VANESSA RIOS DE SOUZA

DEVELOPMENT OF NEW PRODUCTS:

FUNCTIONAL AND LOW CALORIE CERRADO MIXED FRUITS JAM

LAVRAS – MG

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Dissertação apresentada à Universidade Federal de Lavras, como parte das exigências do Programa de Pós Graduação em Ciência dos Alimentos, para obtenção do título de Mestre.

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Ficha Catalográfica Preparada pela Divisão de Processos Técnicos da Biblioteca da UFLA

Souza, Vanessa Rios de.
Development of new products : functional and low calorie Cerrado mixed fruits jam / Vanessa Rios de Souza. – Lavras : UFLA, 2012.
139 p. : il.

Dissertação (mestrado) – Universidade Federal de Lavras, 2012.
Orientador: Fabiana Queiroz.
Bibliografia.

1. Frutas do Cerrado. 2. Doce. 3. Funcional. 4. Edulcorantes. I. Universidade Federal de Lavras. II. Título.

CDD – 664.153

VANESSA RIOS DE SOUZA

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(**DESENVOLVIMENTO DE NOVOS PRODUTOS**: DOCES FUNCIONAIS E DE BAIXO VALOR CALÓRICO ELABORADOS COM FRUTAS DO CERRADO)

Dissertação apresentada à Universidade Federal de Lavras, como parte das exigências do Programa de Pós Graduação em Ciência dos Alimentos, para obtenção do título de Mestre.

APROVADA em 06 de Fevereiro, 2012

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AGRADECIMENTOS

À Universidade Federal de Lavras e ao Departamento de Ciência dos pela oportunidade e contribuição para a minha educação.

Ao CNPQ pelo fornecimento de bolsas de estudos e apoio financeiro ao projeto (nº 559400/10-1).

Ao meu pai pela ajuda, amor, reconhecimento, força e incentivo para que eu siga o meu destino, minha mãe e meu irmão para toda a dedicação e carinho.

Ao Lucas, meu namorado por todo o apoio e companheirismo, além da grande ajuda na preparação de polpas e doces.

À toda equipe de análise sensorial, pela sua dedicação, empenho e contribuição durante todas as fases do experimento. A participação de todos foi fundamental para os resultados deste trabalho! Muito Obrigada!

A todos os meus professores que marcaram de alguma forma a minha jornada. Em particular as minhas duas orientadoras Fabiana Queiroz e Ana Carla Marques Pinheiro, obrigada pela orientação, ensinamentos e paciência.

Ao Vladimir Vietoris, obrigado pela sua participação em minha defesa. Sua presença foi muito importante.

Aos colegas da "Planta Piloto de Processamento de Produtos de Origem Vegetal". Um agradecimento especial a Patty pela ajuda incondicional na execução deste trabalho. Sua ajuda foi fundamental!

À Camila, agradeço pelos valiosos conselhos e ensinamentos. Obrigada pelo carinho!

Às laboratoristas Tina, Creuza e Cidinha e as meninas da faxina, Helô e Denise, obrigada por toda ajuda, sempre que necessário.

Ao Marcelo (Danisco) pela sua atenção e disponibilidade de ajudar, e ao fornecimento de ingredientes necessários para este trabalho.

A toda a minha família e amigos que me ajudaram de alguma forma ou torceram por mim.

Finalmente, agradeço a Deus por tudo, mas principalmente por colocar em minha vida pessoas tão especiais...

RESUMO

Uma maneira de aumentar a disponibilidade e agregar valor aos frutos do cerrado brasileiro é a criação de novos produtos, como doces e geleias. Devido ao aumento da conscientização da estreita relação entre saúde e alimentação, os consumidores estão desejando produtos com reduzido teor de açúcares e produtos que oferecem benefícios à saúde, além das funções básicas de nutrir, conhecidos como funcional. Dado este contexto, o objetivo deste trabalho foi: (1) caracterizar os frutos: marolo murici, jenipapo, maracujá doce e graviola, (2) determinar a melhor combinação e proporção de frutas (marolo murici, jenipapo, maracujá doce e graviola) na elaboração de doce misto de frutas, e (3) determinar a equivalência de doçura, perfil de doçura e amargor e aceitação sensorial do doce de frutas funcional sem açúcar adoçado com diferentes edulcorantes. A partir da caracterização de frutos, observou-se que as frutas em geral têm alto teor de nutrientes, das cinco frutas estudadas, o marolo se destacou. A polpa do marolo apresentou o maior potencial para a atividade antioxidante (131,58 μmol TEs / g), maior teor de compostos fenólicos (739,37 mgGAEs/100g) e maiores concentrações de ácido ascórbico (59,05 mg/100g). As melhores formulações de doce contêm as seguintes proporções de frutas: (1) 50% marolo e 50% de graviola; (2) 33,33% marolo, 33,33% de maracujá doce, e 33,33% de graviola; e (3) 60% marolo e 10% de cada uma das frutas: murici, jenipapo, graviola e maracujá doce. Usando o método de estimação de magnitude, para promover a doçura ideal do doce misto de frutas (33,33% marolo, 33,33% de maracujá doce e 33,33% de graviola) é necessário utilizar uma concentração de 0,0358%, 0,0472%; 0,0464%; 0,1407% e 0,0407% de sucralose, sucralose/acessulfame- k (3:1), sucralose / steviol de glicosídeo (2:1), sucralose / taumatina (1:0.6), e sucralose / acessulfame-k / neotame (5:3:0.1), respectivamente. O doce misto de frutas de baixo valor calórico apresentou perfil de doçura semelhante ao doce tradicional (com sacarose) e perfil de amargor diferente do doce tradional, mas semelhante entre eles. Em relação à aceitação sensorial não foi observada diferença significativa entre o doce sem açúcar e o doce tradional. De todos os adoçantes estudados, sugere-se usar uma combinação de sucralose / acessulfame-k (3:1) no doce de frutas sem adição de açúcar (marolo, graviola, maracujá doce), devido ao melhor custo/benefício

Palavras-chave: Frutas do Cerrado. Doce. Funcional. Edulcorantes

ABSTRACT

One way to increase availability and add value to the fruits of the Brazilian cerrado is the creation of new products such as jams, and jellies. Due to increased awareness of the strict relationship between health and food, consumers desire products with reduced sugar content and products that offer further health benefits beyond those basic to feeding. Such products are known as functional. Given this context, the objective of the work was to: (1) characterize the cerrado fruits: marolo murici, jenipapo, sweet passion fruit and soursop, (2) determine the best combination and proportion of fruit (marolo murici, jenipapo, sweet passion fruit and soursop) in the preparation of mixed fruit jam and (3) determine the equivalence of sweetness, bitterness and sweetness profile and sensory acceptance of the sugar-free functional mixed fruit jam with different sweeteners. From the characterization of fruit, it was observed that fruits generally had high nutrient contents, of the five fruits studied, marolo stood out. The marolo pulp had the greatest potential for antioxidant activity (131.58 μmol TEs/g), a higher content of phenolic compounds (739.37 mg GAEs/100g) and higher concentrations of ascorbic acid (59.05 mg/100g). The best jam formulations contained the following proportions of fruit: (1) 50% marolo and 50% soursop; (2) 33.33% marolo, 33.33% sweet passion fruit and 33.33% soursop; and (3) 60% marolo and 10% each of murici, jenipapo, soursop and sweet passion fruit. Using the magnitude estimation method it was found that to promote that ideal sweetness of mixed fruits jam (33.33% marolo, 33.33% sweet passion fruit and 33.33% soursop) it is necessary to use a concentration of 0.0358%, 0.0472%, 0.0464%, 0.1407% and 0.0407% of sucralose, sucralose/acesulfame- k (3:1), sucralose / steviol glycoside (2:1), sucralose / thaumatin (1:0.6) and sucralose / acesulfame-k / neotame (5:3:0.1), respectively. The reduced calorie jam presented a sweetness profile similar to traditional jam (with sucrose) and bitterness profile different from traditional jam, but similar between them. In relation to sensory acceptance a ,significant difference between the sugar-free jam and the traditional jam was not observed. Of all the sweeteners studied, it is suggested to use a combination of sucralose/acesulfame-k (3:1) in sugar-free mixed fruit (marolo, soursop, sweet passion fruit) jam, the value due to a better cost/benefit.

Keywords: Cerrado fruits. Jam. Funtional. Sweeteners

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SUMMARY

FIRST PART

1 INTRODUTION

Brazil has the largest biodiversity in the world, which allows a large number of fruit species. Many of these species are unknown and therefore have little commercial value. The North and Northeast regions are home to the greatest biodiversity (MATTIETO; LOPES; MENEZES, 2010). Many of these plant species provide fruits with unique sensory characteristics and high nutrient concentrations. Therefore, they are of potential interest to the agroindustry and a possible future source of income for the local population (ALMEIDA et al., 2011; CARDOSO et al., 2011).

However, few people have access to these fruits because they are found in only some regions of the country and during only a few months of the year. One way to increase availability and add even more value to exotic Brazilian fruits is to create new products such as jellies and jams. The production of jelly and jams from the fruits of Brazilian Cerrado is therefore an option for many producers to develop, not only in the domestic market, but also to attain higher prominence in the export trade.

Among the native fruits, we can mention the marolo (*Annona crassiflora* Mart.), jenipapo (*Genipa americana* L.), murici (*Byrsonima crassifolia* L. RICH), soursop (*Anona muricata*, L.) and sweet passion fruit (*Passiflora alata* Dryand).

Given the wide variety of fruits in the Brazilian cerrado, a number of products can be prepared from various mixtures. These fruits are capable of producing jams and jellies with different tastes and appearances. According Zotarelli, Zanatta and Clemente (2008), mixed fruit jams join the nutritional characteristics of two or more fruits while providing pleasant sensory characteristics in order to gradually gain prime space in the consumer market.

People are increasingly concerned about their health and appearance (MORAES; BOLINI, 2010), so consumers are increasingly concern about their food. According to Abdullah and Cheng (2001) consumers are increasingly knowledgeable about diet and health, and as a result, desire foods that offer, in addition to convenience, quality and safety and better balance of nutrients, less fat, cholesterol, sugar and calories. In addition to products known as light and diet, the increased demand for food known as functional, has emerged.

Functional foods are those that offer multiple health benefits in addition to the nutritional value inherent in their chemical composition, and may play a potentially beneficial role in reducing the risk of chronic degenerative diseases (NEUMANN et al., 2000; TAIPINA; FONTS; COHEN, 2002).

In product development which undergoes the replacement of sucrose with sweeteners, a series of sensory tests are necessary to ensure the maximum similarity of the sweetened product to the traditional product with sucrose. According to Sandrou and Arvanitoyannis (2000) individuals who, for various reasons, need to replace the non-caloric sweeteners for sucrose look for products that are endowed with taste and characteristics close to those of sucrose, ie, these consumers are increasingly looking for food with pleasant features in terms of taste, appearance, aroma and texture.

For a sweetener to replace sucrose successfully in food formulations, we must undertake studies towards prior knowledge of the sweetener concentrations to be used and their sweetness equivalent to sucrose (CARDOSO; CARDELO, 2003). There are several methods to obtain this information, but the most applied method is to estimate the magnitude and graphic representation of the results normalized by the law of Stevens or “Power Function "(MOSKOWITZ, 1970; STONE; OLIVER, 1969).

Besides being important in determining the optimal concentration of a sweetener in a product it is necessary to seek the highest similarity with sucrose, in relation to taste. The time-intensity methodology is a way to monitor the sensations perceived during all stages of food intake. This technique allows to trace the sensory profiles in detail, looking for the product with the sensory profile closer to that of sucrose (REIS, 2007).

The objective of this study was to characterize the fruits: marolo murici, jenipapo, sweet passion fruit and soursop (Article 1), determine the best combination and proportion of fruit (marolo murici, jenipapo, sweet passion fruit and soursop) in the preparation of mixed fruit jam (Article 2) and determine the equivalence of sweetness, bitterness and sweetness profile and sensory acceptance of the jam with different sweeteners, elaborated with the best combination and proportion of fruits (Article 3).

2 THEORETICAL BACKGROUND

2.1 Cerrado fruits

Brazil is the third largest producer of fruits, with a natural abundance of tropical fruits (LETERME et al., 2006) and according to Rufino et al. (2010) the consumption of these fruits is increasing in domestic and international markets due to growing recognition of their nutritional and therapeutic value.

The Cerrado covers an area of about 200 million hectares, distributed mainly in the states of Minas Gerais, Goias, Mato Grosso do Sul, Tocantins, Bahia, Piaui, Maranhao and Distrito Federal (Figure 1), corresponding to 22% of Brazil (SILVA et al., 2001).

Figure 1 Map of the Cerrado ecosystem
Font: BIOMA... (2011)

The Cerrado is home to a rich heritage of renewable natural resources adapted to climatic conditions, soil and environmental factors that determine their existence. The biodiversity of the Cerrado is very high, the number of vascular plants is higher than that found in most regions of the world: herbaceous plants, shrubs, trees and lianas total more than 7,000 species. Forty-four percent of the flora is endemic and, accordingly, the Cerrado is the most diverse tropical savanna in the world (PIVELLO et al., 1999).

Many Cerrado species are unknown and, therefore, are poorly marketed (MATTIETO; LOPES; MENEZES, 2010). Thus, Brazil has a large number of underexploited native and exotic fruit species that are of potential interest to agribusiness and a possible source of income for the local populations (ALMEIDA et al., 2011)

These fruits have an important role, both economically, through the marketing of their products, and nutritionally for their consumption (CARDOSO et al., 2011). These fruits also represent an opportunity for local producers to gain access to markets, where consumers emphasize the exotic character and presence of nutrients that can prevent degenerative diseases (ALVES et al., 2008). The fruit is no longer just a result of taste and personal preference, but has become a health concern due to the high nutrient content.

According to Soares et al. (2009) there is currently an emerging and potential market for native Cerrado fruit to be further explored by farmers, since any use of these fruits has been done in an extractive and predatory manner. In this scenario, the Cerrado has been attacked and plundered, placing various species of plants under risk of extinction, including some native fruit.

In recent years, there has been an increase in economic exploration of products and by-products of some specific fruits, attributed to increasing consumers concern of consumers and the relationship between diet and health (YAHIA, 2010). Brazilian fruits have been reported in studies around the world, reporting on their high nutritional value (ALMEIDA et al., 2011; CARDOSO et al., 2011; CLERICI; SILVA, 2011; DEMBITSKY et al., 2011; RUFINO et al., 2010).

2.1.1 Marolo (*Annona crassiflora* Mart.)

The Marolo (Annona crassiflora Mart.) (Figure 2) is a tree species native to the Brazilian Cerrado, belonging to the Magnoliales order and Annonaceae family. In central Brazil, it is popularly known as araticum-do-cerrado, araticum-do-campo and pinha-do-cerrado, and is one of the 25 most common species of the Cerrado (SOARES et al., 2009). The berry-like fruit is sub sphencalz, green when developing and brown when ripe. The pulp, which varies in color from white to yellow, is slightly sweet (SOARES et al., 2009).

Its flowering occurs predominantly during the months of October and November (LORENZI, 1998). The fructification begins in November, with fruit ripening concentrated between the months of January and April (CARVALHO, 2002).

The fruits are used as food and are highly prized for their sweet yellow pulp, and quite strong aroma. The fruit is collected between February and March (ROESLER et al., 2007).

Figure 2 Marolo fruit

2.1.2 Murici (Byrsonima ssp.)

The murici (Byrsonima ssp.) (Figure 3) is a fruit of the Cerrado mainly consumed *in natura*, being found from December to March, in the highlands of the Southeast, in the cerrado of Mato Grosso, Goias and the coast of North and Northeast Brazil. The murici belongs to the family Malpighiaceae, the same as the acerola. It has many species and therefore can be found in different colors, depending on the location of their occurrence. When mature, it appears yellowish, with diameters of 1.5 to 2 cm and a strong rancid cheese-like odor (ALVES; FRANCO, 2003). Marketing is limited to street markets and local markets. The pulp is fleshy and soft, and can be consumed raw or in the form of juices, jams, ice creams and liquors (ALVES; FRANCO, 2003).

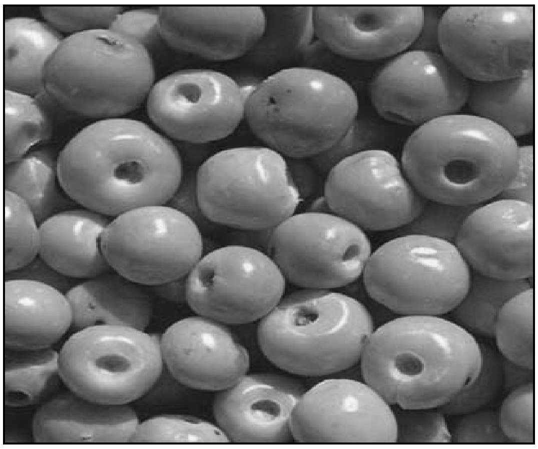

Figure 3 Murici fruit
Font: O PODER...(2011)

2.1.3 Jenipapo (*Genipa americana* L.)

The jenipapeiro (G. americana L.) (Figure 4) belongs to the Rubiaceae family and is considered a species of economic importance, both for its forest essence and food production (BARROS cited by FIGUEIREDO et al., 1986). Its geographical distribution in Brazil ranges from Guyana and Marajó to São Paulo and Mato Grosso. Outside Brazil, the distribution is also wide, stretching from Mexico to the West Indies (GOMES, 1982).

The fruits are berry-type subglobose, 8 to 10 cm long and 6 to 7 cm in diameter, soft shell, brown or brownish-yellow, membranous, thin and wrinkled (CORREA, 1969). According to Figueiredo et al. (1986) the diameter of the fruit can reach up to 8.5 cm. The pulp is sweet containing numerous long, dark gray seeds (PRANCE, 1975). Its flavor is characteristic and pronounced (POPENOE, 1974).

Figure 4 Jenipapo fruit
Font: JENIPAPO (2011)

2.1.4 Soursop (*Annona muricata*)

The sorsoup or cone of Guinea-Bissau (*Annona muricata*) (Figure 5), belonging to the Annonaceae family is native of the Antilles. São José et al. (2000) reported that the producing areas are located mainly in coastal regions and semi-arid Northeast, dominated by Northeastern soursop, Creole or Common. This genetic material has cordiform fruit, bark dark green terminations styles (pseudo-spines) prominent, and numerous mass between 1.5 and 3 kg, soft flesh and sweet flavor of the armpit (RAMOS, 1999).

The soursop is prized for its pleasant aroma and characteristic, described as a cream-like flavor when ripe, due to the presence of ester compounds, fruit sugars, organic acids and esters uncharacterized compounds (MCGORRIN, 2007). Moreover, its flesh is very juicy and sweet, and is commonly consumed as fresh fruit (MACLEOD; PIERIS, 1981).

The production was entirely designed for the agricultural industry, today has a significant volume marketed as fresh fruit, especially in the markets of Sao Paulo, Rio de Janeiro, Recife, Salvador, Fortaleza and Brasília (SÃO JOSÉ et al., 2000). However, the high perishability of the fruit and the short shelf life after harvest (AZIZ; YUSOF, 1994) account for high rates of loss (MOSCA et al., 1997).

Figure 5 Soursop fruit
Font: GRAVIOLA...(2011)

2.1.5 Sweet passion fruit (*Passiflora alata* Dryand)

The botanical genus Passiflora has an extraordinary diversity of species, excluding hybrids. Among the many different species, not all produce edible and usable fruit. And only a small number can occupy space in major national and international markets. The best known and most commercial applications are basically two: the passion fruit and purple passion fruit varieties of the same species (*Passiflora edulis*), and sweet passion fruit (*Passiflora alata* Dryand) (Figure 6) (SILVA et al., 2001).

The sweet passion fruit has its production and marketing limited by the lack of consumption habit. The fruits are oval or pyriform, orange peel, reminiscent of papaya, and weigh 90 to 200 g (SILVA et al., 2001). It is less rich in juice, which is sweet and has a pleasant aroma. It is almost exclusively consumed as fresh fruit, because the sweet pulp, with a strong and pleasant odor, is nauseating when processed as juice. It can be intended for export, because the fruits, due to their charasteristics, please consumers, particularly the European, a still ungained market.

Figure 6 Sweet passion fruit

2.2 Fruits jam

On undertaking a study to characterize the fruit agribusiness in the state of Minas Gerais, Ferraz, Silva and Vilela (2002) developed an agribusiness map of the state showing the location of cities that have fruit agribusiness, and the number of industries and their products, classified as juice / pulp and jams in general, a category that includes paste jam, crystallized and dried fruit and fruit in syrup (Figure 7).

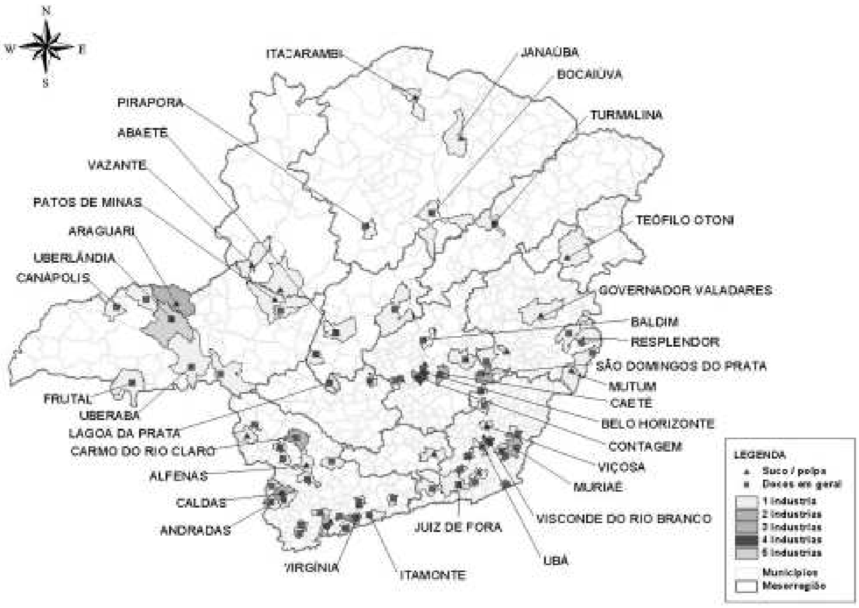

Figure 7 Mapping of fruit agribusiness in Minas Gerais
Font: Ferraz, Silva and Vilela (2002)

This mapping shows the strong presence of the jam agribusiness in Minas Gerais. Therefore, this branch of activity can be very promising, since there are investments to improve the quality of such products since jam production is still based on traditional and often rudimentary methods. According to these authors, the production segment of paste jam, crystallized fruit and fruit in syrup is characterized by micro and small enterprises, the vast majority with an installed capacity of less than 500 kg.

According to the Normative Resolution nº. 9/1978: fruit jam paste is the product resulting from the proper processing of the edible disintegrated parts of plants, with sugar, with or without addition of water, pectin, pH adjuster and other ingredients and additives permitted by these standards, until a proper consistency, and finally packed to ensure their perfect preservation (BRAZIL, 1978).

According this resolution fruit jam is classified as to the plant used and the consistency. As to the plant employed, the jam is called simple when prepared with a single plant species and called mixed when prepared with more than one plant species. The consistency is classified as creamy when the paste has a smooth and soft consistency, it should not offer resistance nor possibility of cutting. The bulk jam is when the paste is homogeneous and the consistency allows cutting.

According to Martins et al. (2007), bulk jams are the result of the proper processing of edible parts of plants, added sugars, water, pectin (0.5 to 1.5%), pH adjuster (3 to 3.4), and other ingredients and additives allowed to reach proper consistency. After processing, the jam must be properly packed and stored under ambient conditions (ABIA, 2001; JACKIX, 1988).

According Marcussi et al. (2003) the production of bulk jam, a subject widely studied by Jackix (1988), involves the heating of the pulp and other ingredients for a specific amount of time, until it reaches a concentration above 70ºBrix, affecting, among other features, the color and texture and flavor of the final product.

The type of sugar has importance in the development of conventional jam. In practice, sucrose is usually added, which is partially hydrolyzed during the cooking process. The low inversion of sucrose may cause crystallization, while the high inversion may result in the granulation of dextrose (glucose) in the gel (GAVA, 1998).

According to Assis et al. (2007), the inversion of sucrose and caramelization reactions are important under the atmospheric pressure cooking.

In the preparation of fruit jams and jellies, the presence of reducing sugars is desirable, considering that these act giving a brighter appearance, avoiding, and in some cases, delaying the crystallization of sucrose, preventing exudation and ultimately reducing the degree of sweetness of the jelly and jams (ASSIS et al., 2007).

Mixed fruit jam joins the nutritional characteristics of two or more fruits, and provides pleasant sensory characteristics in order to gradually gain prime space in the consumer market (ZOTARELLI; ZANATTA; CLEMENTE, 2008).

There are several authors who have studied the preparation of mixed jams and jellies such as Carneiro, Bezerra and Guedes (2009) who studied the manufacture of guava jelly with use of the albedo of the yellow passion fruit, Mélo, Lima and Nascimento (1999), who undertook studies conducted with mixed pitanga and acerola; Abdullh and Cheng (2000) who developed a low-calorie pineapple, papaya and starfruit jelly; Zotarelli, Zanatta and Clemente (2008) who assessed mixed guava and passion fruit jelly and Machado et al. (2008) who studied mixed jelly using umbu and acerola, among others.

2.3 Light and Diet Products

Currently, the consumer has adapted to healthier eating habits, by eating less caloric and more nutritious foods (CHIM; ZAMBIANZI; BRUSCATTO, 2006). According to Abdullah and Cheng (2001) consumers are increasingly knowledgeable about diet and health, and as a result, desire foods that are offer, in addition to convenience, quality and safety, a better balance of nutrients, less fat, cholesterol, sugar and calories. People are increasingly concerned about their health and appearance, and have sought alternative diets to combat major health problems that affect the global population, such as obesity and diabetes, both of which have a close relationship to the high consumption of sucrose (MORAES; BOLINI, 2010; SLOAN, 2005).

In Brazil, a healthy food product consumption trend has been detected in various market research works, including diet / light products. According Fadini et al. (2005), each year more than 180 new diet and light products are launched in Brazil. According to the Dietetic Food Industry Association and for Special Purposes and Congêneses (ABIAD), 47% of the population included in classes A and B consume diet/light products every day and according to ABIAD, in the last 10 years the market for diet/light products grew more than 800% (ASSOCIAÇÃO BRASILEIRA DE INDÚSTRIA E DE ALIMENTOS PARA FINS ESPECIAIS E CONGÊNESES - ABIAD, 2010).

Individuals who, for various reasons, need to replace the non-caloric sweeteners for sucrose look for products that are endowed with taste and characteristics close to those of sucrose. These consumers are increasingly looking for foods with pleasant features in terms of taste, appearance, aroma and texture. Despite the technological problems caused by the substitution of sugar (SANDROU; ARVANITOYANNIS, 2000), it is possible to find competitively priced low-fat products with good sensory characteristics, compared to similar products containing sucrose, thanks to technological advances (CARDOSO; BOLINI, 2008).

The food industry has been offering a great diversification of low-calorie fruit-based products, similar to the conventional, in which sugar is replaced by non-caloric sweeteners. By the relative reduction in carbohydrates and calories, these products have application in low-calorie diets and regimes for diabetics, subject to the quotas allowed, based on chemical composition detailed in the product label (CHIM ; ZAMBIAZI; BRUSCATTO, 2006).

According to the Agência Nacional de Vigilância Sanitária (ANVISA), light foods are those with minimum reduction of 25% content of any of the constituents included in the category of dietetic foods, the specifically for jams, is to reduce the sugar content.

According to ordinance nº 27/1998 for food to be considered light in relation to sugars, it must have a minimum sugar content reduction of 25% in relation to the reference formulation (with sucrose) and this reduction should correspond a difference greater than 40 kcal/100ml in the case of solid food. Furthermore it must have a minimum reduction of 25% sucrose and this reduction should correspond to a difference greater than 5g/100g (BRAZIL, 1998a).

According to ordinance nº 29/1998 the term "diet" can optionally be used for foods for diets restricted in nutrients (carbohydrate, fat, protein, sodium), for food only used for weight control and foods for a controlled sugar intake diet (BRAZIL, 1998b). Under this legislation, foods for a controlled sugar intake diet are specially formulated to meet the needs of people who have sugar metabolism disorders. It allows the presence of naturally occurring sugars in the materials used (BRAZIL, 1998b).

According to Resolution RDC 18/2008, the use of sweeteners for food is justified only when there was partial or total sugar reduction (BRAZIL, 2008). That is, sweeteners are substances used when sugar is removed from food. According to ordinance nº 540/1997 sweeteners are substances different from sugars that give sweet flavor to foods (BRAZIL, 1997).

2.3.1 Low calorie fruits jams

In the preparation of low calorie jams and jellies low pectin methoxy is employed, which form gels in the presence of divalent metal ions (usually calcium). The presence of sugars is not required (NACHTIGALL; ZAMBIAZI, 2004).

The low pectin methoxy pectin does not form gels in the same way as the high pectin methoxy, which by containing less than 50% of esterified carboxyl groups, presents a high proportion of free acid groups (-COOH). The three-dimensional structure of the low pectin methoxy pectin gel involves two sequences of galacturonic acids arranged in parallel, forming the Ca^{+2} ion bridge and interweaving free carboxyls, supplemented by hydrogen bonds. Secondary sealing areas may arise from hydrogen bonds with water molecules and sugar (FISZMAN, 1989). However, high concentrations of calcium ions can cause the formation of repelling forces in junction areas or excessive links between the molecules, causing contraction and generating syneresis, which consists of spontaneous expulsion of the aqueous phase of the gel network (CHIM; ZAMBIAZI; BRUSCATTO, 2006).

Products with reduced sugar content, such as light jams, are susceptible to syneresis, fragile texture, lack of clearness, loss of color and flavor; in this sense, it is necessary to use bulking agents, such as gums, to improve the rheological characteristics and alleviate the problems inherent to the reduction of solids in these products (VENDRAMEL; CÂNDIDO; CAMPOS, 1997).

The gums are polymeric compounds that when dissolved or dispersed in water, form viscous solutions or dispersions. These products have the ability to retain large amounts of water, provide low levels of calories and add texture and oral tactile sensation to the fat substitutes. In addition, gums assist in the stabilization of emulsions and particle suspensions in the control of crystallization, syneresis inhibition, encapsulation and formation of edible films (GRANADA et al., 2005).

The use of hydrocolloids alone or in combination as a gelling agent allows the implementation of the rheological properties, benefiting the characteristics of food products formulated for special purposes, as well as the light jam. Gelation occurs when an aqueous solution of the polymer undergoes cooling, presumably due to formation of double-helix structure to produce a three-dimensional polymer network (VENDRAMEL; CÂNDIDO; CAMPOS, 1997).

2.4 Sweeteners

Sweeteners are substances of low or no caloric value that provide a sweet taste to food. Therefore they are used in low-calorie and / or reduced sugar products. However, there are restrictions on the use of some sweeteners, perhaps due to lack of information on their sensory characteristics (REIS, 2007). Various sweeteners have emerged in the market, but few have been demonstrably established to be considered safe for human consumption, with good stability and satisfactory sweetening power (CARDOSO; BATTACHIO; CARDELLO, 2004).

Ideally, a sweetener must present some specific characteristics, such as functional properties similar to those of sucrose, good water solubility, stability against processing and storage, low caloric content per unit of food, toxicologically harmless and have a competitive price (GIESE, 1993).

The use of combinations of sweeteners in foods and beverages has grown a lot because they have several advantages such as, for example, improved stability and improved sweetener acceptance, since combinations of sweeteners often reduces undesirable characteristics like bitter aftertaste, among other desirable effects (LIM; SETSER; KIM, 1989; LINDLEY, 1991; PORTMANN; KILCAST, 1998). In addition, the use of sweeteners in combination can reduce the consumption of sweeteners, causing the amount of each sweetener used to remain below the acceptable daily intake (ADI) and within legal limits, while reducing caloric intake of the sweetener and the final product (CÂNDIDO; CAMPOS, 1996; GAVA, 1986; LEONARDI, 1990; WELLS, 1989).

All sweeteners receive a recommendation for acceptable daily intake (ADI), defined as that considered harmless, even if its use is continued indefinitely (WORLD HEALTH ORGANIZATION, 1987). The calculations to arrive at the IDA were based on animal studies, and correspond to a dose one hundred times lower than the maximum dose free from detectable effects in animals, which guarantees a wide safety margin (WORLD HEALTH ORGANIZATION, 1987).

Brazilian norms that determine the maximum limits of food additives are developed based on international benchmarks such as the Codex Alimentarius (Codex General Standard for Food Additives - GSFA), the European Union and, further, U. S. Food and Drug Administration (FDA). Resolution RDC 3/ 2001, provides for the use of sweeteners in foods by establishing their limits expressed in g/100 g or g/100 ml of the product ready for consumption. According to this legislation, the use of sweeteners for food is justified only when there has been partial or total sugar reduction. Thus, the RDC 03/2001 approves the use of sweeteners in food and drinks for controlled sugar intake diets, sugar-restricted diets, for weight control and supplemental nutritional information (BRAZIL, 2001).

2.4.1 Estimation of the magnitude method

For a sweetener to replace sucrose successfully in food formulations, we must undertake studies on prior knowledge of the concentrations of the sweeteners to be used and their sweetness equivalent to sucrose (CARDOSO; CARDELLO, 2003). There are several methods to obtain this information, but the most applied method is to estimate the magnitude and graphical representation of the results normalized by Stevens' law or “Power Function" (MOSKOWITZ, 1970; OLIVER; STONE, 1969).

The equivalence of sweetness is an essential preliminary step to determine the amount of a sweetener to be added to a product in the same equivalence of sucrose in order to obtain the same sweetness perception by consumers. However, the perception of sweetness is influenced by several factors such as chemical structure and sweetener concentration, food physicochemical characteristics (acidity, pH, temperature, etc..), methodologies and even by the intrinsic characteristics of the individual (REIS, 2007).

In the magnitude estimation method described by Stone and Oliver (1969), tasters receive a reference sample with an intensity of arbitrary value, for example 100, followed by a series of samples in randomized order, with intensities higher or lower than the reference. The panelists are asked to estimate the sweetness of the samples in relation to a reference sample. If the sample, for example, has twice the sweetness in the reference, should have the value 200 if it were half, 50, and so on. It is not allowed to assign a zero to any sample.

The magnitude estimation principle, or power function, provides the obtaining of several important tools for food sensory analysis evaluation (MOSKOWITZ, 1970). The values obtained from the results of judges and the values of the concentrations are normalized, the result logarithms calculated and graphed along logarithmic coordinates. For each sweetener (or other compound) a straight line is obtained, which obeys the law of Stevens, or "power function": $S=aC^n$, where S is the stimulus perceived, C is the concentration of the stimulus, a is the antilog of the value of Y at the intercept, and n is the slope of the line. Regions of the lines of sweeteners that are on the same level, parallel to the axis of abscissa are equivalent sweetening power (MOSKOWITZ, 1970).

The magnitude estimation method was successfully used by Cardoso; Battachio and Cardello (2004) and Cardoso and Cardello (2003) in determining the equivalence of sweetness of various sweeteners in soluble powder matte tea. Brito, Câmara and Bolini (2004), Marcellini, Chainho and Bolini, 2005, Moraes and Bolini, 2010, Reis (2007) and Souza et al. (2011), determined the equivalent sweetness of sweeteners in strawberrry petit suisse cheese, instant coffe, strawberry yogurt, pineapple juice and guava nectar, respectively.

2.4.2 Time-intensity analysis

The classical sensory evaluation techniques do not provide important information about some particular properties of sweeteners. What is observed is that the non-caloric sweeteners have numerous disadvantages when compared with sucrose, such as the delay in sweetness perception, absence of sweet taste, presence of sweet aftertaste in the mouth, bitter aftertaste, as well as other undesirable characteristics limiting its use in some foods and beverages (CLIFF; HEYMANN, 1993).

The time-intensity methodology is a way to monitor the sensations perceived during all stages of food intake. This methodology was initially developed as a means of studying the persistence of tastes, for example, the sweetness, but has been extended to implement a number of other food characteristics (LEE III; PANGBORN, 1986). This technique allows to trace the sensory profiles in detail, looking for the product with the sensory profile closer to that of sucrose (REIS, 2007).

Through this technique a curve is obtained that records the variation in the intensity of a sensory stimulus, perceived by the panelist with the passage of time.

Today this technique is based on the use of computer programs for time-intensity (TI) data collection and handling, which has an interface in the form of a scale in which the panelists indicate the intensity of the stimulus to be collected using the computer mouse. Such programs allow the choice of scale length to be used in each test and stores the data sequence for future use (CARDELLO; DAMASIO, 1996). According to Cliff and Heymann (1993) the commonly used TI curve parameters are: maximum intensity (Imax), time to reach maximum intensity (Timax) and total time of stimulus duration (Ttot). However, with the advancement of computer technology, other curve parameters could be easily obtained, such as the area under the curve (Area), maximum intensity duration (plateau), and the time at which the maximum intensity begins to decline (Td) are often used (CARDELLO; SILVA; DAMÀSIO, 1999).

In recent years, many studies have been developed in order to quantify the temporal properties of sweeteners such as sweet and bitter taste (CARDELLO; SILVA; DAMÀSIO, 1999, 2001; HORNE et al., 2002; TEMPLE et al., 2002).

2.5 Funcional/Prebiotic foods

Functional foods are characterized by offering numerous health benefits, as well as nutritional value inherent in their chemical composition, may play a potentially beneficial role in reducing the risk of chronic degenerative diseases (NEUMANN et al., 2000; TAIPINA; FONTS; COHEN, 2002). According to Moraes and Colla (2006) the role of food in relation to diseases will in most cases, focused more on risk reduction rather than prevention.

The term prebiotic was introduced by Gibson and Roberfroid in 1953, defined as a food ingredient undigested, which benefits the host by selectively stimulating the growth and / or metabolic activation of one or a limited number of bacteria in the colon (BENGMARK; LORENZO; CULEBRAS, 2001).

Prebiotics are non-digestible oligosaccharides, fermentable but whose function is to change the activity and composition of intestinal microbiota with a view to promoting the health of the host. Dietary fiber and nondigestible oligosaccharides are the main substrates for growth of microorganisms of the intestines (MORAES; COLLA, 2006). Prebiotics stimulate the growth of endogenous microbial population groups, such as *Bifidobacteria* and *Lactobacillos*, which are said to be beneficial to human health (BLAUT, 2002). Prebiotics more efficient will reduce the activity of potentially pathogenic organisms (ROBERFROID, 2002). For a substance (or group of substances) can be defined as such, must meet the following requirements: be of vegetable origin; form part of a heterogeneous set of complex molecules, not be digested by digestive enzymes; be partially fermented by a colony of bacteria and is osmotically active (RODRIGUEZ; MEGÍAS; BAENA, 2003).

Some effects attributed to prebiotics are the modulation of key physiological functions, such as calcium absorption, reducing the risk of osteoporosis, lipid metabolism, modulation of the composition of intestinal micriobiota and reduced risk of colon cancer (ROBERFROID, 2002). The currently identified prebiotics are non-digestible carbohydrates, including lactulose, inulin and oligosaccharides many carbohydrates that provide the beneficial bacteria in the colon are able to ferment (CUMMINGNS; MACFARLANE, 2002).

The frutooligossaccharides (FOS) are formed by the hydrolysis of inulin and plays various physiological functions in the body, such as changes in intestinal transit, promoting: reduction of toxic metabolites, prevention of colon cancer, lowering cholesterol and plasma hypertriglyceridemia, improved bioavailability of minerals and contribute to the increased concentration of bifidobacteria in the colon (GIBSON, 1999). Lactulose lactofermentativa increases the ability of Lactobacillus populations. The use of prebiotics, such as lactulose and fructooligosaccharides has a synergistic action, it stimulates the growth of beneficial bacteria (SCHUMANN, 2002).

Already, polydextrose is a polysaccharide synthesized by random polymerization of glucose. It is used in many countries as an agent of the body and as an ingredient in reduced calorie (1 kcal per gram) in various foods. Polydextrose is partially fermented in the large intestine, but is not digested nor absorbed in the small intestine, and is mostly excreted in the feces (JIE et al., 2000). Several studies have shown the same physiological effects consistent with those caused by dietary fiber (BEEREBOOM, 1979; HAMANAKA, 1987). As polydextrose is partially fermented in the large intestine, the volume increases the volume of the fecal mass, reduces the transit time, softens and lowers the pH of the stool.

According to ANVISA (BRAZIL, 2008) a product containing polydextrose and / or FOS functional property can only claim the portion of the product ready for consumption provide at least 3 g of FOS or polydextrose if the food is solid or 1.5 g if the food is liquid. Even establishes that the use of FOS not exceed the recommended daily intake of 30g product ready for consumption, as indicated by the manufacturer, and the recommendation of daily consumption of products containing polydextrose shall not result in that fiber intake above 90 grams or whose single serving of consumption of polydextrose intake result in more than 50g.

3 FINAL CONSIDERATIONS

From the characterization of the fruit, it was observed that fruits generally had high nutrient content, of the five fruits studied, marolo stood out. Of the fruits studied, the most suitable for use in the preparation of jams, were marolo, sweet passion fruit and soursop. Jams elaborated with murici and jenipapo did not have good acceptability, requiring study to find a better way of using these two fruits. It was possible to prepare reduced calorie (no added sugar) mixed fruit jam with prebiotics, and after determination of the optimum concentration of each sweetener studied, we observed that all sweeteners have sensory acceptance similar to each other and similar to traditional jam (with added sugars), furthermore, all the formulations showed good acceptability. This study demonstrates the great potential of development of low-calorie jam with added prebiotics using combinations of fruits from the Cerrado.

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SECOND PART – ARTICLES

ARTICLE 1: DETERMINATION OF BIOACTIVE COMPOUNDS, ANTIOXIDANT ACTIVITY AND CHEMICAL COMPOSITION OF CERRADO BRAZILIAN FRUITS

Submitted to Food Chemistry - ISSN: 0308-8146, being presented according to the rules of publication of this magazine.

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ABSTRACT

This study aimed to evaluate the chemical composition and to quantify the bioactive compounds and antioxidant activities of five Cerrado Brazilian fruit pulps, including marolo, jenipapo, murici, soursop and sweet passion fruit. All of the analyzed pulps had high moisture contents (80.16-93.48%), and they were low in protein (0.18-1.35%), lipid (0.10-1.84%) and energy value (21.60-85.47 Kcal). The pulp of marolo had the highest content of lipids (1.84%), carbohydrates (16.31%), energy value (85.47%) and highest contents of K (391.48 mg/100g) and Mg (26.28 mg/100g) compared with the other pulps. Murici pulp had the highest content of dietary fiber (3.08%). Sweet passion fruit pulp had the highest content of P (34.9 5mg/100g) and Fe (1.06 mg/100g). The pulp of marolo had the greatest potential for antioxidant activity (131.58 μmol TEs/g), a higher content of phenolic compounds (739.37 mgGAEs/100g) and higher concentrations of ascorbic acid (59.05 mg/100g). The pulps analyzed here were low in β-carotene and lycopene (1.57-1.31 and 0.38-0.88 mg/100g, respectively).

Keywords: bioactive compounds, antioxidant activity, Cerrado Brazilian fruits

1. INTRODUCTION

Brazil has the largest biodiversity of any country in the world, which includes a large number of fruit species (Leterme et al., 2006). Many fruit species in Brazil are unknown, and therefore, relatively few fruit species are commercially available (Mattietto et al., 2010). The Cerrado, is a Brazilian biome that have a large number of underexploited native and exotic fruit species, which is of potential interest to agroindustry and a possible future source of income for the local population (Almeida et al., 2011).

Many native species provide fruits that have unique sensory characteristics and high nutrient concentrations. According to Rufino et al. (2010), tropical fruit consumption is increasing in the domestic and international markets due to growing recognition of the nutritional and therapeutic value of fruit. Therefore, fruits play important roles both economically, through commercialization of their products and nutritionally, through their consumption (Cardoso et al., 2011). Fruits represent an opportunity for local growers to gain access to specialized markets where consumers demonstrate a preference for exotic characteristics and the presence of nutrients capable of preventing degenerative diseases (Alves et al., 2008). Fruit consumption choices are no longer based purely on taste and personal preference, but they are also based on a desire for better health. In recent years, there has been an increase in the economic exploitation of the products and by-products of specific fruits attributed to increasing consumer concerns about the relationship between diet and health (Yahia, 2010). Brazilian fruits have been subjected to several studies throughout the world seeking to analyze their nutritional value (Rufino et al.; 2010; Almeida et al; 2011; Cardoso et al. 2011; Clerici and Silva et al. 2011; Dembitsky et al. 2011).

According Mattieto et al. (2010), the characterization of fruit, exotic or not, has attracted the interest of the scientific community. The physical and chemical characterization of fruits and the quantification of their bioactive components are important for the understanding of their nutritional value and for increasing the quality and value of the final product. Among the compounds present in food that have functional properties, substances with antioxidant activities have received significant attention because they protect the human body against oxidative stress, preventing a number of chronic degenerative disorders (Yahia, 2010; Canuto et al., 2010). Natural antioxidants present in foods have attracted interest because of their safety and potential nutritional and therapeutic effects (Rufino et al. 2009). Fruits are a source of antioxidant compounds, such as phenolics, vitamins, carotenoids and minerals, which contribute to their chemopreventive effects (Almeida et al. 2011).

In this study, we aimed to evaluate the chemical composition, identify the bioactive compounds and measure the antioxidant activity present in the pulp of five types of Cerrado Brazilian fruits, which have not been well studied. The fruits included in this study include: marolo (*Annona crassiflora* Mart.), jenipapo (*Genipa americana* L.), murici (*Byrsonima crassifolia* L. RICH), soursop (*Annona muricata*, L.) and sweet passion fruit (*Passiflora alata* Dryand).

2. MATERIALS AND METHODS

2.1 Pulp Samples

The pulps of jenipapo and murici were acquired from a company located in Uberlândia, Minas Gerais that processes fruit pulp. Soursop pulp was obtained from a company in Jarinu, Sao Paulo. These pulps were stored in sealed plastic bags, frozen and transported in Styrofoam boxes.

The pulps from sweet passion fruit and marolo were processed at the Laboratory of Food Analysis, Department of Food Science, Federal University of Lavras (UFLA) after the acquisition of these fresh fruits from a region to the north of Minas Gerais. The fruits were cleaned with tap water and then separated into peels, seeds and pulp. The pulp was extracted manually with a knife, and the husks and seeds were discarted. The pulps were then mixed in a blender, stored in sealed plastic bags and frozen.

All pulps were stored in a cold room at -18 °C. The full pulp was used from the five studied fruits.

2.2 Chemical reagents

The following chemicals were used for the following experiments. Acetone, 2.2´-Azino-bis(3-ethylbenzenothiazoline6- sulfonic acid) (ABTS), Cloridric Acid (HCl), 2,4 – dinitrophenylhydrazine (DNPH 2.4), Cooper Sulfate, Enzymes: Thermostable alpha-amylase, Protease, Amiloglucosidade, Ethanol, Ether, Folin–Ciocalteu reagent, Gallic acid, Kjeldhal reagent, Methanol, Nitric acid, Perchloric acid, Petroleum ether, Phenolphthalein solution, Phosphate buffe, Potassium Sulphate, Potassium persulfate, Sodium carbonate, Sodium hydroxide (NaOH), Sulfuric Acid, Trolox (6-Hydroxy-2,5,7,8-tetramethylchroman-2-carboxylic acid).

2.3 Chemical analyses

Three repetitions were performed of all chemical analyses. The values of titratable acid, soluble solids and pH (IAL—Instituto Adolfo Lutz, 2005) as well as the moisture, ash, protein, lipid and total dietary fiber contents (AOAC—Association of Official Analytical Chemists, 1998) were determined. The carbohydrate levels were calculated using the formula: (100 –%moisture −%lipids −%protein −%of total dietary fiber −%ash). The total energy value was estimated using the conversion factors of 4 kcal g^{-1} of protein or carbohydrate and 9 kcal g^{-1} of lipid (Merril and Watt, 1973). The method proposed by Dische (1962) was used for the determination of total sugar.

2.4 Minerals

The mineral levels were assessed in crushed and homogenized samples prepared by organic wet digestion in accordance with the methodology described by Salinas and Garcia (1985). For organic digestion, the samples were treated with a mixture of nitric acid and perchloric acid, which were both concentrated at a high temperature. The macro-and microelements were solubilized, subjected to different treatments and diluted for further quantitative evaluation. The quantification of elements was performed by spectrophotometry using a standard curve for each mineral. To determine the concentration of calcium, iron and manganese, we used an atomic absorption spectrophotometer and acetylene. A flame photometer was used for determination of potassium

(768 nm), and a visible-light spectrophotometer was used for the determination of phosphorus (420 nm).

2.5 Carotenoids

β-carotene and lycopene were extracted and quantified according to the method proposed by Rodriguez-Amaya (2001). For the extraction, each sample was added to acetone, and the resulting mixtures were shaken for 1 hour using a Multi Shaker MMS shaker at 200 rpm. Next, each sample was washed with acetone three times by vacuum filtration. A volume of 45 mL of petroleum ether was poured through a separating funnel, and the pigments were then transferred to the funnel in small fractions followed by distilled water. The lower phase was discarded, and the samples were washed four more times to completely remove the acetone. The solution of pigments in petroleum ether was transferred to a volumetric flask and brought to a final volume of 100 mL with petroleum ether. The samples were analyzed in a spectrophotometer at wavelengths of 450 and 470 nm for β-carotene and lycopene, respectively (Rodriguez-Amaya 2001). The extinction coefficients for β-carotene and lycopene in petroleum ether are 3450 and 2592, respectively (Rodriguez-Amaya, 2001). The results are expressed in mg of β-carotene or lycopene per 100 g sample.

2.6 Total Phenolics and Antioxidant activity

The extracts were obtained according to the method described by Larrauri et al. (1997). Briefly, samples were weighed (g) in centrifuge tubes and extracted sequentially with 40 mL of methanol/water (50:50, v/v) at room temperature for 1 hour. The tubes were centrifuged at 25,400 g for 15 min, and the supernatant was recovered. Then, 40 mL of acetone/water (70:30, v/v) was added to the residue at room temperature. The samples were extracted for 60 min and centrifuged. The methanol and acetone extracts were combined and brought to a final volume of 100 mL with distilled water for the determination of antioxidant activity and phenolic content.

2.6.1 Total Phenolic

The total phenolic content was determined according to the adapted Folin–Ciocalteu method (Waterhouse, 2002). The extracts (0.5 mL) were mixed with 2.5 mL of Folin–Ciocalteu reagent (10%) and 2 mL of 20% sodium carbonate solution (4%). The mixture was stirred and kept at room temperature for 2 hour in the dark. The absorbance was measured at 750 nm against a blank. Aqueous solutions of gallic acid were used for calibration. The results are expressed as g gallic acid equivalents (GAE)/100 g.

2.6.2 Antioxidant activity

The antioxidant activity was determined using the ABTS assay according to the method of Re et al. (1999) with minor modifications. The 2,2-azinobis (ABTS) radical cation (ABTS•+) was generated by reaction of 5 mL of aqueous ABTS solution (7 mM) with 88 μL of 140 mM (2.45 mM final concentration) potassium persulfate. The mixture was kept in the dark for 16 hour before use and then diluted with ethanol to obtain an absorbance of 0.7±0.05 units at 734 nm using a spectrophotometer. The fruit extracts (30 μL) or a reference substance (Trolox) were allowed to react with 3 mL of the resulting blue-green ABTS radical solution in the dark. The decrease of absorbance at 734 nm was measured after 6 min. Ethanolic solutions of known Trolox concentrations were used for calibration. The results are expressed as micromoles of Trolox equivalents (TEs) per gram of fresh weight (μmol of TEs/g of FW).

2.7 Ascorbic Acid

The vitamin C content of each fruit pulp was determined by a colorimetric method with 2,4 – dinitrophenylhydrazine (DNPH 2.4) according to Strohecker and Henning (1967). The samples were analyzed in a spectrophotometer at an absorbance of 520 nm. The results are expressed as mg ascorbic/100 g of fresh weight.

3. RESULTS AND DISCUSSION

Table 1 presents the chemical characteristics of the fruit pulp of marolo, murici, jenipapo, soursop and sweet passion fruit. The range of values found in the literature, either for fresh fruit or pulp, is also presented.

TABLE 1 - The composition, pH, titratable acidity (TA), soluble solids (SS) and total sugar content of marolo, murici, jenipapo, soursop and sweet passion fruit pulps.

	FRUITS PULPS				
	Marolo[1]	Murici[2]	Jenipapo[3]	Soursop[4]	Sweet Passion fruit
Moisture (%)	**80.16±0.25**	**93.12±0.59**	**93.48±0.49**	**88.31±1.52**	**84.12±0.13**
Literature	74.2-77.2	75.9-92.8	-	82.2-89	-
Protein (%)	**0.92±0.02**	**0.18 ±0.00**	**0.21±0.01**	**0.57±0.02**	**1.35±0.00**
Literature	0.4-1.22	0.72-0.86	-	0.6-0.8	-
Lipids (%)	**1.84±0.16**	**0.87±0.03**	**0.34±0.01**	**0.30±0.04**	**0.10±0.04**
Literature	1.04-3.83	0.6-3.02	-	0.1-0.2	-
Carbohydrates (%)	**16.31±0.26**	**2.59±0.32**	**4.43±0.36**	**9.84± 1.39**	**13.05±0.17**
Literature	10.3-32.3	5.96-19.6	-	9.8-15.8	-
Dietary fiber (%)	**0.13±0.00**	**3.08±0.26**	**1.15±0.09**	**0.79±0.10**	**0.70±0.00**

Literature	-	-	-	1.2-1.9	-
Ash (%)	**0.64±0.13**	**0.16±0.05**	**0.39±0.13**	**0.19±0.00**	**0.68±0.09**
Literature	0.85-1.37	0.78	-	0.4-1.0	-
Energy value (kcal)	**85.47±0.11**	**18.89±1.12**	**21.60±1.45**	**44.3±5.80**	**58.51±0.34**
Literature	52-146.18	46.43	81.70	38-62	-
pH	**4.44±0.04**	**3.32±0.05**	**3.18±0.02**	**3.19±0.03**	**3.31±0.02**
Literature	4.6-5.21	3.42-3.7	3.39-4.3	3.46-4.5	-
TA/ (g citric acid/100g)	**0.47±0.07**	**0.47±0.07**	**0.37±0.00**	**0.72±0.04**	**2.00±0.19**
Literature	-	1.0	0.13-0.98	0.58-1.5	-
SS (°Brix)	**11.33±0.58**	**1.00±0.00**	**3.33±0.58**	**7.00±0.00**	**13.33±0.58**
Literature	-	1.5	-	10.7-13.11	-
Total sugars (%)	**8.83±0.24**	**1.83±0.02**	**3.89±0.09**	**6.56±0.21**	**11.37±0.18**
Literature	12-14	-	-	8.2	-

Mean value±standard deviation of fruit pulp weight; n=3.

[1] Literature data for marolo in nature and pulp of marolo: Almeida et al. (1998); Franco (1999); Silva et al. (2004); Silva et al. (2008) and Silva et al. (2009).

[2] Literature data for murici in nature: Guimarães e Silva (2008); Silva et al. (2008) and Canuto et al. (2010).

[3] Literature data for jenipapo in nature: Figueiredo et al. (1986); Franco (1992); Silva et al. (1998) and Hansen et al. (2008).

[4] Literature data for soursop in natura and pulp of soursop: Marcellini et al. (2003); Sacramento et al. (2003); Mata et al. (2005); Canuto et al. (2010) and Taco (2006).

Data for sweet passion fruit (Passiflora alata Dryand) were not found in the literature. Furthermore, no similar analysis of the five pulps described in this study has been previously published, which further highlights the importance of this work.

We observed that all of the pulps had high moisture contents, ranging from 80.16% (marolo) to 93.48% (jenipapo). The protein content ranged from 0.18% (murici) to 1,35% (sweet passion fruit). All of the fruits were low in fat content; sweet passion fruit had the lowest fat content (0.10%), and marolo had the highest amount of fat (1.84%). The carbohydrate content ranged from 2.59% (murici) to 16.31% (marolo). With regard to dietary fiber, the levels were between 0.13% (marolo) and 3.08% (murici). The ash ranged from 0.16% (murici) to 0.68% (sweet passion fruit). Based on these results, the energy content was found to range from 18.89 kcal (murici) to 85.47 kcal (marolo).

In general, the pulp of marolo had the lowest moisture content (80.16%) and the highest contents of lipids (1.84%) and carbohydrates (16.31%) as well as the highest energy value (85.47 kcal). Sweet passion fruit had the highest contents of protein (1.35%) and ash (0.68%), and murici pulp had the highest dietary fiber content (3.08%).

The pH values ranged from 3.18 to 4.44 (jenipapo and marolo, respectively), and the levels of acidity ranged from 0.37 g of citric acid/100 g in jenipapo to 2.00 g of citric acid/100 g in sweet passion fruit. Acidity is one of the criteria that affect the classification of fruits based on taste; fruits with levels of citric acid levels ranging from 0.08 to 1.95% can be classified as mild in flavor and are well accepted for consumption in the form of fresh fruit (Paiva et al. 1997). All of the fruits evaluated here fall into this category.

With respect to soluble solids and total sugars, murici had the lowest levels (1 °Brix and 1.83%, respectively) and sweet passion fruit had the highest levels (13.33 °Brix and 11.37%, respectively). The contents of soluble solids correlated with the levels of sugars and organic acids, which is an important feature of products that are sold fresh as consumers prefer sweeter fruits (Silva et al., 2002). Therefore, fruits with the highest probability of acceptance are those with higher levels of soluble solids and total sugars. Among the fruits, marolo and sweet passion fruit had the highest levels of soluble solids and sugars.

The chemical and physical characteristics of fruit can be influenced by several factors, such as the time of harvest, maturity, variety, weather and soil conditions, sun exposure, location of fruit on the plant and post-harvest handling (Fagundes and Yamanishi, 2001; Amira et al. 2011). Moreover, the differences between the chemical characteristics presented in this paper compared with previously published data can be explained by the changes in the fruit associated with isolation of the pulp and freezing. It is important to emphasize that the characterization of exotic fruit pulp is a matter of practical interest because fruits that are produced in specific regions and during brief seasons are most commonly marketed in the form of pulp.

The mineral compositions, including P, K, Ca, Mg and Fe, of the pulps of marolo, murici, jenipapo, soursop and sweet passion fruit are shown in Table 2. The mineral contribution of each fruit pulp to the Dietary Reference Intake (DRI) for a healthy adult male is given in % per 100 g of pulp (Institute of Medicine, 1999-2011).

TABLE 2 - The minerals contents of marolo, murici, jenipapo, soursop and sweet passion fruit pulps and the %DRI contribution per 100 g of pulp.

	Marolo	**Murici**	**Jenipapo**	**Soursop**	**Sweet passion fruit**
P (mg/100g f.w)	**15.97**	**2.60**	**0.59**	**11.79**	**34.95**
% DRI	2.28	0.37	0.08	1.68	4.99
K (mg/100g f.w.)	**391.48**	**103.05**	**92.55**	**163.14**	**375.42**
% DRI	8.33	2.19	1.97	3.47	7.99
Ca(mg/100gf.w.)	**2.18**	**5.50**	**13.23**	**2.22**	**4.76**
% DRI	0.22	0.55	1.32	0.22	0.48
Mg(mg/100g f.w.)	**26.28**	**10.14**	**8.17**	**10.61**	**19.82**
% DRI	6.57	2.53	2.04	2.65	4.95
Fe (mg/100g f.w.)	**0.59**	**0.17**	**0.22**	**0.42**	**1.06**
% DRI	7.37	2.12	2.75	5.25	13.25

Among the pulp samples, the concentration of minerals was found to range between 0.59 (jenipapo) and 34.95 mg/100 g f.w (sweet passion fruit) for P, 92.55 (jenipapo) and 391.48 mg/100 g f.w. (marolo) for K, 2.18 (marolo) and 13.23 mg/100 g f.w. (jenipapo) for Ca, 8.17 (jenipapo) and 26.28 mg/100 g f.w. (marolo) for Mg, and 0.17 (murici) and 1.06 mg/ 100 g f.w. (sweet passion fruit) for Fe.

The sweet passion fruit pulp contributes the most to the Recommended Daily Intake (RDI) of P and Fe, marolo contributes the most to the RDI of K and Mg. For Ca, jenipapo pulp is the richest, but in general, the fruits pulps analyzed in this study contribute little to the RDI of calcium.

According to the Brazilian Table of Food Composition - TACO (2006), frozen soursop pulp contains 10 mg of Mg, 17 mg of P, 0.1 mg of Fe, 170 mg of K and 6 mg of Ca in 100g. The values of K and Mg are very similar to the values reported here, the levels of Ca and Fe were higher in our study, and the P content was lower.

According to the TACO (2006), in 100g of frozen yellow passion fruit pulp contains 10 mg of Mg, 15 mg of P, 0.3 mg of Fe, 228 mg of K and 5 mg of Ca. In our study, the pulp of sweet passion fruit had similar levels of Ca to those reported in the TACO, but it was richer in Mg, P, Fe and K.

Due to lack of studies in the literature on the mineral composition of exotic Brazilian fruits, we decided to make the comparison with the banana, a tropical fruit that is well known for its abundance of minerals.

In general, potassium was the most abundant element in all fruits, as reported by Sulaiman et al. (2011) in their studies with different varieties of banana, fruit, which according to Wall (2006), can be considered a good source of K. According to Sulaiman et al. (2011), the levels of potassium in banana pulp reported in different studies ranged on average from 295.7 to 463.6 mg/100 g of pulp. Therefore, the sweet passion fruit and marolo pulps had potassium levels similar to certain varieties of banana.

Leterme et al. (2006) found values of P ranging from 2 to 3 mg/100 g in banana pulp. All of the fruits analyzed possess a high level of P compared with the banana pulp analyzed by Leterme et al. (2006). Sulaiman et al. (2011) found that the P content in different varieties of banana pulps ranged from 26.4 to 70.9 mg/100 g. In the present study, only the sweet passion fruit was found to have levels of P similar to certain varieties of bananas.

The marolo and even the sweet passion fruit were found to have a significant concentration of Mg compared with the banana. The values of Mg reported in the literature for this fruit are range from 21 to 67 mg/100 g (Hardisson et al., 2001; Leterme et al., 2006; Wall, 2006; Emaga et al., 2007).

The jenipapo and sweet passion fruit had the highest concentrations of Ca (13.23 mg/100 g) and Fe (1.06 mg / 100 g), respectively.

The fruit pulps analyzed in this study presented significant amounts of minerals, and marolo pulp, in particular, was found to be rich in K and Mg. Sweet passion fruit is the richest in P and Fe, and jenipapo presented a higher concentration of Ca.

Our results for antioxidant capacity, total phenolic content, ascorbic acid content and carotenoid content are shown in Table 3.

TABLE 3 - The antioxidant capacity (ABTS), total phenolic content, ascorbic acid content and carotenoid content of marolo, murici, jenipapo, soursop and sweet passion fruits pulp.

Fruits pulps	Antioxidant Capacity (µmol TEs/g f.w.)	Total Phenolics (mg GAEs/100g f.w.)	Ascorbic Acid (mg/100 g f.w)	Carotenoids (mg β-carotene/100 g f.w.)	Carotenoids (mg lycopene/100 g f.w.)
Marolo	131.58 ±19.61	739.37 ±7.92	59.05 ±0.46	0.57 ±0.01	0.38 ±0.01
Murici	57.25 ±4.05	334.37 ±9.07	47.44 ±3.26	1.25 ±0.12	0.88 ±0.08
Jenipapo	7.31 ±1.74	47.94 ±1.81	27.01 ±2.84	0.93 ±0.03	0.63 ±0.03
Soursop	35.95 ±2.04	281.00 ±5.40	21.83 ±3.99	1.21 ±0.17	0.86 ±0.12
Sweet passion fruit	10.84 ±2.20	245.36 ±3.70	24.66 ±4.29	1.31 ±0.03	0.87 ±0.03

Mean value±standard deviation of fruit pulp weight; n=3; TE = trolox equivalentes; GAE: gallic acid equivalents

The lowest level of antioxidant activity was observed in the jenipapo pulps (7.31 μmol TEs/g f.w.), followed by sweet passion fruit (10.84 μmol TEs/g f.w.), soursop (35.95 μmol TEs/g f.w.), murici (57.25 μmol TEs/g f.w.) and marolo (131.58 μmol TEs /g f.w.). The marolo pulp showed high antioxidant activity, soursop and murici had intermediate antioxidant activities, and sweet passion fruit and jenipapo showed low levels of antioxidant activity. In their studies with different exotic fruits in northeastern Brazil, Almeida et al. (2011) concluded that the murici is a fruit with high levels of antioxidant activity. Using the DPPH method, Melo et al. (2008) concluded that soursop pulp has moderate antioxidant activity and that passion fruit has low activity.

According to Almeida et al. (2011), foods rich in antioxidants play an essential role in the prevention of diseases. The antioxidant capacities of fruits vary depending on their contents of vitamin C, vitamin E, carotenoids, and particularly β-carotene (Rice-Evans and Miller et al. 1996) and lycopene (Shami and Moreira 2004) as well as flavonoids and other polyphenols (Saura-Calixto and Goñi, 2006).

Following the example of Vasco et al. (2008), who tested 17 fruits from Ecuador for their polyphenol contents, we classified our fruits into three categories: low (<100 mg GAE/100 g), medium (100–500 mg GAE/100 g) and high (>500 mg GAE/100 g). Marolo pulp had the highest levels of polyphenol (739.37 mg GAE/100 g f.w.) followed by murici (334.37 mg GAE/100 g f.w.), soursop (281.00 mg GAE/100 g f.w.) and sweet passion fruit (245.36 mg GAE/100 g f.w.). The marolo pulp can therefore be categorized as having a high concentration of phenols, indicating that this fruit is an excellent source of phenols. The murici, soursop and sweet passion fruit can be categorized as having an average content of phenols, and they may also be considered a good source of phenols. Jenipapo had the lowest levels of phenols (47.94 mg GAE/100 g f.w.), corresponding to the low category. Hassimotto et al. (2005)

reported that there are 120.8 mg GAE/100 g and 67 mg GAE/100 g of total phenols commercially available frozen soursop pulp and murici, respectively, and these values are lower than the levels reported here. Almeida et al. (2010) found 159.9 mg of GAE/100 g murici in nature, as Rufino et al. (2010) found 2380 GAE/100 g of total phenols in dry murici. Roesler et al. (2007) found 20.31 g GAE/kg in the dry matter of marolo.

Ascorbic acid levels ranged from 21.83 in soursop to 59.05 mg/100 g f.w. in the marolo pulps. Marolo had levels of ascorbic acid equivalent to those found in a variety of oranges from Australia (67 mg/100 g) according to Lim et al. (2007). Ramful et al. (2011) classified fruits according to the ascorbic acid content into three categories: low (<30 mg/100 g), medium (30 - 50 mg/100 g) and high (> 50 mg/100 g). According to this classification, marolo qualifies as a fruit with high ascorbic acid content, murici has average content, and jenipapo, soursop and sweet passion fruit are considered low in vitamin C.

The murici, soursop and sweet passion fruit pulps had higher levels of carotenoids, corresponding to 1.25, 1.21 and 1.31 mg/100 g f.w., respectively, of β carotene and 0.88, 0.86 and 0.87 mg/100 g f.w., respectively, of lycopene. According to Agostini and Cecchi (1996), in the whole marolo contains 0.69 mg/100 g of β-carotene, which is slightly higher than the amount found in the pulp (0.57 mg/100 g). One of the most important roles of carotenes, especially β-carotene, is its provitamin A activity (Rodriguez-Amaya, 1989).

With regard to β-carotene levels, the fruits analyzed in this study were compared with carrots, which are known to have high concentrations of this carotenoid. Campos et al. (2006) concluded that out of seven vegetables studied, carrots had the highest levels of β-carotene, with an average of 5.18 mg/100 g. All of the pulps studied here had low concentrations of β carotene in comparison with carrots, and the fruit with the highest level of β-carotene was the sweet passion fruit with 1.31 mg/100 g.

All of the pulps analyzed had low concentrations of lycopene compared with tomatoes, a lycopene-rich fruit. Carvalho et al. (2005) studied different tomato hybrids and concluded that the content of lycopene in the ripe fruit varies from 8.2 to 10.5 mg/100 g.

The Pearson's correlation coefficients between antioxidant activity, total phenolic contents and ascorbic acid levels are presented in Table 4. There was no significant relationship between antioxidant activity and the contents of minerals, β-carotene or lycopene. The total antioxidant activity was high and positively correlated with the phenolics content ($r=0.964$, $p \leq 0.01$) and ascorbic acid levels ($r=0.902$, $p \leq 0.05$). These results suggest that the ascorbic acid and phenolic compounds, such as phenolic acids, tannic acid and proanthocyanidin, may be the most important contributors to the antioxidant activity in the fruits studied in this research.

TABLE 4 Pearson's Correlation Coefficients (r) between antioxidant capacity parameters and ascorbic acid and the total phenolics contents in marolo, murici, jenipapo, soursop and sweet passion fruit.

Parameters	**Correlation Coefficient (r)**
	Antioxidant Capacity
Ascorbic Acid	0.902*
Total Phenolics	0.964**

* p<0.01
** p<0.05

Several studies have reported relationships between phenolic contents and antioxidant activity; some authors found a high correlation between phenolic content and the antioxidant activity (Roesler et al., 2007; Rufino et al., 2010; Contreras-Calderón et al., 2010; Ramful et al., 2011; Almeida et al., 2011), while others found no relationship (Imeh and Khokhar, 2002; Ismail et al., 2004). The same observation has been reported in the relation to ascorbic acid and antioxidant activity; some authors have reported a positive correlation between ascorbic acid content and antioxidant activity (Contreras-Calderón et al., 2010; Rufino et al., 2010), and others have found no correlation (Barreto et al., 2009; Almeida et al., 2011)

Of all the pulps analyzed, the pulp of marolo has the greatest potential for antioxidant activity as it has a higher content of phenolic compounds and higher concentrations of ascorbic acid. Therefore, this fruit may have a greater nutritional and economic value.

4. CONCLUSION

The fruit pulps analyzed in this study had high moisture content, and they were low in protein, lipid and energy value. The pulp of marolo had higher lipid and carbohydrate contents and a higher energy value compared with the other pulps analyzed. Murici pulp had a higher content of dietary fiber. Sweet passion fruit pulp was found to contribute the most to the DRI of phosphorus (P) and iron (Fe). Marolo was found to contribute more to the DRI of potassium (K) and magnesium (Mg). For calcium (Ca), jenipapo fruit pulp is the richest, but in general, the fruit pulps analyzed in this study contribute little to the DRI of calcium. The pulp of marolo has the greatest potential for antioxidant activity, as it had higher contents of phenolic compounds and higher concentrations of ascorbic acid. The levels of β-carotene and lycopene in the pulps analyzed were found to be low.

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ARTICLE 2: MULTIVARIATE OPTIMIZATION OF SENSORIAL PARAMETERS OF BRAZILIAN CERRADO FRUITS JAM

Submitted to Food Quality and Preference- ISSN: 0950-3293, being presented according to the rules of publication of this magazine.

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ABSTRACT

The Brazilian Cerrado is a cradle of great biodiversity, with many species of fruits that are still unknown or rarely found on the market. These fruits have exotic flavors and high nutrient content, and thus great economic potential. One way of increasing availability and adding value to the fruits of the Brazilian cerrado is the creation of new products such as jams and jellies. The aim of this study was determine the optimum proportion of the fruits murici (Byrsonima crassifólia L. RICH), marolo (Annona crassiflora Mart.), jenipapo (Genipa americana L.), sweet passion fruit (Passiflora alata Dryand) and soursop (Annona muricata L.) in the formulation of cerrado Brazilian mixed fruit jam through the sensory evaluation of the jams' formulations. The Parallel Factor Analysis (PARAFAC) and response surface methodology using mixture design were utilized. The best formulations contained the following proportions of fruit: 50% marolo and 50% soursop; 33.33% marolo, 33.33% sweet passion fruit and 33.33% soursop; and 60% marolo and 10% each of murici, jenipapo, soursop and sweet passion fruit. The use of PARAFAC in conjunction with the modeling of mixtures is useful in elucidating the effects of foods' components on sensory attributes, especially in mixtures with more than three components, in which the graphic analysis is difficult.

Keywords: optimization, jam, Brazilian fruits, mixture design, Parafac

1. INTRODUTION

Brazil has the largest biodiversity in the world, with access to a number of fruit species. Many of these species are unknown and therefore have little commercial value. The North and Northeast regions are home to the greatest biodiversity (Mattieto et al., 2010). Many of these plant species provide fruits with unique sensory characteristics and high nutrient concentrations. Therefore, they are of potential interest to the agroindustry and a possible future source of income for the local population (Almeida et al., 2011; Cardoso et al., 2011).

However, few people have access to these fruits because they are found in only some regions of the country and during only a few months of the year. One way to increase availability and add even more value to exotic Brazilian fruits is to create new products such as jellies and jams. The production of jelly and jams from the fruits of Brazilian Cerrado is therefore an option for many producers to develop not only on the domestic market, but also to attain higher prominence in export trade.

Given the wide variety of fruits in the Brazilian cerrado, a number of products can be prepared from various mixtures. These fruits are capable of producing jams and jellies with different tastes and appearances. According Zotarelli et al. (2008), mixed fruit jams join the nutritional characteristics of two or more fruits while providing pleasant sensory characteristics in order to gradually gain prime space in the consumer market.

Mixture design experiments are a very powerful tool to quantify different factors' effect on production processes, and ultimately to determine which combinations of factors and levels provide optimal output quality (Katelaere et al., 2011). Mixture design methodology can be utilized for the optimization and investigation of the functions of processed foods' ingredients, and supports the importance of ingredient interactions (Abdullah and Cheng, 2001; Dooley et al. 2011). Mixture design experiments are suitable for the study of products that involve more than one ingredient, since the levels and proportions of the components in the mixture are dependent on each other, and the sum of all components is always one or 100% (Hare, 1974; Cornell, 1983; Iop et al., 1999; Dutcosky et al., 2006; Dooley et al., 2011). This technique allows one to obtain a predictive mathematical representation of the relationship between mixture factors and responses. In general, a special cubic model is satisfactory to describe the additive terms and the interactions among components (Cornell, 1983; Neto et al., 2003).

According to Plaehn (2009), product optimization is one of product developers' primary goals, and a number of methods have been developed to address it. Response surface methodology (RSM) can be used to model and optimize any response affected by the levels of one or more quantitative factors (Dean and Voss, 1999), such as ingredients or process variables. RSM uses quantitative data to determine and simultaneously solve multivariate equations that specify the optimum product for a specified set of factors through mathematical models, while considering interactions among test factors (Giovanni, 1983).

This method has been successfully applied by several authors to determine the optimum formulation for a food product while evaluating sensory or physicochemical attributes. Response surface methodology using mixture design was used to determine the optimum ratio of pineapple, papaya and carambola in the formulation of reduced-calorie tropical mixed-fruit jam by Abdullah and Cheng (2001). Acosta et al. (2008) used response surface methodology to evaluate and model the effects of three factors (sweetener, low methoxyl (LM) pectin and calcium content) at three levels each on the overall acceptability of a tropical mixed-fruit (pineapple, banana and passion fruit) jelly. Mixture design experiments were used to study the effect of interactions among pine, flower and highland honeys on the rheological properties of salep-honey drink mixture (SHDM) samples (Karaman et al., 2011).

During the development of new foods, it is extremely important to evaluate sensory attributes, which will define the food's acceptance in the market. At present, various statistical methods are available for this review, and recently the Parallel Factor Analysis (PARAFAC) has proven useful for this purpose (Nunes et al., 2011).

PARAFAC is a method of decomposition of higher-order data and can be considered a generalization of the Principal Component Analysis (PCA) to multidimensional data (Bro, 1997). PARAFAC is able to provide an exploratory interpretation of samples and variables while taking into account the K different conditions in which the data were generated. Therefore, PARAFAC is able to decompose an I x J x K array, which in the case of internal preference mapping studies is an array of products x consumers x attributes. The loadings obtained by PARAFAC can then be used to construct a multiway internal preference map for consumer acceptance data analysis, while can provide an evaluation of several attributes simultaneously. The PARAFAC method has been used successfully for numerous authors; Cocchi et al. (2006) used this method in sensory analysis of Aceto Balsamico Tradizionale di Modena of different ageing and Nunes et al. (2011) used PARAFAC in studies of herb cakes and onion cakes.

The three-way map created by PARAFAC and response surface methodology using mixture design was used to determine the proportions of murici (Byrsonima crassifólia L. RICH), marolo (Annona crassiflora Mart.), jenipapo (Genipa americana L.), sweet passion fruit (Passiflora alata Dryand) and soursop (Annona muricata L.) in the formulation of cerrado Brazilian mixed fruit jam through sensory evaluation of the formulations.

2. MATERIALS AND METHODS

2.1 Materials

We used pulp of murici (Byrsonima crassifólia L. RICH), marolo (Annona crassiflora Mart.), jenipapo (Genipa americana L.), sweet passion fruit (Passiflora alata Dryand) and soursop (Annona muricata L.), high-pectin methoxyl (Danisco ®), citric acid and sucrose.

2.2 Obtention of fruit pulps

Pulp of jenipapo and murici were acquired from a fruit pulp processing company located in Uberlândia - Minas Gerais. The graviola pulp came from a fruit pulp processing company located in Jarinu - Sao Paulo. These pulps were stored in sealed plastic bags, frozen and transported in Styrofoam boxes.

Pulps of sweet passion fruit and marolo were processed at the Laboratory of Processing Plant Products, Federal University of Lavras (UFLA) after the acquisition of fresh fruits from the north of Minas Gerais. These fruits were cleaned with tap water and then separated into peel, seed and pulp. The pulps were extracted manually with a knife and the husk and seed were discarded. The pulps were then beaten in a blender, and after homogenization were stored in sealed plastic bags and frozen.

All pulp was stored in a cold room at 18°C.

2.3 Preparation of the jams

The preparation of Brazilian cerrado fruits jam was conducted in the Laboratory of Processing Plant Products, Federal University of Lavras (UFLA).

To process the jams, a blend of fruit pulps was made (according to Table 1) and added to sucrose.

TABLE 1 Compositions of jam mixture samples in a simplex lattice mixture design.

	Level					Jenipapo (%)	Marolo (%)	Murici (%)	Soursop (%)	Sweet passion fruit (%)
	X_1	X_2	X_3	X_4	X_5					
1	1	0	0	0	0	100	0	0	0	0
2	0	1	0	0	0	0	100	0	0	0
3	0	0	1	0	0	0	0	100	0	0
4	0	0	0	1	0	0	0	0	100	0
5	0	0	0	0	1	0	0	0	0	100
6	0.5	0.5	0	0	0	50	50	0	0	0
7	0.5	0	0.5	0	0	50	0	50	0	0
8	0.5	0	0	0.5	0	50	0	0	50	0
9	0.5	0	0	0	0.5	50	0	0	0	50
10	0	0.5	0.5	0	0	0	50	50	0	0
11	0	0.5	0	0.5	0	0	50	0	50	0
12	0	0.5	0	0	0.5	0	50	0	0	50
13	0	0	0.5	0.5	0	0	0	50	50	0
14	0	0	0.5	0	0.5	0	0	50	0	50
15	0	0	0	0.5	0.5	0	0	0	50	50
16	0.6	0.1	0.1	0.1	0.1	60	10	10	10	10
17	0.1	0.6	0.1	0.1	0.1	10	60	10	10	01
18	0.1	0.1	0.6	0.1	0.1	10	10	60	01	01
19	0.1	0.1	0.1	0.6	0.1	10	10	10	60	10
20	0.1	0.1	0.1	0.1	0.6	10	10	10	10	60
21	0.2	0.2	0.2	0.2	0.2	20	20	20	20	20

The proportion of sugar and fruit pulp used was 1:1. The jams were processed in open pan heated by gas flame (Macanudo, SC, Brazil). After a boil was reached, 1.5% high-methoxyl pectin was added. At the end of the process, after the soluble solids reached 75°Brix, 6% citric acid (2%) was added and cooking was stopped. The total soluble solids were determined using a portable refractometer model RT-82 and °Brix was measured at ± 25°C. The jams were then poured hot into 250 mL sterile bottles, cooled in a container with water and ice and stored in a refrigerator at ± 7°C. Figure 1 describes the processing of the jams.

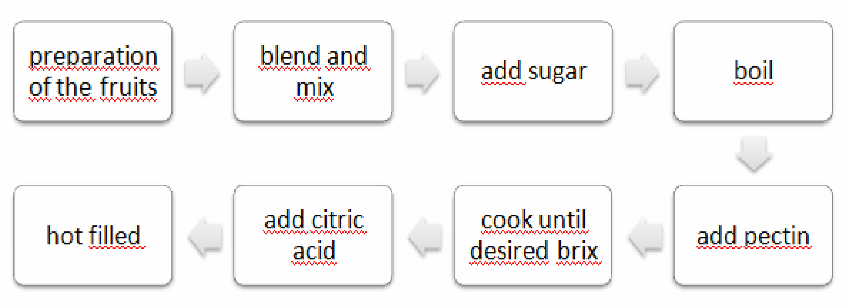


FIGURE 1 Steps used in the preparation of jams

2.4 Sensory Analysis

Sensory analysis was performed in the laboratory of Sensory Analysis, Food Science Department, Federal University of Lavras (UFLA). An acceptance test was conducted on the attributes of color, appearance, smell, taste and the global aspect using a hedonic scale of 9 points (1 = dislike extremely 9 = like extremely) (Stone and Sidel, 1993).

The test was conducted on 85 participants (50 women and 35 men), among them students and office staff aged between 18 and 40 years. Panelists were selected based on their regular consumption of fruit jams and jellies. In the first sensory evaluation, each panelist evaluated 21 formulations in five sessions spread over five consecutive days. In the first four sessions, four formulations were evaluated, and the fifth and final session five formulations were evaluated. In the second sensory evaluation, the panel evaluated five formulations in a single session.

Samples of approximately 5 g of jam (Acosta et al., 2008) were served in cups of 50 mL at refrigeration temperature (7°C) in a balanced manner (Wakeling and MacFie, 1995). These were coded with three-digit numbers drawn from a table of random numbers. The test was conducted in individual booths under white light, with adequate ventilation. Tasters were offered enough water for the analysis. The laboratory temperature was set at 23°C.

For each set of samples, the panelists were instructed to taste and evaluate from left to right and rinse their mouths with water between samples. In addition, testers were instructed on the use of the hedonic scale.

2.5 Experimental Design and Statistical Analysis

From the simplex lattice mixture design (Cornell, 1983), the proportion of fruit jenipapo (X_1), marolo (X_2), murici (X_3), soursop (X_4) and sweet passion fruit (X_5) used in the preparation the mixed fruit jam was determined. In total, 21 formulations were evaluated. The design with coded and experimental levels for these five factors is presented in Table 1.

The polynomial model equation used was:

$$Y= \beta_1X_1 + \beta_2X_2 + \beta_3X_3 + \beta_4X_4 + \beta_5X_5 + \beta_{12}X_1X_2 + \beta_{13}X_1X_3 + \beta_{14}X_1X_4 + \beta_{15}X_1X_5 + \beta_{23}X_2X_3 + \beta_{24}X_2X_4 + \beta_{25}X_2X_5 + \beta_{34}X_3X_4 + \beta_{35}X_3X_5 + \beta_{45}X_4X_5$$

where Y is the estimated response. β are constant coefficients for each linear and non-linear (interaction) term produced for the prediction models of the processing components (Cornell, 1983; Dean and Voss, 1999).

Due to the difficulty of analyzing five variables by response surfaces, variables were initially decided through analysis of data acceptance by parallel factor analysis (PARAFAC). The PARAFAC analysis was chosen because it provides more general information about sensory acceptance by simultaneously considering all the evaluated sensory attributes to indicate differences and similarities between samples.

With this analysis, it is possible to identify the formulations that had higher sensory acceptance and to develop a direction with which to identify a set of two variables (X_1, X_2, X_3, X_4 and / or X_5). From the response surfaces generated by the global aspect model, it is possible to identify the best level at which to set the two selected variables to obtain the optimal formulation.

From the models of sensory attributes evaluated, the average acceptance for samples more accepted by PARAFAC and obtained by the optimal response surface were estimated. The five formulations with higher averages were selected and taken to a second sensory analysis to confirm the best formulation of mixed jam.

To choose the most accepted formulation, sensory analysis parallel factors (PARAFAC) were used again.

To determine the levels of the factors studied and generate the model and contours curves provided by the equations, we used the program Statistica, 1998 (Statistica, 1998 (Statistica for Windows computer program manual, Tulsa, OK)). To develop the internal preference maps obtained by PARAFAC, we used the statistical package SiSMapp (SiSMapp, version 2.0).

3. RESULTS AND DISCUSSION

Table 2 shows the complete predicted models and the significance of regression coefficients and R^2 values for the attributes of color, appearance, smell, taste and global aspect after the sensory analyses of 21 formulations of jam. As shown in the table, the linear terms predicted in all models were significant ($p < 0.01$). The R^2 values of the models provided were in excess of 0.8689, indicating that they were suitable for the purpose of prediction (Henika, 1982).

TABLE 2 Predicted models for sensory data from mixed fruit jams samples.

Atribute	Predicted model	R^2 value
Color	$Y= 4.29X_1^{*} + 6.49X_2^{*} + 6.26X_3^{*} + 5.17X_4^{*} + 6.21X_5^{*} + 2.98X_1X_2 + 2.21X_1X_3 + 7.94\ X_1X_4^{*} + 1.31X_1X_5 – 0.38X_2X_3 + 4.65X_2X_4^{**} + 1.97X_2X_5 + 1.83X_3X_4 – 1.09X_3X_5 + 5.73X_4X_5^{**}$	0.9109
Appearance	$Y= 4.32X_1^{*} + 6.40X_2^{*} + 6.25X_3^{*} + 5.75X_4^{*} + 5.74X_5^{*} + 2.91X_1X_2 + 2.05X_1X_3 + 6.50X_1X_4^{*} + 2.44X_1X_5 + 0.27X_2X_3 + 3.62X_2X_4 + 2.31X_2X_5 + 1.46X_3X_4 – 0.55X_3X_5 + 5.05X_4X_5^{**}$	0.9133
Smell	$Y= 3.99X_1^{*} + 6.15X_2^{*} + 5.45X_3^{*} + 5.47X_4^{*} + 5.91X_5^{*} + 2.44X_1X_2 + 2.65X_1X_3 + 4.63X_1X_4 + 1.72X_1X_5 + 1.07X_2X_3 + 4.05X_2X_4 + 2.44X_2X_5 + 3.66X_3X_4 + 2.25X_3X_5 + 2.92X_4X_5$	0.8689
Taste	$Y= 3.08X_1^{*} + 5.95X_2^{*} + 4.55X_3^{*} + 5.78X_4^{*} + 6.26X_5^{*} + 2.31X_1X_2 + 3.52X_1X_3 + 5.69X_1X_4 – 2.84X_1X_5 + 5.36X_2X_3 + 4.92X_2X_4 + 2.59X_2X_5 + 3.88X_3X_4 + 5.1X_3X_5 + 3.06X_4X_5$	0.9258
Global aspect	$Y= 3.59X_1^{*} + 6.15X_2^{*} + 5.21X_3^{*} + 5.91X_4^{*} + 6.22X_5^{*} + 2.41X_1X_2 + 2.78X_1X_3 + 6.13X_1X_4^{**} - 1.20X_1X_5 + 3.81X_2X_3 + 5.36X_2X_4^{**} + 1.94X_2X_5 + 3.12X_3X_4 + 2.95X_3X_5 + 3.60X_4X_5$	0.9236

$^{*}p<0.01$; $^{**}p<0.05$.

Due to the difficulty of analysis of five variables of the mixture design (or response surface contour curves of the model set), the design was decided primarily by the use of parallel factor analysis (PARAFAC).

Figure 2 shows an internal three-way map, a representation of the distribution of consumers (squares), the samples (vectors), the evaluated sensory attributes (points) and acceptance by consumers. Choosing the number of factors is a critical stage in construction of the internal preference map for a three-way PARAFAC. This choice can be made by a consistency analysis of the core value

(CORCONDIA) (Bro and Kiers, 2003). A CORCONDIA value above 90% can be interpreted as an appropriate model, while a value of 50% would mean a problematic model. A value close to zero or negative implies an invalid model. The most appropriate value is one that provides a greater number of factors and involves a valid model (Bro and Kiers, 2003, Nunes et al., 2011). Therefore, we chose to use a model with two factors that showed a CORCONDIA value of 63.8886%

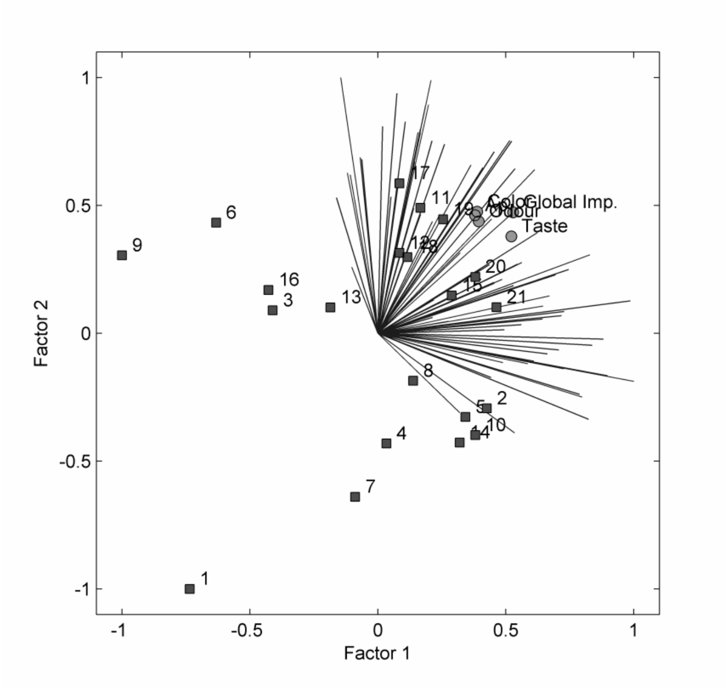
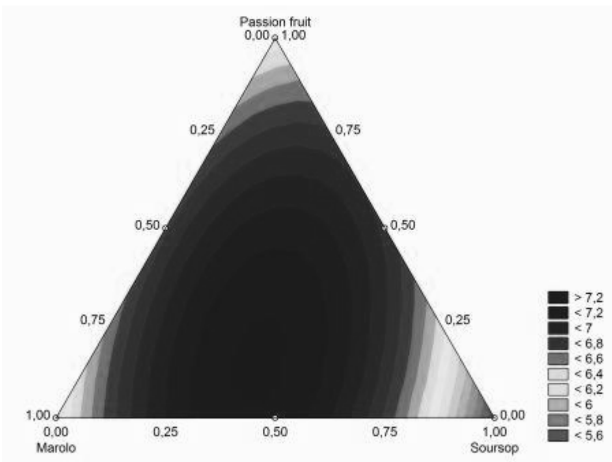


FIGURE 2 Map of three-way internal preferences for color, appearance, smell, taste and global aspect obtained for the 21 formulations of fruit jam.

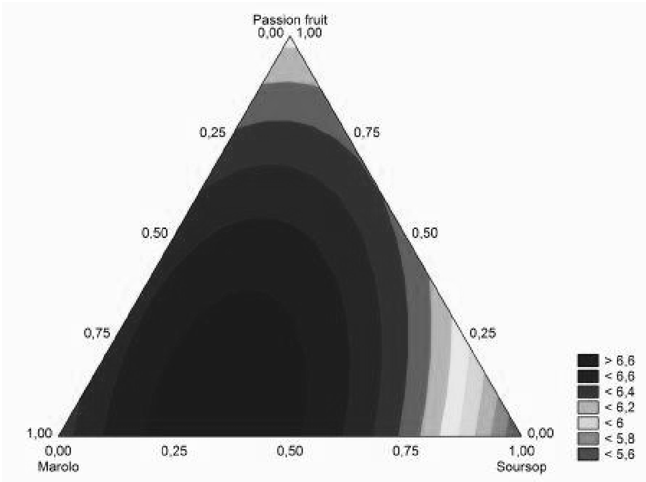
The large number of consumers preferring samples 11, 12, 15, 17, 18, 19, 20 and 21 show that they were the most preferred of all the analyzed parameters. Table 1 shows that of the eight formulations with sensory acceptability, murici is present in five formulations but only appears in large quantities in formulation 18. Jenipapo also appears in five of the eight formulations, but always in small quantities. We could have set these two variables (jenipapo and murici) at low levels, but we decided to set them at 0, because the formulations with 100% jenipapo (1), 60% jenipapo (16), 50% jenipapo (6 and 9), 50% jenipapo and 50% murici (7) and 100% murici (3) did not have good sensory acceptance. No consumers preferred these formulations, which indicates that these two fruits will probably contribute to the reduction of sensory acceptance of the jam.

To confirm this hypothesis, a curved contour of the predictive model of the global aspect of the attributes of these fruits (Table 2) was made, with the variables jenipapo (X_1) and murici (X_3) set to 0 (Figure 3a), 15% (Figure 3b) and 25% (Figure 3c). The fixation on 15% and 25% was only to confirm that the use of these two factors leads to the reduction of sensory acceptance. This same behavior was observed in the acceptance of other attributes evaluated (data not shown).



(a)

(b)



(c)

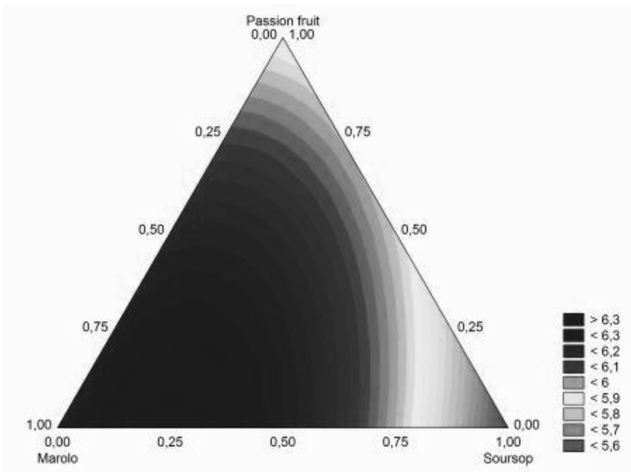


FIGURE 3 Contour curves for global aspect, with jenipapo (X_1) and murici (X_3) set to 0 (a) 15% (b) and 25% (c).

With increasing concentrations of jenipapo (X_1) and murici (X_3) a decrease in sensory acceptance is clear, although low concentrations (15% or less) of these two variables obtain a relatively good acceptance (note around 6, 6, according Figure 3b). However, since the objective in this study is to select the best formulation of fruit jam, it was decided to fix the murici and jenipapo at 0% because the models generated showed (Figure 3) that the lower the levels of jenipapo and murici, the greater the sensory acceptance. By setting these variables to 0% (Figure 3a) it is possible to optimize the formulation (OF), which is the central point. Therefore, the formulation should contain 33.33% marolo, 33.33% soursop and 33.33% sweet passion fruit.

Figure 3 also shows that when the jenipapo and murici are present in high concentrations, a higher concentration of marolo is required to get the highest possible sensory acceptance.

From the models generated (Table 2), we determined the average scores of acceptance provided for the attributes of appearance, smell, color, taste and global aspect. We also established the average overall sensory acceptance (Table 3) of the eight formulations chosen as the most accepted PARAFAC formulations provided by the contour curve generated from the model-predicted global aspect.

TABLE 3 Provided notes to global aspect for the eight most widely accepted formulations, selected by PARAFAC and the optimized formulation (OF) selected by contour of the curve

Formulation	Color	Appearance	Smell	Taste	Global aspect	Overall Average
11	6.99	6.98	6.82	7.10	7.17	7.01
12	6.84	6.65	6.64	6.75	6.68	6.71
15	7.12	7.01	6.42	6.79	6.77	6.82
17	6.82	6.77	6.55	6.63	6.73	6.70
18	6.37	6.39	6.19	6.07	6.22	6.25
19	6.71	6.81	6.47	6.57	6.55	6.64
20	6.61	6.44	6.40	6.43	6.46	6.47
21	6.77	6.74	6.51	6.47	6.58	6.61
OF	7.24	7.10	6.81	7.09	7.09	7.07

In general, the nine formulations selected had good scores for all parameters analyzed, with scores ranging between 6 and 8, which correspond to the hedonic terms “liked slightly” and “liked moderately,” respectively.

We chose to perform a second sensory analysis of five of the nine selected formulations to confirm the mixed jams that really has the best sensory acceptance. Of the nine formulations presented in Table 3, it was concluded that formulations 11, 12, 15, 17 and the optimized formulation (OF) have the highest average score provided for the attributes of color, taste, global aspect and overall average.

Figure 4 shows the internal three-way map, which is the representation of the distribution of consumers, samples and sensory attributes as to the acceptance of five analyzed jam formulations (11, 12, 15, 17 and OF). A model was chosen with two factors that showed a CORCONDIA value of 96.6448%.

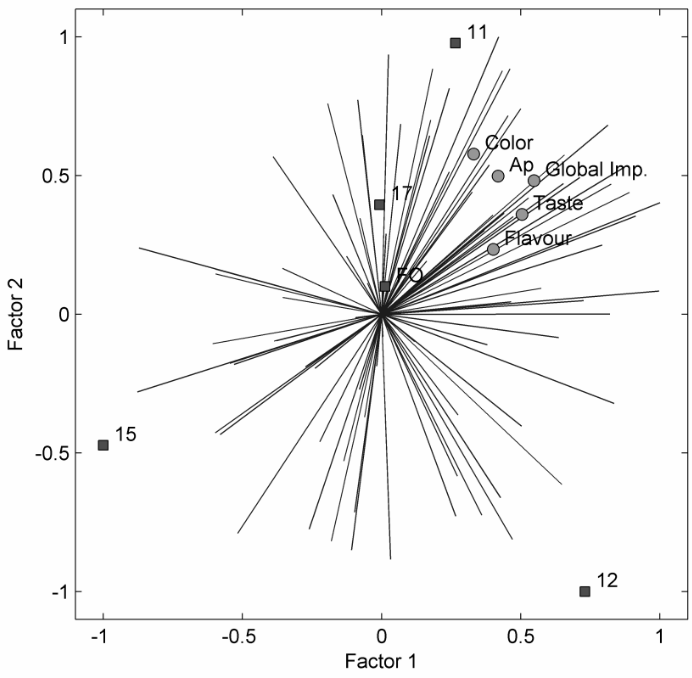


FIGURE 4 Three-way internal preference mapping to color, appearance, smell, taste and global aspect, obtained for the five formulations of jam (11, 12, 15, 17 and OF).

Figure 4 demonstrates that the formulations 11, 17 and the optimized formulation (OF) seem to have better sensory acceptance compared with the others, as the higher density of consumers is situated around these three formulations. Formulation 11 has 50% marolo and 50% soursop; formulation 17 has 60% marolo and 10% each of murici, jenipapo, soursop and sweet passion fruit; the optimized formulation (OF) has 33.33% soursop, 33.33% marolo and 33.33% sweet passion fruit.

Although Figure 3 shows that increasing the concentration of jenipapo and murici reduces its acceptability, formulation 17, which has 10% of each of these two fruits, was one of the most accepted. As discussed earlier, the contour curves for global aspect (Figure 3) show that good acceptability can be obtained from low concentrations of jenipapo and murici (Figure 3B) and that higher concentrations of these two fruits requires a greater concentration of marolo to balance the soursop and sweet passion fruit (Figure 3A and 3B) and obtain better sensory acceptance. The selection of formulation 17, which has a high concentration of marolo and a low concentration of jenipapo, murici, soursop and sweet passion fruit, as one of the most widely accepted formulations confirms the expected contour curves for the global aspect (Figure 3).

Table 4 expresses the average scores for color, appearance, smell, taste and global aspect of the five formulations analyzed.

TABLE 4 Means sensory score of fruits jam

Formulation	**Color**	**Appearance**	**Smell**	**Taste**	**Global aspect**
11	6.36	6.63	6.21	6.45	6.49
12	6.12	6.25	6.25	6.26	6.25
15	6.06	5.42	5.86	5.87	5.72
17	6.29	6.15	6.01	5.73	6.00
FO	6.52	6.52	6.48	6.53	6.42

In general, the five formulations had good sensory acceptance, scoring each of the attributes between 6 and 7, which correspond to the terms “liked slightly” and “liked moderately.”

It is important to emphasize that the hedonic scores observed for the sensory attributes evaluated for 11, 12, 15, 17 and OF formulations were slightly lower than the scores provided

By the models, possibly due to differences in consumer sensory scales.

The difference in the scores presented in these formulations compared to the first sensory analysis in which five samples were evaluated in a group of 21 formulations can be justified by the contrast effect. In other words, the first sensory analysis showed a large variation between formulations and their acceptability. The preferred formulations may have shown higher average scores because there were very few accepted formulations. The second sensory evaluation was performed with only the five most widely accepted formulations, and therefore showed a smaller variability of acceptance. However, it is important for sensory evaluation to validate the model.

Therefore, development of jam made with Brazilian cerrado fruits is viable. Among the fruits studied, the soursop, marolo and sweet passion fruit have the greatest potential for use in jam because these three fruits were present in the formulations selected as the most accepted. Jenipapo and murici are tolerated only in small concentrations; high concentrations contribute to reduction of acceptance of the jam. When they are present in low concentrations, the jam requires a high concentration of marolo to obtain good sensory acceptance. Therefore, more study is needed to determine the best uses and enjoyment of these fruits.

4. CONCLUSION

Multivariate optimization methods are an effective tool for the improvement of sensory characteristics during the development of new products. The use of PARAFAC in conjunction with the modeling of mixtures is useful in elucidating the effects of foods' components on sensory attributes, especially in mixtures with more than three components, in which the graphic analysis is difficult. The best formulations of jam were those with the following proportions of fruit: 50% marolo and 50% soursop; 33.33% marolo, 33.33% soursop and 33.33% sweet passion fruit; and 60% marolo and 10% each of murici, jenipapo, soursop and sweet passion fruit. The preparation of jams made with Brazilian Cerrado fruits is viable because it is possible to obtain a good sensory acceptance, with averages ranging from 6 ("liked slightly") to 7 ("liked moderately"). Through the development of products such as jams, it is possible to add value to fruits from the Brazilian cerrado that are little known and marketed, and to create products with new sensory characteristics.

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ARTICLE 3: ANALYSIS OF VARIOUS SWEETENERS IN SUGAR-FREE MIXED FRUIT JAM: EQUIVALENT SWEETNESS, TIME-INTENSITY ANALYSIS AND ACCEPTANCE TEST

Will be Submitted to Food Research International- ISSN: 0963-9969, being presented according to the rules of publication of this magazine.

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ABSTRACT

For a sweetener to successfully replace sucrose in food formulations, studies must first be conducted to determine the concentrations of the sweeteners to be used and their equivalent sweetness compared to sucrose. After establishing the optimal concentration of each sweetener it is necessary to determine which is more similar to sucrose. The objective of this study was to determine the equivalent amount of different sweeteners (sucralose, sucralose/acesulfame-K (3:1), Thaumatin/sucralose (4:1), sucralose/steviol glicoside (2:1) and sucralose/acesulfame-K/neotame (5:3:0,1)) necessary to promote the same degree of ideal sweetness in mixed fruit (marolo, sweet passion fruit and soursop) jam, and to characterize the time–intensity profile and consumer acceptance of all formulations. Using the magnitude estimation method was found that to promote that ideal sweetness (40% sucrose) of mixed fruit jam it is necessary to use a concentration of 0.0358% of sucralose, 0.0472% of sucralose/acesulfame-K (3:1), 0.0464% of sucralose/steviol glycoside (2:1), 0.1407% of sucralose/thaumatin (1:0.6) and 0.0407% of sucralose/acesulfame-K/neotame (5:3:0.1). The sweeteners presented a sweetness profile similar to sucrose and bitterness profile different from sucrose, but similar between them. In relation to sensory acceptance, a significant difference between the sugar-free jam and the traditional jam was not observed. Of all the sweeteners studied, it is suggested to use a combination of sucralose/acesulfame-K (3:1) in mixed fruit (Marolo, soursop, sweet passion fruit) jam, the value due to a better cost/benefit.

KEYWORDS: sweeteners, mixed fruit jam, equivalent sweetness, time intensity

1. INTRODUCTION

New health concerns associated to high sugar intake include excessive calorie consumption and decreased diet quality (Weaver & Finke, 2003). The growing concern with health and the higher incidence of obesity, metabolic syndrome and diabetes have resulted in an increase in interest for foods with lipid and sugar reduction (Dabelea, Bell, D'Agostino, Imperatore, Johansen, Linder, Liu, Loots, Marcovina, Mayer-Davis, Pettitt & Waitzfelder, 2007; Ogden, Carroll, Curtin, Mcdowell, Tabak & Flegal, 2006). Within this context, there is a growing trend towards the consumption of diet and light products, which are indicated, among other purposes, for people with diabetes or other medical restrictions, including obesity (Cardoso & Bolini, 2007) and for people who are concerned with aesthetics and health. However, the development of new food products turns out to be increasingly challenging, as it must fulfill consumer expectancy for products that are simultaneously appealing and healthy (Cruz, Antunes, Sousa, Faria & Saad, 2009).

Determining the best sweetener for a product requires several sensory tests. These sweeteners, in addition to being safe (meeting current law), must be compatible with the food and present the greatest similarity to the characteristic flavor of the sucrose-based product (Fernandes, 2001), furthermore it is desirable that sweeteners have a low calorie density and commercial viability (Malik, Jeyarani & Raghavan, 2002).

For a sweetener to successfully replace sucrose in food formulations, studies must first be conducted to determine the concentrations of the sweeteners to be used and their equivalent sweetness compared to sucrose (Cardoso & Cardello, 2003). There are several methods for obtaining this information, but the most common method is the estimation of the magnitude and graphic representation of standardized results through the Law of Stevens, or “Power

Function" (Moskowitz, 1970; Stone & Oliver, 1969). Works involving sweetness and equivalent sweetness are already being conducted by several researchers. Among many of these works we can mention those of Pangborn (1959), Powers & Pangborn (1978), Stone & Pangborn (1990), Cardoso & Bolini (2007), Moraes & Bolini (2010); Souza, Pinheiro, Carneiro, Pinto, Abreu & Menezes (2011).

According to Lawless & Heymann (1999) it is widely believed that the consumer acceptability of different intensive sweeteners depends on the similarity of their time profile to that of sucrose. According Bolini-Cardello, Silva & Damasio (1999) the replacement of sucrose by alternative sweeteners can provide changes in the perception of bitter and sweet taste. The goal of intensity-time technique is to monitor these changes in order to find the sweetener that is most similar to the sensory profile of sucrose. The time–intensity technique measures the sensory perception of the intensity of a specific attribute, and enables the monitoring of perceptual intensity changes during product evaluation (Lee & Pangborn, 1986; Cliff & Heymann, 1993; Desobry-Banon & Vickers, 1998; Piggott, 2000; Chung, Heymann & Grün, 2003). According to Cadena & Bolini (2011) the time–intensity analysis has been widely used in studies to determine the behavior of sweeteners, in studies concerning beverages, chewing gum, meat product, salad dressing, olive oil, gelatins and in the study of dairy products. Work involving sweeteners is already being undertaken by several researchers; among the many works we can mention those of Swartz (1980); Lee, Barrick & Welling (1992); Ketelsen, Keay & Wiet (1993); Ujikawa & Bolini (2004); Melo, Bolini & Efraim (2007); Mosca, Van De Velde, Bult, Van Boekel & Stieger (2010); Cadena & Bolini (2011).

The objective of this study was to determine the equivalent amount of different sweeteners (sucralose, sucralose/acesulfame-K (3:1), Thaumatin/sucralose (4:1), sucralose/steviol glicoside (2:1) and sucralose/acesulfame-K/neotame (5:3:0,1)) needed to promote the same degree of ideal sweetness in mixed fruit (marolo, sweet passion fruit and soursop) jam, and to characterize the time–intensity profile and consumer acceptance of all formulations.

2. MATERIALS AND METHODS

2.1 Materials

The following is a list of materials used in the food preparations in this study: marolo, sweet passion fruit and soursop pulp, high-methoxyl pectin (Vetec®) , low-methoxyl pectin (Danisco®), gum carrageenan (Danisco®), locust bean gum (LBG) (Danisco ®), $CaCl_2$ (Isofor®), polydextrose (Nutrmax®), fructooligosaccharides-FOS (Danisco®), citric acid (Nuclear®), potassium sorbate (Vetec®), sucrose, sucralose (Nutramax®), blend of sucralose/acesulfame-K (3:1) (Nutramax®), Thaumatin (Nutramax®), steviol glicoside (Nutramax®), blend of sucralose/acesulfame-K/neotame (5:3:0,1) (Sweetmix®).

The sucralose/acesulfame-K and sucralose/acesulfame-K/neotame blends have been acquired in pre-established proportion from additive suppliers (Nutramax® and Sweetmix®, respectively). The proportion of Thaumatin and steviol glicoside in relation to sucralose was defined by tests and supplier recommendations.

2.2 Preparation of the jams

The jams were processed in an open pot heated by gas flame (Macanudo, SC, Brazil). To process the traditional jam (ideal sweetness), a blend of fruit pulps was made (marolo:sweet passion fruit:soursop (1:1:1)) and added to sucrose. After reaching ebulição, high-methoxyl pectin was added. At the end of the process, after the soluble solids reached 75°Brix, citric acid was added and cooking was stopped. The concentrations of each ingredient are shown in Table 1.

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TABLE 1: Proportions of ingredients used in the traditional jam and in sugar-free mixed fruit jam

Ingredients	Concentration (traditional jam)	Concentration (sugar-free jam) *
Mixed fruit pulp	58.3%	58.3%
Sucrose	40%	-
Polydextrose	-	26.7%
Fructooligosaccharides-FOS	-	13.17%
Low content methoxyl pectin	-	1.16%
High conten methoxyl pectin	1.5%	-
Carrageenan gum	-	0,16%
Locust bean gum	-	0.16%
$CaCl_2$	-	0.3%
Citric acid	0.2%	0.2%
Potassium sorbate	-	0.05%
TOTAL	**100%**	**100%**

* The concentration of sweeteners was based on the total wheight

To process the sugar-free jam, a blend of fruit pulps was made (marolo: sweet passion fruit: soursop (1:1:1)) and polydextrose added. After the soluble solids reached 45°Brix, the low-methoxyl pectin, $CaCl_2$, carrageenan and locust bean gum previously dissolved in water at 80 °C was added, for each 4 g of pectin 50 mL of hot water was used. After the soluble solids reached 55°Brix, the fructooligosaccharides-FOS dissolved in water was added, in a 1:1 proportion. At the end of the process, after the soluble solids reached 75°Brix, citric acid, potassium sorbate and sweeteners were added and the cooking was stopped (Table 1).

The proportion of fruit used and the concentration of each ingredient used in traditional and sugar free jam were previously determined. As has been stripped of its sugar, polydextrose and FOS were used as bulking agents, but beyond this function, these two ingredients give the jam a functional feature, because they are soluble fiber.

The total soluble solids were determined using a portable refractometer model RT-82 and °Brix was measured at ± 25°C. The jams were then hot-poured into 250 mL sterile bottles, cooled in a container with water and ice and stored in a refrigerator at ± 7°C.

2.3 Equivalent sweetness

2.3.1 Selection of panelists

Sixteen subjects were selected for the determination of the equi-sweet concentrations of the different sweeteners. The selection was made using the sequential method proposed by WALD (Amerine, Pangborn & Roessler, 1965), in which triangle tests are used to select subjects with a good ability to discriminate samples ($p = 0.30$; $p_1 = 0.70$, α and $\beta = 0.10$). Two samples were sweetened with a significative difference of 0.1% in sweetness. To establish this difference, a paired comparison test was carried out using 30 subjects, in which the two samples were presented and the difference were confirmed.

2.3.2 Training of tasters to use the magnitude scale

Panelists preselected by the Wald sequential analysis were trained to use magnitude scales with different sweetness potency standards (Souza, Pinheiro, Carneiro, Pinto, Abreu & Menezes, 2011). The training was based on an explanation of the methodology and the correct use of the magnitude scale as well as establishing whether the panelists distinguished if the sweetness intensities of the traditional mixed fruit jam with different concentration of sucrose (10%, 20% and 40% sucrose) were perceived as higher, lower or equal to the reference sample (20% sucrose). The elaboration of the jam was described in the section 2.2.

2.3.3 Determination of the equivalent sweetness

The selected and trained panelists received a reference sample (mixed fruit jam with 40% of sucrose) with a potency designated by an arbitrary sweetness value of 1, followed by several mixed fruit jam samples coded and balanced (Macfie, Bratchell, Greenhoff & Vallis, 1989) with potencies higher than or lower than the reference. The panelists were asked to estimate the intensities of the sweetness of jam samples compared to the reference. For example, if the sample produced twice the sweetness of the reference, it should receive a value of 2; if it presented half the sweetness, it was given a value of 0.5.

Central concentrations of sweeteners were based on the suppliers recommendations confirmed by pretests. To calculate the other concentrations, a multiplication factor of 1.3 was used for sucrose and the factor 1.6 was also used for all the other sweeteners, following Cardoso, Battochio & Cardello (2004); Marcellini, Chainho & Bolini (2005) (Table 2).

TABLE 2 Concentrations of the sweeteners used for determining the equivalent sweetness in mixed fruit jam to 40% sucrose.

Sweetener			**Concentrations for the equivalent sweetness (%)**		
Sucrose	23,67	30,77	40.00	52.00	67,6
Sucralose	0.015	0.024	0.039	0.062	0.099
Sucralose/Acesulfame-K (3:1)	0.018	0.029	0.047	0.075	0.120
Sucralose /Thaumatin (1:0.6)	0.055	0.088	0.141	0.226	0.361
Sucralose/ steviol glicoside (2:1)	0.022	0.035	0.057	0.091	0.145
Sucralose/Acesulfame-K/neotame (5:3:0,1)	0.016	0.025	0.041	0.066	0.105

For data analysis, the estimated sweetness magnitude values of sucrose and sweeteners were converted into geometric averages, and these values were set to a logarithmic scale. The curves of concentration versus sensory response for each sweetener corresponded to a power function ("Power Function") with the following characteristics: $S = a.C^n$, where S is the sensation perceived, C is the concentration of the stimulus, *a* is the antilog of the y value at the intercept and *n* is the slope obtained in a log graphic (Moskowitz, 1970).

To calculate the equivalent concentration of each sweetener, the equation obtained for the jam with sucrose was used, and in place of C (sweetener concentration), the value of 40% was assigned, which is the ideal sweetness of sucrose. Thus, the value of S (sucrose sweetness perceived) was mathematically estimated. The S values for sucrose were substituted into the other equations (for the other sweeteners) and thus determined the optimal concentration of each sweetener or combination thereof in reference to the equivalent mixed fruit jam with 40% sucrose.

2.3.4 Determination of the sweetener potencies

The strength of each sweetener was defined as the number of times that the compound is sweeter than sucrose based on its equivalent sweetness to sucrose. That is, the power of the sweeteners was calculated by the ratio between the optimal concentration of sucrose (40%) and the equivalent concentration of sweetener in the equivalent mixed fruit jam with 40% sucrose.

2.4 Time intensity analyze

2.4.1 Pre-selection

We recruited 10 participants (8 F and 2 M) from sweetness equivalence to participate in the time intensity analysis.

2.4.2 Training section

At this stage, operation time intensity was explained to the ten participants of the program, and initial waiting time, residence time in the mouth and time after ingestion, which were 10, 15 and 45 seconds respectively were defined. To become familiar with the program testers did analysis of traditional jam (40% sucrose) in two replicates using the "System Data Collection Time-Intensity"-SCDTI software (Bolini-Cardello, Silva, Damasio & Lobao, 2003).

2.4.3 Final Selection

The panel evaluated three samples of mixed fruit jam, that is, a ideally-sweet standard sample (40% sucrose), a standard sample with the bitterness intensified (40% sucrose and 0.05% caffeine) and a sugar-free mixed fruit jam with a higher amount of sweetener to intensify the sweetness (0.0624% sucralose). The panelists evaluated the attributes sweetness and bitterness of the samples with the monadic presentation, using a balanced complete block design (Walkeling & MacFie, 1995), and three repetitions, using the mouse to record the intensity of the attribute according to the time spent on the SCDTI software scale (Bolini-Cardello, Silva, Damasio & Lobao, 2003).

In the final selection of the judges with T–I assessment, the analysis of variance (ANOVA) was applied for each panelist and each parameter (Imax, Timax, plateau, area, Td and Ttotal) in each stimulus (sweetness and bitterness) separately, all of 10 panelist were chosen to participate according to their discriminating capability ($p<0.30$) and repeatability ($p>0.05$), while an individual consensus was also considered (Damásio & Costell, 1991).

2.4.4 Time intensity analysis

In this section, for traditional jam (40% sucrose) and five samples of sugar-free mixed fruit jam with different sweeteners, combinations in sweetness equivalence of 40% sucrose were used, equivalence defined in Section 2.3.3.

The 10 panelists evaluated the attributes (sweetness and bitterness) respecting the same criteria used in the selection stage of the tasters.

The TI curve parameters evaluated were: Imax (maximum intensity), TImax (time of maximum intensity), Plateau (running time of maximum intensity), area (area under the curve), Td (time corresponding to the point where the maximum intensity begins to decline) and Ttotal (total time duration of the stimulus). The scale used for the analysis was 10 points, with 0 referring to no perception and 10 referring to an extreme perception of the taste evaluated.

Data collected for all parameters (Imax, Timax, plateau, area, Td and Ttotal) of sweetness and bitterness, were subjected to analysis of variance - ANOVA - (sources of variation: samples and tasters) and interaction for each parameter. The Tukey test was applied to compare means of samples. Statistical analysis was performed using the R Project for Statistical Computing. When significant difference was observed in the sample and tester interaction, we used the Panel Check statistical program (Nofima, 2006; NÆs, Brockhoff & Tomic, 2010) to identify testers who were not in consensus with the team, therefore, after identifying the panelists who disagreed, they were excluded from ANOVA and it was repeated.

To better view results, they were represented graphically. A graph was made representing the sensory profile of the tradional jam sample (ideal sweetness- 40% sucrose) and sugar-free mixed fruit jam with different sweeteners in equivalent sweetness of 40% sucrose for each attribute (sweetness and bitterness). TI curves were obtained with Microsoft Excel 2000, using parameters collected during TI analysis (by means of Calculating parameters of TI curves over all panelists and replicates).

2.5 Acceptance analysis

The test was conducted on 85 participants (50 female and 35 male), among them students and office staff between 18 and 40 years of age. Panelists were selected based on their regular consumption of fruit jams and jellies. An acceptance test was conducted on the attributes of color, appearance, smell, taste, texture and the global aspect using a 9 point hedonic scale (1 = dislike extremely, 9 = like extremely) (Stone & Sidel, 1993).

The formulations evaluated were the tradional jam – ideal sweetness (40 % sucrose) and the five sugar-free mixed fruit jams in the same sweetness that of 40 % sucrose, determined in Section 2.3.3. Samples of approximately 5 g of jam (Acosta et al., 2008) at 7°C were served in 50 mL cups coded with three-digit numbers in a balanced manner (Wakeling & MacFie, 1995).

Data from parameters obtained from the acceptance analysis were evaluated using a univariate statistical analysis (analysis of variance — ANOVA) and the Tukey's mean test, using the R Project for Statistical Computing, to check if there was a difference between the samples at a 5% significance level ($p \leq 0.05$). Such data were also evaluated by an Internal Preference Mapping multivariate statistical analysis (MacFie & Thomson, 1994), which allowed the generation of a multidimensional sensory affective space formed by the consumers and samples using the software Sismapp - version 2.0 (Nunes, 2011).

3. RESULTS AND DISCUSSION

3.1 Equivalent Sweetness

A linear regression of points obtained for sucrose and for the various sweeteners was then made, and a straight line equation was obtained for each of the sweeteners and their combinations (Figure 1).

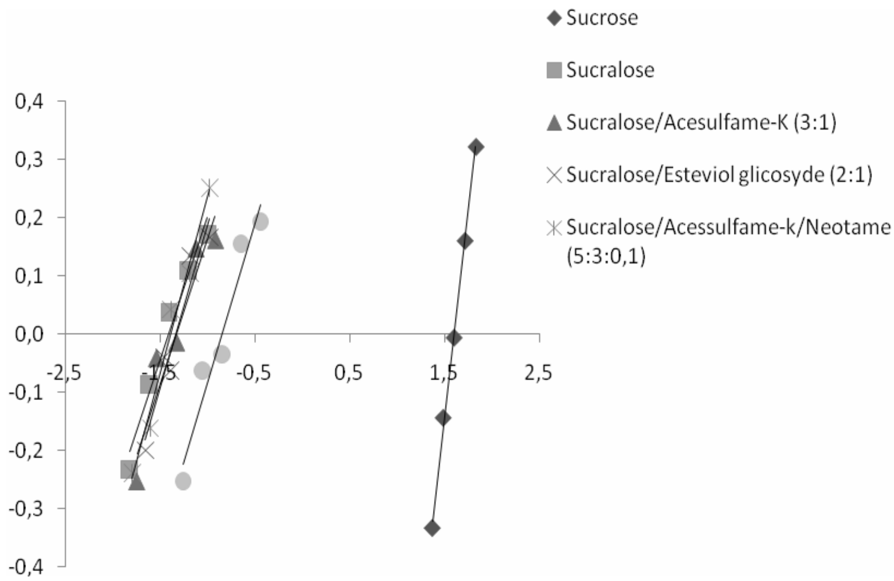


FIGURE 1 Linearized power function for sugar-free mixed fruit jam sweetened with sucralose, sucralose/acesulfame-K (3:1), sucralose/Thaumatin (1:0.6), sucralose/steviol glicoside (2:1), sucralose/acesulfame-K/neotame (5:3:0.1) and sucrose.

x-axis is the logarithmic concentration of the sweeteners (%)

y- axis is the logarithmic values of the estimated magnitudes appropriately normalized.

Comparing the sweeteners (Figure 1), it was observed that the combination of sucralose/thaumathin (1:0.6) in order to reach the same sweetness sensation, a higher concentration is needed than for the other sweetener. Apparently the sucralose, sucralose/acesulfame-K (3:1), sucralose/steviol glicoside (2:1) and sucralose/acesulfame-K/neotame (5:3:0.1) have a similar sweetness, which means that a similar concentration of these sweeteners promote the same feeling of sweetness.

From the equation for sucrose and each sweetener (Figure 1), a simple power function was obtained: $S=a.C^n$ (Table 3).

TABLE 3 Angle coefficient log (a), intercept on the ordinate (n), linear coefficient of determination (R^2) and power function (Power function) of the results to determine the equivalent sweetness of sucrose, sucralose, sucralose/acesulfame-K (3:1), sucralose/Thaumatin (1:0.6), sucralose/steviol glicoside (2:1) and sucralose/acesulfame-K/neotame (5:3:0.1) in relation to the 40% sucrose concentration of mixed fruit jam.

Sweetener	**Log(a)**	**n**	**R^2**	**Power Function**
Sucrose	-2.265	1.4138	0.9983	$S=0.00543C^{1.4138}$
Sucralose	0.6877	0.4872	0.9670	$S=4.8719C^{0.4872}$
Sucralose/Acesulfame-K (3:1)	0.6574	0.4940	0.9116	$S=4.5436C^{0.4940}$
Sucralose /Thaumatin (1:0.6)	0.4632	0.5443	0.9451	$S=2.9054C^{0.5443}$
Sucralose/steviol glicoside (2:1)	0.7471	0.5606	0.9364	$S=5.5859\ C^{0.5606}$
Sucralose/Acesulfame-K/Neotame (5:3:0,1)	0.8434	0.6070	0.9795	$S=6.9727C^{0.6070}$

From the power functions obtained for sucrose and for each sweetener, the equivalent amount of sweetener necessary to provide the same sweetness as

40% sucrose in the mixed fruit jam was calculated; the potency was also calculated (Table 4).

TABLE 4 Concentration and potency sucralose, sucralose/acesulfame-K (3:1), sucralose/Thaumatin (1:0.6), sucralose/steviol glicoside (2:1) and sucralose/acesulfame-K/neotame (5:3:0.1) in relation to the 40% sucrose concentration of mixed fruit jam.

Sweetener	Concentration	Potency
Sucralose	0.0387%	1033.59
Sucralose/Acesulfame-K (3:1)	0.0472%	847.45
Sucralose /Thaumatin (1:0.6)	0.1407%	284.29
Sucralose/steviol glicoside (2:1)	0.0464%	862.07
Sucralose/Acesulfame-K/Neotame (5:3:0,1)	0.0407%	982.80

There are few data in the literature on the use of sweeteners in sugar free mixed fruit jam, the use of the exact combinations of sweeteners used in this work was also not found in the literature. However, comparing the concentration values of pure sucralose, it appears that it was well above the values found in instant coffee with 9.5% sucrose (Moraes & Bolini, 2010), pineapple juice with 8.5% sucrose (Marcellini, Chainho & Bolini, 2005), tea with 8.3% sucrose (Cardoso, Battochio & Cardello, 2004), guava nectar with 9.6% sucrose (Brito, Câmara & Bolini, 2007) and peach nectar with 10% sucrose (Cardoso & Bolini, 2007). On the other hand, the concentration of sucralose found for the mixed fruit jam was lower than that found by Souza, Pinheiro, Carneiro, Pinto, Abreu & Menezes (2011) in petit suisse cheese with 17% sucrose. The concentration found for the combination of sucralose/acesulfame-K was close to pure acesulfame-K, since the concentration found for the combination of sucralose/stevia was well above that found for stevia in its pure form according to data from the literature (Cardoso, Battochio & Cardello, 2004; Marcellini, Chainho & Bolini, 2005; Brito, Câmara & Bolini, 2007; Cardoso & Bolini, 2007; Moraes & Bolini, 2010).

The major difference between the concentration values of sweeteners found for sugar-free mixed fruit jam and the values found in literature can be explained by the difference in the type of product used, according to Wiet & Beyts (1992) and Cardoso, Battochio & Cardello (2004), the perception of the sweetness of a sweetener is influenced by a number of factors such as type and concentration of the sweetener, dispersion medium (aqueous, lipidic or other food ingredients), synergy, temperature, pH and other properties.

According to Table 4 it was observed that sucralose had the highest sweetness, with a potency value of 1033.59, followed by sucralose/acesulfame-K/neotame (5:3:0.1), sucralose/steviol glicoside (2:1), sucralose/acesulfame-K (3:1) and sucralose/Thaumatin (1:0.6). This value potency found for sucralose is much higher than that found in the literature, ranging from 494-635 (Cardoso, Battochio & Cardello, 2004; Marcellini, Chainho & Bolini, 2005; Brito, Câmara & Bolini, 2007; Cardoso & Bolini, 2007; Moraes & Bolini, 2010; Souza, Pinheiro, Carneiro, Pinto, Abreu & Menezes, 2011).

According to studies in the literature, stevia potency ranged from 63-116 and acesulfame-K from177-277 (Cardoso, Battochio & Cardello, 2004; Marcellini, Chainho & Bolini, 2005; Brito, Câmara & Bolini, 2007; Cardoso & Bolini, 2007). In this study, combinations of sucralose/stevia (2:1) and sucralose/acesulfame-K (3:1) showed the potency of 862.07and 847.45. Because frequently in the literature, acesulfame-K and stevia have much lower power than sucralose, and in this work the combinations of sucralose/stevia and sucralose/acesulfame-K showed a high power (slightly below the sucralose), it is suggested that the sucralose increased the potency of stevia and acesulfame-K, although we have not studied stevia and pure acesulfame-K to prove this hypothesis. This fact can be of great interest to industry because the higher the power, the lower the amount required to achieve the necessary sweetness power, hence a cost reduction can occur.

Regarding the combination of sucralose/Thaumatin (1:0.6), a potency of 284.29 was found. Although the literature has reported that Thaumatin has up to 3000 times (Shibao, Santos, Gonçalves & Gollucke, 2009), this paper concludes that the Thaumatin sweetness had low power, since it decreases the sweetness power of the sucralose, which alone had power much above (1033.59); the same was observed by Souza, Pinheiro, Carneiro, Pinto, Abreu & Menezes (2011).

Since the combination of sucralose/acesulfame-K/neotame (5:3:0.1) showed power very close to pure sucralose, acesulfame-K according to the literature, which shows power well below the sucralose, may have contributed to decrease its power, as neotame, according to data from the literature that has power much greater than sucralose, ranging from 6000-13000 (Nofre & Tinti, 2000; Flamm, Blackburn, Comer, Mayhew & Stardel, 2003; Mayhew, Comer & Stargel, 2003) may have contributed to an increase in power. But to confirm this suspicion it would be necessary to determine the power of pure acesulfame-K and neotame in the jam.

3.2 Time intensity analysis

In relation to the attribute sweetness, the samples differ only with respect to the attribute Imax, and the sample with sucrose had higher Imax, significantly similar to sucralose, sucralose/acesulfame-K (3:1) and sucrose/steviol glicoside (2:1). In relation to the attribute bitter taste, a sample sweetened with sucrose differed from the other, showing lower values of the attributes Imax, Timax, Ttotal and Area (Table 5).

TABLE 5 Means from the sensory panel for the time–intensity curve parameters for the sweetness and bitter taste.

SWEETNESS						
Sweetener	Imax	Timax*	Ttotal*	Td*	Plateau	Area
Sucrose	6.19a	23.04	50.19	33.81	12.85	186.34
Sucralose	5.70ab	21.02	48.79	32.88	13.39	166.42
Sucralose/Acesulfame-K (3:1)	5.29ab	21.85	50.40	33.53	13.37	149.34
Sucralose /Thaumatin (1:0.6)	5.10b	23.13	47.73	35.35	13.09	149.40
Sucralose/steviol glicoside (2:1)	6.18a	23.11	53.72	34.94	13.04	197.88
Sucralose/Acesulfame-K/Neotame (5:3:0,1)	5.17b	22.92	51.39	33.17	12.01	151.21
BITTER TASTE						
Sweetener	Imax	Timax*	Ttotal*	Td*	Plateau	Area
Sucrose	1.28a	19.57a	30.97a	28.03	9.39	29.84a
Sucralose	3.63b	25.16b	43.20b	35.07	11.05	96.20b
Sucralose/Acesulfame-K (3:1)	3.76b	24.60b	45.38b	35.11	12.43	102.59b
Sucralose /Thaumatin (1:0.6)	3.70b	24.22b	45.38b	35.68	12.50	101.08b
Sucralose/steviol glicoside (2:1)	3.31b	25.35b	42.37b	34.35	11.56	86.39b
Sucralose/Acesulfame-K/Neotame (5:3:0,1)	3.59b	25.03b	43.85b	35.84	11.88	104.29b

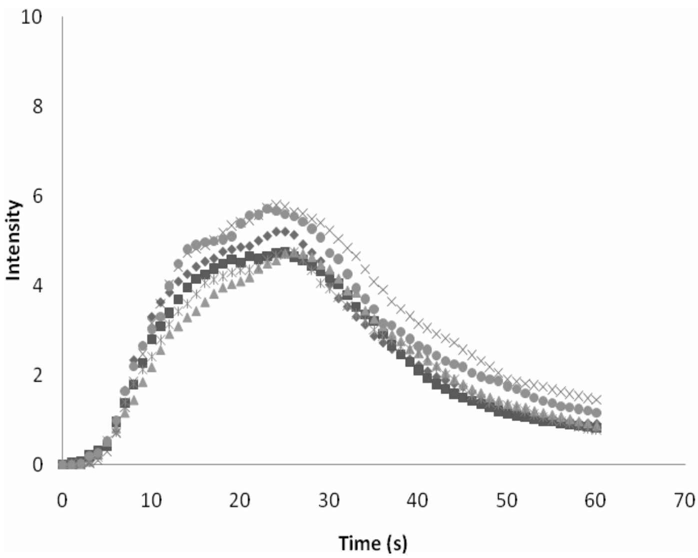
Means with common letters in the same column indicate that there is not a significant difference between samples ($p \leq 0.05$) from Tukey's mean test.

* Time in seconds.

Imax- maximum intensity; TImax - time of maximum intensity; Plateau- Running time of maximum intensity; area-area under the curve; Td-time corresponding to the point where the maximum intensity begins to decline and Ttotal-total time duration of the stimulus.

Time-intensity curves obtained from averages of 10 tasters better illustrate these results (Figure 2A and 2B). The jam with the addition of sucrose and jams sweetened with different sweeteners showed a very similar sweetness profile (Figure 2A). Thus, one can conclude that the sweeteners used do not alter the perception of sweetness compared with sucrose. According to Cliff & Heymann (1993) sweeteners have numerous disadvantages when compared with sucrose, such as the delay in perception of sweetness, which is not observed in the studied sweeteners with mixed fruits jam.

(A)



(B)

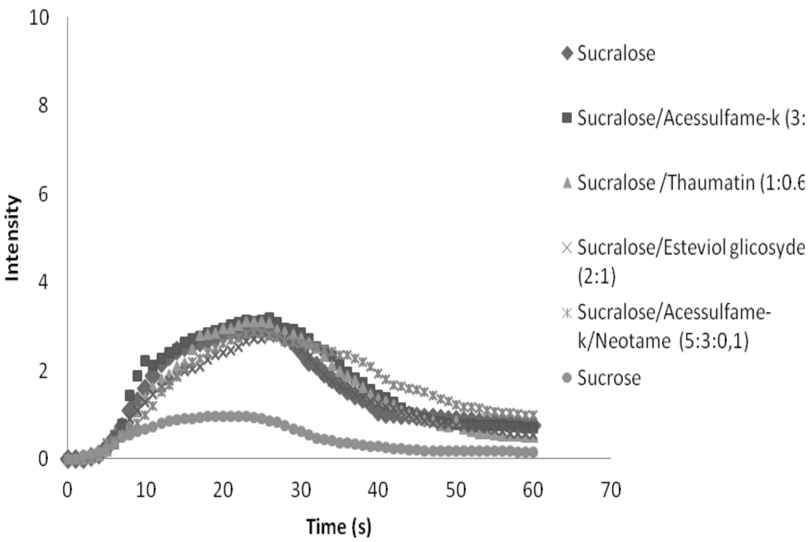


FIGURE 2 Time–intensity profile of mixed fruit jam samples of sucrose and each sweetener for sweetness (A) and bitter taste (B).

In general, samples of jams sweetened with sweeteners have no differences between them in relation to the bitter taste for all parameters, demonstrating that the studied sweeteners have a similar bitter taste profile (Figure 2B). According to Cliff & Heymann (1993) sweeteners leave an aftertaste in the mouth, a bitter residual taste, as well as other undesirable characteristics, so the different behavior of sweeteners compared to sucrose with respect to the bitterness attribute was expected, as has been verified by Cadena & Bolini (2011) working with vanilla ice cream.

In relation to the sweetness, any of the sweeteners could be used, since they were similar with respect to sucrose. However, for the bitterness, as the sweeteners differed from sucrose, it was not clear how best to use them, so we decided to conduct an acceptance test to aid in interpretation of results.

3.3 Acceptance analysis

There was no significant difference ($p \leq 0.05$) between the mixed fruit jam with sucrose and sugar-free mixed fruit jam for all the attributes evaluated (Table 6).

TABLE 6 Means sensory scores of fruits jam

Formulation	Color	Appearance	Texture	Smell	Taste	Global Aspect
Sucrose	6.31	6.25	6.32	6.24	6.64	6.55
Sucralose	6.60	6.37	6.25	6.20	6.29	6.38
Sucralose/Acesulfame-K (3:1)	6.83	6.48	6.07	6.36	6.30	6.34
Sucralose /Thaumatin (1:0.6)	6.51	6.21	6.02	6.22	5.98	6.23
Sucralose/steviol glicoside (2:1)	6.70	6.37	6.24	6.20	6.23	6.35
Sucralose/Acesulfame-K/Neotame (5:3:0,1)	6.88	6.55	5.79	6.20	5.83	6.18

In general, the all formulations had good sensory acceptance, each of the attributes scoring between 6 and 7, which correspond to the terms “liked slightly” and “liked moderately” (Acosta et al, 2008).

The Figure 3 shows a bidimensional MDPREF for global aspect, where Dimension one explains 30.25% and Dimension two explains 22.74% (total 52.99%) of the total variation between the samples. The consumers were represented by points in a vectorial space, which indicated the direction of preference of each consumer in relation to the samples. The consumers are uniformly distributed around the samples, indicating no preference for any specific sample. As the result obtained by analysis of variance - ANOVA, it can be seen in the preference map that the samples showed the same degree of preference in relation to global aspect.

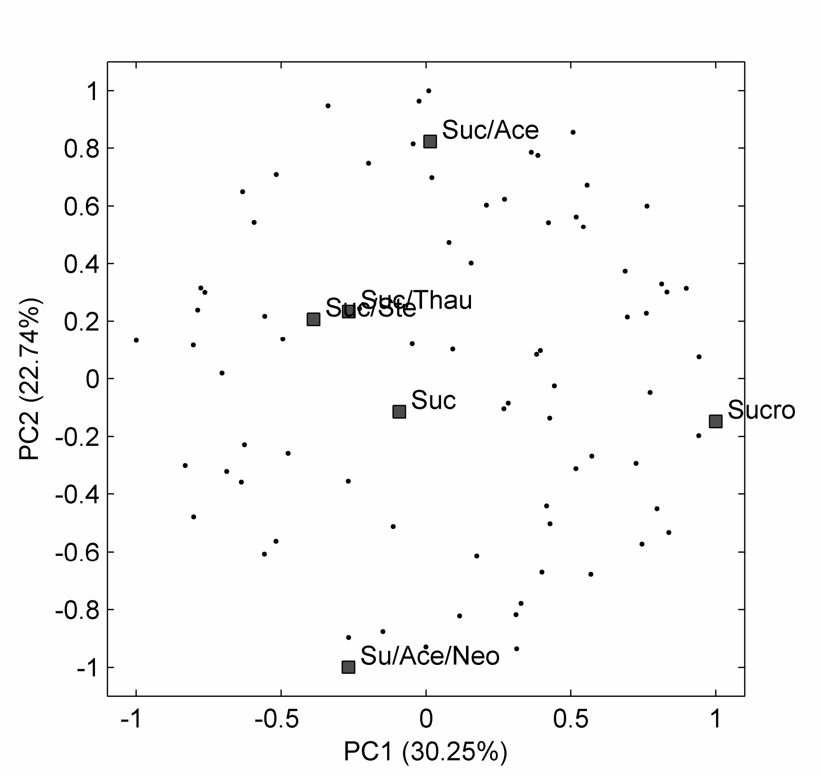


FIGURE 3 Bi-dimensional graphic from the analysis of the internal preference Mapping for the six mixed fruit jam samples to global aspect.

Since sucralose was used alone and in combinations, and since all the blends studied showed a similar profile of sweetness, bitterness and sensory acceptance, there is a hint that sucralose (sweetener in common) contributed to improve the perception of sweetness and reduce bitter and metallic aftertaste. Such occurrence can be supported, because according to Cândido & Campos (1996) sucralose has a sweetness that is quickly perceived, without giving a bitter or metallic aftertaste. In addition, the FOS-fructooligosaccharides and polydextrose may have provided the occurrence of the Maillard reaction in jams without the addition of sucrose (Pfizer, 2000), improving flavor and masking the aftertaste due to production of jam flavors characteristic of conventional (with the addition of sucrose), which may explain the good and similar acceptance of all jams.

It’s important to emphasize that although, in the time-intensity analysis there were differences in the perception of bitterness with the jam with sweeteners in relation to jam with sucrose, this different behavior did not affect the acceptance.

Given these results, choosing the best sweetener or the best sweetener blends for the mixed fruits jam shall be subject to cost and sweetening power. We suggest the use of the combination sucralose/acesulfame-K (3:1) in the preparation of mixed fruit jam marolo/soursop/sweet passion fruit, since, according to Brazilian suppliers, among the studied sweeteners, acesulfame-K has lower cost and, moreover, the combination of sucralose/acesulfame-K (3:1) showed a high power sweetness, requiring a small amount of this blend to achieve the desired sweetness.

4. CONCLUSION

Using the magnitude estimation method it was found that to promote the ideal sweetness (40% sucrose) of mixed fruit jam it is necessary to use a concentration of 0.0387% of sucralose, 0.0472% of sucralose/acesulfame-K (3:1), 0.0464% of sucralose/steviol glycoside (2:1), 0.1407% of sucralose/thaumatin (1:0.6) and 0.0407% of sucralose/acesulfame-K/neotame (5:3:0.1). For time intensity analyze the sweeteners presented a sweetness profile similar to sucrose and bitterness profile different from sucrose, but similar between them. In relation to sensory acceptance significant difference was not observed between the sugar-free jam and the traditional jam. In relation to sensory acceptance, it was found that both the traditional mixed fruit (with sucrose) jam and the sugar-free jam showed good and similar acceptance in respect to all attributes. Of all the sweeteners studied, it is suggested to use a combination of sucralose/acesulfame-K (3:1) in mixed fruit (Marolo, Soursop, Sweet passion fruit) jam, the value due to a better cost/benefit.

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