulp was packaged in 180 g polypropylene jars and separated according to the following treatments: (T1) freezing; (T2) pasteurization + freezing; (T3) refrigeration; and (T4) pasteurization + refrigeration. For the treatments involving pasteurization (T2 and T4), the method of Monteiro, Amaro, and Bonilha (2005) was used, with modifications. The treatments were subjected to heat treatment by immersing the jars containing pulp in a water bath at a

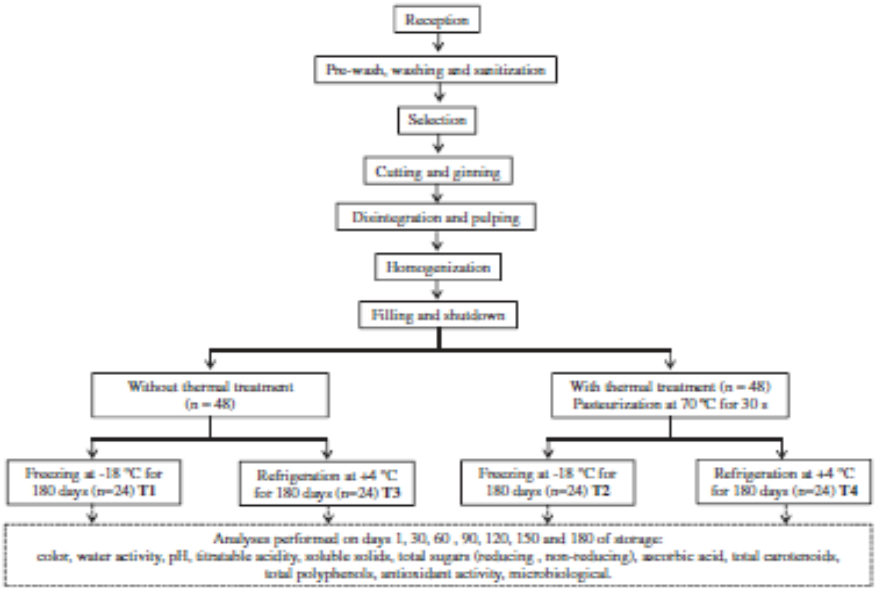

Figure 1. Flowchart of the sequence of operational steps for processing and analyzing of pulp from sapota-do-Solimões (*Quararibea cordata*).

Figura 1. Diagrama de flujo de la secuencia de pasos operativos para procesar y analizar la pulpa de sapota-do-Solimões (*Quararibea cordata*).

temperature of 69–72°C. The internal temperature of the jars was measured with a thermometer at five different points in the water bath, and when the desired temperature was reached, it was maintained for 30 s. The pulps were then immediately stored in a freezer (–18°C) (T1 and T2) or refrigerated (+4°C) (T3 and T4). The samples were analyzed the day after the pulp was obtained and sequentially every 30 days over a period of 180 days of storage.

Color analysis

Color was measured using a Konica Minolta spectrophotometer CM-700d (Osaka, Japan) with color instrumentation technology that used the L*, a*, and b* parameters. The pulp samples were distributed in a sufficient quantity within the glass cell, and the readings were taken from the light-beam of the lens of the spectrophotometer and measured by reflectance. The numerical values of a* and b* were converted into the hue angle (h) and chroma color saturation (c). The results were expressed as L*, which represents the percentage of light ranging from black (0%) to white (100%); a*, where –a* represents direction to green, and +a* represents direction to red; b*, where –b* represents direction to blue, and +b* represents direction to yellow; c (saturation index) and h (hue angle).

Water activity, pH, titratable acidity, and soluble solids

AquaLab® (Series 4 TEV; Decagon Devices Inc., Pullman, USA) equipment was used to measure the water activity. The pH was measured using a Digimed® (Model DM-23, São Paulo, Brazil) digital potentiometer in accordance with the recommendations of the Association of Official Analytical Chemists (AOAC, 1998). The titratable acidity was determined by titration with 0.1 M NaOH to a pink color using 1% phenolphthalein as indicator (AOAC, 1998). The soluble solids were measured directly in an Atago® digital refractometer (Pocket PAL-3 model, Tokyo, Japan) using a scale of 0–93° Brix, with temperature compensation to 20°C, in accordance with the AOAC (1998).

Total, reducing, and nonreducing sugars

In order to determine the levels of total and reducing sugars in glucose, the Lane–Eynon method was employed using Fehling's reagent, as described by the Instituto Adolfo Lutz (IAL, 1985). The nonreducing sugars in sucrose were calculated from the subtraction of the values found for the total and reducing sugars and then multiplied by 0.95. The results were expressed as a percentage (%).

Ascorbic acid and total carotenoids

The ascorbic acid content was determined by the spectrophotometric method at a wavelength equal to 540 nm (Biospectro, model SP-220, São Paulo, Brazil), as described by Cox and Pearson (1976). The results were expressed as mg.100 g^{-1} of pulp. The total carotenoids were determined by the Higby method (1962). The readings were taken using a spectrophotometer (Biospectro, SP-220 model) at a wavelength equal to 450 nm, and the results were expressed in µg.g^{-1} of pulp.

Obtaining the extracts

The extracts for the determination of total phenolics and antioxidant activity were obtained according to the methodology described by Larrauri, Rupérez, and Saura-Calixto (1997), with modifications. The extraction was performed at room temperature (24°C) by taking 5.0 g of each pulp; then 20 mL of 50% ethanol solution was added (first extraction solution); and the mixture that was obtained was homogenized and allowed to stand for 1 h for extraction. After this period, the mixture was centrifuged at 3000 rpm for 10 min and the supernatant that was obtained was filtered and placed in a 50 mL flask protected from light. The precipitate obtained by centrifugation was dissolved in 20 mL of 70% acetone (second extraction solution). This mixture was left to stand for 1 hour and then centrifuged at 3000 rpm for 10 min. The second supernatant that was obtained was mixed with the first, in the same flask, which was completed with distilled water.

Total phenolic compounds

The total phenolics were determined following the method described by Larrauri et al. (1997). The absorbance was read with a spectrophotometer (Biospectro, model SP-220) at 700 nm, using as reference the standard curve of gallic acid $y = 0.0101x - 0.0266$, $R^2 = 0.9963$, which was constructed with concentrations ranging from 5 to 70 mg.L^{-1}. The results were expressed as mg gallic acid equivalent (GAE) per 100 g of extract.

Antioxidant activity by DPPH method

The methodology used was as described by Brand-Williams, Cuvelier and Berset (1995). The following different concentrations of each extract in mg.mL^{-1} were used (100; 50; 25; 12.5; 6.2; 3.1; 1.6; 0.8; 0.4; and 0.2). The readings of the samples were performed using a spectrophotometer (Biospectro, SP-220 model) at a wavelength of 517 nm. The percentage of antioxidant activity (AA%) was calculated by the percentage of uptake of the DPPH (1,1-diphenyl-2-picrylhydrazyl) radical, and the results were expressed in the extract concentration of 0.2 mg.mL^{-1}.

Microbiological analyses

The microbiological analyses were as follows: counts of coliforms, *Salmonella* sp., molds, yeasts, and mesophilic aerobic bacteria at all storage times and methodologies in accordance with the proposals of the American Public Health Association (APHA, 2001).

Statistical analysis

The experiments were conducted using a completely randomized design in split plots with three repetitions. The heat treatments (both with and without pasteurization) represented the plots and the storage temperatures (–18°C and + 4°C) were the sub-plots. Each repetition of the treatments was analyzed at seven storage times (1, 30, 60, 90, 120, 150, and 180 days) in duplicate. The data were subjected to the Shapiro–Wilk test in order to test the normality and Levene's test in order to test the homogeneity of variance that was presupposed by ANOVA (analysis of variance). Not all the variables showed normal distribution and homogeneity of variance. In this case, when some

variables did not present normal distribution and others did, then nonparametric analysis was performed. Consequently, the data were analyzed using the Kruskal–Wallis test to evaluate the difference between the treatments, and Dunn's test was performed to compare the averages of the treatments. The Wilcoxon test was performed to analyze the difference between the times of 1 day and 180 days of storage. All the statistical analyses were performed using Statistica version 7.0 software (Statsoft Inc., Tulsa, USA, 2004). The results were expressed as mean ± standard deviation. The criterion for the selection of the model for the displayed graphics was the *F* test significance ($p < 0.05$) and by the highest value for the coefficient of determination (R^2); a minimum of 0.70 was used (Pimentel-Gomes, 2000). Furthermore, an exploratory analysis of the data using principal component analysis (PCA) was performed to visualize the correlation between the variables and possible groupings between the samples. The Pirouette 3:11 (Woodinville, USA, 2003) statistical program was used. The data matrix consisted of 28 samples and 13 independent variables, which contained the results of the quality parameters, bioactive compounds, and microbiological analyses of pulp from sapota-do-Solimões in relation to the different treatments and storage times. The data for each variable were autoscaled in order to assume the same weight during analysis.

Results and discussion

Table 1 shows that on the first day of storage, the different treatments did not affect the characteristics of water activity, acidity, soluble solids, total sugars, reducing sugars, nonreducing sugars, ascorbic acid, and total phenolics of the pulps. However, the parameters of color, pH, total carotenoids, and antioxidant activity were affected. The differences can be justified by the method of obtaining the pulp because the treatments that were submitted to pasteurization showed changes in color, a reduction in pH, which also affects the color of the product, as well as may have contributed to the oxidation of the carotenoids that resulted in a loss of antioxidant activity (Freire et al., 2009; Rodriguez-Amaya & Kimura, 2004; Santos, Neto, & Donzeli, 2016).

For the color parameters, there was a significant variation from 44.39 to 45.74 between treatments in relation to L*, which indicate a lightening trend. Positive values for a* (17.88–20.20) and b* (26.42–31.54) were observed, and they were attributed to the presence of carotenoids in the pulp; the variations for a* and b* were significant. Carvalho, Damiani, and Asquieri (2014) found values for fresh fruit of 44.90, 18.27, and 43.06 for L*, a*, and b*, respectively. The intensity of color of the pulps represented by Chroma (c) varied significantly from 31.91 to 37.46. The lowest average, which presented the lowest intensity of orange color, color tonality, and hue angle (h), varied significantly from 55.75 to 57.30, indicating the yellow coloring of the fruit.

The physicochemical analyses showed that the sapota pulp had high water activity (0.9919–0.9924); pH that varied significantly from 6.76 to 6.86; and low acidity (0.11–0.13%). Therefore, this type of pulp must be properly processed and stored so that it does not deteriorate quickly. The soluble solids ranged from 12.02% to 12.87% but showed no significant difference, demonstrating that the sapota-do-Solimões pulp was harvested and used at the same degree of ripeness. Total sugars (7.06–7.33%), reducing sugars (2.28–2.35%), and nonreducing sugars (4.54–4.73%) also varied, but did not differ between the treatments. Another study found values of 6.83 for pH, 0.11% for total acidity, 12.20% for soluble solids, 7.06% for total sugars, 2.88% for reducing sugars, and 4.18% for sucrose in the pulp of fresh sapota (Carvalho et al., 2014). Céron et al. (2014) found pH of 7.5 in the pulp of Colombian sapota and 15.9° Brix, while Alegría, Hoyos, and Prado (2007) reported pH of 6.8 and 6.5 for Caucana and Ecuadorian sapota, respectively, as well as 10.9% and 9.0% for soluble solids. In general, the sapota can be considered to be a good source of soluble solids, with low acidity and a high level of total soluble solids and titratable acidity, which characterize it as a fruit with a sweet and mild flavor and potential for agro-industrial processing. It is abundant in water and

Table 1. Physicochemical characteristics and bioactive compounds of pulp from sapota-do-Solimões (*Quararibea cordata*) on day 1 of storage.

Tabla 1. Características fisicoquímicas y compuestos bioactivos de la pulpa de sapota-do-Solimões (*Quararibea cordata*) en el 1 día de almacenamiento.

	Treatments			
Analyses	T1	T2	T3	T4
Lightness (L*)	44.65^{b} ± 1.44	45.74^{a} ± 1.09	45.66^{a} ± 1.99	44.39^{b} ± 2.29
a* parameter	20.07^{a} ± 0.76	20.20^{a} ± 1.18	19.21^{b} ± 1.51	17.88^{c} ± 2.09
b* parameter	31.22^{a} ± 2.19	31.54^{a} ± 2.83	29.53^{b} ± 3.33	26.42^{c} ± 4.12
Chroma (c)	37.12^{a} ± 2.21	37.46^{a} ± 2.97	35.24^{b} ± 3.58	31.91^{c} ± 4.57
Hue angle (h)	57.21^{ab} ± 1.08	57.30^{a} ± 1.20	56.87^{ab} ± 1.21	55.75^{c} ± 1.26
Water activity	0.992^{a} ± 0.001	0.992^{a} ± 0.001	0.992^{a} ± 0.002	0.992^{a} ± 0.001
pH	6.86^{a} ± 0.02	6.78^{b} ± 0.02	6.81^{ab} ± 0.03	6.76^{b} ± 0.02
Titratable acidity[1]	0.11^{a} ± 0.02	0.13^{a} ± 0.02	0.12^{a} ± 0.02	0.13^{a} ± 0.02
Soluble solids[1]	12.6^{a} ± 0.25	12.0^{a} ± 0.67	12.9^{a} ± 0.51	12.6^{a} ± 0.38
Total sugars[1]	7.30^{a} ± 0.36	7.33^{a} ± 0.34	7.06^{a} ± 0.25	7.13^{a} ± 0.46
Reducing sugars[1]	2.34^{a} ± 0.06	2.35^{a} ± 0.10	2.28^{a} ± 0.07	2.33^{a} ± 0.16
Nonreducing sugars[1]	4.72^{a} ± 0.29	4.73^{a} ± 0.25	4.54^{a} ± 0.18	4.56^{a} ± 0.30
Ascorbic acid[2]	10.72^{a} ± 0.60	10.68^{a} ± 0.56	10.25^{a} ± 0.61	10.19^{a} ± 0.69
Total carotenoids[3]	1.50^{a} ± 0.20	1.04^{b} ± 0.11	1.28^{ab} ± 0.04	1.01^{b} ± 0.18
Total phenolics[4]	9.52^{a} ± 0.91	9.11^{a} ± 0.61	9.37^{a} ± 1.36	8.42^{a} ± 0.59
Antioxidant activity[1]	15.32^{ab} ± 0.17	13.79^{ab} ± 0.55	15.39^{a} ± 0.77	13.45^{b} ± 0.23

T1: freezing; T2: pasteurization + freezing; T3: refrigeration; T4: pasteurization + refrigeration.

[1]Expressed as %; [2]Expressed as mg.100 g^{-1} of pulp; [3]Expressed as μg.g^{-1} of pulp; [4]Expressed as mg GAE per 100 g of extract. Values expressed as mean ± standard deviation. Different small letters in the same line indicate 5% level of significance by Dunn's test.

T1: congelación; T2: pasteurización + congelación; T3: refrigeración; T4: pasteurización + refrigeración.

[1]Expresado como %; [2]Expresado en mg.100 g-1 de pulpa; [3]Expresado como μg.g-1 de pulpa; [4]Expresado en mg GAE por 100 g de extracto. Valores expresados como media ± desviación estándar. Diferentes letras pequeñas en la misma línea indican el nivel de significación del 5% por la prueba de Dunn.

sugars and has low acidity (Braga et al., 2003; Carvalho et al., 2014).

In the present study, the ascorbic acid content ranged from 10.19 to 10.72 mg.100 g^{-1} of pulp at the beginning of storage. These values were higher than those found by the Instituto Nacional de Salud Perú (INSP, 2009), where 8.90 mg of ascorbic acid was found in 100 g of pulp from sapota-do-Solimões. There was a significant variation in relation to total carotenoids which varied from 1.01 to 1.50 µg.g^{-1} of pulp (Table 1). Berto et al. (2015) studied the carotenoid content in alcoholic extracts obtained from sapota-do-Solimões pulp acquired in Manaus, Amazonas, Brazil. In relation to the pulp, their study found a total of 6 µg.g^{-1} of extract on a dry basis. The main equivalents of zeaxanthin and β-carotene were 2.5 and 2.2 µg.g^{-1} of extract on a dry basis, respectively. Murillo et al. (2013) detected the presence of 22 carotenoids, including β-carotene (23.3%), and taking into account the large amount of β-carotene detected in sapota-do-Solimões, it presents provitamin A potential. Therefore, this fruit should be considered as an important addition in the diet for those who need to combat hypovitaminosis A.

The total phenolics showed no difference between the means of the treatments at the beginning of storage. There was a variation from 8.42 to 9.52 mg of gallic acid per 100 g of extract. Carvalho et al. (2014) quantified the phenolic content in sapota pulp and found values of 6.31 mg GAE.100 g^{-1} in the alcoholic extract and 15.06 mg GAE.100 g^{-1} in the aqueous extract. Interest in phenolic compounds has increased because of their antioxidant and anti-inflammatory properties. In a recent study, Berto et al. (2015) identified and quantified 10 phenolic compounds in alcoholic extracts obtained from sapota-do-Solimões pulp.

The total antioxidant activity varied significantly from 13.45% to 15.39% in the extract, with a concentration of 0.2 mg.mL^{-1}. In study by Carvalho, Damiani, Asquieri, Orsi, and Nishi (2012), the antioxidant potential was also determined by the scavenging ability in relation to DPPH. In the former study, the total antioxidant activity was 27.85% (10.65% in the alcoholic extract and 16.27% in the aqueous extract).

Table 2 provides a comparison of the means for the sapota-do-Solimões pulps at day 1 and day 180 of storage in relation to the color parameters. There were significant changes in color during storage; the pulps became lighter, with an increase in L* values, except for the pasteurization + refrigeration treatment, and in relation to the a* and b* parameters, there was a significant tendency for the pulps to become redder and yellower, respectively. There was an increase in the intensity of the orange color represented by Chroma (c). The tonality of the frozen pulps did not change significantly, and the refrigerated pulps were closer to yellow, which is the color itself by the hue angle (h). The increase in these values for the a* and b* parameters in the sapota-do-Solimões pulps can be explained by the stability of the carotenoids throughout the storage period, which was due to the method of storage because storage at low temperatures, especially freezing, usually favors the preservation of carotenoids in foods (Rodriguez-Amaya & Kimura, 2004). Furthermore, the decrease in water activity during storage protected the carotenoids from degradation (Zielinski et al., 2014).

According to Damiani et al. (2013), the color may change according to the storage time of pulps. These changes can be prevented with the addition of substances such as pectin and sucrose, before the freezing of the pulp, which significantly decreases color variation among samples of the same fruit (Fernandes et al., 2009). This is due to the reduction of water activity in the frozen pulps, which decreases the degradation of carotenoids (Santos et al., 2016).

In a study of the pulp from acerola fruit, the L* values remained stable throughout storage, and the pasteurized pulps were superior to the non-pasteurized pulps. In terms of the a* parameter, there was a decrease in values at the end of 360 days of storage under freezing. The values for the b* parameter of the acerola pulp showed a small increase. The Chroma (c) values decreased, and the values of the hue

Table 2. Color parameters of sapota-do-Solimões (*Quararibea cordata*) pulp at 1 day and 180 days of storage.

Tabla 2. Parámetros de color de la pulpa sapota-do-Solimões (*Quararibea cordata*) en el 1 día y a los 180 días de almacenamiento.

	Treatments			
Analyses	T1	T2	T3	T4
Lightness (L*)				
Time 1	44.66^{Bb} ± 1.44	45.74^{Ba} ± 1.09	45.66^{Ba} ± 1.99	44.39^{Ab} ± 2.29
Time 180	46.12^{Ab} ± 2.24	48.76^{Aa} ± 1.27	46.54^{Ab} ± 2.35	43.96^{Ac} ± 2.69
a* parameter				
Time 1	20.07^{Ba} ± 0.76	20.20^{Ba} ± 1.18	19.21^{Bb} ± 1.51	17.88^{Bc} ± 2.09
Time 180	22.61^{Aa} ± 1.27	23.20^{Aa} ± 0.86	21.21^{Ab} ± 1.52	19.98^{Ac} ± 1.82
b* parameter				
Time 1	31.22^{Ba} ± 2.19	31.54^{Ba} ± 2.83	29.53^{Bb} ± 3.33	26.42^{Bc} ± 4.12
Time 180	34.78^{Aab} ± 3.91	37.05^{Aa} ± 2.85	36.74^{Aa} ± 5.14	33.25^{Ab} ± 5.52
Chroma (c)				
Time 1	37.12^{Ba} ± 2.21	37.46^{Ba} ± 2.97	35.24^{Bb} ± 3.58	31.91^{Bc} ± 4.57
Time 180	41.50^{Aab} ± 3.94	43.72^{Aa} ± 2.84	42.45^{Aa} ± 5.19	38.79^{Ab} ± 5.64
Hue angle (h)				
Time 1	57.21^{Aab} ± 1.03	57.30^{Aa} ± 1.20	56.87^{Bb} ± 1.21	55.75^{Bc} ± 1.26
Time 180	56.81^{Ac} ± 1.61	57.88^{Ab} ± 1.20	59.80^{Aa} ± 1.79	58.78^{Ab} ± 2.07

T1: freezing; T2: pasteurization + freezing; T3: refrigeration; T4: pasteurization + refrigeration.

Values expressed as mean ± standard deviation. Different small letters in the same line indicate 5% level of significance by Dunn's test. Different capital letters in the same column for each color parameter indicate 5% level of significance by the Wilcoxon test.

T1: congelación; T2: pasteurización + congelación; T3: refrigeración; T4: pasteurización + refrigeración.

Valores expresados como media ± desviación estándar. Diferentes letras pequeñas en la misma línea indican el nivel de significación del 5% por la prueba de Dunn. Diferentes letras mayúsculas en la misma columna para cada parámetro de color indican un nivel de significación del 5% por la prueba de Wilcoxon.

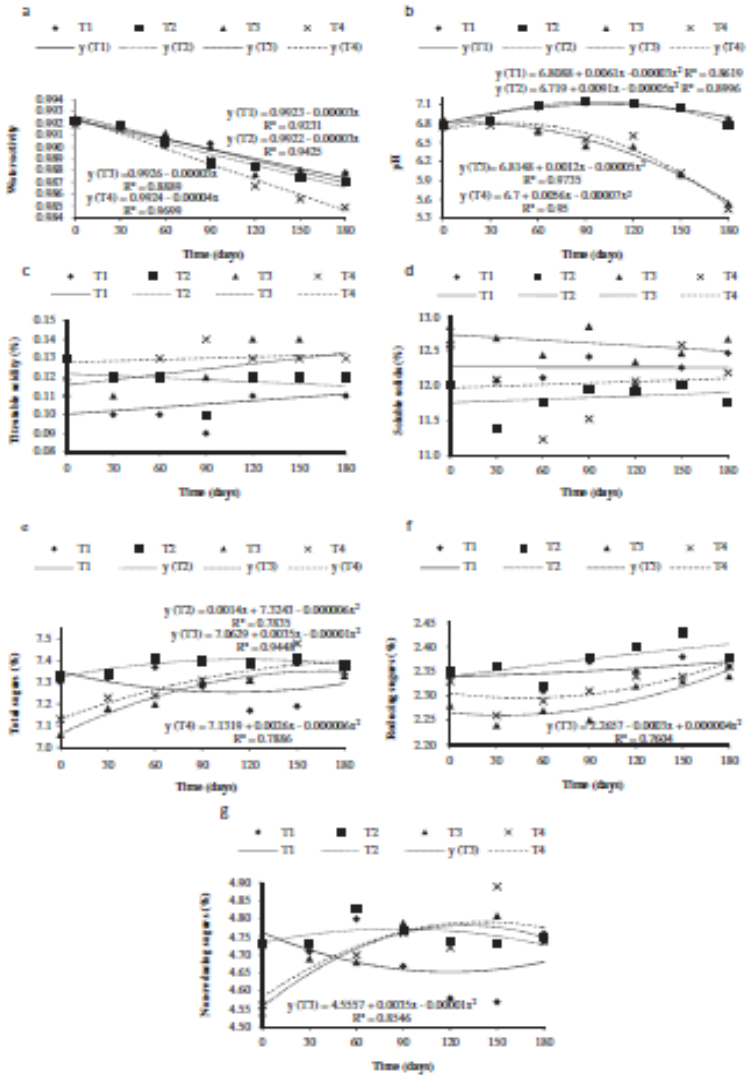

Figure 2. Graphs of the means found for the variables of water activity (a), pH (b), titratable acidity (c), soluble solids (d), total sugars (e), reducing sugars (f), and nonreducing sugars (g) in relation to time of storage in days.

Figura 2. Gráficos de las medias encontradas para las variables de actividad del agua (a), pH (b), acidez titulable (c), sólidos solubles (d), azúcares totales (e) y azúcares reductores (f), azúcares no reductores (g) en relación con el tiempo de almacenamiento en días.

angle (h) showed no significant interaction between the storage time and the treatment (Lima et, 2012).

The quality parameters of sapota-do-Solimões pulp stored for 180 days are shown in Figure 2.

In terms of water activity, there was no difference between the averages for the treatments (Figure 2(a)) and there was a decrease in values for all treatments. According to Gava, Silva, and Frias (2008), water activity influences changes in foods because it is related to the growth and metabolic activity of microorganisms; during hydrolytic reactions, fruit pulps tend to have a value for water activity exceeding 0.98. da Silva et al. (2010) studied the stability of bacuri pulp that was frozen for 12 months and found water activity values that ranged from 0.987 to 0.994, which did not differ statistically over time.

The pH values in the frozen pulps showed no significant differences between the initial and final time of storage; however, in the refrigerated pulps, there was a significant decrease. From a technological point of view, the pH values of the sapota pulps (Figure 2(b)) were above the range considered to be safe because foods that have low acidity levels have a tendency toward the growth of microorganisms. Damiani et al. (2013) studied the behavior of the pH in frozen araçá pulp, which reduced over 12 months of storage. da Silva et al. (2010) studied bacuri pulp and found pH values (3.22–3.48) which showed little variation and did not differ statistically over time. Damiani et al. (2013) reported decreasing pH levels in frozen guava pulp during storage and also the presence of fungi which may have consumed the soluble sugars and produced organic acids via the glycolytic pathway. However, because the sapota-do-Solimões pulp that was stored under freezing in the present study showed low counts of yeasts and molds, this possibly explains the small changes that occurred in the pH in the frozen treatments.

Acidity is an important parameter in assessing the state of preservation of food products. The acidity was stable during storage for all the treatments (Figure 2(c)). This behavior also occurred in another study of pasteurized and unpasteurized acerola pulp during storage (Lima et al., 2012). The acidity in camu-camu pulp remained stable during 4 months of storage for all treatments (freezing, pasteurization, high hydrostatic pressure, and lyophilization) (Moraes-de-Souza, 2011). da Silva et al. (2010) argued that acidity results can be important because this variable is determinative of the quality of fruit for fresh consumption and for industrial processing. Furthermore, acidity values may indicate the deterioration of foods by bacteria that produce acid, so it is important to monitor the stability of foods.

In terms of soluble solids, no significant interactions were detected between the treatments and storage time; a decrease was observed in all treatments throughout the storage period (Figure 2(d)). da Silva et al. (2010) studied soluble solids in bacuri pulp and found that they differed significantly during 12 months of storage. In a study by Moraes-de-Souza (2011) of camu-camu pulp, soluble solids were stable for 4 months of storage, and in relation to total sugars, reducing sugars, and nonreducing sugars, no significant interactions were detected between treatments and storage time. The total sugars, reducing sugars, and nonreducing sugars (Figures 2(e–g), respectively, were directly related to the total soluble solids content; therefore, they varied according to the maturation stage of the fruits.

The figures for bioactive compounds and antioxidant activity of sapota-do-Solimões pulp stored for 180 days are shown in Figure 3.

In relation to ascorbic acid, there was no significant difference between the treatments for each storage period; however, there was significant difference between the time of 1 day and 180 days. The freezing treatment showed no loss of ascorbic acid during storage, and this resulted in better stability (Figure 3(a)). The ascorbic acid content of passion fruit pulp pasteurized at different temperature ranges (69–72°C, 73–76°C, and 77–82°C) declined during a storage period of 180 days under refrigeration (Monteiro et al., 2005). Silva, Júnior, and Ferreira (2008) studied the stability of vitamin C in cagaita pulp frozen for 4 months and observed a gradual reduction of approximately 30% in the first month and 50% in the third month compared with the initial concentration. Lee and Kader (2000) reported that a gradual reduction of ascorbic acid content in fruits occurs in line with an increase in temperature and storage time. In the present study, the pulps stored under refrigeration had lower values for ascorbic acid compared with the frozen pulps.

The total carotenoid content decreased during storage for all the storage times. There was no significant difference in the pasteurization + freezing treatment, which remained stable, but the treatments stored at +4°C showed lower values compared to the treatments stored under freezing (Figure 3 (b)). Lopes, Mattietto, and de Menezes (2005) studied the stability of pitanga pulp that was frozen for 90 days, and they observed that there was a significant drop of about 13.76% in the total carotenoid content in the first 30 days of storage; however, at 45, 60, and 90 days of storage, no significant decrease was observed. Carotenoids are naturally protected in plant tissues; however, when fruit and vegetables are or cut or disintegrate, there is an increase in the exposure of the carotenoids to oxygen and contact with enzymes, which catalyzes the oxidation procedure (Rodriguez-Amaya & Kimura, 2004). In the pasteurization + freezing treatment of the sapota pulp, there was greater protection of carotenoids due to the process of the inactivation of the enzymes, combined with the low temperatures provide by freezing.

The total phenolic content remained stable between the treatments until 150 days of storage; however, the content decreased from 150 to 180 days of storage. Among the storage times, there was a decline in relation to each treatment. There was stability until 30 days of storage, but from that

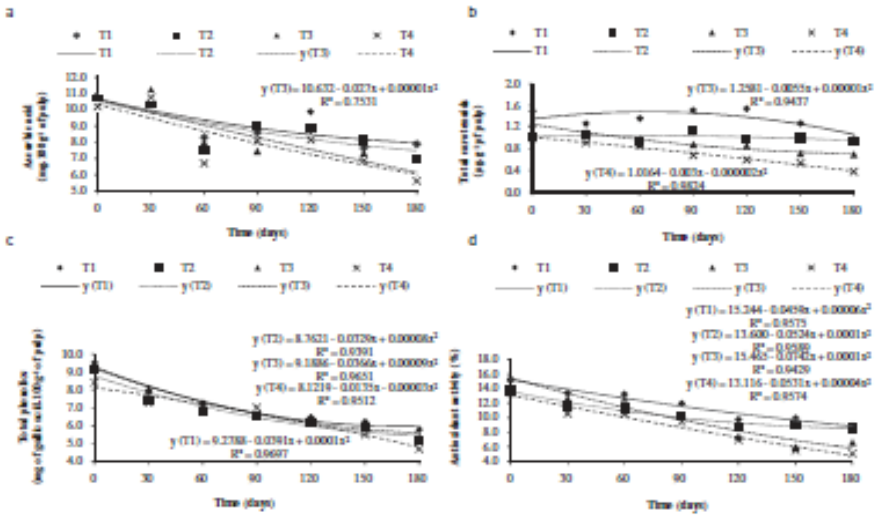

Figure 3. Graphs of the means found for the variables of ascorbic acid (a), total carotenoids (b), total phenolics (c), and antioxidant activity (d) in relation to time of storage in days.

Figura 3. Gráficos de las medias encontradas para las variables de ácido ascórbico (a), carotenoides totales (b), compuestos fenólicos totales (c) y actividad antioxidante (d) en relación con el tiempo de almacenamiento en días.

point, the values decreased greatly, especially at 180 days (Figure 3(c)). Processing and storage can affect the content and bioavailability of fruit pulps, resulting in losses, because they contain components that are susceptible to oxidation processes and are highly unstable (Melo, Maciel, de Lima, & de Araújo, 2008). Lower levels of total phenolics may be a result of a reaction with oxygen (oxidation) during the homogenization of the pulp, which continues to occur during storage, as well as the high temperature used in pasteurization (Damiani et al., 2013).

The antioxidant activity decreased during storage in all the treatments but remained stable up to 90 days. In the freezing treatment, the antioxidant activity was stable up to 150 days, and therefore, pasteurization seems to have influenced the reduction in antioxidant activity of the sapota-do-Solimões pulp (Figure 3(d)). Kaur and Kapoor (2001) argue that natural antioxidants can be significantly lost as a consequence of processing and storage, thereby affecting the antioxidant capacity of food. In general, fruits contain several compounds with antioxidant properties including ascorbic acid, phenolic compounds, and carotenoids (Damodaran, Parkin, & Fennema, 2010). These bioactive compounds are susceptible to oxidation reactions that occur during the processing and storage of food, and the incorporation of air during processing aids aerobic degradation reactions by oxidation (Lima, Mélo, & Lima, 2000) or thermal degradation during pasteurization (Maia et al., 2007). According to Hassimotto, Genovese, and Lajolo (2005), the correlation between phenolics and antioxidant activity of a product is very small and is mainly linked with the difference in the phenolic composition of plant extracts.

Table 3 shows the microbiological results regarding the counts of molds, yeasts, and aerobic mesophilic bacteria in the sapota-do-Solimões pulp. Brasil (2001) defines the microbiological standards for each food. Fruit pulp that is concentrated (or not) and with or without heat treatment, refrigeration or freezing only has parameters for coliforms at 45°C and *Salmonella* ssp., with a maximum 10^2 CFU.g^{-1} and absence in 25 g, respectively. Regarding the analysis of coliforms at 45°C, the results were less than 1 log CFU.g^{-1} for all the treatments during storage, which was consistent with current legislation. In relation to *Salmonella* ssp., all the samples showed an absence in 25 g throughout storage.

Brasil (2000) establishes the maximum microbiological limits for the sum of molds and yeasts as 5×10^3 CFU.g^{-1} for fresh or frozen pulp and 2×10^3 CFU.g^{-1} for chemically conserved pulp and/or pulp which has undergone heat treatment. Brazilian legislation does not set specific limits for the total count of aerobic mesophilic bacteria in fruit pulp.

Yeast and molds are sensitive to the temperatures used in pasteurization, and therefore, it was possible to observe the effectiveness of the process, given that treatments T2 and T4 showed lower counts than T1 and T3. The pulp that was refrigerated for 150 days of storage showed a count for yeasts and molds that was higher than that permitted by law.

The total count of aerobic mesophilic bacteria was also lower in the treatments that used pasteurization, and the treatments that used refrigeration showed higher values than the pulps that were stored frozen. As there is no legislation to limit values for the count of mesophilic aerobic bacteria in fruit pulp, it was not possible to come to a conclusion about the degree of contamination of the pulps, but the presence of mesophilic bacteria in large numbers can indicate factors such as raw material that is excessively contaminated, inadequate cleaning and sanitizing of surfaces, insufficient hygiene in the production or storage of food, inadequate conditions of time/temperature during the production or storage of food, or a combination of these circumstances (Franco & Landgraf, 2005). Monteiro et al. (2005) evaluated the quality of pasteurized passion fruit pulp at three temperature ranges (69–72°C, 73–76°C, and 77–82°C) for 30 s and observed that the pulps showed similar behavior in relation to the growth of mesophilic aerobic microorganisms, independent of heat treatment.

Exploratory data analysis through the multivariate statistical technique PCA was performed. Figure 4 shows the graphs for the scores (samples) and the weights (variables)

Table 3. Count of molds, yeasts, and mesophilic aerobic bacteria in sapota-do-Solimões (*Quararibea cordata*) pulp stored for 180 days.

Tabla 3. Recuento de mohos, levaduras y bacterias aeróbicas mesofílicas en pulpa de sapota-do-Solimões (*Quararibea cordata*) almacenada durante 180 días.

	Treatments			
Analyses	T1	T2	T3	T4
Yeast and molds[1]				
Time 1	$<1.0^{Ab,a}$	$<1.0^{Ba}$	$1.00^{Ba} \pm 0.00$	$<1.0^{Ba}$
Time 30	$<1.0^{Ab,a}$	$<1.0^{Ba}$	$1.00^{Ba} \pm 0.00$	$<1.0^{Ba}$
Time 60	$1.34^{Aab} \pm 0.04$	$1.00^{Bab} \pm 0.00$	$2.04^{Aa} \pm 0.05$	$1.18^{Ab} \pm 0.09$
Time 90	$1.30^{Aab} \pm 0.10$	$1.26^{Ab} \pm 0.12$	$1.86^{Aa} \pm 0.16$	$1.50^{Aab} \pm 0.23$
Time 120	$<1.0^{Bb}$	$<1.0^{Bb}$	$2.87^{Aa} \pm 0.22$	$2.08^{Aab} \pm 0.12$
Time 150	$1.30^{Aab} \pm 0.03$	$<1.0^{Bb}$	$4.04^{Aa} \pm 0.10$	$3.20^{Aab} \pm 0.05$
Time 180	$<1.0^{Bb}$	$<1.0^{Bb}$	$4.18^{Aa} \pm 0.14$	$3.26^{Aab} \pm 0.11$
Aerobic mesophilic count[1]				
Time 1	$2.28^{Ab,a} \pm 0.28$	$1.78^{Aa} \pm 0.22$	$2.46^{Ba} \pm 0.16$	$1.91^{Ba} \pm 0.14$
Time 30	$2.20^{Ba} \pm 0.09$	$1.76^{Aa} \pm 0.17$	$2.95^{Aa} \pm 0.06$	$1.93^{Ba} \pm 0.21$
Time 60	$2.30^{Aab} \pm 0.15$	$1.99^{Ab} \pm 0.03$	$3.04^{Aa} \pm 0.05$	$2.84^{Aab} \pm 0.18$
Time 90	$2.43^{Aab} \pm 0.12$	$2.30^{Ab} \pm 0.09$	$3.18^{Aa} \pm 0.26$	$3.15^{Aa} \pm 0.11$
Time 120	$2.68^{Aab} \pm 0.07$	$2.20^{Ab} \pm 0.14$	$3.61^{Aa} \pm 0.30$	$3.20^{Aab} \pm 0.15$
Time 150	$2.84^{Aab} \pm 0.03$	$2.04^{Ab} \pm 0.21$	$3.76^{Aa} \pm 0.23$	$3.28^{Aab} \pm 0.08$
Time 180	$2.54^{Ab} \pm 0.15$	$2.49^{Ab} \pm 0.20$	$4.00^{Aa} \pm 0.08$	$3.43^{Aab} \pm 0.06$

T1: freezing; T2: pasteurization + freezing; T3: refrigeration; T4: pasteurization + refrigeration.

[1]Log CFU.g^{-1} = colony forming units per gram. Different small letters in the same line indicate 5% level of significance by Dunn's test. Different capital letters in the same column indicate 5% level of significance by Dunn's test.

T1: congelación; T2: pasteurización + congelación; T3: refrigeración; T4: pasteurización + refrigeración.

[1]Log CFU.g^{-1} = unidades formadoras de colonias por gramo. Diferentes letras pequeñas en la misma línea indican el nivel de significación del 5% por la prueba de Dunn. Diferentes letras mayúsculas en la misma columna indican un nivel de significación del 5% por la prueba de Dunn.

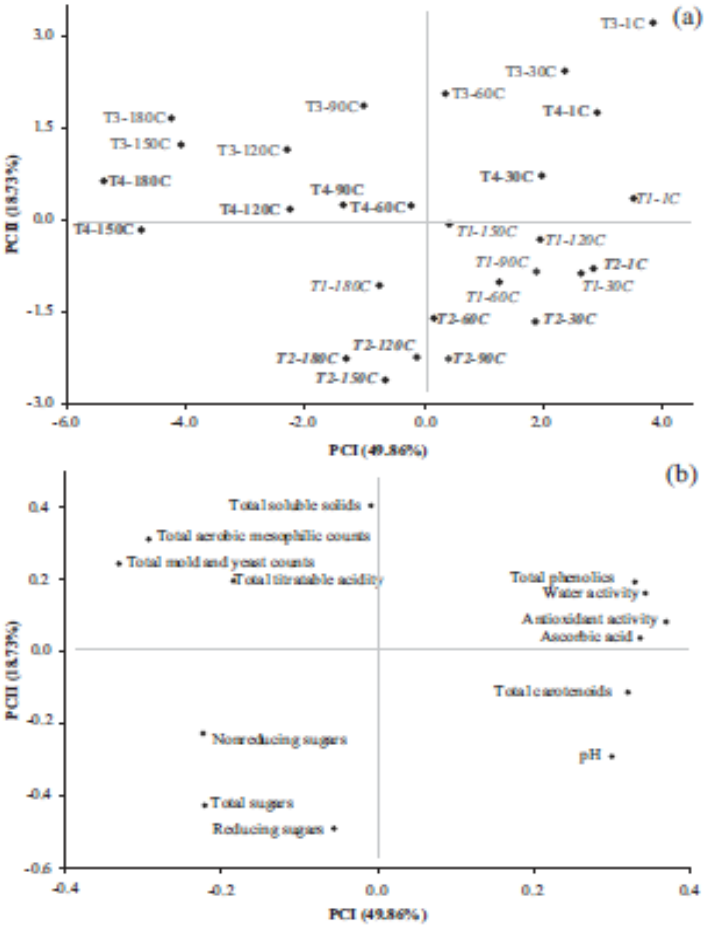

Figure 4. Principal component analysis of the quality parameters, bioactive compounds, and microbiological analyses of sapota-do-Solimões (*Quararibea cordata*) pulp in the different treatments and storage times. (a) – score plots (samples), T1 = freezing. T2 = pasteurization + freezing. T3 = refrigeration. T4 = pasteurization + refrigeration. (b) – weight plots (variables).

Figura 4. Análisis de componentes principales de los parámetros de calidad, compuestos bioactivos y análisis microbiológicos de la pulpa de sapota-do-Solimões (*Quararibea cordata*) en los diferentes tratamientos y tiempos de almacenamiento. (a) – puntuación de parcelas (muestras), T1 = congelación. T2 = pasteurización+congelación. T3 = refrigeración. T4 = pasteurización+refrigeración. (b) – gráficos de pesos (variables).

of the first two principal components (PC) resulting from the PCA, which incorporated 68.59% of the total variance. In this analysis, it was possible to extract relevant information regarding the correlation between the variables to characterize the samples.

There was a partial separation of the samples in relation to the different treatments and storage times of the sapota-do-Solimões pulps so that the frozen samples were positioned in the negative quadrants and the refrigerated samples were in the positive quadrant of PC II. However, the treatment that involved freezing until 150 days of storage was located in the positive quadrant of PC I, as were the samples that were pasteurized + frozen until 90 days of storage. In relation to the pulps that were stored under refrigeration, after 90 days of storage, they were predominantly located in the negative quadrant of PC I. This behavior occurred in relation to the different types of preservation to which the samples were subjected, and consequently, they had different concentrations in relation to the physicochemical and microbiological characteristics and bioactive compounds that were analyzed.

The main difference between the groups regarding the physicochemical characteristics was in relation to the greater concentration of water and pH activity in the initial storage period in all the treatments of the sapota-do-Solimões pulps, while in the final stages of storage, the soluble solids, titratable acidity, total sugars, reducing sugars, and nonreducing sugars stood out. Regarding the microbiological parameters, the main difference between the groups was related to a greater concentration of molds, yeasts, and mesophilic aerobic bacteria count in the treatments that were refrigerated for 90 days of storage. For the bioactive compounds and antioxidant activity, it was observed that in all treatments, and especially in the initial storage times, the concentration of ascorbic acid, carotenoids, and total phenolics was higher, as well as antioxidant activity, which showed that the storage time had a negative influence, except for the treatment which was frozen for 150 days and the treatment which was pasteurized + frozen for 90 days.

Conclusions

The different treatments applied to the sapota-do-Solimões pulp affected the physicochemical parameters during storage. Of particular note was the reduction in water activity and pH in the pulps that were stored under refrigeration, as well as the lightening in color of the pulps.

In relation to the bioactive compounds, ascorbic acid remained stable during freezing; carotenoids were preserved in the pasteurization + freezing treatment; total phenolics remained stable up to 150 days of storage in all the treatments; and the antioxidant activity decreased during storage for all the treatments.

The pulps showed good stability during the 180 days of storage, except for the refrigerated pulp after 150 days. The pasteurization was effective because there were lower counts than in the unpasteurized pulps. The pasteurization + freezing treatment and the freezing treatment maintained pulp quality during the 180 days of storage.

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4.3 ARTIGO 3

Evaluation of the chemical, sensory and volatile composition of sapota-do-Solimões pulp at different ripening stages

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Highlights

The *Quararibea cordata* is an Amazonian fruit.
As *Quararibea cordata* ripened there were observed increase values total carotenoids.
The lipids contents doubled from unripe to ripe collected from the ground.
Eleven fatty acids were detected in the pulps from *Quararibea cordata*.
More of the eighty volatile compounds were identified at different ripening stages.

Abstract

The aim of this study was to evaluate sapota-do-Solimões (*Quararibea cordata*) during ripening, verifying physical, chemical and sensory parameters, bioactive and volatile compounds. The pulps were obtained from fruits from the city of Tefé, AM, Brazil and collected at three different ripening stages: unripe (U); ripe collected from the tree (R); and ripe collected from the ground (RG). The biometric and quality parameters, carotenoids, chemical composition, fatty acids and volatile profiles were analyzed. The sapota-do-Solimões fruits shown positive correlation with evolution of ripened stage of the variables water activity (0.977-0.996), pH (6.53-7.04), soluble solids (8.53-12.65%), total sugars (4.26-7.98%), reducing sugars (0.99-3.14%), non-reducing sugars (3.11-4.60%) and total carotenoids (0.67-1.24 μg/g). Longitudinal and transversal diameters and fruit mass were higher in RG. The lipids contents increased from 0.16% for U to 0.30% for RG. Eleven fatty acids were detected in the pulps (mg/100 g), being, palmitic (47.1-86.4), stearic (3.1-5.9), oleic (44.4-131.1) and vaccenic (25.3-37.7) increased with ripening, whilst palmitoleic (16.4-10.0) and linoleic (6.6-3.5) decreased, possibly due to the formation of compounds during the secondary metabolism of the fruit. A total of 86 volatile compounds were identified, of which

57 were found in U fruits, 54 in R fruits and 68 in RG fruits. The classes most relevant found were alcohols, aldehydes, esters, ketones, furans and terpenes. An increase in the terpenes (0.4-5,6%) from U fruit to RG fruit showed a potentials odoriferous characteristics, as well the increased furans (2.3-20.9%) from U fruit to RG fruit that characterized a sweet and fruity aroma. Consumers didn't detect differences in sensory attributes of the analyzed R and RG fruits. The data showed that the chemical and volatile composition of the fruit was influenced by the ripening stage of the pulp. This is the first time that a study about ripening in sapota-do-Solimões has been reported.

Keywords: *Quararibea cordata*; ripening stages; composition; fatty acids; volatile compounds.

1 Introduction

The sapota-do-Solimões (*Quararibea cordata*) fruit is which is sold in the Amazon region from March to June, usually in markets under natural conditions. It is a bacaceous, globose or ovoid fruit, 7-15 cm in length, and has an average weight of around 418 g. Under normal conditions an adult tree can produce up to 6,000 fruits per year. The pulp is the only edible part of the fruit and before consumption it is necessary to remove the thick peel (Rabelo, 2012; Yuyama et al., 2013). It is harvested when the color of the peel of the fruit under the calyx becomes yellow (Villachica, 1996).

The ripening stage, during which the fruits are harvested, determines the quality of the fruit that can be offered to consumers. When the fruit is harvested at the unripe stage, in addition to being of poor quality, it has a high rate of water loss and is very susceptible to physiological disorders. On the other hand, when the fruit is harvested at a very ripe stage it rapidly becomes senescent (Manica et al., 2000). The correct determination of the ripening stage of the fruit is essential for the harvest to occur at the right time and so-called ripening indices are used for this. These indices include physicochemical aspects that undergo changes during the ripening of the fruit, which greatly influences the post-harvest condition of the fruit (Kluge; Nachtigal; Bilhalva, 2002).

The volatile compounds in fruits have been extensively studied in recent years in order to characterize the volatile profile of a fruit and its different genotypes, as well as to investigate the behavior of these chemical compounds during the ripening, processing or storage of fruits and their by-products (Wang et al., 2009; Damiani et al., 2009; Weldegergis et al., 2011; Galvão et al., 2011; Monteiro et al., 2017). Knowledge about the composition of the volatile fraction of a food is essential in order to characterize and identity it. The flavor of a particular product, which is one of the main sensory attributes of consumer analysis and acceptance, is generally provided by a combination of several volatile molecules (Bicas et al.,

2011). The volatile compounds present in fresh and processed fruits affect significantly the flavor and quality of the aroma, which is formed by a complex mixture of aldehydes, alcohols, ketones, esters, terpenes and other compounds (Riu-Aumatell et al., 2004).

Thus, it is known that ripening influences the softening of the pulp, pigment development, changes in the metabolism of carbohydrates, lipids and volatile compounds due to the biochemical and physiological changes. This is the first time that a study about ripening in sapota-do-Solimões is being presented. In this way, the aim of this study was to evaluate sapota-do-Solimões pulp at three different ripening stages in order to verify the physical, chemical and sensorial parameters, as well as the bioactive and volatile compounds.

2 Materials and methods

2.1 Raw materials

The fruits were collected from a private area in the community of Vila Vale, which is located near the experimental area of the Mamirauá Sustainable Development Institute. The geographical coordinates of the city of Tefé, Amazonas (AM), Brazil, where the samples were collected, are latitude 03°21'15"S and longitude 64°42'41"W, with an altitude of approximately 75 m. According to the Köppen-Geiger classification the climate is type Af, i.e. humid and equatorial tropical with an annual average temperature of 26.85 °C and average rainfall of 211.54 mm. The soil is classified as Plinthosol with reddish colors. The fruits were collected in an area that had 15 plants (individuals) of about 30 m in height, which were approximately 50 years old. The fruits were collected in March 2015. A total of sixty fruits were collected and initially transported via river and then by air, totaling 36 hours of travel, to the Federal University of Santa Maria where the experiments were conducted.

The fruits were carefully collected at the following three different ripening stages: unripe (U); ripe fruit collected from the tree when the color of the peel of the fruit under the calyx turns yellow (R); and ripe fruit collected from the ground when they naturally detach from the tree (RG). When they were received, the fruits were selected for the absence of defects, pests and diseases, and then had their surfaces washed with mild detergent to remove dirt. They were then rinsed in running water. Sanitization was subsequently performed with 50 mg/Kg chlorine and an immersion time of 30 minutes.

2.2 Methods

2.2.1 Biometry

Thirty fresh fruits were analyzed individually in terms of the following features: longitudinal and transversal diameters (mm) were measuring using Eccofer® digital callipers, and the total fruit mass (g) was weigh using a Toledo® digital scale (Exata 2 SC model, São Paulo, Brazil).

2.2.2 Water activity, pH, titratable acidity and soluble solids

AquaLab® (Series 4 TEV, Decagon Device Inc., Pullman, USA) equipment was used to measure the water activity as recommend the manufacturer. The pH was measured using a Digimed® (DM-23 model, São Paulo, Brazil) digital potentiometer (AOAC, 1998). The titratable acidity was determined by diluting the pulp in distilled water using 0.1 M NaOH, using phenolphthalein as ending point (AOAC, 1998). The soluble solids were measured directly in a digital refractometer (Atago®, Pocket PAL-3 model, Tokyo, Japan) according to AOAC (1998).

2.2.3 Total, reducing and non-reducing sugars

In order to determine the levels of total and reducing sugars in glucose the Lane Eynon method was employed using Fehling's reagent (1934). The non-reducing sugars in sucrose were calculated from the difference of the values found for the total and reducing sugars and then multiplied by 0.95. The results were expressed as a percentage (%).

2.2.4 Ascorbic acid and total carotenoids

The ascorbic acid content was determined by the spectrophotometric method at a wavelength equal to 540 nm (Biospectro, SP-220 model, São Paulo, Brazil), as described by Cox and Pearson (1976). The results were expressed as mg/100 g of pulp. The total carotenoids were determined by the Higby method (1962). The readings were taken using a spectrophotometer (Biospectro, SP-220 model, São Paulo, Brazil) at a wavelength equal to 450 nm and the results were expressed as μg/g of pulp.

2.2.5 Sample preparation to total phenolics and antioxidant activity

The extracts for the determination of total phenolics and antioxidant activity were obtained according to Larrauri, Rupérez and Saura-Calixto (1997) method, with modifications. The extraction was performed at room temperature (24 °C) by taking 5.0 g of each pulp; then 20 mL of 50% ethanol solution was added (first extraction solution) and the mixture that was obtained was homogenized and allowed to stand for one hour for extraction.

After this period, the mixture was centrifuged at 3000 rpm for 10 minutes and the supernatant that was obtained was filtered and placed in a 50 mL flask protected from light. The precipitate obtained by centrifugation was dissolved in 20 mL of 70% acetone (second extraction solution). This mixture was left to stand for one hour and then centrifuged at 3000 rpm for 10 minutes. The second supernatant that was obtained was mixed with the first, in the same flask, which was completed with distilled water.

2.2.6 Total phenolic compounds

The total phenolics were determined following the method described by Larrauri, Rupérez and Saura-Calixto (1997). The absorbance was read with a spectrophotometer (Biospectro, SP-220 model, São Paulo, Brazil) at 700 nm, using as reference the standard curve of gallic acid ($y=0.0101x-0.0266$, $R^2=0.9963$), which was constructed with concentrations ranging from 5 to 70 mg/L. The results were expressed as mg gallic acid equivalent (GAE)/100 g of extract.

2.2.7 Antioxidant activity by DPPH method

The method described by Brand-Williams, Cuvelier and Berset (1995) was used to determine antioxidant activity. The technique consisted in the incubation for 30 minutes of 5 mL of a solution of DPPH with 5 mL of solutions containing increasing concentrations of each extract in mg/mL (0.2; 0.4; 0.8; 1.6; 3.1; 6.2; 12.5; 25; 50 and 100), and were analysed in a spectrophotometer (Biospectro, SP-220 model, São Paulo, Brazil) at 517 nm. The percentage of antioxidant activity (AA%) was calculated by the percentage of uptake of the DPPH radical. After evaluating the range of optimal concentration, the concentration required to capture 50% of the DPPH free radical was calculated (IC_{50}).

2.2.8 Chemical composition

The fruits were dried in an oven with forced air circulation at a temperature of 60 °C for 36 hours. The samples were crushed in a micro mill that was cooled to 4 °C (Quimis, Q 298A21 model, Brazil). The chemical composition of the sapota-do-Solimões was determined by following the AOAC (1998) methods. The moisture determination was performed by drying in an oven at 105 °C to constant weight. The fixed mineral waste was assessed by incineration in a muffle furnace at 550 °C. The protein content was determined by the Kjeldahl method. The fraction of total dietary fiber was determined by the enzymatic

gravimetric method. The total lipids were obtained by extraction using the Bligh and Dyer (1959) method. The carbohydrates were obtained by difference.

2.2.9 Fatty acids composition

The lipids were extracted with chloroform:methanol:water, as described by Bligh and Dyer (1959). The triglycerides were transesterified/esterified to fatty acid methyl esters (FAME) using methanolic solutions of KOH and H_2SO_4 according to Hartman and Lago (1973) method. The FAME were determined using a Varian Star 3400CX (CA, USA) gas chromatograph equipped with a flame ionization detector (GC-FID). The FAME were injected manually (1 μL) and separated in a capillary column SP^{TM}-2560 (Bellefonte, USA) (100 m × 0.25 mm i.d. × 0.20 μm film thickness). Hydrogen was used as carrier gas at a constant pressure of 25 psi. The injector remained in the splitless mode at 250 °C. The heating program of the column began at 120 °C with 1 min of standing, and then increased to 240 °C with a heating rate of 3 °C/min, maintained at isothermal conditions for 15 min. The identification of the fatty acids was performed by a comparison of the retention times of the analytes with the standard (FAME Mix-37, Sigma-Aldrich, USA). The quantification was performed by the normalization of the area of the fatty acid. Fatty acids were expressed in mg/100 g of pulp, considering the concentration of lipid content and composition for each ripening stage.

2.2.10 Volatile compounds

The volatile composition was analyzed using the headspace of the solid sample (HS-SPME). About 5.0 ± 0.1 g of sample, with 30% of salt (NaCl), was weighed in 4 mL vials and immediately sealed with a septum with an internal surface of polytetrafluoroethylene (PTFE). The solid phase microextraction (SPME) technique was used to extract the volatile compounds. Divinylbenzene/carboxen/polydimethylsiloxane fiber (DVB/Car/PDMS) 50/30 μm × 20 mm was used as a manual holder for the extractions. The extraction of the volatile compounds was performed at 35 °C using a water bath for 45 min. Before the exposure of the fiber to the headspace, the flask containing the samples was maintained at the same temperature as the extraction for 10 min to equilibrate. The volatile compounds were thermally desorbed by inserting the fiber into the injection port of a gas chromatograph. The samples were analyzed in triplicate.

The volatile fraction was analyzed in a gas chromatograph coupled to a mass spectrometer (GC/MS), GC/MS QP-2010 *Plus* model (Shimadzu Corporation, Kyoto, Japan).

The thermal desorption of the SPME fiber was carried out at 250 °C in splitless mode using a liner of 0.75 mm internal diameter. The separation of the volatiles was performed using a polar capillary column phase of polyethyleneglycol (PEG), Chrompack-WAX 52 CB (Chrompack Middelburg, Netherlands) of 60 m × 0.25 mm of i.d. × 0.25 µm of stationary phase thickness. Helium was employed as carrier gas, at a constant pressure of 30 psi. The oven temperature was held at 35 °C for 5 min, raised to 80 °C at 2 °C/min, then increased to 250 °C at 4 °C/min, and held at this temperature for 5 min. The GC/MS interface and ionization source were maintained at 250 °C. The instrument was run in the electron ionization mode with the ion source at +70 eV. The mass spectra were collected using a range of 35–350 m/z. The identification of the volatile compounds was carried out by matching the unknown mass spectra with those provided by the library mass spectra (National Institute of Standards & Technology library – NIST 05), by a comparison of the experimental and retention indices (RI) from the literature, and by the elution order of the compounds. A series of n-alkanes (C6–C18) was analyzed under the same conditions to obtain the RI values. The volatiles compounds were expressed in total ion count area.

2.2.11 Sensory analysis

An affective acceptability test was conducted with 50 consumers using a seven-point hedonic scale (1 = extremely dislike and 7 = extremely like) according to Dutcosky (2011) method. These individuals resided in the city of Tefé, AM, Brazil and they were invited to participate in the analysis for being considered consumers of the fruit. The evaluation was conducted in the Mamirauá Sustainable Development Institute, in the morning between 9 and 11 am and in the afternoon between 14 and 16 pm. The samples of sapota-do-Solimões at two distinct ripening stages (R and RG) were chopped and each participant tasted the two samples, which were served sequentially in completely balanced blocks with respect to the order of presentation. Each treatment was served in a plastic cup, properly identified with three-digit random numbers and presented in a monodic form to the consumers. Each consumer was also given a glass of water to clean the taste buds.

The attributes that were evaluated were color, odor, taste, texture and appearance. For the calculation of the product acceptability index the following expression was adopted: IA (%) = A x 100/B, where A = the average grade obtained for the product and B = the maximum grade given to the product. A good IA is considered to be ≥ 70% (Dutcosky, 2011).

The project was sent to the Ethics and Research Committee (CEP-CONEP) of the Federal University of Santa Maria and it was approved (protocol No. 50521715.1.0000.5346). The volunteers who participated in the sensorial analysis signed an informed consent form.

2.2.13 Statistical analysis

The analyses were performed in triplicate. The results were expressed as mean ± standard deviation. The data were statistically analyzed by analysis of variance (ANOVA or t-Student) and Tukey´s test ($p < 0.05$), was using Statistica 7.0 software (Tulsa, USA, 2004). Furthermore, an exploratory analysis of the data using principal component analysis (PCA) was performed to visualize the correlation between the variables and the possible groupings among the samples. The Pirouette 3.11 (Woodinville, USA, 2003) statistical program was used. The data matrix consisted of nine samples and 47 independent variables, which contained statical significance from results of the parameters regarding quality, bioactive compounds, chemical composition, fatty acids profile, and volatile compounds of samples. The data for each variable were autoscaled in order to assume the same weight during analysis.

3 Results and Discussion

3.1 Biometric parameters of quality and bioactive compounds

The biometric parameters of quality and bioactive compounds of the sapota-do-Solimões pulp at different ripening stages are shown in Table 1. The longitudinal and transverse diameters were larger in the RG fruit. This was also true for the total fruit mass, showing that at this ripening stage the fruits were larger than the others. The total fruit mass, longitudinal diameter (length) and transverse diameter (width) varied significantly, from 352 to 645 g, from 101.3 to 111.7 mm and from 81.6 to 106.5 mm for the U and the RG fruit, respectively.

As the fruit ripened, there was a significant increase in water activity (0.977-0.996), pH (6.53-7.04), soluble solids (8.53-12.65%), total sugars (4.26-7.98%), reducing sugars (0.99-3.14%), non-reducing sugars (3.11-4.60%) and total carotenoids (0.67-1.24 μg/g of pulp). There was also a significant reduction in titratable acidity (0.18-0.09%), ascorbic acid (12.48-10.21 mg/100 g pulp), total phenolics (11.07-8.48 mg GAE/100 g of pulp) and the lowest IC_{50} value was for the U fruit.

Table 1 – Biometric parameters, of quality and bioactive compounds of sapota-do-Solimões (*Quararibea cordata*) at different ripening stages

Analyses	Ripening stages		
	U	R	RG
Longitudinal diameter* (mm)	$101.3^{b} \pm 5.94$	$101.9^{b} \pm 6.40$	$111.7^{a} \pm 6.86$
Transverse diameter** (mm)	$81.6^{c} \pm 8.24$	$89.6^{b} \pm 3.66$	$106.5^{a} \pm 4.15$
Total fruit mass (g)	$352^{c} \pm 80.76$	$405^{b} \pm 34.31$	$645^{a} \pm 61.74$
Water activity	$0.977^{c} \pm 0.002$	$0.992^{b} \pm 0.001$	$0.996^{a} \pm 0.003$
pH	$6.53^{c} \pm 0.05$	$6.82^{b} \pm 0.03$	$7.04^{a} \pm 0.12$
Titratable acidity (%)	$0.18^{a} \pm 0.03$	$0.12^{b} \pm 0.03$	$0.09^{b} \pm 0.02$
Soluble solids (%)	$8.53^{c} \pm 0.12$	$12.27^{b} \pm 0.26$	$12.65^{a} \pm 0.09$
Total sugars (%)	$4.26^{c} \pm 0.04$	$7.25^{b} \pm 0.23$	$7.98^{a} \pm 0.11$
Reducing sugars (%)	$0.99^{c} \pm 0.04$	$2.48^{b} \pm 0.03$	$3.14^{a} \pm 0.05$
Non-reducing sugars (%)	$3.11^{b} \pm 0.07$	$4.53^{a} \pm 0.20$	$4.60^{a} \pm 0.11$
Ascorbic acid (mg/100 g)	$12.48^{a} \pm 0.12$	$10.93^{b} \pm 0.45$	$10.21^{b} \pm 0.37$
Total carotenoids (μg/g)	$0.67^{b} \pm 0.06$	$1.27^{a} \pm 0.02$	$1.24^{a} \pm 0.18$
Total phenolics (mg GAE/100 g)	$11.07^{a} \pm 0.23$	$9.22^{b} \pm 0.24$	$8.48^{c} \pm 0.14$
IC_{50}*** (mg/mL)	$3.33^{b} \pm 0.02$	$3.44^{a} \pm 0.03$	$3.47^{a} \pm 0.04$

U = unripe. R = ripe and collected from the tree. RG = ripe and collected from the ground. *Longitudinal diameter = length; **Transverse diameter = width. ***IC_{50} = concentration necessary to capture 50% of the free radical DPPH. Values expressed as mean ± standard deviation. Different lowercase letters in the same line indicate 5% significance by Tukey´s test.

Many important reactions occur during ripening, including a series of complex biochemical reactions, such as the hydrolysis of starch, the conversion of chloroplasts into chromoplasts with chlorophylls degradation, carotenoid production, and the formation of volatile compounds (Speirs; Brady, 1991; Vendramini; Trugo, 2000); however, this has not previously been reported for sapota-do-Solimões fruit. An increase in pH and soluble solids and a decrease in titratable acidity are common, due to the consumption of organic acids as a substrate for respiration (Cantillo et al., 2011). High levels of soluble solids are important for the commercialization of fresh fruit and for processing. In some fruits, the soluble solids content is used to indicate the point of ripening, i.e. it can be useful to determine the harvesting point (Lopes et al., 2001; Nascimento; Martins; Hojo, 2008) and for the sapota-do-Solimões it was found that these levels increased with ripening. Sugar content varies depending on the ripening stage of the fruit because the sugar content in fruit pulp is directly related to the total soluble solids content (Sousa et al., 2012).

Water-soluble vitamins, especially ascorbic acid, are very susceptible to post-harvest degradation when fruits are exposed to adverse handling and storage conditions. Other research regarding the stability of ascorbic acid in fruits has produced diverse results. Cardello and Cardello (1998) observed a considerable reduction of this vitamin during fourteen days of ripening of Haden mango. However, Lee and Kader (2000) reported an

increase in ascorbic acid content in peach and papaya and a reduction in apple and mango, as ripening continued.

Carotenoids are very stable compounds that remain intact even when senescence is well advanced and their synthesis is important during the development of fruit (Rodriguez-Amaya; Kimura, 2004). Phenolic content is usually higher in unripe fruits than in ripe; therefore, fruits show a decrease in phenolic compounds during ripening (Ozawa; Lilley; Haslam, 1987).

3.2 Chemical composition and analysis of fatty acids

The chemical composition of the pulps varied depending on the ripening stage (Table 2). Moisture increased significantly (79.23-87.05%) and ash decreased significantly (0.95-0.62%) throughout the period of ripening. The level of crude protein was higher in the U fruit (1.25%) and presented a significant difference when compared to the R and the RG fruit (0.63-0.68%). Protein decreased about 50% with ripening due to biochemical degradation and proportional proximate composition distribution. It is well known that amino acids are precursors of a series of volatiles formed during ripening (Vendramini; Trugo, 2000).

The lipids increased significantly in relation to the U (0.16%) and the RG fruit (0.30%). The level of total dietary fiber reduced during ripening and there was an increase in the soluble fiber content (0.22-0.93%) and a decrease in the insoluble fiber content (10.23-2.59%). During ripening, there was a reduction in the level of carbohydrates (7.95-7.83%) and calories (38.26-36.73%), and it was therefore concluded that sapota-do-Solimões is a low-calorie fruit.

Table 2 – Chemical composition of sapota-do-Solimões (*Quararibea cordata*) pulp in 100 g of fresh sample at different ripening stages

Constituents g%	Ripening stages		
	U	R	RG
Moisture	$79.23^{c} \pm 0.03$	$86.83^{b} \pm 0.01$	$87.05^{a} \pm 0.02$
Ash	$0.95^{a} \pm 0.01$	$0.68^{b} \pm 0.01$	$0.62^{c} \pm 0.01$
Protein	$1.25^{a} \pm 0.05$	$0.63^{b} \pm 0.04$	$0.68^{b} \pm 0.00$
Lipids	$0.16^{b} \pm 0.05$	$0.22^{ab} \pm 0.05$	$0.30^{a} \pm 0.03$
Dietary fiber	$10.45^{a} \pm 0.81$	$4.64^{b} \pm 0.01$	$3.52^{b} \pm 0.06$
Soluble fiber	$0.22^{c} \pm 0.08$	$0.57^{b} \pm 0.20$	$0.93^{a} \pm 0.03$
Insoluble fiber	$10.23^{a} \pm 0.90$	$4.07^{b} \pm 0.21$	$2.59^{c} \pm 0.09$
Carbohydrates	$7.95^{a} \pm 0.83$	$6.99^{b} \pm 0.08$	$7.83^{a} \pm 0.07$
Calories (Kcal)	$38.26^{a} \pm 3.08$	$32.48^{b} \pm 0.29$	$36.73^{a} \pm 0.23$

U = unripe. R = ripe and collected from the tree. RG = ripe and collected from the ground. Values expressed as mean ± standard deviation. Different letters in the same line indicate 5% significance by Tukey´s test.

Eleven fatty acids were detected in the pulp of sapota-do-Solimões samples from different ripening stages, nine of which were identified and two of which were unidentified (Table 3). Some fatty acids present a significant difference among the treatments. The palmitic (16:0), stearic (18:0), oleic (18:1 n9) and vaccenic (18:1 n7) increased with ripening. The major saturated fatty acid that was found was palmitic acid, which presented a significant increase in the U (47.10 mg/100 g) compared to the RG (86.39 mg/100 g). The unsaturated fatty acids presented higher concentrations and the major fatty acid was oleic acid, which presented a significant increase in the U (44.38 mg/100 g) compared to the RG (131.13 mg/100 g). The palmitoleic (16:1 n7) and linoleic (18:2 n6) presented a significant reduction during ripening, possibly due to the formation of compounds during the secondary metabolism of the fruit. The total amount of saturated and unsaturated fatty acids were as follows: U 52.16 and 104.7 mg/100 g; R 78.19 and 134.46 mg/100 g; and RG 95.27 and 193.10 mg/100 g, respectively.

The widest variety of flavor compounds formed from lipids arises via lipoxygenase activity. Many of the esters and alcohols, for example, found in fruits are derived from the oxidative degradation of linoleic and linolenic acids (Reineccius, 2006).

Table 3 – Profile of fatty acids from sapota-do-Solimões (*Quararibea cordata*) pulp in mg/100 g of fresh sample at different ripening stages

Fatty acids (mg/100 g)	Ripening stages		
	U	R	RG
Lauric (12:0)	nd	$1.76^{a} \pm 0.77$	$0.78^{a} \pm 0.90$
Myristic (14:0)	$1.93^{a} \pm 0.48$	$3.51^{a} \pm 1.08$	$2.25^{a} \pm 0.31$
Palmitic (16:0)	$47.10^{c} \pm 7.15$	$68.64^{b} \pm 2.50$	$86.39^{a} \pm 7.48$
Palmitoleic (16:1 n7)	$16.44^{a} \pm 2.79$	$12.89^{ab} \pm 1.93$	$9.96^{b} \pm 1.51$
Unidentified	nd	$2.91^{a} \pm 0.67$	$5.60^{a} \pm 1.25$
Stearic (18:0)	$3.13^{b} \pm 0.37$	$4.28^{b} \pm 0.19$	$5.85^{a} \pm 0.64$
Oleic (18:1 n9)	$44.38^{c} \pm 5.08$	$66.49^{b} \pm 2.71$	$131.13^{a} \pm 11.13$
Vaccenic (18:1 n7)	$25.25^{c} \pm 3.31$	$30.55^{b} \pm 0.96$	$37.74^{a} \pm 1.24$
Linoleic (18:2 n6)	$6.55^{a} \pm 0.91$	$6.42^{a} \pm 1.62$	$3.45^{b} \pm 0.74$
Unidentified	$3.11^{b} \pm 0.37$	$4.43^{b} \pm 0.71$	$6.05^{a} \pm 1.19$
Linolenic (18:3 n3)	$12.11^{b} \pm 3.79$	$18.11^{a} \pm 1.76$	$10.82^{b} \pm 0.68$
Total saturated fatty acids	52.16	78.19	95.27
Total unsaturated fatty acids	104.73	134.46	193.10
Total unidentified fatty acids	3.11	7.34	11.65
Ratio n-6/n-3	0.54	0.35	0.32

U = unripe. R = ripe and collected from the tree. RG = ripe and collected from the ground. nd = not detected. Values expressed as mean ± standard deviation. Different letters in the same line indicate 5% significance by Tukey´s test or different by t-Student test.

3.3 Analysis of volatile compounds

The chromatographic analysis of the volatile fraction extracted by HS-SPME in relation to the three ripening stages of the sapota-do-Solimões pulp resulted in the identification of 86 compounds; 57 components in U stage, 54 in R and 68 in RG. The identified components, their respective retention indices and mean areas at each ripening stage is shown in Table 4.

Table 4 – Volatile chemical composition (area x 10^5) of sapota-do-Solimões (*Quararibea cordata*) pulps at different ripening stages

Component	RI[1]	RI_{lit}[2]	U[3]	R[3]	RG[3]
Alcohols					
Ethanol	940	936	$485.71^{a} \pm 60.44$	$933.94^{a} \pm 948.85$	$770.96^{a} \pm 113.90$
1-Propanol	1043	1040	$10.41^{a} \pm 6.37$	$2.12^{a} \pm 1.42^{**}$	$3.97^{a} \pm 0.32$
3-Penten-2-ol	1099	1100	$42.38^{a} \pm 15.25$	$24.37^{a} \pm 7.87$	nd
2-Methyl-1-propanol	1101	1095	nd	nd	41.11 ± 8.82
2-Pentanol	1131	1124	2.12 ± 1.57	nd	nd
2-Methyl-2-propanol	1155	1150	$15.61^{ab} \pm 0.21^{**}$	$24.54^{a} \pm 6.87^{**}$	$1.93^{b} \pm 0.07^{**}$
1-Penten-3-ol	1166	1164	$14.65^{a} \pm 4.66$	$12.62^{a} \pm 3.98$	$16.58^{a} \pm 5.73$
3-Hexanol	1200	1200	$2.92^{a} \pm 1.92^{**}$	nd	$1.85^{a} \pm 1.05$
3-Methyl-1-butanol	1210	1203	$111.76^{a} \pm 37.22^{**}$	$42.98^{a} \pm 32.27$	$48.09^{a} \pm 22.78$
(Z)-2-Penten-1-ol	1317	1314	$7.82^{a} \pm 3.96$	$1.98^{a} \pm 0.57$	$4.87^{a} \pm 1.64$
1-Hexanol	1347	1345	$184.45^{a} \pm 79.21$	$9.78^{b} \pm 2.68$	$28.51^{b} \pm 20.88$
(E)-3-Hexen-1-ol	1365	1365	$9.23^{ab} \pm 4.93$	$42.12^{a} \pm 21.80$	$3.14^{b} \pm 2.33^{**}$
4-Octanol	1374	1376	$0.71^{a} \pm 0.35^{**}$	nd	$0.65^{a} \pm 0.09^{**}$
(Z)-3-Hexen-1-ol	1377	1370	$302.51^{a} \pm 115.46$	nd	$136.41^{a} \pm 77.44$
(E)-2-Hexen-1-ol	1398	1397	$19.39^{a} \pm 8.85$	$3.40^{a} \pm 1.19^{**}$	$10.10^{a} \pm 3.52$
1-Octen-3-ol	1442	1456	nd	$2.18^{a} \pm 0.00^{*}$	$3.55^{a} \pm 1.20$
2-Ethyl-1-hexanol	1480	1465	$0.68^{a} \pm 0.00^{*}$	$1.67^{a} \pm 0.00^{*}$	$4.07^{a} \pm 1.67$
1-Octanol	1556	1562	nd	nd	3.21 ± 1.85
(Z)-6-Nonen-1-ol	1721	1720	$3.94 \pm 0.30^{**}$	nd	nd
(E,Z)-3,6-Nonadien-1-ol	1758	1764	$3.61 \pm 2.63^{**}$	nd	nd
2-Phenylethanol	1931	1931	$7.90 \pm 2.24^{**}$	nd	nd
1-Dodecanol	1970	1973	$3.43^{a} \pm 0.64^{**}$	nd	$2.89^{a} \pm 0.00^{*}$
1-Tridecanol	2063	2041	$2.08^{a} \pm 1.48^{**}$	$0.40^{a} \pm 0.00^{*}$	$1.35^{a} \pm 0.00^{*}$
1-Hexadecanol	2398	2381	nd	nd	$6.35 \pm 5.14^{**}$
Total (%)			*33.59*	*32.60*	*32.30*
Aldehydes					
Ethanal	724	727	$257.80^{a} \pm 81.93$	$345.10^{a} \pm 264.49$	$117.45^{a} \pm 17.54$
Propanal	797	798	$2.57^{b} \pm 1.15$	$11.23^{a} \pm 3.84$	$2.88^{b} \pm 1.24$
2-Methyl-1-propanal	811	812	$15.32^{a} \pm 11.50$	$24.83^{a} \pm 6.11$	$13.98^{a} \pm 3.98$
Butanal	885	853	$3.72^{a} \pm 4.06^{**}$	$0.59^{a} \pm 0.16^{**}$	nd
2-Methyl-1-butanal	917	916	$51.99^{a} \pm 37.16$	$46.02^{a} \pm 7.26$	$18.12^{a} \pm 6.27$
3-Methyl-1-butanal	921	921	$82.66^{a} \pm 50.95$	$90.53^{a} \pm 32.39$	$21.71^{a} \pm 9.96$
Hexanal	1080	1080	$235.40^{a} \pm 123.41$	$15.48^{b} \pm 1.94$	$34.28^{b} \pm 7.66$
(Z)-2-Hexenal	1206	1208	$14.63^{a} \pm 1.13^{**}$	nd	$15.27^{a} \pm 1.90$
(E)-2-Hexenal	1219	1218	$760.50^{a} \pm 361.94$	$138.48^{b} \pm 35.92$	$562.78^{ab} \pm 105.84$
(E,E)-2,4-Hexadienal	1429	1411	$6.19^{a} \pm 0.00^{*}$	nd	$6.62^{a} \pm 4.44^{**}$
(Z)-6-Nonenal	1445	1459	34.13 ± 15.14	nd	nd
(E)-2-Nonenal	1550	1556	$3.91 \pm 0.00^{*}$	nd	nd
(E,E)-2,6-Nonadienal	1596	1597	$11.27^{a} \pm 7.12$	nd	$0.97^{a} \pm 0.60^{**}$
Phenylacetaldehyde	1661	1650	$15.19^{a} \pm 8.62^{**}$	$20.97^{a} \pm 6.93$	$16.69^{a} \pm 1.64^{**}$
Total (%)			*40.52*	*20.51*	*22.39*
Ketones					
2-Propanone	822	814	$16.05^{a} \pm 4.48$	$26.13^{a} \pm 2.16$	$12.56^{a} \pm 0.00^{*}$
2-Butanone	913	905	$6.85^{a} \pm 9.79$	$0.99^{a} \pm 0.00^{*}$	$1.29^{a} \pm 0.25$
3-Methyl-2-butanone	935	929	$7.72^{a} \pm 10.84$	$6.49^{a} \pm 8.07$	nd
2,3-Butanedione	993	984	94.74 ± 6.29	nd	nd
3-Hexanone	1052	1055	$2.19 \pm 0.00^{*}$	nd	nd
3-Hydroxy-2-butanone	1284	1270	$135.21^{a} \pm 34.30$	$13.40^{b} \pm 3.36$	nd
2,3-Octanedione	1318	-	$7.23 \pm 1.65^{**}$	nd	nd
6-Methyl-5-hepten-2-one	1331	1325	nd	$2.64^{a} \pm 0.00^{*}$	$9.64^{a} \pm 2.13$
Isobutyl-2-heptenone	1342	-	nd	nd	8.10 ± 2.67

Table 4 – Continued

Component	RI[1]	RI_{lit}[2]	U[3]	R[3]	RG[3]
4-Methoxy-3-octen-2-one	1670	-	$39.63^{a} \pm 3.76$	$218.50^{a} \pm 168.03$	$131.78^{a} \pm 122.55$
3-Methyl-4-octanone	1994	1964	$1.13^{b} \pm 0.00^{**}$	$1.47^{b} \pm 0.13^{**}$	$6.85^{a} \pm 1.88$
Total (%)			*8.41*	*7.97*	*4.70*
Esters					
Ethyl ethanoate	897	890	$324.77^{a} \pm 120.74$	$314.51^{a} \pm 27.76$	$115.45^{b} \pm 48.98$
Ethyl isobutanoate	966	955	$22.50^{a} \pm 17.16^{**}$	$11.56^{a} \pm 10.66$	$0.78^{a} \pm 0.45$
Ethyl butanoate	1035	1039	nd	$8.83^{a} \pm 4.07$	$3.88^{a} \pm 1.92^{**}$
Ethyl 2-methylbutanoate	1047	1053	$11.74^{a} \pm 5.58$	$9.48^{a} \pm 4.46$	$0.11^{a} \pm 0.05$
Butyl ethanoate	1071	1078	nd	36.47 ± 8.43	nd
3-Methylbutyl ethanoate	1114	1119	nd	2.06 ± 0.44	nd
Ethyl (E)-2-butenoate	1162	1161	nd	11.68 ± 4.96^{a}	$2.28 \pm 1.07^{a**}$
Ethyl 2-methyl-2-butenoate	1230	1234	$6.83^{b} \pm 3.85$	$37.42^{a} \pm 13.62$	nd
Ethyl 3-hydroxybutanoate	1524	1527	nd	$7.56^{a} \pm 1.65$	$2.30^{b} \pm 0.95^{**}$
Methyl benzoate	1636	1628	nd	nd	122.13 ± 53.14
Ethyl benzoate	1678	1662	nd	$0.95^{a} \pm 0.00^{*}$	$28.04^{a} \pm 27.40$
Ethyl benzenepropanoate	1896	1886	nd	$0.79^{b} \pm 0.05^{**}$	$2.48^{a} \pm 0.00^{*}$
Dibutyl (Z)-2-butenedioate	2096	-	$0.41 \pm 0.00^{*}$	nd	nd
Total (%)			*9.92*	*13.05*	*7.79*
Terpenoids					
α-Pinene	1012	1017	nd	$0.78^{b} \pm 0.12$	$13.70^{a} \pm 1.99$
β-Pinene	1085	1099	nd	$7.16^{b} \pm 0.82$	$27.58^{a} \pm 5.74$
Limonene	1175	1180	$2.26^{b} \pm 1.00$	$4.87^{ab} \pm 3.11^{**}$	$9.38^{a} \pm 0.89$
Eucalyptol	1190	1197	$5.20^{a} \pm 6.99$	nd	$11.11^{a} \pm 2.26$
(E)-β-Ocimene	1234	1240	$1.49^{b} \pm 0.31^{**}$	$12.02^{a} \pm 2.75$	$7.45^{ab} \pm 1.33^{**}$
o-Cymene	1249	1245	nd	nd	9.45 ± 2.54
cis-Linalool oxide	1432	-	nd	nd	9.41 ± 1.48
Linalool	1547	1550	nd	$2.19^{a} \pm 0.50$	$4.41^{a} \pm 2.07$
4-Terpineol	1601	1609	nd	nd	11.80 ± 3.71
β-Cyclocitral	1620	1616	nd	nd	$1.06 \pm 0.00^{*}$
(E)-Pinocarveol	1651	1664	$5.81^{b} \pm 2.74$	$9.13^{ab} \pm 0.78$	$15.49^{a} \pm 4.87$
α-Terpineol	1701	1708	nd	nd	74.43 ± 20.06
Myrtenol	1796	-	nd	nd	7.91 ± 1.43
Geranyl acetone	1869	1850	nd	nd	9.90 ± 2.30
Total (%)			*0.40*	*1.07*	*5.90*
Miscellaneous					
Hexane	600	600	nd	$181.01^{a} \pm 0.00^{*}$	$76.59^{b} \pm 3.23^{**}$
Dimethyl sulfide	751	752	$109.35^{a} \pm 28.45$	$143.24^{a} \pm 36.17$	$121.08^{a} \pm 15.76$
Propionic anhydride	960	966	nd	$24.03^{a} \pm 0.00^{*}$	$0.51^{b} \pm 0.35$
Methoxymethyl-benzene	1387	1396	nd	nd	9.27 ± 1.69
Acetic acid	1454	1455	$52.31^{a} \pm 14.83$	$7.05^{a} \pm 3.00^{**}$	$5.84^{a} \pm 0.00^{*}$
2,5-Dimethyl-2,4-dihydroxy-3(2H)-furanone	1502	1554	nd	$10.97^{b} \pm 7.56$	$56.93^{a} \pm 48.88$
Pyrrole	1514	1516	$2.26 \pm 0.58^{**}$	nd	nd
Furaneol	1692	-	$86.84^{b} \pm 26.15$	$465.53^{a} \pm 59.37$	$661.30^{a} \pm 190.93$
1,2-Dimethoxybenzene	1756	1741	nd	$0.69^{a} \pm 0.22^{**}$	$1.75^{a} \pm 1.52^{**}$
2,4-Di-tert-butylphenol	2328	2321	$13.68^{a} \pm 8.74$	$5.74^{a} \pm 1.51$	$12.48^{a} \pm 12.56$
Total (%)			*7.16*	*24.80*	*26.92*

U = unripe. R = ripe and collected from the tree. RG = ripe and collected from the ground. nd = not detected. [1]Retention indices exhibited by the compounds in the column; [2]Retention indices according to data available in the NIST database; [3]Average area x 10^5 of the peak of the chromatogram obtained by HS-SPME. Values expressed as mean ± standard deviation. **Two values detected. *One value detected. Different letters in the same line indicate 5% significance by Tukey´s test or different by t-Student test.

The volatile compounds found in the sapota-do-Solimões pulp belong to different classes, and most relevant were alcohols, aldehydes, esters, furans, ketones and terpenes. Although the total percentage of alcohols did not change during ripening (33.59%, 32.60% and 32.30%, respectively for U, R and RG). There was an increase in the levels of ethanol ripening fruits. On the other hand, hexanol, (Z)-3-hexen-1-ol and 3-methyl-1-butanol, which was present in the greatest concentration in the U, with exception of the last one, it is formed

from metabolism of fatty acids, also providing green or herbaceous aromas (Romeo et al., 2007).

The aldehydes decreased about 20% in the R and RG treatments in relation to U fruit. There was a reduction in the ethanal, as well as a reduction in the hexanal and (E)-2-hexenal, which are related to herbaceous odors (Cantillo et al., 2011). Hexenal and (E)-2-hexenal are formed by action of lipoxygenase pathway (Mattheis; Buchanan; Fellman, 1997). The 2-methyl and 3-methyl-1-butanal (apple-like odor) (Lewis, 2007) compounds were found at all ripening stages of sapota-do-Solimões pulp and possibly formed from the interaction of amino acids and sugars (Hui, 2010).

Ketones result from biosynthesis and/or degradation of fatty acids by β-oxidation (Schwab et al., 2008). From ketones class, were observed a decrease of the 3-hydroxy-2-butanone with ripening and in RG fruits this compound was not detected. 3-Hydroxy-2-butanone is known an odor of acetoin that resembles butter and cream (Smogrovicová; Dömény, 1999). However, the 4-methoxy-3-octen-2-one areas increased with ripening, as well as 3-methyl-4-octanone and 6-methyl-5-hepten-2-one. The latter compound is citrus and known to be an oxidative byproduct or derived from carotenoids degradation (Furia, 1980; Goff; Klee, 2006).

Esters are compounds that are sensorially described as having fruity odors. The effect of different ripening stages on the volatile composition of sapota-do-Solimões it was showed that the development of the aroma profile was evidenced by an increase in the number of compounds from 4 to 11 in the U fruit and R fruit, respectively. In the present study, the RG presented the benzoate esters of methyl and ethyl, which are sensory described as plum, sweet and floral odors. Ethyl 3-hydroxybutanoate and ethyl benzenepropanoate appeared in the ripe samples (R and RG). The values found for this class of compounds correspond to the sum of the endogenous content and the formation by enzymatic action, which act to degrade linolenic and linoleic acids (Cantillo et al., 2011).

There was also an increase in the terpene compounds in conjunction with ripening; from 0.4% in U fruit to 5.6% in the RG fruit. These volatile compounds can be formed by the metabolism of the fruit or by the enzymatic or chemical degradation of precursors such as carotenoids or their glycosides forms. During the last stage of ripening the fruit pulp is characterized by an intense orange color providing of carotenoids compounds and it degradation can occur in postharvest, as mentioned above for ketones. The terpenes have potential odoriferous characteristics such as α-terpineol (floral), eucalyptol (freshness, mint), linalool (flowers, lavender) and o-cymene (citrus) (Jirovetz; Buchbauer; Ngassoum, 1998;

Ceva-Antunes et al., 2003). Santos et al. (1998) showed the concentrations of terpenoids compounds varied according to the different ripening stages.

In relation to the sapota-do-Solimões, the terpenes, α-pinene and β-pinene appeared in the ripe fruits and, among these treatments, in the ripe fruit collected from the ground (RG) the concentration was higher than in the ripe fruit collected from the tree (R). Both of these compounds are referred to as having a pine odor (Andrade et al., 2001; Oliveira et al., 2006). In relation to (E)-β-ocimene and limonene, there was an increase during ripening and both compounds have a citric odor (Santos et al., 1998; Vendramini; Trugo, 2000). These terpenoids are primarily oxidation - degraded products of the carotenoids (Hui, 2010).

In the group miscellaneous, stand out the furans that increased from 2.4% U fruit to 20.7% from RG. The increased formation of furans compounds is characterized by a sweet and fruity aroma (Cantillo et al., 2011). The 2,5-dimethyl-2,4-dihydroxy-3 (2H) furanone and furaneol compounds increased with the ripening of the fruit, enhancing an odor that resembles caramel (Mosciano et al., 1996).

3.4 Sensory analysis

The attributes of color, odor, flavor, texture and appearance of the ripe samples R and RG were evaluated. The panel of 50 consumers were composed of 68% female and 32% male. The predominant age group (54%) was 18-30 and 46% were aged 31-60. The sensory characteristics and acceptability index are presented in Table 5.

Table 5 – Scores provided by consumers regarding sensory characteristics and acceptability index (%) for color, odor, flavor, texture and appearance for samples of sapota-do-Solimões (*Quararibea cordata*) at different ripening stages

Ripening stages	Sensory characteristics - attributes				
	Color	Odor	Taste	Texture	Appearance
R	$5.82^{ns} \pm 1.27$	5.64 ± 1.10	5.70 ± 1.23	5.36 ± 1.31	5.78 ± 1.11
RG	$5.92^{ns} \pm 1.12$	5.60 ± 0.95	5.86 ± 1.01	5.34 ± 1.33	5.64 ± 1.19
Ripening stages	Acceptability index (%) - attributes				
	Color	Odor	Taste	Texture	Appearance
R	83.14	80.57	81.43	76.57	82.57
RG	84.57	80.00	83.71	76.29	80.57

R = ripe fruit collected from the tree. RG = ripe fruit collected from the ground. Values expressed as mean ± standard deviation. ns = not significant by t-Student test. Scores: 1 = disliked greatly; 2 = disliked a lot; 3 = moderately disliked; 4 = neither liked nor disliked; 5 = moderately liked; 6 = liked a lot; 7 = liked very much.

The scores attributed to the analyzed attributes ranged from 5-6, which were classified as "moderately liked" and "liked a lot" in the structured seven-point hedonic scale. There were

no significant difference ($p > 0.05$) between the ripe samples collected from the tree and the ground in terms of the analyzed attributes. Regarding the acceptability index of the samples, the values for all the attributes were higher than 70%.

The consumers reported that the sapota-do-Solimões reminded them of papaya and mango fruits, as has already been described in the literature (Cavalcante, 1991), and they also mentioned that sapota-do-Solimões reminded them of fruits such as *abiu* (*Pouteria caimito*), *jerimum* (*Curcubita noschata*), *pupunha* (*Bactris gasipaes*) and kaki (*Diospyrus kaki*).

The fact that there were no significant differences for the analyzed attributes possibly indicates that a short post-harvest period between R and RG fruits can be consumed without differentiation in acceptance. Also, in relation to the odor, at the moment of the sensorial analysis, the fruits probably had a similar level of aromatic compounds, being not perceptible the distinction of the terpenes compounds that increased their concentration or appeared in the RG fruit and different notes were equally accepted.

3.5 Exploratory data analysis

Exploratory data analysis was performed using the principal component analysis (PCA). The selection criterion for the compounds that was adopted was the power of discrimination among the samples, i.e. those compounds that presented significance statistical in area values were used. The variables that were excluded were those that presented a low power of discrimination (equal areas) and also those that were only found in one sample. Figure 1 shows the graphs of the scores (samples) and the loadings (compounds) of the first two principal components (PCs) resulting from the PCA, which accumulated 82.04% of the total data variance. Using PCA it was possible to easy access to relevant information about the correlation between the variables and samples. There was a separation of the samples in relation to the different ripening stages of the sapota-do-Solimões pulps, so that the U samples were positioned in the negative quadrants (PCI) and the ripe samples R and RG were located in the positive quadrants (Figure 1a). The U and RG fruit were located in opposite quadrants because they had high concentrations of distinct quality characteristics, as well as different chemical composition and volatile compounds.

In relation to the parameters of quality, chemical composition and fatty acids (Figure 1b), the main difference between the groups was regarding the higher concentration of titratable acidity, ascorbic acid, total phenolics, ash, protein, dietary fiber, insoluble fiber, carbohydrates, calories and fatty acids palmitoleic and linoleic from U fruit, while in the RG fruit there was a higher concentration of water activity, pH, soluble solids, total sugars,

reducing sugars, non-reducing sugars, total carotenoids, moisture, lipids, soluble fiber and fatty acids palmitic, stearic, oleic and vaccenic.

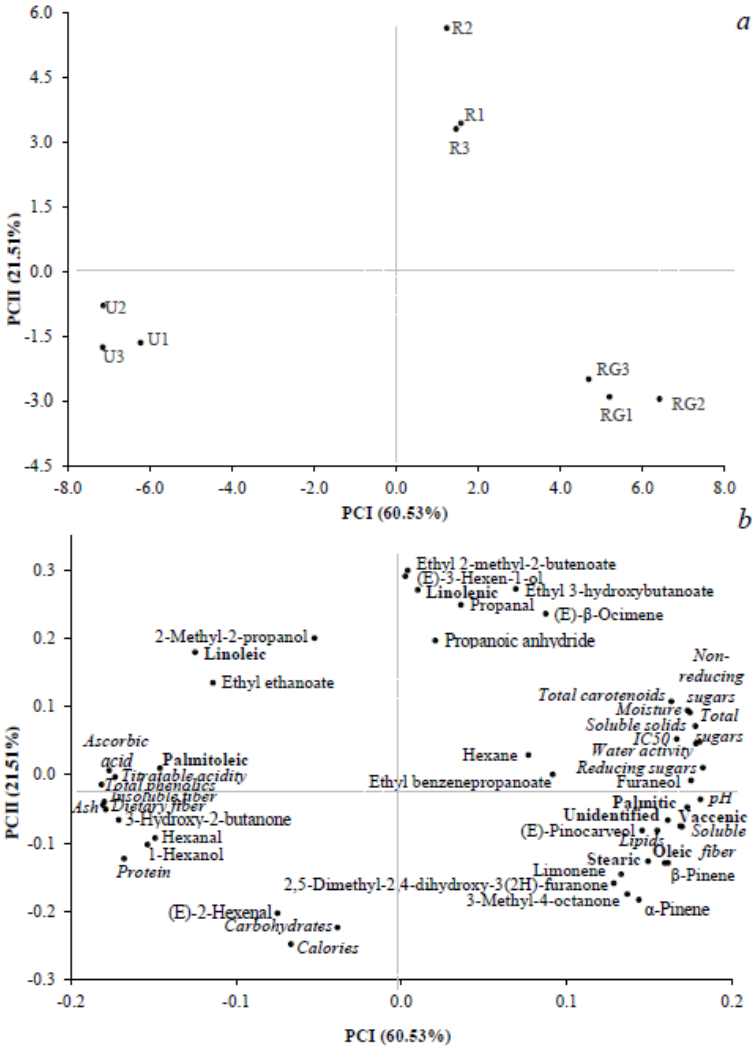

Figure 1 – Analysis of the main components of the chemical and volatile composition of sapota-do-Solimões (*Quararibea cordata*) pulp at different ripening stages. *a* - scoring plots (samples), U = unripe. R = ripe and collected from the tree. RG = ripe and collected from the ground. *b* - plots of weight (variables).

The main difference between the groups in relation to volatile compounds (Figure 1b) was the higher concentration of alcohols (2-methyl-2-propanol and 1-hexanol) and aldehydes (hexanal and (E)-2-hexenal), also showed ketone (3-hidroxy-2-butanone) and ester (ethyl ethanoate) in U samples, which had a negative influence on this ripening stage, while the RG samples stood out in terms of their content of furans (2,5-dimethyl-2,4-dihydroxy-3(2H)-furanone and furaneol), terpenes (α-pinene, β-pinene, limonene and (E)-pinocarveol), hydrocarbon (hexane) also showed ketone (3-methyl-4-octanone) and ester (ethyl benzenepropanoate), which had a positive influence at this ripening stage. Consequently, this

analysis was useful in terms of visualizing the volatile characteristics of each sample, grouping them by similarity in relation to the content of the various volatile compounds.

The R samples were positioned in the positive quadrants, discriminated by PCII, and R fruit is positioned between the U and RG samples in the PCI. This point of ripening differs from others in relation to volatile compounds was the higher concentration of esters (ethyl 2-methyl-2-butenoate and ethyl 3-hidroxybutanoate), also showed terpene ((E)-β-ocimene), aldehyde (propanal), alcohol ((E)-3-hexen-1-ol) and anhydride (propanoic anhydride).

The aroma of the sapota-do-Solimões pulps was influenced by the ripening stage, so that some compounds, and even some chemical classes, were exclusively detected in one of these stages, thereby acting as chemical markers of ripening. The sapota-do-Solimões at the U fruit was characterized by the presence of alcohols, aldehydes and ketones, while the main chemical characteristic of the ripe sapota-do-Solimões collected from the tree (R) and the ground (RG) was an increase in characteristically fruity odor compounds such as esters, terpenes and furans.

4 Conclusions

The results showed that the composition of the fruits was influenced by the ripening stage of the pulps. The ripe samples presented a higher content of carotenoids and lipids, as well as a profile of fatty acids that may be important for the formation of flavor precursors, which consequently contribute to the quality of the fruit.

The volatile compounds, during the ripening from sapota-do-Solimões pulps, increased the presence esters, furans and terpenes. This is the first time that a study about ripening in sapota-do-Solimões has been reported, as well fatty acids and volatile compounds of sapota-do-Solimões pulp.

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5 CONCLUSÃO

O estudo possibilitou verificar que houve pouca variação nas características biométricas dos frutos da sapota-do-Solimões, portanto, as sapotazeiras cultivadas em Vila Vale, Tefé-AM, produzem frutos homogêneos o que possibilita garantir um padrão de qualidade para apresentação desses frutos para outros mercados consumidores.

A sapota-do-Solimões apresentou maior quantidade de casca em relação à polpa e sementes. O alto teor de fibra alimentar foi notável em todas as partes da fruta. O endocarpo contém maiores teores de minerais, com exceção do cálcio encontrado no epicarpo. O mineral magnésio na polpa atingiu um bom percentual da Ingestão Diária Recomendada, sendo o mineral de maior relevância para essa parte da sapota-do-Solimões.

As polpas processadas de sapota-do-Solimões têm elevada atividade de água e são pouco ácidas. O congelamento, a refrigeração e a pasteurização da polpa praticamente não afetaram os parâmetros físico-químicos que variaram em função do tempo de armazenamento, destacando a diminuição da atividade de água em todos os tratamentos e a redução do pH nas polpas armazenadas sob refrigeração. Ao longo do armazenamento, as polpas ficaram mais claras, houve um aumento na intensidade da cor alaranjada e a tonalidade das polpas congeladas não variou significativamente.

Em relação aos compostos com potencial bioativo, o ácido ascórbico manteve-se estável durante o congelamento, o teor de carotenoides totais foi preservado no tratamento pasteurizado e armazenado sob congelamento, os polifenóis totais permaneceram estáveis entre os tratamentos até os 150 dias de armazenamento e os tratamentos pasteurizados apresentaram valores inferiores, por fim, a atividade antioxidante diminuiu ao longo do armazenamento em todos os tratamentos e, nos tratamentos mantidos sob refrigeração, houve uma perda maior de 50% na atividade antioxidante no tempo 180.

As polpas, congeladas e refrigeradas, apresentaram boa estabilidade e estavam aptas para o consumo até o tempo de 180 dias de armazenamento, exceto a polpa refrigerada a partir do período 150, de acordo com a legislação brasileira indicando que foi processada em boas condições higiênicas e sanitárias e a pasteurização foi eficaz, pois apresentou contagens inferiores em relação às polpas não pasteurizadas.

A composição dos frutos foi influenciada pelo estádio de maturação das polpas e as amostras maduras apresentaram características desejáveis como, maior teor de carotenoides, lipídeos e um perfil de ácidos graxos que pode ser importante para a formação de precursores de sabor, que consequentemente contribuem para a qualidade da fruta e de seus produtos.

A análise dos compostos voláteis das polpas de sapota-do-Solimões permitiu caracterizar quimicamente o aroma desenvolvido pelos frutos ao longo do amadurecimento. O aumento da presença de ésteres, furanos e terpenos foi associada à maturação. Esta é a primeira vez que um estudo sobre amadurecimento em sapota-do-Solimões foi relatado, bem como ácidos graxos e compostos voláteis da polpa sapota-do-Solimões.

Para os próximos trabalhos, sugere-se que a temperatura de pasteurização mais alta seja utilizada na obtenção das polpas com intuito de inativação de enzimas, que o padrão respiratório da sapota-do-Solimões seja analisado, que a análise sensorial seja realizada em outro local para testar a aceitação da fruta em um novo mercado consumidor e que a análise sensorial, por meio de uma Análise Descritiva Qualitativa (ADQ), seja realizada para correlacionar com os compostos voláteis encontrados nos diferentes estágios de amadurecimento da sapota-do-Solimões.

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