Universidade Estadual de Campinas
Faculdade de Engenharia de Alimentos
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BEBIDA DE MARACUJÁ NATURAL "LIGHT" PRONTA PARA BEBER: FORMULAÇÃO, PRODUÇÃO E ESTUDO DE VIDA-DE-PRATELEIRA

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Tese apresentada à Faculdade de Engenharia de Alimentos da Universidade Estadual de Campinas para obtenção do título de Doutora em Alimentos e Nutrição.

Campinas
2006

FICHA CATALOGRÁFICA ELABORADA PELA
BIBLIOTECA DA FEA – UNICAMP

M332b

Marchi, Renata De
Bebida de maracujá natural light pronta para beber: formulação, produção e estudo de vida-de-prateleira / Renata De Marchi. -- Campinas, SP: [s.n.], 2006.

Orientador: Helena Maria André Bolini
Tese (doutorado) – Universidade Estadual de Campinas. Faculdade de Engenharia de Alimentos

1. Bebidas. 2. Maracujá. 3. Adoçantes. 4. Formulação. 5. Perfil sensorial. 6. Vida de prateleira. I. Bolini, Helena Maria André. II. Universidade Estadual de Campinas. Faculdade de Engenharia de Alimentos. III. Título.

(cars/fea)

Titulo em inglês: Passion fruit juice beverage with different sweetener systems: formulation, production and shelf life study
Palavras-chave em inglês (Keywords): Beverages, Passion fruit, Sweeteners, Formulation, Sensory profile, Shelf-life
Área de concentração: Consumo e Qualidade de Alimentos
Titulação: Doutor em Alimentos e Nutrição
Banca examinadora: Helena Maria André Bolini
Maria Aparecida Azevedo Pereira da Silva
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Magali Monteiro da Silva
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Aos meus pais, Carlos e Aparecida, meus irmãos, Ana Lúcia, Carlos Alberto, Denise e Dayse, e meu marido, Guilherme, que me proporcionaram amor, coragem e tranqüilidade do início ao fim deste trabalho.

AGRADECIMENTOS

A Deus, sobre todas as coisas;

À Professora Dra. Helena Maria André Bolini, pela orientação e amizade;

À Professora Dra. Mina R. McDaniel, por ter-me recebido na Universidade de Oregon, ampliado minha visão na área da Análise Sensorial e encorajado a ganhar autoconfiança;

Ao Professor Dr. Ulrich Orth, por ter-me introduzido à área de Marketing e enriquecido o estudo comparativo dos mercados brasileiro e americano, além da amizade e valorização do meu trabalho;

À Professora Dra. Magali Monteiro, pelo apoio constante e sugestões indispensáveis;

À Professora Dra. Flávia Maria Netto, pelo fundamental apoio no pedido da bolsa sanduíche;

Aos Professores membros da banca examinadora, pelas correções e pertinentes sugestões;

Ao meu irmão Carlos Alberto De Marchi e à amiga Dra. Natália Janzantti, por terem conduzido o processamento das bebidas na planta piloto Tetra Pak® ao mesmo tempo em que eu conduzia outra etapa do trabalho nos Estados Unidos;

À Cindy Lederer, por sua valiosa ajuda durante o preparo dos testes sensoriais realizados no Laboratório da OSU, e por sua amizade;

À Dra. Nilda D. M. Villanueva, pela preciosa colaboração nas análises estatísticas;

Aos colegas e técnicos do Laboratório de Análise Sensorial da UNICAMP, Lia e Nice, e à estagiária Ana Patrícia, que contribuíram para a coleta dos dados;

A todos os provadores da UNICAMP e da OSU, cuja participação foi fundamental para a realização deste trabalho;

Ao CNPq, pela bolsa de estudo concedida para a pesquisa realizada no Brasil e nos Estados Unidos;

À De Marchi Indústria e Comércio de Frutas Ltda, pela viabilização deste trabalho através da contribuição e suporte financeiro na obtenção, processamento e armazenamento da polpa de maracujá, assim como na produção das bebidas;

Às empresas Steviapharma, Givaudan e ISP do Brasil, pelos adoçantes, aroma e estabilizante fornecidos;

Ao meu pai, meu maior modelo de coragem, determinação, paciência e alegria;

À minha mãe, pelo amor incondicional e orações;

Aos meus irmãos Ana Lúcia, Carlos Alberto, Denise e Dayse, e seus filhos, por terem tornado esta jornada mais leve e prazerosa;

Ao meu marido Guilherme, pelo amor, compreensão, paciência e companheirismo em todos os momentos.

SUMÁRIO

Sensory profile and stability of a new ready-to-drink passion fruit juice beverage sweetened with different sweetener systems

Shelf-life study of a new ready-to-drink passion fruit juice beverage with different sweetener systems

RESUMO GERAL

O mercado de bebidas à base de frutas está em constante expansão. Os consumidores querem desfrutar de bebidas que vão além de apenas saciar a sede, e que ofereçam vantagens nutricionais e conveniência. Paralelamente à preferência dos consumidores por bebidas saudáveis, há uma crescente tendência ao consumo de bebidas de baixa caloria. Os consumidores estão cada vez melhor informados sobre a importância de uma dieta saudável, com menor ingestão de açúcar e gordura. Assim, o presente trabalho teve como objetivo formular, produzir, avaliar a aceitação em dois diferentes mercados consumidores – Brasil e Estados Unidos, determinar o perfil sensorial e estudar a vida-de-prateleira de bebidas de maracujá naturais, prontas para beber, adoçadas com sacarose (referência), aspartame, sucralose, e mistura aspartame/acesulfame-K (4:1) (*light*), respectivamente, durante 180 dias de estocagem. A bebida de maracujá referência foi formulada utilizando-se metodologia de superfície de resposta e testes de aceitação. O conteúdo de polpa de maracujá e a concentração de sacarose, selecionados para serem usados em tal bebida foram, respectivamente, 2,5°Brix (resultantes da mistura: polpa de maracujá e água) e 10%. Para a formulação das bebidas *light*, determinou-se a equivalência em doçura dos adoçantes aspartame, sucralose e mistura aspartame/acesulfame-K (4:1) em relação à sacarose na bebida referência utilizando-se dois métodos sensoriais: estimação de magnitude e diferença do controle. As concentrações de aspartame, sucralose, e mistura aspartame/acesulfame-K (4:1) utilizadas em tais bebidas foram: 0,043%, 0,016%, e 0,026%, respectivamente. As bebidas foram produzidas em planta piloto Tetra Pak®, pasteurizadas a 98°C/30 segundos, acondicionadas em embalagens tetrabrik de 125mL e estocadas durante 180 dias à temperatura ambiente e sob refrigeração. A fim de avaliar sua aceitação em dois mercados consumidores (Brasil e Estados Unidos), um questionário e um teste sensorial de consumidor foram conduzidos, simultaneamente, nos dois mercados. Os resultados indicaram que as propriedades sensoriais das bebidas poderiam ser padronizadas, isto é, a mesma formulação, com pequenos ajustes, poderia ser comercializada com sucesso tanto no Brasil como nos Estados Unidos. Tais ajustes dizem respeito aos níveis de doçura, acidez e sabor de maracujá, além de

uma melhora no sabor residual das bebidas *light*. Avaliações adicionais de uma versão carbonatada da bebida também poderiam ser conduzidas. O tamanho da embalagem deveria ser adaptado em cada país a fim de melhor atender às exigências de consumidores locais. O perfil e a estabilidade sensoriais das bebidas durante os 180 dias de estocagem foram determinados utilizando-se um painel treinado. O tipo de adoçante exerceu importante papel na percepção da cor, do gosto doce e dos gostos doce e ácido residuais. As bebidas adoçadas com sacarose e sucralose apresentaram alta estabilidade sensorial, enquanto aquelas adoçadas com aspartame e aspartame/acesulfame-K tiveram a intensidade de tais descritores preservada apenas quando estocadas sob refrigeração. A estocagem sob refrigeração mostrou-se crucial para a preservação das características de aroma e sabor de frutas frescas, independentemente do tipo de adoçante, durante um período mínimo de 120 dias de estocagem, após o qual, a intensidade de tais características começou a diminuir ao mesmo tempo em que a intensidade de características de aroma e sabor de frutas enlatadas, passadas, e de peixe começou a aumentar. A vida-de-prateleira das bebidas foi avaliada a partir de análises microbiológicas, físico-químicas e sensoriais de consumidor. As bebidas apresentaram boa estabilidade microbiológica durante todo o período de estocagem, em ambas temperaturas. Os parâmetros físico-químicos que sofreram as maiores alterações durante a estocagem, e que podem ter influenciado a qualidade sensorial das bebidas, foram os teores de açúcares totais e redutores e, principalmente, o conteúdo de ácido ascórbico. Os atributos hedônicos que determinaram o fim da vida-de-prateleira das bebidas foram: sabor, doçura, sabor residual, e aceitação global, de acordo com os quais foi possível atribuir um período de vida-de-prateleira mínimo de 180 dias para as bebidas adoçadas com sacarose e sucralose, e um período inferior a 60 dias para aquelas adoçadas com aspartame e mistura aspartame/acesulfame-K. Com base em tais resultados, os melhores adoçantes para uso neste tipo de bebida, de modo que esta seja aceita não apenas imediatamente após ser produzida como também durante a estocagem, foram identificados como sendo a sacarose para a versão tradicional e a sucralose para a versão *light*.

GENERAL ABSTRACT

The volume of fruit based beverages is growing daily. Consumers want to enjoy the use of beverages that not only quench thirst, but also offer innovation, health, convenience and some nutritional value. Parallel to the consumer preference for health beverages, there is an increasing trend for consumption of low calorie beverages. Consumers are increasingly better informed about diet and, as a result, they look for foods with reduced content of sugars and oils. Accordingly, the aim of this work was to formulate, produce, evaluate the acceptance on two different markets – Brazil and USA, determine the sensory profile and study the shelf-life of four ready-to-drink natural passion fruit juice beverages, sweetened with sucrose (standard beverage), aspartame, sucralose and aspartame/acesulfame-K blend (4:1) (light beverages), respectively, during 180 days of storage. Acceptability of the standard beverage was optimized using response surface methodology. The selected pulp content (total soluble solids content resultant from moisturizing pulp and water) and sucrose concentration (%) to be used in the standard beverage were respectively, 2.5°Brix and 10%. The concentrations of aspartame, sucralose, and aspartame/acesulfame-K blend (4:1) found as equi-sweet to 10% sucrose in the studied beverage were determined using two types of sensory method: magnitude estimation and difference-from-control, and were, respectively, 0.043%, 0.016% and 0.026%. The beverages were pasteurized at 98°C/30seconds in a Tetra Pak® pilot plant, packaged into 125mL tetrabrik units, and stored during 180 days at room temperature and under refrigeration. In order to gauge the likely acceptance of the passion fruit juice beverages on both the American and Brazilian markets, a consumer survey and a consumer sensory test were conducted on both markets, simultaneously. The results indicated that the sensory properties of the beverages could be standardized, that is, the same formula, with only minor adjustments, could be successfully commercialized both in Brazil and the USA. The adjustments have to do with sweetness, sourness and passion fruit flavor levels, besides improving the light beverages aftertaste. Further evaluations with a carbonated version of the beverage should also be carried out, and the package size of the beverages should be adapted in each country in order to better meet local market preferences. Descriptive sensory profile and stability of the beverages during 180 days of storage were determined using a trained panel. Sweetener type played a very important role in the perception of color, sweet taste, sweet aftertaste and sour aftertaste. The beverages sweetened with sucrose and sucralose were the most stable concerning those characteristics. The beverages containing aspartame, on the other hand, had the intensities of those descriptors preserved only if stored under refrigeration. Storing the beverages under refrigeration was crucial to preserve the fresh fruit aroma and flavor characteristics in all the beverages, independent of sweetener type, during at least 120 days of storage, period after which those characteristics started to decrease at the same time as the canned fruit aroma and flavor, overripe fruit aroma and fishy aroma and flavor started to increase. The shelf-life study of the beverages comprised microbiological, physical-chemical, and consumer sensory analyses. The beverages showed microbiological safety during the whole 6 months of storage both at room temperature and under refrigeration. The physical-chemical parameters that changed most during storage, and may have influenced the sensory quality of the beverages, were the total and reducing sugars contents and the ascorbic acid content. The liking attributes that determined the end of beverage shelf-life were flavor, sweetness, aftertaste and overall liking, according to which the sucrose and sucralose-sweetened beverages could be attributed a shelf-life period of at least 180 days of storage, while the aspartame and the aspartame/acesulfame-K-blend - sweetened beverages should be attributed a storage period inferior to 60 days. Accordingly, the best sweeteners to be used in this type of beverage in order to be well accepted not only immediately after production, but also during storage, were sucrose for the traditional version and sucralose for the light version.

INTRODUÇÃO GERAL

O constante crescimento do setor de bebidas, baseado tanto no aumento do volume de produção quanto no aumento do consumo *per capita*, tem despertado o interesse da indústria de bebidas para a produção de novos tipos de produtos. Estimuladas por este potencial, as indústrias têm buscado novos nichos de mercado visando aumentar a oferta de novos produtos e sabores, além de melhorar sua qualidade e popularizar seu consumo (DE MARCHI, 2001).

O segmento industrial de bebidas pode ser caracterizado por dois grandes grupos: o das bebidas alcoólicas e o das bebidas não alcoólicas, sendo este último responsável pelo recente desenvolvimento de uma grande variedade de novos produtos.

O mercado brasileiro de bebidas não alcoólicas está em constante expansão. De 1996 até 2000, as vendas cresceram 35% em volume. Dentro dessa categoria, o destaque fica para as bebidas não carbonatadas, que vêm atraindo consumidores de refrigerantes nos últimos anos. Esse comportamento pode ser explicado pela tendência ao consumo de bebidas consideradas saudáveis, como bebidas à base de frutas, bebidas à base de extratos vegetais – como a soja, chás, águas e isotônicos (REINOLD, 2000). Beneficiado por essa tendência, o segmento de bebidas à base de frutas prontas para beber vem apresentando crescimento de 30% ao ano (LÓPEZ, 2005). No entanto, o consumo *per capita* destas bebidas, de cerca de 2 litros por ano, ainda é baixo se comparado ao dos países desenvolvidos (DATAMARK, 2005).

As bebidas não gaseificadas à base de frutas são caracterizadas como produtos que contém polpa ou suco de frutas na concentração de 1,5-70%, água e açúcares, podendo tanto ser formuladas com conteúdo energético maior que o dos sucos de frutas como com baixo teor calórico (GIESE, 1992).

Dentre os vários sucos de frutas tropicais consumidos nos mercados interno e externo, destaca-se o suco de maracujá devido ao seu sabor exótico e intenso, forte aroma e alta acidez (MELETTI & MAIA, 1999; SOUZA et al., 2002; GARRUTI, 1989; DE MARCHI et al., 2003).

Paralelamente ao aumento do consumo de bebidas consideradas saudáveis, verifica-se, atualmente, uma tendência cada vez maior para o consumo de bebidas de baixa caloria, que atendam a exigências dietéticas. A principal razão para a substituição da sacarose advém da constante preocupação da população com a saúde em função dos riscos causados pela alta ingestão dessa substância, tais como os representados pela obesidade, diabetes e cárie dental (NABORS & GELARDI, 1986). Além disso, os consumidores estão cada vez melhor informados sobre a importância de uma dieta saudável, com menor ingestão de açúcar e gordura.

Assim como os demais tipos de alimentos *diet* e *light*, embora as bebidas *light* representem uma parcela pequena dos alimentos vendidos no Brasil (entre 3 e 5% do total), o setor cresce rápido. De acordo com os dados da Associação Brasileira da Indústria de Alimentos Dietéticos e para Fins Especiais (ABIAD), nos últimos dez anos, o crescimento do setor foi de 870%. A cada ano, mais de 180 novos itens *diet* e *light* são lançados no mercado. No entanto, o mercado brasileiro ainda é pequeno se comparado aos dos países desenvolvidos, ou seja, é um mercado com um enorme potencial de crescimento (GERMANN, 2004).

Os adoçantes permitidos para uso em alimentos e bebidas dietéticas são vários, cada um com características específicas de intensidade e persistência de gosto doce e presença ou não de gosto residual. Tais substâncias apresentam, portanto, perfis sensoriais diferentes dependendo do meio ao qual são adicionadas (CARDELLO et al., 2000). Logo, é importante ressaltar que o desenvolvimento de bebidas de baixa caloria não se dá apenas pela substituição do açúcar por adoçantes não calóricos; os produtos devem ser reformulados. Os vários tipos de edulcorantes interagem diferentemente com outros ingredientes, podendo modificar as características de sabor da bebida (NABORS, 2002).

Apesar da importância econômica e tecnológica que as bebidas não-alcoólicas à base de frutas e de baixa caloria representam atualmente, existe pouca informação na literatura especializada sobre tal produto. Nesse sentido, este trabalho teve como objetivo formular, produzir, avaliar a aceitação em dois diferentes mercados consumidores - Brasil e EUA, e estudar a vida-de-prateleira de bebidas de maracujá naturais *light* e referência (adoçada com sacarose), prontas para beber.

Os objetivos específicos do trabalho foram:

- Otimizar a aceitação de uma bebida de maracujá natural utilizando-se diferentes concentrações de polpa de maracujá e sacarose;
- Determinar a equivalência em doçura dos adoçantes aspartame, sucralose e mistura aspartame/acesulfame (4:1) em relação à sacarose na bebida de maracujá em estudo;
- Avaliar a aceitação das bebidas de maracujá *light* e referência, recém-produzidas, em dois diferentes mercados consumidores: Brasil e EUA;
- Determinar o perfil sensorial das bebidas de maracujá recém-produzidas e ao longo da vida-de-prateleira;
- Realizar o estudo da vida-de-prateleira das bebidas de maracujá *light* e referência, estocadas à temperatura ambiente (20-25°C) e sob refrigeração (2-5°C) durante seis meses, utilizando-se avaliações microbiológicas, físico-químicas e sensoriais.

REVISÃO BIBLIOGRÁFICA

ASPECTOS DE MERCADO, FORMULAÇÃO, PROPRIEDADES SENSORIAIS E VIDA-DE-PRATELEIRA DE BEBIDAS À BASE DE FRUTAS PRONTAS PARA BEBER

1. O mercado de bebidas à base de frutas

O crescimento constante do setor de bebidas, baseado tanto no aumento do volume de produção quanto no aumento do consumo *per capita*, tem despertado o interesse da indústria de bebidas para a produção de novos tipos de produtos. De acordo com o instituto de pesquisa ACNielsen, três das cinco categorias de produtos alimentícios que mais cresceram no mercado mundial em 2001 foram as bebidas (BEVERAGES, 2002).

O segmento industrial de bebidas pode ser caracterizado por dois grandes grupos, o das bebidas alcoólicas e o das bebidas não alcoólicas, sendo este último, responsável pelo recente desenvolvimento de uma grande variedade de novos produtos.

A categoria das bebidas não alcoólicas tem, atualmente, seu mercado dividido entre água mineral, leite, sucos de frutas, *soft drinks* e chás e cafés gelados, prontos para beber. Dentre os *soft drinks*, as bebidas gaseificadas (refrigerantes) representam a parcela mais significativa do mercado, que ainda encontra-se dividido entre as bebidas não gaseificadas à base de frutas e os *sports drinks* (A NEW, 1998).

O mercado brasileiro de bebidas não alcoólicas está em constante expansão. De 1996 até 2000, as vendas cresceram 35% em volume. Dentro dessa categoria, o destaque fica para as bebidas não carbonatadas, que vêm atraindo consumidores de refrigerantes nos últimos anos. Esse comportamento pode ser explicado pela tendência ao consumo de bebidas consideradas saudáveis, como bebidas à base de frutas, chás, águas e isotônicos (REINOLD, 2000). Essa tendência é decorrente da crescente preocupação da população com o bem-estar e a saúde: os consumidores querem desfrutar de bebidas que vão além de apenas saciar a sede.

O segmento de bebidas à base de frutas prontas para beber, beneficiado pela tendência ao consumo de bebidas saudáveis, vem apresentando crescimento de cerca de 30% ao ano. No Brasil, desde 1998, este segmento não parou de crescer, tendo o consumo destas bebidas passado de 65,7 milhões de litros para 285,7 milhões de litros em 2004 (LÓPEZ, 2005). No entanto, apesar das bebidas à base de frutas prontas para beber estarem presentes em mais de 11 milhões de lares brasileiros, seu consumo *per capita*, de cerca de 2 litros por ano, ainda é baixo se comparado ao dos países desenvolvidos. Na Alemanha, por exemplo, esse número alcança 47 litros; nos Estados Unidos é de 30 litros; na Espanha, 16 litros; e no México, 9 litros. Para aumentar o consumo, as indústrias têm pela frente o obstáculo da renda dos brasileiros, já que as bebidas à base de frutas prontas para beber são itens de maior valor agregado e, conseqüentemente, competem com as versões mais baratas dos refrigerantes, das bebidas em pó e das bebidas de frutas preparadas pelos próprios consumidores com frutas *in natura* (DATAMARK, 2005).

Um dos fatores que contribuiu significativamente para o aumento do consumo de bebidas à base de frutas foi a criação da embalagem asséptica. Os consumidores atuais, principalmente o público jovem, buscam praticidade, além de desejarem consumir uma bebida natural e saudável. As embalagens longa vida atendem diretamente a esta necessidade: elas conservam a bebida por longos períodos sem adição de conservadores artificiais, mantém as propriedades nutricionais e de sabor das frutas, além de oferecerem a praticidade do conceito “pronto para beber" (LÓPEZ, 2005).

Tradicionalmente, as bebidas não gaseificadas à base de frutas são obtidas pela dissolução em água potável, do suco de fruta, polpa ou extrato vegetal de sua origem, adicionado de açúcares (ANVISA, 2002).

Os açúcares são importantes componentes de muitas bebidas, contribuindo para o aumento de densidade, viscosidade e conteúdo energético, além da redução da atividade de água no produto, proporcionando-lhe proteção antimicrobiana (GIESE, 1992). Verifica-se, no entanto, uma tendência cada vez maior para o consumo de bebidas de baixa caloria, que atendam a exigências dietéticas (FOOTE, 2002). A principal razão para a substituição da sacarose advém da constante preocupação da população com a saúde em função dos riscos causados pela ingestão dessa substância, tais como os representados pela obesidade, diabetes e cárie dental (NABORS & GELARDI, 1986). Além disso, os consumidores estão cada vez melhor informados sobre a importância de uma dieta saudável, com menor ingestão de açúcar e gordura.

Um dos segmentos com maior potencial de crescimento dentro da área de bebidas é, sem dúvida, o de produtos *light*. De acordo com o instituto de pesquisas ACNielsen, a participação dos refrigerantes *diet*/*light* nas vendas do setor foi de 8,3% em 2002, enquanto em 2001 era de 5% (PARRA, 2003). Embora as bebidas *light* representem uma parcela pequena dos alimentos vendidos no Brasil (entre 3 e 5% do total), o setor cresce rápido. De acordo com os dados da Associação Brasileira da Indústria de Alimentos Dietéticos e para Fins Especiais (ABIAD), nos últimos dez anos, o crescimento do setor foi de 870%, e hoje, 35% dos lares brasileiros consomem algum tipo de produto *diet* ou *light*. A cada ano, mais de 180 novos itens *diet* e *light* são lançados no mercado (GERMANN, 2004). Ou seja, o segmento *diet/light* vem deixando de ser nicho e ganhando economia de escala (PARRA, 2003). No entanto, o mercado brasileiro ainda é pequeno se comparado aos dos países desenvolvidos, ou seja, é um mercado com um enorme potencial de crescimento (GERMANN, 2004). Vale lembrar que *light* são os produtos que apresentam no mínimo 25% menos calorias, gorduras ou outro nutriente em relação a um produto similar, sendo indicados para quem busca uma alimentação mais leve. Já os produtos *diet* são os que não contêm gordura, açúcar, sódio ou proteína e são próprios para quem deve abolir esses ingredientes da dieta (ABIAD, 2002).

2. Maracujá

O maracujá é uma planta trepadeira de grande porte, vigorosa, com produção anual e crescimento rápido. Pertence à família Passifloraceae e seu nome científico é *Passiflora edulis* Sims. Tem sua origem nas regiões tropicais, provavelmente no Brasil, onde existem quase 200 espécies nativas, das quais 60 são comestíveis (MELETTI & MAIA, 1999). No momento, apenas duas espécies de maracujá são aproveitadas comercialmente no Brasil: o maracujá amarelo ou azedo (*Passiflora edulis* f. *flavicarpa*), e o maracujá doce (*Passiflora alata*). O maracujá doce é consumido na sua totalidade *in natura*, e caracteriza-se, portanto, como fruta de mesa. O maracujá amarelo representa cerca de 97% da área plantada e do volume comercializado no país. Estima-se que mais de 60% da produção brasileira desta fruta são destinados ao consumo *in natura*, e o restante, às indústrias de processamento, sendo o suco o principal produto. O Brasil é o maior produtor e também o maior consumidor mundial de maracujá (FRACARO, 2004).

Atualmente, as regiões responsáveis pelos maiores volumes de produção de maracujá amarelo são o Nordeste e o Sudeste do Brasil, com cerca de 80% da produção nacional. Na região Nordeste, a Bahia se destaca como principal produtor regional, com 48% da produção, vindo, em seguida, o Estado do Sergipe, com 26% da produção. Na região Sudeste, três Estados merecem destaque: São Paulo, Minas Gerais e Rio de Janeiro (FRACARO, 2004).

O setor agro-industrial de produção de sucos de maracujá subdivide-se em dois segmentos principais: polpa e suco (integral e concentrado). A produção de suco concentrado (50°Brix) é privilégio de poucas unidades industriais, pois o investimento em equipamentos é elevado. Assim, destina-se basicamente ao mercado internacional, cujos principais compradores têm sido os Países Baixos, seguidos dos Estados Unidos e da Alemanha (FRACARO, 2004). ROSSI et al. (2001), relataram que o suco de maracujá é responsável por 22,2% das 227,8 mil toneladas de sucos tropicais, polpas e água de coco produzidas no Brasil.

As principais características dos frutos de maracujá são o seu sabor intenso e sua alta acidez, constituindo-se, portanto, uma base interessante para a fabricação de bebidas e sucos de frutas. Os principais componentes dos sólidos solúveis totais do suco de maracujá amarelo são os carboidratos (32,4% de sacarose, 38,1% de glicose, e 29,4% de frutose). A acidez do maracujá é conferida principalmente pelo ácido cítrico (83%), seguido pelo ácido málico (16%) e, em menores proporções, pelos ácidos láctico (0,87%), malônico (0,20%) e succínico (traços) (CHAN, 1993). As espécies principais (maracujá-amarelo e maracujá-roxo) são, ainda, boas fontes de pró-vitamina A e niacina (TEIXEIRA, 1994).

3. Adoçantes

O gosto doce pode ser conferido a um alimento utilizando-se carboidratos (usualmente sacarose), edulcorantes ou uma combinação de carboidratos e edulcorantes.

Dentre os ingredientes adoçantes, a sacarose é largamente considerada como padrão para o gosto doce. É o carboidrato mais empregado na indústria de alimentos e bebidas devido às suas características nutricionais, químicas e físicas. Sua importância decorre de fatores como: aceitabilidade, palatabilidade, alta disponibilidade e baixo custo de produção. Essa substância foi adotada como padrão de doçura relativa (poder edulcorante igual a 1) e de perfil de sabor (MORI, 1992). Sua substituição por outros tipos de adoçantes pode ser crítica para o sucesso do produto, particularmente em *soft drinks*, cujas características de doçura são extremamente importantes para sua aceitação.

Dentre os vários substitutos de açúcar utilizados na indústria de bebidas, destacam-se o aspartame, o acesulfame-K e a sucralose.

O aspartame (NutraSweet®) é produzido a partir da combinação química de dois aminoácidos: ácido aspártico e fenilalanina. É o adoçante que apresenta perfil de doçura mais próximo ao da sacarose, apesar de a doçura se desenvolver mais lentamente e persistir por mais tempo. Não deixa qualquer sabor residual amargo, químico ou metálico, freqüentemente associado aos demais edulcorantes (DA RÉ, 1990). Sua doçura é cerca de 200 vezes a da sacarose a 5%, e seu valor calórico igual a 0,4 Kcal/g. A doçura relativa dessa substância varia de acordo com o sistema de sabor, pH e temperatura (HOMLER et al., 1991). Estudos demonstram que o aspartame, além de conferir gosto doce, realça vários sabores, especialmente o de frutas (BALDWIN & KORSCHGEN, 1979; LARSON-POWERS & PANGBORN, 1978; MATYSIAK & NOBLE, 1991; WISEMAN & McDANIEL, 1991). Essa substância é altamente solúvel em água, porém insolúvel em óleos e gorduras. Em alimentos com baixo teor de umidade, apresenta alta estabilidade, porém em líquidos a determinadas condições de temperatura e pH (tais como 40°C e pH 6,0-8,0, ou 80°C e pH>2,5), pode hidrolisar-se, resultando em perda de doçura. Apesar disso, o aspartame suporta o tratamento térmico utilizado em produtos a base de leite e sucos, o processamento asséptico, e outros processamentos que empregam altas temperaturas e curto tempo como UHT (*Ultra High Temperature*) ou HTST (*High Temperature Short Time*) (NABORS, 2002; DA RÉ, 1990). Outra importante característica do aspartame é o efeito sinérgico promovido pela sua mistura com outros adoçantes (NABORS, 2002). A única restrição ao consumo de aspartame é feita às pessoas portadoras de fenilcetonúria, doença metabólica caracterizada pela deficiência da enzima fenilalanina hidroxilase, envolvida diretamente no metabolismo da fenilalanina. O acúmulo de fenilalanina no sangue causa anormalidades nas respostas cerebrais, podendo resultar em retardo mental, caso não haja o controle da ingestão deste aminoácido (HARPER, 1984).

O acesulfame-K (Sunett®) apresenta perfil de doçura semelhante ao da glicose: doçura rapidamente perceptível, com decréscimo lento, mas não persistente, porém de duração ligeiramente superior à da sacarose. No entanto, quando utilizado em soluções aquosas e em altas concentrações, um gosto amargo pode ser percebido. É cerca de 180 a 200 vezes mais doce que soluções de sacarose a 5% (LIPINSKI, 1991). O acesulfame-K dissolve-se rapidamente em água e é altamente estável na faixa de pH de alimentos e bebidas (3 a 7), além de não ser afetado por processos como pasteurização, esterilização e UHT (NABORS, 2002). Apesar de poder ser utilizado como único sistema adoçante, o acesulfame-K apresenta propriedades sinergísticas que o tornam bastante interessante quando associado a outros edulcorantes. Assim, apesar de apresentar custo substancialmente maior que o da sacarina, o acesulfame-K é utilizado em muitas formulações como seu substituto em mistura com o aspartame. Essa mistura melhora o sabor do produto, além de apresentar maior estabilidade que o aspartame (CÂNDIDO, 1996). Essa melhora qualitativa nas características sensoriais do produto adoçado com o acesulfame-K combinado a outros edulcorantes parece ser causada pela soma dos perfis tempo-intensidade de cada edulcorante (LIPINSKI, 1991). O nível máximo de sinergismo entre aspartame e acesulfame-k ocorre com uma mistura 50:50. No entanto, essa mistura pode desenvolver um gosto amargo à medida que o acesulfame-K passa a ser o adoçante predominante, enquanto uma mistura com 80% de aspartame e 20% de acesulfame-K fornece gosto doce bom e persistente (FOOD PROCESSING, 2002). O acesulfame-K apresenta, ainda, efeito sinérgico com adoçantes calóricos, como frutose, isomaltitol e sorbitol, mas muito pouco com a sacarina (CÂNDIDO, 1996). Um estudo realizado pela Nutrinova (PSZCZOLA, 2003) revelou que, após oito semanas de estocagem, bebidas carbonatadas sabor limão e adoçadas apenas com aspartame perderam doçura, enquanto as mesmas bebidas adoçadas com mistura acesulfame-K/aspartame (30:70) mantiveram doçura similar à da bebida controle (adoçada com sacarose). Tal resultado, de acordo com PSZCZOLA (2003), é devido ao fato de 50% do aspartame terem sido degradados durante a estocagem da bebida contendo apenas aspartame, ao passo que a mistura do aspartame com o acesulfame-K minimizou esse efeito, preservando a qualidade sensorial da bebida. Estudos toxicológicos realizados com o acesulfame-K demonstraram sua segurança para uso em alimentos e bebidas (LIPINSKI, 1991).

A sucralose (Splenda®), derivado clorado da sacarose, é cerca de 600 vezes mais doce que soluções de sacarose a 5%. Porém, a potência desse edulcorante depende de da concentração em que é usado: quando altos níveis de doçura são necessários, sua potência diminui, e quando baixos níveis de doçura são necessários, sua potência aumenta (PSZCZOLA, 2003). Como não é metabolizada pelo organismo, não fornece calorias. Estudos demonstram que a sucralose é um adoçante de alta qualidade e apresenta perfil de doçura semelhante ao da sacarose (MILLER, 1991). Sua excelente estabilidade química e biológica, tanto em soluções aquosas como em pós, permite seu uso em qualquer tipo de produto, podendo, portanto, ser utilizada em alimentos de baixo pH, pasteurizados, esterilizados ou assados. Sua segurança toxicológica foi comprovada após mais de 100 estudos (NABORS, 2002). Quando combinada a outros adoçantes, a sucralose pode oferecer vantagens de um gosto doce melhor ao produto final. Graças a suas propriedades sinergísticas, é possível a elaboração de um produto *light* que atenda às expectativas dos consumidores, os quais desejam produtos pouco calóricos, mas sem abrirem mão do sabor, que deve ser semelhante ao do produto adoçado com sacarose (PSZCZOLA, 2003).

4. Análise Sensorial

A Análise Sensorial é usada para evocar, medir, analisar e interpretar reações às características dos alimentos e materiais como são percebidas pelos sentidos da visão, olfato, gosto, tato e audição (ABNT, 1993).

Diferentes tipos de testes sensoriais podem ser efetuados de acordo com a informação que se deseja obter. Se o objetivo é descobrir o grau de aceitação ou a preferência de um produto em relação a outro, testes afetivos devem ser conduzidos com a população consumidora do produto. Se o objetivo é saber se existe diferença significativa entre duas amostras, testes discriminativos devem ser conduzidos. E, se o objetivo é descobrir se existem diferenças significativas entre duas ou mais amostras, quais são elas e qual a sua ordem de grandeza, testes descritivos devem ser conduzidos com uma equipe de provadores treinada (STONE & SIDEL, 1993).

4.1 Testes afetivos

Os testes afetivos, também chamados de testes de consumidor, são uma importante ferramenta, pois acessam diretamente a opinião (preferência e/ou aceitação) do consumidor potencial de um produto sobre suas características específicas. Os testes de consumidor estão sendo cada vez mais usados (MEILGAARD et al., 1999). Dentre suas principais aplicações, podem-se citar: manutenção da qualidade de um produto, otimização de produtos e/ou processos, desenvolvimento de novos produtos, acesso de mercado em potencial, revisão de categoria, suporte para propaganda (ASTM, 1979; MEILGAARD et al., 1999). Os testes de aceitação podem ser classificados de acordo com o local de aplicação, em teste de laboratório, teste de localização central, e teste de uso doméstico, sendo que todos apresentam vantagens e desvantagens que devem ser avaliadas antes da escolha (MEILGAARD et al., 1999; STONE & SIDEL, 1993). Os testes afetivos são classificados, ainda, em qualitativos e quantitativos. Os testes qualitativos são aqueles que medem respostas subjetivas de uma amostra de consumidores às propriedades sensoriais do produto através de uma entrevista ou discussão em grupo. Tais testes se classificam em: “focus groups”, “focus panels”, e “one-on-one interviews”. Os testes quantitativos são aqueles que utilizam um grande número de consumidores (mínimo de 50) para responder perguntas relativas à preferência ou valor hedônico de um produto de um modo geral ou com relação a determinados atributos, e também para responder perguntas relativas a atributos sensoriais específicos (respostas afetivas: preferência ou valor hedônico; respostas de intensidade; respostas de intensidade em relação à intensidade ideal). Tais testes são classificados em: teste de preferência e teste de aceitação (MEILGAARD et al., 1999).

Dentro da área de desenvolvimento de produtos, os testes afetivos têm, também, importante aplicação nos estudos “cross-cultural”. Dada a globalização do mercado de alimentos, torna-se cada vez mais necessário obter informações sobre os públicos alvos de produtos que são lançados em diversos países ou diversas regiões de um determinado país, ou seja, públicos alvos com diversos hábitos culturais. Tratar consumidores de diferentes nações ou culturas como se formassem um grupo homogêneo pode ser muito prejudicial para a imagem do novo produto, tanto do ponto de vista sensorial como de mercado (ORTH et al., 2005). Ao contrário, os profissionais responsáveis pelo desenvolvimento de novos produtos devem satisfazer as necessidades dos consumidores acessando as diferenças entre estes em termos de suas preferências sensoriais, além dos fatores de mercado. Nesse sentido, o uso de técnicas sensoriais de consumidor possibilita medir objetivamente os fatores que norteiam a preferência de consumidores com diferentes hábitos culturais (MURRAY, 2001).

4.2 Testes descritivos

Testes sensoriais descritivos são úteis em qualquer situação em que se deseja uma especificação detalhada dos atributos sensoriais de um ou vários produtos (GILLETTE, 1984). Os métodos descritivos são muito úteis para estudos de vida-de-prateleira, especialmente quando os provadores são bem treinados e consistentes ao longo do tempo. Tais métodos são, também, freqüentemente utilizados na área de desenvolvimento de produtos, para acessar a adequação de protótipos de produtos (LAWLESS & HEYMANN, 1998).

Nos últimos 40 anos, vários métodos de análise sensorial descritiva foram desenvolvidos, sendo que alguns ganharam popularidade e foram mantidos como métodos padrões (ASTM, 1992, 1996). Dentre tais métodos destacam-se: Perfil de Sabor, Análise Descritiva Quantitativa, Perfil de Textura, Spectrum, Análise Tempo-Intensidade e Perfil Livre (MEILGAARD et al., 1999).

4.2.1 Perfil de Sabor

O método descritivo Perfil de Sabor é uma técnica de consenso. Foi desenvolvido no final da década de 40 e início da década de 50 por Arthur D. Little, Inc. O vocabulário usado para descrever um produto é obtido quando se alcança uma concordância entre os membros da equipe de provadores (LAWLESS & HEYMANN, 1998). Este método envolve a análise das características de aroma, sabor e sabor residual, suas intensidades e ordem em que são percebidas, por um painel de 4 a 6 provadores treinados. Os provadores se sentam ao redor de uma mesa, avaliam as amostras individualmente e na forma em que são apresentadas aos consumidores, e registram os atributos e suas intensidades, ordem em que são percebidos, e sabor residual. O líder do painel conduz uma discussão geral para que se obtenham perfis sensoriais consensuais para cada amostra. A escala utilizada é a de intensidade de 7 pontos específica para o método (MEILGAARD et al., 1999).

4.2.2 Análise Descritiva Quantitativa

A Análise Descritiva Quantitativa (ADQ) foi desenvolvida pela Tragon Corp. na década de 70 para corrigir alguns dos problemas associados ao método Perfil de Sabor (STONE & SIDEL, 1993). Em contraste com o Perfil de Sabor, na Análise Descritiva Quantitativa os dados não são gerados a partir do consenso da equipe de provadores. Da mesma forma, os líderes de painel não são participantes ativos, e a escala utilizada é a linear não estruturada. O motivo do uso dessa escala é a redução da tendência dos provadores usarem apenas sua parte central, evitando seus extremos (MEILGAARD et al., 1999).

Durante as sessões de treinamento, 10 a 12 provadores são expostos a possíveis variações do produto em estudo. Após os provadores terem gerado os termos descritores do produto, é gerado um vocabulário padronizado para a avaliação das amostras, através de uma discussão consensual. Os provadores decidem, ainda, quais referências e definições verbais devem ser usadas para ancorar os termos descritores. No final da fase do treinamento, uma série de três avaliações é conduzida a fim de que o líder do painel avalie o desempenho de cada provador. Este procedimento pode também ser efetuado durante a etapa de avaliação das amostras. Diferentemente do procedimento usado no método Perfil de Sabor, na Análise Descritiva Quantitativa as amostras não são servidas exatamente na forma em que são apresentadas aos consumidores. As avaliações são conduzidas por cada provador em cabines individuais, protegidas de ruídos e odores (LAWLESS & HEYMANN, 1998).

Os resultados obtidos podem ser analisados estatisticamente usando-se análise de variância e técnicas estatísticas multivariadas. É necessário que os provadores apresentem repetibilidade e que suas respostas sejam consensuais. As repetições também permitem a análise de variância univariada de cada provador para todas as amostras, e esses resultados permitem ao líder do painel saber se os provadores apresentam poder de discriminação das amostras ou se precisam de mais sessões de treinamento. Apesar do extenso treinamento de provadores usado neste método, a maioria dos pesquisadores assume que os provadores utilizam diferentes partes da escala. Logo, os valores absolutos da escala não são importantes, mas sim as diferenças relativas entre os produtos (LAWLESS & HEYMANN, 1998).

A ADQ é um método prático, cujos resultados são facilmente analisados, o que, na verdade, pode ser considerado um dos problemas dessa técnica. É muito comum o uso das escalas para medidas absolutas de um atributo ao invés de servirem para medir as diferenças relativas entre as amostras. E a ADQ deve ser vista como medida de valores relativos e não absolutos. Logo, a ADQ deve ser usada quando se quer avaliar mais de uma amostra. Uma das vantagens da ADQ, citadas pelos seus usuários, é que, neste método, os provadores fazem julgamentos individuais, que não derivam de uma discussão consensual. Além disso, os resultados são facilmente analisados estatisticamente e graficamente representados. Por fim, a linguagem do painel não sofre influência do líder (LAWLESS & HEYMANN, 1998).

4.2.3 Perfil de Textura

Este método foi desenvolvido na década de 60, por pesquisadores da General Foods, os quais desejavam uma técnica que os permitisse acessar todas as características de textura de um produto. O método Perfil de Textura utiliza uma terminologia padronizada, a partir da qual são escolhidos os termos específicos a serem empregados para a descrição do produto (LAWLESS & HEYMANN, 1998). Tal terminologia é baseada em análises instrumentais (SZCZESNIAK, 1963; BRANDT et al., 1963). O método Perfil de Textura original usa uma versão expandida da escala usada no método Perfil de Sabor, de 13 pontos. No entanto, nos últimos anos, os painéis para Perfil de Textura têm sido treinados utilizando-se escalas de categoria, linear e de estimação de magnitude. Dependendo do tipo de escala utilizada e do tipo de tratamento dos resultados, estes podem derivar de uma discussão consensual, como no método Perfil de Sabor, ou de análise estatística dos dados (MEILGAARD et al., 1999).

4.2.4 Spectrum

O método Spectrum foi desenvolvido por Gail Civille, a partir de idéias inerentes ao método Perfil de Textura, quando trabalhava para a General Foods, na década de 70. Tal método é uma expansão das técnicas descritivas (LAWLESS & HEYMANN, 1998). A principal característica do Spectrum é que os provadores não geram um vocabulário específico para descrever as características do produto, mas usam uma lista padronizada de temos descritores (CIVILLE & LYON, 1996). Além disso, as escalas são padronizadas e ancoradas com muitos pontos de referência. Os provadores são treinados a usar a escala de modo idêntico e, por causa disso, os proponentes do método dizem que os resultados são valores absolutos. Isso significa que seria possível delinear experimentos que incluem apenas uma amostra, e comparar os resultados obtidos a partir de tal amostra a resultados que derivam de outro estudo. Os proponentes do Spectrum dizem que os descritores usados em tal método são mais técnicos do que aqueles usados na ADQ. Uma vez que o painel é um grupo único, permitir aos provadores que gerem seus próprios termos descritores pode acarretar em má interpretação dos resultados quando estes forem aplicados a uma população generalizada. O treinamento dos provadores é bem mais extenso nesse método que no método ADQ, e o líder tem um papel mais direto (LAWLESS & HEYMANN, 1998).

Da mesma forma que na ADQ, os provadores são expostos a uma variedade de produtos pertencentes à categoria do produto em estudo e, da mesma forma que no Perfil de Textura, o líder fornece várias informações a respeito dos ingredientes do produto. Similarmente ao Perfil de Textura, listas de descritores chamadas “lexicons” são apresentadas aos provadores. A escala utilizada é, usualmente, numérica, de 15 pontos, e “absoluta”, ou seja, o valor de intensidade 5 na escala de doçura é idêntico ao valor de intensidade 5 na escala de salgado, por exemplo. Da mesma forma que no Perfil de Textura, as escalas são ancoradas com uma série de pontos de referência. Preferencialmente, 3 a 5 pontos de referência são recomendados, e servem para calibrar os provadores. Após o treinamento, os provadores devem usar a escala de modo idêntico. Em contraste com o método ADQ, no Spectrum, os provadores são treinados a usarem as escalas para cada termo descritor da mesma forma. Logo, os resultados devem ter valor absoluto (LAWLESS & HEYMANN, 1998).

As desvantagens do método estão associadas às dificuldades do desenvolvimento e manutenção do painel, além do alto consumo de tempo. Os provadores precisam entender o vocabulário escolhido para a descrição do produto. Além disso, devem ter conhecimentos básicos de fisiologia e psicologia da percepção sensorial. Por fim, devem estar em fina sintonia uns com os outros, a fim de garantir que todos usem a escala da mesma forma. No entanto, nem sempre esse objetivo é alcançado. Na prática, diferenças individuais entre os provadores, como diferente sensibilidade a certos ingredientes, podem causar discordância entre os mesmos no uso da escala (LAWLESS & HEYMANN, 1998).

Os dados obtidos são analisados da mesma forma que os dados da ADQ (LAWLESS & HEYMANN, 1998).

4.2.5 Análise Descritiva Genérica

Os métodos Análise Descritiva Quantitativa e Spectrum têm sido adaptados de diversas formas. No entanto, é claro que qualquer adaptação invalida o uso dos nomes ADQ e Spectrum (LAWLESS & HEYMANN, 1998). Pesquisadores têm adaptado o uso destas duas metodologias para a análise de vários alimentos (MCDANIEL & SAWYER, 1981; GUINARD & CLIFF, 1987; HEYMANN & NOBLE, 1987; MCDANIEL et al., 1987; NOBLE & SHANNON, 1987; TUORILA, 1986; THEERAKULKAIT et al., 1995).

Os três passos básicos para se efetuar uma Análise Descritiva são: treinamento de provadores, avaliação dos provadores (discriminação, repetibilidade, e concordância com a equipe), avaliação das amostras (LAWLESS & HEYMANN, 1998).

Como já detalhado nos métodos ADQ e Spectrum, há duas formas de treinar os provadores. A primeira é fornecer aos mesmos uma ampla variedade de produtos pertencentes à categoria do produto em estudo. Os provadores são, então, solicitados a fornecer os termos descritores e materiais de referência, normalmente através de uma discussão consensual. LAWLESS & HEYMANN (1998) chamam este método de “concensus training” (treinamento consensual). A segunda consiste em fornecer aos provadores uma ampla variedade de produtos pertencentes à categoria do produto em estudo, assim como uma lista de possíveis termos descritores e referências. LAWLESS & HEYMANN (1998) chamam este método de “ballot training” (treinamento com ficha). De acordo com estes pesquisadores, ambos os métodos têm aplicação individual, porém, freqüentemente, usa-se uma combinação dos dois métodos. No método combinado, os provadores geram seus termos descritores, aos quais são adicionados outros sugeridos pelo líder ou a partir da lista de descritores. LAWLESS & HEYMANN (1998) reportaram utilizar o método combinado quando efetuam trabalhos para empresas de alimentos, uma vez que estas, freqüentemente, já têm alguns termos que julgam importantes e que, portanto, devem fazer parte da lista de descritores (LAWLESS & HEYMANN, 1998).

Uma vez terminada a fase de treinamento, o líder do painel inicia a fase de determinação da reprodutibilidade dos provadores. Algumas das amostras a serem estudadas são servidas aos provadores em triplicata. Os provadores são informados de que a fase de avaliação das amostras se inicia. Os dados são analisados, sendo verificada a significância dos efeitos que envolvem interações com provadores. Em um painel bem treinado, esses efeitos não são significativamente diferentes entre os provadores. Se há um número significativo de provadores associados aos efeitos de interação, é possível determinar quais provadores devem continuar o treinamento (LAWLESS & HEYMANN, 1998).

Finalmente, na fase de avaliação das amostras, os provadores são solicitados a avaliar as amostras em triplicata. Em condições ideais, todas as amostras são servidas numa única sessão, com diferentes sessões para as replicatas. Se isso não é possível, um delineamento experimental adequado como, por exemplo, o de blocos balanceados incompletos, deve ser seguido. Os resultados são normalmente analisados por análise de variância, podendo algumas análises multivariadas adicionar informações importantes (LAWLESS & HEYMANN, 1998).

4.2.6 Análise Tempo-Intensidade

Todos os métodos sensoriais descritivos discutidos até agora fornecem informações sobre as características sensoriais de uma amostra no momento em que o provador a está avaliando. No entanto, são freqüentes os casos em que determinados gostos e sabores variam à medida que o produto é avaliado. Um método sensorial indicado para estes casos é o tempo-intensidade, pois provê informações sensoriais temporais sobre o estímulo percebido (CARDELLO et al., 1999; ARAZI, 2001).

O primeiro estudo realizado para avaliar os parâmetros tempo-intensidade de diferentes substâncias em sistemas alimentares foi realizado por NEILSON (1957), o qual demonstrou que um mesmo gosto ou aroma é percebido em diferentes intensidades ao longo de um determinado período (CARDELLO et al., 1999). Desde então, pesquisadores têm desenvolvido procedimentos de análise tempo-intensidade automatizados e computadorizados, empregando diferentes instrumentos e representações visuais de escalas (DUIZER et al., 1995). No Brasil foi desenvolvido o programa SCDTI (Sistema de Coleta de Dados Tempo-Intensidade) no Laboratório de Análise Sensorial da Faculdade de Engenharia de Alimentos – UNICAMP (CARDELLO et al., 1996a).

Metodologias de avaliação tempo-intensidade têm sido utilizadas em uma grande variedade de sistemas e produtos comerciais, como: doçura e amargor de extrato de folhas de estévia (CARDELLO et al., 1999); doçura e amargor de aspartame (CARDELLO et al., 1996b); análise da potência edulcorante de aspartame e taumatina (CALVINO et al., 2000); efeito da orientação da escala nas respostas tempo-intensidade (DUIZER et al., 1995); efeito da concentração, temperatura e viscosidade nas características tempo-intensidade de doçura de glicose, frutose e sacarose em água (PORTMANN et al., 1992), entre outros.

4.2.7 Perfil Livre

Na década de 80, pesquisadores britânicos criaram uma nova técnica descritiva conhecida como Perfil Livre (LAWLESS & HEYMANN, 1998). Tal método, apesar de compartilhar de muitas características dos métodos ADQ, Spectrum, Perfil de Sabor e Perfil de Textura, apresenta duas diferenças marcantes. Em primeiro lugar, ao invés de treinar os provadores para o uso de um mesmo vocabulário de termos descritores, o Perfil Livre requer que cada provador gere seu próprio vocabulário para descrever o produto. Em segundo, o tratamento estatístico dos dados é feito usando-se Análise Procrustes Generalizada, que fornece uma figura consensual dos dados de cada provador num espaço bi ou tridimensional (LAWLESS & HEYMANN, 1998). A principal vantagem desta técnica é o fato de que requer muito menos tempo do que os outros métodos descritivos, dado que os provadores não precisam de treinamento. A segunda vantagem é que os provadores, por não serem treinados, podem ser tratados como "consumidores" do produto. No entanto, questões relacionadas à habilidade do analista sensorial ao "interpretar" os termos descritores devem ser acessadas (MEILGAARD et al., 1999).

5. Estudo de vida-de-prateleira

A vida-de-prateleira de um alimento é o período de tempo necessário para que um produto estocado sob condições específicas atinja seu ponto final, ou seja, o produto não mais atende a determinados critérios definidos por testes como de aceitação, descritivos, de discriminação, analíticos, microbiológicos e/ou físico-químicos (ASTM, 1993).

O critério utilizado para a determinação do fim da vida-de-prateleira de um produto é estabelecido a partir de requerimentos legais, critérios sensoriais, requerimentos de mercado e distribuição, e custos. Do ponto de vista da indústria de alimentos, a vida-de-prateleira está baseada na extensão da perda de qualidade de um produto antes de ser consumido. Para o consumidor, o final da vida-de-prateleira de um produto é o período de tempo em que este deixa de ser aceito (FU & LABUZA, 1993).

A determinação de forma acurada da vida-de-prateleira de um alimento é um importante objeto de pesquisa na área da Ciência dos Alimentos, não apenas para as indústrias produtoras, como também para os órgãos governamentais e para os consumidores. A perda prematura da qualidade de um produto pode levar à perda da credibilidade por parte do consumidor e ao menor lucro por parte da indústria. Testes de determinação de vida-de-prateleira também possibilitam à empresa minimizar custos em formulações e acondicionamento de produtos. Da mesma forma, informações como "melhor consumir em até x dias" precisam ser baseadas em algum tipo de estudo de vida-de-prateleira (FU & LABUZA, 1993).

Os métodos utilizados por diferentes indústrias alimentícias para a determinação da vida-de-prateleira de seus produtos podem ser extremamente sofisticados e até utilizar sistemas computadorizados de monitoramento da relação tempo-temperatura a fim de se determinar o motivo da perda de qualidade do produto (LABUZA & SCHMIDL, 1988).

Medidas objetivas para se determinar o fim da vida-de-prateleira de um produto geralmente envolvem parâmetros estreitamente relacionados com a segurança microbiológica e nutricional do produto. Tais parâmetros são ditados às indústrias de alimentos por regulamentações do Estado. No entanto, órgãos fiscalizadores não monitoram as alterações sensoriais nos produtos alimentícios, a não ser que tais alterações tornem o alimento inapropriado para venda por conta do surgimento de odores e sabores desagradáveis ou toxicidade potencial (LABUZA & SCHMIDL, 1988). Do ponto de vista sensorial, o fim da vida-de-prateleira de um produto é efetivamente determinado pelo consumidor a partir de sua intenção de compra repetida negativa, caso as propriedades sensoriais do produto, percebidas no primeiro contato o mesmo, não tenham atendido às suas expectativas (FU & LABUZA, 1993).

Várias alterações podem ocorrer nos alimentos durante o processamento e a estocagem, o que pode desencadear uma série de reações que podem levar à sua degradação e conseqüente rejeição pelos consumidores (SINGH, 1994). Do ponto de vista nutricional, a vitamina C é o composto mais afetado em sucos de frutas (SANTOS, 2004).

PRATI et al. (2004) estudaram a vida-de-prateleira de uma bebida elaborada pela mistura de garapa parcialmente clarificada e estabilizada, e suco natural de maracujá durante 30 dias. Os resultados indicaram perda significativa de 19,7% de vitamina C durante o armazenamento.

EDWAIDAH (1988) efetuou estudos com diferentes sucos de frutas enlatados e verificou perdas significativas de vitamina C nos sucos de laranja e de tomate estocados durante 12 meses (37,7% e 34,0%, respectivamente).

A qualidade sensorial também é afetada durante o armazenamento de sucos processados. MODESTA et al. (2003) avaliaram o perfil sensorial de suco de maracujá amarelo pasteurizado armazenado durante 90 dias a 32°C. Mudanças sensoriais significativas foram observadas após os 90 dias de estocagem: os aromas e sabores “artificial” e “cozido” aumentaram, enquanto o “sabor de maracujá” diminuiu.

DE MARCHI et al. (2003) estudaram a vida-de-prateleira de um isotônico de maracujá natural estocado à temperatura ambiente e sob refrigeração durante 66 e 141 dias, respectivamente. As características físico-químicas (teor de sólidos solúveis totais, pH, acidez total, e teor de vitamina C) e microbiológicas (contagem total de bactérias aeróbias mesófilas e de bolores e leveduras) não foram determinantes do fim da vida útil da bebida. Os resultados da avaliação sensorial, por outro lado, revelaram que, com base na aceitação da cor, aroma, sabor e impressão global da bebida, um período de 15 a 30 dias deveria ser atribuído à bebida estocada a temperatura ambiente, e um período mínimo de 141 dias àquela estocada sob refrigeração.

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Formulating a new passion fruit juice beverage with different sweetener systems

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This paper was submitted to Food Quality and Preference on Oct 10th, 2004.

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Abstract

The aim of this work was to optimize the acceptability of a natural passion fruit juice beverage using different levels of passion fruit pulp and sucrose, and to determine the equi-sweet concentrations of aspartame, sucralose, and aspartame/acesulfame-K blend (4:1). A 2^2 central composite design was used to optimize the acceptability of the sucrose-sweetened beverage, which was assessed using a 9-point structured hedonic scale. Acceptability data were fitted to a second order model equation provided in the design. The selected pulp content and sucrose concentration were, respectively, 2.5°Brix and 10% (g/mL). Measurements of sweetness equivalence were accomplished using two types of sensory methods: magnitude estimation and difference-from-control. The concentrations of aspartame, sucralose, and aspartame/acesulfame-K blend (4:1) found as equi-sweet to 10% sucrose in the studied passion fruit juice beverage were, respectively, 0.043%, 0.016%, and 0.026%.

Keywords: passion fruit juice beverage, sweeteners, response surface methodology, magnitude estimation

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1. Introduction

The volume of fruit-based beverages is growing daily, in response to consumer preference for health beverages. Consumers want to enjoy the use of beverages that not only quench thirst, but also offer innovation, health, convenience and some nutritional value (LÓPEZ, 2004; BERTO, 2003; ABDULLAH & CHENG, 2001). According to the ACNielsen Institute, a 40% growth in the ready-to-drink fruit juices was registered in 2002, with an approximate consumption of 170 million liters. However, the Brazilian market still presents a low per capita consumption of ready-to-drink fruit juices: around 1-1.5 liters a year, a low value compared to other countries with a similar economy such as Mexico and Argentina, which registered a per capita consumption of more than 3 liters a year in 2003 (LÓPEZ, 2004).

The passion fruit is a very attractive and exotic tropical fruit, whose aroma and flavor are much appreciated by Brazilian consumers (DE MARCHI et al., 2003; MELETTI & MAIA, 1999; SOUZA et al., 2002; GARRUTI, 1989). The growth in production and commercialization of the yellow passion fruit indicates that there is an increasing tendency for the consumption of both fruit and juice on both national and international markets (SOUZA et al., 2002). Taking advantage of the potential for growth shown by the health beverages category, and the availability and acceptability of the passion fruit on the Brazilian market, this work concentrated, initially, on optimizing the acceptability of a natural passion fruit juice beverage, using different levels of passion fruit pulp and sucrose. This step was performed using Response Surface Methodology, which is a popular and effective method to solve multivariate problems and optimize several responses in many types of experimentation, as it can simultaneously consider several factors at many different levels and corresponding interactions among these factors using a small number of observations (ALVAREZ et al., 1999).

Parallel to the consumer preference for health beverages, there is an increasing trend for the consumption of low calorie beverages; today's consumers are more and more concerned with health regarding the risks represented by sucrose intake such as obesity, diabetes and dental caries. More than this, consumers are increasingly better informed about diet, and as a result, seek more foods that offer fewer calories.

Although light beverages represent a small portion of the foods sold in Brazil (between 3% and 5% of the total), this segment is increasing. Since the 90's, when the first diet and light products began selling on the Brazilian market, nearly 750 new low calorie products have appeared, resulting in a 25% growth per year (ABIAD, 2002).

Individually, sweeteners vary in intensity, speed of flavor buildup and disappearance, and aftertaste. Relative sweetness is also influenced by temperature and acidity (GIESE, 1992). Furthermore, the various sweeteners interact differently with other food ingredients, so the flavoring acid/sweetness ratio may require modification, promoting changes in the product's flavor characteristics (NABORS, 2002). So, when replacing sucrose with high intense sweeteners it is essential to have a clear understanding of which sweetener and which concentration of sweetener best matches the sweetness intensity and characteristics of the equivalent product sweetened with sucrose.

The availability of aspartame to food manufacturers worldwide has been one of the major factors responsible for the growth of the light and "low-calorie" segments of the food industry (HOMLER et al., 1991). Studies have demonstrated that the taste profile of aspartame (Nutrasweet®) closely resembles that of sucrose. It enhances various food and beverage flavors, especially fruit flavors. One important limitation for the use of aspartame is that this sweetener may hydrolyze with excessive heat. However, studies have demonstrated that it can withstand the heat processing used for aseptic processing (NABORS, 2002).

Acesulfame-K (Sunett®) is characterized by a fast-acting impact sweetness, which can be considered similar to aspartame's sweetness. However, in acid foods and beverages with the same concentrations, a slightly greater sweetness may be perceived as compared to neutral solutions. Although acesulfame-K can be used as an intense sweetener by itself, its combination with aspartame has shown a strong synergistic taste enhancement. Moreover, studies have demonstrated that blending aspartame with acesulfame-K minimizes the degradation of aspartame during storage (PSZCZOLA, 2003; LIPINSKI, 1991; MEYER & RIHA, 2002). The maximum level of synergism between aspartame and acesulfame-K has been reported as being 1:1. However, this mixture can develop a bitter taste when the acesulfame-K becomes predominant, while a mixture of 80% of aspartame and

20% of acesulfame-K provides a persistently pleasing sweet taste (FOOD PROCESSING, 2002).

The sugar-derived sweetener – sucralose (Splenda®), offers zero calories because it cannot be metabolized by the human body. This ingredient has a clean, sugar-like taste with no aftertaste and remains stable at high temperatures and across a wide pH range (PSZCZOLA, 2003).

Sweetness equivalence to sucrose of many sweeteners, including aspartame, acesulfame-K and sucralose in water has been extensively profiled. But nothing has been found in the literature about substituting sugar by these high intense sweeteners in passion fruit beverages. It is important to emphasize that sweetness equivalency values for high intense sweeteners are highly system-dependent and may vary in different food products (REDLINGER & SETSER, 1987). So, it is essential to study the substitution of sucrose by high intense sweeteners every time a formulation is changed or a new product is developed. Accordingly, this study concentrated, in a second moment, on determining the sweetness equivalence of aspartame, sucralose and a blend of aspartame/acesulfame-K (4:1) to a 10% sucrose-sweetened passion fruit juice beverage.

2. Material and Methods

2.1 Acceptability optimization of a natural passion fruit juice beverage sweetened with sucrose

600 Kg of yellow passion fruits (*Passiflora edulis* f. *flavicarpa* Deg.) were obtained from Livramento do Brumado/Bahia, Brazil, in the 2003 Brazilian harvest. These fruits were transported to a processing plant at De Marchi Indústria e Comércio de Frutas Ltda, São Paulo, Brazil, where they were screened, inspected and washed. Once cleaned and selected, the fruits passed through two extractors. In the first extractor, pulp and seeds were separated from peel, which was discarded, and in the second extractor, seeds were screened out leaving only clean pulp. This pulp was directly packed into 5Kg and 0.2Kg plastic bags and moved to a freezer at -35ºC where it quickly froze. The frozen pulp was kept at -20ºC until its utilization.

Eleven samples of passion fruit juice beverage were formulated with passion fruit pulp (De Marchi Indústria e Comércio de Frutas Ltda®), sucrose (União®), propylene glycol alginate (ISP do Brasil®), natural passion fruit aroma (Givaudan®), and water. In order to optimize the pulp content and the sucrose concentration, samples were formulated using a 2^2 central composite design, as described by KHURI & CORNELL (1987). The levels of the independent variables, pulp and sucrose, were coded as (1) -1 and +1, representing the levels of the 2^2 factorial design; (2) 0 (zero), representing the central point of the design, which made it possible to estimate the lack of fit of the linear statistical model obtained as well as the pure error of the experiments; and (3) $-\alpha$ and $+\alpha$, representing the axial points, allowing for the study of a quadratic statistical model (Table 1). The concentration levels used for each variable are presented in Table 2. The sucrose concentrations were expressed in % (g/mL), and the pulp content was expressed as the total soluble solids (°Brix) resulted from moisturizing pulp and water. The propylene glycol alginate and the passion fruit natural flavor concentrations used were 0.03% and 0.05%, respectively. These concentrations were determined based on laboratory tests and suggestions provided by the suppliers of those ingredients.

A group of 51 consumers, 40 women and 11 men, was recruited among students and employees from the Faculty of Food Engineering, UNICAMP, Brazil, according to their acceptability of natural or industrialized passion fruit juice: all these people liked passion fruit juice.

Each consumer evaluated the acceptability of each one of the 11 passion fruit juice beverage samples using a 9-point structured hedonic scale with ends anchored "I dislike extremely" and "I like extremely". Approximately 30mL samples were presented to panelists with random three-digit codes and in completely randomized order, at 5ºC. Between each sample, panelists were instructed to cleanse their palates with distilled water and unsalted crackers to avoid the effects of residual flavors. All the evaluations were conducted in individual booths under white illumination, placed in the Laboratory of Sensory Analysis of the Food Engineering Faculty, UNICAMP.

Table 1. Variables coded values and acceptability scores.

Treatments	% Sucrose	Pulp (°Brix)	Acceptability scores
1	-1	-1	2.1
2	+1	-1	5.6
3	-1	+1	3.2
4	+1	+1	4.5
5	-1,41	0	3.2
6	+1,41	0	5.8
7	0	-1,41	2.0
8	0	+1,41	4.4
9	0	0	5.5
10	0	0	5.6
11	0	0	5.6

Table 2. Variables values.

Variables	-1,41	-1	0	+1	+1,41
Pulp (°Brix)	0,5	1,1	2,5	3,9	4,5
Sucrose (%)	2,5	4,7	10	15,3	17,5

2.2 Determination of equi-sweet concentrations of aspartame, sucralose, and aspartame/acesulfame-K blend (4:1)

Samples of passion fruit juice beverage were formulated with passion fruit pulp (De Marchi Indústria e Comércio de Frutas Ltda®), propylene glycol alginate (ISP do Brasil®), natural passion fruit aroma (Givaudan®) and water. According to the results obtained from the optimization study, the standard beverage was sweetened with 10% sucrose (União®) and the light beverages with different concentrations of aspartame, sucralose, and aspartame/acesulfame-K blend (4:1) (Steviafarma do Brasil®).

Measurements of sweetness equivalence to sucrose of the high intense sweeteners and sweetener blend were accomplished in two steps, using two types of sensory methods: magnitude estimation and difference-from-control.

2.2.1 Magnitude estimation

The method of magnitude estimation (STONE & OLIVER, 1969) was used in order to obtain the aspartame, sucralose and aspartame/acesulfame-K blend (4:1) power functions.

Ten panelists (all university students) were selected according to their ability to discriminate sweet taste in sequential analysis with triangular tests (AMERINE et al., 1965). The triangular tests consisted of 2 samples of passion fruit juice beverage differing in sweetness at 1% of significance. The panelists were informed that they would be presented with a reference sample with an arbitrary sweetness value of 100, followed by a random series of samples with intensities both less and greater than the reference intensity. They were asked to estimate the sweetness intensity of the light beverages sweetened with high intense sweeteners relative to the reference. For example, the value 200 should indicate a sample twice as sweet as the reference, while a value of 50 should be half as sweet as the reference. The test concentrations utilized are listed in Table 3 (CARDELLO et al., 1999).

Table 3. Aspartame, sucralose and aspartame/acesulfame-K blend concentrations tested to determine their equivalence in sweetness to a 10% sucrose-sweetened passion fruit beverage.

Stimuli	**Concentrations (%)**				
Sucrose	3.9100	6.2500	10.0000	16.0000	25.6000
Aspartame	0.0200	0.0340	0.0550	0.0880	0.1408
Sucralose	0.0063	0.0100	0.0160	0.0256	0.0410
Aspartame (80%) +	0.0160	0.0272	0.0440	0.0704	0.1126
Acesulfame-K (20%)	0.0040	0.0068	0.0110	0.0176	0.0282

2.2.2 Difference-from-control

After obtaining the high intense sweetener power functions, the preliminary determined equi-sweet concentrations of aspartame, sucralose and aspartame/acesulfame-K blend (4:1) were evaluated by a group of professional panelists. The professional panelists found that the studied light beverages were still not equivalent in sweetness to 10% sucrose - they were slightly sweeter. Thus a narrower concentration range of the high intense sweeteners was screened and a confirmation study of equi-sweetness was performed using 2 difference-from-control tests.

In the first test, twenty-two experienced panelists (professional panelists, sensory staff and graduate students) were presented with a control sample of passion fruit beverage sweetened with 10% sucrose, and 4 samples sweetened with 0.054%, 0.047%, 0.040% and 0.033% of aspartame, plus a blind control sample. The same procedure was used for the sucralose and the aspartame/acesulfame-K blend-sweetened beverages, the concentrations studied being: 0.016%, 0.014%, 0.012% and 0.010% of sucralose, and 0.036%, 0.031%, 0.026% and 0.021% of the aspartame/acesulfame-K blend.

In the second test, twenty-one experienced panelists were presented with 0.047% and 0.043% of aspartame, 0.016% and 0.015% of sucralose, and 0.026% of aspartame/acesulfame-K blend, plus a blind control sample (10% sucrose). 95% of the panelists were the same as in the first test.

In both tests, panelists were asked to rate the size of the difference between each sample and the control using the scale: very much less sweet (-3), moderately less sweet (-2), slightly less sweet (-1), equal to control (0), slightly sweeter (1), moderately sweeter (2) and very much sweeter (3). Tests were done in triplicate.

2.3 Data analysis

Acceptability data were fitted to a second order model equation provided in the design. Analysis of variance of the regression equation allowed the calculation of goodness of fit and of the significance of the effects. These analyses were conducted using the Statistica® software version 5.0.

Data provided by the magnitude estimation tests were normalized using the geometric mean and magnitude estimates were converted into logarithmic values. Response curves for each sweetener were fitted to the power function $S=aC^n$, where S was the stimuli perceived, C was the concentration of the stimuli, a was the antilog of the value of the y-intercept and n was the slope.

Data generated from the difference-from-control tests were evaluated using the analysis of variance, and post-hoc comparisons of arithmetic means were performed using the Dunnett test.

3. Results and Discussion

3.1 Acceptability optimization of a natural passion fruit juice beverage sweetened with sucrose

Acceptability scores assigned to experimental samples ranged between 2.0 and 5.8 (Table 1). Acceptability (Y) was related to concentration of ingredients by the regression equation:

$$Y = 5.57 + 1.06X_1 + 0.42X_2 - 0.55X_1X_2 - 0.53X_1^2 - 1.18X_2^2$$

where X_1 represents sucrose concentration (%) and X_2 , pulp content (°Brix). As shown (Table 4), 92% (R^2=0.92) of the acceptability variation were explained by the regression model. Sucrose concentration (%) as well as pulp content (°Brix) had both linear and quadratic significant effects on acceptability ($p<0.1$). Sucrose x pulp interaction was also significant ($p<0.1$).

Table 4. Analysis of variance of the regression model relating acceptability with sucrose concentration (%) and pulp content (°Brix).

Source of variation	df	SS	MS	F
Regression	5	19.752	3.95	12.34*
Residual	5	1.604	0.32	176.7
Lack of fit	3	1.598	0.53	
Experimental	2	0.006	0.003	
Total	10	21.356		

R^2=0.92
*Significant ($p<0.1$)

Figure 1 refers to the response surface generated from the coded fitted model. This figure shows the effects of sucrose concentration (%) and pulp content (°Brix) on the acceptability of the passion fruit juice beverages studied, allowing for a visualization of the optimized regions of the consumer responses.

From Figure 1 it can be seen that the predictive model indicated the optimized region for the passion fruit beverage acceptability as being between the values of 1.8 and 3.2°Brix, and between 10 and 17.5% sucrose. Treatments 2, 6, 9, 10 and 11 were found in this region, whose acceptability means were respectively 5.6, 5.8, 5.5, 5.6 and 5.6 (between the terms "neither like nor dislike" and "like slightly"). Treatments 9, 10 and 11 were the same, and corresponded to the central point (2.5°Brix and 10% sucrose). The remaining treatments were found in the regions with acceptability means below 5.0 (between the terms "neither like nor dislike" and "dislike very much"). So, any pulp (°Brix) x sucrose (%) combination comprised within the optimized region cited above could be selected. Based on previous knowledge and experience, the centered point, corresponding to 2.5°Brix and 10% sucrose was selected to represent the optimum formulation.

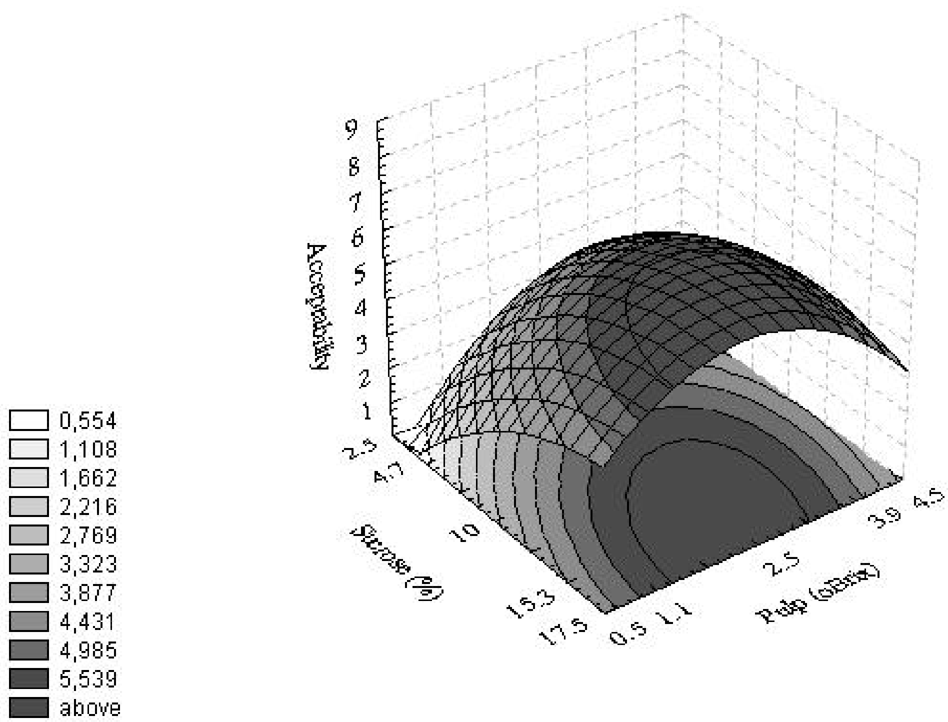

Figure 1. Response surface from the coded fitted model relating consumer acceptability to sucrose concentration and passion fruit content (1=dislike extremely; 5=neither like nor dislike; 9=like extremely).

There are several papers reporting product development and acceptability optimization of food products using Response Surface Methodology (DEKA et al., 2001; ABDULLAH & CHENG, 2001; DAMÁSIO et al., 1999; BARON & HANGER, 1998; MOSKOWITZ, 1997; HOUGH et al., 1997; PASTOR et al., 1996; HOUGH et al., 1992; CHOMPREEDA et al., 1989; HUOR et al., 1980; HORSFIELD & TAYLOR, 1976), but nothing was found in the literature about the optimization of passion fruit beverages. In this study, similarly to those cited above, the Response Surface Methodology was a very useful technique for optimizing the sensory quality of the passion fruit juice beverage studied.

3.2 Determination of equi-sweet concentrations of aspartame, sucralose, and aspartame/acesulfame-K blend (4:1)

3.2.1 Magnitude estimation

The relationship between sweetness intensity and concentration of each high intense sweetener studied is presented in Table 5 and illustrated in Figure 2.

Table 5. Slope values, y-intercepts, correlation coefficients (R) and power functions for the stimuli obtained for passion fruit juice beverages sweetened with sucrose (SUC), aspartame (APM), sucralose (SA) and aspartame/acesulfame-K blend (A/A).

Stimuli	**Slope**	**y-intercept**	**R**	**Power function**
SUC 10%	1.6845	-1.6846	0.9850	$P = 0.0207 \times S^{1.6845}$
APM SES 10%	1.3454	1.7043	0.9809	$P = 50.6174 \times S^{1.3454}$
SA SES 10%	1.4489	2.6009	0.9603	$P = 398.9330 \times S^{1.4489}$
A/A SES 10%	1.1329	1.6364	0.9923	$P = 43.2912 \times S^{1.1329}$

R=Pearson correlation coefficient.

SES=Sweetness Equivalence to Sucrose

The aspartame/acesulfame-K blend showed an exponent value close to 1.0 (Table 5), indicating that the perceived sweetness intensity grew commensurate with an increase in physical concentration. Aspartame and sucralose showed similar exponent values, but reasonably higher than 1.0, indicating that perceived sweetness intensity grew faster than the concentration growth. The same was true for sucrose, whose exponent value was the highest.

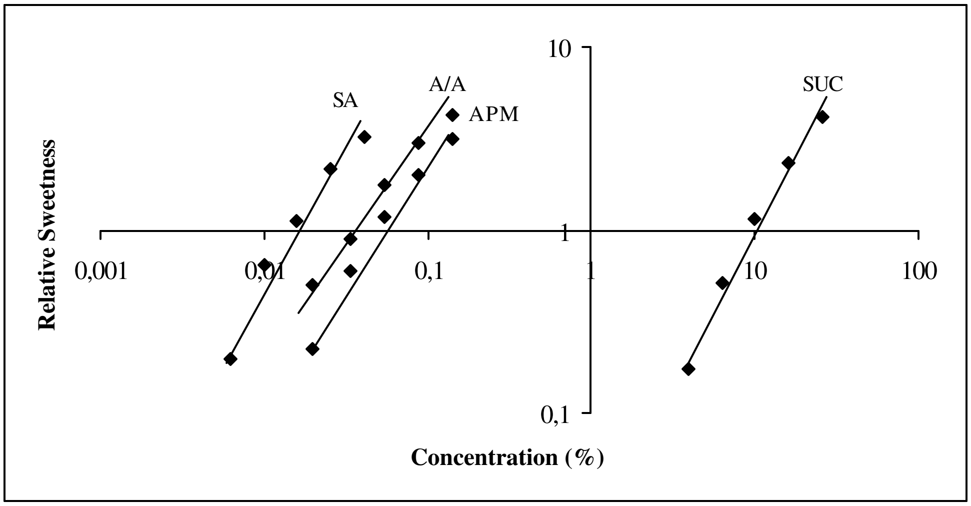

Figure 2. Sweetness power functions of Sucrose (SUC), Aspartame (APM), Sucralose (SA), and Aspartame/Acesulfame-K blend (A/A) in passion fruit juice beverage.

No published report describing the sweetness of sucrose, aspartame, sucralose and aspartame/acesulfame-K blend in passion fruit beverages was found in the literature. CARDELLO et al. (1999) reported exponent values of 1.2976 and 1.3364 for sucrose, and 1.2048 and 0.9411 for aspartame in water at pH 3.0 and 7.0, respectively. WIET & BEYTS (1992) reported exponent values of 0.94 for sucralose in water. Both studies of sweetness equivalence to sucrose in water showed exponent values lower than those obtained in this study for passion fruit juice beverage. Studying the sweetness equivalence to 8.3% sucrose of different sweeteners in tea, CARDOSO et al. (2004) reported exponent values of 1.79 and 2.07 for sucrose, 1.51 and 1.68 for aspartame, and 1.87 and 0.91 for sucralose, at 45ºC and 6ºC, respectively. Except for sucralose, the exponent values obtained by CARDOSO et al. (2004) in tea were higher than those obtained in this study for passion fruit juice beverage. So, in the passion fruit juice beverage studied, the perceived sweetness intensity growth, related to the concentration growth, was higher than in water and lower than in tea at 45ºC and 6ºC. These results confirm that sweetness equivalency values for high intense sweeteners are very system-dependent, and may vary in different food products (RELINGER & SETSER, 1987), pointing towards the need to study the substitution of sucrose by high intense sweeteners every time a formulation is changed or a new product is developed.

Based on the power functions obtained for aspartame, sucralose and the aspartame/acesulfame-K blend, the concentrations of these high intense sweeteners found as equi-sweet to 10% sucrose in the passion fruit juice beverage studied were: 0.054% of aspartame, 0.016% of sucralose and 0.036% of aspartame/acesulfame-K blend (0.029% of aspartame + 0.007% of acesulfame-K).

3.2.2 Difference-from-control

According to the results generated by the first difference-from-control test (Table 6), the only concentration of aspartame which did not differ from the control ($p<0.05$), besides the blind control sample, was 0.047%, a concentration lower than that obtained from the magnitude estimation test. However, both 0.047% and 0.040% of aspartame generated mean values close to 0 (equal to control), reason by which an intermediate concentration of aspartame (0.043%) was evaluated in the second test besides 0.047%. Similarly, for the aspartame/acesulfame-K blend, the only concentration that did not differ from control ($p<0.05$), besides the blind control, was 0.026%, a concentration smaller than that obtained from the magnitude estimation test. For sucralose, the only concentration that did not differ from control ($p<0.05$) was 0.016%, concentration found as equi-sweet to 10% sucrose in the magnitude estimation test. However, both 0.016% and 0.014% of sucralose generated mean values close to 0 (equal to control). So, 0.016% and 0.015% of sucralose were evaluated in the second difference-from-control test.

The results obtained in the second difference-from-control test are presented in Table 7.

According to the results generated by the second difference-from-control test, the concentrations of the high intense sweeteners that did not differ from control ($p<0,05$) were: 0,043% of aspartame, 0,016% of sucralose and 0,026% of aspartame/acesulfame-K blend. These results confirmed those obtained for sucralose and aspartame/acesulfame-K blend in the first difference-from-control test and indicated that the concentration of aspartame equi-sweet to 10% sucrose was 0,043%.

Table 6. Mean values obtained for each concentration of aspartame (APM), sucralose (SA) and aspartame/acesulfame-K blend (A/A) evaluated in the first difference-from-control test.

APM	Concentration	0.054%	0.047%	0.040%	0.033%	Blind control (10% sucrose)
	Mean	1.44*	0.35	-0.38*	-1.32*	0.39
SA	Concentration	0.016%	0.014%	0.012%	0.010%	Blind control (10% sucrose)
	Mean	0.41	-0.53*	-1.20*	-1.82*	0.18
A/A	Concentration	0.036%	0.031%	0.026%	0.021%	Blind control (10% sucrose)
	Mean	1.50*	0.83*	-0.8	-1.24*	0.24

* Means significantly different from control ($p<0.05$).

Table 7. Mean values obtained for the concentrations of aspartame (APM), sucralose (SA) and aspartame/acesulfame-K blend (A/A) evaluated in the second difference-from-control test.

Sample	APM 0.047%	APM 0.043%	SA 0.016%	SA 0.015%	A/A 0.026%	Blind control (10% sucrose)
Mean	0.57*	-0.08	-0.06	-0.65*	0.03	-0.08

* Means significantly different from control ($p<0.05$).

Based on the results obtained from the power curves and the difference-from-control tests, sweetness potency, defined as the number of times sweeter a compound is, on a weight basis, than an iso-sweet concentration of sucrose, was calculated for each sweetener. Sucralose displayed the greatest potency among the three high intense sweeteners. This sweetener was 625 times more potent than sucrose at a 10% equi-sweet concentration. The aspartame/acesulfame-K blend (4:1) was the second most potent sweetener system in the passion fruit juice beverage studied. This blend was 385 times more potent than sucrose at a 10% equi-sweet concentration. Aspartame was the least potent sweetener among the three high intense sweeteners. It was 233 times more potent than sucrose at a 10% equi-sweet concentration. No published report describing the potency of sucrose, aspartame, sucralose and aspartame/acesulfame-K blend in passion fruit beverages was found in the literature, only in water. WIET & BEYTS (1992) found that sucralose in water was about 500 times more potent than sucrose at 9% sucrose sweetness equivalency. CARDELLO et al. (1999) reported that aspartame in water at pH 3.0 and pH 7.0 was about 186 times more potent than sucrose at a concentration equi-sweet to 10% sucrose.

4. Conclusions

The formulation of a natural passion fruit juice beverage sweetened with sucrose was optimized by Response Surface Methodology, considering passion fruit pulp content (°Brix resulted from moisturizing passion fruit pulp and water) and sucrose concentration (%) as independent variables. The selected pulp content and sucrose concentration were, respectively, 2.5°Brix and 10%.

The magnitude estimation method was crucial to assess the sweetness equivalency of the high intense sweeteners studied, but not enough because of the wide range of concentrations of sweeteners studied. Thus a confirmation study was necessary to provide the exact equi-sweet concentrations of aspartame, sucralose, and aspartame/acesulfame-K (4:1), and this step was efficiently performed using the two difference-from-control tests. The concentrations of aspartame, sucralose and aspartame/acesulfame-K blend found as equivalent to sucrose 10% in passion fruit juice beverage were, respectively, 0,043%, 0,016% and 0,026%.

5. Acknowledgments

We acknowledge CNPq, Brazil, for the financial support, De Marchi Indústria e Comércio de Frutas, the passion fruit pulp supplier, and Oregon State University Sensory Analysis laboratory, where part of this study was performed. The authors are also grateful to the sensory panelists who contributed their time and efforts to this study.

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Consumer acceptance of a new ready-to-drink passion fruit juice beverage with different sweetener systems: A cross-cultural study

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This paper will be submitted to Food Quality and Preference

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Abstract

This work examined the acceptance of a new passion fruit juice beverage with different sweetener systems both in the United States and Brazil. Four ready-to-drink passion fruit juice beverages, sweetened with sucrose and high intense sweeteners were evaluated according to their microbiological, physical-chemical and sensory properties and consumer acceptance. The results indicated that the sensory properties of the beverages could be standardized, that is, the same formula could be successfully sold both in Brazil and the USA, with only minor adjustments. These adjustments have to do with sweetness, sourness and passion fruit flavor levels, besides improving the light beverages' aftertaste. Further evaluations with a carbonated version of the beverages could also be carried out, and the package size of the beverages should be adapted in each country in order to better meet local market preferences.

Keywords: passion fruit juice beverage, sweeteners, cross-cultural study, sensory evaluation

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1. Introduction

Cross-cultural product development is becoming increasingly important as companies strive to compete in a marketplace comprising the entire world (MOSKOWITZ & KRIEGER, 1998). Understanding cross-national differences is often considered a key prerequisite for successful international marketing. Over decades, the issue of standardized (universal) versus adapted (specialized) products has elicited controversial debates among scholars and practitioners alike. While the pros and cons of both approaches to international product development continue to be debated, evidence suggests that the feasibility of standardization varies with the level of cultural similarity between markets. Chances of success for international marketers can thus be increased if similarities / differences are taken into consideration.

Product developers must satisfy the needs of consumers, with the solutions tempered by market realities such as the cost of goods and crop variability (MOSKOWITZ & KRIEGER, 1998). In particular, they should address the differences between consumers in terms of their sensory preferences, and manufacture products that meet their expectations (MURRAY, 2001).

When introducing a new product into different cultures, the basic strategies to be considered, in order to match products to demand, are adaptation versus standardization of products and communications. Product adaptation consists of adapting the product to meet local conditions or wants, while product standardization consists of slight adjustments to the product in order to answer the needs of local consumers. So instead of assuming that its original product can be launched in another country without being modified, the company should evaluate all possible adaptation elements and determine which of them would result in higher profitability. For example, Coca-Cola is less sweet or less carbonated in certain countries depending on the local consumers (KOTLER & ARMSTRONG, 2005). Accordingly, it is extremely important for a product developer to know what the existing differences are across the nations in question. Treating consumers from different nations and cultures as a homogeneous group can be dangerous from a managerial perspective. Neglecting even very small national differences, sensory and marketwise, can lead to erroneous consumer perceptions and may result in serious damage to the product image (ORTH et al., 2005).

There has been a little research on how preferences for fruit juice based beverages might vary across cultures (PRESCOTT et al., 1997; PRESCOTT et al., 1998; DRUZ & BALDWIN, 1982; HOLT et al., 2000; COX et al., 2001; MOSKOWITZ & KRIEGER, 1998). Such research is important, given the fact that the consumption of fruit based beverages is growing all over the world due to consumer preference for health beverages. Consumers want to enjoy the use of beverages that not only quench thirst, but also offer innovation, health, convenience, and some nutritional value (LÓPEZ, 2004; BERTO, 2003; ADBDULLAH & CHENG, 2001). In addition, it could be expected that preferred sensory properties of a certain fruit juice would depend, to a large extent, on prior exposure to those particular sensory properties.

Among the tropical fruit juices consumed on both the internal and external markets, passion fruit juice stands out due to its exotic and intense flavor, strong aroma, high acidity and pulp yield (SOUZA et al., 2002; GARRUTI, 1989; MELETTI & MAIA, 1999; DE MARCHI et al., 2003). This beverage is very appreciated by Brazilian consumers, who are responsible for 90% of the total passion fruit juice consumed in the world (VERA et al., 2003; SANDI et al., 2003). Passion fruit juice is also exported - but mostly frozen and concentrated (50°Brix), to Holland, followed by the USA and Germany (FRACARO, 2004). However, American consumers are not at all familiar with ready-to-drink passion fruit juice (ORTH & DE MARCHI, 2005, 2006). Accordingly, the purpose of this work was to compare the acceptance of a new passion fruit juice beverage in the United States – a new market for introducing the beverage, with acceptance of the same beverage in Brazil, where it is well established. In addition, the current study examined the use of different sweetener systems, including sucrose and high intense sweeteners. This is important because, parallel to the consumer preference for health beverages, there is an increasing trend for consumption of low calorie beverages; today's consumers are more and more concerned with health regarding the risks represented by sucrose intake such as obesity, diabetes and dental caries. More than this, consumers are increasingly better informed about diet, and as a result, desire more foods that offer fewer calories. Nevertheless, there is evidence that the sweetness hedonic responses are different across cultures (PRESCOTT et al., 1997, LAING et al., 1994).

Product development and marketing activities are frequently conducted in separate if not competing departments, often leading to inconsistent executions. The current research brings a unique contribution to the literature as far as it integrates sensory and marketing data by examining sensory properties and acceptance of a new juice beverage and marketing factors such as identification of close competitors and identification of the physical product (in terms of attribute-level combination) most likely to be accepted on each of the two markets studied. Both sensory evaluation and marketing communication are crucial in stimulating purchases. Thus, when launching a new product on the market, especially cross-culturally, it is fundamental not only to address its acceptance by consumers in terms of its sensory properties, but also to investigate its market characteristics. In other words, more and closer collaboration between R&D and marketing departments is needed in order to sustain success in the food and beverage companies.

Accordingly, the present study focused on evaluating the consumer acceptance of four passion fruit juice beverages, sweetened with sucrose, aspartame, sucralose, and a aspartame/acesulfame-K blend (4:1), respectively, as well as investigating the most relevant characteristics of two different markets for launching the new beverage: Brazil and United States.

2. Material and Methods

2.1 Production of ready-to-drink passion fruit juice beverages

Four ready-to-drink natural passion fruit juice beverages, containing passion fruit pulp (De Marchi Indústria e Comércio de Frutas Ltda®), propylene glycol alginate (ISP do Brasil®), natural passion fruit aroma (Givaudan®) and water, and sweetened with sucrose (União®) (standard beverage), or equi-sweet concentrations of aspartame, sucralose, and aspartame/acesulfame-K blend (4:1) (Steviafarma do Brasil®) (light beverages), respectively, were produced in a Tetra Pak® pilot plant installed in the Tecnolat-ITAL, Campinas/Brazil (Table 1). The pilot plant was cleaned using 2% caustic soda and 1% nitric acid solutions, both at 80°C, and water steam between the application of the solutions. 110L of each of the four beverages were pasteurized at 98°C/30 seconds, using the sterilab tubular aseptic system (IADA, 2002). 55L of each beverage were obtained and packaged into 125mL tetrabrik units, previously sterilized with a 35% hydrogen peroxide solution and sterile air (Figure 1).

Table 1. Formulations of passion fruit beverages sweetened with sucrose, aspartame, sucralose, and aspartame/acesulfame-K blend (4:1).

Ingredients \ Beverages*	B1	B2	B3	B4
Passion fruit pulp	21700g	21700g	21700g	21700g
Propylene glycol alginate	33g	33g	33g	33g
Natural passion fruit aroma	61mL	61mL	61mL	61mL
Water	88300g	88300g	88300g	88300g
Sweetener	11000g Sucrose	47.30g Aspartame	17.60g Sucralose	22.88g Aspartame 5.72g Acesulfame-K

*B1: Sucrose-sweetened passion fruit beverage (Standard)
B2: Aspartame-sweetened passion fruit beverage
B3: Sucralose-sweetened passion fruit beverage
B4: Aspartame/Acesulfame-K blend (4:1)-sweetened passion fruit beverage

Figure 1. Tetrabrik units of passion fruit juice beverage.

2.2 Microbiological evaluation

In order to evaluate the beverages' safety, samples of each beverage were submitted to microbiological evaluation before and immediately after being pasteurized and packaged. Previously to pasteurization, 250mL samples of each beverage were collected in sterilized plastic bags and submitted to the following microbiological analyses: Standard Plate Count (CFU/mL), Total Coliforms (MPN/mL), Fecal Coliforms (MPN/mL), Molds and Yeasts (CFU/mL), Thermophiles Molds (CFU/mL), *Salmonella* sp, Thermophiles spores (CFU/mL), Mesophiles spores (CFU/mL), *lactobacillus* (CFU/mL) and *alicyclobacillus* sp (CFU/mL). Immediately after pasteurization, 2 tetrabrik units of each beverage (250mL) were submitted to the same microbiological analyses performed on the fresh beverages (VANDERZANT & SPLITTSTOESSER, 1992).

2.3 Physical-chemical evaluation

Immediately after pasteurization and packaging, 250mL samples of each beverage were analyzed for total soluble solids (°Brix), pH, total acidity, ascorbic acid content and total and reducing sugars contents (AOAC, 1993). Analyses were done in triplicate.

2.4 Consumer acceptance and sensory properties of the beverages in Brazil and the USA

In order to gauge the likely acceptance of the passion fruit juice beverages on both the American and Brazilian markets, a consumer survey was conducted. The content of the survey was identical for both markets and addressed two major objectives: 1) an assessment of the competitive position of the new beverage, that is, identification of close competitors, and 2) identification of the physical product with the highest acceptance on each of the markets. Both consumer tests were carried out in university settings, one at the Faculty of Food Engineering, Campinas State University - Brazil, and the other at the Department of Food Science and Technology, Oregon State University – USA. In both cases consumers were recruited from standing panels.

Testing procedures were identical at each site, with consumers first completing the marketing questionnaire, before moving on to the sensory evaluation.

The first section of the questionnaire was concerned with fruit juice positioning. Rather than solicit aggregated judgments of similarities or dissimilarities, consumers were asked to rank a number of fruit juices according to their preference from 1 (most preferred) to 8 (least preferred). The juice beverages selected for this ranking procedure differed between markets but were identical according to high respective sales figures. The list submitted to American consumers included apple juice, cranberry juice, grape juice, grapefruit juice, orange juice, passion fruit juice, pineapple juice and strawberry juice. Brazilian consumers ranked apple juice, grape juice, guava juice, mango juice, orange juice, passion fruit juice, peach juice, pineapple juice and strawberry juice.

The second part of the consumer survey was aimed at identifying the product (in terms of attributes and attribute-level combinations) most likely to be accepted on each of the markets.

According to previous studies, a product is capable of contributing several types of utility to the consumer, such as the functional utility (satisfying the needs of the physical environment) (KIM, 1990; KELLER, 1993; PARK & SRINIVASAN, 1994). Accordingly, the second session of the questionnaire was concerned with the utility of the passion fruit juice beverage attributes. A conjoint experiment was conducted to elicit important and partial utilities of the product attributes (LUCE & TUKEY, 1964; HUBER et al., 1993). This technique (GREEN & RAO, 1971) is frequently used in market research to study the effects of controlled stimuli or information on a particular consumer response and has been employed before to prepare for launching a novel apple juice in Germany (ORTH, 1999) and passion fruit in England (DELIZA et al., 2003).

The following attributes (attribute levels) were included: carbonation (non-carbonated, carbonated), color (orange, red), packaging shape (organic, Tetra Pak®), packaging size (200mL, 330mL, 1000mL), and price ($2.67 per liter, 3.27 per liter). Of the resulting 48 hypothetical attribute level combinations, eight combinations were selected to systematically represent all possible combinations. These stimuli were presented to consumers on both markets for their evaluation. Each attribute was introduced systematically at two levels in a fractional factorial design (HAN & SHAPIRO, 1966). This design permitted a simultaneous evaluation of the main effects of the five product attributes, independent of all two-way interactions. Simplified images of eight passion fruit juice beverages were displayed as stimuli (LOOSSCHILDER et al., 1995) (Table 2 and Figure 2). Consumers were asked to rank the displayed stimuli according to their preferences, from 1 (most preferred) to 8 (least preferred). Eliciting consumer preferences in an environment characterized by a number of alternatives that are competing for buyers' budgets is one of the strengths of this approach (known as conjoint measurement) and increases the practical usefulness and explanatory power of the results. The method further allows for simultaneously estimating 1) the relative importance of selected product attributes in the consumer choice process and 2) the partial utilities of selected attribute levels. These insights allow researchers to identify the most preferred attribute level combinations, even for hypothetical products, that is, combinations that were not explicitly included in the set of stimuli.

Following the marketing questions, the study proceeded with the sensory evaluation. Consumers were presented with 50mL samples of each of the four differently-sweetened beverages, one at a time. Samples were coded with three-digit random numbers and served at 5°C in plastic cups covered with plastic lids. Testing took place in individual booths under white lighting. A 9-point hedonic scale (1=dislike extremely, 2=dislike very much, 3=dislike moderately, 4=dislike slightly, 5=neither like nor dislike, 6=like slightly, 7=like moderately, 8=like very much, 9=like extremely) was used to assess overall liking, color liking, aroma liking, flavor liking, sweetness liking, aftertaste liking and texture liking. Consumers were asked to rate overall liking on two different occasions: immediately after rating color and aroma (at the beginning of the sensory evaluation), and again after rating flavor, sweetness, aftertaste, and texture (at the end of the sensory evaluation). A 9-point intensity scale (1=no sweetness, 3=slightly sweet, 5=moderately sweet, 7=very sweet, 9=extremely sweet) was used to assess the sweetness intensity of the beverages. A just right scale (not nearly enough, not quite enough, just about right, somewhat too, way too) was used to assess the sweetness, sourness and passion fruit flavor levels. Finally, the purchase intent was assessed using the scale: 1=definitely would purchase, 2=probably would purchase, 3=may or may not purchase, 4=probably would not purchase, 5=definitely would not purchase (Figure 3).

Table 2. Selected stimuli in the reduced design.

Image#	Color	Carbonation	Package shape	Package size[1]	Price[2]
792	red	non-carbonated	Square	200mL / 7oz	R$4.45 / $2.67
175	red	carbonated	Square	200mL / 7oz	R$5.05 / $3.27
364	orange	non-carbonated	Square	1L / quart	R$5.05 / $3.27
442	orange	non-carbonated	Shapely	200mL / 7oz	R$4.45 / $2.67
930	orange	carbonated	Shapely	200mL / 7oz	R$5.05 / $3.27
550	orange	carbonated	Square	335mL / 12oz	R$4.45 / $2.67
788	red	carbonated	Shapely	1L / quart	R$4.45 / $2.67
234	red	non-carbonated	Shapely	335mL / 12oz	R$5.05 / $3.27

[1]Package size was indicated in mL for Brazilian consumers, and the equivalent value was given in oz for American consumers
[2]Price was expressed as R$ for Brazilian consumers and as $ for American consumers

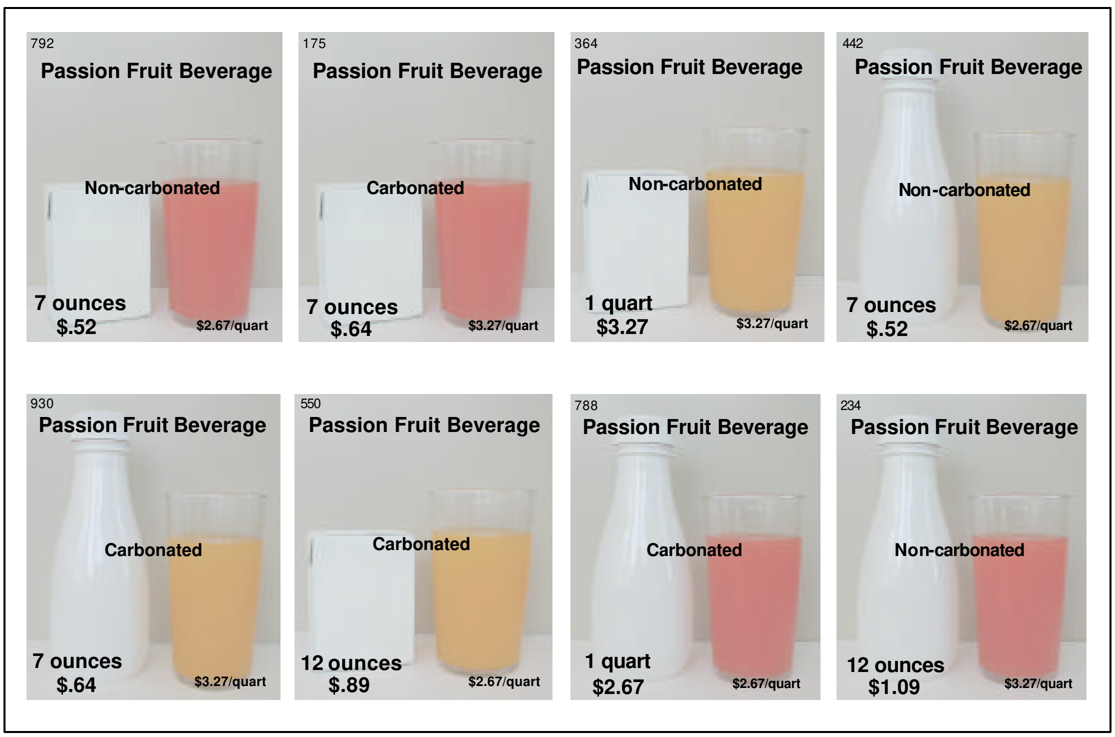

Figure 2. Images with different product descriptions used in the consumer test in the USA.

Please look at sample X and answer the first question. Then smell sample X and answer the second question.

Looking at the color, please rate how much you like or dislike this product.

Dislike Extremely	Dislike Very Much	Dislike Moderately	Dislike Slightly	Neither Like nor Dislike	Like Slightly	Like Moderately	Like Very Much	Like Extremely

Smelling this product, please rate how much you like or dislike this product.

Dislike Extremely	Dislike Very Much	Dislike Moderately	Dislike Slightly	Neither Like nor Dislike	Like Slightly	Like Moderately	Like Very Much	Like Extremely

Please taste the sample provided and answer the following questions.

Overall, considering appearance, aroma, flavor and texture, please rate how much you like or dislike this product.

Dislike Extremely	Dislike Very Much	Dislike Moderately	Dislike Slightly	Neither Like nor Dislike	Like Slightly	Like Moderately	Like Very Much	Like Extremely

Considering the flavor, please rate how much you like or dislike this product.

Dislike Extremely	Dislike Very Much	Dislike Moderately	Dislike Slightly	Neither Like nor Dislike	Like Slightly	Like Moderately	Like Very Much	Like Extremely

Considering the sweetness, please rate how much you like or dislike this product.

Dislike Extremely	Dislike Very Much	Dislike Moderately	Dislike Slightly	Neither Like nor Dislike	Like Slightly	Like Moderately	Like Very Much	Like Extremely

Considering the sweetness of this product, please rate the sweetness intensity.

Not Sweet		Slightly Sweet		Moderately Sweet		Very Sweet		Extremely Sweet

Thinking about the sweetness level of this product, would you say it is ....?

Not nearly sweet enough	Not quite sweet enough	Just about right in sweetness	Somewhat too sweet	Way too sweet

Figure 3. Consumer ballot.

Figure 3 (cont.)

Thinking about the sourness level of this product, would you say it is ...?

Not nearly sour enough	Not quite sour enough	Just about right in sourness	Somewhat too sour	Way too sour
☐	☐	☐	☐	☐

Thinking about the passion fruit flavor level of this product, would you say there is ...?

Not nearly enough passion fruit flavor	Not quite enough passion fruit flavor	Just about right in passion fruit flavor	Somewhat too much passion fruit flavor	Way too much passion fruit flavor
☐	☐	☐	☐	☐

Considering the texture of this product, please rate how much you like or dislike this product.

dislike extremely	dislike very much	dislike moderately	dislike slightly	neither like nor dislike	like slightly	like moderately	like very much	like extremely
☐	☐	☐	☐	☐	☐	☐	☐	☐

Considering the aftertaste, please rate how much you like or dislike this product.

dislike extremely	dislike very much	dislike moderately	dislike slightly	neither like nor dislike	like slightly	like moderately	like very much	like extremely
☐	☐	☐	☐	☐	☐	☐	☐	☐

Overall, considering appearance, aroma, flavor and texture, please rate how much you like or dislike this product.

dislike extremely	dislike very much	dislike moderately	dislike slightly	neither like nor dislike	like slightly	like moderately	like very much	like extremely
☐	☐	☐	☐	☐	☐	☐	☐	☐

How likely would you be to purchase this product?

Definitely would purchase	Probably would purchase	May or may not purchase	Probably would not purchase	Definitely would not purchase
☐	☐	☐	☐	☐

What would make this a better passion fruit beverage?

____

____

____

____

2.5 Data analysis

The physical-chemical data were analyzed using the analysis of variance, (ANOVA) and post-hoc comparisons of means were performed using the Tukey test (SAS Software, version 8.2).

The fruit juice positioning data were analyzed using multidimensional scaling (SPSS Software, version 11.0).

The data obtained from the consumer preferences for passion fruit juice beverage variations were analyzed using the conjoint analysis (SPSS Conjoint Software, version 11.0).

Consumer acceptance data were evaluated using the analysis of variance (ANOVA) (SAS Software, version 8.2). Overall liking 1 and overall liking 2 scores were compared using the multivariate analysis of variance (MANOVA).

3. Results and Discussion

3.1 Microbiological evaluation

The results obtained from the microbiological analyses performed on the passion fruit juice beverages before and after pasteurization and packaging are presented in Tables 3 and 4, respectively.

It can be seen from Table 3 that the microorganisms detected in all the beverages before pasteurization were mesophiles, mesophilic spores, thermophilic spores, and molds and yeasts. Coliforms, Lactobacillus, *Alicyclobacillus*, and *Salmonella* were not detected in any beverage. After heat treatment (Table 4), the only microorganisms detected in the beverages were mesophilic microorganisms, with counts not exceeding 7×10^1 CFU/mL.

The ANVISA (National Agency of Sanitary Vigilance) Resolution number 12, of January 2nd, 2001, regulates the food microbiological standards and establishes the absence of coliform microorganisms in 50mL at 35°C in soft drinks, juices, nectars and other non-alcoholic beverages (except for dairy and chocolate based beverages), with or without preservatives, frozen or otherwise (ANVISA, 2005). Thus, from the results obtained it was concluded that besides conforming to the Brazilian legislation, the passion fruit juice beverages sweetened with sucrose and high intense sweeteners showed satisfactory microbiological quality. That is, the heat treatment (98°C/30 seconds) and the aseptic system of packaging (Tetra

Pak®) used in the production of the beverages were adequate to guarantee the required microbiological safety.

Table 3. Results of the microbiological analyses performed on the passion fruit juice beverages sweetened with sucrose (B1), aspartame (B2), sucralose (B3), and aspartame/acesulfame-K (4:1) (B4) before pasteurization and packaging.

Microbiological determinations	**B1**	**B2**	**B3**	**B4**
Standard Plate Count (CFU/mL)	530	250	56000	290
Mesophilic spores (CFU/mL)	30	90	100	30
Thermophilic spores (CFU/mL)	<10	<10	<10	<10
Molds and Yeasts (CFU/mL)	540	40	42000	160
Coliforms at 35ºC (MPN/mL)	<0.3	<0.3	<0.3	<0.3
Coliforms at 45ºC (MPN/mL)	<0.3	<0.3	<0.3	<0.3
Lactobacillus (CFU/mL)	<10	<10	<10	<10
Alicyclobacillus sp (CFU/mL)	<10	<10	<10	<10
Salmonella sp	Absence / 25mL	Absence / 25mL	Absence / 25mL	Absence /25mL
Thermophilic Molds (CFU/mL)	Absence / 25mL	Absence / 25mL	Absence / 25mL	Absence /25mL

Table 4. Results of the microbiological analyses performed on the passion fruit juice beverages sweetened with sucrose (B1), aspartame (B2), sucralose (B3), and aspartame/acesulfame-K (4:1) (B4) immediately after heat treatment and packaging.

Microbiological determinations	**B1**	**B2**	**B3**	**B4**
Standard Plate Count (CFU/mL)	60	70	20	<10
Mesophilic spores (CFU/mL)	30	<10	<10	10
Thermophilic spores (CFU/mL)	<10	<10	<10	<10
Molds and Yeasts (CFU/mL)	<10	<10	<10	<10
Coliforms at 35ºC (MPN/mL)	<0.3	<0.3	<0.3	<0.3
Coliforms at 45ºC (MPN/mL)	<0.3	<0.3	<0.3	<0.3
Lactobacillus (CFU/mL)	<10	<10	<10	<10
Alicyclobacillus sp (CFU/mL)	<10	<10	<10	<10
Salmonella sp	Absence / 25mL	Absence / 25mL	Absence / 25mL	Absence /25mL
Thermophilic Molds (CFU/mL)	Absence / 25mL	Absence / 25mL	Absence / 25mL	Absence /25mL

SANDI et al. (2003), evaluating the quality of a passion fruit juice pasteurized using three equivalent time-temperature binomials (85°C/27seconds, 80°C/41seconds, 75°C/60seconds), verified that the binomial 75°C/60seconds was not sufficient to reduce the microbiological counts, while the binomial 85°C/27seconds – slightly inferior to that used in this experiment, besides being sufficient, caused fewer changes on the sensory characteristics of the juices.

3.2 Physical-chemical evaluation

The results obtained from the physical-chemical analyses performed on the passion fruit juice beverages immediately after pasteurization and packaging are presented in Table 5.

Table 5. Results of the physical-chemical analyses performed on the passion fruit juice beverages sweetened with sucrose (B1), aspartame (B2), sucralose (B3), and aspartame/acesulfame-K (4:1) (B4) immediately after heat treatment and packaging.

Physical-chemical determinations	B1	B2	B3	B4
Total soluble solids (°Brix)	$11.40^{a} \pm 0.00$	$2.40^{b} \pm 0.00$	$2.40^{b} \pm 0.00$	$2.40^{b} \pm 0.00$
pH	$3.13^{a} \pm 0.03$	$3.18^{a} \pm 0.03$	$3.13^{a} \pm 0.03$	$3.17^{a} \pm 0.03$
Total acidity (g citric acid/100mL)	$0.75^{a} \pm 0.00$	$0.70^{b} \pm 0.01$	$0.68^{c} \pm 0.01$	$0.69^{b} \pm 0.00$
Ascorbic acid (mg/100mL)	$4.64^{b} \pm 0.04$	$3.55^{c} \pm 0.00$	$4.90^{a} \pm 0.01$	$3.59^{b} \pm 0.06$
Total sugars (g glucose/100mL)	$7.49^{a} \pm 0.06$	$0.97^{b} \pm 0.03$	$0.95^{c} \pm 0.01$	$1.06^{b} \pm 0.03$
Reducing sugars (g glucose/100mL)	$1.67^{a} \pm 0.01$	$0.68^{b} \pm 0.03$	$0.70^{b} \pm 0.01$	$0.69^{b} \pm 0.03$

[a, b, c] Averages in the same row followed by different letters represent significant differences (p<0.05).

The sucrose-sweetened beverage (B1), as expected, presented the highest total soluble solids content (11.4°Brix), and differed significantly (p<0.05) from the light beverages (B2, B3 and B4), whose total soluble solids contents were 2.4°Brix (p>0.05) (Table 5). The pH values ranged between 3.13 and 3.18 (p>0.05). The highest total acidity content was found in the sucrose-sweetened beverage (B1) (0.75g/100mL), followed by the aspartame-sweetened beverage (B2) (0.70g/100mL), the aspartame/acesulfame-K-blend - sweetened beverage (B4) (0.69g/100mL), and the sucralose-sweetened beverage (B3) (0.68g/100mL) (p<0.05). The sucralose-sweetened beverage (B3) presented the highest ascorbic acid content (4.90mg/100mL), and differed significantly ($p<0.05$) from the other beverages. Similarly to the results obtained for total soluble solids, the sucrose-sweetened beverage presented significantly higher total and reducing sugars than the light beverages ($p<0.05$).

The physical-chemical results obtained in this research conformed to the requirements of the Brazilian legislation for passion fruit based beverages (BRASIL, 2005).

DE MARCHI et al. (2003) evaluated the physical-chemical properties of a natural passion fruit isotonic beverage formulated with 11% passion fruit pulp, 20% potassium, 110% sodium, and 6% sucrose, and pasteurized at 92°C/4 seconds. They determined total soluble solids contents of 8.2°Brix, pH equal to 3.20, total acidity content of 0.47g/100mL, and ascorbic acid content of 0.29mg/100mL. The results obtained in the present study were similar to those described by DE MARCHI et al. (2003) concerning the pH, superior concerning the total acidity and remarkably superior concerning the ascorbic acid content, which was expected as the beverages evaluated in this research were formulated with a higher passion fruit pulp content (20%).

3.3 Consumer acceptance and sensory properties of the beverages in Brazil and the USA

Identification of fruit juice positioning

A Multidimensional Scaling procedure was performed with the individual ranks transformed into measures of similarity. Figures 4 and 5 shows the results with juice group centroids mapped in a reduced two-dimensional discriminant space. The positions of fruit juice centroids relative to each other provide insight into respective similarities and differences with similar fruit juices grouped in close proximity to each other. For example, pineapple juice is plotted in a relatively tight formation with passion fruit juice. The mango juice is distinctively set apart from passion fruit juice (Figure 4). Considering the significant results, the relative positions of fruit juice group centroids provide information about what other fruit juice beverages the new passion fruit beverage is likely to compete against from the consumer perspective.

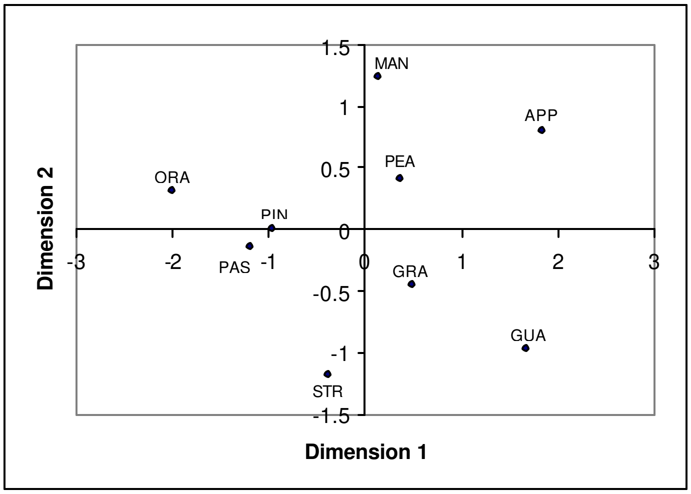

Figure 4. Configuration for passion fruit juice and competing products in Brazil (N=130). (APP=apple juice, GRA=grape juice, GUA=guava juice, MAN=mango juice, ORA=orange juice, PAS=passion fruit juice, PEA=peach juice, PIN=pineapple juice, STR=strawberry juice).

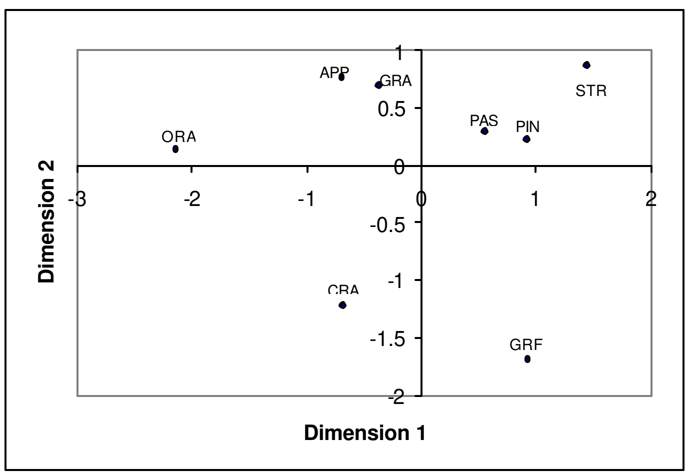

Figure 5. Configuration for passion fruit juice and competing products in the USA (N=189). (APP=apple juice, CRA=cranberry juice, GRA=grape juice, GRF=grapefruit juice, PAS=passion fruit juice, PIN=pineapple juice, ORA=orange juice, STR=strawberry juice).

In general, the closer individual products are to each other in the configuration, the more similar they are perceived to be by the consumers. Considering the distances between individual fruit juices, pineapple juice can be identified as a strong competitor for passion fruit juice on both market segments, Brazil and the USA (Figures 4 and 5, respectively). Except for orange juice, the other fruit juices (mango, apple, peach, grape, guava and strawberry), as compared to passion fruit juice in Brazil, were perceived by the consumers as quite unique products (Figure 4). In the USA, on the other hand, a second arranged group of similar juices was formed by apple, grape and strawberry juices. Orange, cranberry and grapefruit juices were perceived by consumers as unique products, with little similarity to the groups mentioned before (Figure 5).

In Brazil as in the USA, the similarity between passion fruit and pineapple juices, as perceived by consumers, provides product developers with more insight into the kind of competition to be expected when launching a passion fruit juice beverage on any of these markets.

Designing the "Ideal" passion fruit juice beverage

As can be seen in Tables 6 and 7, attribute importance and attribute level utilities differ significantly between the markets. In Brazil, where the beverage is well-established, color and carbonation are the most important product attributes, possibly because respective product modifications are unusual and attract consumer attention (Table 6). This is in stark contrast to the U.S. market, where package size is the single most important attribute (Table 7). Consumers in Brazil prefer the traditional orange color and non-carbonated beverage (positive utilities); the U.S. market also prefers the orange color, but a carbonated beverage. Further differences emerge regarding the package size. While the medium size is preferred least by consumers on both markets, U.S. consumers prefer the quart size (1 liter) while Brazilian respondents prefer the traditional 200mL package. On both markets, the lower price and the organic packaging design find greater acceptance. Overall, an orange, non-carbonated juice, sold in a 200mL organic package for $.53 per unit is the product with the highest acceptance on the Brazilian market, while an orange, carbonated beverage in a 1 quart organic packaging sold for $2.67 apiece best meets consumer preference on the U.S. market.

Table 6. Results of the conjoint analysis performed in Brazil (N=132, Pearson's correlation R=1.000, p=0.000, Kendall's tau=1.000, p=0.000).

Attribute	Relative weight	Most important attributes for individuals	Partial utilities	Preferred expressions (individuals)
Color	42.97	88	±1.4269	orange
Carbonation	30.69	31	±1.0327	non-carbonated
Package shape	9.09	0	±0.0365	shapely
Package size	10.47	5	+0.0795, -0.0494, -0.0301	200mL
Price	6.78	0	±0.1423	R$4.45

Table 7. Results of the conjoint analysis performed in the USA (N=189, Pearson's correlation R=0.600, p=0.058, Kendall's tau=0.500, p=0.042).

Attributes	Relative weight	Most important attributes for individuals	Partial utilities	Preferred expressions (individuals)
Color	15.19	9	±0.1085	orange
Carbonation	14.47	5	±0.0966	carbonated
Package shape	15.71	8	±0.2712	shapely
Package size	40.80	130	+0.1111; -0.7341; +0.6230	quart (946mL)
Price	13.84	3	±0.0794	US$0.89

Sensory evaluation

The results obtained in the sensory evaluation performed by Brazilian consumers are presented in Tables 8 and 9 and Figures 6-12.

As can be seen in Table 8, the sucrose-sweetened beverage (B1) received the highest acceptance scores across all liking attributes.

Concerning the color of the beverages, the sucrose-sweetened beverage (B1) received the highest liking scores, with average acceptance between 7 and 8 on the hedonic scale, that is, between the terms "like moderately" and "like very much" (Table 8). The lowest scores were attributed to the sucralose-sweetened beverage (B3), with an average acceptance between 6 and 7 on the hedonic scale, that is, between the terms "like slightly" and "like moderately". The aspartame (B2) and aspartame/acesulfame-K blend (B4) - sweetened beverages received intermediate average scores.

Table 8. Average scores attributed by Brazilian consumers to color liking, aroma liking, overall liking 1, flavor liking, sweetness liking, sweetness intensity, texture liking, aftertaste liking, and overall liking 2 of passion fruit juice beverages sweetened with sucrose (B1), aspartame (B2), sucralose (B3), and aspartame/acesulfame-K blend (4:1) (B4) (N=132).

Beverages	Color	Aroma	Overall 1	Flavor	Sweetness	Sweetness Intensity	Texture	Aftertaste	Overall 2
B1	7.23^{a}	6.73^{a}	6.70^{a}	6.67^{a}	6.57^{a}	4.55^{a}	7.08^{a}	6.28^{a}	6.78^{a}
B2	6.92^{ab}	6.02^{b}	5.43^{b}	5.23^{b}	5.20^{b}	4.07^{bc}	6.45^{b}	4.94^{b}	5.57^{b}
B3	6.73^{b}	5.80^{b}	5.17^{b}	5.04^{b}	5.11^{b}	4.35^{ab}	6.36^{b}	4.72^{b}	5.30^{b}
B4	7.21^{a}	6.07^{b}	5.32^{b}	5.14^{b}	4.98^{b}	3.78^{c}	6.45^{b}	5.08^{b}	5.39^{b}

$^{a, b, c}$ Averages in a column followed by different letters represent significant differences (p<0.05).

Concerning aroma, flavor, sweetness, texture and aftertaste, the sucrose-sweetened beverage (B1) received significantly higher acceptance scores than the light beverages (B2, B3 and B4) (p<0.05), which did not differ significantly between each other (p>0.05) (Table 8). The sucrose-sweetened beverage (B1) showed average acceptance between 6 and 7 on the hedonic scale for all the attributes mentioned above, that is, between the terms "like slightly" and "like moderately". Differently, the light beverages (B2, B3 and B4), showed average acceptance between 5 and 6 on the hedonic scale, that is, between the terms "neither like nor dislike" and "like slightly" for aroma, flavor and sweetness; between 6 and 7 for texture (between the terms "like moderately" and "like very much"); and between 4 and 5 for aftertaste (between the terms "dislike slightly" and "neither like nor dislike").

When evaluating the consumer assessor distributions as a function of the scores attributed to the color of the beverages (Figure 6), it can be seen that most of the consumers (between 86% and 93%) liked the beverages sweetened with sucrose, aspartame, sucralose and the aspartame/acesulfame-K blend, attributing scores corresponding to the terms “neither like nor dislike” or more. Similar behavior was observed for aroma and texture: most of the consumers (between 67% and 89%, and between 86% and 97%, respectively) liked all the beverages, attributing scores corresponding to the term “neither like nor dislike” or better, despite the fact that 21% of the consumers attributed a score of 4 (“dislike slightly”) for the aspartame-sweetened beverage with respect to its aroma (Figure 6).

When evaluating the consumer assessor distributions as a function of the scores attributed to the flavor, sweetness and aftertaste of the beverages (Figure 7), it can be seen that most of the consumers (between 53% and 94%) liked the beverages, attributing scores corresponding to the term “neither like nor dislike” or better. It is important to notice, however, that the percentage of consumers who liked the standard beverage was notably superior to the percentage of consumers who liked the light beverages with respect to all these attributes.

Relative to the sweetness intensity of the beverages, the sucrose-sweetened beverage (B1) received the highest scores, not being significantly different from the sucralose-sweetened beverage (B3) ($p>0.05$) (Table 8). The lowest scores were attributed to the aspartame/acesulfame-K blend-sweetened beverage (B4), which did not differ from the aspartame-sweetened beverage (B2) ($p>0.05$).

When evaluating the consumer assessor distributions as a function of the scores attributed to the sweetness intensity of the beverages (Figure 8), it can be seen that most consumers (67% to 75%) rated all the beverages between 3 and 5, that is, between the terms “slightly sweet” and “moderately sweet”. Amongst these percentages, the highest percentages of consumers (45% and 35%) answered that the sucrose and sucralose-sweetened beverages, respectively, were “moderately sweet” (5 on the intensity scale). With respect to the aspartame and aspartame/acesulfame-k blend – sweetened beverages on the other hand, the highest percentages of consumers (35% and 39%, respectively) answered that these beverages were "slightly sweet" (3 on the intensity scale).

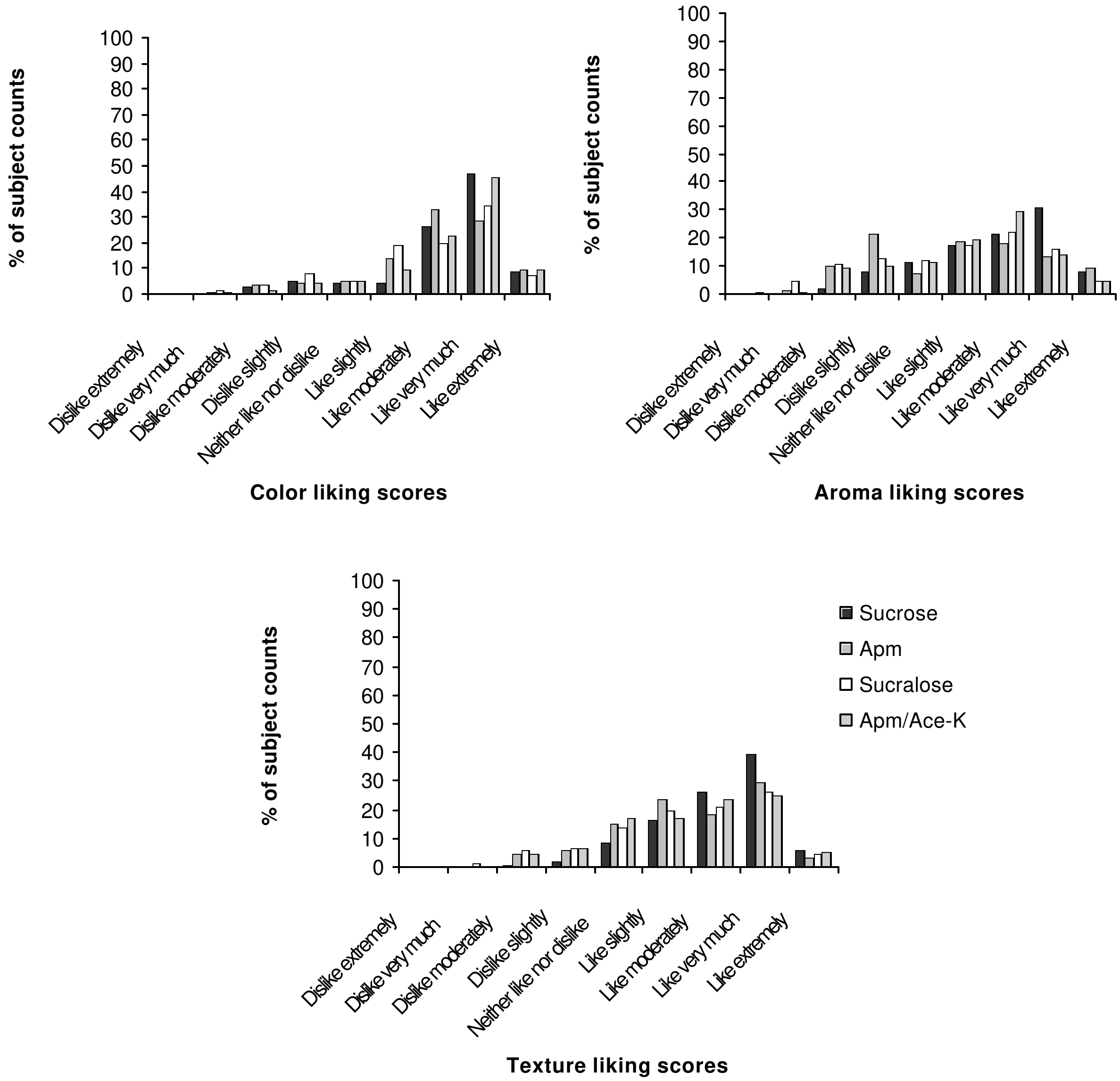

Figure 6. Distribution of Brazilian consumers as a function of the hedonic scores attributed to the color, aroma and texture of the beverages sweetened with sucrose, aspartame, sucralose and the aspartame/acesulfame-K blend (4:1).

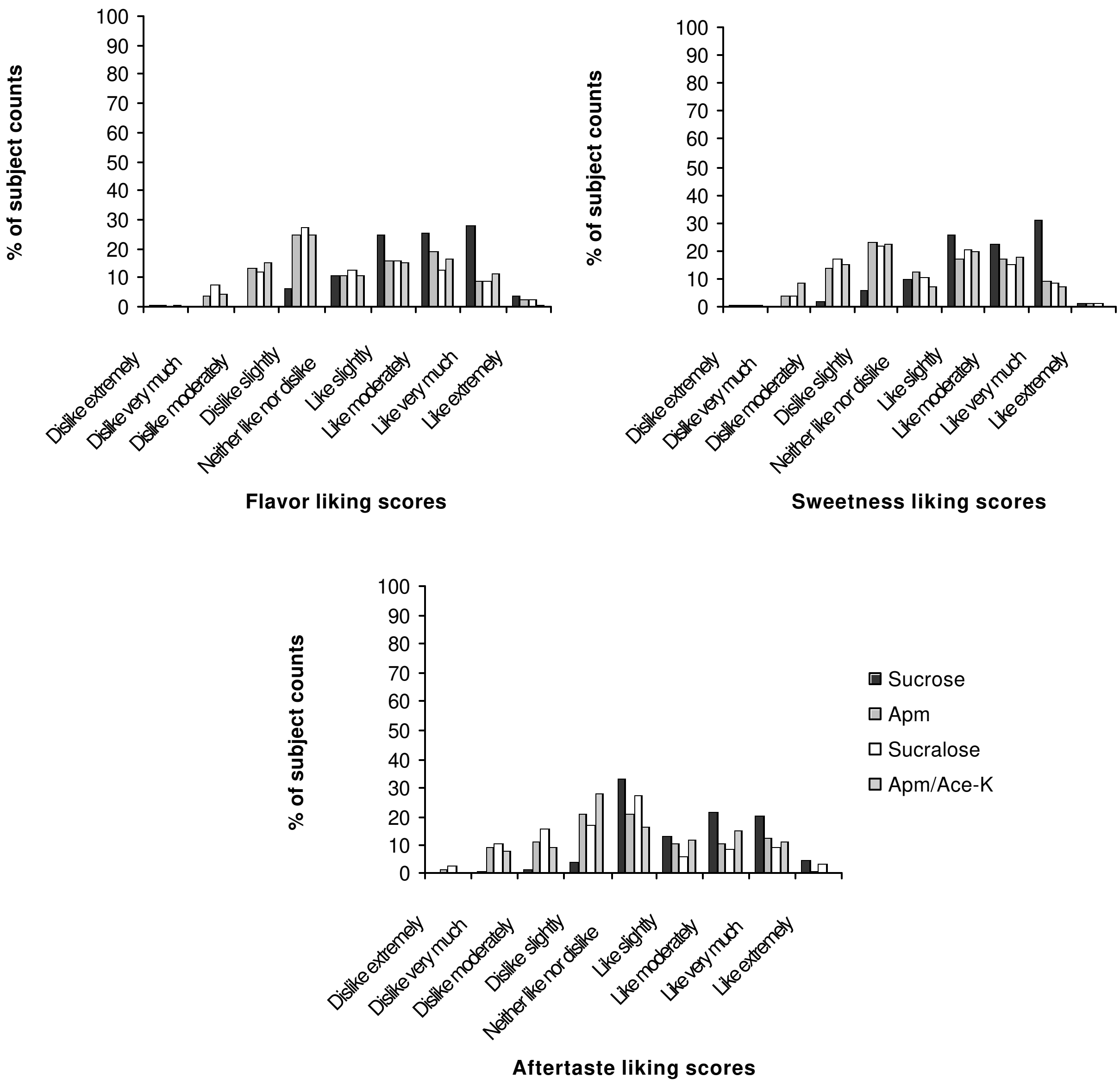

Figure 7. Distribution of Brazilian consumers as a function of the hedonic scores attributed to the flavor, sweetness and aftertaste of the beverages sweetened with sucrose, aspartame, sucralose and the aspartame/acesulfame-K blend (4:1).

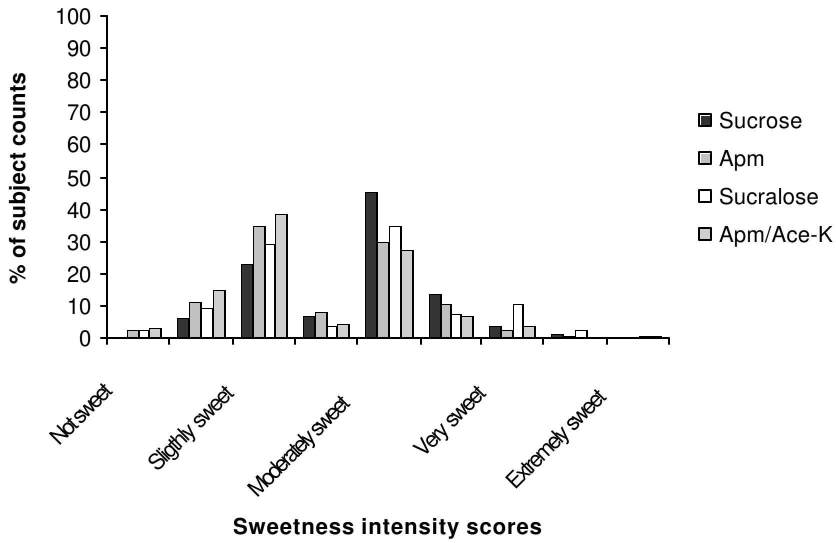

Figure 8. Distribution of Brazilian consumers as a function of the intensity scores attributed to the sweetness of the beverages sweetened with sucrose, aspartame, sucralose and the aspartame/acesulfame-K blend (4:1).

The overall liking evaluated at the beginning of the sensory testing (overall liking 1) and that evaluated at the end of the sensory testing (overall liking 2) were first compared using the multivariate analysis of variance (MANOVA), of which the results are presented in Figure 9.

It can be seen from Figure 9 that no significant difference between the overall liking 1 and the overall liking 2 scores – which showed a linear correlation coefficient of $r=0.90$ ($p=0.05$), was observed for all the beverages studied ($p>0.05$). This means that the initial expectation shown by Brazilian consumers was met at the end of testing, after they had evaluated each attribute individually. For this reason, only the overall liking 2 scores were discussed.

The average consumer scores attributed to overall liking 2 of the sucrose-sweetened beverage (B1), following the tendency observed for aroma, flavor, sweetness, texture and aftertaste, were significantly higher ($p<0.05$) than those attributed to overall liking 2 of the light beverages (B2, B3 and B4) ($p<0.05$), which did not differ significantly between each other ($p>0.05$) (Table 8). The sucrose-sweetened beverage (B1) showed average acceptance values between 6 and 7 on the hedonic scale, that is, between the terms “like slightly” and “like moderately”, while the light beverages (B2, B3 and B4) showed average acceptance scores between 5 and 6 on the hedonic scale, that is, between the terms “neither like nor dislike” and “like slightly”.

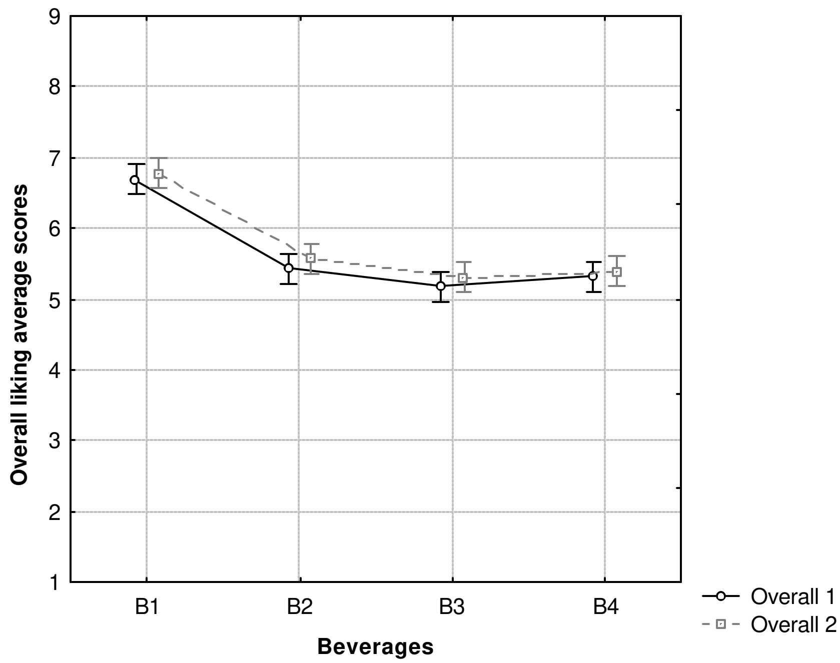

Figure 9. Distribution of the average scores attributed by Brazilian consumers to overall liking 1 (beginning of testing) and overall liking 2 (end of testing) of passion fruit juice beverages sweetened with sucrose (B1), aspartame (B2), sucralose (B3) and the aspartame/acesulfame-K blend (4:1) (B4).

When evaluating the consumer assessor distribution as a function of the scores attributed to the overall liking 2 of the beverages (Figure 10), it can be seen that 97% and around 65% of the consumers liked the beverages sweetened with sucrose and with high intense sweeteners, respectively, attributing scores between the corresponding terms “neither like nor dislike” and “like extremely”.

Another important finding with regard to the beverages overall liking was that the attributes flavor, sweetness, and aftertaste were the most considered by Brazilian consumers when rating the beverages overall. These results are shown in

Table 9, which presents the Pearson correlations between the overall liking 1 and overall liking 2 scores and the flavor, sweetness and aftertaste liking scores.

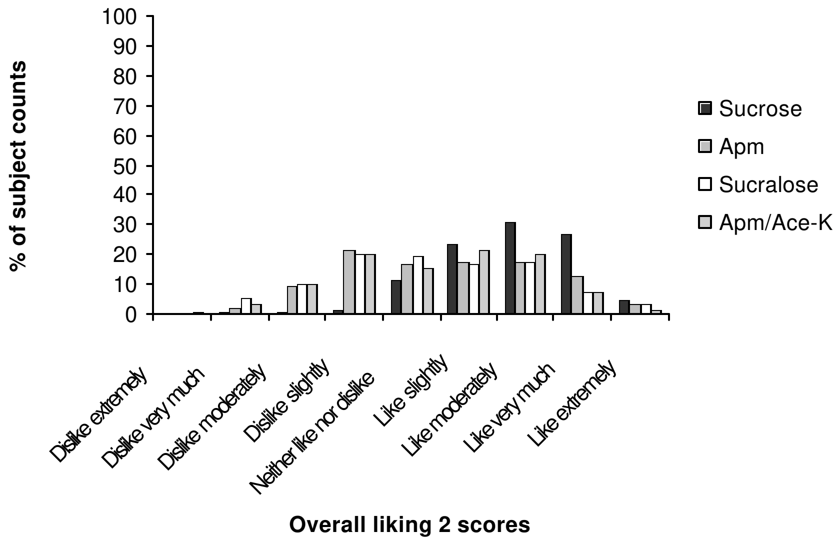

Figure 10. Distribution of Brazilian consumers as a function of the hedonic scores attributed to the overall liking 2 of the beverages sweetened with sucrose, aspartame, sucralose and the aspartame/acesulfame-K blend (4:1).

Table 9. Pearson correlations (r) between the overall liking 1 and overall liking 2 scores and the flavor, sweetness, and aftertaste liking scores (p=0.05) attributed by Brazilian consumers to sucrose, aspartame, sucralose and the aspartame/acesulfame-K blend (4:1) - sweetened beverages.

	Overall 1	**Overall 2**
Flavor	0.87	0.84
Sweetness	0.71	0.70
Aftertaste	0.63	0.70

When rating the beverages overall, the first attribute Brazilian consumers took into consideration was flavor, followed by sweetness and aftertaste. All these attributes correlated with overall liking 1 and overall liking 2 with similar strength, except for the attribute aftertaste, for which the correlation with overall liking 2 was stronger than the correlation with overall liking 1, that is, after evaluating each single taste, flavor, and texture attribute, the aftertaste had a stronger influence on the overall beverage acceptance than when rating the beverage overall at the beginning of testing.

Figure 11 illustrates the results obtained for sweetness, sourness and passion fruit flavor levels.

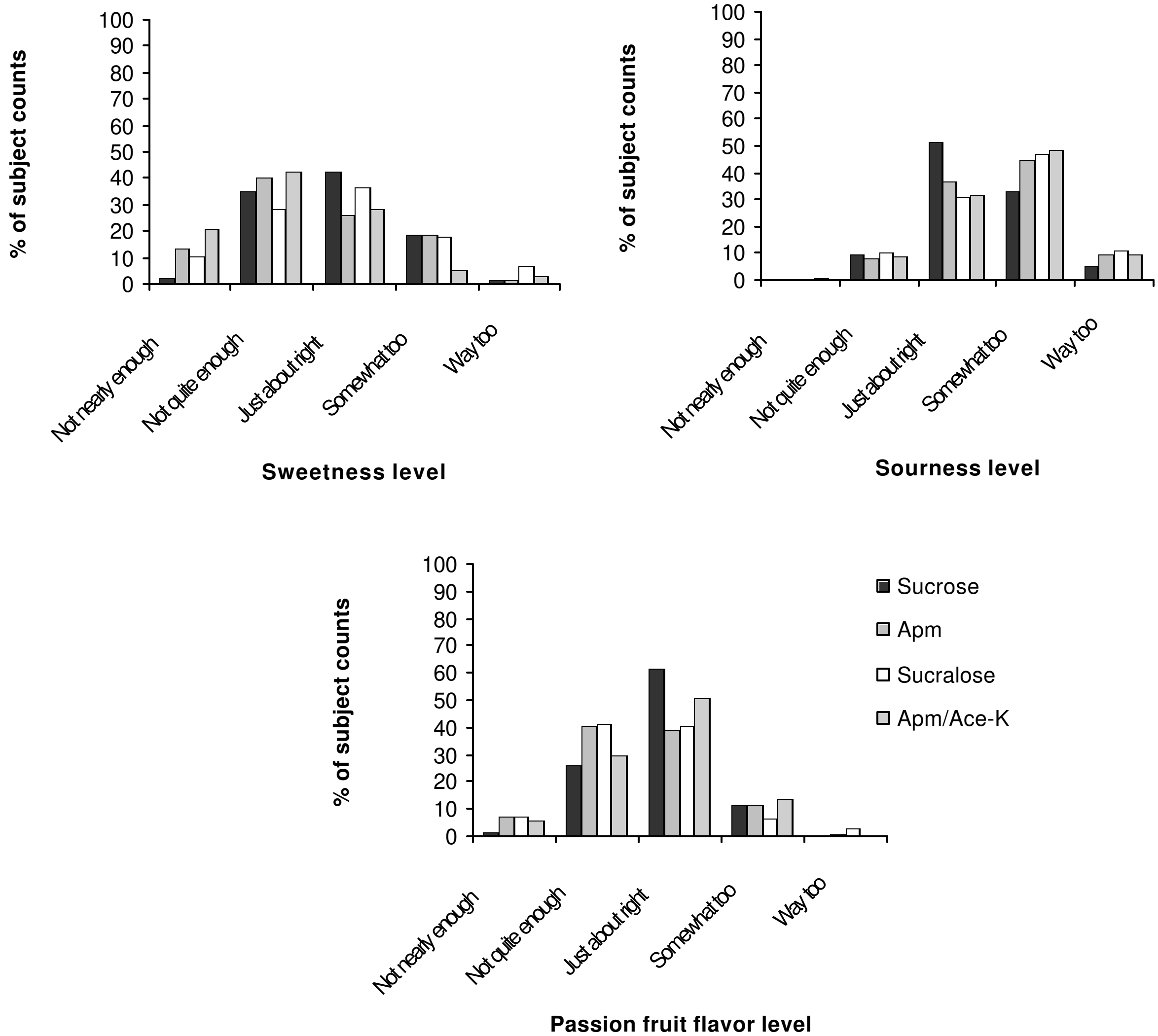

Figure 11. Distribution of Brazilian consumers as a function of the just right scale scores attributed to the passion fruit flavor of the beverages sweetened with sucrose, aspartame, sucralose and the aspartame/acesulfame-K blend (4:1).

As can be seen in Figure 11, the highest percentages of consumers (between 42% and 61%) answered that the sucrose-sweetened beverage was “just about right” in sweetness, sourness and passion fruit flavor level. With respect to the light beverages, most consumers (64%-70% and 80%-83%, respectively) answered that these beverages were between “not quite enough” and “just about right” in sweetness and passion fruit flavor, and the highest percentages of consumers (45%-48%) answered that these beverages were “somewhat too sour”. It is important to notice, however, that the sucralose-sweetened beverage showed similar behavior to that of the sucrose-sweetened beverage in regard to the sweetness level: the highest percentage of consumers (36%) answered that this beverage was “just about right” in sweetness. These results corroborated those obtained for sweetness intensity (Table 8, Figure 8). As mentioned before, the sucrose and the sucralose-sweetened beverages were rated the sweetest beverages and did not differ significantly ($p>0.05$) between each other. Following these beverages were the aspartame and the aspartame/acesulfame-K blend – sweetened beverages, less intense in sweetness than the first two beverages, and not significantly different from each other ($p>0.05$). These results could be attributed to the low stability of aspartame under certain pH, temperature, and time conditions. According to HOMLER et al. (1988), as the time at any given temperature increases, the percentage of aspartame remaining decreases; as the temperature increases for a given process time, the amount of aspartame remaining also decreases; and, concerning pH, aspartame is stable in the pH range 2.5 - 5.5, which includes the pH range of the passion fruit beverages studied (3.13 – 3.18). Thus, one possible conclusion is that losses in sweetness potency of aspartame may have occurred during the pasteurization of the beverages. Another possible conclusion is that consumers were not able to rate the sweetness intensity properly due to the fact that aspartame, sucralose and acesulfame-K have different sweetness profiles, that is, different sweetness impact, persistency and residual.

Figure 12 illustrates the purchase intention results. For the sucrose-sweetened beverage, 94% of consumers showed purchase intention between “Definitely would purchase” and “May or may not purchase” and the highest percentage of consumers (47%) showed purchase intention “Probably would purchase". For the aspartame, sucralose and the aspartame/acesulfame-K blend - sweetened beverages, 67%, 60% and 61% of consumers, respectively, showed purchase intention between "Definitely would purchase" and "May or may not purchase". Among these percentages, the highest percentages of consumers (37%, 33% and 33%, respectively) showed purchase intention "May or may not purchase" for all the light beverages (Figure 12). These results matched the overall liking results (Table 8, Figure 10).

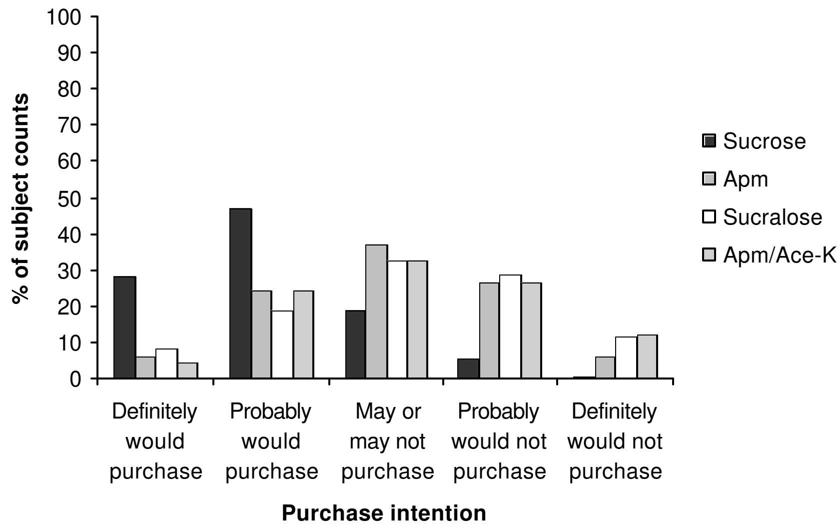

Figure 12. Distribution of Brazilian consumers as a function of purchase intention scores attributed to the beverages sweetened with sucrose, aspartame, sucralose and the aspartame/acesulfame-K blend (4:1).

The results obtained from the sensory evaluation performed by American consumers are presented in Tables 10 and 11 and Figures 13-19.

Concerning the color of the beverages, the sucralose-sweetened beverage (B3) received the highest liking scores, with an average acceptance of 7 on the hedonic scale, that is, corresponding to the term "like moderately", and did not differ significantly from the sucrose (B1) and the aspartame/acesulfame-K blend (B4) – sweetened beverages (p>0.05) (Table 10). The lowest color liking scores were attributed to the aspartame-sweetened beverage (B2), with an average acceptance between 6 and 7, that is, between the terms "like slightly" and "like moderately", being not significantly different (p>0.05) from the aspartame/acesulfame-K blend–sweetened beverage (B4). These results were different from those obtained in Brazil, where the sucralose-sweetened beverage (B3) was the least accepted beverage (Table 8).

Table 10. Average scores attributed by American consumers to color liking, aroma liking, overall liking 1, flavor liking, sweetness liking, sweetness intensity, texture liking, aftertaste liking and overall liking 2 of passion fruit juice beverages sweetened with sucrose (B1), aspartame (B2), sucralose (B3) and the aspartame/acesulfame-K blend (4:1) (B4) (N=189).

Beverages	Color	Aroma	Overall 1	Flavor	Sweetness	Sweetness Intensity	Texture	Aftertaste	Overall 2
B1	6.89^{a}	6.83^{a}	7.06^{a}	7.02^{a}	6.72^{a}	5.19^{a}	6.64^{a}	6.43^{a}	6.97^{a}
B2	6.57^{b}	6.69^{a}	6.37^{b}	6.20^{b}	5.86^{b}	5.14^{a}	6.25^{b}	5.54^{b}	6.12^{b}
B3	6.99^{a}	6.66^{a}	6.23^{b}	6.06^{b}	5.67^{b}	5.14^{a}	6.30^{b}	5.21^{b}	6.02^{b}
B4	6.75^{ab}	6.63^{a}	6.14^{b}	5.98^{b}	5.59^{b}	4.44^{b}	6.28^{b}	5.48^{b}	5.88^{b}

^{a,b} Averages in a column followed by different letters represent significant differences (p<0.05).

Concerning the aroma, no significant difference (p>0.05) was observed among the beverages, which presented average acceptance scores between 6 and 7 on the hedonic scale, that is, between the terms “like slightly” and “like moderately”. These results were different from those obtained in Brazil, where consumers attributed significantly higher acceptance scores to the sucrose-sweetened beverage than to the light beverages (p<0.05) (Table 8).

Concerning flavor, sweetness, texture and aftertaste, similarly to that observed in Brazil, the sucrose-sweetened beverage (B1) received significantly higher acceptance scores than the light beverages (B2, B3 and B4) (p<0.05), which did not differ significantly between each other (p>0.05) (Table 10). The sucrose-sweetened beverage (B1) showed average acceptance between 6 and 7 on the hedonic scale for all the attributes mentioned above, that is, between the terms “like slightly” and “like moderately”. Differently, the light beverages (B2, B3 and B4) showed average acceptance scores between 6 and 7 on the hedonic scale, that is, between the terms “like slightly” and “like moderately”, for flavor and texture, and between 5 and 6, that is, between the terms “neither like nor dislike” and “like slightly” for sweetness and aftertaste.

When evaluating the consumer assessor distributions as a function of the scores attributed to the color of the beverages (Figure 13), it can be seen that most consumers (between 89% and 93%) liked all the beverages, attributing scores corresponding to the term “neither like nor dislike” or better. Similar behavior was observed for aroma and texture: most consumers (between 86% and 89%, and between 85% and 91%, respectively) liked all the beverages, attributing scores corresponding to the term “neither like nor dislike” or better. These results were very similar to those obtained in Brazil.

When evaluating the consumer assessor distribution as a function of the scores attributed to the flavor, sweetness and aftertaste of the beverages (Figure 14), it can be seen that most consumers (between 58% and 94%) liked the beverages, attributing scores corresponding to the term “neither like nor dislike” or better. It’s important to notice however, that similarly to that observed in Brazil, the percentage of American consumers who liked the standard beverage was notably superior to the percentage of consumers who liked the light beverages concerning all those attributes.

Differences were observed when comparing the two markets concerning the sweetness intensity of the beverages. In the USA, the sucrose (B1), aspartame (B2) and sucralose (B3) - sweetened beverages were perceived to be significantly sweeter ($p<0.05$) than the aspartame/acesulfame-K blend – sweetened beverage (B4) (Table 10), while in Brazil, the sucrose (B1) and the sucralose (B3) – sweetened beverages were rated the most intense in sweetness, followed by the aspartame and last by the aspartame/acesulfame-K blend-sweetened beverages (Table 8). Moreover, Americans rated the sweetest beverages around 5.0 (moderately sweet) and the least sweet beverage between 4 and 5, while Brazilians rated the sweetest beverages between 4 and 5 and the least sweet beverage between 3 and 4.

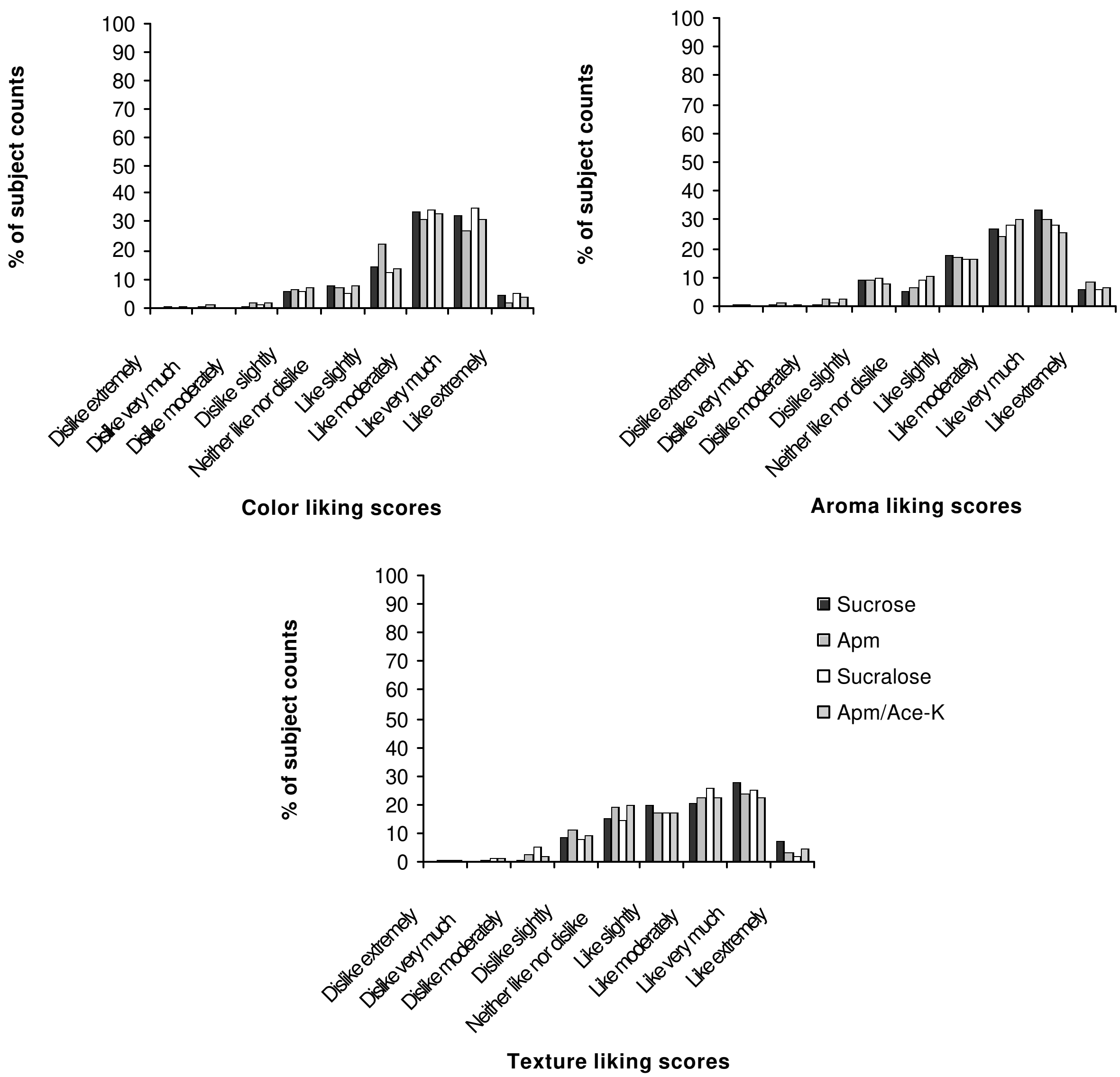

Figure 13. Distribution of American consumers as a function of the hedonic scores attributed to the color, aroma and texture of the beverages sweetened with sucrose, aspartame, sucralose and the aspartame/acesulfame-K blend (4:1).

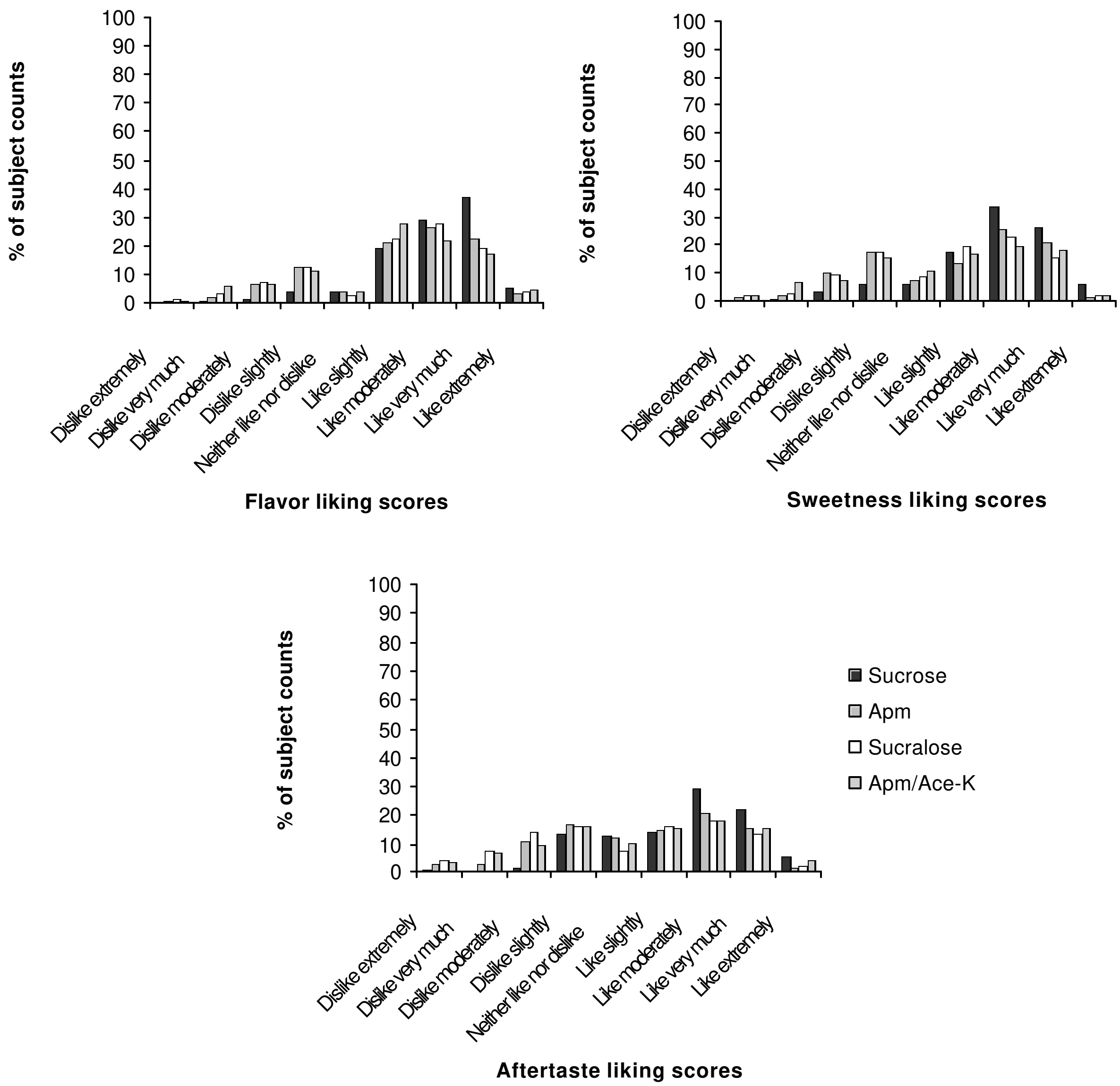

Figure 14. Distribution of American consumers as a function of the hedonic scores attributed to the flavor, sweetness and aftertaste of the beverages sweetened with sucrose, aspartame, sucralose and the aspartame/acesulfame-K blend (4:1).

When evaluating the consumer assessor distribution as a function of the scores attributed to the sweetness intensity of the beverages (Figure 15), it can be seen that 59% to 67% of the consumers rated the beverages sweetened with sucrose, aspartame and sucralose between 5 and 7, that is, between the terms “moderately sweet” and “very sweet”, and 61% of the consumers rated the beverage sweetened with the aspartame/acesulfame-K blend (4:1) between 3 and 5 (between the terms “slightly sweet” and “moderately sweet”). Among these percentages, the highest percentages of consumers (27%-34%) answered that all the beverages were “moderately sweet” (5 on the intensity scale). These results differed from those obtained in Brazil, where the sucrose and sucralose-sweetened beverages were rated “moderately sweet” by most consumers while the aspartame and the aspartame/acesulfame-K blend – sweetened beverages were rated “slightly sweet” by most consumers (Figure 8).

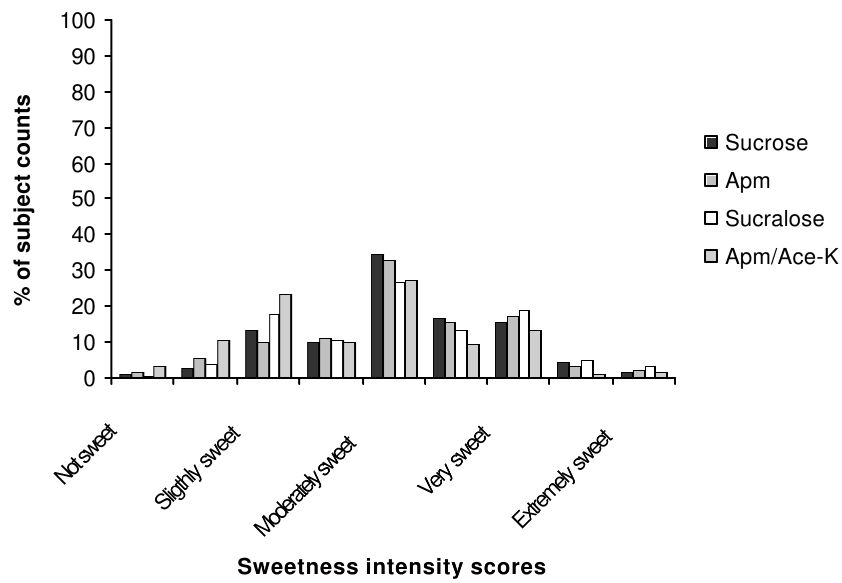

Figure 15. Distribution of American consumers as a function of intensity scores attributed to the sweetness of the beverages sweetened with sucrose, aspartame, sucralose and the aspartame/acesulfame-K blend (4:1).

Figure 16 illustrates the results obtained from comparing the overall liking 1 and overall liking 2 scores.

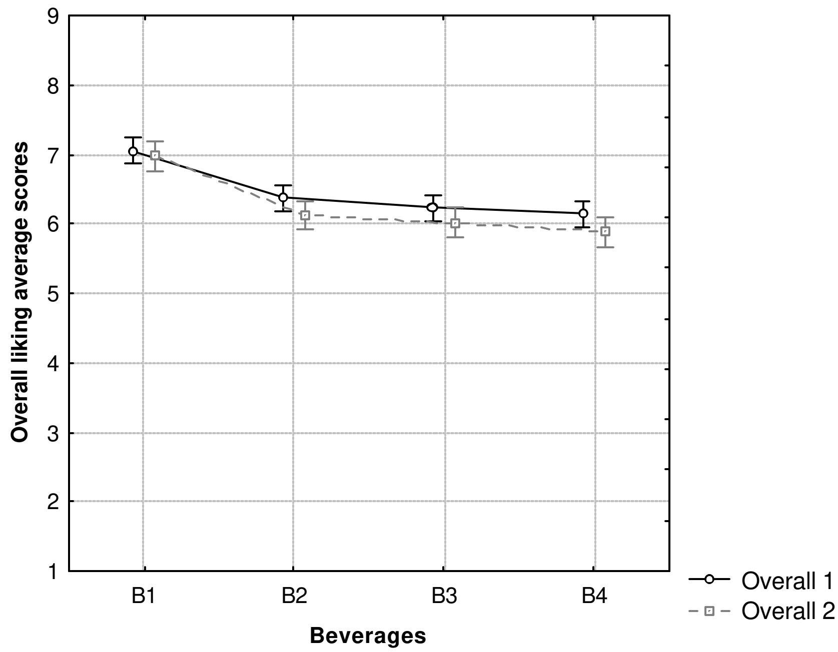

Figure 16. Distribution of the average scores attributed to overall liking 1 (beginning of testing) and overall liking 2 (end of testing) of passion fruit juice beverages sweetened with sucrose (B1), aspartame (B2), sucralose (B3) and the aspartame/acesulfame-K blend (4:1) (B4).

Similar to that observed in Brazil, no significant difference between the overall liking 1 and overall liking 2 scores – which showed a linear correlation coefficient of $r=0.87$ ($p=0.05$), was observed for all the beverages studied in the USA ($p>0.05$) (Figure 16). That is, the initial expectation shown by American consumers was met at the end of testing, after they had evaluated each single attribute. For this reason, only the overall liking 2 scores were discussed.

The consumer average scores attributed to overall liking 2 of the sucrose-sweetened beverage (B1), following the tendency observed for flavor, sweetness, texture and aftertaste, were significantly higher ($p<0.05$) than those attributed to overall liking 2 of the beverages sweetened with aspartame (B2), sucralose (B3) and the aspartame/acesulfame-k blend (B4), which did not differ significantly between each other ($p>0.05$) (Table 10). The sucrose-sweetened beverage (B1) showed average acceptance scores very close to 7 on the hedonic scale, that is, corresponding to the term "like moderately". Differently, the light beverages (B2, B3 and B4) showed average acceptance scores around 6 on the hedonic scale, that is, corresponding to the term “like slightly”. These results were similar to those obtained in Brazil (Table 8). Worth noting, however, is that American consumers attributed higher scores to the light beverages as compared to Brazilians.

When evaluating the consumer assessor distribution as a function of the scores attributed to the overall liking 2 of the beverages (Figure 17), it can be seen that 91% and around 75% of the consumers liked the beverages sweetened with sucrose and with high intense sweeteners, respectively, attributing scores between the corresponding terms “neither like nor dislike” and “like extremely”.

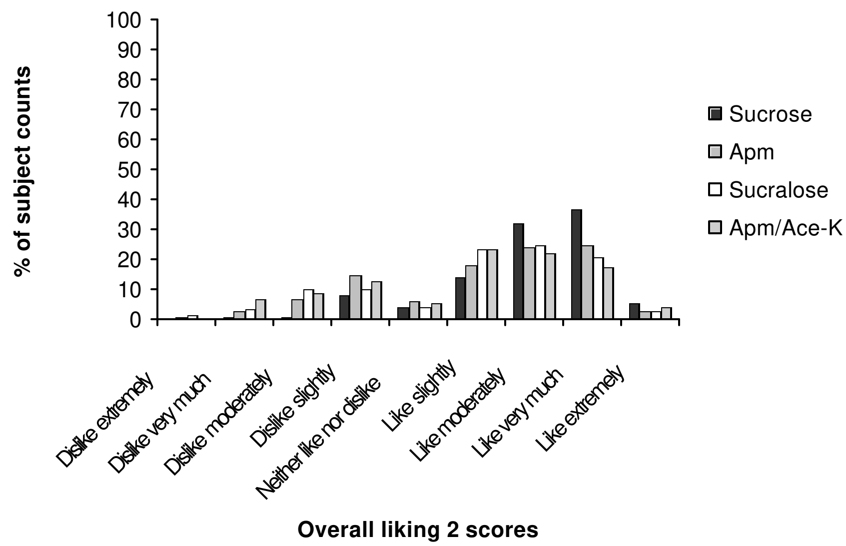

Figure 17. Distribution of American consumers as a function of the hedonic scores attributed to the overall liking 2 of the beverages sweetened with sucrose, aspartame, sucralose and the aspartame/acesulfame-K blend (4:1).

Similar to that observed in Brazil, flavor, sweetness and aftertaste were the most considered by American consumers when rating the beverages overall. These results are shown in Table 11, which presents the Pearson correlations between the overall liking 1 and overall liking 2 scores and the flavor, sweetness and aftertaste liking scores.

Table 11. Pearson correlations (r) between the overall liking 1 and overall liking 2 scores and the flavor, sweetness and aftertaste liking scores (p=0.05) attributed by American consumers to the sucrose, aspartame, sucralose and the aspartame/acesulfame-K blend (4:1) - sweetened beverages.

	Overall 1	**Overall 2**
Flavor	0.86	0.85
Sweetness	0.74	0.76
Aftertaste	0.65	0.74

As can be seen in Table 11, flavor and sweetness correlated with overall liking 1 and overall liking 2 with similar strength. The correlation between aftertaste and overall liking 2, however, was stronger than that with overall liking 1, indicating that the aftertaste had a stronger influence on the beverage overall acceptance after the consumers had evaluated each single taste, flavor and texture attribute (at the end of sensory testing). These results were very similar to those obtained in Brazil.

Besides sweetness intensity, the most evident differences observed when comparing the two markets concerned the sweetness, sourness and passion fruit flavor levels (Figure 18).

As can be seen in Figure 18, the highest percentages of consumers (between 65% and 74%) answered that the sucrose-sweetened beverage was "just about right" in sweetness, sourness and passion fruit flavor level. With respect to the light beverages, over 50% of the consumers answered that the aspartame and sucralose-sweetened beverages were "just about right" in sweetness, while 71% of the consumers answered that the aspartame/acesulfame-K blend – sweetened beverage was between the terms "not quite enough" and "just about right" in sweetness. These results corroborated those obtained for sweetness intensity (Table 10, Figure 15). As mentioned before, the aspartame/acesulfame-K blend – sweetened beverage was rated less sweet than the other beverages ($p<0.05$). Over 50% of the consumers answered that all the light beverages were "just about right" in sourness and passion fruit flavor level. These results were different from those obtained in Brazil, where all the light beverages were rated by most of the consumers as between “not quite enough” and “just about right” in sweetness and passion fruit flavor level, and “somewhat too sour” (Figure 11).

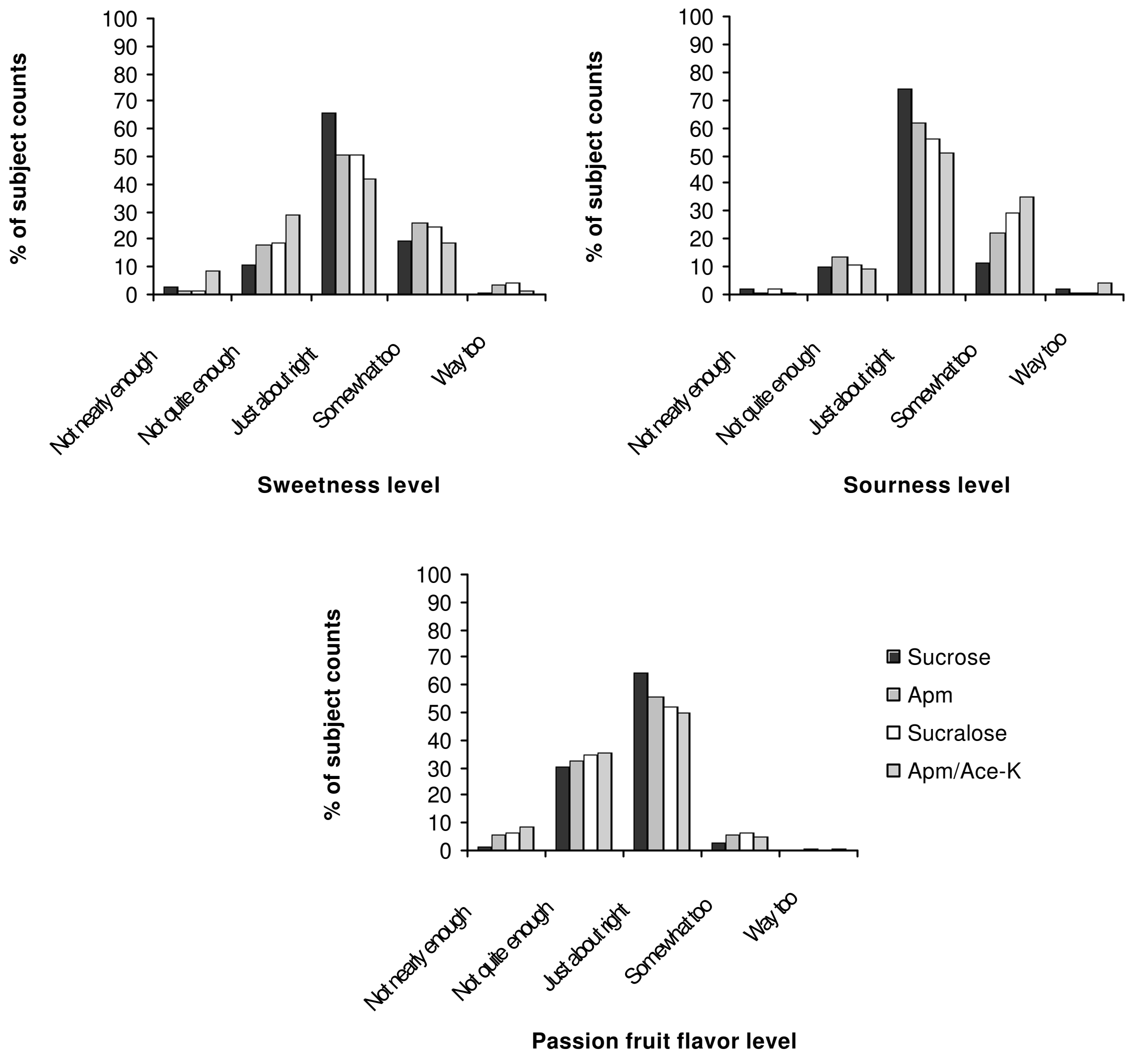

Figure 18. Distribution of American consumers as a function of the just right scale scores attributed to sweetness, sourness and passion fruit flavor of the beverages sweetened with sucrose, aspartame, sucralose and the aspartame/acesulfame-K blend (4:1).

Figure 19 illustrates the purchase intention results. It can be seen from this figure that for the sucrose-sweetened beverage, 83% of the consumers showed purchase intention between “Definitely would purchase” and “May or may not purchase”. Amongst these, the highest percentage of consumers (38%) showed purchase intention of “Probably would purchase”. For the aspartame, sucralose and the aspartame/acesulfame-K blend - sweetened beverages, 66%, 65% and 63% of consumers, respectively, showed purchase intention between “Definitely would purchase” and “May or may not purchase”. Amongst these, the highest percentage of consumers (30%, 30% and 28%, respectively) showed purchase intention of “May or may not purchase” for all the light beverages (Figure 19). These results were similar to those obtained in Brazil (Figure 12) and coherent with the overall liking results (Table 11, Figure 16).

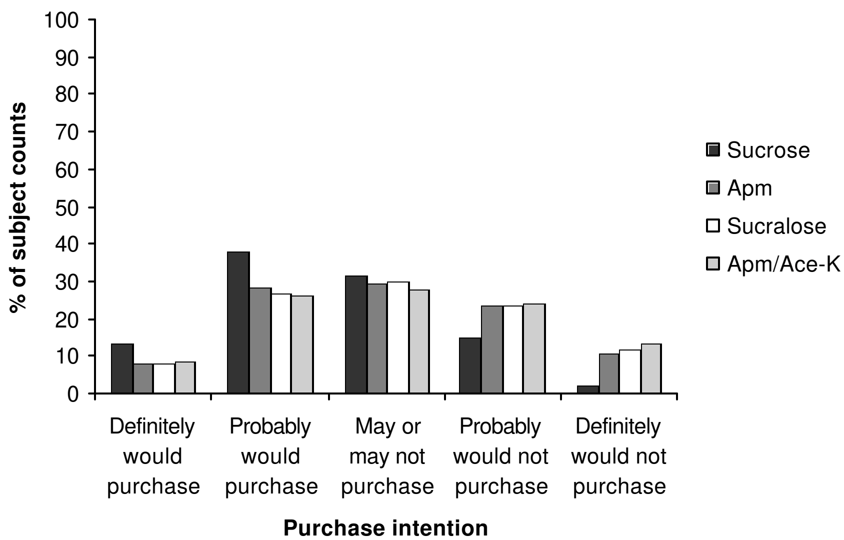

Figure 19. Distribution of American consumers as a function of the purchase intention scores attributed to the beverages sweetened with sucrose, aspartame, sucralose and the aspartame/acesulfame-K blend (4:1).

Overall, in Campinas/BR as well as in Corvallis/USA, the sucrose-sweetened beverage was more accepted than the light beverages with respect to most of the evaluated attributes. All the same, consumers rated all the beverages above 5.0 (“neither like nor dislike”) with respect to their overall acceptance, and showed favorable purchase intention. Moreover, the initial overall expectation shown by consumers was confirmed at the end of the sensory evaluation with respect to all the beverages. It is interesting to note, however, that the scores given to most of the attributes were slightly higher in the USA when compared to those given in Brazil, except for color and texture. One explanation for this could be that Brazilians are very familiar with passion fruit juice while Americans are not at all familiar with it (ORTH & DE MARCHI, 2005, 2006). Despite this, in general, no expressive differences were found between the two markets concerning the liking attributes. Differences did occur, however, when consumers were asked to rate the sweetness intensity, and the sweetness, sourness, and passion fruit flavor levels of the beverages. It appears that American consumers liked the beverages less sweet than the Brazilians, since most of them rated the beverage sweetness intensity and sweetness level higher as compared to the Brazilians. It is also interesting to notice that, according to the Brazilian consumers, the sucrose and sucralose-sweetened beverages were very similar with respect to their sweetness intensity, being followed by the aspartame and aspartame/acesulfame-K blend-sweetened beverages, while American consumers perceived the sucrose, aspartame and sucralose-sweetened beverages as sweeter than the aspartame/acesulfame-K blend-sweetened beverage. In other words, the sweetness intensity of the light beverages was perceived as slightly different depending on the local consumers. Rather than attributing these differences in sweetness to the low stability of aspartame under certain temperature conditions (HOMLER et al., 1998), it is much more probable that it occurred because high intense sweeteners such as those used in this research (aspartame, sucralose and acesulfame-K) have different sweetness profiles, that is different sweetness impact, persistence and residual, which makes it difficult for untrained panelists to rate its sweetness intensity properly. The results of the descriptive analysis (Chapter “Sensory profile and stability of a new passion fruit juice beverage with different sweetener systems”, Table 2 and Figure 3) support this conclusion since no significant difference ($p>0.05$) was observed between the four differently-sweetened beverages at 0 day of storage. Descriptive results demonstrate that losses in the sweetness potency of aspartame occurred more during storage than during the pasteurization.

Americans liked the beverage sourness and passion fruit flavor level, whereas Brazilians would show higher acceptance were the beverages less sour and more intense in passion fruit flavor. Again, an explanation for this could be the high degree of familiarity of Brazilians with passion fruit juice, which makes them more demanding consumers. However, other cultural factors should also be investigated, such as the consumption of artificially flavored versus naturally flavored passion fruit juices.

Flavor, sweetness and aftertaste were the most important attributes for consumers on both markets when they were asked to rate the beverages overall, revealing the need for giving them a strong emphasis when formulating similar beverages. Besides, both in Brazil and the USA, pineapple juice was found to be a strong competitor for the studied passion fruit juice beverage. This information is very useful since it provides product developers with more insight into the kind of competition to be expected when launching a new passion fruit juice based beverage on either of these markets.

Finally, when designing the “ideal” passion fruit juice beverage, an orange, non-carbonated beverage, sold in a 200mL organic package for $0.53 per unit is the product with the highest acceptance on the Brazilian market, while an orange, carbonated beverage in a 1 quart organic package sold for $2.67 apiece best meets consumer preference on the U.S. market.

4. Conclusions

Based on the results obtained in this research it was concluded that the sensory properties of the beverages could be standardized, that is, the same formula, with only minor adjustments, could be successfully commercialized both in Brazil and the USA. Those adjustments concerned sweetness, sourness and passion fruit flavor levels, besides improving the light beverage aftertaste. Further evaluations with a carbonated version of the beverages could also be performed, and the package size of the beverages should be adapted for each country in order to better meet local market preferences.

5. Acknowledgments

We acknowledge CNPq, Brazil, for the financial support, De Marchi Indústria e comércio de Frutas, the passion fruit supplier, and Oregon State University, where this study was performed. The authors are also grateful to the sensory panelists who contributed their time and efforts to this study.

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Sensory profile and stability of a new ready-to-drink passion fruit juice beverage with different sweetener systems

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This paper will be submitted to Journal of Sensory Studies

Sensory profile and stability of a new ready-to-drink passion fruit juice beverage with different sweetener systems

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Abstract

The aim of this work was to determine the sensory profile and stability of a new ready-to-drink passion fruit juice beverage sweetened with different sweetener systems: sucrose, aspartame, sucralose and an aspartame/acesulfame-K blend (4:1), during six months of storage. Samples of each beverage were stored at room temperature and under refrigeration, and were evaluated at 0, 60, 120 and 180 days of storage. Descriptive sensory profiles and the stability of the beverages were determined using a trained panel (n=8). The sweetener type played a very important role in the perception of color, sweet taste, sweet aftertaste and sour aftertaste. The beverages sweetened with sucrose and sucralose were the most stable with respect to those characteristics. In the beverages containing aspartame, on the other hand, the intensities of those descriptors were only preserved if stored under refrigeration. Storing the beverages under refrigeration was crucial to preserve the fresh fruit aroma and flavor characteristics in all the beverages, independently of the sweetener type, during at least 120 days of storage, period after which those characteristics started to decrease at the same time as the canned fruit aroma and flavor, overripe fruit aroma and fishy aroma and flavor increased. The results indicated that the best option of sweetener to be used in the ready-to-drink natural passion fruit juice beverage studied was the sucrose for the standard version and the sucralose for the light version.

Keywords: passion fruit juice beverage, sweeteners, sensory profile, stability

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1. Introduction

The ready-to-drink fruit based beverages segment is growing all over the world due to consumer preference for health beverages. Consumers want to enjoy beverages that not only quench thirst but also offer innovation, health, convenience and some nutritional value (LÓPEZ, 2004; BERTO, 2003; ADBDULLAH & CHENG, 2001).

Among the tropical fruit juices consumed on both internal and external markets, passion fruit juice stands out due to its exotic and intense flavor, strong aroma, high acidity and pulp yield (SOUZA et al., 2002; GARRUTI, 1989). This beverage is very appreciated by Brazilian consumers, who are responsible for 90% of the total passion fruit juice consumed in the world (VERA, 2003; SANDI, 2003). Passion fruit juice is also exported - mostly frozen and concentrated (50°Brix), to Holland, followed by the USA and Germany (FRACARO, 2004).

Parallel to consumer preference for health beverages, there is an increasing trend for the consumption of low calorie beverages. Today's consumers are increasingly better informed about diet and, as a result, they look for foods with reduced content of sugars and oils. Therefore, the production of beverages containing less sucrose or sucrose substitutes is of increasing importance to the beverage industry (NABORS & GELARDI, 1986).

Sweetness plays a major role in the sensory acceptance of many foods, especially beverages. Different sweetener types may provide similar sweetness but simultaneously impart different "flavor" characteristics to the beverage system in which they are used (BALDWIN & KORSCHGEN, 1979; REDLINGER & SETSER, 1987; NAHON et al., 2002). Relative sweetness is also influenced by temperature and acidity (GIESE, 1992). Furthermore, the sweetness intensity of many high intense sweeteners may change during storage. Thus when food products and beverages are sweetened with high intense sweeteners, it is important to determine that the products have adequate shelf lives and that there is no effective loss of sweetness under the conditions of use or storage (QUINLAN & JENNER, 1990). Accordingly, the objective of this study was to determine the sensory profile and stability of a new ready-to-drink passion fruit juice beverage sweetened with different sweetener systems: sucrose, aspartame, sucralose and an aspartame/acesulfame-K blend (4:1), during six months of storage.

2. Material and Methods

Samples

The samples consisted of four ready-to-drink, Tetra-Pak® packaged passion fruit juice beverages, of which the ingredients included: passion fruit pulp (De Marchi Indústria e Comércio de Frutas Ltda®), propylene glycol alginate (ISP do Brasil®), natural passion fruit aroma (Givaudan®), water and sweetener. The standard beverage was sweetened with 10% sucrose (União®), and the light beverages with 10% sucrose equi-sweet concentrations of aspartame, sucralose and an aspartame/acesulfame-K blend (4:1): 0.043%, 0.016% and 0.026%, respectively.

The sucrose, aspartame, sucralose and aspartame/acesulfame-K blend - sweetened beverages were stored at room temperature (20-25°C) and under refrigeration (2-5°C) during 6 months. Samples of each beverage, stored under both temperature conditions, were evaluated at each of the following shelf-life periods: 0, 60, 120 and 180 days. In order to avoid retraining the panelists at every period of evaluation, the samples were frozen and evaluated at the end of the study. Thus for each period of shelf-life (0, 60, 120 and 180 days), 250mL samples of each beverage, stored under both temperature conditions, were bottled into 375 mL glass bottles, filled in with N_2, covered with plastic screw caps and frozen. Frozen samples were kept at -23°C until used. At the end of the shelf-life period, all the samples were thawed and submitted to a Descriptive Analysis.

Descriptive analysis

The sensory profile of the four different-sweetened passion fruit juice beverages and the changes occurring in the beverages during 6 months of storage were monitored by a trained descriptive panel.

Eight panelists, from a group of 16 professional panelists from the Department of Food Science and Technology of Oregon State University (with a minimum of 250 hours of sensory work on a wide variety of foods using the Generic Descriptive Analysis), were selected according to their perception of sweetness and passion fruit flavor. Ranking tests with samples of passion fruit juice beverage containing five different concentrations of sucrose and passion fruit pulp were performed in triplicate.

The panelists were trained in 12 sessions over a period of 4 weeks. In the initial training sessions, the panelists evaluated the samples and generated their own descriptive terms for appearance, aroma, flavor, texture and aftertaste. In subsequent sessions, reference materials were provided to help standardize the panelists in the use of each descriptive term. Further training sessions and group discussions under the panel leader's guidance resulted in the final ballot (Figure 1). A written, consensus definition of each descriptive term was developed and reviewed by each panelist before each testing session (Table 1). The discussion and evaluation of a wide array of passion fruit beverages was also conducted during training to enable panelists to consistently differentiate and replicate the samples. The intensity of each descriptor was rated on a 16-point structured scale (0=none, 3=slight, 7=moderate, 11=large, 15=extreme). Intensity standards were provided as scale reference points to reduce the variability among panelists. The standards were anchored at point 3 (40 ml of safflower oil, Saffola Quality Foods Inc.), 7 (30 ml of orange drink, Hi-C, Coca Cola Foods), 11 (30 ml of grape juice, Welch's) and 13 (cinnamon bubble gum, Plen T-Pak Big Red). The panelists were also presented with reference solutions of basic tastes. An analysis of the data collected from training sessions confirmed that the panel results were consistent and that the terms were not redundant.

For the sensory evaluation, samples of each beverage were served at 5°C in tulip shaped wine glasses coded with random 3-digit numbers and capped with plastic lids. Sample evaluation was carried out in individual booths under white lighting.

Experimental design

A randomized full factorial design (4 types of sugar x 2 temperature conditions x 4 times of shelf-life study) was used to test the appearance, aroma, flavor, texture and aftertaste of the 32 samples, which were evaluated in 8 distinct sessions. This procedure was repeated three times (three replications over the treatments), amounting to a total of 96 samples per panelist.

Data analysis

Analysis of variance (ANOVA), correlation and principal component analyses were conducted using the SAS statistical package (SAS Institute, Cary, NC). ANOVA was based on a randomized complete block design, with panelists as a block.

Please, evaluate each sample using the 16-point scale presented below.

0 – None
1 – Just detectable
2
3 – Slight
4
5 – Slight to Moderate
6
7 – Moderate
8
9 – Moderate to Large
10
11 – Large
12
13 – Large to Extreme
14
15 – Extreme

Appearance	
Color intensity	
Amount of particles	
Aroma	
Overall intensity	
Overall fresh fruit	
passion fruit	
Pineapple	
Orange	
Peach	
Overall canned fruit	
Overripe fruit	
Fir-pine tree	
Grassy	
Fishy	

Flavor	
Overall flavor	
Sweet	
Sour	
Overall fresh fruit	
passion fruit	
pineapple	
orange	
peach	
Overall canned fruit	
Fishy	
Texture	
Wateriness	
Aftertaste	
Sour	
Sweet	
Artificial sweetness	

Figure 1. Sensory ballot used by the descriptive sensory panel during the evaluation of the passion fruit beverage appearance, aroma, flavor, texture and aftertaste.

Table 1. Attribute definitions and reference standards used by the descriptive sensory panel during the evaluation of the passion fruit beverage appearance, aroma, flavor, texture and aftertaste.

Descriptor	Definition and reference preparation
Appearance	
Color intensity	The intensity of yellow from light to dark.
Amount of particles	The total amount of visible yellow particles.
Aroma	
Overall aroma intensity	The overall impact (intensity) of all aromas as perceived by the nose.
Overall fresh fruit	The overall impact (intensity) of fresh fruit aromas.
Passion fruit	An aroma note associated with 30mL passion fruit pulp (De Marchi Indústria e Comércio de Frutas Ltda).
Pineapple	An aroma note associated with 30g of 2cm pieces of fresh pineapple.
Orange	An aroma note associated with 30g of 2cm pieces of fresh orange.
Peach	An aroma note associated with 30g of 2cm pieces of fresh peach.
Overall canned fruit	An aroma note associated with a mixture of 6g canned apricot nectar (Kerns), 6g canned peach (Del Monte), 6g canned pineapple (Dole), 6g canned mandarin orange (Del Monte), and 6g canned pear (Kroger).
Overripe fruit	An aroma note associated with overripe fruits.
Fir-pine tree	An aroma note associated with 10g fresh fir-pine needles.
Grassy	Green, slightly sweet aromatic associated with 10g fresh cut grass.
Fishy	Aromatic associated with 30mL Norwegian cod liver oil (Natural Choices).
Flavor	
Overall flavor intensity	The overall flavor impact (intensity) as perceived in the mouth, which includes all the aromatic, taste and feeling factors contributing to the product flavor.
Sweet	Taste on the tongue stimulated by sugars and high potency sweeteners.
Sour	Taste on the tongue stimulated by acids.
Overall fresh fruit	The overall intensity of fresh fruit flavor.
Passion fruit	Flavor associated with 30mL passion fruit pulp (De Marchi Indústria e Comércio de Frutas Ltda).
Pineapple	Flavor associated with 30g of 2cm pieces of fresh pineapple.
Orange	Flavor associated with 30g of 2cm pieces of fresh orange.
Peach	Flavor associated with 30g of 2cm pieces of fresh peach.
Overall canned fruit	Flavor associated with a mixture of 6g canned apricot nectar (Kerns), 6g canned peach (Del Monte), 6g canned pineapple (Dole), 6g canned mandarin orange (Del Monte), and 6g canned pear (Kroger).
Fishy	Flavor associated with fish.
Texture	
Wateriness	Watery mouthfeel.
Aftertaste	
Sour	Aftertaste on the tongue stimulated by 0.1% citric acid in water.
Sweet	Aftertaste on the tongue stimulated by 5% sucrose in water.
Artificial sweetness	Artificial aftertaste on the tongue stimulated by solutions containing 0.02% aspartame, 0.006% sucralose, and 0.02% aspartame/acesulfame-K (4:1) in water.

3. Results and Discussion

Principal Component Analysis (PCA)

To visualize, in space, the differences among the samples and the intercorrelation among the descriptors, the samples were firstly analyzed using the principal component analysis.

Three principal components (PC) accounted for 70.20% of the total variance (Figures 2.1-2.3).

The attributes that contributed to each PC are listed in descendant order according to their relative importance in explaining the variability among the samples.

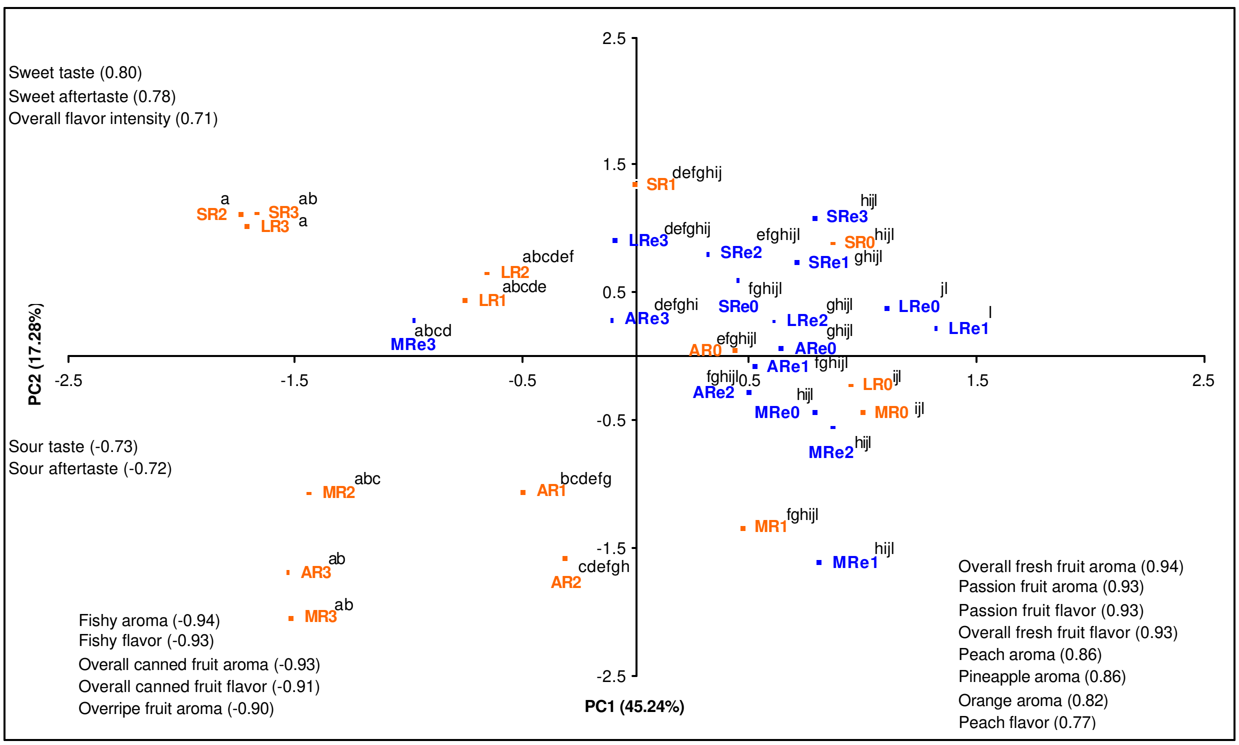

Figure 2.1 Principal component plot of passion fruit juice beverages separated according to their sensory descriptive attributes on the PC1 and PC2 axes. [PC 1 sample effect p<0.001; samples with different superscript letters on PC1 are significantly different from one another (Tukey's p<0.05)].

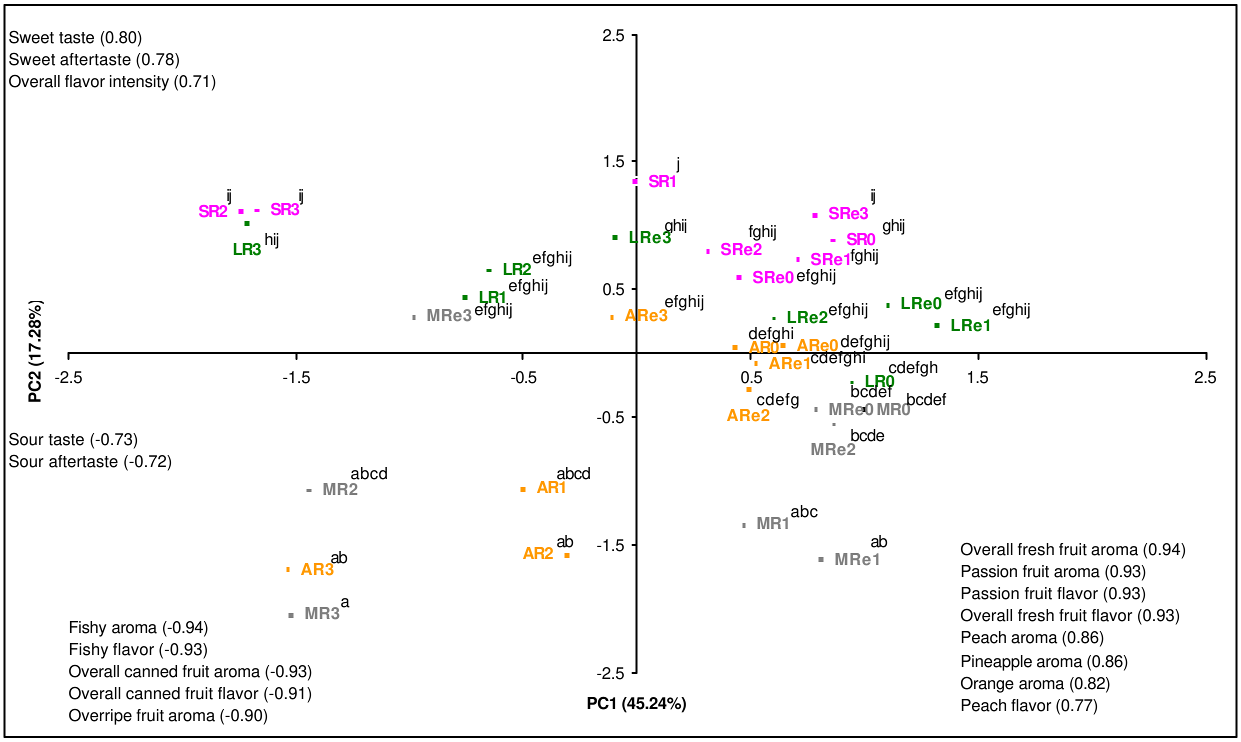

Figure 2.2 Principal component plot of passion fruit juice beverages separated according to their sensory descriptive attributes on the PC1 and PC2 axes. [PC2 sample effect p<0.001; samples with different superscript letters on PC2 are significantly different from one another (Tukey's p<0.05)].

PC1 was positively weighted by overall fresh fruit aroma, passion fruit aroma, passion fruit flavor, overall fresh fruit flavor, peach aroma, pineapple aroma, orange aroma and peach flavor (Figure 2.1). The standard beverage stored under refrigeration during 0, 60, 120 and 180 days of storage (SRe0, SRe1, SRe2, SRe3) had positive scores on PC1. The same occurred with the light beverages stored under refrigeration during 0, 60 and 120 days of storage (ARe0, ARe1, ARe2, LRe0, LRe1, LRe2, MRe0, MRe1, MRe2), and with the aspartame/acesulfame-K blend – sweetened beverage stored at room temperature during 60 days of storage (MR1). It is important to note that the beverages SR0, AR0, LR0 and MR0 were identical to the beverages SRe0, ARe0, LRe0, and MRe0. These results indicate that, when kept under refrigeration, the sucrose-sweetened beverage retained its fresh fruit (and "positive") sensory characteristics during 180 days of storage while the light beverages preserved these characteristics for a shorter period of 120 days of storage.

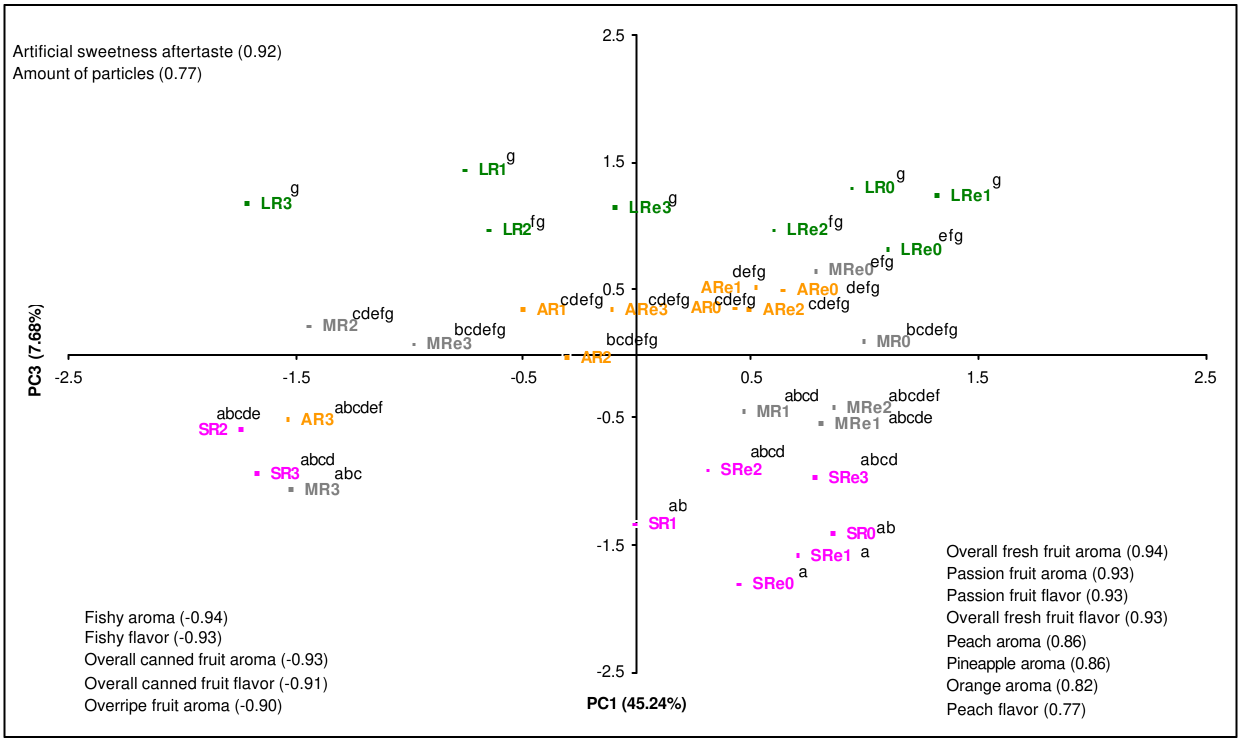

Figure 2.3 Principal component plot of passion fruit beverages separated according to their sensory descriptive attributes on the PC1 and PC3 axes. [PC3 sample effect $p<0.001$; samples with different superscript letters on PC3 are significantly different from one another (Tukey's $p<0.05$)].

PC1 was negatively weighted by fishy aroma, fishy flavor, overall canned fruit aroma, overall canned fruit flavor and overripe fruit aroma (Figure 2.1). The standard beverage stored at room temperature during 60, 120, and 180 days of storage (SR1, SR2, and SR3) had negative scores on PC1. The same was true for the light beverages stored at room temperature during 60, 120 and 180 days of storage (AR1, AR2, AR3, LR1, LR2, LR3, MR2, MR3), as well as for the light beverages stored under refrigeration during 180 days of storage (ARe3, LRe3, MRe3). The only exception was the aspartame/acesulfame-K blend – sweetened beverage stored at room temperature during 60 days of storage (MR1), which had positive scores on PC1. From these results we observed that, in general, when stored at room temperature during 60 to 180 days, the light beverages developed "negative" characteristics of fishy aroma and flavor, canned fruit aroma and flavor, and overripe fruit aroma. The same was true for the light beverages stored under refrigeration during 180 days.

PC2 was weighted positively by sweet taste, sweet aftertaste, and overall flavor intensity, and negatively by sour taste and sour aftertaste (Figure 2.2). In general, the beverages sweetened with sucrose (SR0, SR1, SR2, SR3, SRe0, SRe1, SRe2, SRe3) and sucralose (LR0, LR1, LR2, LR3, LRe0, LRe1, LRe2, LRe3) had high positive scores on PC2, that is, were characterized by sweet taste, sweet aftertaste, and overall flavor intensity, while those sweetened with aspartame (AR0, AR1, AR2, AR3, ARe0, ARe1, ARe2, ARe3) and the aspartame/acesulfame-K blend (MR0, MR1, MR2, MR3, MRe0, MRe1, MRe2, MRe3) had high negative scores on PC2 and were characterized by a sour taste and sour aftertaste.

PC3 was weighted positively by artificial sweetness aftertaste and amount of particles (Figure 2.3). The beverage sweetened with sucralose stored both at room temperature and under refrigeration (LR0, LR1, LR2, LR3, LRe0, LRe1, LRe2, LRe3) during the whole 180 days of storage had the highest scores on PC3 and therefore, was characterized by the artificial sweetness aftertaste and presence of particles.

Highly significant positive correlations ($p<0.05$) were found between the descriptors overall fresh fruit aroma and passion fruit aroma ($r=0.96$), overall fresh fruit aroma and overall fresh fruit flavor ($r=0.80$), overall fresh fruit aroma and passion fruit flavor ($r=0.83$), passion fruit aroma and overall fresh fruit flavor ($r=0.78$), passion fruit aroma and passion fruit flavor ($r=0.86$), overall fresh fruit flavor and passion fruit flavor ($r=0.93$), fishy aroma and fishy flavor ($r=0.80$).

Significant negative correlations ($p<0.05$) were found between overall fresh fruit aroma and overall canned fruit aroma ($r=-0.50$), overall fresh fruit aroma and fishy flavor ($r=-0.50$), fishy aroma and overall fresh fruit flavor ($r=-0.50$), overall fresh fruit flavor and overall canned fruit flavor ($r=-0.50$), overall fresh fruit flavor and fishy flavor ($r=-0.60$), passion fruit flavor and fishy flavor ($r=-0.50$).

Analysis of variance

The results of the analysis of variance are presented in Tables 2-5 and Figures 3-25.

The most important differences across the beverages (sweetener type) as a function of storage time were observed for color intensity, sweet taste, sweet aftertaste, and sour aftertaste.

The perceptions of color intensity were significantly higher ($p<0.05$) for the beverages sweetened with sucrose (B1) and sucralose (B3) than for those sweetened with aspartame (B2) and the aspartame/acesulfame-K blend (B4) during the whole storage period (Tables 2-5; Figure 3). At 120 and 180 days of storage, this descriptor was also influenced by the temperature conditions: all the beverages kept under refrigeration showed significantly higher scores than those kept at room temperature ($p<0.05$). It is important to remember that at 0 day, the beverages stored at room temperature were identical to those stored under refrigeration. A significant difference was also observed among the beverages for the sweet taste ($p<0.05$) after the first 60 days of storage (Tables 2-5; Figure 4). The beverages sweetened with sucrose (B1) and sucralose (B3) were perceived as significantly sweeter than those sweetened with aspartame (B2) and the aspartame/acesulfame-K blend (B4) ($p<0.05$) stored at room temperature. Furthermore, the sweet taste of the beverages B1 and B3 did not change with storage temperature while that of B2 and B4 (beverages containing aspartame) was significantly ($p<0.05$) more stable when the beverages were stored under refrigeration than when stored at room temperature. Similar behavior was observed for the sweet aftertaste (Tables 2-5; Figure 5). When the beverages were stored at room temperature for 60, 120 and 180 days of storage, this descriptor was perceived to be significantly higher for the beverages sweetened with sucrose (B1) and sucralose (B3) than for those sweetened with aspartame (B2) and the aspartame/acesulfame-K blend (B4) ($p<0.05$). When stored under refrigeration, despite the small differences among the beverages, the sweet aftertaste of B2 and B4 was much more stable. Finally, the sour aftertaste was perceived to be higher for the beverage sweetened with the aspartame/acesulfame-K blend (B4) than for the standard beverage (B1) when the beverages were stored at room temperature for 60, 120 and 180 days of storage (Tables 2-5; Figure 6). When stored under refrigeration, this difference was only observed at 60 days of storage.

Table 2. Descriptive attribute averages (n=8) for the passion fruit juice beverages sweetened with sucrose (B1), aspartame (B2), sucralose (B3) and the aspartame/acesulfame-K blend (B4) stored at room temperature (Room) and under refrigeration (Refr), at 0 day of storage.

Descriptors	B1		B2		B3		B4	
	Room	Refr	Room	Refr	Room	Refr	Room	Refr
Appearance								
Color intensity	8.13^{Aab}	7.88^{Aa}	7.33^{Ab}	6.67^{Ab}	8.83^{Aa}	8.50^{Aa}	7.08^{Ab}	7.75^{Aa}
Amount of particles	5.08^{Ab}	3.75^{Bc}	9.21^{Aa}	8.67^{Ab}	10.63^{Aa}	10.38^{Aa}	9.67^{Aa}	10.42^{Aa}
Aroma								
Overall aroma intensity	8.50^{Aa}	8.29^{Aa}	8.46^{Aa}	8.46^{Aa}	8.33^{Aa}	8.46^{Aa}	8.75^{Aa}	8.75^{Aa}
Overall fresh fruit	6.79^{Aa}	6.33^{Aa}	5.75^{Ab}	6.04^{Aa}	6.58^{Aab}	6.88^{Aa}	6.71^{Aab}	5.88^{Aa}
Passion fruit	6.42^{Aa}	5.88^{Aa}	5.29^{Ab}	5.54^{Aa}	6.21^{Aab}	6.29^{Aa}	6.04^{Aab}	5.58^{Aa}
Pineapple	2.75^{Aa}	2.00^{Aa}	2.13^{Aa}	2.21^{Aa}	2.21^{Aa}	2.63^{Aa}	2.00^{Aa}	1.92^{Aa}
Orange	1.83^{Aa}	1.58^{Aa}	1.50^{Aa}	1.58^{Aa}	1.83^{Aa}	1.96^{Aa}	1.50^{Aa}	1.67^{Aa}
Peach	2.00^{Aa}	1.33^{Ba}	1.50^{Aa}	1.79^{Aa}	1.96^{Aa}	1.75^{Aa}	1.88^{Aa}	1.92^{Aa}
Overall canned fruit	2.21^{Aa}	2.75^{Aa}	2.79^{Aa}	1.96^{Bab}	2.17^{Aa}	1.54^{Ab}	1.96^{Aa}	2.25^{Aab}
Overripe fruit	0.21^{Aa}	0.58^{Aa}	0.75^{Aa}	0.67^{Aa}	0.71^{Aa}	0.21^{Aa}	0.42^{Aa}	0.71^{Aa}
Fir-pine tree	1.04^{Aab}	0.75^{Aa}	0.79^{Ab}	1.17^{Aa}	1.33^{Aab}	1.08^{Aa}	1.46^{Aa}	1.25^{Aa}
Grassy	0.83^{Aa}	0.63^{Aa}	0.67^{Aa}	0.92^{Aa}	0.75^{Aa}	0.75^{Aa}	0.88^{Aa}	0.75^{Aa}
Fishy	1.38^{Aa}	0.75^{Aa}	0.63^{Aa}	0.29^{Aab}	0.25^{Aa}	0.21^{Ab}	0.29^{Aa}	0.42^{Aab}
Flavor								
Overall flavor intensity	9.58^{Aa}	9.17^{Aa}	9.13^{Aa}	9.21^{Aa}	9.08^{Aa}	9.38^{Aa}	9.13^{Aa}	9.17^{Aa}
Sweet	6.71^{Aa}	6.75^{Aa}	6.08^{Aa}	6.17^{Aab}	6.29^{Aa}	6.04^{Aab}	6.13^{Aa}	5.83^{Ab}
Sour	4.00^{Ab}	4.04^{Aa}	4.17^{Aab}	4.50^{Aa}	4.83^{Aa}	4.29^{Ba}	4.75^{Aa}	4.92^{Aa}
Overall fresh fruit	7.29^{Aa}	6.96^{Aa}	6.29^{Ab}	6.17^{Aa}	6.50^{Aab}	6.92^{Aa}	6.75^{Aab}	6.29^{Aa}
Passion fruit	6.67^{Aa}	6.21^{Aa}	5.79^{Ab}	5.75^{Aa}	6.13^{Aab}	6.38^{Aa}	6.13^{Aab}	5.83^{Aa}
Pineapple	2.79^{Aa}	2.75^{Aa}	2.29^{Aa}	2.25^{Aa}	2.17^{Aa}	2.79^{Aa}	2.58^{Aa}	2.13^{Aa}
Orange	2.00^{Aa}	1.83^{Aa}	1.88^{Aa}	1.71^{Aa}	1.79^{Ba}	2.38^{Aa}	2.13^{Aa}	1.96^{Aa}
Peach	1.83^{Aa}	1.88^{Aa}	1.75^{Aa}	1.67^{Aa}	1.54^{Ba}	2.13^{Aa}	1.63^{Aa}	1.54^{Aa}
Overall canned fruit	1.83^{Ba}	2.63^{Aa}	2.04^{Aa}	2.04^{Aab}	1.75^{Aa}	1.50^{Ab}	2.00^{Aa}	1.96^{Aab}
Fishy	0.08^{Aa}	0.33^{Aa}	0.38^{Aa}	0.25^{Aa}	0.29^{Aa}	0.08^{Aa}	0.04^{Aa}	0.13^{Aa}
Texture								
Wateriness	7.13^{Ab}	7.54^{Ab}	8.33^{Aa}	8.46^{Aa}	8.50^{Aa}	8.25^{Aab}	8.21^{Aa}	8.71^{Aa}
Aftertaste								
Sour	3.00^{Aa}	3.13^{Aa}	3.54^{Aa}	3.38^{Aa}	3.71^{Aa}	3.46^{Aa}	3.75^{Aa}	3.88^{Aa}
Sweet	4.21^{Aa}	4.33^{Aa}	4.04^{Aa}	4.21^{Aa}	4.13^{Aa}	4.46^{Aa}	3.96^{Aa}	4.04^{Aa}
Artificial sweetness	1.17^{Ac}	0.75^{Ab}	3.00^{Aab}	2.88^{Aa}	3.88^{Aa}	3.33^{Aa}	2.38^{Abc}	2.46^{Aa}

$^{A, B, C}$ For each beverage, averages in a row followed by different capital letters represent significant differences (p<0.05).

$^{a, b, c}$ For each temperature of storage, averages in a row followed by different tinny letters represent significant differences (p<0.05).

Table 3. Descriptive attribute averages (n=8) for the passion fruit juice beverages sweetened with sucrose (B1), aspartame (B2), sucralose (B3) and the aspartame/acesulfame-K blend (B4) stored at room temperature (Room) and under refrigeration (Refr), at 60 days of storage.

Descriptors	B1		B2		B3		B4	
	Room	Refr	Room	Refr	Room	Refr	Room	Refr
Appearance								
Color intensity	8.25^{Aa}	7.91^{Aa}	5.54^{Bc}	6.38^{Ab}	7.75^{Aab}	8.04^{Aa}	6.88^{Ab}	6.38^{Ab}
Amount of particles	5.25^{Ab}	4.42^{Ac}	8.96^{Aa}	9.21^{Ab}	9.71^{Ba}	10.63^{Aa}	8.92^{Aa}	9.29^{Ab}
Aroma								
Overall aroma intensity	8.08^{Ab}	8.33^{Aa}	9.00^{Aa}	8.33^{Ba}	9.17^{Aa}	8.42^{Ba}	8.92^{Aa}	8.08^{Ba}
Overall fresh fruit	5.50^{Aab}	6.46^{Aa}	4.79^{Bb}	6.33^{Aa}	4.96^{Bab}	7.13^{Aa}	6.25^{Aa}	6.17^{Aa}
Passion fruit	5.13^{Aa}	6.08^{Aa}	4.71^{Ba}	5.79^{Aa}	4.79^{Ba}	6.67^{Aa}	5.79^{Aa}	5.96^{Aa}
Pineapple	1.63^{Aa}	2.29^{Aa}	1.58^{Aa}	1.79^{Aa}	1.46^{Ba}	2.67^{Aa}	2.04^{Aa}	1.79^{Aa}
Orange	1.25^{Aa}	1.67^{Aa}	1.21^{Aa}	1.75^{Aa}	1.00^{Ba}	2.04^{Aa}	1.71^{Aa}	1.29^{Aa}
Peach	1.38^{Aa}	1.96^{Aab}	1.04^{Ba}	1.79^{Aab}	1.33^{Ba}	2.21^{Aa}	1.67^{Aa}	1.29^{Ab}
Overall canned fruit	2.83^{Ab}	2.46^{Aa}	4.29^{Aa}	2.08^{Bab}	3.79^{Aab}	1.42^{Bb}	2.79^{Ab}	2.21^{Aab}
Overripe fruit	1.08^{Aa}	0.33^{Ba}	1.71^{Aa}	0.46^{Ba}	2.00^{Aa}	0.29^{Ba}	1.04^{Aa}	0.50^{Aa}
Fir-pine tree	0.83^{Aa}	1.00^{Aab}	0.75^{Aa}	0.92^{Ab}	0.86^{Ba}	1.46^{Aa}	0.86^{Aa}	0.83^{Ab}
Grassy	0.75^{Aa}	0.92^{Aa}	0.63^{Aa}	0.83^{Aa}	0.96^{Aa}	0.79^{Aa}	0.63^{Aa}	0.75^{Aa}
Fishy	0.75^{Aa}	0.42^{Aab}	1.54^{Aa}	0.67^{Bab}	1.71^{Aa}	0.08^{Bb}	1.13^{Aa}	0.71^{Aa}
Flavor								
Overall flavor intensity	9.29^{Aa}	9.29^{Aa}	8.67^{Aa}	9.00^{Aa}	9.29^{Aa}	9.37^{Aa}	8.92^{Aa}	8.71^{Aa}
Sweet	6.75^{Aa}	6.50^{Aa}	5.00^{Bb}	5.88^{Aab}	6.00^{Aa}	6.58^{Aa}	5.00^{Ab}	5.58^{Ab}
Sour	3.75^{Ab}	3.83^{Ab}	4.79^{Aa}	4.17^{Bab}	4.92^{Aa}	4.25^{Bab}	4.79^{Aa}	4.71^{Aa}
Overall fresh fruit	6.13^{Ba}	6.92^{Aa}	4.75^{Bb}	6.17^{Aa}	4.75^{Bb}	6.88^{Aa}	5.58^{Aab}	6.04^{Aa}
Passion fruit	5.63^{Ba}	6.46^{Aa}	4.50^{Ba}	5.71^{Aa}	4.58^{Ba}	6.50^{Aa}	5.17^{Aa}	5.71^{Aa}
Pineapple	3.00^{Aa}	2.75^{Aab}	1.38^{Bb}	2.13^{Aab}	1.71^{Bb}	2.83^{Aa}	1.96^{Ab}	1.92^{Ab}
Orange	2.21^{Aa}	2.00^{Aa}	1.25^{Ab}	1.67^{Aa}	1.00^{Bb}	2.00^{Aa}	1.46^{Ab}	1.33^{Aa}
Peach	1.75^{Aa}	1.75^{Aab}	0.92^{Aa}	1.42^{Ab}	1.21^{Ba}	2.29^{Aa}	1.46^{Aa}	1.54^{Aab}
Overall canned fruit	3.08^{Aa}	1.67^{Bab}	3.67^{Aa}	2.21^{Ba}	3.75^{Aa}	1.29^{Bb}	2.79^{Aa}	2.17^{Aa}
Fishy	0.54^{Ab}	0.13^{Bb}	1.46^{Aab}	0.67^{Ba}	1.75^{Aa}	0.00^{Bb}	1.13^{Aab}	0.17^{Bb}
Texture								
Wateriness	7.21^{Ac}	7.46^{Ab}	8.79^{Aa}	8.46^{Aa}	7.83^{Abc}	8.33^{Aa}	8.46^{Aab}	9.04^{Aa}
Aftertaste								
Sour	3.46^{Ab}	2.83^{Ab}	4.08^{Aab}	3.21^{Bb}	3.96^{Aab}	3.71^{Aab}	4.54^{Aa}	4.25^{Aa}
Sweet	4.38^{Aa}	4.08^{Aab}	3.00^{Bb}	4.21^{Aa}	4.21^{Aa}	4.58^{Aa}	3.38^{Ab}	3.42^{Ab}
Artificial sweetness	0.83^{Ac}	0.79^{Ab}	2.67^{Ab}	3.13^{Aa}	4.21^{Aa}	3.29^{Ba}	1.88^{Abc}	1.63^{Ab}

$^{A,\ B,\ C}$ For each beverage, averages in a row followed by different capital letters represent significant differences (p<0.05).

$^{a,\ b,\ c}$ For each temperature of storage, averages in a row followed by different tinny letters represent significant differences (p<0.05).

Table 4. Descriptive attribute averages (n=8) for the passion fruit juice beverages sweetened with sucrose (B1), aspartame (B2), sucralose (B3) and the aspartame/acesulfame-K blend (B4) stored at room temperature (Room) and under refrigeration (Refr), at 120 days of storage.

Descriptors	B1		B2		B3		B4	
	Room	Refr	Room	Refr	Room	Refr	Room	Refr
Appearance								
Color intensity	7.08^{Ba}	8.42^{Aa}	5.13^{Bb}	5.88^{Ab}	6.46^{Ba}	8.17^{Aa}	5.04^{Bb}	6.63^{Ab}
Amount of particles	5.45^{Ab}	5.96^{Ab}	8.21^{Aa}	8.96^{Aa}	7.96^{Ba}	10.29^{Aa}	8.08^{Aa}	9.13^{Aa}
Aroma								
Overall aroma intensity	9.21^{Aab}	8.71^{Aa}	8.67^{Ab}	8.67^{Aa}	8.88^{Aab}	8.54^{Aa}	9.63^{Aa}	8.75^{Ba}
Overall fresh fruit	3.71^{Bb}	6.38^{Aa}	4.75^{Bab}	6.46^{Aa}	4.88^{Ba}	6.42^{Aa}	4.13^{Bab}	6.46^{Aa}
Passion fruit	3.58^{Bb}	5.88^{Aa}	4.46^{Bab}	5.96^{Aa}	4.75^{Ba}	5.79^{Aa}	3.88^{Bab}	6.04^{Aa}
Pineapple	0.96^{Ba}	1.79^{Aa}	1.46^{Ba}	2.25^{Aa}	1.42^{Aa}	2.04^{Aa}	0.83^{Ba}	2.46^{Aa}
Orange	0.67^{Ba}	1.46^{Aa}	1.67^{Aa}	1.33^{Aa}	1.13^{Aa}	1.50^{Aa}	0.75^{Ba}	1.87^{Aa}
Peach	0.67^{Ba}	1.54^{Aa}	1.25^{Aa}	1.46^{Aa}	1.08^{Ba}	1.75^{Aa}	0.88^{Ba}	1.67^{Aa}
Overall canned fruit	4.46^{Aa}	2.75^{Ba}	3.58^{Aa}	2.50^{Ba}	3.71^{Aa}	2.21^{Ba}	4.21^{Aa}	2.08^{Ba}
Overripe fruit	2.17^{Aab}	0.42^{Ba}	1.46^{Ab}	0.58^{Ba}	1.58^{Ab}	0.63^{Ba}	2.83^{Aa}	0.38^{Ba}
Fir-pine tree	0.58^{Ba}	1.17^{Aa}	0.83^{Aa}	1.00^{Aa}	0.67^{Ba}	1.25^{Aa}	0.67^{Ba}	1.17^{Aa}
Grassy	0.86^{Aa}	0.92^{Aa}	0.83^{Aa}	0.92^{Aa}	1.04^{Aa}	1.08^{Aa}	1.29^{Aa}	0.88^{Aa}
Fishy	2.50^{Aa}	0.96^{Ba}	1.50^{Aa}	0.79^{Aa}	1.67^{Aa}	0.42^{Ba}	2.58^{Aa}	0.54^{Ba}
Flavor								
Overall flavor intensity	9.58^{Aa}	9.33^{Aa}	8.50^{Ab}	9.00^{Aa}	9.13^{Aab}	9.13^{Aa}	8.92^{Aab}	9.00^{Aa}
Sweet	6.21^{Aa}	6.67^{Aa}	4.54^{Bb}	6.25^{Aab}	6.00^{Aa}	6.58^{Aa}	4.58^{Bb}	5.67^{Ab}
Sour	4.04^{Ab}	4.13^{Aa}	5.13^{Aa}	4.04^{Ba}	4.46^{Aab}	4.42^{Aa}	5.17^{Aa}	4.25^{Ba}
Overall fresh fruit	3.75^{Bb}	6.29^{Aa}	4.54^{Bab}	6.25^{Aa}	5.13^{Ba}	6.29^{Aa}	3.58^{Bb}	6.38^{Aa}
Passion fruit	3.67^{Bb}	5.92^{Aa}	4.17^{Bab}	5.88^{Aa}	4.79^{Ba}	5.88^{Aa}	3.29^{Bb}	6.00^{Aa}
Pineapple	1.58^{Bab}	2.54^{Aa}	1.63^{Aab}	2.21^{Aa}	2.21^{Aa}	2.17^{Aa}	1.08^{Bb}	2.17^{Aa}
Orange	0.96^{Bab}	1.96^{Aa}	1.25^{Aa}	1.25^{Aa}	1.46^{Aa}	1.75^{Aa}	0.54^{Bb}	1.75^{Aa}
Peach	0.75^{Bab}	1.79^{Aa}	1.13^{Aab}	1.42^{Aa}	1.42^{Aa}	1.63^{Aa}	0.50^{Bb}	1.33^{Aa}
Overall canned fruit	4.54^{Aa}	2.38^{Ba}	3.83^{Aab}	2.04^{Ba}	3.17^{Ab}	1.92^{Ba}	4.58^{Aa}	1.71^{Ba}
Fishy	2.89^{Aa}	0.58^{Ba}	1.50^{Ab}	0.46^{Ba}	1.25^{Ab}	0.46^{Aa}	3.08^{Aa}	0.42^{Ba}
Texture								
Wateriness	7.38^{Ab}	7.21^{Ab}	9.00^{Aa}	8.58^{Aa}	8.04^{Bb}	8.63^{Aa}	9.00^{Aa}	8.50^{Aa}
Aftertaste								
Sour	3.33^{Ab}	3.29^{Aa}	4.50^{Aa}	3.63^{Ba}	3.21^{Ab}	3.29^{Aa}	4.38^{Aa}	3.13^{Ba}
Sweet	4.13^{Aa}	4.25^{Aa}	3.04^{Ab}	3.50^{Ab}	4.04^{Aa}	4.29^{Aa}	2.54^{Bb}	3.71^{Aab}
Artificial sweetness	1.54^{Ab}	1.13^{Ab}	2.21^{Ab}	2.96^{Aa}	3.83^{Aa}	2.96^{Ba}	2.13^{Ab}	1.54^{Ab}

$^{A,\ B,\ C}$ For each beverage, averages in a row followed by different capital letters represent significant differences (p<0.05).

$^{a,\ b,\ c}$ For each temperature of storage, averages in a row followed by different tinny letters represent significant differences (p<0.05).

Table 5. Descriptive attribute averages (n=8) for the passion fruit juice beverages sweetened with sucrose (B1), aspartame (B2), sucralose (B3) and the aspartame/acesulfame-K blend (B4) stored at room temperature (Room) and under refrigeration (Refr), at 180 days of storage.

Descriptors	B1		B2		B3		B4	
	Room	**Refr**	**Room**	**Refr**	**Room**	**Refr**	**Room**	**Refr**
Appearance								
Color intensity	5.92^{Ba}	8.50^{Aa}	4.21^{Bb}	6.13^{Ac}	5.58^{Ba}	7.25^{Ab}	4.46^{Bb}	6.42^{Ac}
Amount of particles	5.54^{Ab}	6.13^{Ab}	8.29^{Aa}	8.96^{Aa}	8.42^{Ba}	10.29^{Aa}	8.08^{Ba}	9.21^{Aa}
Aroma								
Overall aroma intensity	9.29^{Aa}	8.63^{Bb}	9.54^{Aa}	8.96^{Ab}	8.92^{Aa}	9.29^{Aab}	9.50^{Aa}	9.75^{Aa}
Overall fresh fruit	4.04^{Ba}	6.25^{Aa}	3.29^{Ba}	5.58^{Aab}	3.58^{Ba}	5.88^{Aab}	3.83^{Ba}	4.79^{Ab}
Passion fruit	4.08^{Ba}	6.08^{Aa}	3.17^{Ba}	5.13^{Aab}	3.46^{Ba}	5.67^{Aa}	3.83^{Aa}	4.50^{Ab}
Pineapple	1.21^{Ba}	2.50^{Aa}	1.00^{Ba}	2.00^{Aa}	0.79^{Ba}	2.08^{Aa}	0.96^{Ba}	1.54^{Aa}
Orange	0.75^{Bab}	2.00^{Aa}	0.92^{Aa}	1.33^{Aab}	0.38^{Bb}	1.50^{Aab}	0.58^{Aab}	0.92^{Ab}
Peach	0.92^{Ba}	2.00^{Aa}	0.63^{Aa}	1.25^{Aab}	0.50^{Ba}	1.50^{Aab}	0.50^{Aa}	0.92^{Ab}
Overall canned fruit	4.67^{Aa}	2.50^{Bb}	4.54^{Aa}	3.29^{Bab}	4.67^{Aa}	3.08^{Bab}	5.00^{Aa}	3.79^{Ba}
Overripe fruit	2.17^{Aa}	0.29^{Bb}	2.50^{Aa}	0.92^{Bab}	2.13^{Aa}	1.17^{Bab}	2.38^{Aa}	1.75^{Aa}
Fir-pine tree	0.83^{Ba}	1.29^{Aa}	0.50^{Ba}	1.00^{Aa}	0.58^{Aa}	0.83^{Aa}	0.42^{Ba}	0.92^{Aa}
Grassy	1.04^{Aa}	0.83^{Aa}	0.79^{Aa}	0.58^{Aa}	0.88^{Aa}	0.58^{Aa}	0.67^{Aa}	0.96^{Aa}
Fishy	2.46^{Aa}	0.75^{Bb}	3.04^{Aa}	1.58^{Bab}	2.71^{Aa}	1.63^{Bab}	3.38^{Aa}	2.33^{Ba}
Flavor								
Overall flavor intensity	9.63^{Aa}	9.58^{Aab}	8.42^{Ab}	9.00^{Ab}	9.42^{Aa}	9.83^{Aa}	9.04^{Aab}	9.25^{Aab}
Sweet	6.21^{Aa}	6.75^{Aa}	3.46^{Bb}	6.13^{Aa}	6.21^{Aa}	6.42^{Aa}	3.96^{Bb}	5.96^{Aa}
Sour	4.04^{Ac}	3.83^{Aa}	5.04^{Aab}	4.25^{Ba}	4.21^{Abc}	4.17^{Aa}	5.54^{Aa}	4.33^{Ba}
Overall fresh fruit	3.79^{Ba}	6.75^{Aa}	3.21^{Ba}	5.58^{Abc}	3.88^{Ba}	6.04^{Aab}	3.21^{Ba}	4.79^{Ac}
Passion fruit	3.63^{Ba}	6.29^{Aa}	3.00^{Ba}	5.38^{Aa}	3.67^{Ba}	5.67^{Aa}	3.04^{Ba}	4.33^{Ab}
Pineapple	1.71^{Ba}	3.29^{Aa}	1.13^{Bab}	2.42^{Aab}	1.46^{Bab}	2.58^{Aab}	0.83^{Bb}	1.71^{Ab}
Orange	1.21^{Bab}	2.63^{Aa}	0.58^{Bc}	1.67^{Ab}	1.33^{Ba}	1.75^{Ab}	0.63^{Bbc}	1.25^{Ab}
Peach	0.75^{Bab}	2.13^{Aa}	0.46^{Bab}	1.46^{Aab}	1.04^{Ba}	1.88^{Aa}	0.25^{Bb}	0.79^{Ab}
Overall canned fruit	4.92^{Aa}	2.46^{Bb}	4.21^{Aa}	2.83^{Bab}	4.25^{Aa}	2.75^{Bab}	4.75^{Aa}	3.67^{Ba}
Fishy	2.79^{Aa}	0.38^{Bb}	3.17^{Aa}	1.13^{Bab}	2.83^{Aa}	1.33^{Ba}	3.63^{Aa}	2.00^{Ba}
Texture								
Wateriness	7.54^{Aa}	7.33^{Aa}	8.17^{Aa}	7.75^{Aa}	8.17^{Aa}	7.46^{Aa}	8.25^{Aa}	7.79^{Aa}
Aftertaste								
Sour	3.04^{Ac}	3.29^{Aa}	4.46^{Aab}	3.54^{Ba}	3.67^{Abc}	3.88^{Aa}	4.67^{Aa}	3.79^{Ba}
Sweet	4.04^{Aa}	4.42^{Aa}	2.04^{Bb}	3.96^{Aab}	4.33^{Aa}	4.25^{Aab}	1.88^{Bb}	3.63^{Ab}
Artificial sweetness	0.83^{Ac}	1.25^{Ac}	2.00^{Bb}	2.75^{Aab}	3.25^{Aa}	3.75^{Aa}	1.17^{Abc}	1.83^{Abc}

$^{A,\ B,\ C}$ For each beverage, averages in a row followed by different capital letters represent significant differences (p<0.05).

$^{a,\ b,\ c}$ For each temperature of storage, averages in a row followed by different tinny letters represent significant differences (p<0.05).

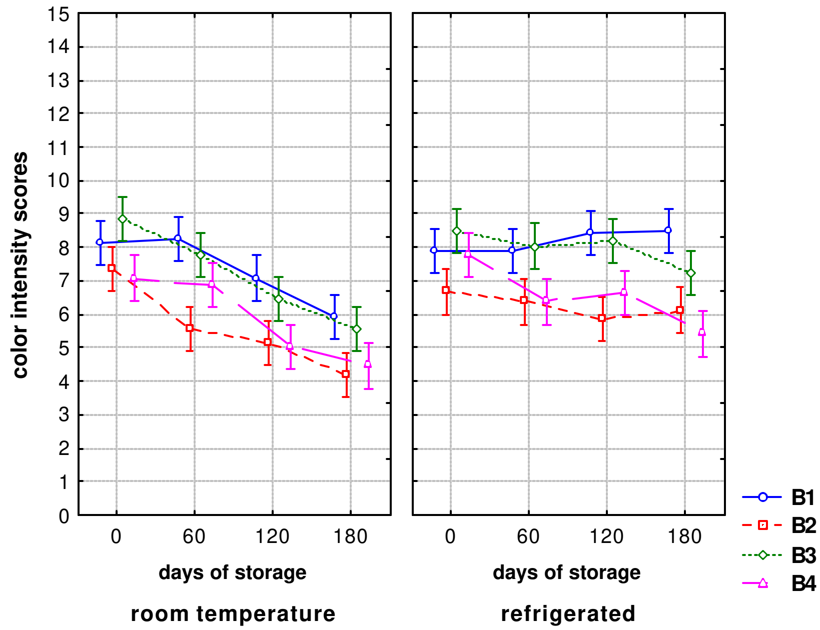

Figure 3. Distribution of the average scores attributed to color intensity of passion fruit juice beverages sweetened with sucrose (B1), aspartame (B2), sucralose (B3) and the aspartame/acesulfame-K blend (B4) at 0, 60, 120 and 180 days of storage.

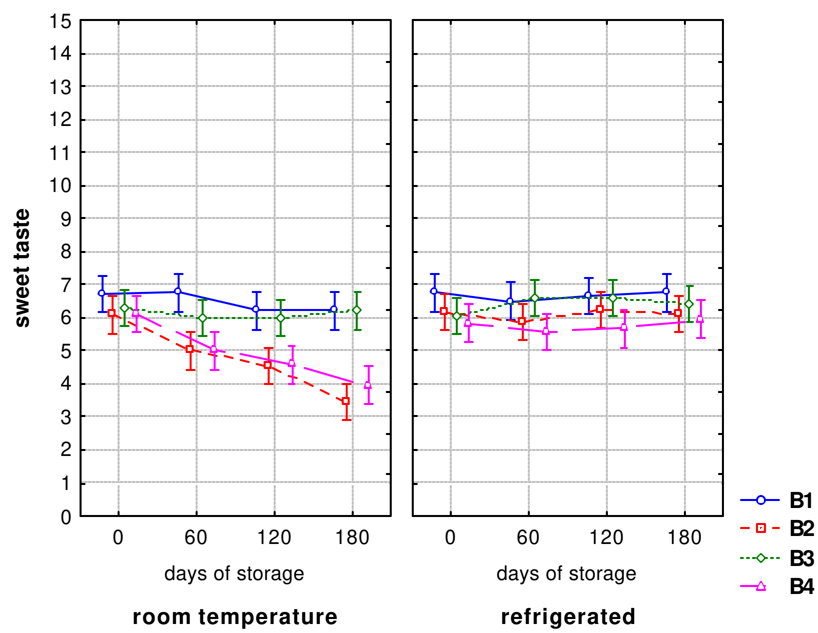

Figure 4. Distribution of the average scores attributed to sweet taste of passion fruit juice beverages sweetened with sucrose (B1), aspartame (B2), sucralose (B3) and the aspartame/acesulfame-K blend (B4) at 0, 60, 120 and 180 days of storage.

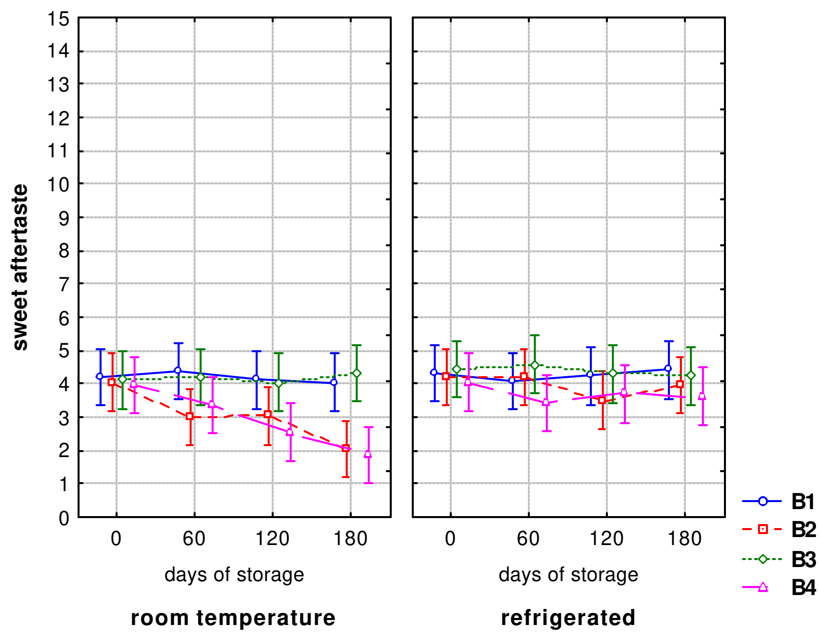

Figure 5. Distribution of the average scores attributed to sweet aftertaste of passion fruit juice beverages sweetened with sucrose (B1), aspartame (B2), sucralose (B3) and the aspartame/acesulfame-K blend (B4) at 0, 60, 120 and 180 days of storage.

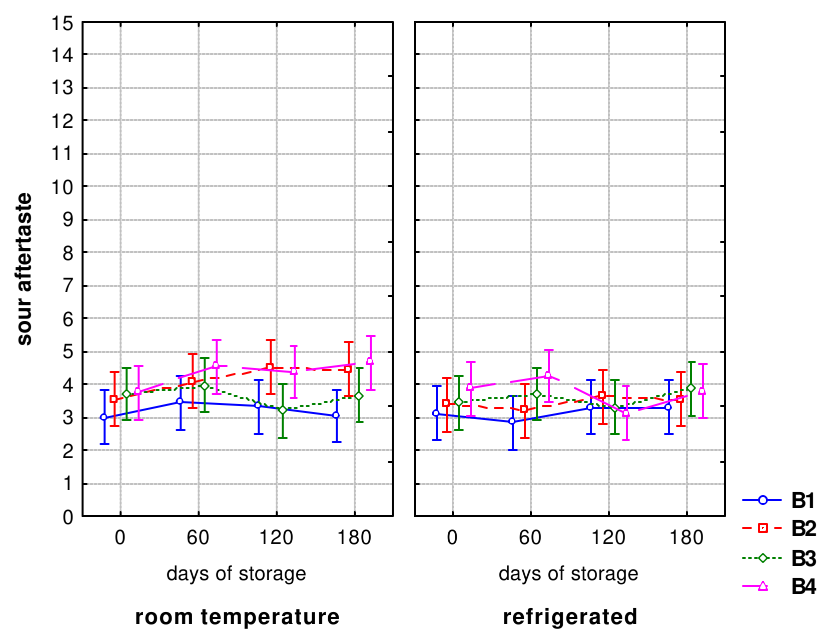

Figure 6. Distribution of the average scores attributed to sour aftertaste of passion fruit juice beverages sweetened with sucrose (B1), aspartame (B2), sucralose (B3) and the aspartame/acesulfame-K blend (B4) at 0, 60, 120 and 180 days of storage.

Further differences across the beverages were observed for the amount of particles and artificial sweetness aftertaste (Tables 2-5, Figures 7 and 8). However, these descriptors did not change with time ($p<0.05$). The amount of particles for the light beverages (B2, B3, B4) was always superior to that for the standard beverage (B1) ($p<0.05$). Besides, the sucralose-sweetened beverage (B3) was the most influenced by the different temperatures of storage, being characterized by a higher amount of particles when kept under refrigeration than when kept at room temperature ($p<0.05$) (Tables 2-5; Figure 7). With respect to the artificial sweetness aftertaste, when the beverages were stored at room temperature, this descriptor was perceived higher for the sucralose-sweetened beverage at 60, 120 and 180 days of storage ($p<0.05$) than for the other beverages. When stored under refrigeration, though, the beverages sweetened with aspartame (B2) and sucralose (B3) did not differ between each other ($p>0.05$) (Tables 2-5; Figure 8).

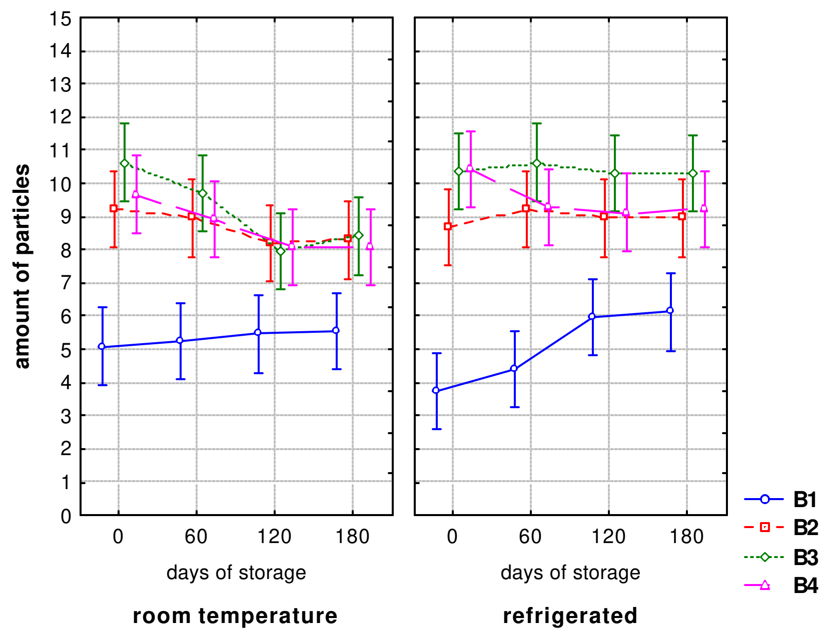

Figure 7. Distribution of the average scores attributed to amount of particles of passion fruit juice beverages sweetened with sucrose (B1), aspartame (B2), sucralose (B3) and the aspartame/acesulfame-K blend (B4) at 0, 60, 120 and 180 days of storage.

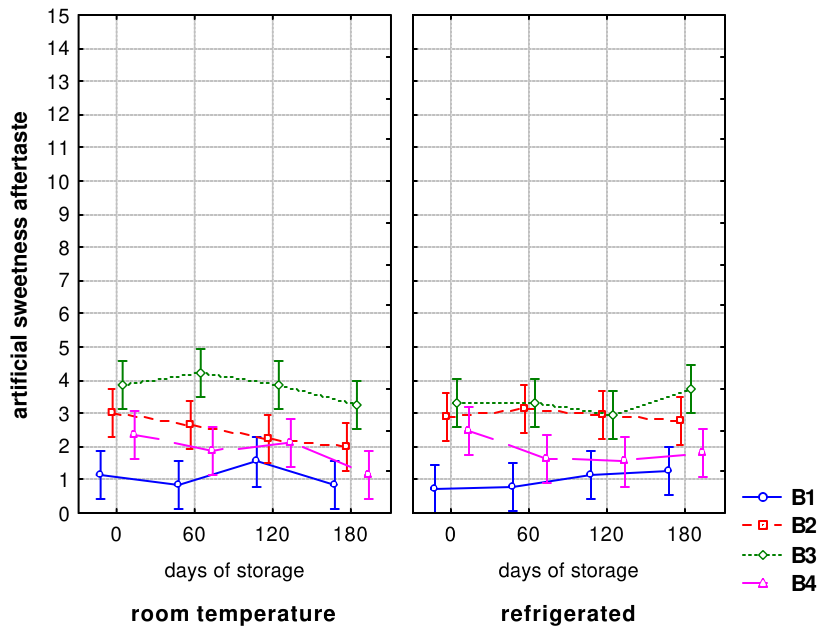

Figure 8. Distribution of the average scores attributed to the artificial sweetness aftertaste of passion fruit juice beverages sweetened with sucrose (B1), aspartame (B2), sucralose (B3) and the aspartame/acesulfame-K blend (B4) at 0, 60, 120 and 180 days of storage.

Concerning the differences across the temperatures of storage as a function of time, the only descriptors that did not show any significant difference ($p>0.05$) were grassy aroma, overall flavor and wateriness: the panelists perceived them for all the beverages, stored under both temperature conditions, indistinctively. In other words, the storage temperature played a major role on most of the descriptors, the refrigerated temperature being much more suitable for preserving the original sensory properties of the beverages, especially after 120 days of storage, when the most expressive changes were observed.

The perceived intensities of color, overall fresh fruit aroma, passion fruit aroma, pineapple aroma, orange aroma, peach aroma, fir-pine tree aroma, overall fresh fruit flavor, passion fruit flavor, pineapple flavor, orange flavor and peach flavor were significantly higher for most of the beverages stored under refrigeration than for those stored at room temperature, especially after 120 days of storage ($p<0.05$) (Tables 2-5; Figures 3, 9-19). The perceived intensities of overall canned fruit aroma, overripe fruit aroma, fishy aroma, overall canned fruit flavor and fishy flavor, on the other hand, were significantly higher ($p<0.05$) for most of the beverages stored at room temperature than for those stored under refrigeration (Tables 2-5; Figures 20-24). These differences were also more evident after 120 days of storage. Concerning the sweet taste (Figure 4), sweet aftertaste (Figure 5), sour aftertaste (Figure 6) and sour taste (Figure 25), significant differences ($p<0.05$) were observed between the storage temperatures only for the beverages containing aspartame (B2 and B4). The aspartame-sweetened beverage was perceived to be significantly less sweet ($p<0.05$) when stored at room temperature than when stored under refrigeration from the first 60 days of storage, and the aspartame/acesulfame-K blend – sweetened beverage, from 120 days of storage (Tables 2-5; Figure 4). The sweet taste and sweet aftertaste were perceived to be less intense ($p<0.05$) in the beverages containing aspartame (B2 and B4) stored at room temperature and the sour taste and sour aftertaste were perceived to be more intense ($p<0.05$) (Figures 4, 5, 6, and 25). When stored under refrigeration, however, the beverages were more stable with respect to these descriptors.

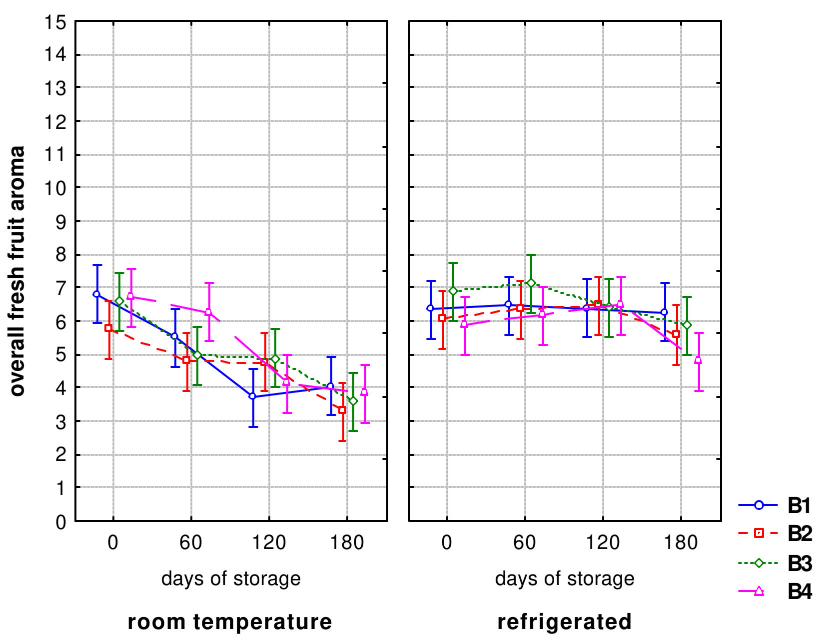

Figure 9. Distribution of the average scores attributed to the overall fresh fruit aroma of passion fruit juice beverages sweetened with sucrose (B1), aspartame (B2), sucralose (B3) and the aspartame/acesulfame-K blend (B4) at 0, 60, 120 and 180 days of storage.

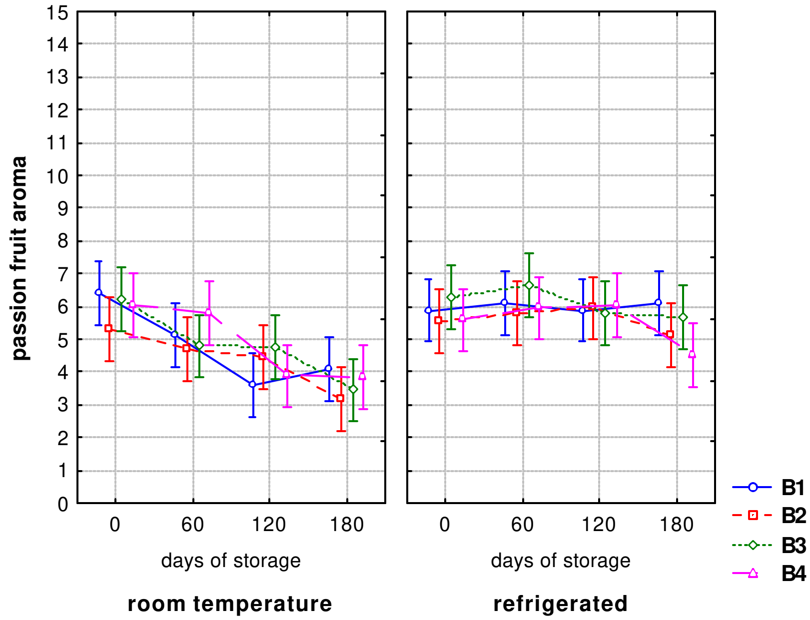

Figure 10. Distribution of the average scores attributed to the passion fruit aroma of passion fruit juice beverages sweetened with sucrose (B1), aspartame (B2), sucralose (B3) and the aspartame/acesulfame-K blend (B4) at 0, 60, 120 and 180 days of storage.

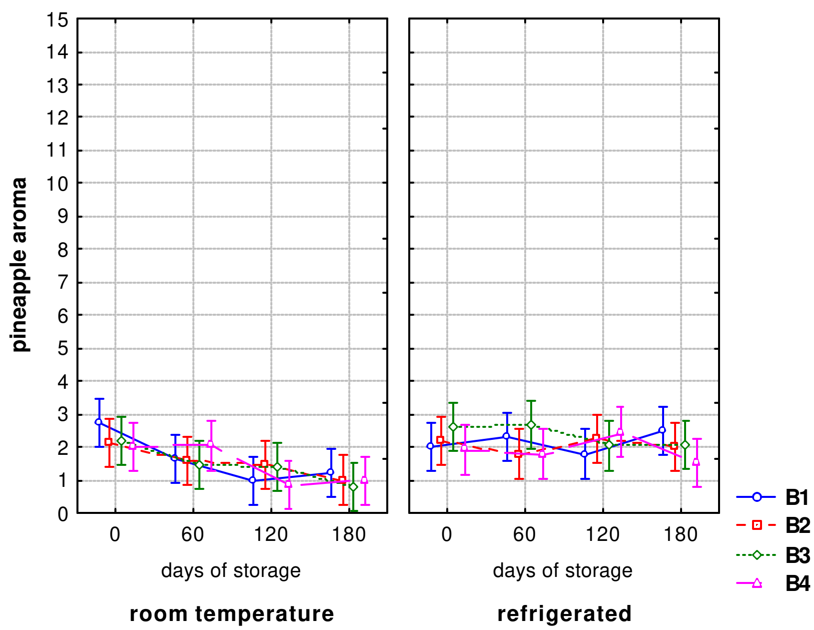

Figure 11. Distribution of the average scores attributed to the pineapple aroma of passion fruit juice beverages sweetened with sucrose (B1), aspartame (B2), sucralose (B3) and the aspartame/acesulfame-K blend (B4) at 0, 60, 120 and 180 days of storage.

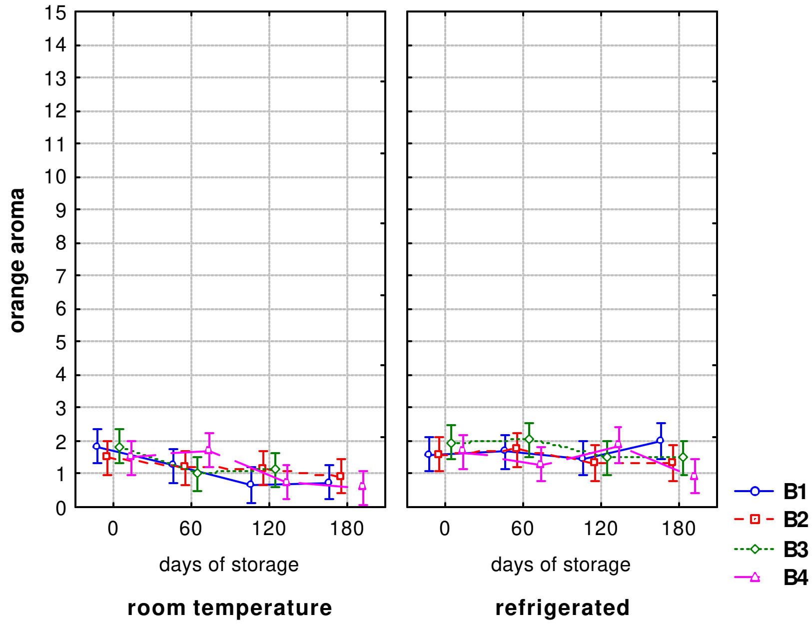

Figure 12. Distribution of the average scores attributed to the orange aroma of passion fruit juice beverages sweetened with sucrose (B1), aspartame (B2), sucralose (B3) and the aspartame/acesulfame-K blend (B4) at 0, 60, 120 and 180 days of storage.

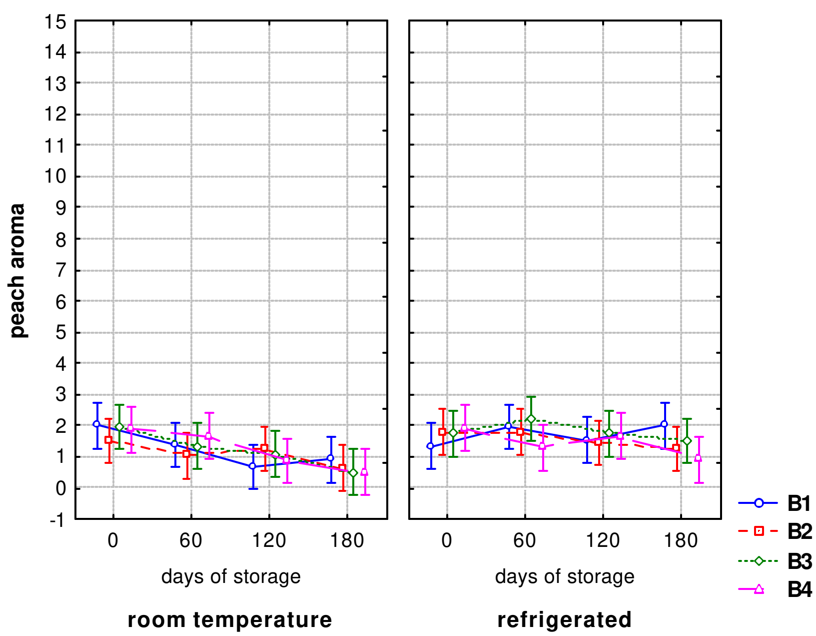

Figure 13. Distribution of the average scores attributed to the peach aroma of passion fruit juice beverages sweetened with sucrose (B1), aspartame (B2), sucralose (B3) and the aspartame/acesulfame-K blend (B4) at 0, 60, 120 and 180 days of storage.

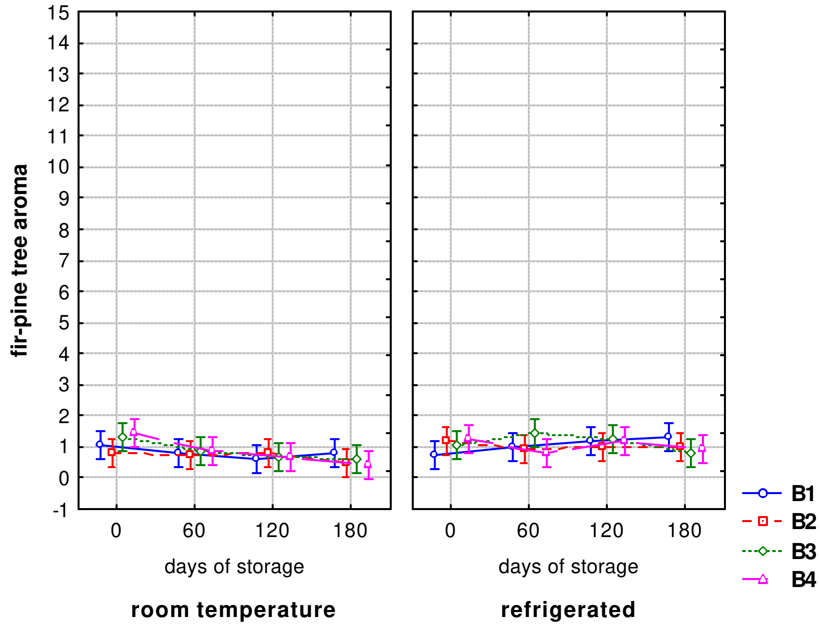

Figure 14. Distribution of the average scores attributed to the fir-pine tree aroma of passion fruit juice beverages sweetened with sucrose (B1), aspartame (B2), sucralose (B3) and the aspartame/acesulfame-K blend (B4) at 0, 60, 120 and 180 days of storage.

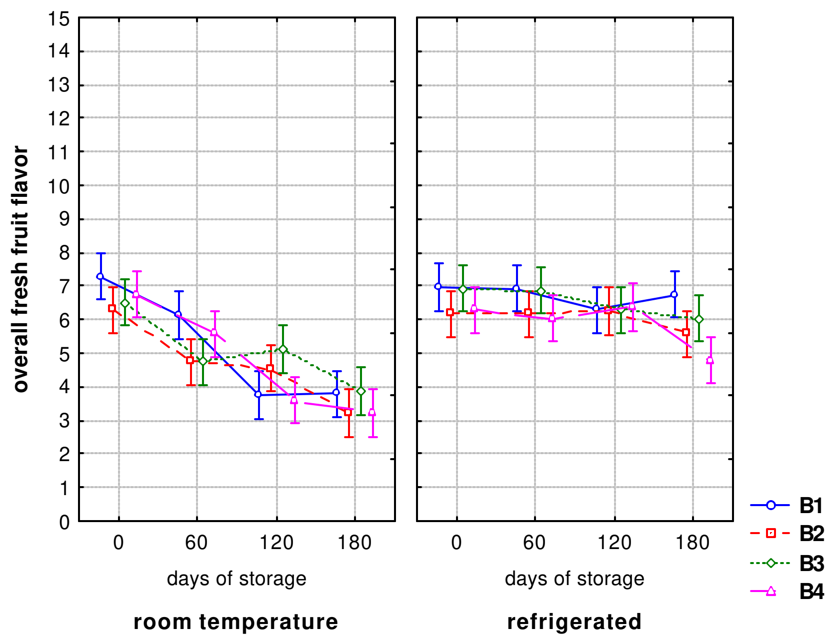

Figure 15. Distribution of the average scores attributed to the overall fresh fruit flavor of passion fruit juice beverages sweetened with sucrose (B1), aspartame (B2), sucralose (B3) and the aspartame/acesulfame-K blend (B4) at 0, 60, 120 and 180 days of storage.

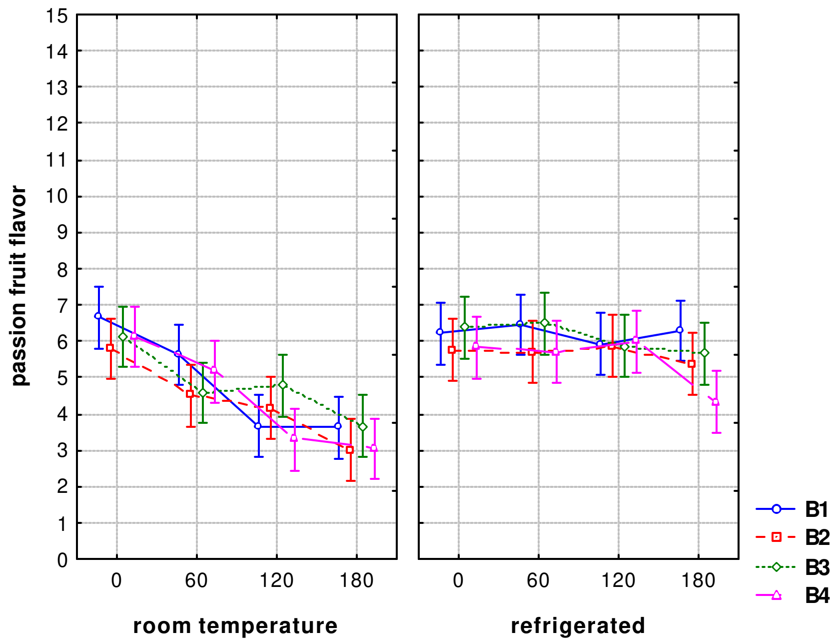

Figure 16. Distribution of the average scores attributed to the passion fruit flavor of passion fruit juice beverages sweetened with sucrose (B1), aspartame (B2), sucralose (B3) and the aspartame/acesulfame-K blend (B4) at 0, 60, 120 and 180 days of storage.

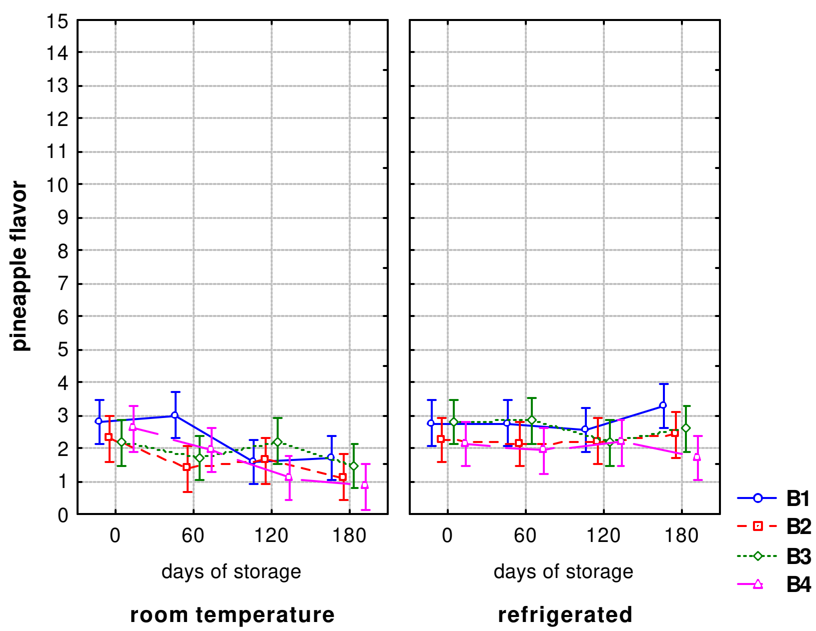

Figure 17. Distribution of the average scores attributed to the pineapple flavor of passion fruit juice beverages sweetened with sucrose (B1), aspartame (B2), sucralose (B3) and the aspartame/acesulfame-K blend (B4) at 0, 60, 120 and 180 days of storage.

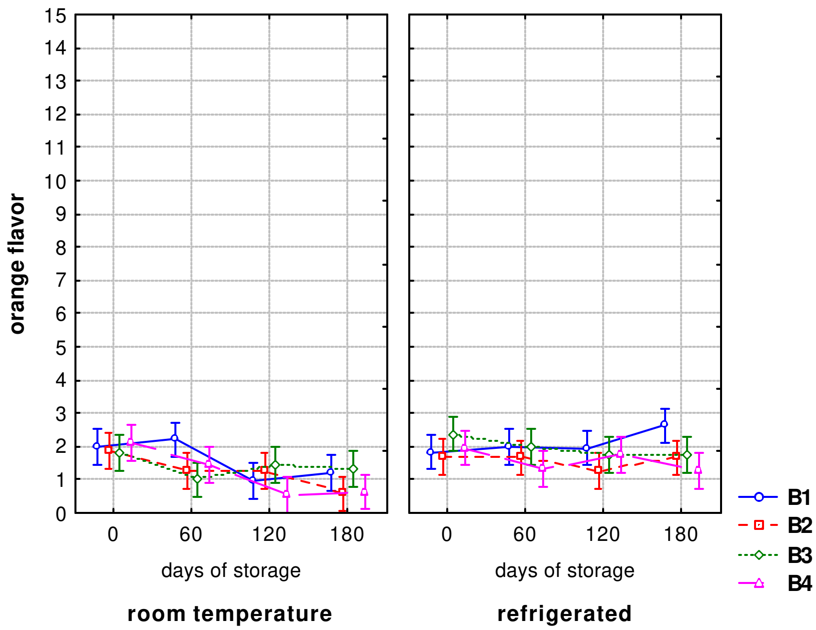

Figure 18. Distribution of the average scores attributed to the orange flavor of passion fruit juice beverages sweetened with sucrose (B1), aspartame (B2), sucralose (B3) and the aspartame/acesulfame-K blend (B4) at 0, 60, 120 and 180 days of storage.

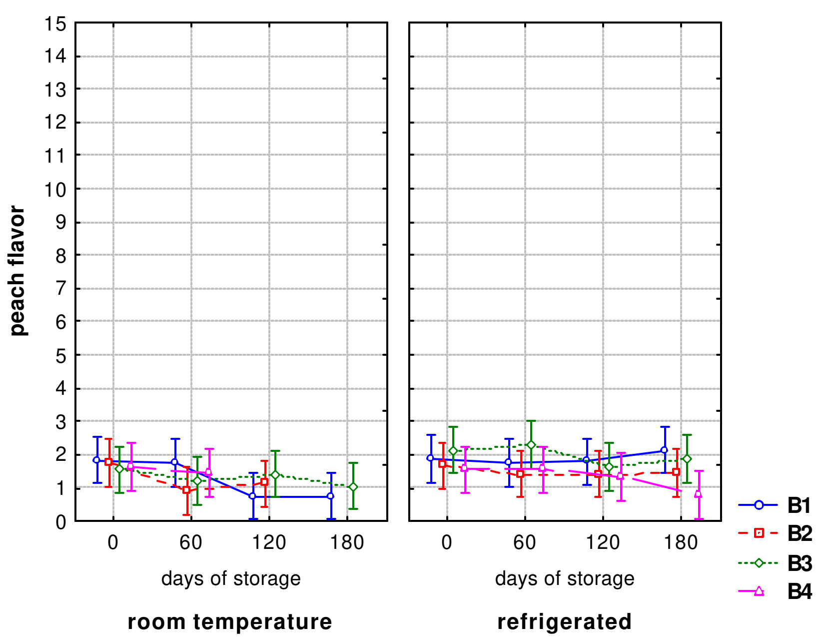

Figure 19. Distribution of the average scores attributed to the peach flavor of passion fruit juice beverages sweetened with sucrose (B1), aspartame (B2), sucralose (B3) and the aspartame/acesulfame-K blend (B4) at 0, 60, 120 and 180 days of storage.

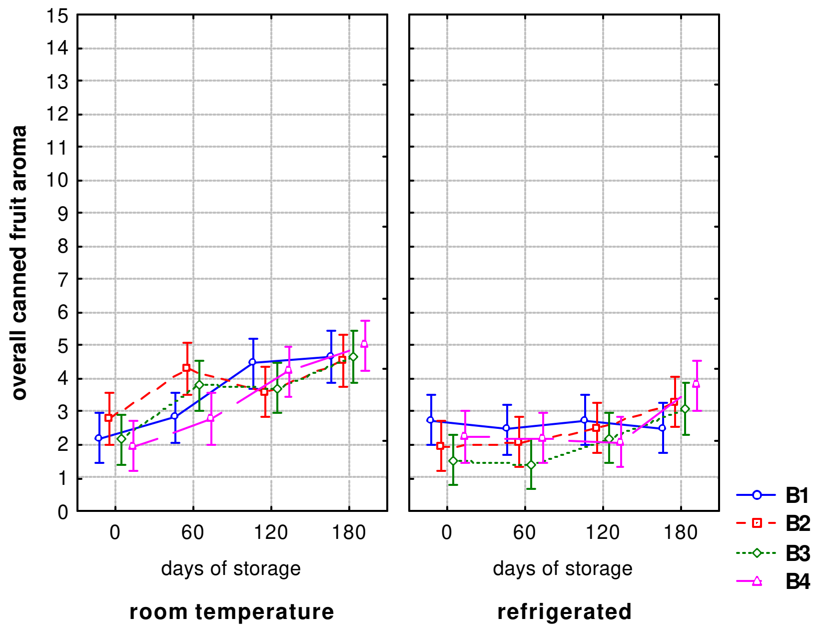

Figure 20. Distribution of the average scores attributed to the overall canned fruit aroma of passion fruit juice beverages sweetened with sucrose (B1), aspartame (B2), sucralose (B3) and the aspartame/acesulfame-K blend (B4) at 0, 60, 120 and 180 days of storage.

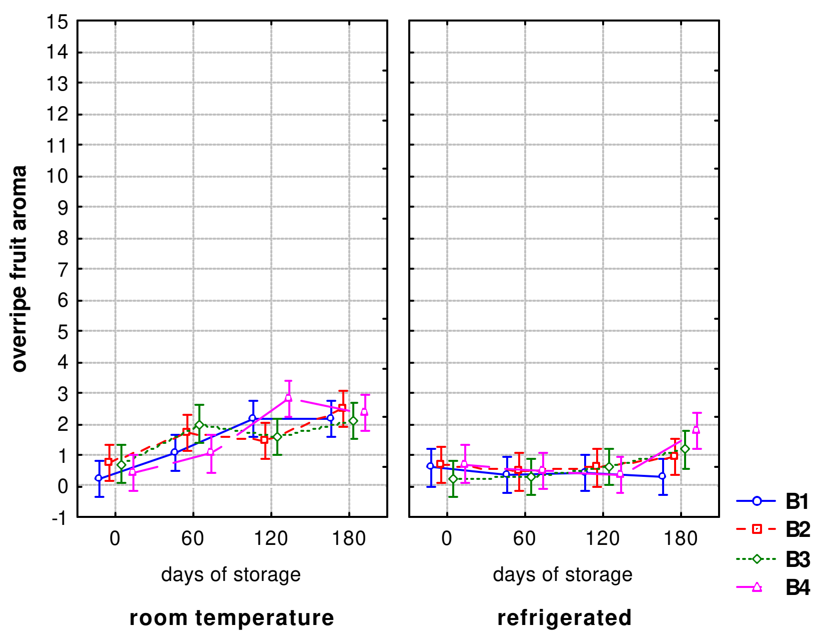

Figure 21. Distribution of the average scores attributed to the overripe fruit aroma of passion fruit juice beverages sweetened with sucrose (B1), aspartame (B2), sucralose (B3) and the aspartame/acesulfame-K blend (B4) at 0, 60, 120 and 180 days of storage.

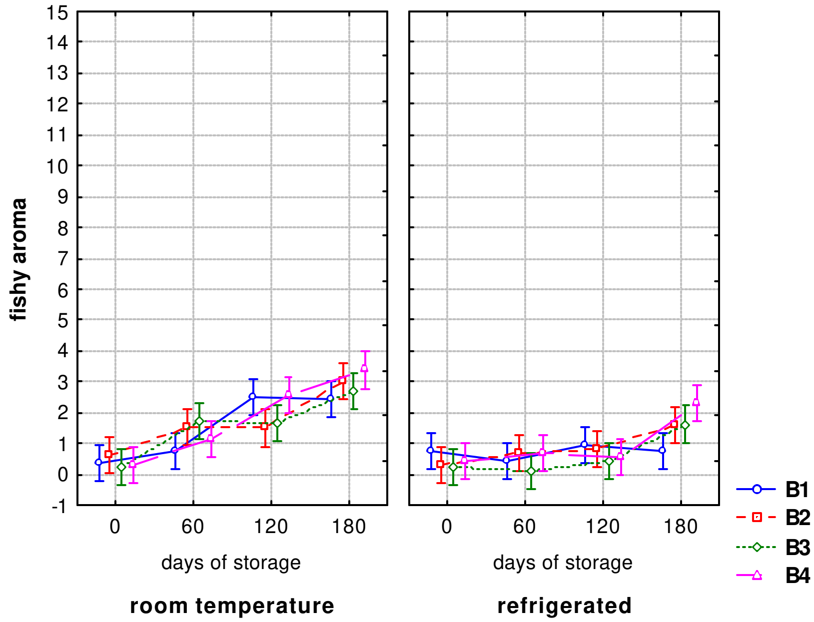

Figure 22. Distribution of the average scores attributed to the fishy aroma of passion fruit juice beverages sweetened with sucrose (B1), aspartame (B2), sucralose (B3) and the aspartame/acesulfame-K blend (B4) at 0, 60, 120 and 180 days of storage.

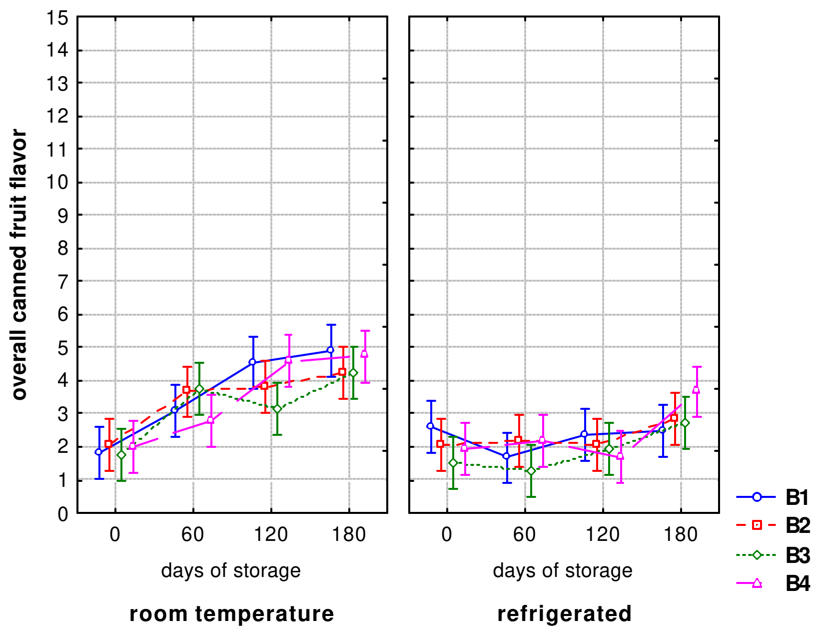

Figure 23. Distribution of the average scores attributed to the overall canned fruit flavor of passion fruit juice beverages sweetened with sucrose (B1), aspartame (B2), sucralose (B3) and the aspartame/acesulfame-K blend (B4) at 0, 60, 120 and 180 days of storage.

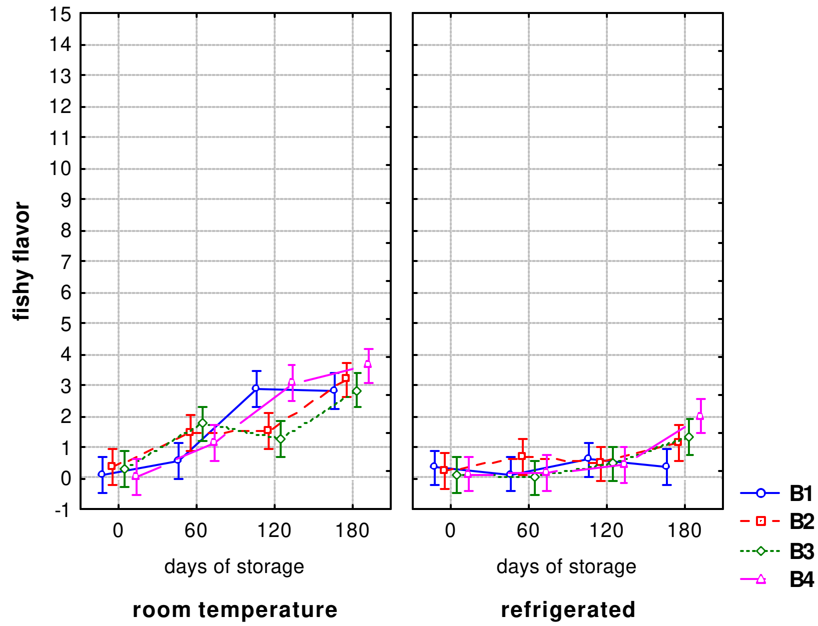

Figure 24. Distribution of the average scores attributed to the fishy flavor of passion fruit juice beverages sweetened with sucrose (B1), aspartame (B2), sucralose (B3) and the aspartame/acesulfame-K blend (B4) at 0, 60, 120 and 180 days of storage.

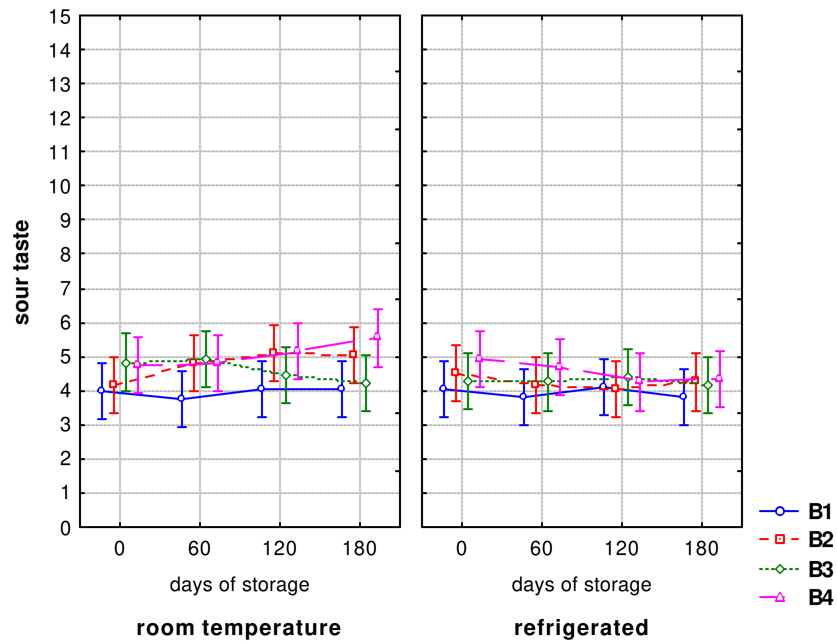

Figure 25. Distribution of the average scores attributed to the sour taste of passion fruit juice beverages sweetened with sucrose (B1), aspartame (B2), sucralose (B3) and the aspartame/acesulfame-K blend (B4) at 0, 60, 120 and 180 days of storage.

General discussion

Sweetener type played a very important role in the perception of color, sweet taste, sweet aftertaste and sour aftertaste. The beverages sweetened with sucrose and sucralose were the most stable with respect to those characteristics, independently of storage temperature. In the beverages sweetened with aspartame and aspartame/acesulfame-K blend, on the other hand, the intensities of those descriptors were only preserved if stored under refrigeration. These results were in line with those of QUINLAN & JENNER (1990), who studied the stability of sucralose in carbonated beverages and instant black coffee during 12 months, using HPLC and sensory analysis. They observed no significant changes in the sucralose level in any of the products investigated, that is, no loss of sweetness nor any interaction with other sample ingredients during storage, even when subjected to elevated temperatures.

Storing the beverages under refrigeration was crucial in order to preserve the fresh fruit aroma and flavor characteristics, as well as the fir-pine tree aroma and the color intensity characteristics, in all the beverages, independently of sweetener type, during a minimum period of 120 days. Only after 120 days of storage did these “positive” characteristics start to decrease. Storing the beverages at room temperature, on the contrary, not only favored the loss of these characteristics, but also contributed to the appearance and/or increase in the intensity of “negative” characteristics, such as canned fruit aroma and flavor, overripe fruit aroma, and fishy aroma and flavor. It is worth noting that these changes in the beverages stored at room temperature were constant, from the first 60 days of storage. These results were in line with those of SANDI et al. (2003), who studied the sensory quality of a passion fruit juice submitted to three equivalent time-temperature binomials (85°C/27s, 80°C/41s, 75°C/60s) and stored for 120 days at 25°C and 5°C. They found that, even though the passion fruit juice presented good microbiological quality and could be stored at room temperature, storing the juice under refrigeration contributed significantly ($p<0.05$) to the preservation of its sensory quality.

The sweet taste, sweet aftertaste, sour taste and sour aftertaste were also perceived differently depending on the temperature of storage, but only in the beverages sweetened with aspartame and the aspartame/acesulfame-K blend.

These beverages were perceived as less sweet and more sour when stored at room temperature than when stored under refrigeration. These findings were consistent with those obtained by BARON & HANGER (1997), who verified that increasing acid levels increased sourness and slightly decreased sweetness in a raspberry flavored beverage sweetened with an aspartame/acesulfame-K blend.

The flavor enhancer effect of aspartame in certain fruit flavored non-carbonated beverages demonstrated by BALDWIN & KORSCHGEN (1979) was not evident in the passion fruit based beverages evaluated in this study.

The only disadvantage of the beverage sweetened with sucralose was the higher amount of particles perceived in this beverage relative to the others, especially when stored under refrigeration, as well as the artificial sweetness aftertaste, also perceived to be higher in this beverage as compared to the others. Apart from this, the beverage sweetened with sucralose was much more stable and similar to the beverage sweetened with sucrose during storage, than those containing aspartame, and this stability was effectively improved by the use of refrigerated storage.

4. Conclusions

The results obtained in this study make two important contributions to juice beverage developers and researchers alike. Firstly, they demonstrate that the use of aspartame should be avoided when formulating a natural passion fruit juice beverage to be stored at room temperature, even for periods inferior to 60 days, as losses to its sweetness potency occur. The use of this sweetener would be appropriate only if the beverage were formulated to be stored under refrigeration. Sucralose, on the other hand, can be efficiently used in this type of beverage, as it does not change during the storage time, neither at room nor refrigerated temperatures. Secondly, and conversely, despite the high stability of sucralose and consequent advantage of not requiring refrigeration, the results revealed that the use of a refrigerated temperature is crucial to preserve the "positive" fresh fruit aroma and flavor characteristics of the beverage for a minimum period of 120 days. In this case, aspartame emerges again as an option for sweetening the low calorie passion fruit juice beverage. However, there is evidence of beverages sweetened with aspartame and aspartame/acesulfame-K and stored at room temperature being accepted by consumers only immediately after they are produced (at 0 day of storage), whilst those sweetened with sucrose and sucralose were accepted by consumers for a minimum period of 180 days of storage at room temperature (Chapter “Shelf-life study of a new ready-to-drink passion fruit juice beverage with different sweetener systems”). The sensory profile and stability results, therefore, indicated that the best option of sweetener to be used in the ready-to-drink natural passion fruit juice beverage studied was sucrose for the standard version and sucralose for the light version.

5. Acknowledgments

The authors acknowledge CNPq, Brazil, for the financial support, De Marchi Indústria e Comércio de Frutas, the passion fruit supplier, and Oregon State University, where this study was performed. The authors are also grateful to the sensory panelists who contributed their time and efforts to this study.

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Shelf-life study of a new ready-to-drink passion fruit juice beverage with different sweetener systems

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This paper will be submitted to Journal of Science of Food and Agriculture

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Abstract

The aim of this work was to study the shelf-life of four passion fruit juice beverages, sweetened with sucrose, aspartame, sucralose and an aspartame/acesulfame-K blend (4:1), respectively, during 6 months of storage, by assessing their microbiological, physical-chemical and sensory properties. The beverages showed microbiological safety during the whole 6 months of storage, both at room temperature (20-25°C) and under refrigeration (2-5°C). The physical-chemical characteristics of the beverages during storage did not determine their end of shelf-life. The liking attributes that determined the end of the shelf-life were flavor, sweetness, aftertaste and overall liking, according to which the sucrose and sucralose-sweetened beverages could be attributed a shelf-life period of at least 180 days of storage, while the aspartame and aspartame/acesulfame-K-blend - sweetened beverages should be attributed a period inferior to 60 days of storage. Accordingly, the best sweeteners to be used in this type of beverage in order to have satisfactory acceptance not only immediately after production but also during storage, were sucrose for the standard version and sucralose for the light version. The results obtained in this study also showed that the sweetness liking played a major role in flavor acceptance and pointed to the need to study the substitution of sucrose by high intense sweeteners every time a new product is formulated.

Keywords: passion fruit juice beverage, sweeteners, shelf-life, consumer acceptance

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1. Introduction

The volume of fruit based beverages is growing daily, in response to the consumer preference for health beverages. Consumers want to enjoy the use of beverages that not only quench thirst, but also offer innovation, health, convenience and some nutritional value (LÓPEZ, 2004; BERTO, 2003; ADBDULLAH & CHENG, 2001). Among the tropical fruit juices consumed on both the internal and external markets, passion fruit juice stands out due to its exotic and intense flavor, strong aroma, high acidity and pulp yield (SOUZA et al., 2002; GARRUTI, 1989).

Fruit based beverages are stored in warehouses and groceries for extended periods of several months, and few studies have been conducted on the shelf-life determination of ready-to-drink fruit based beverages, especially of passion fruit flavored beverages (PRATI et al., 2004, DE MARCHI et al., 2003, MODESTA et al., 2003; SANDI et al., 2003).

According to FU & LABUZA (1993), the shelf-life of a food or beverage is the time period for the product to become unacceptable from the sensory, nutritional or safety perspectives. For consumers, the end of the shelf-life is the time when the food or beverage no longer has an acceptable flavor (FU & LABUZA, 1993).

Knowledge of why a product deteriorates after it is manufactured as well as how much deterioration occurs, and of how one can limit or inhibit this deterioration, can be a determining factor for the success or failure of a product in the marketplace (LABUZA & SCHMIDL, 1988). The shelf-life of a product is controlled by: 1) the interaction of components of the system, 2) the process used, 3) the package permeability to light, moisture and gases, and 4) the time-temperature-relative humidity distribution during transportation and storage. With this information, the processor can choose the best system to maximize shelf-life, put an open date on the product indicating the maximum high quality life of the product, or insure the reliability of the nutritional label (WALETZKO & LABUZA, 1976).

Shelf-life determination usually requires several tests over time under different conditions followed by projection to the real world. The methods used for shelf-life prediction may be extremely sophisticated and may even utilize time-temperature computer systems to aid in monitoring product quality in the field. Objective measurements for the end of shelf-life generally comprise parameters related to microbiological safety, nutritional labeling and sensory properties (LABUZA & SCHMIDL, 1988). Accordingly, the aim of this work was to study the shelf-life of four new ready-to-drink passion fruit juice beverages, sweetened with sucrose, aspartame, sucralose and an aspartame/acesulfame-K blend (4:1), respectively, during 6 months of storage, by assessing their microbiological, physical-chemical and sensory properties.

2. Material and Methods

2.1 Material

The samples consisted of four ready-to-drink, Tetra-Pak® packaged passion fruit juice beverages, including the following ingredients: passion fruit pulp (De Marchi Indústria e Comércio de Frutas Ltda®), propylene glycol alginate (ISP do Brasil®), natural passion fruit aroma (Givaudan®), water and sweetener. The standard beverage was sweetened with 10% sucrose (União®) and the light beverages with 10% sucrose equi-sweet concentrations of aspartame (0.043%), sucralose (0.016%) and the aspartame/acesulfame-K blend (4:1) (0.026%).

2.2 Methods

2.2.1 Microbiological evaluation

250mL samples of each beverage, stored at room temperature (20-25°C) and under refrigeration (2-5°C), were submitted to microbiological evaluations immediately after production of the beverages (0 day of storage), at 90 days of storage and at 180 days of storage. The Standard Plate Count (CFU/mL), Total Coliforms (MPN/mL), Fecal Coliforms (MPN/mL), Molds and Yeasts (CFU/mL), Thermophilic Molds (CFU/mL), *Salmonella* sp, Thermophilic spores (CFU/mL), Mesophilic spores (CFU/mL), *lactobacillus* (CFU/mL) and *alicyclobacillus* sp (CFU/mL) were the microbiological analyses performed on each passion fruit juice beverage at each shelf-life period (VANDERZANT & SPLITTSTOESSER, 1992).

2.2.2 Physical-chemical evaluation

Total soluble solids (°Brix), pH, total acidity, ascorbic acid content and total and reducing sugars (AOAC, 1993) were determined in the four different-sweetened passion fruit juice beverages, stored at room temperature (20-25°C) and under refrigeration (2-5°C). 250mL samples of each beverage were analyzed immediately after production of the beverages (0 day of storage) and at 7, 15, 30, 60, 90 and 180 days of storage. Analyses were done in triplicate.

2.2.3 Sensory evaluation

In order to evaluate the acceptance of the four differently-sweetened passion fruit juice beverages during 6 months of storage, four consumer tests were carried out at 0, 60, 120 and 180 days of storage. The beverages were stored at room temperature (20-25°C) during the storage time. All the consumer tests were performed by 73 panelists, recruited among the Faculty of Food Engineering – FEA/UNICAMP students and workers. Consumers were presented with 30mL samples of each of the four different-sweetened beverages, one at a time. The samples were coded with three-digit random numbers and served at 5°C in plastic cups covered with plastic lids. Testing took place in individual booths under white lighting. A 9-point hedonic scale (1=dislike extremely, 2=dislike very much, 3=dislike moderately, 4=dislike slightly, 5=neither like nor dislike, 6=like slightly, 7=like moderately, 8=like very much, 9=like extremely) was used to assess overall liking, color liking, aroma liking, flavor liking, sweetness liking, aftertaste liking and texture liking. The consumers were asked to rate overall liking on two different occasions: immediately after rating color and aroma (at the beginning of the sensory evaluation), and again after rating flavor, sweetness, aftertaste and texture (at the end of the sensory evaluation). A 9-point intensity scale (1=no sweetness, 3=slightly sweet, 5=moderately sweet, 7=very sweet, 9=extremely sweet) was used to assess the sweetness intensity of the beverages. A just right scale (not nearly enough, not quite enough, just about right, somewhat too, way too) was used to assess the sweetness, sourness and passion fruit flavor levels. Finally, the purchase intention was assessed using the scale: 1=definitely would purchase, 2=probably would purchase, 3=may or may not purchase, 4=probably would not purchase, 5=definitely would not purchase (Figure 1).

2.2.4 Data analysis

The physical-chemical data was analyzed using the analysis of variance (ANOVA) and regression analysis (SAS Software version 8.2; Origin version 7.0). Post-hoc comparisons of means were performed using the Tukey test.

The consumer acceptance results were analyzed using correlation analysis and the analysis of variance (ANOVA), and post-hoc comparisons of means were performed using the Tukey test. Overall liking 1 and overall liking 2 scores were compared using the multivariate analysis of variance (MANOVA) (SAS Software version 8.2, Statistica Software version 5.0).

Please look at sample X and answer the first question. Then smell sample X and answer the second question.

Looking at the color, please rate how much you like or dislike this product.

Dislike Extremely	Dislike Very Much	Dislike Moderately	Dislike Slightly	Neither Like nor Dislike	Like Slightly	Like Moderately	Like Very Much	Like Extremely

Smelling this product, please rate how much you like or dislike this product.

Dislike Extremely	Dislike Very Much	Dislike Moderately	Dislike Slightly	Neither Like nor Dislike	Like Slightly	Like Moderately	Like Very Much	Like Extremely

Please taste the sample provided and answer the following questions.

Overall, considering appearance, aroma, flavor and texture, please rate how much you like or dislike this product.

Dislike Extremely	Dislike Very Much	Dislike Moderately	Dislike Slightly	Neither Like nor Dislike	Like Slightly	Like Moderately	Like Very Much	Like Extremely

Considering the flavor, please rate how much you like or dislike this product.

Dislike Extremely	Dislike Very Much	Dislike Moderately	Dislike Slightly	Neither Like nor Dislike	Like Slightly	Like Moderately	Like Very Much	Like Extremely

Considering the sweetness, please rate how much you like or dislike this product.

Dislike Extremely	Dislike Very Much	Dislike Moderately	Dislike Slightly	Neither Like nor Dislike	Like Slightly	Like Moderately	Like Very Much	Like Extremely

Figure 1. Consumer ballot.

Figure 1 (cont.)

Considering the sweetness of this product, please rate the sweetness intensity.

Not Sweet		Slightly Sweet		Moderately Sweet		Very Sweet		Extremely Sweet
☐	☐	☐	☐	☐	☐	☐	☐	☐

Thinking about the sweetness level of this product, would you say it is ....?

Not nearly sweet enough	Not quite sweet enough	Just about right in sweetness	Somewhat to sweet	Way too sweet
☐	☐	☐	☐	☐

Thinking about the sourness level of this product, would you say it is ...?

Not nearly sour enough	Not quite sour enough	Just about right in sourness	Somewhat too sour	Way too sour
☐	☐	☐	☐	☐

Thinking about the passion fruit flavor level of this product, would you say there is ...?

Not nearly enough passion fruit flavor	Not quite enough passion fruit flavor	Just about right in passion fruit flavor	Somewhat too much passion fruit flavor	Way too much passion fruit flavor
☐	☐	☐	☐	☐

Considering the texture of this product, please rate how much you like or dislike this product.

dislike extremely	dislike very much	dislike moderately	dislike slightly	neither like nor dislike	like slightly	like moderately	like very much	like extremely
☐	☐	☐	☐	☐	☐	☐	☐	☐

Considering the aftertaste, please rate how much you like or dislike this product.

dislike extremely	dislike very much	dislike moderately	dislike slightly	neither like nor dislike	like slightly	like moderately	like very much	like extremely
☐	☐	☐	☐	☐	☐	☐	☐	☐

Overall, considering appearance, aroma, flavor and texture, please rate how much you like or dislike this product.

dislike extremely	dislike very much	dislike moderately	dislike slightly	neither like nor dislike	like slightly	like moderately	like very much	like extremely
☐	☐	☐	☐	☐	☐	☐	☐	☐

How likely would you be to purchase this product?

Definitely would purchase	Probably would purchase	May or may not purchase	Probably would not purchase	Definitely would not purchase
☐	☐	☐	☐	☐

What would make this a better passion fruit juice beverage?

____

____

____

3. Results and Discussion

3.1 Microbiological evaluation

The results obtained from the microbiological analyses performed on the passion fruit juice beverages sweetened with sucrose, aspartame, sucralose and the aspartame/acesulfame-K blend (4:1), stored at room temperature (20-25°C) and under refrigeration (2-5°C), at 0, 90 and 180 days of storage are presented in Tables 1-4.

It can be seen from Tables 1-4 that the only microorganisms detected in the beverages were mesophilic microorganisms. These microorganisms were detected at 0 and 90 days of storage in the beverages sweetened with sucrose (Table 1), aspartame (Table 2) and sucralose (Table 3), and at 0 day of storage in the beverage sweetened with the aspartame/acesulfame-K blend (4:1) (Table 4). At 180 days of storage, no microorganism was detected in any of the beverages studied. The counts of mesophilic microorganisms were all less than 7×10^1 CFU/mL in all the beverages and no microbial growth was observed during storage. Moreover, there was no expressive difference between the beverages stored at room temperature and under refrigeration, during the whole 6 months of storage.

The ANVISA (National Agency of Sanitary Vigilance) Resolution number 12, of January 2nd, 2001, regulates the food microbiological standards and establishes the absence of coliform microorganisms in 50mL at 35°C in soft drinks, juices, nectars and other non-alcoholic beverages (except for dairy and chocolate based beverages), with or without preservatives, frozen or otherwise (ANVISA, 2005). Thus, from the obtained results it was concluded that besides observing the Brazilian legislation microbiological requirements, the passion fruit juice beverages sweetened with sucrose, aspartame, sucralose and aspartame/acesulfame-K (4:1) showed good microbiological quality during the whole 6 months period of storage both at room temperature and under refrigeration. That is, the heat treatment (98°C/30 seconds) together with the aseptic system of packaging (Tetra Pak®) used in the production of the beverages were adequate to guarantee the required microbiological safety of the beverages studied during at least 6 months of storage.

Accordingly, the microbiological quality of the beverages studied did not determine the end of their shelf-life.

SANDI et al. (2003), evaluating the quality of a passion fruit juice pasteurized at three equivalent time-temperature binomials (85°C/27seconds, 80°C/41seconds, 75°C/60 seconds), verified that the binomial 75°C/60seconds was not sufficient to reduce the microbiological counts, while the binomial 85°C/27seconds – slightly inferior to that used in this experiment, besides being sufficient, caused fewer changes in the sensory characteristics of the juice.

DE MARCHI et al. (2003), evaluating the microbiological quality of a natural passion fruit isotonic drink stored at room temperature and under refrigeration during 120 days, verified that the counts of molds and yeasts as well as those of mesophiles were low (<10CFU/mL and inferior to 6 x 10CFU/mL, respectively) and no microbial growth was shown throughout the time the drinks were stored, either at room temperature or under refrigeration.

Table 1. Results from the microbiological analyses performed on the sucrose-sweetened passion fruit juice beverage, stored at room temperature (20-25°C) and under refrigeration (2-5°C), at 0, 90 and 180 days of storage.

Microbiological determinations	**0 day of storage**		**90 days of storage**		**180 days of storage**	
	Room	Refrigerated	Room	Refrigerated	Room	Refrigerated
Standard Plate Count (CFU/mL)	60	60	<10	30	<10	<10
Mesophilic spores (CFU/mL)	30	30	10	10	<10	<10
Thermophilic spores (CFU/mL)	<10	<10	<10	<10	<10	<10
Molds and Yeasts (CFU/mL)	<10	<10	<10	<10	<10	<10
Coliforms at 35ºC (MPN/mL)	<0.3	<0.3	<0.3	<0.3	<0.3	<0.3
Coliforms at 45ºC (MPN/mL)	<0.3	<0.3	<0.3	<0.3	<0.3	<0.3
Lactobacillus (CFU/mL)	<10	<10	<10	<10	<10	<10
Alicyclobacillus sp (CFU/mL)	<10	<10	<10	<10	<10	<10
Salmonella sp	Absence / 25mL	Absence / 25mL	Absence / 25mL	Absence / 25mL	Absence / 25mL	Absence / 25mL
Thermophilic Molds (CFU/mL)	Absence / 25mL	Absence / 25mL	Absence / 25mL	Absence / 25mL	Absence / 25mL	Absence / 25mL

Table 2. Results from the microbiological analyses performed on the aspartame-sweetened passion fruit juice beverage, stored at room temperature (20-25°C) and under refrigeration (2-5°C), at 0, 90 and 180 days of storage.

Microbiological determinations	**0 day of storage**		**90 days of storage**		**180 days of storage**	
	Room	Refrigerated	Room	Refrigerated	Room	Refrigerated
Standard Plate Count (CFU/mL)	70	70	<10	30	<10	<10
Mesophilic spores (CFU/mL)	<10	<10	<10	<10	<10	<10
Thermophilic spores (CFU/mL)	<10	<10	<10	<10	<10	<10
Molds and Yeasts (CFU/mL)	<10	<10	<10	<10	<10	<10
Coliforms at 35ºC (MPN/mL)	<0.3	<0.3	<0.3	<0.3	<0.3	<0.3
Coliforms at 45ºC (MPN/mL)	<0.3	<0.3	<0.3	<0.3	<0.3	<0.3
Lactobacillus (CFU/mL)	<10	<10	<10	<10	<10	<10
Alicyclobacillus sp (CFU/mL)	<10	<10	<10	<10	<10	<10
Salmonella sp	Absence / 25mL	Absence / 25mL	Absence / 25mL	Absence / 25mL	Absence / 25mL	Absence / 25mL
Thermophilic Molds (CFU/mL)	Absence / 25mL	Absence / 25mL	Absence / 25mL	Absence / 25mL	Absence / 25mL	Absence / 25mL

Table 3. Results from the microbiological analyses performed on the sucralose-sweetened passion fruit juice beverage, stored at room temperature (20-25°C) and under refrigeration (2-5°C), at 0, 90 and 180 days of storage.

Microbiological determinations	**0 day of storage**		**90 days of storage**		**180 days of storage**	
	Room	Refrigerated	Room	Refrigerated	Room	Refrigerated
Standard Plate Count (CFU/mL)	20	20	10	60	<10	10
Mesophilic spores (CFU/mL)	<10	<10	10	20	<10	<10
Thermophilic spores (CFU/mL)	<10	<10	<10	<10	<10	<10
Molds and Yeasts (CFU/mL)	<10	<10	<10	<10	<10	<10
Coliforms at 35ºC (MPN/mL)	<0.3	<0.3	<0.3	<0.3	<0.3	<0.3
Coliforms at 45ºC (MPN/mL)	<0.3	<0.3	<0.3	<0.3	<0.3	<0.3
Lactobacillus (CFU/mL)	<10	<10	<10	<10	<10	<10
Alicyclobacillus sp (CFU/mL)	<10	<10	<10	<10	<10	<10
Salmonella sp	Absence / 25mL	Absence / 25mL	Absence / 25mL	Absence / 25mL	Absence / 25mL	Absence / 25mL
Thermophilic Molds (CFU/mL)	Absence / 25mL	Absence / 25mL	Absence / 25mL	Absence / 25mL	Absence / 25mL	Absence / 25mL

Table 4. Results from the microbiological analyses performed on the aspartame/acesulfame-K-sweetened passion fruit juice beverage, stored at room temperature (20-25°C) and under refrigeration (2-5°C), at 0, 90 and 180 days of storage.

Microbiological determinations	**0 day of storage**		**90 days of storage**		**180 days of storage**	
	Room	Refrigerated	Room	Refrigerated	Room	Refrigerated
Standard Plate Count (CFU/mL)	<10	<10	<10	<10	<10	<10
Mesophilic spores (CFU/mL)	10	10	<10	<10	<10	<10
Thermophilic spores (CFU/mL)	<10	<10	<10	<10	<10	<10
Molds and Yeasts (CFU/mL)	<10	<10	<10	<10	<10	<10
Coliforms at 35ºC (MPN/mL)	<0.3	<0.3	<0.3	<0.3	<0.3	<0.3
Coliforms at 45ºC (MPN/mL)	<0.3	<0.3	<0.3	<0.3	<0.3	<0.3
Lactobacillus (CFU/mL)	<10	<10	<10	<10	<10	<10
Alicyclobacillus sp (CFU/mL)	<10	<10	<10	<10	<10	<10
Salmonella sp	Absence / 25mL	Absence / 25mL	Absence / 25mL	Absence / 25mL	Absence / 25mL	Absence / 25mL
Thermophilic Molds (CFU/mL)	Absence / 25mL	Absence / 25mL	Absence / 25mL	Absence / 25mL	Absence / 25mL	Absence / 25mL

3.2 Physical-chemical evaluation

The results obtained from the physical-chemical analyses performed on the sucrose, aspartame, sucralose and aspartame/acesulfame-K-blend - sweetened beverages, stored at room temperature (20-25°C) and under refrigeration (2-5°C), for 0, 7, 15, 30, 60, 90 and 180 days of storage are presented in Table 5 and Figures 2-7.

The sucrose-sweetened beverage (B1) presented a total soluble solids content of from 11.1 to 11.8°Brix during the 180 days of storage and, as expected, these values were significantly higher than those presented by the light beverages (B2, B3 and B4), which ranged between 2.3 and 3.0°Brix (Table 5). Concerning the temperature conditions, the light beverages showed slight variations in their total soluble solids contents at 7, 15 and 30 days of storage ($p<0.05$). No significant changes ($p>0.05$) were observed in the total soluble solids of any of the beverages either at room temperature or under refrigeration during the storage time (Figure 2). This finding is in line with the study of DE MARCHI et al. (2003), who found that the total soluble solids of a natural passion fruit isotonic drink did not change during

141 days of storage at both room and refrigerated temperatures. In addition, the total soluble solids contents determined in the passion fruit juice beverages evaluated in this study attended the Brazilian legislation requirements for passion fruit juice based beverages (BRAZIL, 2003).

The pH of the beverages ranged between 3.00 and 3.40 during 180 days of storage, and no significant difference (p>0.05) was observed between the beverages stored under refrigeration at each period of storage (Table 5). The same behavior was observed for the beverages stored at room temperature at 0, 7, 90, and 180 days. The pH of the beverages was not affected by the temperature conditions during the whole period of storage (p>0.05). No significant changes (p>0.05) were observed in the pH of the beverages either at room temperature or under refrigeration during the storage time (Figure 3). These results were very similar to those obtained by DE MARCHI et al. (2003), who, studying a natural passion fruit isotonic drink stored at room temperature and under refrigeration, determined a pH range of 2.85-3.23, which did not change during 141 days of storage.

The total acidity of the beverages ranged between 0.68 and 0.85g of citric acid/100mL. The light beverages (B2, B3 and B4) stored at room temperature as well as those stored under refrigeration presented significantly higher total acidity (g/100mL) than the standard beverage (p<0.05) at most of the time points studied (Table 5). Concerning the temperature conditions, only at 180 days of storage did the beverages fail to differ significantly from each other (p>0.05). Similarly to what was observed for total soluble solids, no significant changes (p>0.05) were observed in the total acidity of any of the beverages either at room temperature or under refrigeration during the storage time (Figure 4). These results were superior to those obtained by DE MARCHI et al. (2003), who determined 0.46 to 0.47g of citric acid/100mL in a natural passion fruit isotonic drink stored at room temperature and under refrigeration during 141 days. It is important to notice, however, that the isotonic drink was formulated with 11% passion fruit pulp while the beverages evaluated in this study were formulated with 20% passion fruit pulp. Moreover, these results matched the Brazilian legislation requirements for passion fruit juice based beverages (BRAZIL, 2003).

Table 5. Results from the physical-chemical analyses performed on the passion fruit juice beverages sweetened with sucrose (B1), aspartame (B2), sucralose (B3) and the aspartame/acesulfame-K blend (B4), stored at room temperature[1] (20-25°C) and under refrigeration[2] (2-5°C), at 0, 7, 15, 30, 60, 90 and 180 days of storage.

Beverages	Total soluble solids (°Brix)		pH		Total acidity (g/100mL)		Ascorbic acid (mg/100mL)		Total sugars (g glucose/100mL)		Reducing sugars(g glucose/100mL)	
	Room[1]	Refr[2]	Room	Refr	Room	Refr	Room	Refr	Room	Refr	Room	Refr
0 day												
B1	11.40^{Aa}	11.40^{Aa}	3.13^{Aa}	3.13^{Aa}	0.75^{Aa}	0.75^{Aa}	4.64^{Ba}	4.64^{Ba}	7.49^{Aa}	7.49^{Aa}	1.67^{Aa}	1.67^{Aa}
B2	2.40^{Ba}	2.40^{Ba}	3.18^{Aa}	3.18^{Aa}	0.70^{Ba}	0.70^{Ba}	3.55^{Ca}	3.55^{Ca}	0.97^{BCa}	0.97^{BCa}	0.68^{Ba}	0.68^{Ba}
B3	2.40^{Ba}	2.40^{Ba}	3.13^{Aa}	3.13^{Aa}	0.68^{Ca}	0.68^{Ca}	4.90^{Aa}	4.90^{Aa}	0.95^{Ca}	0.95^{Ca}	0.70^{Ba}	0.70^{Ba}
B4	2.40^{Ba}	2.40^{Ba}	3.17^{Aa}	3.17^{Aa}	0.69^{Ba}	0.69^{Ba}	3.59^{Ca}	3.59^{Ca}	1.06^{Ba}	1.06^{Ba}	0.69^{Ba}	0.69^{Ba}
7 days												
B1	11.60^{Aa}	11.47^{Aa}	3.20^{Aa}	3.17^{Aa}	0.78^{Bb}	0.79^{Ca}	2.94^{Aa}	2.95^{Aa}	6.73^{Aa}	6.17^{Ab}	1.36^{Aa}	1.36^{Aa}
B2	2.80^{Ba}	2.33^{Cb}	3.20^{Aa}	3.20^{Aa}	0.84^{Aa}	0.77^{Db}	2.83^{ABa}	2.87^{Aa}	0.95^{Ba}	0.89^{Cb}	0.52^{Ba}	0.52^{Ba}
B3	2.40^{Da}	2.40^{BCa}	3.23^{Aa}	3.25^{Aa}	0.73^{Cb}	0.82^{Ba}	2.71^{Cb}	2.84^{Aa}	0.93^{Ca}	0.66^{Db}	0.51^{Ca}	0.50^{Ca}
B4	2.60^{Ca}	2.60^{Ba}	3.22^{Aa}	3.23^{Aa}	0.84^{Aa}	0.84^{Aa}	2.87^{ABb}	2.94^{Aa}	0.92^{Ca}	0.92^{Ba}	0.50^{Ca}	0.49^{Ca}
15 days												
B1	11.53^{Aa}	11.47^{Aa}	3.27^{Ba}	3.30^{Aa}	0.78^{Ba}	0.79^{Ca}	1.78^{Aa}	1.82^{Aa}	5.08^{Aa}	4.75^{Ab}	1.22^{Aa}	1.22^{Aa}
B2	3.00^{Ba}	3.00^{Ba}	3.40^{Aa}	3.33^{Aa}	0.84^{Ab}	0.85^{Aa}	1.79^{Aa}	1.85^{Aa}	0.73^{Ba}	0.72^{Ba}	0.51^{Ba}	0.51^{Ba}
B3	2.80^{Cb}	3.00^{Ba}	3.30^{Aba}	3.27^{Aa}	0.84^{Aa}	0.84^{Ba}	1.73^{Ab}	1.83^{Aa}	0.64^{Cb}	0.74^{Ba}	0.51^{Ba}	0.51^{Ba}
B4	3.00^{Bb}	3.17^{Ba}	3.33^{ABa}	3.40^{Aa}	0.76^{Ca}	0.76^{Da}	1.78^{Aa}	1.81^{Aa}	0.71^{Ba}	0.71^{Ba}	0.50^{Ba}	0.50^{Ba}
30 days												
B1	11.20^{Aa}	11.13^{Aa}	3.15^{Bb}	3.20^{Aa}	0.76^{Ca}	0.75^{Ab}	1.45^{Aa}	1.49^{Aa}	4.96^{Aa}	4.38^{Ab}	1.06^{Aa}	1.06^{Aa}
B2	2.73^{Ba}	2.80^{Ba}	3.20^{Aa}	3.23^{Aa}	0.77^{Ba}	0.75^{Ab}	1.49^{Aa}	1.53^{Aa}	0.72^{Ba}	0.72^{Ba}	0.49^{Ca}	0.49^{Ca}
B3	2.67^{Ba}	2.60^{Ca}	3.20^{Aa}	3.20^{Aa}	0.68^{Db}	0.75^{Aa}	1.49^{Aa}	1.53^{Aa}	0.74^{Ba}	0.74^{Ba}	0.51^{Ba}	0.51^{Ba}
B4	2.60^{Bb}	2.80^{Ba}	3.20^{Aa}	3.20^{Aa}	0.79^{Aa}	0.75^{Ab}	1.49^{Aa}	1.53^{Aa}	0.74^{Ba}	0.74^{Ba}	0.50^{Ba}	0.50^{Ba}
60 days												
B1	11.40^{Aa}	11.40^{Aa}	3.00^{Ba}	3.07^{Aa}	0.77^{Cb}	0.79^{Ba}	0.78^{Bb}	0.89^{Aa}	4.60^{Aa}	4.45^{Ab}	1.05^{Aa}	1.05^{Aa}
B2	2.80^{Ba}	2.73^{Ba}	3.13^{Aa}	3.13^{Aa}	0.82^{Bb}	0.85^{Aa}	0.71^{Bb}	0.77^{Ba}	0.68^{Bb}	0.75^{Ba}	0.34^{BCa}	0.34^{Ba}
B3	2.80^{Ba}	2.80^{Ba}	3.10^{ABa}	3.07^{Aa}	0.84^{Ab}	0.85^{Aa}	0.86^{Aa}	0.78^{Ba}	0.67^{Bb}	0.72^{Ba}	0.34^{Ba}	0.34^{Ba}
B4	2.80^{Ba}	2.80^{Ba}	3.07^{ABa}	3.03^{Aa}	0.84^{Ab}	0.84^{Aa}	0.72^{Bb}	0.78^{Ba}	0.67^{Ba}	0.65^{Ca}	0.32^{Ca}	0.32^{Ca}
90 days												
B1	11.60^{Aa}	11.53^{Aa}	3.07^{Aa}	3.07^{Aa}	0.77^{Ca}	0.77^{Ca}	0.56^{Ab}	0.63^{Aa}	4.30^{Aa}	4.23^{Aa}	1.01^{Aa}	1.01^{Aa}
B2	2.80^{Ba}	2.67^{Ba}	3.07^{Aa}	3.07^{Aa}	0.85^{Aa}	0.84^{Aa}	0.54^{Ab}	0.61^{Ba}	0.65^{Bb}	0.68^{Ba}	0.30^{Ba}	0.30^{Ba}
B3	2.80^{Ba}	2.80^{Ba}	3.07^{Aa}	3.10^{Aa}	0.82^{Ba}	0.81^{Bb}	0.55^{Ab}	0.61^{Ba}	0.62^{Bb}	0.69^{Ba}	0.31^{Ba}	0.31^{Ba}
B4	2.60^{Ca}	2.60^{Ba}	3.03^{Aa}	3.10^{Aa}	0.82^{Ba}	0.81^{Ba}	0.55^{Ab}	0.62^{ABa}	0.65^{Ba}	0.65^{Ba}	0.31^{Ba}	0.31^{Ba}
180 days												
B1	11.80^{Aa}	11.67^{Aa}	3.07^{Aa}	3.13^{Aa}	0.78^{Ca}	0.79^{Ca}	0.40^{Ab}	0.47^{Aa}	4.16^{Aa}	4.10^{Aa}	1.01^{Aa}	1.01^{Aa}
B2	2.80^{Ba}	2.80^{Ba}	3.07^{Aa}	3.07^{Aa}	0.84^{Aa}	0.84^{Aa}	0.38^{Cb}	0.45^{Ba}	0.60^{Ba}	0.60^{Ba}	0.30^{Ba}	0.30^{Ba}
B3	2.73^{Ba}	2.80^{Ba}	3.07^{Aa}	3.07^{Aa}	0.84^{Aa}	0.84^{Aa}	0.39^{Bb}	0.45^{Ba}	0.61^{Bb}	0.62^{Ba}	0.31^{Ba}	0.31^{Ba}
B4	2.80^{Ba}	2.73^{Ba}	3.10^{Aa}	3.13^{Aa}	0.81^{Ba}	0.81^{Ba}	0.39^{BCb}	0.45^{Ba}	0.61^{Bb}	0.62^{Ba}	0.31^{Ba}	0.31^{Ba}

Averages in a column followed by different capital letters represent significant differences ($p<0.05$).

Averages in a row followed by different small letters represent significant differences ($p<0.05$).

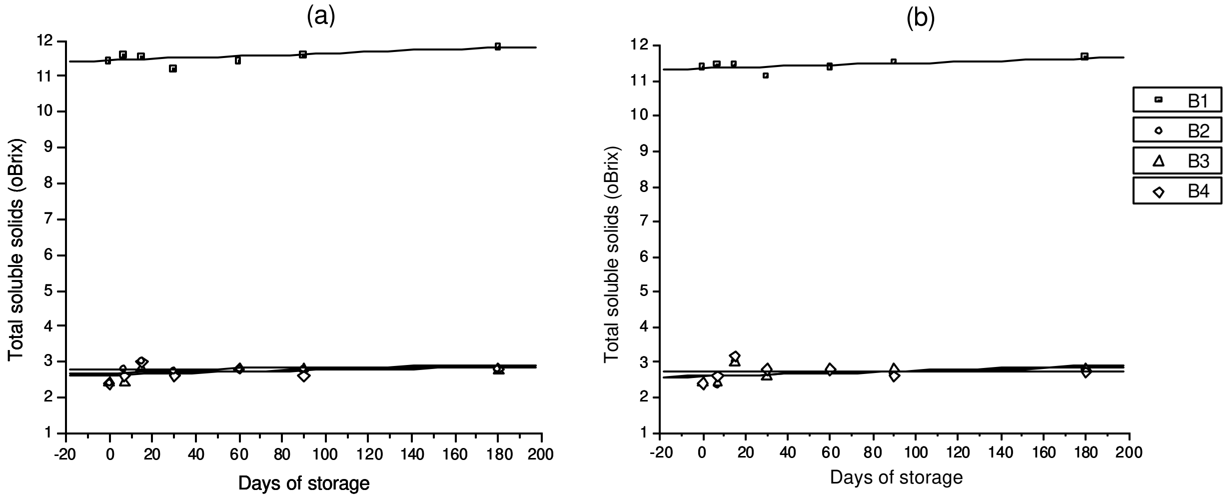

Figure 2. Total soluble solids (°Brix) of passion fruit juice beverages sweetened with sucrose (B1), aspartame (B2), sucralose (B3) and the aspartame/acesulfame-K blend (B4), stored at room temperature (a) and under refrigeration (b) during 180 days.

B1 [(a) y=11.40+0.002X, r^2=0.42, p=0.12 / (b) y=11.35+0.002X, r^2=0.38, p=0.12]

B2 [(a) y=2.73+6.40X, r^2=0.05, p=0.62 / (b) y=2.61+0.001, r^2=0.12, p=0.45]

B3 [(a) y=2.59+0.001X, r^2=0.26, p=0.25 / (b) y=2.60+0.002X, r^2=0.19, p=0.33]

B4 [(a) y=2.64+8.70X, r^2=0.08, p=0.54 / (b) y=2.73+3.42X, r^2=0.001, p=0.98]

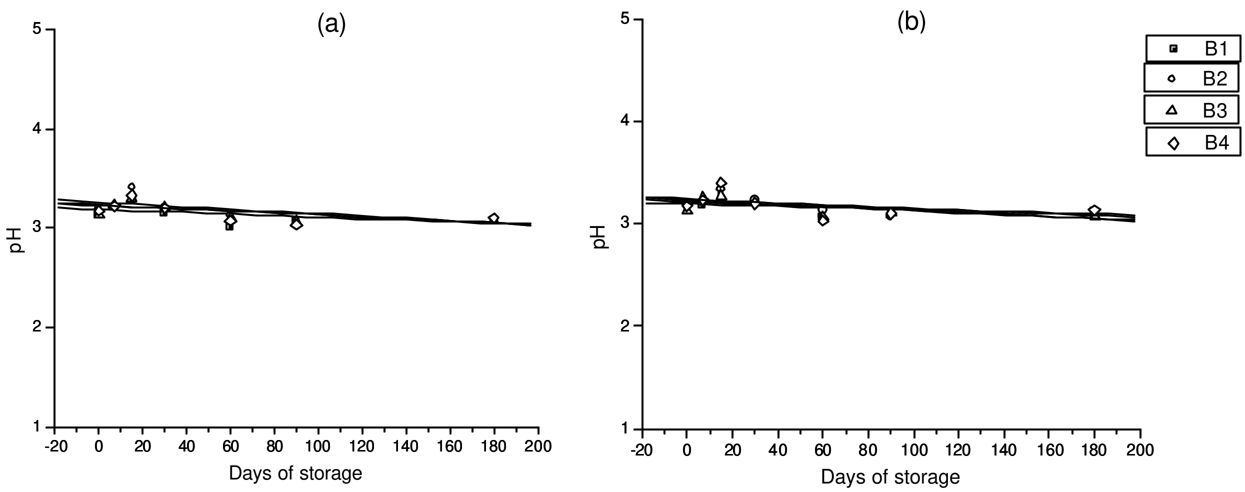

Figure 3. pH of passion fruit juice beverages sweetened with sucrose (B1), aspartame (B2), sucralose (B3) and the aspartame/acesulfame-K blend (B4), stored at room temperature (a) and under refrigeration (b) during 180 days.

B1 [(a) y=3.17-8.07X, r^2=0.33, p=0.18 / (b) y=3.18-5.24X, r^2=0.17, p=0.35]

B2 [(a) y=3.24-0.001X, r^2=0.43, p=0.11 / (b) y=3.23-0.001X, r^2=0.54, p=0.06]

B3 [(a) y=3.22-9.42X, r^2=0.64, p=0.09 / (b) y=3.21-8.96X, r^2=0.59, p=0.09]

B4 [(a) y=3.21-9.71X, r^2=0.37, p=0.15 / (b) y=3.23-8.58X, r^2=0.27, p=0.29]

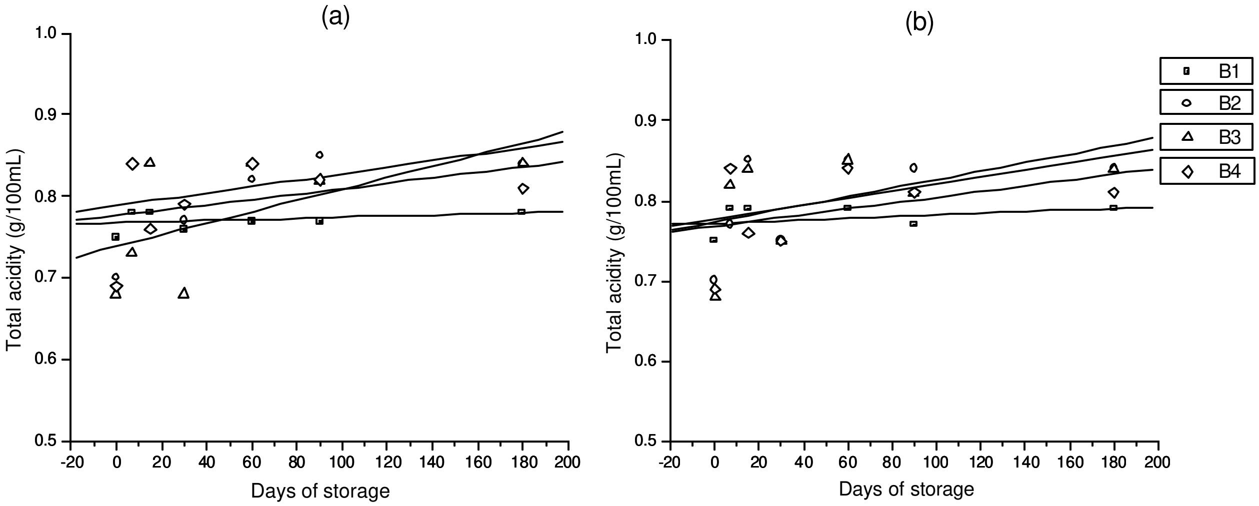

Figure 4. Total acidity (g/100mL) of passion fruit juice beverages sweetened with sucrose (B1), aspartame (B2), sucralose (B3) and the aspartame/acesulfame-K blend (B4), stored at room temperature (a) and under refrigeration (b) during 180 days.
B1 [(a) y=0.76+7.04X, r^2=0.15, p=0.39 / (b) y=0.77+1.01X, r^2=0.11, p=0.46]
B2 [(a) y=0.79+3.93X, r^2=0.21, p=0.30 / (b) y=0.77+5.26X, r^2=0.31, p=0.19]
B3 [(a) y=0.74+7.04X, r^2=0.35, p=0.16 / (b) y=0.77+4.46X, r^2=0.21, p=0.30]
B4 [(a) y=0.77+3.32X, r^2=0.16, p=0.38 / (b) y=0.77+3.58X, r^2=0.17, p=0.36]

The ascorbic acid content (mg/100mL) determined at 0 day of storage ranged between 3.55 and 3.90mg/100mL, the sucralose-sweetened beverage (B3) being that with the highest content, followed by the sucrose-sweetened beverage (B1), and in last place, by the aspartame (B2) and the aspartame/acesulfame-K blend (B4) – sweetened beverages ($p<0.05$) (Table 5). As observed in Figure 5, the ascorbic acid content of the beverages characterized a first order decay during the shelf-life period ($p<0.05$), 97 to 99% of the variations in the ascorbic acid content of the beverages being explained by time of storage. This finding is in line with earlier studies on vitamin C losses during storage (WANNINGER, 1972; WALETZKO & LABUZA, 1976; LEE et al., 1977; NAGY & SMOOT, 1977; CLEMENTE, 1998). The ascorbic acid content of the beverages showed a noticeable decrease (48%-65%) during the first 15 days of storage, and kept decreasing gradually up to the end of 180 days of storage, when it ranged between 0.38 and 0.47mg/100mL. Thus at the end of 180 days of storage, the beverages presented 87.32% to 92.04% less ascorbic acid as compared to the day when they were produced. These results were similar to those obtained by SANTOS (2004), who determined the highest vitamin C losses (over 50%) in organic passion fruit pulp during the first 15 days of storage. Furthermore, these results confirmed the statement of DEL CARO et al. (2004), according to whom, despite the losses in vitamin C content due to heat treatment, the highest losses occurred during the storage of the product. In general, the beverages stored under refrigeration showed significantly higher ascorbic acid content ($p<0.05$) than those stored at room temperature, especially after 60 days of storage.

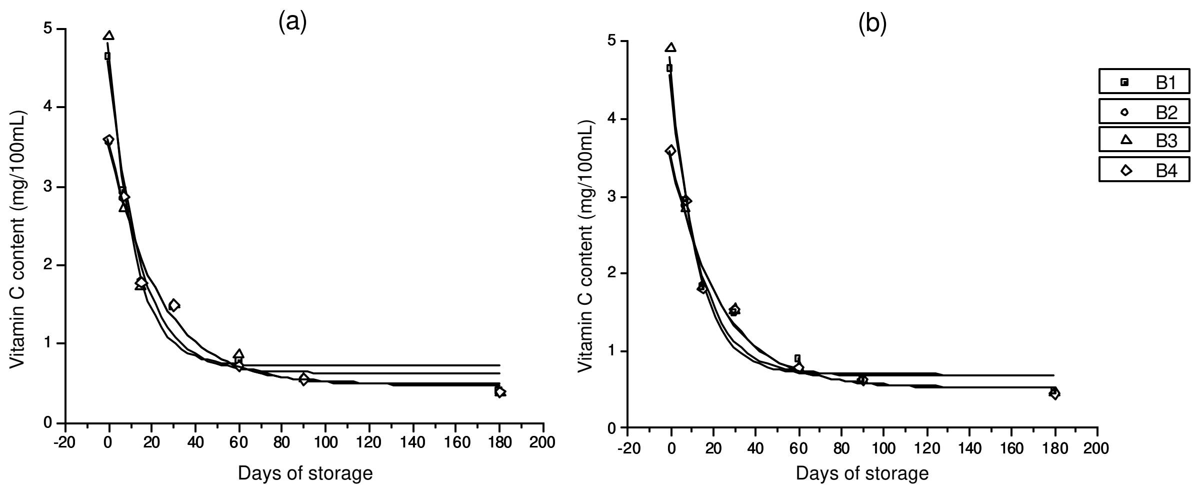

Figure 5. Ascorbic acid content (mg/100mL) of passion fruit juice beverages sweetened with sucrose (B1), aspartame (B2), sucralose (B3) and the aspartame/acesulfame-K blend (B4), stored at room temperature (a) and under refrigeration (b) during 180 days.

B1 [(a) $y=0.61+3.95^{(-x/14.16)}$, $r^2=0.98$, $p<0.05$ / (b) $y=0.69+3.87^{(-x/13.88)}$, $r^2=0.98$, $p<0.05$]

B2 [(a) $y=0.45+3.08^{(-x/23.34)}$, $r^2=0.99$, $p<0.05$ / (b) $y=0.52+3.02^{(-x/23.56)}$, $r^2=0.99$, $p<0.05$]

B3 [(a) $y=0.69+4.11^{(-x/11.49)}$, $r^2=0.97$, $p<0.05$ / (b) $y=0.69+4.12^{(-x/12.62)}$, $r^2=0.98$, $p<0.05$]

B4 [(a) $y=0.47+3.11^{(-x/22.76)}$, $r^2=0.98$, $p<0.05$ / (b) $y=0.53+3.07^{(-x/22.85)}$, $r^2=0.98$, $p<0.05$]

According to CHAN (1993), the total carbohydrates are the second largest constituents in passion fruit juice, after the water, and the sugars make up most of the carbohydrates.

The standard beverage (B1), as expected, presented total and reducing sugar contents (g glucose/100mL) significantly higher than the light beverages (B2, B3 and B4) during the whole storage period ($p<0.05$) (Table 5). At 0 day of storage, the total and reducing sugar contents determined in the standard beverage (B1) were 7.49g glucose/100mL and 1.67g glucose/100mL, respectively, and those determined in the light beverages (B2, B3 and B4) ranged between 0.95 and 1.06g glucose/100mL, and between 0.68 and 0.70g glucose/100mL, respectively. These values, similarly to what was observed for the vitamin C content, decreased noticeably during the first 15 days of storage, and kept decreasing gradually up to the end of 180 days of storage ($p<0.05$). 79 to 99% of the variations in the total and reducing sugar contents of the beverages were explained by time of storage (Figures 6 and 7). At the end of the shelf-life period, the standard beverage showed total sugar contents of 4.10 to 4.16 g glucose/100mL and reducing sugar contents of 1.01 g glucose/100mL, while the light beverages showed total sugar contents of 0.60 to 0.79 g glucose/100mL and reducing sugar contents of 0.30 g glucose/100mL.

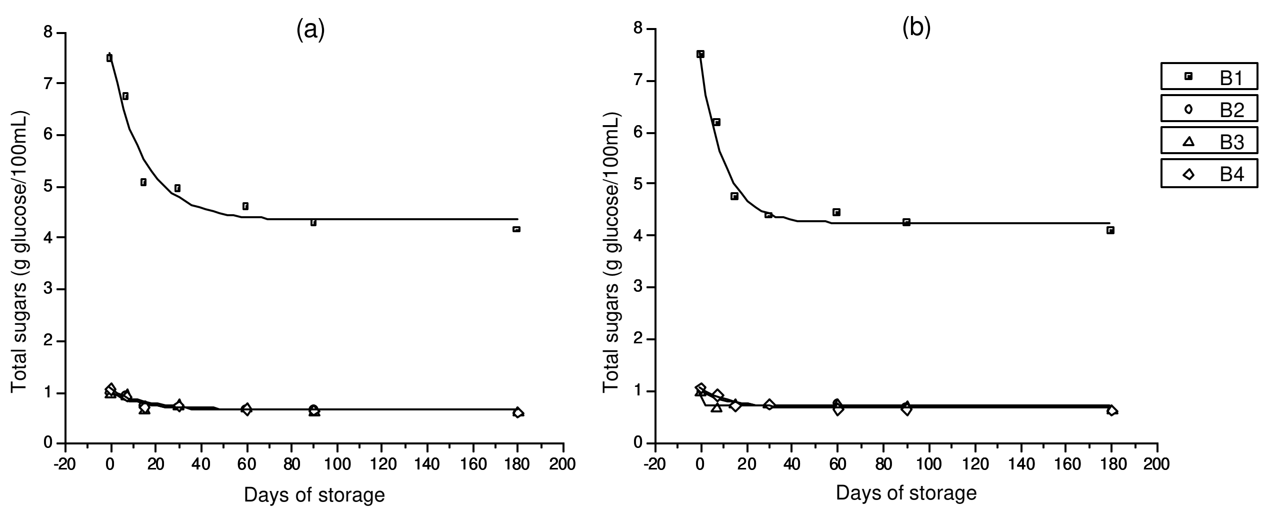

Figure 6. Total sugars (g glucose/100mL) of passion fruit juice beverages sweetened with sucrose (B1), aspartame (B2), sucralose (B3) and the aspartame/acesulfame-K blend (B4), stored at room temperature (a) and under refrigeration (b) during 180 days.

B1 [(a) $y=4.33+3.24^{(-x/15.19)}$, $r^2=0.95$, $p<0.05$ / (b) $y=4.22+3.33^{(-x/10.33)}$, $r^2=0.98$, $p<0.05$]

B2 [(a) $y=0.63+0.36^{(-x/19.90)}$, $r^2=0.91$, $p<0.05$ / (b) $y=0.67+0.30^{(-x/13.27)}$, $r^2=0.84$, $p<0.05$]

B3 [(a) $y=0.63+0.33^{(-x/15.07)}$, $r^2=0.79$, $p<0.05$ / (b) $y=0.70+0.23^{(-x/0.16)}$, $r^2=0.82$, $p<0.05$]

B4 [(a) $y=0.65+0.42^{(-x/12.54)}$, $r^2=0.94$, $p<0.05$ / (b) $y=0.65+0.42^{(-x/12.63)}$, $r^2=0.95$, $p<0.05$]

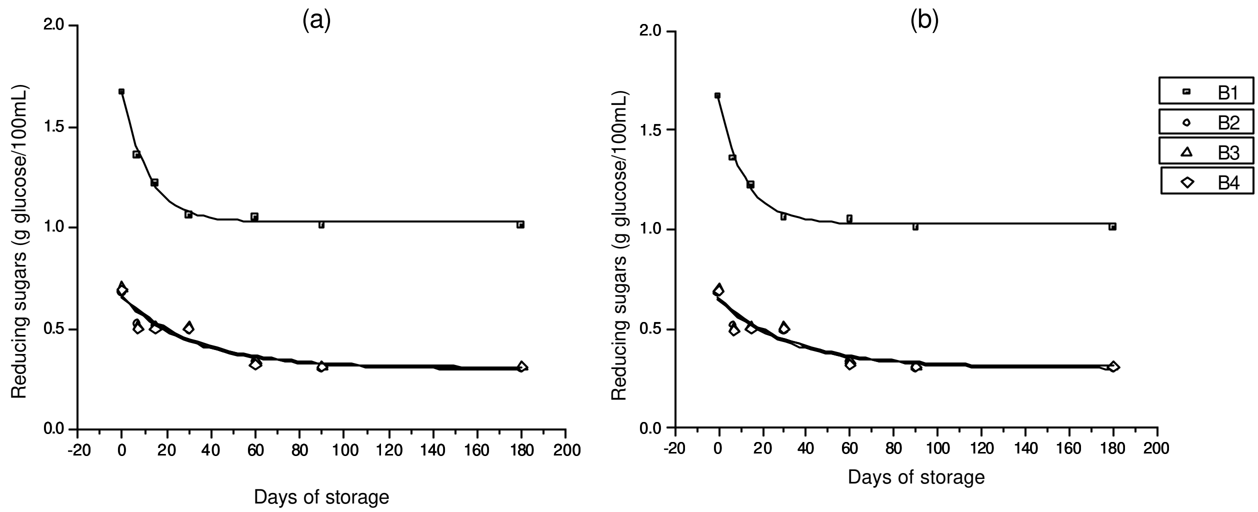

Figure 7. Reducing sugars (g glucose/100mL) of passion fruit juice beverage sweetened with sucrose (B1), aspartame (B2), sucralose (B3) and the aspartame/acesulfame-K blend (B4), stored at room temperature (a) and under refrigeration (b) during 180 days.

B1 [(a) $y=1.02+0.64^{(-x/11.77)}$, $r^2=0.99$, $p<0.05$ / (b) $y=1.02+0.64^{(-x/11.77)}$, $r^2=0.99$, $p<0.05$]

B2 [(a) $y=0.29+0.35^{(-x/34.55)}$, $r^2=0.93$, $p<0.05$ / (b) $y=0.29+0.35^{(-x/34.55)}$, $r^2=0.93$, $p<0.05$]

B3 [(a) $y=0.30+0.35^{(-x/32.91)}$, $r^2=0.89$, $p<0.05$ / (b) $y=0.30+0.35^{(-x/32.87)}$, $r^2=0.88$, $p<0.05$]

B4 [(a) $y=0.30+0.34^{(-x/30.29)}$, $r^2=0.89$, $p<0.05$ / (b) $y=0.30+0.34^{(-x/30.18)}$, $r^2=0.87$, $p<0.05$]

According to the results obtained in this research, the only physical-chemical parameters that showed significant changes during storage and may have influenced the sensory characteristics of the beverages were the total and reducing sugars content and especially the ascorbic acid content.

During the ascorbic acid degradation in fruit juices, several compounds are formed, within which furfural. The increase in this compound in fruit juices has been highly correlated with flavor degradation and browning, especially in orange juice (DINSMORE & NAGY, 1974; KAANANE et al., 1988; SOLOMON et al., 1995). Accordingly, it is strongly recommended that determination of furfural and derivates be included as an index of quality in future researches involving shelf-life study of fruit juices.

3.3 Sensory evaluation

The results obtained from the four consumer tests, performed at 0, 60, 120 and 180 days of storage, are presented in Tables 6 and 7 and Figures 6-18.

Table 6. Average scores attributed to color liking, aroma liking, overall liking 1, flavor liking, sweetness liking, sweetness intensity, texture liking, aftertaste liking and overall liking 2 of passion fruit juice beverages sweetened with sucrose (B1), aspartame (B2), sucralose (B3) and the aspartame/acesulfame-K blend (4:1) (B4), evaluated at 0, 60, 120 and 180 days of storage.

Beverage	Color	Aroma	Overall 1	Flavor	Sweetness	Sweetness Intensity	Texture	Aftertaste	Overall 2
0 day of storage									
1	7.32^{a}	6.71^{a}	6.59^{a}	6.52^{a}	6.41^{a}	4.47^{a}	6.90^{a}	6.18^{a}	6.66^{a}
2	7.01^{ab}	6.25^{ab}	5.58^{b}	5.21^{b}	5.18^{b}	4.08^{ab}	6.27^{b}	5.05^{b}	5.56^{b}
3	6.68^{b}	6.03^{b}	5.14^{bc}	4.99^{b}	5.16^{b}	4.42^{a}	6.15^{b}	4.68^{b}	5.29^{b}
4	7.22^{a}	6.11^{ab}	4.99^{c}	4.82^{b}	4.67^{b}	3.70^{b}	6.22^{b}	5.10^{b}	5.14^{b}
60 days of storage									
1	7.19^{a}	6.89^{a}	6.32^{a}	5.58^{a}	5.84^{a}	3.96^{a}	6.52^{a}	5.59^{a}	6.21^{a}
2	6.64^{b}	6.37^{a}	4.75^{c}	4.40^{c}	4.51^{b}	2.90^{b}	6.10^{ab}	4.36^{b}	4.62^{c}
3	6.79^{b}	6.34^{a}	5.51^{b}	5.21^{b}	5.25^{a}	3.81^{a}	6.21^{ab}	4.82^{b}	5.51^{b}
4	6.78^{b}	6.32^{a}	4.71^{c}	4.10^{c}	4.23^{b}	2.77^{b}	5.92^{b}	4.47^{b}	4.51^{c}
120 days of storage									
1	6.82^{a}	6.41^{a}	6.01^{a}	5.92^{a}	5.96^{a}	4.01^{a}	6.56^{a}	5.71^{a}	6.05^{a}
2	6.15^{b}	5.77^{b}	4.42^{b}	4.08^{b}	3.80^{b}	2.74^{b}	5.47^{b}	4.63^{b}	4.42^{b}
3	6.88^{a}	5.99^{ab}	5.62^{a}	5.52^{a}	5.79^{a}	4.53^{a}	6.55^{a}	4.92^{b}	5.64^{a}
4	6.03^{b}	5.93^{ab}	4.40^{b}	4.01^{b}	3.93^{b}	2.77^{b}	5.74^{b}	4.30^{b}	4.16^{b}
180 days of storage									
1	5.60^{b}	5.89^{ab}	5.36^{a}	5.12^{a}	5.41^{a}	4.21^{a}	6.04^{a}	5.18^{a}	5.47^{a}
2	5.41^{b}	5.53^{b}	4.49^{b}	4.22^{b}	4.10^{b}	2.82^{b}	5.60^{ab}	4.60^{b}	4.58^{b}
3	6.84^{a}	6.04^{a}	5.59^{a}	5.34^{a}	5.53^{a}	4.70^{a}	5.90^{a}	4.96^{ab}	5.62^{a}
4	5.55^{b}	5.56^{ab}	4.45^{b}	4.16^{b}	4.01^{b}	2.79^{b}	5.38^{b}	4.42^{b}	4.47^{b}

$^{a,\ b}$ Averages in a column followed by different letters represent significant difference ($p<0.05$).

Concerning the color of the beverages, at 0 day of storage, the sucrose-sweetened beverage (B1) received the highest acceptance scores, not being significantly different from the beverages sweetened with aspartame (B2) and the aspartame/acesulfame-K blend (B4) ($p>0.05$), and being significantly different from the sucralose-sweetened beverage (B3), which received the lowest acceptance scores (Table 6). At 60 days of storage, the sucrose-sweetened beverage (B1) received significantly higher acceptance scores than the light beverages (B2, B3 and B4) ($p<0.05$). At 120 days of storage, the sucralose (B3) and the sucrose (B1) - sweetened beverages received significantly higher acceptance scores than the aspartame (B2) and the aspartame/acesulfame-K blend (B4) – sweetened beverages ($p<0.05$). Finally, at 180 days of storage, the sucralose-sweetened beverage (B3) received the highest acceptance scores, significantly different from all the other beverages ($p>0.05$). These results are also illustrated in Figure 6.

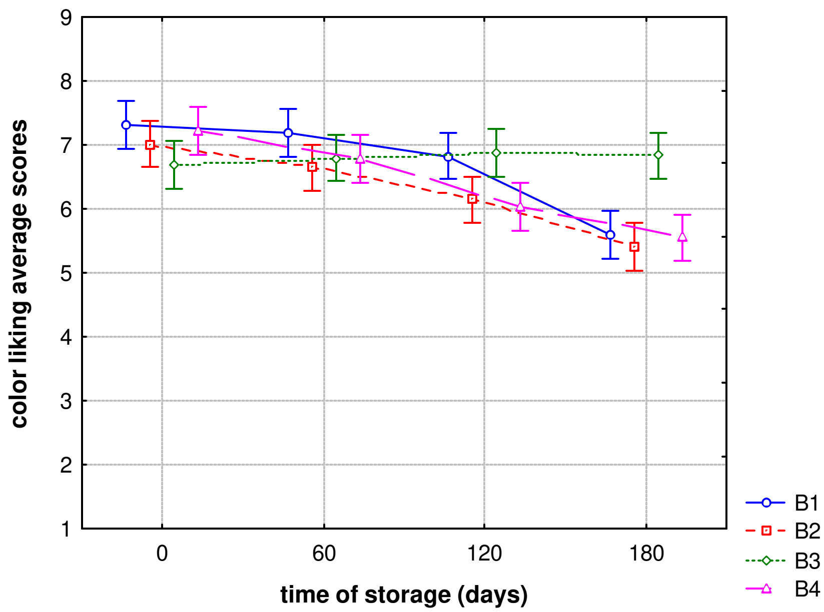

Figure 6. Distribution of the average scores attributed to color liking of passion fruit juice beverages sweetened with sucrose (B1), aspartame (B2), sucralose (B3) and the aspartame/acesulfame-K blend (B4) at 0, 60, 120 and 180 days of storage.

It can be seen from Figure 6 that there was a decrease in the color liking acceptance scores attributed to the beverages sweetened with sucrose, aspartame, and the aspartame/acesulfame-K blend during the 6 months of storage, while those attributed to the beverage sweetened with sucralose remained the same during storage time. In other words, the sucralose-sweetened beverage was the most stable beverage during storage concerning color. At the end of the shelf-life study this beverage was rated between “like slightly” and “like moderately", while the other beverages were rated between "neither like nor dislike" and "like slightly". Despite this difference, all the beverages were attributed with color liking scores equal or superior to 5.0 during the whole 6 months of storage, that is, the attribute color did not determine the end of shelf-life of the beverages studied.

Concerning the aroma of the beverages, at 0 day of storage, the sucrose-sweetened beverage (B1) received the highest acceptance scores, and the sucralose-sweetened beverage (B3), the lowest scores ($p<0.05$). The beverages sweetened with aspartame (B2) and the aspartame/acesulfame-K blend (B4) received intermediate acceptance scores ($p>0.05$) (Table 6). At 60 days of storage, no significant difference between the beverages was observed ($p>0.05$). At 120 days of storage, the sucrose-sweetened beverage (B1) received the highest acceptance scores, and the aspartame-sweetened beverage (B2), the lowest scores ($p<0.05$). The sucralose (B3) and the aspartame/acesulfame-K blend (B4) – sweetened beverages received intermediate acceptance scores ($p>0.05$). Finally, at 180 days of storage, the highest acceptance scores were given to the sucralose-sweetened beverage (B3); the lowest scores, to the aspartame-sweetened beverage (B2); and intermediate scores to the sucrose (B1) and the aspartame/acesulfame-K blend (B4) – sweetened beverages. These results are also illustrated in Figure 7.

It can be seen from Figure 7 that the sucrose (B1), aspartame (B2) and the aspartame/acesulfame-K blend (B4) - sweetened beverages showed a decrease in the acceptance scores attributed to aroma liking after 60 days of storage, while the sucralose-sweetened beverage (B3) showed constant scores during storage time. Despite this difference, at the end of the shelf-life study all the beverages were rated between "neither like nor dislike" and "like slightly". So, similarly to the results obtained for color liking, the attribute aroma did not determine the end of shelf-life of the beverages studied, which received scores equal or superior to 5.0 during the whole storage period.

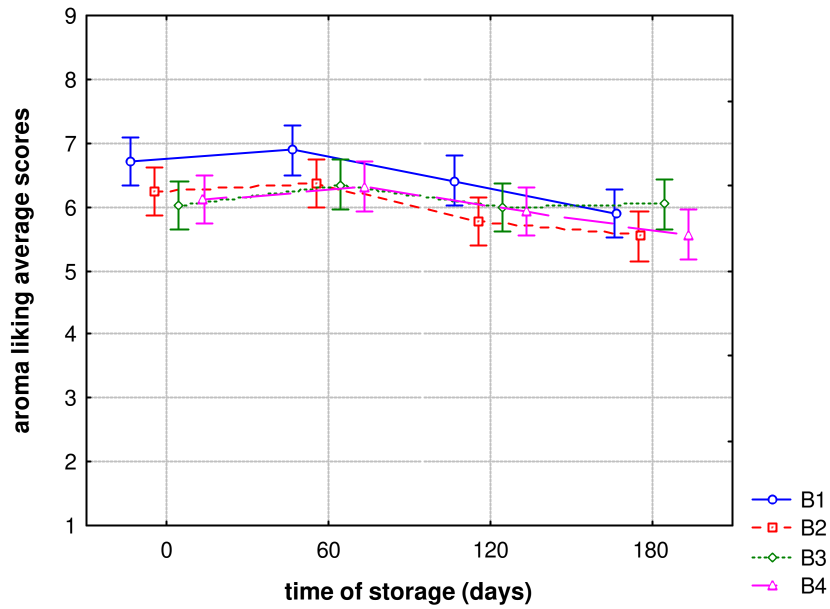

Figure 7. Distribution of the average scores attributed to aroma liking of passion fruit juice beverages sweetened with sucrose (B1), aspartame (B2), sucralose (B3) and the aspartame/acesulfame-K blend (B4) at 0, 60, 120 and 180 days of storage.

Concerning the flavor of the beverages, at 0 day of storage, the sucrose-sweetened beverage (B1) received significantly higher acceptance scores ($p<0.05$) than the light beverages (B2, B3 and B4) ($p>0.05$) (Table 6). At 60 days of storage, the highest scores were attributed to the sucrose-sweetened beverage (B1), followed by the sucralose-sweetened beverage (B3) and finally, by the aspartame (B2) and the aspartame/acesulfame-K blend (B4) – sweetened beverages ($p<0.05$). At 120 and 180 days of storage, the sucrose (B1) and the sucralose (B3) - sweetened beverages were significantly more accepted ($p<0.05$) than the aspartame (B2) and the aspartame/acesulfame-K blend (B4) – sweetened beverages. These results are also illustrated in Figure 8.

As can be seen from Figure 8, the sucrose, aspartame and aspartame/acesulfame-K blend - sweetened beverages showed a decrease in the acceptance scores given to the flavor during storage time, while the sucralose-sweetened beverage showed constant scores. As the standard beverage had always received higher acceptance scores than the light beverages (at 0, 60 and 120 days of storage), at the end of the shelf-life study the sucralose and the sucrose-sweetened beverages were, equally, the most accepted beverages. These beverages were rated between “neither like nor dislike” and “like slightly”, while the aspartame and the aspartame/acesulfame-K blend-sweetened beverages were rated between “dislike slightly” and “neither like nor dislike”. Actually, the aspartame and the aspartame/acesulfame-K-sweetened beverages received flavor liking scores around 5.0 only immediately after they were produced (at 0 day of storage). So, based on flavor liking, these beverages should be attributed a shelf-life period inferior to 60 days of storage, while the sucrose and the sucralose-sweetened beverages could be attributed a shelf-life period of at least 180 days.

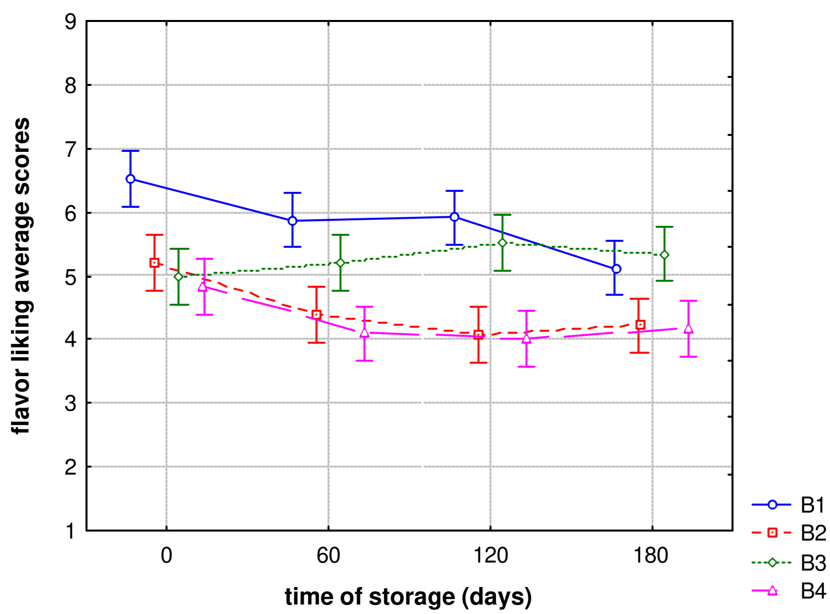

Figure 8. Distribution of the average scores attributed to flavor liking of passion fruit juice beverages sweetened with sucrose (B1), aspartame (B2), sucralose (B3) and the aspartame/acesulfame-K blend (B4) at 0, 60, 120 and 180 days of storage.

Concerning the sweetness of the beverages, at 0 day of storage the sucrose-sweetened beverage (B1) received significantly higher acceptance scores ($p<0.05$) than the light beverages (B2, B3, and B4) ($p>0.05$) (Table 6). At 60, 120 and 180 days of storage, the sucrose (B1) and the sucralose (B3) - sweetened beverages received significantly higher scores ($p<0.05$) than the aspartame (B2) and the aspartame/acesulfame-K blend (B4) - sweetened beverages. These results are also illustrated in Figure 9.

From Figure 9 it can be seen that the passion fruit juice beverages showed, for sweetness liking, similar behavior to that showed for flavor liking during storage time. The sucrose, aspartame and the aspartame/acesulfame-K blend-sweetened beverages showed a decrease in the acceptance scores during storage time while the sucralose-sweetened beverage showed constant acceptance scores. At the end of the shelf-life study, the sucrose and the sucralose-sweetened beverages were significantly ($p<0.05$) more accepted than the aspartame and the aspartame/acesulfame-K blend-sweetened beverages. The sucrose and the sucralose-sweetened beverages were rated between "neither like nor dislike" and "like slightly" while the aspartame and the aspartame/acesulfame-K blend-sweetened beverages were rated between "dislike slightly" and "neither like nor dislike". Actually, the aspartame and the aspartame/acesulfame-K-sweetened beverages received scores around 5.0 only at 0 day of storage. In other words, based on sweetness liking, these beverages should be attributed a shelf-life period inferior to 60 days of storage, while the sucrose and the sucralose-sweetened beverages could be attributed a shelf-life period of at least 180 days.

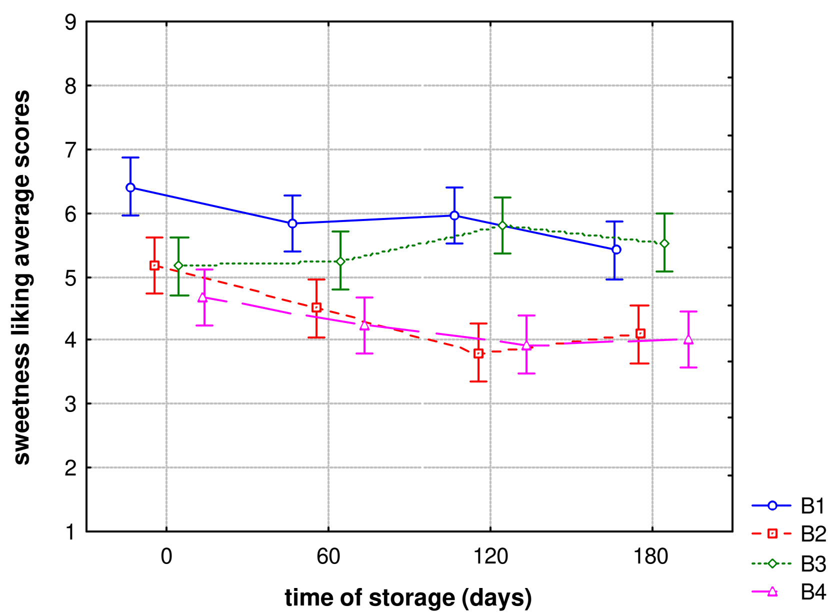

Figure 9. Distribution of the average scores attributed to sweetness liking of passion fruit juice beverages sweetened with sucrose (B1), aspartame (B2), sucralose (B3) and the aspartame/acesulfame-K blend (B4) at 0, 60, 120 and 180 days of storage.

Concerning the sweetness intensity of the beverages, at 0 day of storage the sucrose (B1) and the sucralose (B3) - sweetened beverages received significantly higher intensity scores than the aspartame/acesulfame-K blend (B4) – sweetened beverage ($p<0.05$). At 60, 120 and 180 days of storage, the sucrose (B1) and sucralose (B3) -sweetened beverages were rated significantly sweeter ($p<0,05$) than the aspartame (B2) and the aspartame/acesulfame-K blend (B4) - sweetened beverages. Figure 10 also illustrates these results.

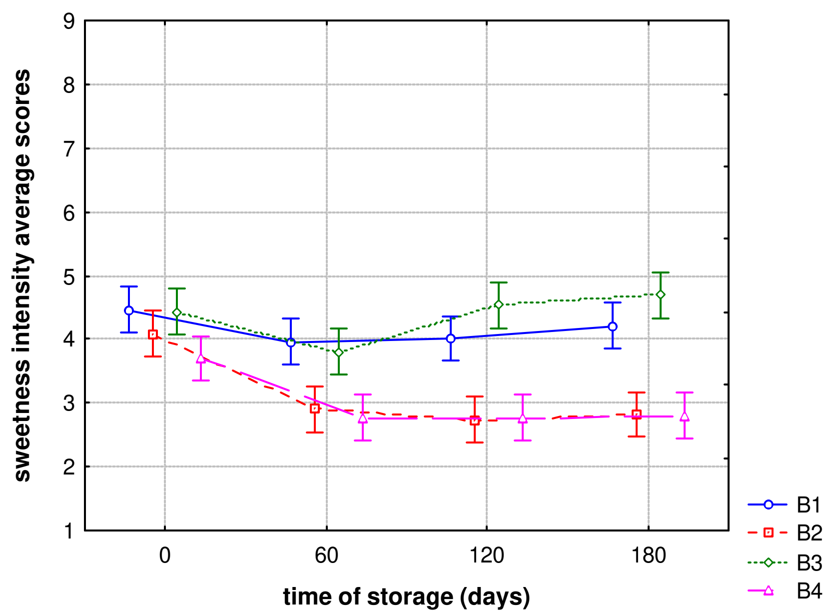

Figure 10. Distribution of the average scores attributed to sweetness intensity of passion fruit juice beverages sweetened with sucrose (B1), aspartame (B2), sucralose (B3) and the aspartame/acesulfame-K blend (B4) at 0, 60, 120 and 180 days of storage.

It can be seen from Figure 10, that the aspartame (B2) and the aspartame/acesulfame-K blend (B4) - sweetened beverages showed a decrease in sweetness intensity during the first 60 days of storage, period after which the sweetness intensity remained the same. These beverages were rated, at the end of the shelf-life study, between “not sweet” and “slightly sweet”. The sucrose (B1) and the sucralose (B3) - sweetened beverages, on the other hand, showed constant sweetness intensity scores during storage time. These beverages were rated at the end of the shelf-life study between “slightly sweet” and “moderately sweet”. These results indicate that losses in sweetness potency occurred during the storage of the beverages containing aspartame (B2 and B4). This could be attributed to the low stability properties of aspartame during storage in liquids. According to NABORS (2002), under dry conditions, aspartame is highly stable, but in liquids, under certain conditions of moisture, temperature and pH, it may hydrolyze, resulting in a loss of sweetness.

Concerning the texture of the beverages, at 0 day of storage, the sucrose-sweetened beverage (B1) received significantly higher acceptance scores than the light beverages (B2, B3 and B4) ($p<0.05$) (Table 6). At 60 days of storage, the sucrose-sweetened beverage (B1) received the highest acceptance scores, differing significantly ($p<0.05$) only from the aspartame/acesulfame-K blend-sweetened beverage (B4), which received the lowest scores. At 120 days of storage, the sucrose (B1) and the sucralose (B3) - sweetened beverages received significantly higher scores ($p<0.05$) than the aspartame (B2) and the aspartame/acesulfame-K blend (B4) - sweetened beverages. Finally, at 180 days of storage, the sucrose (B1) - sweetened beverage received significantly higher scores ($p<0.05$) than the aspartame/acesulfame-K blend-sweetened beverage (B4). These results are also illustrated in Figure 11.

From Figure 11 it can be seen that the sucrose, aspartame and aspartame/acesulfame-K-sweetened beverages showed a slight decrease in the acceptance scores given to the texture during the 6 months of storage, while the sucralose-sweetened beverage showed constant scores. At the end of the shelf-life study, the sucrose and the sucralose-sweetened beverages were significantly more accepted ($p<0.05$) than the aspartame/acesulfame-K blend-sweetened beverage. Despite this difference, all the beverages were rated between “neither like nor dislike” and “like slightly”. Accordingly, the attribute texture did not determine the end of shelf-life of the beverages studied.

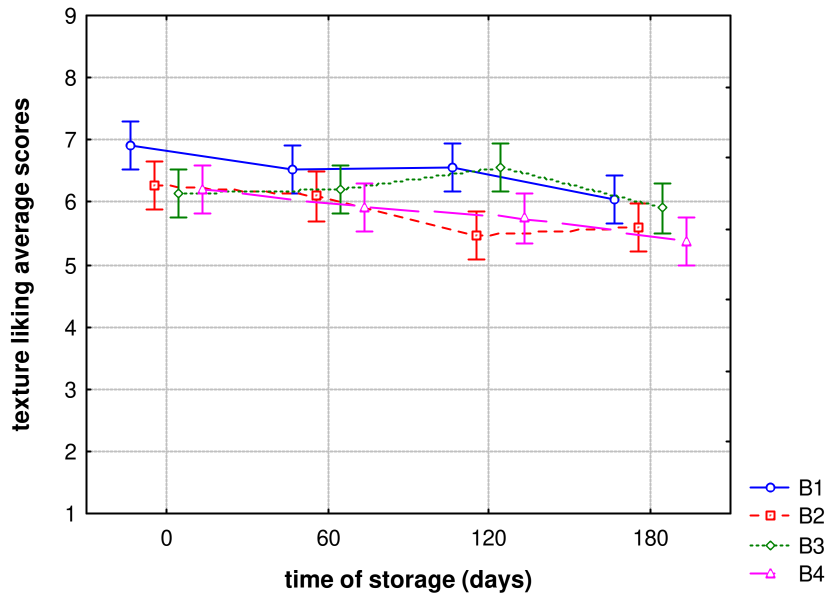

Figure 11. Distribution of the average scores attributed to texture liking of passion fruit juice beverages sweetened with sucrose (B1), aspartame (B2), sucralose (B3) and the aspartame/acesulfame-K blend (B4) at 0, 60, 120 and 180 days of storage.

Concerning the aftertaste, at 0, 60, and 120 days of storage, the sucrose-sweetened beverage (B1) received acceptance scores significantly higher ($p<0.05$) to those received by the light beverages (B2, B3 and B4) ($p>0.05$) (Table 6). At 180 days of storage, however, the sucrose-sweetened beverage did not differ significantly from the sucralose-sweetened beverage ($p>0.05$). These results are also illustrated in Figure 12.

From Figure 12 it can be seen that there was a slight decrease in the acceptance scores attributed to the aftertaste of all beverages, except for the sucralose-sweetened beverage, for which the scores were constant during the 6 months of storage. As the sucrose-sweetened beverage had always been rated as the most acceptable beverage (at 0, 60 and 120 days of storage), at the end of the shelf-life period this beverage did not differ significantly from the sucralose-sweetened beverage ($p>0.05$). These beverages were rated, at the end of the shelf-life study between “neither like nor dislike” and “like slightly”, while the beverages sweetened with aspartame and aspartame/acesulfame-K blend were rated between “dislike slightly” and “neither like nor dislike”. Actually, from 60 days of storage, all the light beverages received aftertaste scores inferior to 5.0. Even though, the sucralose-sweetened beverage received scores very close to 5.0 while the aspartame and the aspartame/acesulfame-K-sweetened beverages received scores close to 4.0 most of the time. Considering that at the end of the shelf-life study the sucralose-sweetened beverage received scores not significantly different from those received by the sucrose-sweetened beverage, we could conclude that these beverages could be attributed a shelf-life period of at least 180 days while the aspartame and the aspartame/acesulfame-K blend – sweetened beverages should be attributed a shelf-life period inferior to 60 days concerning their aftertaste.

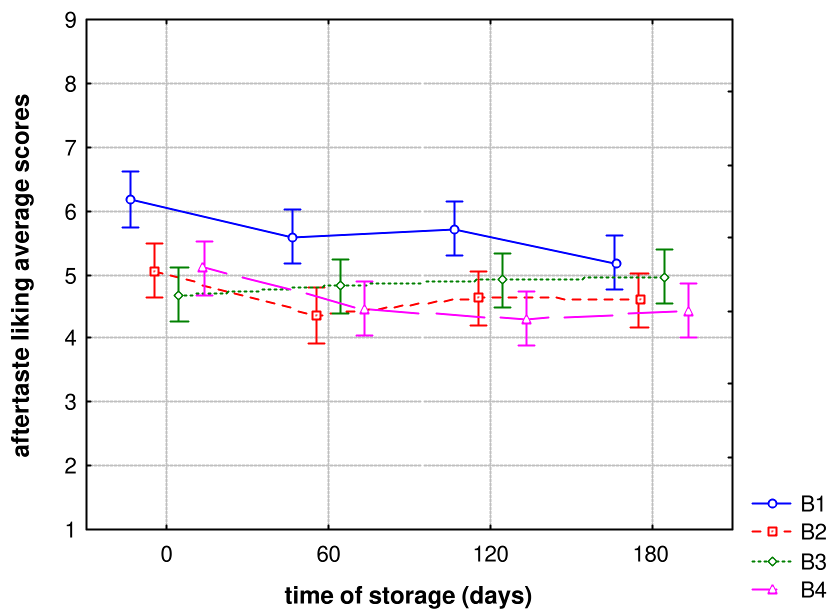

Figure 12. Distribution of the average scores attributed to aftertaste liking of passion fruit juice beverages sweetened with sucrose (B1), aspartame (B2), sucralose (B3) and the aspartame/acesulfame-K blend (B4) at 0, 60, 120 and 180 days of storage.

The overall liking evaluated at the beginning of the sensory testing (overall liking 1) and that evaluated at the end of sensory testing (overall liking 2) were first compared using the multivariate analysis of variance (MANOVA), of which the results are presented in Figure 13.

No significant difference between the overall liking 1 scores and the overall liking 2 scores was observed for all the samples at 0, 60, 120 and 180 days of storage (p>0.05) (Figure 13). For this reason, only the overall liking 2 scores were discussed.

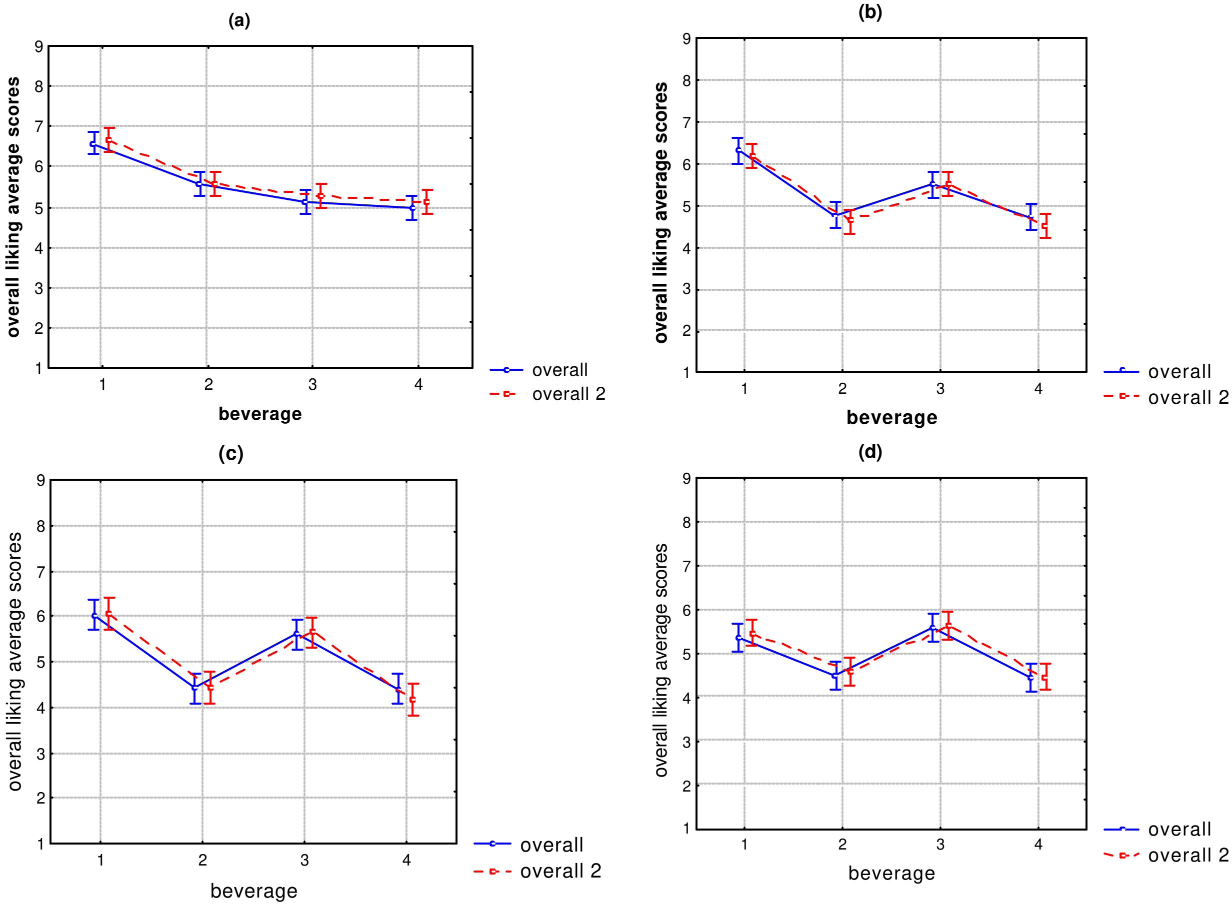

Figure 13. Distribution of the average scores attributed to overall liking 1 (beginning of testing) and overall liking 2 (end of testing) of passion fruit juice beverages sweetened with sucrose (sample 1), aspartame (sample 2), sucralose (sample 3) and the aspartame/acesulfame-K blend (sample 4) at (a) 0 day of storage, (b) 60 days of storage, (c) 120 days of storage and (d) 180 days of storage.

At 0 day of storage, the sucrose-sweetened beverage (B1) received significantly higher acceptance scores than the light beverages (B2, B3 and B4) (p<0.05) (Table 6). At 60 days of storage, the highest acceptance scores were attributed to the sucrose-sweetened beverage (B1), followed by the sucralose-sweetened beverage (B3) and last by the aspartame (B2) and the aspartame/acesulfame-K blend (B4) - sweetened beverages. At 120 and 180 days of storage, the sucrose (B1) and the sucralose (B3) - sweetened beverages were rated significantly ($p<0.05$) higher than the aspartame (B2) and the aspartame/acesulfame-K blend (B4) - sweetened beverages ($p>0.05$). Figure 14 also illustrates these results.

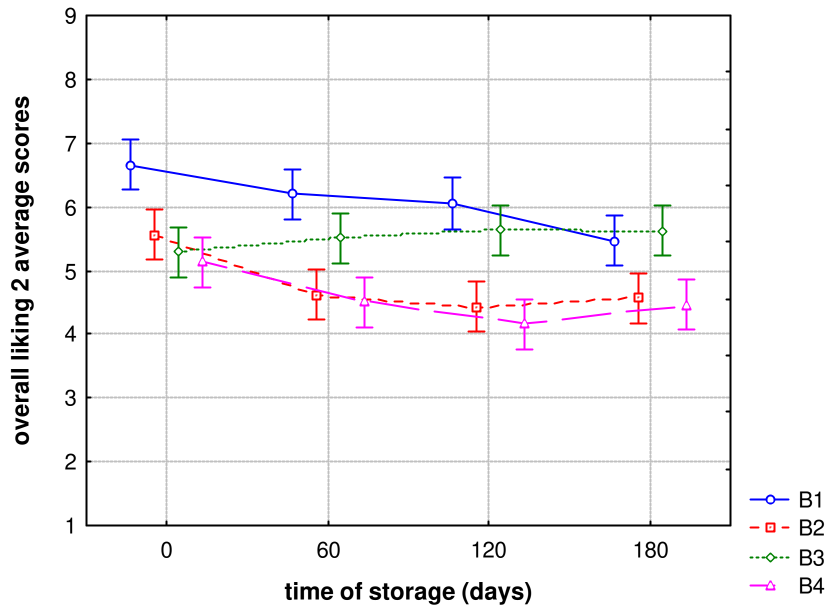

Figure 14. Distribution of the average scores attributed to overall liking 2 of passion fruit juice beverages sweetened with sucrose (B1), aspartame (B2), sucralose (B3) and the aspartame/acesulfame-K blend (B4) at 0, 60, 120 and 180 days of storage.

It can be seen from Figure 14 that there was a decrease in the overall liking scores given to the beverages sweetened with sucrose, aspartame and the aspartame/acesulfame-K blend during storage time, while those given to the sucralose-sweetened beverage remained constant. As the standard beverage had always received higher acceptance scores than the light beverages (at 0, 60 and 120 days of storage), at the end of the shelf-life period the sucralose and the sucrose-sweetened beverages were the most accepted beverages. These beverages were rated between “neither like nor dislike” and “like slightly”, while the aspartame and the aspartame/acesulfame-K blend-sweetened beverages were rated between “dislike slightly” and “neither like nor dislike”. Actually, the aspartame and the aspartame/acesulfame-K-sweetened beverages were attributed overall liking scores equal or superior to 5.0 only at 0 day of storage, while the sucrose and the sucralose-sweetened beverages received overall liking scores superior to 5.0 during the whole shelf-life period. Accordingly, based on overall liking, a shelf-life period inferior to 60 days should be attributed to the aspartame and the aspartame/acesulfame-K-sweetened beverages, and one of at least 180 days to the sucrose and the sucralose-sweetened beverages.

It is important to point out that when consumers rated the beverages overall, the first attribute they considered was the flavor, followed by the sweetness, the aftertaste and finally, the texture, which was taken into consideration only after 120 days of storage. These results are shown in Table 7, which presents the Pearson correlations between overall liking 1 and overall liking 2 scores and flavor, sweetness, aftertaste and texture liking.

Table 7. Pearson correlations (r) between overall liking 1 and overall liking 2 scores and flavor, sweetness, aftertaste and texture liking scores attributed to sucrose, aspartame, sucralose and the aspartame/acesulfame-K blend-sweetened beverages at 0, 60, 120, and 180 days of storage.

	0 day		60 days		120 days		180 days	
	Overall 1	**Overall 2**	**Overall 1**	**Overall 2**	**Overall 1**	**Overall 2**	**Overall 1**	**Overall 2**
Flavor	0.88	0.84	0.84	0.82	0.86	0.83	0.85	0.81
Sweetness	0.71	0.70	0.71	0.72	0.69	0.70	0.67	0.69
Aftertaste	0.58	0.67	0.54	0.63	0.59	0.65	0.64	0.71
Texture	0.33	0.38	0.36	0.42	0.45	0.42	0.53	0.56

As can be seen from Table 7, the correlation between flavor liking and overall liking 1, as well as the correlation between flavor liking and overall liking 2 were the strongest during the 6 months of storage, indicating that the flavor was the first attribute consumers considered when evaluating the beverages overall. The second overall correlated attribute was the sweetness, equally important to consumers at each period of evaluation. The correlation between aftertaste liking and overall liking 2 was higher than the correlation between aftertaste liking and overall liking 1 at all the evaluation periods. That means that when rating the overall liking 2 (at the end of the testing session), the aftertaste was more important for the consumers than when rating the overall liking 1 (at the beginning of the testing session). The texture was also considered important for consumers when evaluating the beverages overall, but only at the end of the shelf-life period, after 120 days of storage.

Figures 15, 16, and 17 illustrate the results obtained for sweetness, sourness, and passion fruit flavor levels.

As can be seen in Figures 15.a and 15.c, most of the consumers (70-77% and 63-69%) answered that the sucrose and the sucralose - sweetened beverages, respectively, were between “not quite enough” and “just about right” in sweetness during the whole 6 months of storage. Among these percentages, the highest percentages of consumers (37-45% and 33-43%) answered that these beverages were “Just about right” in sweetness during the period studied. For the aspartame and the aspartame/acesulfame-K blend - sweetened beverages, on the other hand, most of consumers (75-80% and 74-75%, respectively) answered that these beverages were between “not nearly enough” and “not quite enough” for most of the periods studied, except at 0 day of storage, when these beverages were rated between “not quite enough” and “just about right” by most of the consumers (64% and 73%, respectively) (Figure 15.b and Figure 15.d). Among these percentages, the highest percentages of consumers (40-52% and 45-47%, respectively) answered that the aspartame and the aspartame/acesulfame-K blend – sweetened beverages were “not quite sweet enough” at all periods studied. These results corroborated those obtained for sweetness intensity and could be attributed to the low stability of aspartame during storage in liquids (NABORS, 2002).

From Figure 16, it can be seen that most of the consumers (81-88%, 73-75%, 71-90% and 73-77%) answered that the sucrose, the aspartame, the sucralose and the aspartame/acesulfame-K blend - sweetened beverages, respectively, were between “just about right” and “somewhat too sour” during the whole period of storage. Among these percentages, at 0 and 120 days of storage, the highest percentages of consumers (48% and 49%) answered that the sucrose-sweetened beverage was “just about right” in sourness, and at 60 and 180 days of storage, the highest percentages of consumers (45% and 45%) answered that this beverage was “somewhat too sour” (Figure 16.a). For the sucralose-sweetened beverage, at 0 and 60 days of storage, the highest percentages of consumers (43% and 52%) answered that this beverage was “somewhat too sour”, and at 120 and 180 days of storage, the highest percentages of consumers (48% and 53%) answered that this beverage was “just about right in sourness”. For the aspartame and the aspartame/acesulfame-K blend – sweetened beverages, on the other hand, the highest percentages of consumers (38-53%, and 40-56%, respectively) answered these beverages were “somewhat too sour” at all periods of storage (Figures 16.b and 16.d).

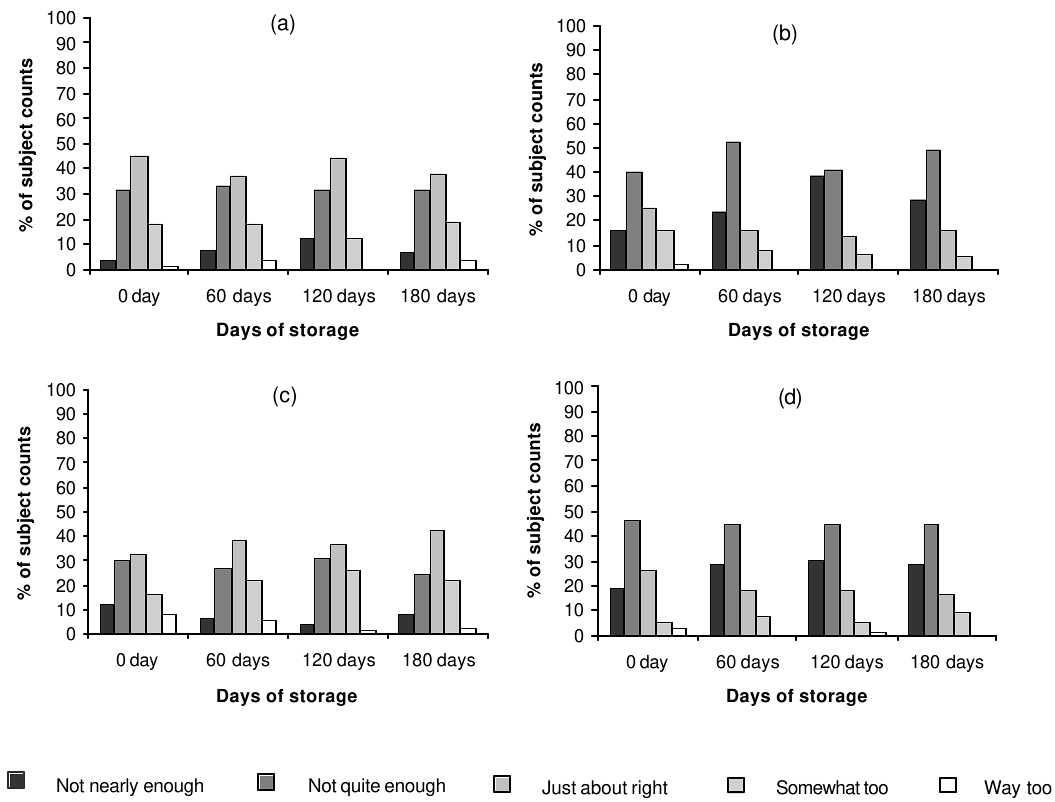

Figure 15. Distribution of scores attributed to the sweetness level of passion fruit juice beverages sweetened with sucrose (a), aspartame (b), sucralose (c) and the aspartame/acesulfame-K blend (d) at 0, 60, 120 and 180 days of storage.

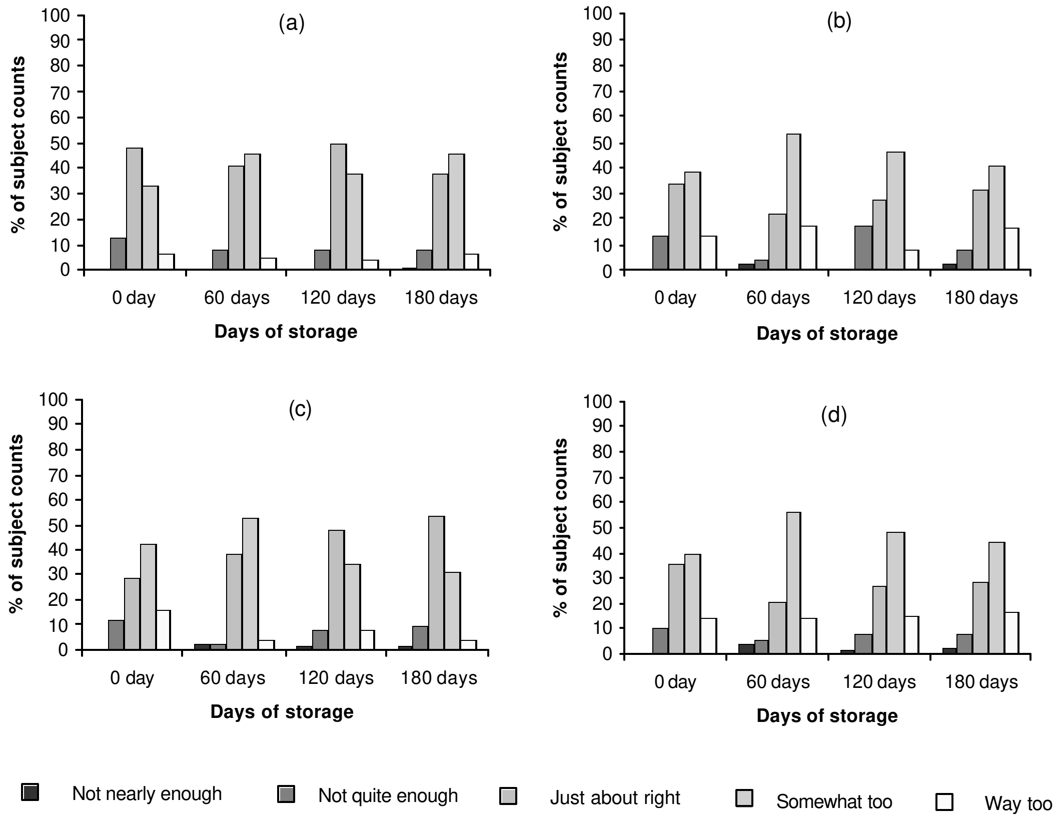

Figure 16. Distribution of scores attributed to the sourness level of passion fruit juice beverages sweetened with sucrose (a), aspartame (b), sucralose (c), and aspartame/acesulfame-K blend (d) at 0, 60, 120 and 180 days of storage.

From Figure 17 it can be seen that most of the consumers (81-87%, 71-86%, 80-86% and 71-81%) answered that the beverages sweetened with sucrose, aspartame, sucralose, and the aspartame/acesulfame-K blend, respectively, were between "not quite enough" and "just about right" in passion fruit flavor during the whole 6 months of storage. Among these percentages, the highest percentages of consumers (45-60%, and 41-56%) answered that the sucrose and the sucralose-sweetened beverages were "just about right" in passion fruit flavor at all periods studied. For the aspartame and the aspartame/acesulfame-K blend – sweetened beverages, on the other hand, the highest percentages of consumers answered that these beverages were "just about right" in passion fruit flavor only at 60 days of storage (40%), and at 0 and 60 days of storage (45% and 41%), respectively.

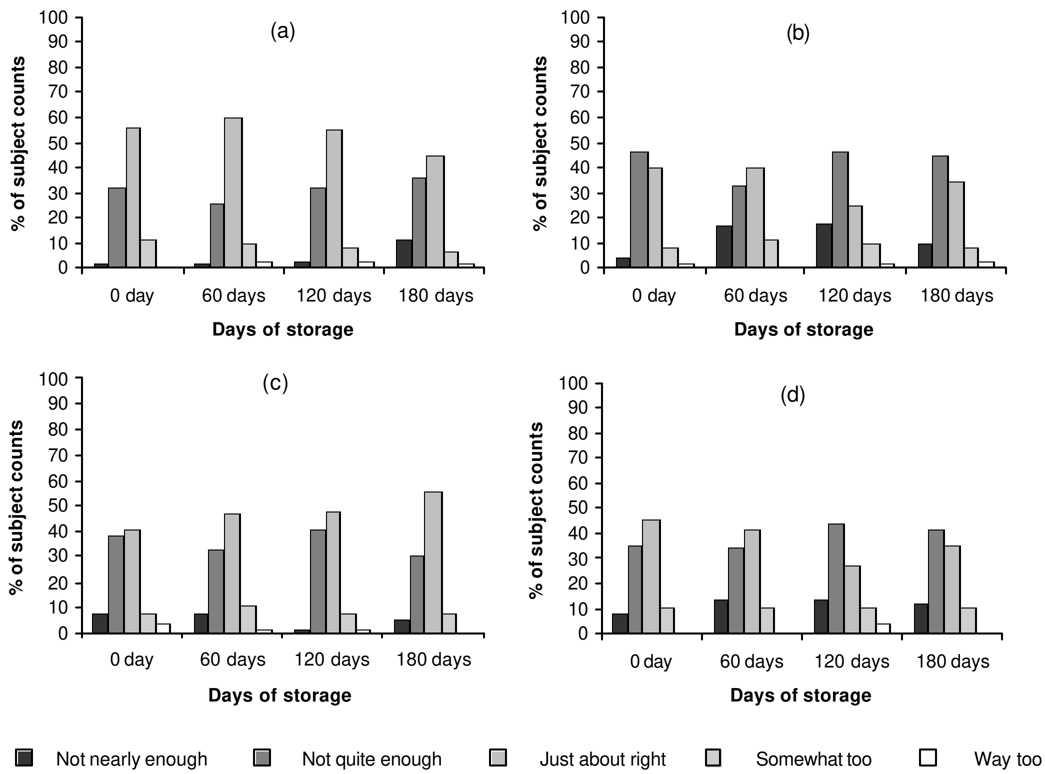

Figure 17. Distribution of scores attributed to the passion fruit flavor level of passion fruit juice beverages sweetened with sucrose (a), aspartame (b), sucralose (c) and the aspartame/acesulfame-K blend (d) at 0, 60, 120 and 180 days of storage.

Figure 18 illustrates the purchase intention results obtained for the sucrose, aspartame, sucralose, and aspartame/acesulfame-K blend-sweetened beverages during 0, 60, 120, and 180 days of storage.

For the sucrose-sweetened beverage (Figure 18.a) it can be seen that most of the consumers showed positive purchase intention at 0, 60 and 120 days of storage: 90%, 84% and 73% of consumers, respectively, rated their purchase intention between "definitely would purchase" and "may or may not purchase". Among these percentages, the highest percentages of consumers (44%, 45% and 37%) answered they "probably would purchase" the beverage. At 180 days of storage, however, most of the consumers showed negative purchase intention: 77% of consumers rated their purchase intention between "may or may not purchase" and "definitely would not purchase". Despite this, the highest percentage of consumers (37%) answered that they "may or may not purchase" the sucrose-sweetened beverage.

For the sucralose-sweetened beverage (Figure 18.c), although most consumers (73%) showed negative purchase intention during the whole 6 months of storage, that is, between "may or may not purchase" and "definitely would not purchase", the highest percentages of consumers (33%, 38%, 36% and 34%) answered that they "may or may not purchase" the beverage at 0, 60, 120 and 180 days of storage, respectively.

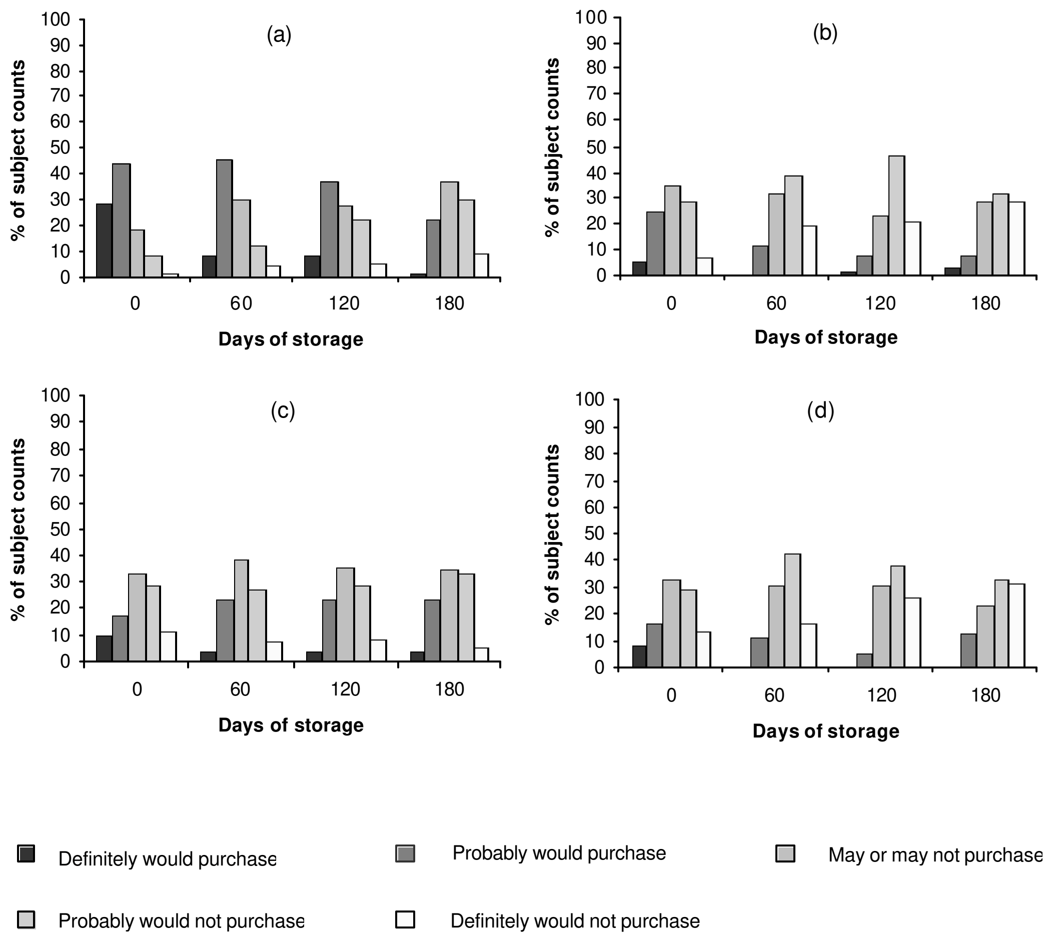

Figure 18. Distribution of scores attributed to purchase intention of passion fruit juice beverages sweetened with sucrose (a), aspartame (b), sucralose (c) and the aspartame/acesulfame-K blend (d) at 0, 60, 120 and 180 days of storage.

For the aspartame and the aspartame/acesulfame-K blend – sweetened beverages (Figures 18.b and 18.d), most of the consumers (70%-90% and 75%-95%, respectively) showed negative purchase intention during the whole 6 months of storage, that is, between “may or may not purchase” and “definitely would not purchase”. Among these percentages, at 0 day of storage, the highest percentages of consumers (34% and 33%) answered that they “may or may not purchase” the beverages sweetened with aspartame and the aspartame/acesulfame-K blend, respectively. At 60, 120, and 180 days of storage, however, the highest percentages of consumers (32%-47% and 33%-45%) answered that they “probably would not purchase” the aspartame and the aspartame/acesulfame-K blend – sweetened beverages, respectively.

In summary, color, aroma and texture liking were attributes that did not determine the end of beverage shelf-life, as all the beverages were attributed with scores equal or superior to 5.0 during the whole 6 months of storage. The liking attributes that determined the end of beverage shelf-life were flavor, sweetness, aftertaste, and overall liking, and different shelf-life periods were determined for each beverage depending on the type of sweetener. The passion fruit juice beverages sweetened with sucrose and sucralose were attributed with scores equal or superior to 5.0 during the whole 6 months of storage concerning their flavor, sweetness, aftertaste and overall liking, while those sweetened with aspartame and aspartame/acesulfame-K blend were attributed with scores around 5.0 only immediately after their production, that is, at 0 day of storage. Similarly, the highest percentages of consumers showed positive purchase intention during the whole 6 months of storage for the beverages sweetened with sucrose and sucralose. For the beverages sweetened with aspartame and the aspartame/acesulfame-K blend, on the other hand, consumers showed positive purchase intention only immediately after these beverages were produced (at 0 day of storage). Accordingly, based on the sensory properties of the beverages, the sucrose and the sucralose-sweetened beverages could be attributed a shelf-life period of at least 180 days of storage, while the aspartame and the aspartame/acesulfame-K-blend - sweetened beverages should be attributed a period inferior to 60 days of storage. Consequently, according to the results obtained in this study, the best sweeteners to be used in this type of beverage in order to obtain good acceptance not only immediately after production but also during storage, were sucrose for the standard version and sucralose for the light version.

4. Conclusions

The passion fruit juice beverages sweetened with sucrose, aspartame, sucralose and the aspartame/acesulfame-K blend (4:1) showed microbiological safety during the whole 6 months of storage at room temperature and under refrigeration.

The only physical-chemical parameters that changed with storage time and may have influenced the sensory quality of the beverages were the total and reducing sugars and the ascorbic acid content.

According to the consumer acceptance results, the sucrose and sucralose-sweetened beverages could be attributed a shelf-life period of at least 180 days of storage, while the aspartame and the aspartame/acesulfame-K-blend - sweetened beverages should be attributed a period inferior to 60 days of storage. Consequently, the best sweeteners to be used in this type of beverage in order to be well accepted not only immediately after production but also during storage, were sucrose for the standard version and sucralose for the light version.

5. Acknowledgments

We are grateful to CNPq, Brazil, for the financial support; to De Marchi Indústria e Comércio de Frutas Ltda., for supplying the passion fruit and supporting the production of the beverages at Tetra Pak®; to Oregon State University, where part of this research was conducted; and to the sensory panelists.

5. References

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CONCLUSÕES GERAIS

As concentrações de polpa de maracujá (teor de sólidos solúveis totais resultantes da mistura polpa de maracujá + água) e de sacarose (%) a serem utilizadas na formulação de uma bebida de maracujá natural pronta para beber foram otimizadas graças ao uso da Metodologia de Superfície de Resposta. Os conteúdos de polpa de maracujá e sacarose selecionados foram 2.5°Brix e 10%, respectivamente.

No estudo de determinação da equivalência de doçura dos adoçantes aspartame, sucralose e mistura aspartame/acesulfame-K (4:1) em relação à bebida de maracujá adoçada com 10% de sacarose (bebida referência), o método Estimação de Magnitude foi imprescindível, porém não suficiente devido à ampla faixa de concentração de adoçantes utilizada. Logo, um estudo de confirmação foi necessário a fim de se obterem as exatas concentrações dos respectivos adoçantes e mistura de adoçantes equivalentes em doçura à bebida de maracujá adoçada com sacarose. Tal estudo foi eficientemente conduzido usando-se testes Diferença do Controle. As concentrações de aspartame, sucralose e mistura aspartame/acesulfame-K (4:1) equivalentes em doçura a 10% de sacarose na bebida de maracujá estudada foram, respectivamente: 0,043%, 0,016% e 0,026%.

No estudo de comparação da aceitação das bebidas de maracujá por consumidores brasileiros e americanos observou-se, de um modo geral, que a bebida referência obteve maior aceitação do que as bebidas *light* nos dois mercados consumidores, considerando-se a maioria dos atributos avaliados. Apesar disso, as bebidas *light* receberam notas superiores à nota de corte de aceitação (5) para aceitação global, além de respostas de atitude de compra favoráveis. Diferenças entre respostas de consumidores brasileiros e americanos foram observadas para: intensidade de doçura, nível de doçura, nível de acidez, e nível de sabor de maracujá. Para os consumidores americanos o nível de doçura deveria ser menor, enquanto os níveis de acidez e de sabor de maracujá poderiam ser mantidos. Para os brasileiros, por outro lado, o nível de doçura deveria ser mantido, o de acidez diminuído, e o de sabor de maracujá aumentado. Os atributos mais importantes quando da avaliação da aceitação global das bebidas, tanto no Brasil como nos EUA, foram: o sabor, a doçura, e o sabor residual, revelando a necessidade de uma atenção especial a tais características durante a formulação de bebidas similares. Do ponto de vista dos aspectos de mercado, observou-se que o suco de abacaxi seria um forte concorrente da bebida estudada, tanto no Brasil como nos EUA. Além disso, ao delinear a bebida de maracujá natural "ideal", os atributos "cor" e "carbonatação" foram os mais importantes de acordo com consumidores brasileiros, enquanto o atributo "tamanho da embalagem" foi o mais importante de acordo com consumidores americanos. Os consumidores brasileiros preferiram a tradicional bebida de maracujá com cor laranja e não carbonatada. Os consumidores americanos também preferiram a bebida de maracujá com cor laranja, porém, carbonatada. Além disso, no Brasil foi preferida a embalagem de 200mL, enquanto nos EUA, de 1 litro. Em ambos os mercados, o preço baixo e o formato "não retangular" tiveram maior aceitação. Em suma, as propriedades sensoriais das bebidas poderiam ser padronizadas, ou seja, a mesma fórmula, com pequenos ajustes, poderia ser comercializada com sucesso tanto no Brasil como nos EUA. Tais ajustes dizem respeito aos níveis de doçura, de acidez, e de sabor de maracujá, além de uma melhora no sabor residual das bebidas *light*. Já o tamanho da embalagem das bebidas deveria ser adaptado às exigências dos consumidores de cada país. Além disso, uma versão carbonatada das bebidas deveria ser estudada, dada a resposta favorável obtida dos consumidores americanos.

O tipo de adoçante utilizado exerceu grande influência na percepção do gosto doce, do gosto doce residual e do gosto ácido residual das bebidas durante a estocagem. As bebidas adoçadas com sacarose e sucralose mostraram-se notavelmente mais estáveis durante o período de vida-de-prateleira considerando-se tais características, independentemente da temperatura de estocagem. A intensidade da cor das bebidas adoçadas com sacarose e sucralose também foi preservada em relação à das outras bebidas, porém dependeu da temperatura refrigerada. Já as bebidas adoçadas com aspartame e mistura aspartame/acesulfame-K tiveram a intensidade de tais atributos preservada apenas quando estocadas sob refrigeração.

A estocagem sob refrigeração mostrou-se imprescindível a fim de que todas as bebidas tivessem as características de aroma e sabor de frutas frescas, assim como de aroma de pinheiro e de intensidade da cor, preservadas, independentemente do tipo de adoçante, durante um período mínimo de 120 dias. Aos 180 dias, todavia, a intensidade de tais características diminuiu, inevitavelmente. Quando estocadas à temperatura ambiente, as bebidas não apenas apresentaram perda das características "positivas" de aroma e sabor como aparecimento e/ou aumento na intensidade das características "negativas" de aroma e sabor, como as de frutas enlatadas, fruta passada e peixe.

Apesar de ter apresentado a desvantagem do alto conteúdo de partículas e do gosto doce residual artificial, a bebida adoçada com sucralose mostrou-se muito mais estável e com perfil sensorial similar ao da bebida adoçada com sacarose durante a estocagem do que as bebidas adoçadas com aspartame e mistura aspartame/acesulfame-K.

As bebidas de maracujá adoçadas com sacarose, aspartame, sucralose e aspartame/acesulfame-K (4:1) apresentaram boa qualidade e estabilidade microbiológica durante os 180 dias de estocagem à temperatura ambiente e sob refrigeração. As características físico-químicas das bebidas estiveram em conformidade com a legislação vigente para bebidas à base de maracujá. O teor de açúcares totais e redutores, e principalmente o conteúdo de ácido ascórbico foram os parâmetros físico-químicos que sofreram maior influência do tempo de estocagem e podem ter influenciado a qualidade sensorial das bebidas. As características sensoriais que determinaram o final da vida-de-prateleira das bebidas foram o sabor, a doçura, o sabor residual, e a aceitação global. De acordo com os resultados obtidos foi possível atribuir um período de vida-de-prateleira de pelo menos 180 dias de estocagem para as bebidas adoçadas com sacarose (referência) e sucralose, e inferior a 60 dias de estocagem para aquelas adoçadas com aspartame e aspartame/acesulfame-K.

Por fim, com base no estudo da aceitação e do perfil sensorial das bebidas recém-processadas e durante 180 dias de estocagem à temperatura ambiente e sob refrigeração, concluiu-se que, além do uso da sacarose na versão tradicional, o uso da sucralose na versão *light* da bebida de maracujá estudada constituiu-se na melhor opção de adoçante a fim de que esta tivesse boa aceitação não apenas imediatamente após ser produzida, mas também durante a estocagem. Não obstante, concluiu-se também que tais bebidas deveriam ser estocadas sob refrigeração a fim de que as características "positivas" de aroma e sabor de frutas frescas e de aroma de pinheiro fossem preservadas, e que o surgimento das características "negativas" de aroma e sabor de frutas enlatadas, fruta passada e peixe fossem evitadas.

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