UNIVERSIDADE ESTADUAL DE CAMPINAS
FACULDADE DE ENGENHARIA DE ALIMENTOS

KAZUMI KAWASAKI RAMOS

APPLICATION OF ATLANTIC FOREST NATIVE FRUITS BY-PRODUCTS IN CONFECTIONERY PRODUCTS

APROVEITAMENTO DE SUBPRODUTOS DO PROCESSAMENTO DE FRUTAS NATIVAS DA MATA ATLÂNTICA EM CONFEITOS

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Thesis presented to the Faculty of Food Engineering of the University of Campinas in partial fulfillment of the requirements for the degree of Doctor in Food Technology

Tese apresentada à Faculdade de Engenharia de Alimentos da Universidade Estadual de Campinas como parte dos requisitos exigidos para a obtenção do título de Doutora em Tecnologia de Alimentos

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RESUMO

O consumo de frutas é de extrema importância para a saúde uma vez que as mesmas são fontes de nutrientes e compostos bioativos. Os subprodutos obtidos do processamento das frutas também podem conter alta quantidade desses e de outros compostos de interesse como as fibras. O Brasil é um país com grande diversidade de plantas frutíferas, incluindo espécies não-convencionais, com potencial de serem exploradas. Dentre elas encontram-se algumas frutas nativas da Mata Atlântica. O interesse em explorar de forma sustentável a biodiversidade brasileira é crescente. Neste sentido, a produção e a comercialização de polpas de frutas podem permitir a agregação de valor e a exploração da biodiversidade com baixo ou nenhum impacto, a não ser pela geração de subprodutos que muitas vezes são subutilizados. Dado a necessidade de explorar de forma sustentável os recursos naturais, torna-se relevante buscar formas de aproveitar esses subprodutos e agregar valor aos mesmos, como por exemplo através de sua utilização em produtos destinados à alimentação humana. São escassos os estudos que propõem métodos de baixo custo para o aproveitamento direto dos subprodutos do processamento de frutas na obtenção de alimentos para o consumo humano. Sendo assim, no presente trabalho foram escolhidas três espécies frutíferas não convencionais nativas da Mata Atlântica, cambuci, uvaia e grumixama, para a caracterização físico-química e química da fruta *in natura*, da polpa e dos resíduos gerados. Verificou-se grande quantidade de compostos de interesse, como compostos fenólicos e fibras, remanescente nos subprodutos. A concentração de compostos fenólicos nos resíduos foi 1,64, 4,86 e 1,92 vezes maior quando comparada à polpa de cambuci, grumixama e uvaia, respectivamente. Além disso, foi estudado o efeito da secagem convencional dos subprodutos na perda de compostos bioativos, em 6 diferentes condições de secagem: 40NC (40 °C, não centrifugado), 60NC (60 °C, não centrifugado), 80NC (80 °C, não centrifugado), 40C (40 °C, centrifugado), 60C (60 °C, centrifugado), 80C (80 °C, centrifugado). As secagens com centrifugação prévia resultaram em uma maior retenção dos compostos fenólicos e capacidade antioxidante, além da redução no tempo de secagem, o que pode resultar em economia de energia. O ácido ascórbico, composto sensível a altas temperaturas, não permaneceu no produto seco. Considerando os compostos fenólicos totais, 80 °C com centrifugação (cambuci) e 40 °C com centrifugação (grumixama e uvaia) apresentaram as menores perdas. Por fim, foram conduzidos testes de aplicação das polpas e subprodutos em três tipos de confeitos: barras de fruta, balas de goma e confeitos drageados de fruta e chocolate ou cupulate. A produção dos confeitos a partir de polpa e resíduo de fruta mostrou-se viável tecnicamente, resultando em produtos com presença de compostos bioativos e capacidade antioxidante. Os produtos foram analisados sensorialmente por testes de aceitação, além da nova metodologia: *Check all that apply*. A partir dos resultados obtidos no presente estudo, demonstrou-se a possibilidade de aproveitamento dos subprodutos com agregação de valor e a obtenção de confeitos com a fruta como fonte de cor, aroma e sabor, diferentes daqueles comumente disponíveis no mercado formulados com de corantes e aromatizantes artificiais.

Palavras-chave: subprodutos, capacidade antioxidante, secagem, frutas, confeitos.

ABSTRACT

The consumption of fruits is considered of extreme importance for human health since they are sources of nutrients and bioactive compounds. In addition, the by-products obtained from fruit processing may also contain high amounts of these and other interesting compounds as fibers. Brazil is a country with a great diversity of fruit plants, including several considered unconventional, with potential to be explored. Among them, there are some native fruits of the Atlantic Forest. The interest in sustainable exploration of Brazilian biodiversity has been growing. In this sense, the production and commercialization of fruit pulps can add value to these fruits and allow the exploitation of biodiversity with little or no impact, except for the generation of by-products, often underutilized. It is interesting to study ways not only to take advantage of these by-products, but also to add value to them, for example through their use in products intended for human consumption. There are few studies that propose low cost methods for the direct use of fruit by-products in products for human nutrition. Thus, in the present work three unconventional fruit species native to the Atlantic Forest (cambuci, uvaia and grumixama) were chosen for the physical and chemical characterization. Fruit, pulp and by-product were analyzed. A large amount of compounds of interest, such as phenolic compounds and fibers, were found in the by-products. The amount of phenolic compounds in the residue was 1.64, 4.86 and 1.92 times greater in the by-product when compared to the pulp for cambuci, grumixama and uvaia, respectively. In addition, the effect of conventional drying of the by-products in the loss of bioactive compounds was studied in six conditions: 40NC (40 °C, non-centrifuged), 60NC (60 °C, non-centrifuged), 80NC (80 °C, non-centrifuged), 40C (40 °C, centrifuged), 60C (60 °C, centrifuged), 80C (80 °C, centrifuged). In general, the drying with previous centrifugation resulted in a greater retention of the phenolic compounds and antioxidant capacity, besides the lower drying times, which can result in energy economy. Compounds that do not resist heating may be reduced in the final product, such as ascorbic acid, which did not remain in the dry product. Considering the total phenolic compounds, 80 °C with centrifugation (cambuci) and 40 °C with centrifugation (grumixama and uvaia) presented fewer losses. Finally, pulp and by-product were used to produce three types of confectionery: fruit bars, jelly candies and panned confectionery of fruit and chocolate or cupulate. The production of the confectionery products from pulp and by-product was viable, resulting in final products with the presence of phenolic compounds and antioxidant capacity. The products were

analyzed for their sensory characteristics through acceptance tests and a new methodology: Check all that apply. Confectionery was a good alternative for the use of pulp and residues from native fruits of the Atlantic Forest. This study demonstrated the possibility of using by-products and obtaining confectionery with the fruit (pulp or by-product) as a source of color, aroma and flavor, different from those currently available in the market based on artificial colors and flavorings.
Keywords: by-products, antioxidant capacity, drying, fruits, confectionery

SUMÁRIO

INTRODUÇÃO GERAL

O Brasil é o terceiro maior produtor de frutas e o sétimo maior país em produção de frutas tropicais frescas, com uma quantidade de 823284 t de frutas tropicais frescas/ano em 2014 (FAO, 2016). O Brasil possui uma grande variedade de frutas produzidas por todo o país e estados como São Paulo, Bahia, Minas Gerais, Rio Grande do Sul e Pará destacam-se no cenário da fruticultura brasileira (REETZ et al., 2015).

Frutas são consideradas essenciais para a alimentação. Devido à maior preocupação dos consumidores com a dieta e sua relação com a saúde, além da busca por novos sabores, algumas frutas nativas específicas têm sido exploradas, com potencial para o consumo *in natura* e para a agroindústria. Além disso, é crescente o interesse em estudar a composição das frutas e compreender sua relação com a saúde (ALVES *et al.,* 2008; YAHIA, 2010; RODRIGUES-CASADO, 2016). O Brasil apresenta grande variedade de espécies frutíferas, muitas das quais pouco conhecidas e somente utilizadas pela população local para consumo *in natura* ou na produção de bebidas e doces caseiros, porém com potencial de serem amplamente comercializadas, tanto *in natura* como processadas. (VALLILO et al., 2005; SUGUINO, 2006; RUFINO, 2008; MIYAZAWA, 2009; DONADO-PESTANA et al, 2015).

A família das mirtáceas reúne mais de três mil espécies, distribuídas em cerca de 140 gêneros, com ocorrência principalmente nas regiões tropicais e subtropicais de todo o mundo. No Brasil, são mais de 1000 espécies aceitas, distribuídas entre 23 gêneros aceitos. No entanto, poucas espécies desta família são comercializadas atualmente, representando uma oportunidade para o desenvolvimento deste mercado, como é o caso do cambuci, da grumixama e da uvaia, frutas não convencionais representantes da família das Mirtáceas e nativas da Mata Atlântica, abordadas no presente estudo (FRANZON et al., 2009; SOBRAL et al., 2015).

O cambuci (*Campomanesia phaea)* é uma fruta verde-amarelada típica da Mata Atlântica, encontrada principalmente na Serra do Mar, nos estados de São Paulo e Minas Gerais (MALUF e PISCIOTTANO-EREIO, 2005; DONADO-PESTANA et al., 2015). Em 2016, Bianchini e colaboradores analisaram o teor de sólidos solúveis e a acidez dos frutos, bem como sua relação, denominada *ratio*. O baixo *ratio* (de aproximadamente 2,5 a 7,5) foi considerado o fator limitante ao consumo da fruta *in natura*, mas o baixo pH, o alto rendimento no despolpamento e o sabor podem potencializar oportunidades de industrialização. Além disso, o cambuci (Figura 1) possui propriedade antioxidante, sendo boa fonte de compostos bioativos como o ácido elágico (GONÇALVES et al., 2010).

Figura 1. Cambuci (*Campomanesia phaea).*
Fonte: próprio autor

A uvaia (*Eugenia pyriformis*) é uma fruta de coloração amarela, encontrada na Argentina, Paraguai e sul do Brasil. (FISCHER et. al., 2005). É fonte de compostos bioativos, como polifenóis, ácido ascórbico e carotenoides, além de possuir elevada capacidade antioxidante, auxiliando na prevenção de doenças degenerativas (DE ROSSO, 2007; RUFINO, 2010; WOLFE; LIU, 2007; BRANCO et al., 2016). A uvaia (Figura 2) é uma fruta ácida, altamente perecível, o que torna interessante seu processamento (BRANCO et al., 2016). Em recentes estudos o processamento de uvaia, como a produção de *sherbet* e a produção de uvaia em pó (BRANCO et al., 2016, GIAROLA et al., 2015) são destacados.

Figura 2. Uvaia (*Eugenia pyriformis*)

Fonte: próprio autor

A grumixama (*Eugenia brasiliensis Lam.*) é uma espécie nativa da mata litorânea do Brasil, sendo encontrada da Bahia até Santa Catarina (LORENZI, 2002). A coloração roxa-escura de uma das variedades do fruto é devida às antocianinas, que possuem elevada atividade biológica, atuando, principalmente, como antioxidantes, promovendo efeitos nutricionais positivos aos consumidores (BANERJEE & DASGUPTA, 2005). Em sua pesquisa, Aguiar e colaboradores (2015) realizaram a caracterização físico-química da polpa de grumixama, concluindo que esta pode ser considerada ácida e de baixo teor calórico. A polpa tem gosto doce e ácido, muito apreciado, e é utilizada para a fabricação de xaropes, doces, licores e geleias (MORTON, 1987).

Figura 3. Grumixama (*Eugenia brasiliensis Lam.*)
Fonte: próprio autor

O cultivo dessas espécies frutíferas pode ser interessante para o reflorestamento de áreas de Mata Atlântica amplamente devastadas. Além disso, pode constituir uma fonte de empregos e desenvolvimento de pequenos produtores, quando se opta por trabalhar na comercialização das frutas e seu processamento, que pode resultar em produtos de maior valor agregado. O crescente interesse dos consumidores por produtos naturais incentiva pesquisas relacionadas ao desenvolvimento de novos produtos mais saudáveis e que, ao mesmo tempo, apresentem conveniência (rápido consumo).

Os vegetais (frutas, hortaliças, leguminosas) apresentam diversos micronutrientes de interesse, e também compostos secundários do metabolismo que podem conferir cor, sabor e características antimicrobianas, dentre outras. Muitos desses compostos podem ser de interesse para a alimentação humana, por apresentarem função além da nutrição básica, de auxílio na prevenção de doenças, muitas vezes devido à sua capacidade antioxidante. Exemplos de tais compostos são os carotenoides, ácido ascórbico e compostos fenólicos, como flavonoides. Outro componente de interesse para a saúde também presente nos vegetais são as fibras. O consumo de vegetais tem sido frequentemente combinado a tratamentos médicos (CASSIDY; KAY, 2010; RODRIGUEZ-CASADO, 2016).

Os compostos fenólicos presentes nos vegetais podem ser subdivididos em grupos como flavonoides, ácidos fenólicos, taninos, estilbenos e lignanas. A classificação de composto fenólico está associada à presença de anel aromático com um ou mais grupamentos hidroxila e pode estar relacionada às características de cor, e sabor do alimento (CASSIDY; KAY, 2010).

Os flavonoides são os polifenóis mais comuns presentes em diversos vegetais, sendo importantes antioxidantes. Alguns flavonoides conferem características de cor, e outros atuam como co-pigmentos. Alguns grupos e exemplos de fontes de flavonoides são: flavonas (limão, laranja e cenoura), flavonóis (laranja e brócolis), antocianinas (uva), flavononas (limão e laranja), catequinas (maçã e vinho) e isoflavonas (soja). Os flavonoides têm sido associados a diversas atividades tais como antimicrobiana, antinflamatória, antiviral, antitumoral, antialérgica e antioxidante. A atividade antioxidante está relacionada à redução da formação e remoção de radicais livres, retardando ou inibindo a oxidação de DNA, proteínas e lipídeos. A quantidade de flavonoides pode variar no vegetal de acordo com fatores como variedade, clima, tempo, solo, localização geográfica, estádio de maturação, processamento e estocagem. Em frutas, os flavonoides predominantes são as catequinas, os flavonóis e as proantocianidinas. As flavononas e as flavonas são mais comuns às frutas cítricas. A extração dos flavonoides geralmente pode ser feita com metanol ou etanol (PETERSON; DWYER, 1998; PIETTA, 2000; AHERNE; O'BRIEN, 2002; SIVAM, 2002; KYLE; DUTHIE, 2005; MONFILLIETTE-COTELLE, 2005; CHEYNIER et al., 2012; FERRERES; TOMÁS-BARBERÁN, 2012; AYALA-ZAVALA et al., 2011).

O ácido ascórbico (vitamina C) também é conhecido por atuar como antioxidante. Frutas e hortaliças são as principais fontes de ácido ascórbico na alimentação humana, sendo fontes importantes as frutas cítricas e vegetais, como brócolis, couve flor e tomate. Segundo a *Food and Agriculture Organization* (FAO), a recomendação diária de consumo de vitamina C na dieta de um adulto é de 45 mg. O ácido ascórbico é solúvel em água e em etanol absoluto (ARRIGONI; TULLIO, 2002; BOBBIO; BOBBIO, 2003; FAO, 2016).

Fibras alimentares são partes não digeríveis presentes naturalmente nos vegetais, incluindo polissacarídeos, lignina, oligossacarídeos, como inulina e amido resistente. Podem ser classificadas como solúveis e insolúveis. As solúveis, como a pectina, são fibras viscosas, fermentadas no cólon quando consumidas. As insolúveis têm alta absorção de água, sendo fermentadas de modo limitado no cólon. A introdução de fibras na alimentação pode promover diversos efeitos benéficos à saúde do indivíduo, como a redução do colesterol, o aumento da saciedade, a redução da ingestão de calorias, a perda de peso e o controle de glicemia em pessoas com diabetes tipo 2. Segundo a Diretriz Brasileira sobre Dislipidemias e Prevenção da Aterosclerose da Sociedade Brasileira de Cardiologia, a recomendação de ingestão total de fibras alimentares para adultos é de 20 a 30 g / dia, sendo 5 a 10 g de fibras solúveis (BROWN et al., 1999; CHANDALIA et al., 2000; HOWARTH et al., 2001; SLAVIN, 2005; JONES et al., 2006; SOCIEDADE BRASILEIRA DE CARDIOLOGIA, 2007, KENDALL et al., 2010). Uma possível fonte.de fibras são aquelas oriundas dos sub-produtos do processamento de frutas e hortaliças, que apresentam vantagens como a grande disponibilidade e o baixo custo por serem resíduos tradicionalmente descartados. Além disso, apresentam baixo valor calórico e eventual presença de compostos bioativos de interesse (GONZÁLEZ-CENTENO et al., 2010).

Apesar de características sensoriais como cor, sabor e textura das frutas tropicais serem mais apreciadas quando as mesmas estão na forma *in natura*, sua perecibilidade favorece o processamento. A produção de polpa de fruta congelada é um exemplo de processamento que permite aumentar a vida útil, além de facilitar o transporte e agregar valor (INFANTE et al., 2013).

As indústrias de frutas geram grandes quantidades de subprodutos sólidos, decorrentes da retirada de partes, antes ou durante o processamento, como cascas e bagaço ou também da classificação dos frutos, na qual são separados produtos com avarias ou fora do padrão para comercialização. Algumas indústrias destinam seus resíduos apenas para a simples deposição em aterros sanitários ou compostagem para produção de fertilizantes. No entanto, os subprodutos podem ser utilizados também em diversas aplicações como produtos para a alimentação humana e animal, indústria farmacêutica, produção de etanol e biogás, extração de óleos essenciais e extração de compostos de interesse (como pectina, bromelina, carotenoides, fibras, aromas naturais, flavonoides, tartarato e pigmentos naturais) (EIPESON; RAMTEKE, 2003; WANG, 2008; DJILAS et al., 2009).

Por razões econômicas e ambientais, há um grande interesse no aproveitamento desses subprodutos em função da presença de nutrientes como fibras e compostos bioativos, do seu baixo (ou nenhum) custo de obtenção e da possibilidade de reduzir os volumes necessários no tratamento de efluentes nas indústrias (EIPESON; RAMTEKE, 2003; PESCHEL et al, 2006; WANG, 2008; DJILAS et al., 2009; ROHM et al., 2015).

Os subprodutos de frutas são ricos em componentes funcionais tais como polissacarídeos, polifenóis, vitaminas, carotenoides, que podem ser utilizados como fontes de fibras dietéticas e compostos antioxidantes (KOSMALA et al., 2010). Peschel et al. (2006) estudaram diversos subprodutos do processamento de frutas e hortaliças quanto à atividade antioxidante, viabilidade econômica e conteúdo fenólico. Os autores concluíram haver a possibilidade de recuperar compostos fenólicos com atividade antioxidante com potencial de uso tanto em alimentos como em cosméticos.

Uma vez que esses resíduos são ricos em compostos benéficos à saúde humana, é interessante aplicá-los na indústria de alimentos, seja como fonte de aditivos alimentares (AYALA-ZAVALA et al., 2011) ou como um meio de enriquecer diferentes tipos de produtos. No entanto, mesmo após a retirada da polpa, o resíduo ainda permanece com elevada umidade, o que o torna altamente perecível. Para reduzir custos com transporte frigorificado e com câmaras de armazenamento em temperatura de congelamento para este produto, uma alternativa é optar pela sua secagem.

A secagem ou desidratação de alimentos visa a remoção de grande parte da água presente pela aplicação de calor, promovendo a evaporação da água, a redução da atividade de água e o aumento da vida útil. De forma positiva, a secagem pode reduzir o crescimento microbiano e a atividade de enzimas. No entanto, pode trazer prejuízos quanto às características sensoriais e aspectos nutricionais do produto. Sendo assim, o cálculo e o dimensionamento dos parâmetros e equipamentos de secagem visam reduzir as perdas descritas anteriormente (FELLOWS, 2006; RODRÍGUEZ et al., 2015). Garau et al. (2007) estudaram os efeitos da temperatura de secagem na capacidade antioxidante e nas características da fibra alimentar de resíduos do processamento de laranja. De forma geral, os autores observaram que os subprodutos apresentaram alta retenção dos compostos bioativos em temperaturas entre 40-70 °C.

A Tabela 1 apresenta exemplos de estudos em que houve a aplicação de subprodutos do processamento de frutas para a obtenção de produtos destinados à alimentação humana.

Tabela 1. Exemplos de aplicação de resíduos de fruta em produtos alimentícios

Subproduto	**Aplicação**	**Referência**
Casca de manga	Biscoito	(AJILA et al., 2008)
Casca de manga	Massa alimentícia	(AJILA et al., 2010)
Resíduo de maçã	Extrusados	(PARAMAN et al., 2015)
Resíduo de maçã	Bolo	(SUDHA et al., 2007)
Resíduo de maçã	Substituto de gordura em biscoito tipo *cookie*	(MIN et al., 2010)
Casca de maracujá	Doce em massa	(DIAS et al., 2011)
Pedúnculo de caju	Hambúrgueres com teores reduzidos de gordura	(PINHO et al., 2011)
Resíduo de uva	Pães	(MILDNER-SZKUDLARZ et al., 2011)
Resíduo de uva	Muffin	(MILDNER-SZKUDLARZ et al., 2015)
Resíduo do vinho	Iogurte e molho de salada	(TSENG e ZHAO, 2013)
Fibra de uva	Hambúrguer	(SÁYAGO-AYERDI et al., 2009)
Resíduos diversos	Produtos cárneos	(BISWAS et al., 2015)
Casca de uva	Confeito	(CAPPA et al., 2014)
Resíduos de frutas diversas	Barra de cereal e biscoito	(FERREIRA et al., 2015)
Resíduo de laranja	Pão sem glúten	(O'SHEA et al., 2015)
Resíduo de banana	Pão	(HO et al., 2013)
Casca de bacuri	Estruturado de fruta	(CARVALHO et al., 2008)

Um segmento bastante interessante para a utilização de resíduos de frutas é o de confeitos, como por exemplo, balas de goma, barras de frutas e confeitos drageados. A utilização de resíduos nestes produtos pode permitir, além da incorporação de compostos de interesse (como fibras e compostos bioativos), a agregação de características sensoriais da fruta. Trata-se de uma oportunidade de substituir, por exemplo, ingredientes como aromas e corantes artificiais, amplamente utilizados pela indústria de confeitos (AYALA-ZALVA et al., 2011). Corantes artificiais têm sido alvo de recentes questionamentos por todo o mundo em relação a possíveis efeitos à saúde, tais como alergia, sensibilidade e hiperatividade (TAN et al., 2014; TZE et al., 2012). Além disso, a utilização de corantes de fontes naturais é atualmente uma tendência de marketing (WROLSTAD; CULVER, 2012).

Balas de goma são uma classe de confeitos produzidos sob baixa temperatura e tempo de cocção. Estas possuem alto conteúdo de umidade comparadas a outras balas (20% ou mais) e cuja textura é fornecida pelo agente gelificante utilizado, como goma arábica, ágar, gelatina, pectina e amidos especiais (SWEETMAKER, 1981; WIENEN & KATZ, 1991; QUEIROZ, 1999).

A fruta estruturada, também denominada de estruturado de fruta ou barra de fruta, é um produto formulado a partir da concentração de polpas de frutas e agentes de geleificação e posteriormente desidratado. É considerado um produto de conveniência e fácil consumo, com textura maleável e que pode conter compostos bioativos com ação antioxidante oriundos das frutas de origem (SILVA et al., 2009; LINS, 2010; OFFIA-OLUA e EKWUNIFE, 2015).

A barra de frutas é um produto que permite a utilização de matérias-primas de baixo custo, como frutas que estejam fora do padrão de classificação para comercialização, além de permitir uma aplicação econômica e conveniente de frutas *in natura,* cuja procura é baixa, ou excedentes do comércio, mantendo os componentes nutricionais (SHARMA, 2016). Além disso, para a produção da fruta estruturada, pode-se utilizar resíduos de frutas, sendo também uma alternativa para evitar o desperdício de frutas *in natura*. (CARVALHO et al., 2008).

Confeitos drageados são obtidos por meio do engrossamento controlado de um centro com um líquido ou uma combinação de substâncias líquidas, e em pó, em várias camadas ou fases contínuas, que são fixadas, endurecidas ou secas para criar uma superfície lisa. O produto geralmente é finalizado com a aplicação de agentes selantes e de polimento, em drageadeiras. Os tipos de confeitos drageados podem variar de acordo com a composição da cobertura de drageamento, para a qual geralmente são utilizados açúcares, chocolate, entre outros (BECKETT, 2009). O núcleo pode ser um produto natural, como por exemplo amendoim, castanhas, ou formulado a partir de frutas ou resíduos de frutas. As barras de frutas podem ser opções interessantes para produzir núcleos a partir de ingredientes naturais para o drageamento.

Entre as categorias de confeitos drageados, o drageado de chocolate é um dos mais apreciados. É produzido por meio da aplicação de camadas sucessivas de chocolate derretido sobre os núcleos, e posterior resfriamento para promover a cristalização (AEBI, 2009). Uma alternativa ao uso de chocolate é o cupulate, produto obtido da semente do cupuaçu (*Theobroma grandiflorum* ex. Schum) por um processo semelhante ao utilizado para produzir chocolate a partir do cacau. O uso da semente do cupuaçu para a produção do cupulate é uma forma de aproveitamento do resíduo obtido no processamento de polpa de cupuaçu. Brevemente, as sementes são fermentadas, pela fermentação da camada de polpa que as recobre, secas, torradas e moídas, dando origem ao líquor. A mistura deste com manteiga de cupuaçu e açúcar forma o cupulate (OLIVEIRA et al., 2004). Este produto foi desenvolvido pelo CPATU (Centro de Pesquisa Agroflorestal da Amazônia Oriental) da Embrapa, em 1986. Uma vez que as sementes de cupuaçu ainda não apresentam alto valor comercial, o cupulate pode apresentar menor custo de produção e pode dar origem a produtos distintos como ao leite, branco, amargo e meio amargo (LANNES et al., 2002).

Poucos estudos foram encontrados sobre compostos bioativos e capacidade antioxidante de uvaia, grumixama e cambuci e não foram encontrados estudos sobre a caracterização, a secagem e o aproveitamento dos subprodutos dessas frutas na indústria alimentícia, o que justifica o enfoque que será dado no presente trabalho.

Os capítulos 1, 2 e 3 abordam a secagem dos resíduos de uvaia, cambuci e grumixama, respectivamente, e qualidade do produto seco. O capítulo 4 trata das propriedades físicas e da capacidade antioxidante dos resíduos secos das três frutas. Por fim, os capítulos 5 e 6 abordam a aplicação dos resíduos das frutas em confeitos (barra de fruta, confeito drageado e bala de goma), com avaliação química e sensorial dos produtos finais.

OBJETIVO

GERAL

Estudar a secagem de subprodutos do processamento de cambuci, grumixama e uvaia e a aplicação em confeitos, visando o aproveitamento e a agregação de valor.

ESPECÍFICOS

- Caracterização e determinação da capacidade antioxidante e dos compostos bioativos presentes em cambuci, grumixama e uvaia *in natura*, suas polpas e os resíduos do seu processamento.
- Secagem dos subprodutos das frutas de interesse, avaliando o efeito de diferentes temperaturas de secagem na perda dos compostos bioativos.
- Aplicação das polpas e dos subprodutos em confeitos: barra de fruta, bala de goma e confeito drageado, analisando sensorialmente os produtos obtidos.

CAPÍTULO 1

Mathematical modeling and quality of dried uvaia by-product

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Mathematical modeling and quality of dried uvaia by-product

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Abstract

Uvaia (*Eugenia pyriformis*) frozen pulp processing generates a solid by-product. By-products usually contain important components to human nutrition. In this work, drying of uvaia by-product was studied. Two different drying treatments were tested: drying of wet waste and drying of waste with prior removal of water by centrifugation. Three different drying temperatures were used: 40 °C, 60 °C, 80 °C. Eight different models were applied to fit the drying curves: Page, Lewis, Modified Page, Logarithmic, Midilli, Wang and Singh, Henderson and Pabis and Weibull. Midilli presented the best fit to the curves. The effective moisture diffusivity of uvaia by-product ranged between 8.52×10^{-10} to 3.22×10^{-9} m^2/s and the activation energy was 25.65 and 24.97 kJ/mol for non-centrifuged and centrifuged assays, respectively. The dried by-products had a reduction of 3 to 21% of total phenolic content against the freeze dried by-product. Assay performed at 40 °C with centrifugation presented the lower total color difference value in comparison to freeze dried by-product.

Keywords: uvaia, by-product, drying, Brazilian native fruit, solid waste, drying mathematical model

Introduction

Fruit processing industries generate a lot of solid waste throughout their chain, consisting mostly of peel, seeds and pulp. In many cases, residues are considered operating costs for the companies or environmental contamination sources, being wasted (1,2).

Fruit residues may still have many interesting compounds, such as nutrients, fibers, minerals and carbohydrates and bioactive compounds, such as polyphenolic compounds, which are important for human physiological functions. Therefore, it is desirable to reuse these residues in the food industry in order to minimize losses and add value to other products (3).

Many authors have studied ways to reuse the solid waste generated by the fruit industry. Examples of application can be found in the ethanol, biogas, cosmetic and pharmaceuticals, feed (1,4) and other food industries. Some examples of food products that were formulated using fruit by-products are: bread formulation with orange pomace (5); sweet formulation with passion fruit peel (6); flour with apple pomace (7); cereal bars and biscuits with orange, passion fruit and watermelon residues (8), among other applications.

By-products resulting from the processing of fruit pulps generally exhibit high moisture, which makes them perishable. One way to facilitate their subsequent use is to dry them. In the drying process, water is removed through the heat, reducing the water activity of the product and increasing its shelf life (9).

Brazilian fruit production is quite diverse, but few species are widely commercialized. There are many species still unknown by the population and that have great potential for exploitation. Many species have even aroused the domestic and foreign interest (10,11). Uvaia (*Eugenia pyriformis*) is a native fruit from the Myrtaceae family that has great potential to be exploited economically and technologically and is currently present in Brazil from the state of São Paulo to Rio Grande do Sul (12,13).

No studies on drying of uvaia solid waste were found. Thus, the objective of this work was to study drying kinetics and quality parameters of uvaia by-product dried in conventional dryer, under different conditions, for later application by the food industry.

Materials and Methods

Materials

Uvaia by-product sample was obtained from a native fruit producer, located in the city of Paraibuna (23° 27’53.94” South, 45º 42’31.88” West), state of São Paulo, Brazil, in October (2013). The by-product was obtained after the fresh fruit pulp extraction, which was carried out in a pulper with nylon scraper blades (Tortugan, No. 56,032, MS25 model, Brazil). The by-product is composed of peels, bagasse and seeds. The samples were stored in metalized bags (Metalized polyethylene terephthalate 17g/m^2 + white polystyrene 100 g/m^2) at -18 °C until their use.

Methods

Drying experiment

Drying experiments were performed in a convective dryer (Marconi MA035, Brazil), at the Department of Food Technology, State University of Campinas, with the dimensions of 80 cm x 100 cm x 61 cm. The air velocity of 0.4 m/s was measured with an anemometer (Lutron – AM 4202, Taiwan) positioned in the air entrance in the drying chamber. A 1 kg by-product sample at 25 °C was disposed in a thin layer (about 1.0 cm) on a perforated tray with dimensions of 51 cm x 73 cm and mesh size of 0.3 cm x 0.3 cm. Three drying temperatures were tested: 40, 60 and 80 °C. In addition, two pretreatments were performed: drying with or without previous centrifugation of the sample. The assays without previous centrifugation received the following nomenclature (being the number correspondent to the drying temperature, in °C): 40NC, 60NC and 80NC. The assays with prior centrifugation received the following nomenclature: 40C, 60C and 80C. For the 40C, 60C and 80C assays, the by-product was centrifuged for 5 min at 1036 x g (Mueller Eletrodomésticos S.A, Brazil) before drying, aiming at removing part of the initial water present in the by-product. The convective dryer was started and had the temperature set 30 min before beginning each drying procedure. This period was necessary to achieve steady-state conditions. In order to obtain the drying curves, the samples were weighted every 30 min for the assays at 40 and 60 °C and every 15 min for the assays at 80 °C, until constant sample weight. The digital balance had a sensitivity of 0.01 g and was positioned as closest to the dryer as possible (1.5 m). The assays were performed in triplicate and the averages were used to data analysis.

Mathematical modeling

The collected results were used to calculate the moisture ratio (MR) and the curves were constructed with the data of MR versus time.

Moisture ratio was calculated according to Equation 1.

$$MR = \frac{M_t - M_e}{M_0 - M_e} \qquad (1)$$

M_t, M_e e M_0 corresponds, respectively, to the moisture contents at the time of weighing (t), at equilibrium and at the beginning of the assay.

The drying rate (DR) of the by-products was calculated according to Equation 2 and expressed as kg water/(kg dry matter·min):

$$DR = \frac{M_{n+1} - M_n}{t_{n+1} - t_n} \qquad (2)$$

t_{n+1} and t_n are the drying times and M_{n+1} and M_n are the moisture contents at the time of weighting.

The mathematical models used to quantify the drying kinetics were: Page (14); Lewis (15); Modified Page (16); Logarithmic (17); Midilli (18); Wang and Singh (17); Henderson and Pabis (19); and Weibull (20). The equations are shown in Table 1.

Table 1. Mathematical models used to fit the drying curves

Model	Equation	Reference
Page	$MR = \exp(-kt^n)$	(14, 21)
Lewis	$MR = \exp(-kt)$	(15)
Modified page	$MR = a\ \exp(-kt)^n$	(16)
Logarithmic	$MR = a\ \exp(-kt) + c$	(17)
Midilli	$MR = a\ \exp(-kt^n) + bt$	(18)
Wang and Singh	$MR = 1 + at + bt^2$	(17)
Henderson and Pabis	$MR = \mathrm{a}\ \exp(-kt)$	(19)
Weibull	$MR = \exp\left(-\left(\frac{t}{b}\right)^a\right)$	(20)

In order to verify if the models had adjusted well to the drying curves, the following parameters were used: R^2 (coefficient of determination), RMSE (root mean square error) and χ^2 (reduced chi-square). The higher R^2 values and the lower RMSE and χ^2 values, the best was the quality of the curves (14,21). RMSE and χ^2 formulas are presented in Equations 3 and 4, respectively. MRexp is experimental value for the moisture ratio, MRpre is predicted value for the moisture ratio, N is the number of observations, and z is the number of constants.

$$RMSE = \left[\frac{1}{N}\sum^{N}\left(MR_{pre,i} - MR_{exp,i}\right)^2\right]^{1/2} \qquad (3)$$

$$\chi^2 = \frac{\sum_{i=1}^{N}(MR_{pre,i} - MR_{exp,i})^2}{N - z} \qquad (4)$$

Effective moisture diffusivity

Fick's second diffusion law (Equation 5) is commonly used to calculate effective moisture diffusivity (D_{eff}) (16,22).

$$\frac{\partial M}{\partial t} = \frac{\partial}{\partial x}\left(D_{eff}\frac{\partial M}{\partial x}\right) + \frac{\partial}{\partial y}\left(D_{eff}\frac{\partial M}{\partial y}\right) + \frac{\partial}{\partial z}\left(D_{eff}\frac{\partial M}{\partial z}\right) \quad (5)$$

Considering the thin layer of by-product an infinite slab, just the z axis can be considered. In addition, considering uniform initial moisture distribution, negligible shrinkage, constant moisture diffusivity and sample surface in equilibrium with the environment, Crank (24) obtained the solution for Equation 5, that is presented at Equation 6. And for long drying periods, the equation can be simplified (Equation 7), being L half the thickness (m) of the slab (25).

$$\mathrm{MR} = \frac{8}{\pi^2}\sum_{i=0}^{\infty}\frac{1}{(2i+1)^2}\exp\left[\frac{-(2i+1)^2 D_{eff}\pi^2 t}{4L^2}\right] \quad , (t=0, M_t=M_0) \quad (6)$$

$$\mathrm{MR} = \frac{8}{\pi^2} exp\left[\frac{-D_{eff}\pi^2 t}{4L^2}\right] \quad (7)$$

To calculate D_{eff} for each assay, the slope of the plot of lnMR versus time was calculated.

Activation energy

The relationship between the effective moisture diffusivity and the temperature can be represented by Arrhenius equation (25,26).

$$D_{eff} = D_o \exp\left(-\frac{E_a}{RT}\right) \quad (8)$$

E_a is the activation energy (kJ/mol), R is the gas constant (8.314 J/mol.K) and D_o is the Arrhenius factor (m^2/s). E_a and D_o were obtained, respectively, from the slope and the interception of the plot of ln D_{eff} versus 1/T.

The activation energy was calculated separately for the centrifuged assays (40C, 60C and 80C) and non-centrifuged assays (40NC, 60NC and 80NC).

Total phenolic content

Total phenolic content of the dried by-products for all drying conditions was estimated following the method of Singleton & Rossi (1965), described by HAMINIUK et al. (2011), using the Folin-Ciocalteu reagent. The samples (0.5g) were extracted with 40 mL of a 40% ethanol solution for one hour with agitation in a stirring table (120 bpm). After the extraction, they were centrifuged at 1535 x g and the supernatant filtered with Whatman n°1 filter paper. The extraction for each sample was performed in triplicate.The extracts were pipetted (100 µL) into 5 mL of distilled water and 500 µL of Folin-Ciocalteu reagent was added to the mixture. Three minutes later, 1.5 mL of a 15% sodium carbonate solution was added and finally, distilled water was added to complete a final volume of 10 mL. After a period of two hours in the dark at room temperature, the absorbance of the mixture was measured at 765 nm using a spectrophotometer model BU70 (Beckman Instruments, Inc., Fullerton, CA, USA). Gallic acid was used as standard. The results were expressed as gallic acid equivalents.

Color evaluation

The evaluation of the color of the dried by-products for all drying conditions was held in a colorimeter (Mini Scan XE Hunter Associates Laboratory, Inc, Reston, Virginia, USA), calibrated against white pattern (x=80.3; y=85.1, z=91.0), in triplicate. The color system used in the analysis was the CIELab. L* value represents the lightness/darkness of the sample, ranging from zero to 100, being zero for black and 100 for white. The “a*” value represents greenness and redness, ranging from -60 to 60, respectively. Finally, the “b*” value represents blueness and yellowness, ranging from -60 to 60, respectively (28). To compare the samples, the ratio a*/b* and total color difference (ΔE) were calculated, according to the following equations (29):

$$\Delta E = \sqrt{(L^* - L_0^*)^2 + (a^* - a_0^*)^2 + (b^* - b_0^*)^2} \quad (9)$$

L^*_0, a^*_0 and b^*_0 are the color values for the powder control sample (freeze dried). In order to compare the drying processes, a freeze dried control sample was obtained (Control). The freeze-drying process was carried out in a freeze-dryer (Christ, Alpha 2-4 LD plus model, Germany). The samples were frozen in trays and then freeze dried under the following conditions (in dark): 44 h, 0.12 mbar, T=- 40ºC (main drying) and 4 h, 2.5 mbar, T= -10ºC (final drying). The product can be classified as very distinct (ΔE higher than 3), distinct (ΔE between 1.5 and 3) and small difference (ΔE lower than 1.5) (29).

Statistical analysis

Drying assays were performed in triplicate. Nonlinear regression of the drying curves was performed using MATLAB R2016a software (The Mathworks, Inc, Natick, USA).

The parameters of color and total phenolic content were analyzed by ANOVA test and Tukey's test ($p<0.05$).

Results and discussion

Drying curves

The drying curves (moisture ratio vs. time) are shown in Figure 1A and the changes in the drying rate with moisture ratio during drying of uvaia by-product at the different studied conditions are shown in Figure 1B. As expected, the samples dried at higher temperatures had lower drying times. The times varied between 330 and 1110 min (80C and 40NC, respectively). Moreover, samples that have passed through the previous centrifuging process had lower drying times than samples that were directly dried. The centrifugation process assists in the prior removal of water from the material having a 30 to 44% reduction of the initial mass. This prior removal of the water was carried out in order to try to reduce the exposure of the waste to high temperatures and to minimize the loss of important bioactive compounds. When assays of same temperature were compared, the drying time of the samples with prior centrifugation was 24.5% lower for the conditions at 40 °C, 16.7% for 60 °C and 21.4% for 80 °C. For example, samples 40NC and 40C had drying time of 1110 min and 840 min, respectively. Still, the samples 60NC, 60C, 80NC and 80C presented drying times (in minutes) of 540, 450, 420 and 330, respectively. The prior centrifugation of the material can bring interesting results. The drying time of the residue at 60°C with prior centrifugation was close to the residue without prior centrifugation at 80 °C. The fruit waste obtained from the mechanical pulping process of fruits has undergone total disintegration and therefore exhibits a great surface area available for mass transfer, and consequently presents higher water loss on drying.

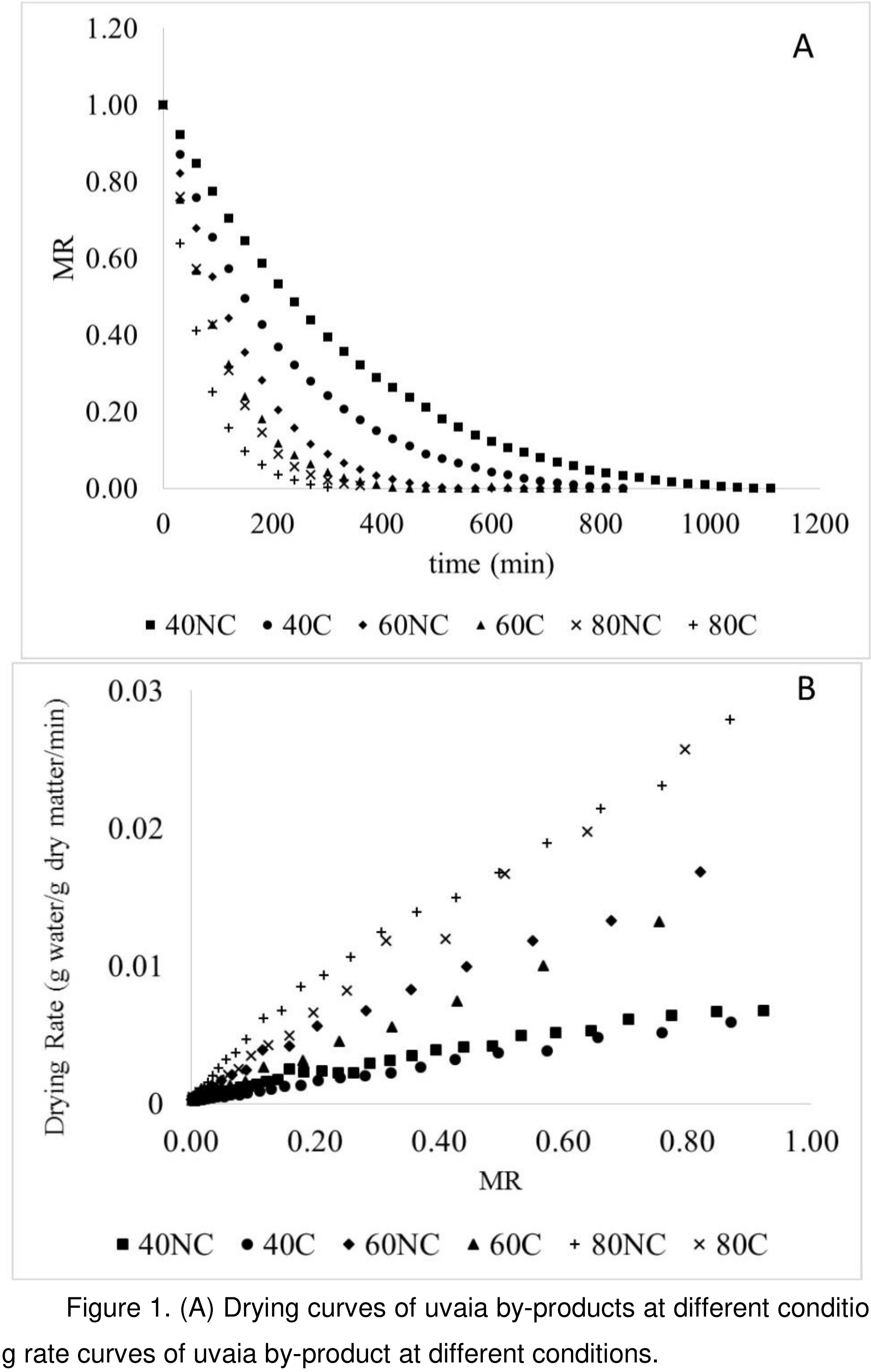

Figure 1. (A) Drying curves of uvaia by-products at different conditions. (B) Drying rate curves of uvaia by-product at different conditions.

Initial (after centrifugation in previously centrifuged assays) and final mean moistures (kg/kg dry basis), respectively: 2.78 and 0.12 (40NC), 1.5 and 0.09 (40C), 2.9 and 0.08 (60NC), 1.7 and 0.07 (60C), 3.3 and 0.06 (80NC) and 2.0 and 0.05 (80C).

Figure 1B shows the drying rate for each studied condition. It was possible to observe that the drying rate was not constant for any of the conditions. The lower temperature assays presented a lower variation between the initial and final drying rates and presented a lower drying rate when compared to the higher temperature assays. The higher rate of moisture loss when higher temperatures were used was previously observed by other authors when drying vegetable by-products, like pomegranate peels and lemon peels (14,30). In addition, when comparing same temperatures, the assay with prior centrifugation presented lower drying rates, as expected, since the drying rates consider the moisture content at the time of weighting. The moisture ratio data was used to calculate the mathematical drying models.

Mathematical modeling

Eight different models were tested. Table 2 shows the constants, R^2, RMSE and χ^2 for all models and assays. The selection of the mathematical model that best fitted the curves was based on a high R^2 and low RMSE and χ^2 values. Almost all models, except for Wang and Singh, presented excellent R^2 values, above 0.99. Midilli was considered the model that best fitted the experimental 40NC, 60NC, 80NC, and 80C drying curves and Logarithmic was considered the model that best fitted 40C and 60C drying curves, because of the higher R^2 values and lower RMSE and χ^2 values. For 40C and 60C assays, Midilli was the second best model and R^2, RMSE and χ^2 parameters were really close to the ones calculated to Logarithmic model. The plot of MR values predicted by Midilli versus experimental values for all non-centrifuged and centrifuged assays are shown in Figures 2 A and B, respectively.

Table 2. Parameters of the mathematical models for all uvaia by-product drying conditions

Model	Condition	Constants			R^2	RMSE	X^2
		A	K				
Henderson and Pabis	40NC	1.0440	0.204		0.9947	0.02154	0.000461
	40C	1.0130	0.293		0.9987	0.01054	0.000078
	60NC	1.0310	0.451		0.9954	0.02123	0.000450
	60C	1.0090	0.586		0.9988	0.01082	0.000117
	80NC	1.0350	0.633		0.9952	0.02054	0.000422
	80C	1.0060	0.924		0.9997	0.00506	0.000026
		k					
Lewis	40NC	0.1959			0.9928	0.02482	0.000613
	40C	0.2888			0.9985	0.01104	0.000088
	60NC	0.4382			0.9944	0.02279	0.000520
	60C	0.5809			0.9987	0.01086	0.000118
	80NC	0.6132			0.9941	0.02246	0.000504
	80C	0.9186			0.9997	0.00519	0.000027
		a	K	C			
Logarithmic	40NC	1.0740	0.174	-0.0566	0.9994	0.00717	0.000047
	40C	1.0250	0.271	-0.0247	1.0000	0.00150	0.000002
	60NC	1.0560	0.400	-0.0423	0.9988	0.01124	0.000126
	60C	1.0210	0.551	-0.0203	0.9998	0.00441	0.000019

	80NC	1.0530	0.568	-0.0365		0.9985	0.01183	0.000140
	80C	1.0090	0.900	-0.0077		0.9999	0.00273	0.000007
		A	K	B	N			
Midilli	40NC	0.9938	0.154	-0.0016	1.1020	0.9998	0.00429	0.000002
	40C	0.9997	0.275	-0.0016	1.0100	1.0000	0.00162	0.000003
	60NC	0.9924	0.373	-0.0019	1.1200	0.9996	0.00706	0.000050
	60C	0.9982	0.556	-0.0021	1.0230	0.9998	0.00476	0.000023
	80NC	0.9858	0.536	-0.0021	1.1360	0.9994	0.00754	0.000057
	80C	0.9990	0.905	-0.0012	1.0150	0.9999	0.00258	0.000007
		A	K	N				
Modified page	40NC	1.0440	2.28	0.0896		0.9947	0.02184	0.000474
	40C	1.0130	0.189	1.5510		0.9987	0.01074	0.000064
	60NC	1.0310	0.586	0.7700		0.9954	0.02188	0.000261
	60C	1.0090	0.765	0.7660		0.9988	0.01123	0.000092
	80NC	1.0350	0.807	0.7845		0.9952	0.02093	0.000288
	80C	1.0060	0.995	0.9289		0.9997	0.00519	0.000016
		k	N					
Page	40NC	0.148	1.1520			0.9987	0.01083	0.000091
	40C	0.267	1.0530			0.9993	0.00775	0.000019
	60NC	0.376	1.1460			0.9990	0.00984	0.000023
	60C	0.557	1.0550			0.9994	0.00778	0.000013

	80NC	0.552	1.1450	0.9988	0.01037	0.000042
	80C	0.911	1.0270	0.9998	0.00374	0.000007
		a	B			
Wang and Singh	40NC	-0.1357	0.0046	0.9885	0.03178	0.000926
	40C	-0.1909	0.0090	0.9666	0.05285	0.002748
	60NC	-0.2932	0.0211	0.9827	0.04132	0.001708
	60C	-0.3689	0.0330	0.9616	0.06115	0.003739
	80NC	-0.3973	0.0382	0.9752	0.04670	0.002181
	80C	- 0.5402	0.0692	0.9245	0.07890	0.006225
		a	B			
Weibull	40NC	1.1520	5.2520	0.9987	0.01083	0.000080
	40C	1.0530	3.5030	0.9993	0.00775	0.000019
	60NC	1.1460	2.3480	0.9990	0.00984	0.000023
	60C	1.0550	1.7430	0.9994	0.00778	0.000013
	80NC	1.1450	1.6800	0.9988	0.01037	0.006243
	80C	1.0270	1.0950	0.9998	0.00374	0.002542

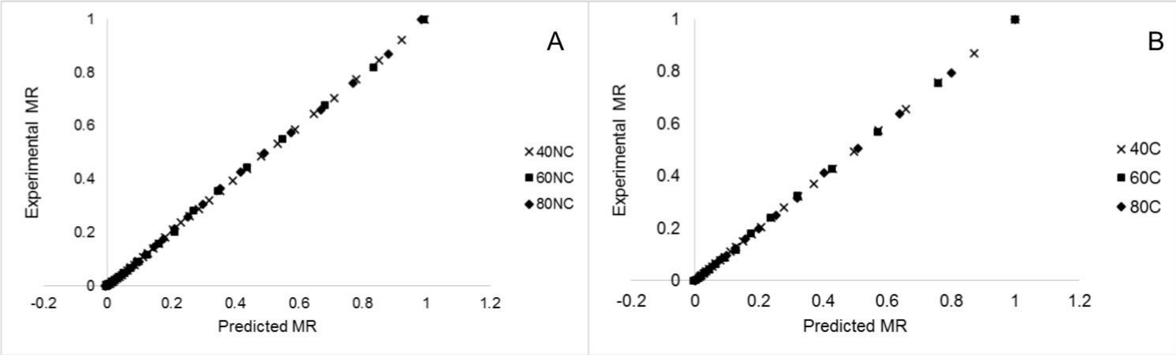

Figure 2. Experimental MR versus predicted MR by Midilli model. A – non-centrifuged assays. B – centrifuged assays

Effective moisture diffusivity

The effective moisture diffusivity values were calculated according to Equation 5. For non-centrifuged assays (40NC, 60NC and 80NC), effective moisture diffusivities were, respectively: 8.52×10^{-10}, 1.75×10^{-9}, 2.59×10^{-9} m^2/s. For previously centrifuged assays (40C, 60C and 80C), the values were, respectively: 1.09×10^{-9}, 2.07×10^{-9} and 3.22×10^{-9} m^2/s. As expected, higher temperatures resulted in higher effective moisture diffusivity. The values obtained in this study are comparable to the values obtained by other authors for other vegetable by-products: 2.03×10^{-9} to 1.71×10^{-9} m^2/s in the range of 50 to 90 °C for olive cake waste (25); and 4.02 to 5.31×10^{-9} m^2/s for pomegranate peels at 50 to 70 °C (14).

Activation energy

According to Equation 8, the values of lnDeff versus 1/T were plotted and the activation energy was calculated. For both non-centrifuged and centrifuged assays, the plot showed a linear tendency, with a R^2 of 0.9817 and 0.9946, respectively. The non-centrifuged and centrifuged assays presented activation energies of 25.65 and 24.97 kJ/mol, respectively. These values are comparable to the activation energy obtained by other authors for vegetable by-products: 17.97 kJ/mol for olive cake (31); 39.66 kJ/mol for pomegranate by-products (20); 29.571 and 34.726 kJ/mol for 2.0 and 3.5 m/s (air drying velocity) for passion fruit peels (32).

Total phenolic content

Phenolic compounds can be related to properties like antioxidant and free radicals scavenging capacities. Total phenolic content can give a general idea of the antioxidant capacity of the product (33). The results for total phenolic content for the dried by-product in the different drying assays and for the freeze dried by-product are presented at Figure 3. It is possible to observe that the total phenolic content varied between the samples. Freeze drying is a drying process that is recognized for maintaining and preserving the characteristics of the raw product the most. In this sense, in the present work, a freeze dried product was used as a control sample for the drying process. Comparing the results, the dried by-products had a reduction of up to 21% (80NC) against the freeze dried by-product. 40C did not present significant difference to the control ($p \leq 0.05$). ZILLO et al. (2013) compared the fresh fruit and the frozen pulp. They obtained 4.89 and 6.07 mg gallic acid per 100 g for the fruit and pulp, respectively, in wet basis. In this study, the values for the dried by-products varied between 30.5 to 38.5 mg of gallic acid per g (dry basis). Considering the quantity of water of the wet by-product (moisture of 89.2%), the quantity of total phenolic content that the wet by-product would have was calculated, resulting in a maximum of 404mg per 100g. As Zillo et al. (2013) did not describe their extraction methodology for TPC, it is hard to directly compare their values with the values obtained in the present research.

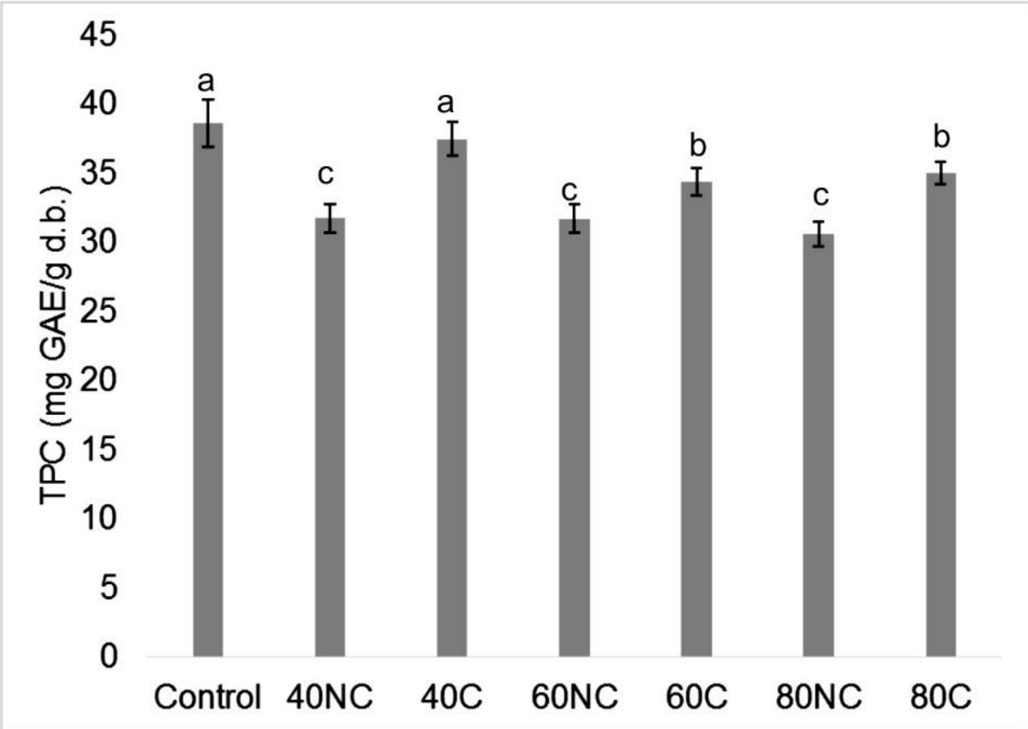

Figure 3. Total Phenolic Content of uvaia control by-product and uvaia dried under different condition.

Results with same letters indicate no significant statistical difference ($p \leq 0.05$). The maximum coefficient of variation was 4.4%.

HAMINIUK et al. (2011) evaluated uvaia pulp and obtained 24.09 mg of gallic acid per gram (dry basis). In the present work, the by-product dried in hot air dryer showed a value 23 to 55% higher than the fruit extract evaluated by HAMINIUK et al. (2011). RAMIREZ et al. (2012) evaluated different uvaia genotypes, obtaining 373 to 652 mg per 100 g of freeze dried fruit. It was not found any record in literature for the phenolic compound evaluation of any uvaia by-product, only results for both pulp and entire fruit were found. Considering the results obtained for total phenolic content of uvaia by-product, it was possible to observe that even after hot-air drying, the by-products remained with phenolic compounds. Therefore, there is a great potential to develop food products containing the dried uvaia by-product as a healthier ingredient.

Color evaluation

Table 3. Color parameters of uvaia control by-product and uvaia dried under different conditions

Sample	L*[1]	a*[1]	b*[1]	ΔE[1]	a*/b*[1]
Control	76.8±0.3[a]	9.49±0.09[e]	48.7±0.3[a]	0	0.195±0.002[f]
40NC	58±1[d]	13.0±0.3[a]	42.0±0.4[c]	20±1[a]	0.31±0.01[a]
40C	66.8± 0.7[b]	10.1±0.1[e]	43.6± 0.4[b]	11.2±0.7[c]	0.231±0.003[e]
60NC	59±1 [d]	12.6±0.4[a]	39.7±0.3[e]	20±1[a]	0.32±0.01[a]
60C	62.3±0.5[c]	11.6±0.3[c]	42.0±0.3[c]	16.2±0.4[b]	0.276±0.005[c]
80NC	59.0±0.7[d]	12.1±0.3[b]	40.8±0.4[d]	19.6±0.5[a]	0.298±0.005[b]
80C	61.1±0.8[c]	10.8±0.4[d]	42.2±0.4[c]	17.1±0.6[b]	0.257±0.007[d]

[1]Different letters in the same column indicate significant statistical difference ($p \leq 0.05$)

Color is an important parameter related to the quality of the product, being an important criteria to consumers of dried fruits (36, 37). The values of L^*, a^* and b^* of the dried fruit residues were measured (Table 3). The freeze dried by-product was used as control. There was variation in the color of the final product according to the different drying conditions. It was possible to verify that the previous centrifugation exerted influence on the dried product color. It has been previously reported that its desirable that dried products have high L^* and low a^*/b^* values (38). Samples with prior centrifugation showed higher L^* and lower a^*/b^* values, probably due to the reduced exposure to the heating. As an example, L and a/b values for the 60NC treatment were 59 and 0.32 and for 60C, 62.3 and 0.276. The other temperature assays showed similar tendencies. Compared to the control sample, for all assays, there was a decrease of the luminosity value (L^*) and yellow color (b^*) and an increase of the red color (a*). The color changes of the dried by-product can be related to the Maillard reaction, pigments degradation and oxidation reactions, such as oxidation of ascorbic acid (30).

According to ANOVA test, ΔE values differed significantly ($p<0.05$) between the different assays. For ΔE, there was no significant difference between the 40NC, 60NC and 80NC assays. 40C assay presented the lower ΔE, followed by 60C and 80C. In terms of color of the final product, the best treatment was 40C, showing the lowest ΔE among the samples. All assays though can be considered very distinct when compared to the control (ΔE higher than 3). ZILLO et al. (2013) obtained the following L^* values for the fresh fruit and frozen pulp: 47.657 and 53.337. No records of uvaia by-product color were found.

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CAPÍTULO 2

Drying kinetics and quality of cambuci (*Campomanesia phaea*) by-product

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Drying kinetics and quality of cambuci (*Campomanesia phaea*) by-product

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Abstract

Fruit pulp processing generates high quantities of solid by-product. Drying is an alternative to preserve the residues that can be further used by other industries. The present work aimed to study the conventional drying of cambuci by-product, focusing in the mathematical modeling and in the impact of drying in final product's quality. Three temperatures were tested: 40 °C, 60 °C and 80 °C. Two treatments before drying were applied: with and without centrifugation. Eight models were fitted to experimental drying curves: Henderson and Pabis; Lewis; Logarithmic; Midilli; Modified Page; Page; Wang and Singh; and Weibull. Midilli was the model that best fitted the curves. Effective moisture diffusivity ranged between 2.46 x 10^{-9} to 9.70 x 10^{-9} m^2/s. Activation energy was 32.8 kJ/mol and 29.6 kJ/mol for non-centrifuged and centrifuged assays, respectively. Between the assays, the maximum reduction of total phenolic compounds was 42%. There was a high total color difference for all treatments and the assays with prior centrifugation presented the lowest color variation.

Keywords: cambuci, Brazilian native fruit, hot-air drying, by-product, mathematical modeling

1 Introduction

Cambuci is a native fruit from Brazilian Atlantic Forest, with acid flavor and strong and distinctive aroma. Furthermore, this fruit has an intense and pleasant fragrance and is an important source of phenolic compounds, vitamins A and B and iron complex [1]. Cambuci has returned to arouse consumer interest, being grown by many small producers in the state of São Paulo, Brazil [2]. In addition to the fruit *in natura* consumption, cambuci can be used in gastronomy, jellies, liqueurs, sweets, pulp and juices, among others [3]. The Holistic Association of Ecological Community production, group that stimulates cambuci crop, estimates that the annual production of the state of São Paulo has reached 400 tons in 2014 [2].

The fruit and vegetables processing chain generates large amounts of waste, from 40 to 50%, according to FAO (Food and Agriculture Organization of the United Nations). The fruit pulp processing industry, more specifically, is responsible for generating solid residue, which does not compose the final pulp, such as peel and pomace. This residue can be quite rich in fiber and other compounds, such as sugars, minerals, phenolic compounds, organic acids and fiber. There is a great current interest both to somehow take advantage of these residues, which still have interesting compounds, and to minimize the dumping of this waste into the environment, giving a higher value-added destination to it [4,5].

An alternative to increase the shelf life of waste and make the packaging and storage easier is to dry it. Drying can improve the product's shelf life by reducing the water activity so that the growth of microorganisms is inhibited as long as enzimatic and deteriorative reactions. The convective drying is one of the drying methods that requires smaller investments. The dried product can be used as an ingredient. However, during the drying process, modifications occur in the product, which may cause change in both their physical characteristics, such as color, and chemical characteristics, as the amount of bioactive compounds [6–9].

Many authors have studied the drying of fruit by-products, like apple pomace [10], pomegranate by-product [11], passion fruit peels [7], lemon peels [12], among others.

Therefore, the objective of the present work was to study the hot air drying parameters of cambuci by-product as well as the influence of the drying process on the product's quality.

2 Materials and Methods

2.1 Material

Samples of cambuci (*Campomanesia phaea*) by-product were obtained from a native fruit producer located in the city of Paraibuna, state of São Paulo, Brazil (23° 27`53.94" South, 45º 42`31.88 West), in January (2014). The fruits were processed in a pulper with nylon scraper blades (Tortugan, No. 56,032, MS25, Brazil) in order to obtain the pulp. The waste generated from the frozen pulp processing was vacuum conditioned in 1kg bags and immediately frozen. The bags were kept at -18ºC until the beginning of the experiment.

2.2 Drying experiment

In the drying procedure, two pre-treatments were tested: drying of the solid waste with and without prior centrifugation. For the assays with prior centrifugation, 1kg cambuci waste sample was centrifuged (Mueller Eletrodomésticos S.A, Brazil) at 1036 x g for 5 minutes in order to eliminate part of the water before drying. Also, three drying temperatures were tested: 40, 60 and 80 °C. A total of 6 different drying conditions were studied: 40NC (assay at 40 °C, non centrifuged), 60NC (assay at 60 °C, non centrifuged), 80NC (assay at 80 °C, non centrifuged), 40C (assay at 40 °C, centrifuged), 60C (assay at 60 °C, centrifuged), 80C (assay at 80 °C, centrifuged).

The drying procedure took place at a conventional cabin dryer, with air velocity of 0.4 m/s measured with an anemometer (Lutron – AM 4202, Taiwan) and dimensions of 80 cm x 100 cm x 61 cm (Marconi MA035, Brazil), in the Faculty of Food Engineering (State University of Campinas, state of São Paulo, Brazil). The by-product was positioned in thin layers (about 1.4 cm) in perforated trays with mesh of 0.3 cm x 0.3 cm. The tray with the by-product was weighted every 30 minutes for 40 and 60 °C experiments and every 15 minutes for 80 °C experiments, until constant weight. The dryer was turned on and set to the correct temperature at least 30 minutes before the experiment began, in order to achieve steady state conditions. The scale with a sensitivity of ±0.01 g was positioned close to the dryer (1.5 m). The assays were repeated in triplicate.

Finally, the dried residues were milled (Tecnal TE 631/2, Brazil) and stored in vacuum metalized bags (Metalized polyethylene terephthalate 17g/m² + white polystyrene 100 g/m²).

2.3 Curve fitting

The obtained results were used to calculate the moisture ratio (MR), according to Equation 1.

$$MR = \frac{M_t - M_e}{M_0 - M_e} \qquad (1)$$

In Equation 1, M_t, M_e e M_0 corresponds to the moisture contents at the time of weighting (t), at equilibrium and at the beginning of the assay, respectively. The drying curves were calculated in terms of MR versus time.

Equation 2 was used to calculate the drying rate (DR), in kg water/(kg dry matter*min).

$$DR = \frac{M_{n+1} - M_n}{t_{n+1} - t_n} \qquad (2)$$

t_{n+1} and t_n are the drying times and M_{n+1} and M_n are the moisture contents at the time of weighting.

Eight mathematical models (Table 1) were used to calculate the drying kinetics: Henderson and Pabis; Lewis; Logarithmic; Midilli; Modified Page; Page; Wang and Singh; and Weibull.

TABLE 1. Mathematical models applied to cambuci by-product drying curves

Model	Equation	Reference
Page	$MR = \exp(-kt^n)$	[11]
Lewis	$MR = \exp(-kt)$	[13]
Modified page	$MR = a\ \exp(-kt)^n$	[14]
Logarithmic	$MR = a\ \exp(-kt) + c$	[15]
Midilli et al. (2013)	$MR = a\ \exp(-kt^n) + bt$	[16]
Wang and Singh	$MR = 1 + at + bt^2$	[17]
Henderson and Pabis	$MR = \mathrm{a}\exp(-kt)$	[18]
Weibull	$MR = \exp\left(-\left(\frac{t}{b}\right)^a\right)$	[11]

2.4 Effective Moisture Diffusivity and activation energy

Fick's second diffusion law was used to calculate effective moisture diffusivity (D_{eff}). The by-product was considered an infinite slab, with no shrinkage during drying [14,19]. In addition, the Equation consider uniform initial moisture distribution, constant moisture diffusivity and sample surface in equilibrium with the environment. Equation 3 expresses MR, being L half the thickness (m) of the slab [20].

$$\mathrm{MR} = \frac{8}{\pi^2}\sum_{i=0}^{\infty}\frac{1}{(2i+1)^2}\exp\left[\frac{-(2i+1)^2 D_{eff}\pi^2 t}{4L^2}\right] \qquad (t=0,\ M_0 = M_t) \qquad (3)$$

Considering long drying times, the equation can be simplified (Equation 4)

$$\mathrm{MR} = \frac{8}{\pi^2} exp\left[\frac{-D_{eff}\pi^2 t}{4L^2}\right] \qquad (4)$$

In order to calculate Deff for each assay, the slope of the plot of lnMR versus time was calculated (Equation 5).

$$\ln MR = \ln\left(\frac{8}{\pi^2}\right) - \left(\frac{\pi^2 D_{eff} t}{4L^2}\right) \qquad (5)$$

The activation energy was calculated with Arrhenius equation (Equation 6).

$$D_{eff} = D_o \exp\left(-\frac{E_a}{RT}\right) \qquad (6)$$

Ea is the activation energy (kJ/mol), R is the gas constant (8.314 J/mol.K) and D_o is the Arrhenius factor (m^2/s). E_a and D_o were calculated from the slope and the interception of the plot of ln Deff versus 1/T, respectively.

The activation energy was calculated separately for the assays with prior centrifugation (40C, 60C and 80C) and without prior centrifugation assays (40NC, 60NC and 80NC).

2.5 Models analysis

The quality of fit of the experimental data to the curves was evaluated using the following parameters: coefficient of determination (R^2), root mean square error (RMSE) and reduced chi-square (χ^2). A good fit of the model was indicated by a high R^2 and low RMSE and χ^2 [9]. The formulas to calculate RMSE and χ^2 are presented in Equations 7 and 8.

$$RMSE = \left[\frac{1}{N}\sum^{N}\left(MR_{pre,i} - MR_{exp,i}\right)^2\right]^{1/2} \qquad (7)$$

$$\chi^2 = \frac{\sum_{i=1}^{N}(MR_{pre,i} - MR_{exp,i})^2}{N-z} \qquad (8)$$

MRexp is the experimental value for the moisture ratio, MRpre is the predicted value for the moisture ratio, N is the number of observations, and z is the number of constants.

2.6 Control sample

With the aim to compare both total phenolic content and color parameters, a freeze dried control sample was used. The by-product was dried in a freeze dryer (Christ, Alpha 2-4 LD plus model) under the following conditions (in dark): 44 hours, 0.12 mbar, T=- 40 ºC (main drying) and 4 hours, 2.5 mbar, T= -10 ºC (final drying).

2.7 Total phenolic content (TPC)

Total phenolic content was evaluated using Folin-Ciocalteu reagent, with Singleton & Rossi (1965) methods, described by Haminiuk et al. (2011), using gallic acid as standard. First, the dried samples (0.4 g) were submitted to a solvent extraction, with an ethanol 40% solution for 1 hour with agitation in a stirring table (120 bpm). The extraction for each sample was performed in triplicate. The samples were centrifuged at 1535g for 30 minutes and the supernatant was filtered with filter paper Whatman n°1. 100µL of the extract and 5mL of distilled water were pipetted. 500µL of Folin-Ciocalteu reagent was added to the extract and water. After three minutes, 1.5 mL of saturated sodium carbonate solution (15%) was added to the mixture. The final volume was completed to 10mL. After two hours, the absorbance was measured in a spectrophotometer (Beckman DU70), at 765 nm.

2.8 Color evaluation

Color evaluation was carried out using a colorimeter (Mini Scan XE Hunter Associates Laboratory, Inc, Reston, Virginia, USA), calibrated against white pattern (x=80.3; y=85.1, z=91.0), in triplicate. Color values were expressed in terms of L*, a* and b* (CIElab). In order to compare the samples, the following parameters were calculated: a/b ratio and total color difference (ΔE) (Equation 9).

$$\Delta E = \sqrt{(L^* - L_0^*)^2 + (a^* - a_0^*)^2 + (b^* - b_0^*)^2} \quad (9)$$

L^*_0, a^*_0 and b^*_0 are the color values for the powder control sample (freeze dried). According to total color difference, the product can be classified as very distinct (ΔE higher than 3), distinct (ΔE between 1.5 and 3) and small difference (ΔE lower than 1.5) [22].

2.9 Statistical analysis

Color and total phenolic content results were analyzed by ANOVA test and Tukey's test ($p<0.05$). Nonlinear regression of the drying curves was performed using MATLAB R2016a software (The Mathworks, Inc, Natick, USA).

3 Results and Discussion

3.1 Drying curves analysis

Cambuci by-product drying data (in terms of MR versus time) is shown in Figure 1, presenting all different studied drying conditions. As expected, the drying times were higher for the lower temperatures assays [11,23]. The drying times of all experiments were (in hours): 24 (40NC), 11 (40C), 9.5 (60NC), 5 (60C), 6.75 (80NC) and 3.75 (80C). After analyzing the results, it was possible to note great influence of centrifugation pretreatment in reducing the drying time. Comparing the centrifuged to the non-centrifuged assays at same temperatures, the reductions in the drying time were 54% (40 °C), 47% (60 °C) and 44% (80 °C). The previous centrifugation process was an attempt to try reducing the exposure of the residue to the drying temperatures and preserving better its quality.

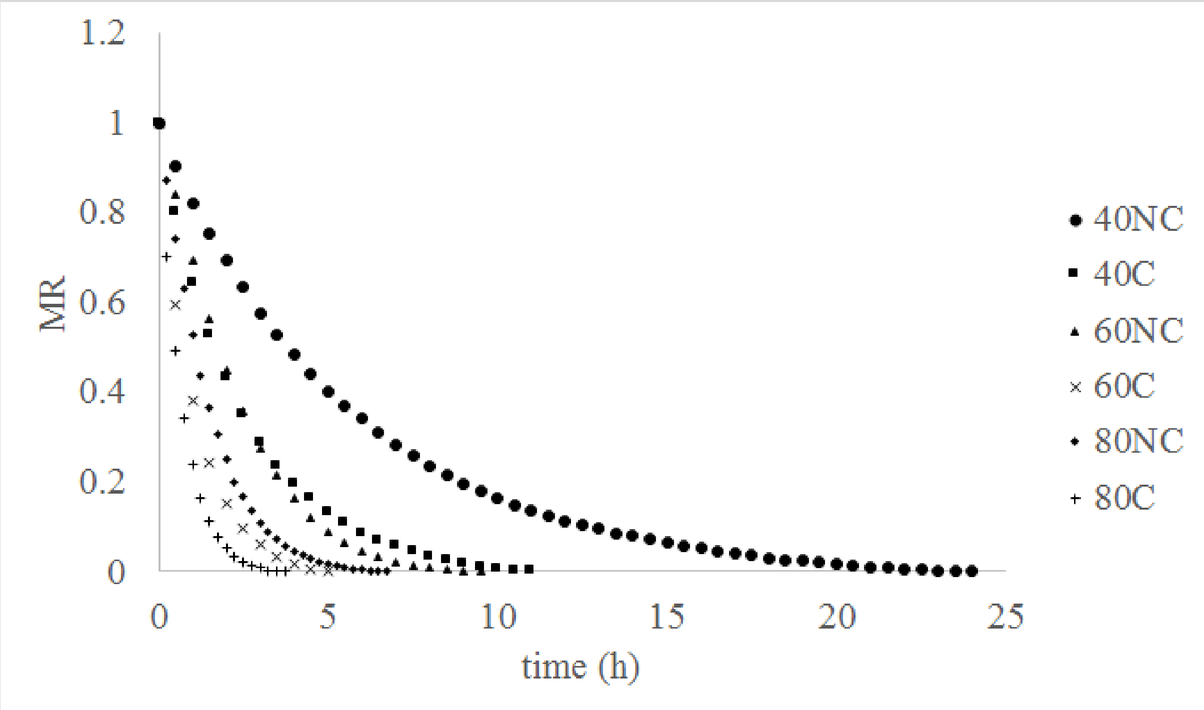

Fig. 1 Cambuci by-product drying curves.

Initial (after centrifugation in previously centrifuged assays) and final mean moistures (kg/kg dry basis), respectively: 3.7 and 0.08 (40NC), 1.8 and 0.09 (40C), 4.0 and 0.08 (60NC), 1.8 and 0.06 (60C), 3.8 and 0.06 (80NC) and 1.9 and 0.05 (80C).

3.2 Drying rate

Figure 2 presents the data of drying rate (in grams of water/g dry matter/ min) versus moisture ratio. In all studied conditions, there is a tendency of reduction of the drying rate during the process. Comparing the studied temperatures, higher temperatures resulted in increased drying rates. While comparing the centrifugation treatment in the same temperature, for all temperatures the centrifuged assay resulted in higher drying rates. The drying rate is not constant and decreases as long as the product is dried. The same behavior was observed by other authors during drying of fruit by-products [11,24].

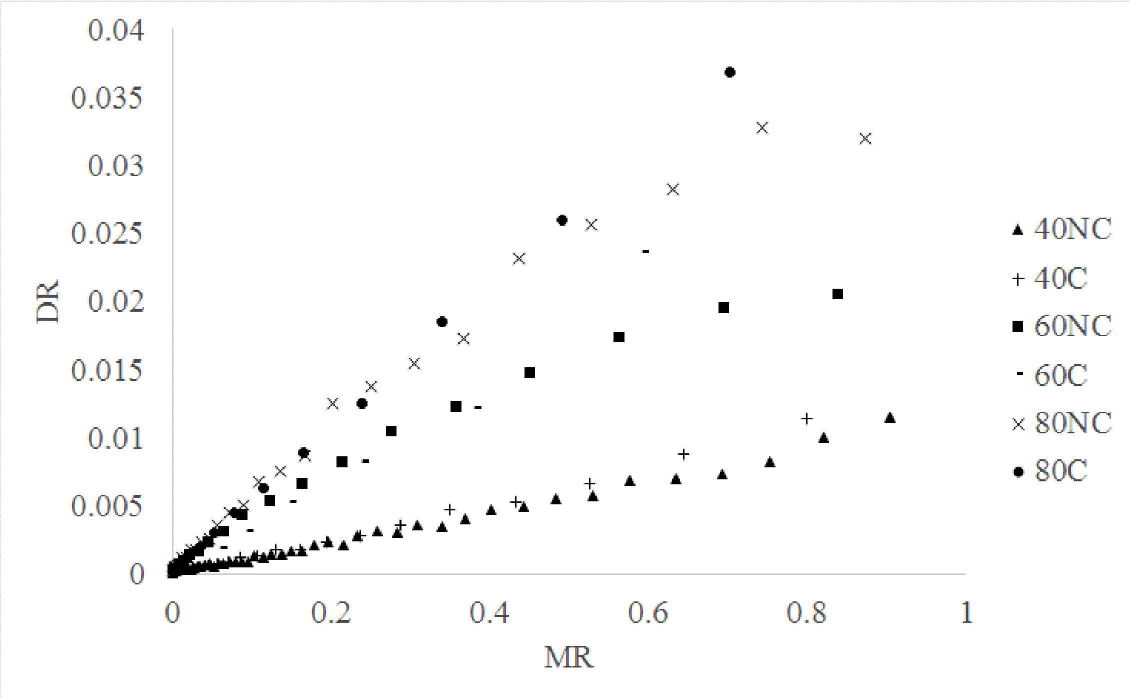

Fig. 2 Drying rate (DR) versus MR for cambuci by-product drying at different conditions.

3.3 Curve fitting

For all assays, MR data was fitted to eight different models (Table 1). Table 2 shows the parameters of the mathematical models applied to the cambuci residue drying data and the results of R^2, RMSE e χ^2. To select the model that best fitted the drying data, higher R^2 values and lower RMSE and χ^2 values were evaluated [25]. R^2, RMSE and χ^2 values ranged, respectively, from 0.9144 to 1.0000, 0.0008 to 0.08886 and 0.000001 to 0.007897. The model that best fitted the drying curve was Midilli. The other models also gave good fits to the curves. Wang and Singh was the model among the tested models that gave the worst fit. Other studies also found Midilli to be a good mathematical model to describe the vegetable products drying curves [26–28]. Figure 3 shows predicted by Midilli model and real MR values versus time. It is possible to observe a huge similarity between predicted and real curves.

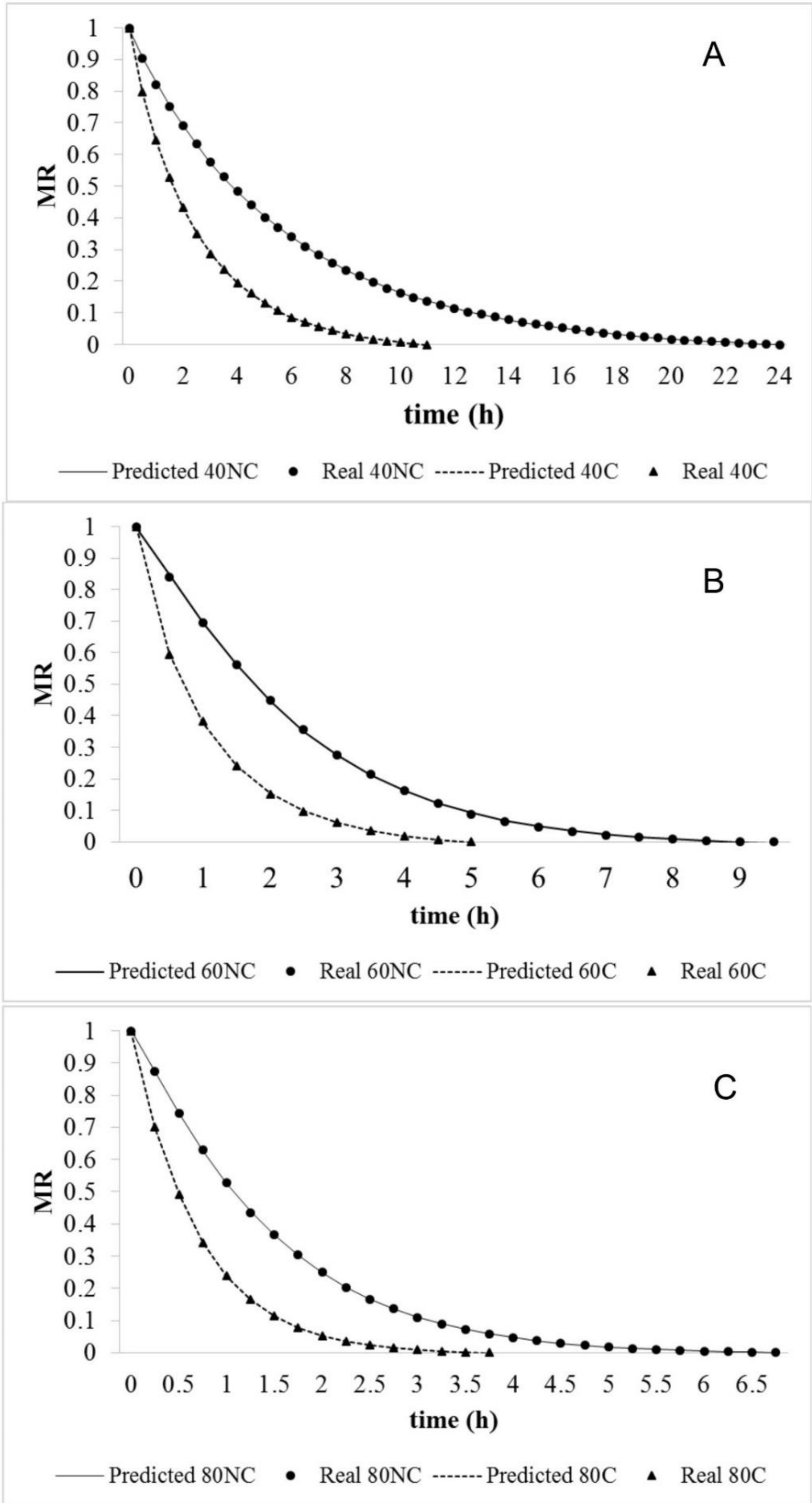

Fig. 3 Predicted (Midilli) and real MR versus time. (A) 40 °C assays; (B) 60 °C assays; (C) 80 °C assays.

TABLE 2. Cambuci by-product drying mathematical models parameters

Model	Condition	Constants			R^2	RMSE	χ^2
		A	k				
Henderson and Pabis	40NC	0.9950	0.182		0.9995	0.0061	0.000046
	40C	0.9894	0.414		0.9995	0.0067	0.000044
	60NC	1.0420	0.449		0.9947	0.0230	0.000529
	60C	0.9918	0.960		0.9992	0.0091	0.000083
	80NC	1.0380	0.714		0.9976	0.0143	0.000203
	80C	1.0040	1.45		0.9998	0.0039	0.000015
		k					
Lewis	40NC	0.183			0.9995	0.0062	0.000047
	40C	0.418			0.9993	0.0072	0.000051
	60NC	0.432			0.9929	0.0258	0.000667
	60C	0.967			0.9992	0.0091	0.000083
	80NC	0.690			0.9963	0.0174	0.000303
	80C	1.441			0.9998	0.0039	0.000015
		a	K	C			
Logarithmic	40NC	0.9991	0.175	-0.0116	0.9999	0.0032	0.000012
	40C	0.9918	0.406	-0.0054	0.9995	0.0063	0.000039
	60NC	1.0660	0.399	-0.0412	0.9982	0.0136	0.000184
	60C	0.9929	0.954	-0.0017	0.9993	0.0096	0.000092

	80NC	1.0470	0.670	-0.0204		0.9989	0.0098	0.000095
	80C	1.0070	1.47	-0.0062		1.0000	0.0009	0.000001
		a	k	B	n			
Midilli	40NC	0.9973	0.187	-0.0007	0.9724	1.0000	0.0016	0.000003
	40C	1.0010	0.436	-0.0015	0.9409	1.0000	0.0016	0.000002
	60NC	0.9946	0.355	-0.0013	1.1630	0.9999	0.0040	0.000016
	60C	0.9994	0.967	-0.0033	0.9200	0.9999	0.0035	0.000012
	80NC	0.9994	0.638	-0.0007	1.1190	1.0000	0.0016	0.000003
	80C	0.9999	1.43	-0.0015	1.0100	1.0000	0.0008	0.000001
		a	K	N				
Modified page	40NC	0.9939	0.134	1.3590		0.9995	0.0062	0.000047
	40C	0.9894	0.626	0.6610		0.9995	0.0068	0.000047
	60NC	1.0420	0.700	0.6409		0.9947	0.0237	0.000560
	60C	0.9918	0.961	0.9991		0.9992	0.0097	0.000093
	80NC	1.0370	1.78	0.3973		0.9976	0.0146	0.000212
	80C	1.0040	1.24	1.1650		0.9998	0.0040	0.000016
		k	n					
Page	40NC	0.182	1.0020			0.9995	0.0062	0.000048
	40C	0.430	0.9751			0.9995	0.0063	0.000040
	60NC	0.356	1.1810			0.9995	0.0068	0.000046
	60C	0.980	0.9573			0.9995	0.0073	0.000054

	80NC	0.639	1.1290	0.9999	0.0026	0.000007
	80C	1.44	1.0220	0.9999	0.0028	0.000008
		a	B			
Wang and Singh	40NC	-0.1164	0.0033	0.9429	0.0642	0.005103
	40C	-0.2577	0.0161	0.9324	0.0741	0.005485
	60NC	-0.2850	0.0198	0.9819	0.0423	0.001791
	60C	-0.5719	0.0781	0.9335	0.0855	0.007303
	80NC	-0.4288	0.0440	0.9571	0.0608	0.003696
	80C	-0.8092	0.1532	0.9144	0.0889	0.007897
		a	b			
Weibull	40NC	1.0020	5.4810	0.9995	0.0062	0.000048
	40C	0.9751	2.3770	0.9995	0.0063	0.000040
	60NC	1.1810	2.3940	0.9995	0.0068	0.000044
	60C	0.9573	1.0220	0.9995	0.0073	0.000054
	80NC	1.1290	1.4870	0.9999	0.0026	0.000007
	80C	1.0220	0.6978	0.9999	0.0028	0.000008

3.4 Effective diffusivity and activation energy

Equations 4 and 5 were used to determine effective diffusivity values. As shown in Figure 4, when comparing same treatments (with or without prior centrifugation), the effective diffusivity was higher for higher temperature assays. For all temperatures, the prior centrifugation led to an increase on effective moisture diffusivity.

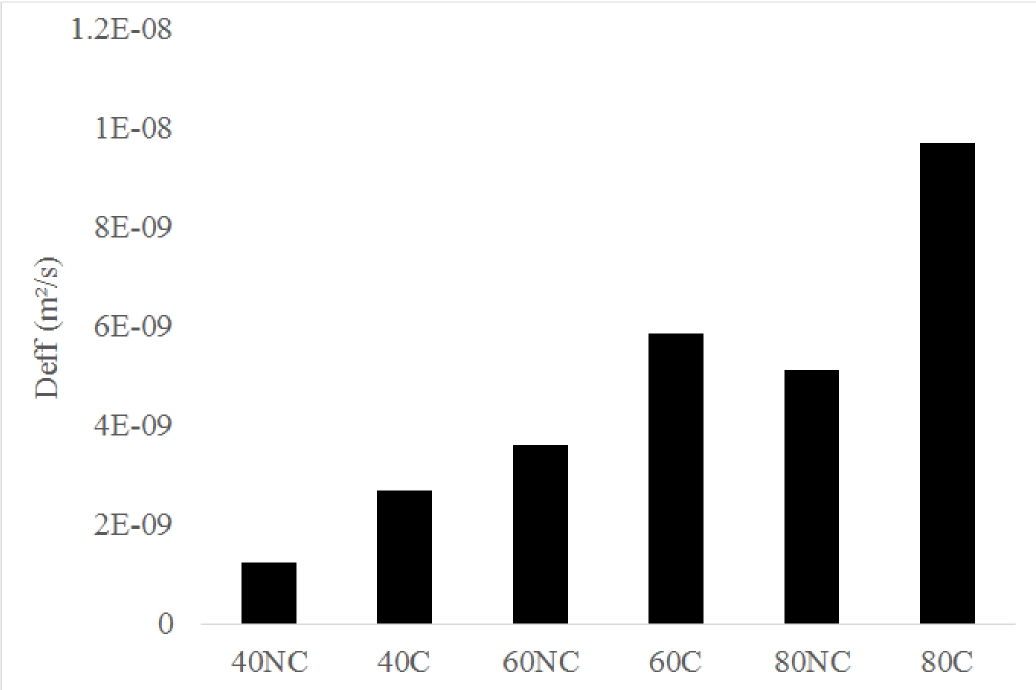

Fig. 4 Effective moisture diffusivity

The effective moisture diffusivity ranged from 2.46 x 10^{-9} to 9.70 x 10^{-9} m^2/s to 40NC and 80C assays, respectively. This values are comparable to the values of effective moisture diffusivity of vegetable by-products found by other authors: 2.03 x 10^{-9} to 1.71 x $10^{-9}$$m^2/s$ for olive waste [20], 1.73 × 10^{-10} to 4.40 × 10^{-10} m^2/s for apple pomace [10] and 1.22 to 4.29 x 10^{-10} m^2/s for pomegranate by-product [11]. Also, they are according to the values expected for food and agricultural products: from 10^{-12} to 10^{-8} m^2/s [10]. Some parameters like drying equipment, product's structure and shape, initial moisture content and drying conditions can influence in effective moisture diffusivity values [9].

Equation 6 was used to calculate the activation energy, which was 32.8 kJ/mol for the non-centrifuged assays and 29.6 kJ/mol for the centrifuged assays. These values are comparable to other values found in literature for vegetable by-products: 29.65 kJ/mol for apple pomace [10] and 29.571 and 34.726 kJ/mol for passion fruit peel [24].

3.5 Total phenolic content (TPC)

In order to evaluate the effect of drying treatment on the quantity of phenolic compounds and on the color quality of the by-product, a cambuci freeze dried by-product sample was used as control.

The results of total phenolic compounds are shown in Figure 5. Comparing the six hot air drying assays, total phenolic contents ranged between 36.44 (60NC) to 47.50 (80C) mg of gallic acid equivalent per g of dry matter (mg GAE/g). Comparing the dried assays to the control sample, there was a reduction of 24.9 to 42.4% in total phenolic compounds.

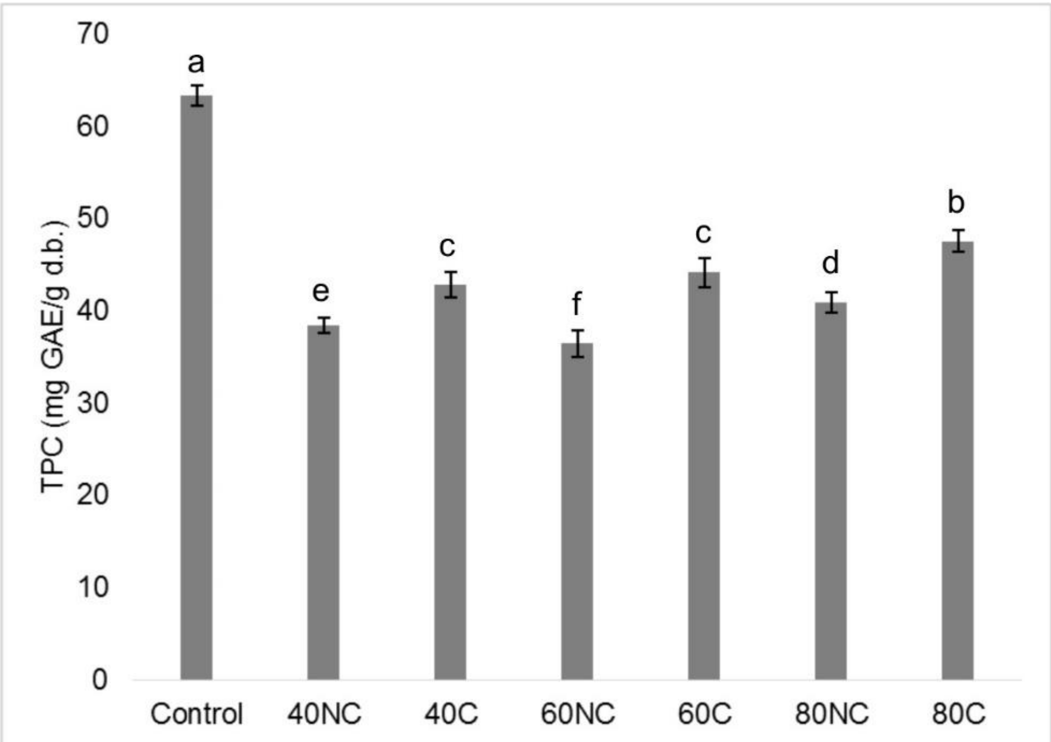

Fig. 5 Cambuci dried by-product total phenolic content.

Results with same letters indicate no significant statistical difference ($p \leq 0.05$). The maximum coefficient of variance was 3.9%.

For all temperatures, it was possible to note that centrifuged assays, when comparing same temperatures, presented statistically different and higher values than non-centrifuged assays. For example, at 80 °C, assay 80C presented a TPC value 15.7% higher than 80NC.

80C showed the highest phenolic compounds content. Although it was the highest temperature that was used, the drying time was shorter. It has been described by other authors that the quality of dried product depends both of the temperature and time parameters and that longer drying times can result in a higher bioactive compounds loss.

Mrad & Boudhrioua (2012) observed a 3% loss of phenolic content of pear slices dried for 2 hours at 70 °C against a 30% loss of total phenolic content of pear slices dried for 10 hours at 30 °C. Ghanem Romdhane, Bonazzi, Kechaou, & Mihoubi, (2015) observed higher loss of phenolic compounds of lemon by-product that was dried at a low temperature (40 °C) for longer times.

It was not found any work in literature that evaluated cambuci in the by-product form. Some authors evaluated the pulp and the fruit. Haminiuk et al. (2011) obtained the following results for cambuci pulp evaluation: 107.69 mg GAE per g (dry basis). De Souza Schmidt Gonçalves, Lajolo, & Genovese, (2010) evaluated cambuci fruit and found about 27 mg catechin equivalent/g of dry fruit. Genovese, Da Silva Pinto, De Souza Schmidt Goncalves & Lajolo (2008) evaluated both cambuci pulp and fruit and found 246 mg GAE/100g fresh fruit weight and 176 mg GAE/100g fresh pulp weight.

3.6 Color evaluation

Color evaluation results of the six drying assays and the control are showed in Table 3.

Comparing the hot air dried samples to the control, it was possible to note a decrease of L^* and an increase of a^* and b^* values for all drying conditions. The decrease of L^* value represents an increase in the darkness of the dried sample. Comparing the drying conditions, all centrifuged assays lead to final products with higher luminosity values. I has been described in literature that high L^* values and low a^*/b^* values are desirable for dried products [18]. Among the dried samples, the centrifuged assays presented the highest L^* values and the lowest a/b.

Total color difference values varied between 21.1 and 28.4. Therefore, for all assays, the final dried products were classified as very distinct compared to the control. Considering the color variation of the final dried product, the best treatments were the centrifuged assays: 40C, 60C and 80C, which presented the lowest total color difference (ΔE). Some factors can be related to the color changes in dried products, as Maillard reaction, pigments degradation and oxidation reactions, such as oxidation of ascorbic acid [12].

TABLE 3. Cambuci dried by-product color parameters

Sample	L^*	a^*	b^*	ΔE^*	a^*/b^*
Control	74.8±0.2[a]	-2.05±0.02[g]	30.54±0.07[d]	-	-0.0700±0.0008[g]
40NC	51.8±0.7[c]	7.1±0.2[c]	35.6±0.3[b]	25.2±0.7[b]	0.200±0.003[c]
40C	55.3±0.6[b]	5.4±0.2[f]	35.7±0.2[b]	21.5±0.7[c]	0.152±0.005[f]
60NC	51.6±0.5[c]	7.7±0.1[b]	35.6±0.2[b]	25.6±0.5[b]	0.217±0.004[b]
60C	55.5±0.3[b]	6.41±0.07[d]	34.3±0.2[c]	21.4±0.3[c]	0.187±0.002[d]
80NC	49.5±0.4[d]	9.5±0.1[a]	36.2±0.3[a]	28.4±0.4[a]	0.263±0.006[a]
80C	56.0±0.5[b]	5.9±0.1[e]	35.8±0.3[ab]	21.1±0.4[c]	0.164±0.002[e]

*Different letters in the same column indicate significant statistical difference ($p \leq 0.05$)

4 Conclusions

Drying kinetics of cambuci by-product was studied for three different temperatures (40, 60 and 80 °C) with two pretreatments (with and without centrifugation). Higher temperatures resulted in lower drying times. Prior centrifugation helped reducing drying time. Among the eight tested models, Midilli was evaluated as the best model to fit cambuci drying curves. Effective moisture diffusivity values ranged between 2.46 x 10^{-9} to 9.70 x 10^{-9} m^2/s and activation energy was 32.8 kJ/mol and 29.6 kJ/mol for non-centrifuged and centrifuged assays, respectively. Centrifuged assays, when comparing same temperatures, presented higher values for total phenolic content than non-centrifuged assays. 80C was the recommended condition for the highest TPC. All dried conditions resulted in products with high total color difference, being considered very distinct to the control sample. Among the assays, the centrifuged conditions preserved better the product's color.

Acknowledgments

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CAPÍTULO 3

Grumixama (*Eugenia brasiliensis Lam*) by-product drying: kinetics and effect on quality

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Este capítulo será submetido à revista Ciência e Tecnologia de Alimentos

Grumixama (*Eugenia brasiliensis Lam*) by-product drying: kinetics and effect on quality

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Abstract
Brazil has an enormous variety of fruits. Grumixama is a fruit native to Atlantic Forest. Fruit industries usually generate high amounts of solid by-product. The aim of the present work was to study the drying kinetics and the effect of the different drying conditions on the product quality. Samples were dried in conventional oven, in three temperatures: 40 °C, 60 °C and 80 °C. Moreover, two pre-treatments were considered: with and without previous centrifugation. Eight mathematical models usually applied to drying curves were used to fit to the experimental drying data. Midilli was the model that best fitted to the data. Activation energy was 26.4 kJ/mol to the non-centrifuged assays and 24.9 kJ/mol to the centrifuged assays. Effective moisture diffusivity varied 6.95 x 10^{-10} and 2.53 x 10^{-10} m²/s. There was a total color difference between 6.47 and 11.57 compared to the control and a total phenolic content reduction between 0.2 and 33.8%.
Keywords: food drying, fruits and vegetables, mathematical modeling; quality

1 Introduction

Grumixama is a fruit from *Myrtacea* family that can be found in the coastal Atlantic forest from the south of Bahia to Santa Catarina states, especially in the Southeast region of Brazil. This fruit is a globular berry type, that is sticky, viscous and dark purple colored. *Grumixama* tree blooms between the months of November and February. The pulp has a sweet and acid flavor, is very appreciated and used to produce frozen fruit pulp, syrups, liqueurs and jams. It is also a good source of bioactive compounds, such as anthocyanins, flavonols and ellagitannins, being potential functional foods. Although still unknown by part of the population, the commercial cultivation of *grumixama* trees started in recent years [1–3].

Fruit industries generally produce large amounts of by-products. Waste numbers can reach 70%. Fruit waste may also present compounds of interest to human nutrition. Therefore, given the growing concern about the environmental impacts of the food industry and high wastage rate of raw material and the pursuit of minimizing production costs, there is a great demand for viable alternatives for waste utilization for generating new products for human consumption. The solid waste generated by the fruit pulp industry usually consists of peels, bagasse and seeds and represents a major disposal problem for the industry. In many cases, these residues are simply disposed in landfills, are used as fertilizer or follow for the animal feed industry. However, as there may be compounds of interest in this waste, there is interest in applying these residues in processed foods intended for human consumption, modifying or enhancing the product’s flavor, texture, aroma, color and nutritional value [4–7].

One way to preserve the by-product for further use by other industries is to dry it. The preservation of fruit by drying processes is widely used in commercial vegetable products. Drying consists in water removal and consequently reduces the water activity, thereby preventing the growth of microorganisms, increasing its shelf life. Besides preserving the product, another advantage of the drying process is to reduce the space used for storage [7,8]. However, according to the type of drying and its parameters, it may be subject to losses of compounds of interest and nutritional value [9].

The aim of this research was to study the drying kinetics of *grumixama* by-product in convective hot-air dryer, verifying the effect of different drying conditions. In addition, this study intended to verify how well the drying data fitted to different drying models and to study the effect of the air-drying conditions on quality parameters of the final dried product, such as color and total phenolic content.

2 Materials and Methods

2.1 Material

The by-product that was used in the drying procedure was obtained after the pulp processing of *grumixama* fresh fruit. The pulp was processed in a native fruit processor, located in the state of São Paulo (Brazil), in the city of Paraibuna (23° 27`53.94" South, 45º 42`31.88 West). Fruits were harvested in November of 2013 and immediately processed in a pulper with nylon scraper blades (Tortugan, No. 56,032, MS25 model). The solid part of the fruit that was not part of the processed pulp was considered the by-product, composed by peels, bagasse and seeds. The by-product samples were stored at -18 °C until used.

2.2 Drying experiment

The by-product samples were dried in a convective cabin dryer, with the dimensions: 80 cm x 100 cm x 61 cm (Marconi MA035, Brazil), installed at the pilot plant of the Fruits and Vegetables Laboratory, at the Department of Food Technology of the State University of Campinas (Campinas, São Paulo, Brazil). The air-drying velocity of 0.4 m/s was measured with an anemometer (Lutron – AM 4202, Taiwan). Three drying temperatures were tested: 40, 60 and 80 °C. Each assay only began after the dryer reached steady-state conditions (minimum of 30 minutes).

In addition, there were two types of treatments before drying: with and without prior centrifugation. For the samples with prior centrifugation, that presented the objective to eliminate part of the water of the by-product before drying, 1kg of the by-product was centrifuged (Mueller Eletrodomésticos S.A, Brazil) at 1036 x g for 5 minutes and then dried. For the samples without prior centrifugation, 1 kg by-product sample was directly dried. According to the prior treatment and the drying temperature, the assays were named as: 40NC, 60NC and 80NC (40 °C, 60 °C and 80 °C, respectively, without prior centrifugation) and 40C, 60C and 80C (40 °C, 60 °C and 80 °C, respectively, with prior centrifugation). The samples were dried in a thin layer (about 0.8 cm) in a perforated tray with mesh of 0.3 cm x 0.3 cm. To acquire the drying data, the tray with the sample was weighted every 15 minutes for the 80 °C assays and every 30 minutes for the 40 and 60 °C assays, until steady state conditions were achieved. All assays were performed in triplicate and the average values were used to calculate the drying curves. The dried residues were milled (Tecnal TE 631/2, Brazil), heat-sealed and stored in vacuum metalized bags (Metalized polyethylene terephthalate 17g/m² + white polystyrene 100 g/m²).

In order to compare both total phenolic content and color parameters, a freeze dried control sample was produced. *Grumixama* by-product was dried in a freeze dryer (Christ, Alpha 2-4 LD plus model). The frozen samples were freeze dried under the following conditions (in dark): 44 hours, 0.12 mbar, T=- 40 ºC (main drying) and 4 hours, 2.5 mbar, T= -10 ºC (final drying).

2.3 Curve fitting

With the data obtained in the drying experiments, the drying curves were constructed in terms of moisture ratio (MR) versus time (in hours). To calculate MR values, Equation 1 was used, where M_t, M_e e M_0 correspond to the moisture contents at the time of weighting (t), at equilibrium and at the beginning of the assay, respectively.

$$MR = \frac{M_t - M_e}{M_0 - M_e} \quad (1)$$

In addition, the drying rate (DR) of *grumixama* by-product was calculated using Equation 2. The results were expressed in kg water/(kg dry matter*min).

$$DR = \frac{M_{n+1} - M_n}{t_{n+1} - t_n} \quad (2)$$

t_{n+1} and t_n are the drying times and M_{n+1} and M_n are the moisture contents at the time of weighting.

To fit the curves, eight different models were tested: Henderson and Pabis [10,11], Lewis [12], Logarithmic [13,14], Midilli [15], Modified Page [16], Page [17,18], Wang and Singh [19,20] and Weibull [21]. Table 1 shows the mathematical equations that were used in the curve fitting.

Table 1. Mathematical models

Model	Equation
Henderson and Pabis	$MR = \mathrm{a}\exp(-kt)$
Lewis	$MR = \exp(-kt)$
Logarithmic	$MR = a\ \exp(-kt) + c$
Midilli	$MR = a\ \exp(-kt^n) + bt$
Modified page	$MR = a\ \exp(-kt)^n$
Page	$MR = \exp(-kt^n)$
Wang and Singh	$MR = 1 + at + bt^2$
Weibull	$MR = \exp\left(-\left(\frac{t}{b}\right)^a\right)$

With the aim of verifying which mathematical model best fitted the drying curves, R^2 (coefficient of determination), RMSE (root mean square error) and χ^2 (reduced chi-square) were calculate. These parameters have been used by other authors to evaluate the goodness of the drying curve fit. Higher values of R^2 and lower values of RMSE and χ^2 are considered a good adjustment [22–25].

Equations 3 and 4 present RMSE and χ^2 formula, respectively.

$$RMSE = \left[\frac{1}{N}\sum^{N}\left(MR_{pre,i} - MR_{exp,i}\right)^2\right]^{1/2} \quad (3)$$

$$\chi^2 = \frac{\sum_{i=1}^{N}(MR_{pre,i} - MR_{exp,i})^2}{N-z} \quad (4)$$

2.4 Determination of effective moisture diffusivity and activation energy

One common way to calculate effective moisture diffusivity (D_{eff}) parameter is using Fick's second diffusion law, considering three axis: x, y and z. (Equation 5) [21,26].

$$\frac{\partial M}{\partial t} = \frac{\partial}{\partial x}\left(D_{eff}\frac{\partial M}{\partial x}\right) + \frac{\partial}{\partial y}\left(D_{eff}\frac{\partial M}{\partial y}\right) + \frac{\partial}{\partial z}\left(D_{eff}\frac{\partial M}{\partial z}\right) \quad (5)$$

If the thin layer of by-product in the tray is considered an infinite slab, just the z axis can be used. So, Equation 5 can be solved and the solution is presented at equation 6, considering uniform initial moisture distribution, negligible shrinkage, constant moisture diffusivity and sample surface in equilibrium with the environment [27]. In addition, the equation may be simplified for long drying periods (Equation 7). L is half the thickness (m) of the slab.

$$\mathrm{MR} = \frac{8}{\pi^2}\sum_{i=0}^{\infty}\frac{1}{(2i+1)^2}\exp\left[\frac{-(2i+1)^2\, D_{eff}\pi^2 t}{4L^2}\right] \quad (t=0,\ M_0=M_t)(6)$$

$$\mathrm{MR} = \frac{8}{\pi^2} exp\left[\frac{-D_{eff}\pi^2 t}{4L^2}\right] \qquad (7)$$

The slope of the plot of lnMR versus time was calculated to obtain D_{eff} values for each assay (Equation 8).

$$\ln MR = \ln\left(\frac{8}{\pi^2}\right) - \left(\frac{\pi^2 D_{eff} t}{4L^2}\right) \qquad (8)$$

The activation energy can be calculated with Arrhenius equation, which presents the relationship between the effective moisture diffusivity and the temperature

$$D_{eff} = D_o \exp\left(-\frac{E_a}{RT}\right) \qquad (9)$$

D_o is the Arrhenius factor (m^2/s), E_a is the activation energy (kJ/mol) and R is the gas constant (8.314 J/mol.K). From the slope and the interception of the plot of ln D_{eff} versus 1/T, it was possible to obtain E_a and D_o, respectively. The activation energy was calculated separately for the centrifuged assays (40C, 60C and 80C) and non-centrifuged assays (40NC, 60NC and 80NC).

2.5 Color measurement

In order to evaluate the color of the dried samples, a colorimeter (Mini Scan XE Hunter Associates Laboratory, Inc, Reston, Virginia, USA) calibrated against white pattern (x=80.3; y=85.1, z=91.0) was used. Measures were made in triplicate. Color results are shown in the CIElab system. L^* measures the lightness/darkness, a^* measures the redness/greenness and b^* measures the yellowness/blueness of the sample.

Furthermore, total color difference (ΔE) parameter was calculated with the color results:

$$\Delta E = \sqrt{(L^* - L_0^*)^2 + (a^* - a_0^*)^2 + (b^* - b_0^*)^2} \qquad (10)$$

L^*, a^* and b^* are the color values of each sample and L^*_0, a^*_0 and b^*_0 are the color values of the powder control sample.

Some authors use the total color difference parameter in order to verify the degree of difference compared to the control. If ΔE is higher than 3, the sample is considered very distinct. If ΔE is between 1.5 and 3, the sample is considered distinct and if ΔE is lower than 1.5, a small difference is observed [28–30].

2.6 Total phenolic content

Folin-Ciocalteu reagent was used to evaluate total phenolic content, using Singleton & Rossi methods, described by Haminiuk et al. [31]. First, the extracts were obtained. The dried samples (0.2 g) were extracted with 40mL of a 40% ethanol solution for 1 hour with agitation in a stirring table (120 bpm). The extracts were centrifuged at 1535 x g for 30 minutes and the supernatant was filtered with filter paper Whatman n°1. The extraction for each sample was performed in triplicate.

100µL of the extract and 5mL of distilled water were pipetted. 500µL of Folin-Ciocalteu reagent was added to the extract and water. After three minutes, 1.5 mL of saturated sodium carbonate solution (15%) was added to the mixture. The final volume was completed to 10 mL. After two hours of reaction, the absorbance was measured in a spectrophotometer (Beckman DU70, Germany) at 765 nm. Gallic acid was used as standard and the results were expressed in mg Gallic Acid Equivalents/g db (mg GAE/g db).

2.7 Statistical analysis

Statistical analysis was performed by ANOVA test and Tukey's test ($p<0.05$). Nonlinear regression of the drying curves was performed using MATLAB R2016a software (The Mathworks, Inc, Natick, USA).

3 Results and Discussion

3.1 Drying curves

The drying curves of all studied assays are presented in Figure 1A in terms of MR versus time (in hours). According to Figure 1A, drying times ranged from 4.25h (80C) to 14.5h (40NC). It was possible to note that the previous centrifugation, as expected, resulted in a reduction in the drying time, when comparing same temperature assays. At 40 °C, there was a difference of 3.5h between the centrifuged and non-centrifuged assays, which represents 24%. Comparing the two other temperatures, the differences were: 2.5h (31%) at 60 °C and 0.75h (15%) at 80 °C. The previous centrifugation brought interesting results. For example, the assay at 60 °C with prior centrifugation presented a drying time really close to the assay at 80 °C without prior centrifugation.

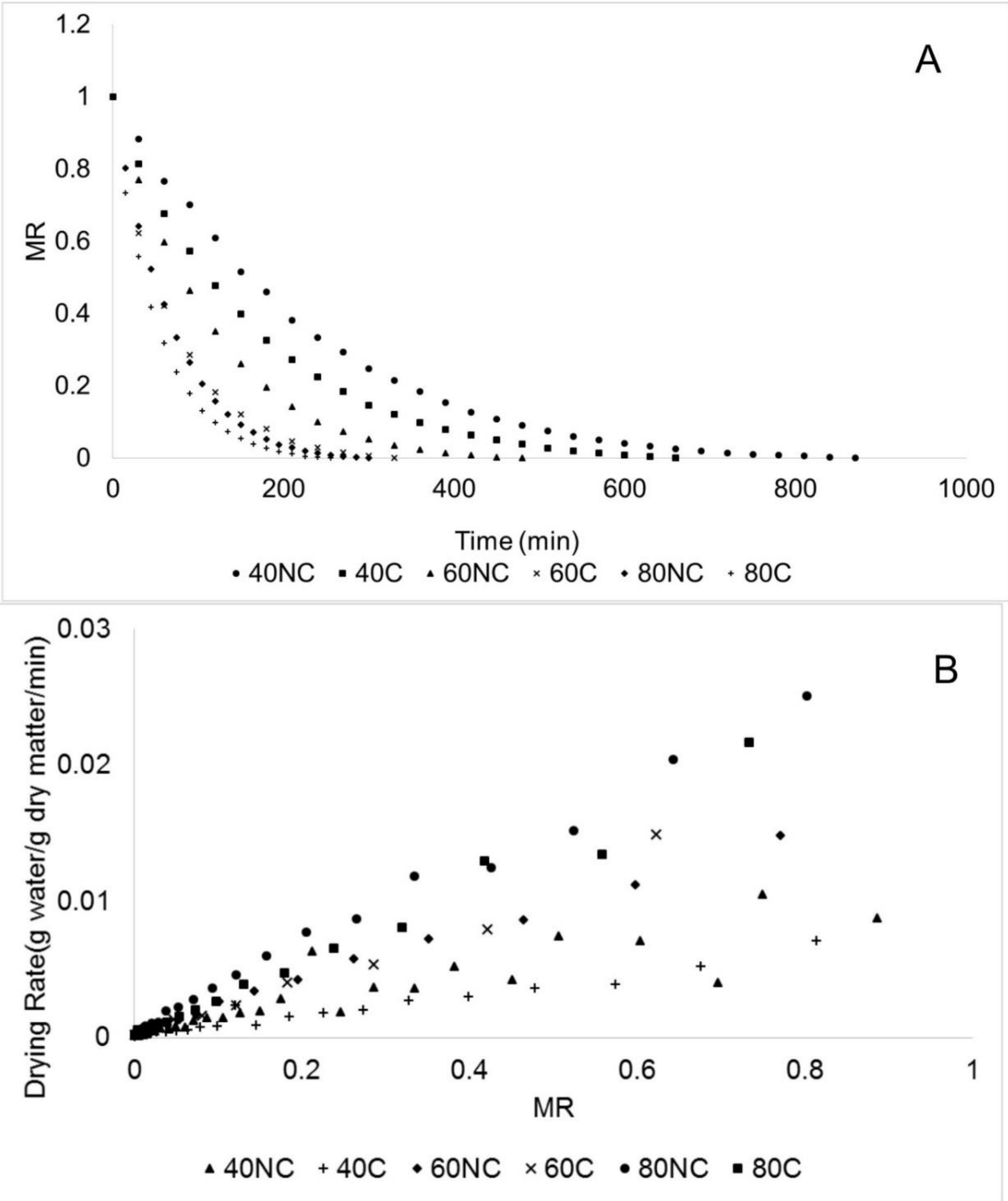

Figure 1. (A) Drying curves of grumixama by-products at different conditions. (B) Drying rate curves of grumixama by-product at different conditions.

Initial (after centrifugation in previously centrifuged assays) and final mean moistures (kg/kg dry basis), respectively: 2.4 and 0.08 (40NC), 1.2 and 0.08 (40C), 2.0 and 0.04 (60NC), 1.2 and 0.04 (60C), 1.9 and 0.02 (80NC) and 1.2 and 0.01 (80C).

Moisture content of the by-products decreased with time in dryings procedures. It was possible to note that the drying temperature exerted influence in the drying time. Higher temperatures resulted in lower drying times. Other authors have previously reported the same tendency [10,32–34]. For centrifuged assays, the drying time difference between 40 °C and 80 °C assay was 61%. The same comparison for the non-centrifuged assays resulted in a difference of 66%.

The drying rate of the assays versus the moisture ratio is presented in Figure 1B. The drying process of *grumixama* by-product took place in the falling rate period, with decreasing drying rates with decreasing moisture contents, and constant rate period is not observed. Comparing the temperatures, higher temperature assays presented higher rates of moisture loss when compared to the lower temperature assays. Other authors that evaluated vegetable by-products drying also observed the same tendency [12,35,36].

3.2 Curve fitting

Table 2 shows all the constants and statistical parameters (R^2, RMSE and χ^2). R^2 values ranged between 0.9272 and 0.9999, RMSE ranged between 0.00268 and 0.08202 and χ^2 ranged between 0.00001 and 0.00673. There was a good adjustment of the drying data to all the drying mathematical models. So, the models in the study can be used to describe the drying kinetics of *grumixama* by-product. Considering high R^2 and low RMSE and χ^2 values, the model that best fitted *grumixama* drying curves was Midilli. For Midilli model R^2, RMSE and χ^2 ranged from 0.9994 to 0.9999, 0.00268 to 0.00764 and 0.00001 to 0.00006. Wang and Singh was the model that gave the worst fit to the curves. The coefficients of determination of Midilli model were really close to 1. Figure 2 shows that the predicted by Midilli and real drying curves are similar to each other.

Table 2. Statistics and constants of the models at the six different drying conditions

Model	Condition	Constants			R^2	RMSE	χ^2
		A	k				
Henderson and Pabis	40NC	1.028	0.291		0.9968	0.01669	0.00031
	40C	0.9996	0.380		0.9988	0.01025	0.00011
	60NC	1.014	0.550		0.9983	0.01300	0.00017
	60C	0.9902	0.858		0.9990	0.00998	0.00010
	80NC	1.012	0.915		0.9984	0.01182	0.00014
	80C	0.9952	1.16		0.9996	0.00558	0.00003
		k					
Lewis	40NC	0.283			0.9960	0.01829	0.00038
	40C	0.380			0.9988	0.01001	0.00010
	60NC	0.542			0.9980	0.01336	0.00018
	60C	0.866			0.9989	0.01005	0.00010
	80NC	0.905			0.9983	0.01208	0.00015
	80C	1.17			0.9996	0.0056	0.00003
		a	k	c			
Logarithmic	40NC	1.044	0.264	-0.0321	0.9990	0.00925	0.00010
	40C	1.01	0.356	-0.0207	0.9998	0.00468	0.00002
	60NC	1.028	0.510	-0.0245	0.9997	0.00536	0.00003
	60C	0.9925	0.847	-0.0038	0.9991	0.01028	0.00011

	80NC	1.023	0.857	-0.0211		0.9997	0.00550	0.00003
	80C	0.9986	1.13	-0.0068		0.9998	0.00426	0.00002
		A	K	B	N			
Midilli	40NC	0.9929	0.242	-0.0011	1.083	0.9994	0.00764	0.00006
	40C	0.9946	0.372	-0.0021	0.9836	0.9998	0.00457	0.00002
	60NC	0.9964	0.506	-0.0019	1.05	0.9998	0.00449	0.00002
	60C	0.9988	0.869	-0.0034	0.9196	0.9998	0.00510	0.00003
	80NC	0.9948	0.869	-0.0029	1.042	0.9997	0.00530	0.00003
	80C	0.9982	1.15	-0.0029	0.9699	0.9999	0.00268	0.00001
		a	k	N				
Modified page	40NC	1.028	0.530	0.5497		0.9968	0.01699	0.00032
	40C	0.9996	0.632	0.6017		0.9988	0.0105	0.00011
	60NC	1.014	0.585	0.94		0.9983	0.01346	0.00018
	60C	0.9902	0.927	0.9255		0.9990	0.01052	0.00011
	80NC	1.012	5.88	0.1556		0.9984	0.01215	0.00015
	80C	0.9952	0.479	2.421		0.9996	0.00576	0.00003
		k	N					
Page	40NC	0.241	1.108			0.9989	0.0099	0.00009
	40C	0.370	1.024			0.9989	0.00958	0.00009
	60NC	0.507	1.079			0.9994	0.00765	0.00006
	60C	0.880	0.96			0.9993	0.00874	0.00008

	80NC	0.885	1.066	0.9993	0.00796	0.00006
	80C	1.17	0.9936	0.9996	0.0057	0.00003
		A	B			
Wang and Singh	40NC	-0.1867	0.008533	0.9735	0.0478	0.00209
	40C	-0.2468	0.01493	0.9596	0.05872	0.00345
	60NC	-0.3458	0.02896	0.9654	0.05785	0.00335
	60C	-0.5179	0.06422	0.9356	0.08202	0.00673
	80NC	-0.5665	0.07722	0.9571	0.06184	0.00382
	80C	-0.6887	0.1129	0.9272	0.08001	0.00640
		A	B			
Weibull	40NC	1.108	3.61	0.9989	0.0099	0.00009
	40C	1.024	2.645	0.9989	0.00958	0.00009
	60NC	1.079	1.877	0.9994	0.00765	0.00006
	60C	0.9601	1.143	0.9993	0.00874	0.00008
	80NC	1.066	1.122	0.9993	0.00796	0.00006
	80C	0.9936	0.8572	0.9996	0.0057	0.00003

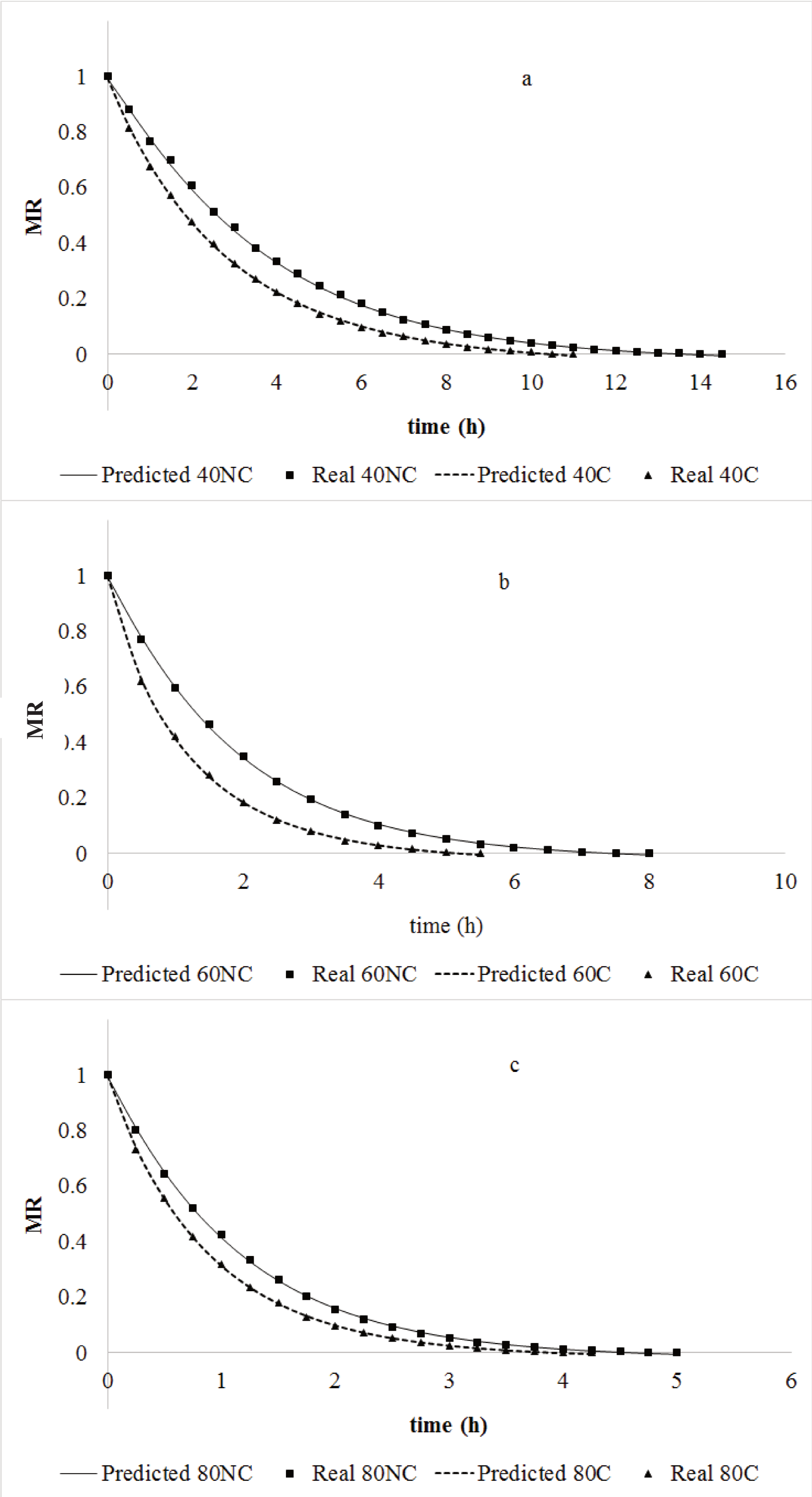

Figure 2. Predicted (Midilli) and real MR versus time. (a) 40 °C assays; (b) 60 °C assays; (c) 80 °C assays

3.3 Effective moisture diffusivity and Activation energy

Effective moisture diffusivity values (Deff) ranged between 6.95 x 10^{-10} (40NC) and 2.53 x 10^{-10} m^2/s (80C). Deff values were higher for higher temperature assays. The same tendency was verified by other authors when drying fruit by-products [12,37]. The other treatments presented the following results: 8.50 x 10^{-10} (40C), 1.32 x 10^{-9} (60NC), 1.72 x 10^{-9} (60C) and 2.19 x 10^{-9} m^2/s (80NC). The values obtained in the present study are according to the values that are generally expected for food and agricultural products: from 10^{-12} to 10^{-8} m^2/s [38,39]. In addition, the Deff results obtained in the present work can be compared to the results that were obtained by other authors that studied vegetables by-product drying: 1.73 × 10^{-10}– 4.40 × 10^{-10} m^2/s for apple pomace dried from 50-80 °C [37] and 1.22 × 10^{-10} m^2/s to 4.29 × 10^{-10} m^2/s for pomegranate by-product dried 50-80 °C [35], both in conventional drying.

Activation energy was calculated with Equation 9, by plotting In Deff values versus 1/T. The plot of the values gave a linear tendency. The correlation coefficients were 0.9986 for non-centrifuged assays and 0.9838 for centrifuged assays. The values obtained were 26.4 kJ/mol to the non-centrifuged assays and 24.9 kJ/mol to the centrifuged assays. The activation energy values found in this study for *grumixama* by-product are comparable to the values found by other authors that also studied vegetable products drying. They were higher than the values obtained to olive waste (17.97kJ/mol) and garlic slices (13.48–16.50 kJ/mol) [40,41] and lower than the values obtained to kiwi slices (34.337 and 38.073 kJ/mol) [42].

3.4 Color measurement

Color can often be considered a quality indicator, being used in optimization of drying conditions, for example [43]. Color parameters (L^*, a^*, b^*, ΔE and a^*/b^*) of *grumixama* by-product dried under different conditions are presented in Table 3.

Table 3. Color and total phenolic content results

	L^*	a^*	b^*	ΔE	a^*/b^*
Control	30.68 ± 0.09^{a}	21.7 ± 0.1^{a}	9.0 ± 0.5^{a}		2.4 ± 0.1^{cd}
40NC	24 ± 1^{d}	15.9 ± 0.5^{bc}	6.6 ± 0.5^{b}	9 ± 1^{b}	2.4 ± 0.2^{cd}
40C	26.8 ± 0.2^{b}	14.3 ± 0.2^{d}	6.2 ± 0.4^{b}	8.9 ± 0.1^{b}	2.3 ± 0.2^{d}
60NC	30 ± 1^{a}	16.1 ± 0.3^{b}	6.2 ± 0.2^{b}	6.5 ± 0.4^{c}	2.6 ± 0.1^{bc}
60C	27 ± 1^{b}	14.6 ± 0.2^{d}	5.2 ± 0.3^{d}	8.7 ± 0.5^{b}	2.8 ± 0.2^{a}
80NC	30.3 ± 0.6^{a}	15.6 ± 0.2^{c}	5.7 ± 0.3^{c}	7.1 ± 0.2^{c}	2.8 ± 0.1^{ab}
80C	25.1 ± 0.7^{c}	12.7 ± 0.1^{e}	4.5 ± 0.3^{e}	11.6 ± 0.3^{a}	2.8 ± 0.2^{ab}

Different letters in the same column indicate significant statistical difference ($p<0.05$).

For all treatments, total color difference ranged between 6.5 and 11.6, being considered very distinct. Higher total color difference occurred to 80C and lower total color difference was observed to 60NC drying treatment. Conventional drying procedure changed color parameters of *grumixama* by-product, when compared to control sample. For example, a* values of all treatments were different to the control, presenting lower values, which represents values less red than control. Maillard reaction and pigments degradation can be responsible for these color changes [43].

3.5 Total phenolic content

Freeze drying is a drying process that is known for maintaining the characteristics of the product close to fresh product. In this sense, a freeze dried *grumixama* by-product was used as control. Total phenolic content of dried *grumixama* by-product is presented in Figure 3 and was different for the different drying conditions. 40C did not present statistical difference ($p<0.05$) to the control. All treatments with prior centrifugation presented higher total phenolic content than the treatments without previous centrifugation. Analyzing the influence of the temperature on total phenolic content, higher temperatures led to dried products with lower total phenolic content. Comparing to the control sample, the dried *grumixama* residue presented the following total phenolic content reduction: 15.2% (40NC), 0.2% (40C, statistical equal to the control), 28.6% (60NC), 6.2% (60C), 33.8% (80NC) and 8.0% (80C). It is possible to note that higher temperature assays resulted in higher total phenolic content loss.

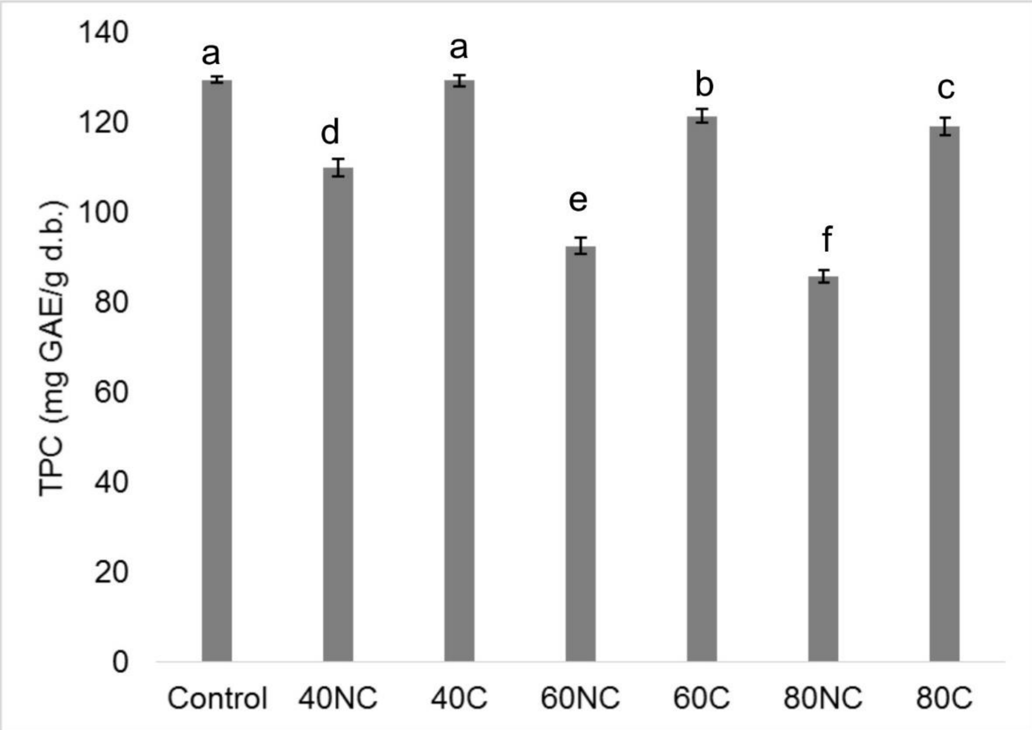

Figure 3. Total phenolic content of control by-product and dry samples. Results with same letters indicate no significant statistical difference (p≤0.05). The maximum coefficient of variation was 1.9%.

Comparing total phenolic content of same temperature assays to verify the influence of the prior centrifugation: 40NC was 15.1% lower than 40C, 60NC was 23.8% lower than 60C and 80NC was 28.0% lower than 80C. It was possible to note that the previous centrifugation of the sample was important in total phenolic content retention.

No other studies about total phenolic content in *grumixama* by-product were found. Haminiuk et al. (2011) studied *grumixama* pulp and verified a content of phenolic compounds of 25.98 mg GAE/g db. The dried by-product samples of the present study presented values 400% higher than the pulp evaluated by Haminiuk (2011).

4 Conclusion

In the present work, the influence of the temperature and the previous centrifugation in *grumixama* by-product conventional drying was studied. The previous centrifugation reduced the drying time up to 34%, considering same temperature assays. Midilli model was the one between the eight tested models that best fitted *grumixama* residue drying curves. The drying procedure occurred in the falling rate period. Drying rate and effective moisture diffusivity were higher for higher temperature assays. Activation energy was 26.4 kJ/mol to the non-centrifuged assays and 24.9 kJ/mol to the centrifuged assays. All assays were classified as very distinct according to total color difference value comparing to the freeze dried by-product. Total phenolic content losses were higher for higher temperatures and for non-centrifuged assays. According to TPC retention, 40C was consider the best condition.

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CAPÍTULO 4

Physical properties and antioxidant capacity of dried native Brazilian fruit by-product

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Physical and antioxidant properties of dried native Brazilian fruit by-product

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Abstract

Fruit pulp industries generate large amounts of solids by-products. The aim of the present study was to evaluate the effect of air drying conditions on physical characteristics and antioxidant capacity of three Brazilian native fruit by-products (uvaia, cambuci and grumixama). By-products received or not a centrifugation pre-treatment and then were dried at 40, 60 or 80 °C. Both physical parameters (water and oil holding capacity, swelling, solubility, hygroscopicity, apparent density, bulk density and specific volume) and antioxidant assays (ORAC, FRAP, ABTS, total phenolic content and total anthocyanins) varied for the different drying conditions. The by-products still presented nutritional compounds, such as dietary fiber, high total phenolic content and antioxidant activity. The assays with previous centrifugation step presented higher total phenolic content and antioxidant activity when compared to the assays where the product was directly dried. The main organic acids present in the three fruits were citric (grumixama and cambuci) and malic (uvaia). As expected, after drying, ascorbic acid was no longer present in the by-products.

Keywords: Fruit, by-product, waste, drying, antioxidant activity, phenolic content

1 Introduction

Brazil is a country with a great diversity of climate and soil, which allows the cultivation of a wide variety of fruits (Genovese et al. 2008, Rufino et al. 2010, Paz et al. 2015). The consumption of tropical and exotic fruits is growing worldwide with the recognition of its nutritional and therapeutic value. These fruits are increasingly present in national and international markets (Haminiuk et al. 2011, Paz et al. 2015). Uvaia, cambuci and grumixama are Brazilian native fruits from Atlantic Forest with great potential of exploitation.

The consumption of fruit is not only a matter of taste or personal preference, they come also making an appeal to health because they contain important nutrients to human nutrition (Haminiuk et al. 2011, Neves et al. 2015). In fruits, some components are involved in the prevention of degenerative diseases such as soluble and insoluble fiber, vitamin C, vitamin E, carotenoids, anthocyanins and other phenolic compounds (Haminiuk et al. 2011). In particular, some Brazilian native fruits have demonstrated *in vitro* high antioxidant capacity and a significant amount of flavonoids and vitamin C (Gonçalves et al. 2010).

Fruits are perishable foods, some of which can only last for a few days (Medeiros et al. 2006, Neves et al. 2015). Considering this and in order to try to minimize losses of fruit during the harvest, it is interesting to think about fruit processing forms, promoting its conservation. Among the types of fruit processing, one very common is the frozen fruit pulp. After processed and frozen, fruit pulp can be preserved for several months, allowing its consumption after the fruit's season and minimizing its discard. On the other hand, the frozen fruit pulp processing can generate a large amount of solid waste that often represents an environmental disposal problem or an operating cost for fruit processing companies (Lopez et al. 2000, Santo et al. 2012, O'Shea et al. 2015a).

Fruit wastes are usually composed by skins, bagasse and seeds and may still contain compounds of interest for human consumption, such as fiber and bioactive compounds. Furthermore, they can also contain interesting compounds for technological development of other food products such as coloured and savoury compounds. It is interesting to find ways to take advantage of these components, adding value to a by-product that often follows for simple disposal or are used as fertilizers (Schieber et al. 2001, Sousa et al. 2011, Ayala-Zavala et al. 2011, O'Shea et al. 2012, 2015a).

The solid waste generated in the processing of fruits still have very high moisture content, which makes them quite perishable. In order to increase the shelf life of the waste, an alternative is to dry it (Lopez et al. 2000). Food drying aims at removing a large amount of the water present in the product, promoting the reduction of water activity. Positively, drying can reduce microbial growth and enzyme activity. However, it can bring modifications in sensory characteristics such as colour and flavour, in its nutritional aspects and physical characteristics, due to the variation on its original structure. Thus, the drying parameters and drying equipment should be designed to reduce the losses described previously (Madamba et al. 1996, Miranda & Maureira 2009, Vega-Gálvez et al. 2012, Rodríguez et al. 2015, Botrel et al. 2016). Dried products have advantages such as requiring less storage and packaging room as well having longer shelf life (Rodríguez et al. 2015).

Therefore, the aim of the present work was to determine the effect of air-drying temperature and the pre-treatment of centrifugation on physical characteristics, antioxidant capacity and bioactive compounds of dried cambuci, uvaia and grumixama by-products.

2 Material and Methods

2.1 Material

Samples of three Atlantic Forest native fruits were studied: grumixama (*Eugenia brasiliensis Lam.*), uvaia (*Eugenia pyriformis*) and cambuci (*Campomanesia phaea*). Fruit, pulp and by-product fractions of the three fruits were obtained from Sitio do Bello, a pulp processor and supplier located in the city of Paraibuna, state of São Paulo, Brazil. The fruits were processed in a pulper with nylon scraper blades (Tortugan, No. 56,032, MS25 model), obtaining the pulp and the by-product. The samples were stored at -18 °C until used.

2.2 Methods

2.2.1 Obtaining the dry by-product

The by-products went through two different drying treatments: drying of wet waste and drying of waste with prior removal of water by centrifugation. The centrifugation occurred in a centrifuge (Mueller Eletrodomésticos SA) at 1036 g for 5 min. Three drying temperatures were used: 40, 60 and 80 °C. Therefore, for each fruit, six different treatments were studied: 40, 60 and 80 °C without prior centrifugation

(40NC, 60NC and 80NC) and 40, 60 and 80 °C with prior centrifugation (40C, 60C and 80C). One kilogram of the by-product was disposed in a thin layer in a perforated tray (mesh of 0.3 cm x 0.3 cm) and the drying procedure occurred in conventional oven (Marconi MA035, Brazil), at the Department of Food Technology, State University of Campinas, with the dimensions of 80 cm x 100 cm x 61 cm with air velocity of 0.4 m/s until constant weight. Grumixama and uvaia by-products had the seeds removed and discarded after the drying procedure. Then, the by-product was milled in a Tecnal ET 631/2 mill until size was lower than 0.25 mm. The dried powders were stored in vacuum packaging (Metalized polyethylene terephthalate 17g/m^2 + white polystyrene 100 g/m^2) at -18 ° C until use. Table 1 presents the drying times for each condition and for each fruit. Figure 1 presents fresh fruit, fresh pulp and fresh and dried by-product fractions.

Table 1. Time required for drying the waste of three Brazilian native fruit processing under different temperature conditions with and without centrifugation

Drying conditions	Time (min)		
(Temperature/Centrifugation)*	Uvaia	Cambuci	Grumixama
40C	840	660	660
40NC	1110	1440	870
60C	450	300	330
60NC	540	570	480
80C	315	225	255
80NC	405	405	300

40, 60 and 80 were the drying temperatures (in °C) and C is the centrifuged condition and NC is the non centrifuged.

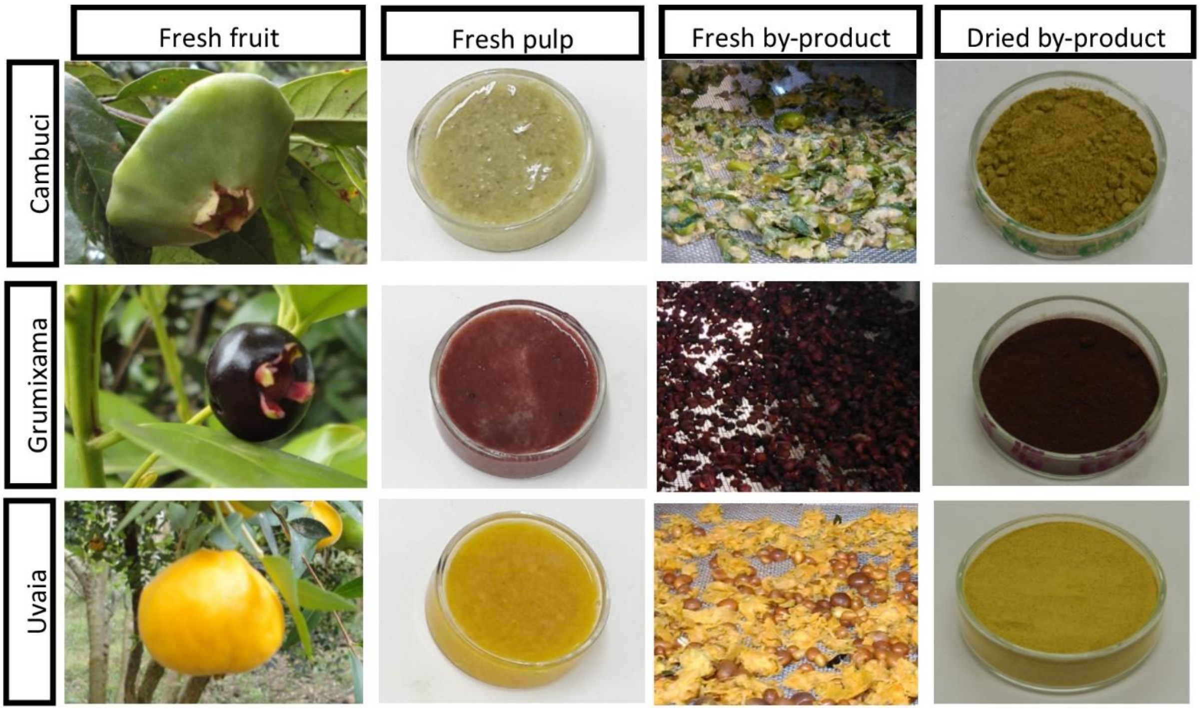

Figure 1. Fresh fruit, fresh pulp, fresh by-product and dried by-product fractions from cambuci, grumixama and uvaia.

2.2.2 Proximate composition

Fresh fruits, pulps and by-products had total proximate composition evaluated. AOAC methods were used to determine nitrogen (method 920.152), ash (method 940.26), total and insoluble fiber (method 958.29), and moisture (method 920.151) contents (AOAC, 2006). Protein content was calculated as nitrogen x 6.25. The lipid content was determined according to the method described by Bligh & Dyer (1959). Carbohydrate content was estimated by difference.

2.2.3 Physical characteristics

The by-products from the three fruits dried under different conditions were evaluated for their water and oil holding capacity, solubility, swelling, hygroscopicity, specific volume, apparent density and bulk density.

2.2.3.1 Water and oil holding capacity, solubility and swelling

Both water holding capacity (WHC) and Oil Holding Capacity (OHC) were determined following the methodology described by Garau, Simal, Rosselló, & Femenia, (2007). WHC and OHC results were expressed in terms of g of water/g of residue and g oil/g residue, respectively. The solubility (SL) and swelling (SW) were also measured according to Garau, Simal, Rosselló, & Femenia, (2007) and the results were presented as the % of soluble content against the initial by-product weight and mL water/ g of residue, respectively.

2.2.3.2 Hygroscopicity

Higroscopicity (HG) was evaluated according to Tonon, Brabet, & Hubinger, (2008). The results were expressed in g of water per 100 g of by-product (dry basis).

2.2.3.3 Specific volume, apparent density and bulk density

The apparent density (AD) and bulk density (BD) values were determined according to Pla et al. (2012). The specific volume (SV) was determined by calculating the inverse of the apparent density.

2.2.4 Bioactive compounds extraction

In order to determine total phenolic content, total anthocyanins and antioxidant capacity, extracts were obtained from the by-products that were dried under different conditions and from freeze dried pulp, freeze dried fruit and freeze dried by-product fractions. The freeze drying process occurred in a freeze dryer (Christ, Alpha 2-4 LD plus model, Germany), under the following conditions (in dark): 44 h, 0.12 mbar, T=- 40ºC (main drying) and 4 h, 2.5 mbar, T= -10ºC (final drying).

The extraction occurred following methodology of Haminiuk et al. (2011). The samples (0.2 to 0.8 g) were extracted with 40 mL of a 40% ethanol solution for one hour with agitation in a stirring table (120 bpm). After the extraction, they were centrifuged at 1535 x g and the supernatant filtered with Whatman n°1 filter paper. The extraction for each sample was performed in triplicate.

2.2.5Total phenolic content

Total phenolic content (TPC) was evaluated according to the method of Singleton & Rossi (1965), described by HAMINIUK et al. (2011), that uses the Folin-Ciocalteu reagent. The extracts were pipetted (100 µl) into 5 mL of distilled water and 500 µL of Folin-Ciocalteu reagent was added to the mixture. Three minutes later, 1.5 mL of a 15% sodium carbonate solution was added and distilled water was added to complete a final volume of 10 mL. After a period of two hours in the dark at room temperature, the absorbance of the mixture was measured at 765 nm using a spectrophotometer (Beckman DU70, Germany). Gallic acid was used as standard and the results were expressed as gallic acid equivalents (GAE) per gram (dry basis).

2.2.6 Total Anthocyanins

Grumixama samples were analyzed for the content of anthocyanins, following methodology of Chaovanalikit and Wrolstad (2004), using pH differential methodology. Two buffers were prepared: a 0.025 M potassium chloride (pH 1.0) and a 0.4 M sodium acetate (pH 4.5). The extracts were mixed with buffer at pH 1.0 or 4.5, in a proper proportion and had their absorbance measured in a spectrophotometer (Beckman DU-70, Germany), at two absorbances: 510 and 700 nm. The absorbance of the diluted sample (A) was calculated by the equation:

$$A = (A_{510} - A_{700})_{pH\,1.0} - (A_{510} - A_{700})_{pH\,4.5} \qquad (1)$$

The concentration of monomeric anthocyanins was calculated according to Equation 2:

$$\text{monomeric anthocyanin pigments } (\text{mg}/L) = \frac{A\,x\,MW\,x\,DF\,x\,1000}{\varepsilon\,x\,1} \qquad (2)$$

“A” was the previously calculated absorbance (Equation 1), MW is the molecular weight of cyanidin-3-glucoside (449.2 g/mol), DF is the dilution factor and ε is the extinction coefficient of cyanidin-3-glucoside (26900 L/cm*mol). The final results were expressed in mg of cyaniding-3- glucoside equivalents /g of dry sample.

2.2.7 Antioxidant capacity

The extracts had the antioxidant capacity determined using three methodologies: FRAP, ABTS and ORAC. FRAP and ABTS assays were evaluated according to Rufino et al. (2010). ORAC assay was performed according to methodology described by DÁVALOS & CARMEN GÓMEZ-CORDOVÉS (2004). FRAP results were expressed in µmol $FeSO_4$/100g (dry basis). ORAC and ABTS results were expressed as micromoles of Trolox equivalent per g of sample in dry basis (µmol of TE/g).

2.2.8 Organic acids quantification using HPLC

The organic acids were determined for freeze dried pulp, fruit and by-product fractions and for dried by-product that presented the highest total phenolic content.

Organic acids (tartaric, ascorbic, malic and citric) were determined following the procedure described by Scherer et al. (2012) with modifications, using a liquid chromatograph (Shimadzu LC-10, Shimadzu Scientific Instruments, Columbia, USA) with degasser, quaternary pump (LC-10AT VP), column oven (CTO-10AS VP), manual injector (Rheodyne modelo 7725i, with a 20 µL loop), diode array detector SPD-M20A VP and an interface SCL-10A, operated with the software Class VP Workstation version 6.14. The powder samples were weighed (150 mg) and extracted with 2.5mL of MilliQ water with vortexing for two minutes. Then the sample was centrifuged in a refrigerated centrifuge (Mikro 200R, Hettich, Tuttlingen, Germany) at 9830xg for 10 min at 4 °C. The extract supernatant was diluted with mobile phase (10 times) and then filtered through PVDF 0.45 µm syringe filter (Millipore Corporation, Bedford, USA). The chromatographic separation was performed on Gemini C_{18} column (4.6mm x 250mm, 5µm) (Phenomenex, Torrance, USA) at a temperature of 25 °C, with isocratic elution of the mobile phase, composed by a buffer solution of 0.01 mol/L KH_2PO_4 (pH 2.60 adjusted with o-phosphoric acid) with a flow rate of 0.5 mL/min. The peak areas were calculated at 210 nm for tartaric, malic and citric acids, and 250 nm for ascorbic acid. The analytes were quantified by external standard calibration. All determinations were carried out in triplicate.

2.2.9 Statistical Analysis

Significant differences between averages were calculated by using one-way ANOVA and Tukey's test ($p<0.05$), using XLSTAT (2016).

3 Results and discussion

Table 2 shows the proximate composition of the fruit (f), pulp (p) and by-product (bp) of cambuci (C), grumixama (G) and uvaia (U), in wet basis.

Table 2. Proximate composition of the fresh fruit (f), fresh pulp (p) and fresh by-product (bp) of cambuci (C), grumixama (G) and uvaia (U), wet basis

Sample	Moisture (g/100g)	Protein (g/100g)	Lipid (g/100g)	Ash (g/100g)	Carbohydrate (g/100g)*	Total fiber (g/100g)	Insoluble fiber (g/100g)
Cf	86.6 ± 0.3	0.31 ± 0.04	0.42 ± 0.02	0.31 ± 0.02	9.3 ± 0.3	3.1 ±0.1	2.26 ± 0.04
Cp	88.1 ± 0.3	0.30 ± 0.02	0.18 ± 0.02	0.36 ± 0.02	8.1 ± 0.3	2.95 ± 0.06	1.53 ± 0.01
Cbp	80.0 ± 0.4	0.88 ± 0.03	1.46 ± 0.07	0.46 ± 0.03	7.2 ± 0.4	10.0 ± 0.1	6.82 ± 0.04
Gf	87.8 ± 0.7	0.71 ± 0.02	0.33 ± 0.03	0.52 ± 0.04	8.6 ± 0.7	2.06 ± 0.04	1.76 ± 0.06
Gp	90.0 ± 0.5	0.60 ± 0.01	0.21 ± 0.04	0.44 ± 0.04	7.4 ± 0.5	1.4 ± 0.1	0.85 ± 0.06
Gbp	80.0 ± 0.6	1.63 ± 0.06	0.53 ± 0.03	0.86 ± 0.06	11.1 ± 0.7	5.8 ± 0.3	4.0 ± 0.2
Uf	91.9 ± 0.7	1.24 ± 0.04	0.31 ± 0.02	0.28 ± 0.03	4.3 ± 0.7	1.96 ± 0.04	1.8 ± 0.3
Up	95.4 ± 0.6	0.94 ± 0.05	0.19 ± 0.02	0.22 ± 0.02	2.3 ± 0.6	1.00 ± 0.07	0.7 ± 0.2
Ubp	89.2 ± 0.5	2.64 ± 0.03	0.36 ± 0.02	0.25 ± 0.03	2.8 ± 0.5	4.7 ± 0.1	3.63 0.04

* Carbohydrate content was estimated by difference.

Values presented in the tables represent the standard of 3 replicates.

The studied fruit by-products have important nutritional components, such as protein (0.88 to 2.64%), lipid (0.36 to 1.46%), ash (0.25 to 0.86%), carbohydrate (2.8 to 11.1%) and fiber (4.7 to 10%). Many companies simply discard these fruit by-products in land fields, but they still have good potential to be used in products designated to human nutrition.

Proximate composition analysis showed high amounts of total dietary fiber in the by-product fraction of the three fruits. The amount of fiber present in the by-product fractions was from 3.4 to 4.7 times and 2.4 to 3.2 times the amount of fiber present in the pulp and fruit fractions, respectively. Fruit by-product have been reported by other author for having high amounts of dietary fiber (O'Shea et al. 2015b). For all analyzed fractions and fruits, insoluble fiber was the main dietary fiber.

Table 3 presents the physical characteristics of water and oil holding capacity, swelling, solubility and higroscopicity.

Table 3. Water holding capacity (WHC), Oil holding capacity (OHC), Swelling (SW), Solubility (SL), Hygroscopicity (HG) and Moisture content (MC) results for the by-products of the three types of fruit processed at 40 °C, 60 °C and 80 °C (centrifuged and not centrifuged)

Assay	Fruit	WHC (g/g)	OHC (g/g)	SW (mL/g)	SL (%)	HG (g/100g)	MC (%)
40NC	Grumixama	6.9 ± 0.3^{ab}	3.9 ± 0.2^{a}	6.8 ± 0.1^{a}	36.5 ± 0.5^{b}	8.53 ± 0.05^{c}	11.6±0.4
40C	Grumixama	6.9 ± 0.3^{ab}	3.6 ± 0.2^{a}	6.5 ± 0.3^{ab}	23.5 ± 0.6^{e}	3.41 ± 0.03^{f}	10.0±0.1
60NC	Grumixama	6.3 ± 0.3^{b}	3.00 ± 0.07^{b}	5.5 ± 0.2^{c}	39 ± 1^{a}	11.1 ± 0.1^{b}	8.8±0.4
60C	Grumixama	7.4 ± 0.4^{a}	3.03 ± 0.07^{b}	6.4 ± 0.2^{ab}	25.3 ± 0.6^{d}	6.46 ± 0.05^{e}	7.9±0.2
80NC	Grumixama	4.6 ± 0.6^{c}	2.7 ± 0.1^{b}	4.81 ± 0.06^{d}	37.6 ± 0.2^{ab}	13.3 ± 0.2^{a}	6.0± 0.2
80C	Grumixama	6.6 ± 0.2^{ab}	2.9 ± 0.1^{b}	6.2 ± 0.1^{b}	27.2 ± 0.4^{c}	7.96 ± 0.05^{d}	6.0± 0.4
40NC	Uvaia	7.7 ± 0.1^{b}	3.27 ± 0.06^{ab}	7.40 ± 0.03^{a}	24.9 ± 0.2^{b}	8.44 ± 0.08^{c}	11.94± 0.07
40C	Uvaia	8.3 ± 0.2^{a}	3.29 ± 0.06^{ab}	7.3 ± 0.2^{a}	15.6 ± 0.3^{d}	6.1 ± 0.2^{e}	8.7± 0.2
60NC	Uvaia	6.4 ± 0.4^{c}	3.1 ± 0.2^{b}	6.4 ± 0.2^{c}	24.5 ± 0.7^{b}	9.6 ± 0.4^{b}	11.6± 0.5
60C	Uvaia	7.6 ± 0.1^{b}	3.3 ± 0.2^{ab}	6.86 ± 0.02^{b}	17.7 ± 0.4^{c}	7.3 ± 0.2^{d}	7.3± 0.2
80NC	Uvaia	5.64 ± 0.04^{d}	2.9 ± 0.2^{b}	5.43 ± 0.08^{d}	26.8 ± 0.7^{a}	11.6 ± 0.3^{a}	7.8± 0.2
80C	Uvaia	7.6 ± 0.1^{b}	3.6 ± 0.2^{a}	6.22 ± 0.09^{c}	16.3 ± 0.4^{cd}	5.7 ± 0.4^{e}	8.0± 0.3
40NC	Cambuci	3.7 ± 0.2^{ab}	2.8 ± 0.1^{ab}	4.69 ± 0.08^{d}	33.2 ± 0.9^{b}	6.7 ± 0.1^{c}	13.7± 0.2
40C	Cambuci	4.4 ± 0.2^{a}	3.00 ± 0.06^{a}	6.8 ± 0.1^{a}	21.7 ± 0.9^{c}	4.4 ± 0.2^{e}	11.7± 0.3
60NC	Cambuci	3.2 ± 0.2^{b}	2.76 ± 0.03^{ab}	5.5 ± 0.2^{bc}	35 ± 2^{b}	7.79 ± 0.08^{b}	13.3± 0.2
60C	Cambuci	3.6 ± 0.8^{ab}	2.7 ± 0.1^{ab}	5.9 ± 0.2^{b}	20.8 ± 0.6^{c}	5.6 ± 0.7^{d}	10.6± 0.1
80NC	Cambuci	2.7 ± 0.1^{b}	2.5 ± 0.2^{b}	4.9 ± 0.1^{d}	40 ± 1^{a}	12.2 ± 0.2^{a}	10.2± 0.1
80C	Cambuci	3.6 ± 0.2^{ab}	2.85 ± 0.09^{a}	5.1 ± 0.2^{cd}	22.6 ± 0.5^{c}	6.60 ± 0.05^{c}	9.3± 0.2

Values in the same column having the same letter for each fruit are not significantly different at a confidence level of 95%. Conditions = 40, 60 and 80 °C without prior centrifugation (40NC, 60NC and 80NC) and 40, 60 and 80 °C with prior centrifugation (40C, 60C and 80C).

WHC is the ability of the material to retain the water with the application of an external force, such as centrifugation (Borchani et al. 2012) and can vary according to the studied material. Analysing the obtained results for the present study, it was possible to observe that cambuci by-products showed lower values compared to other fruits. WHC for different by-products ranges from 10.5 to 16.1 g/g for peel and 10.6 to 14.0 g/g for pulp by-product (Garau et al. 2007); from 3.39 to 6.77g/g for WHC of date fiber samples (Borchani et al. 2012) and from 1.62 to 2.26 g/g for apple, grape, lemon and orange (Figuerola et al. 2005).

WHC may be related, among other factors, to the presence of sugars. Fruit fiber samples, which had passed through a washing process for its production, had sugars removed and increased WHC (Viuda-Martos et al. 2012; Larrauri, 1999). In this study, this washing step can be compared to the previous centrifugation step, which removed water and soluble compounds. For uvaia, for example, treatments with previous centrifugation showed a little higher (8 to 35%) WHC values when compared to drying without prior centrifugation. Grumixama showed a behaviour similar to uvaia except for treatments at 40 ° C, in which waste with and without prior centrifugation did not differ at the level of significance of 5%. For cambuci waste, however, no difference was observed in WHC related to the previous centrifugation of the sample. The differences observed in WHC values of different samples can also be related to changes in the fiber structure, degradation of some components of dietary fiber and protein denaturation that can occur during drying (Lou et al. 2009, Borchani et al. 2012).

Authors reported the reduction in WHC of orange by-products which were dried at higher temperatures (90 °C) compared to samples that were dried at lower temperatures (40 °C), indicating the influence of temperature on the change in the structure of the sample (Garau et al. 2007, Borchani et al. 2012). Borchani et al. (2012) have observed a decrease in WHC of dried date residue from 50 °C. In the present study, in general, it was also observed lower WHC values for high temperature assays.

Swelling is a physical property, which along with WHC can give an idea of the hydration of the product (Pla et al. 2012). It corresponds to the volume occupied by a certain mass of the material hydrated with distilled water. The values obtained in this study ranged from 4.69 to 7.4 mL/g. The values are according to the findings of other authors, such as Borchani et al. (2012), that evaluated date residue (5.69 to 8.97 mL/g), and Figuerola et al. (2005), that evaluated apple, orange, lemon and grape residues (6.11 to 9.19 ml / g). Garau et al. (2007) found values higher than 20 mL/g of alcohol insoluble residue for orange peel. As for WHC, the fiber structure, including the porosity, can exert a great influence on the swelling volume of the sample (Figuerola et al. 2005, Marques et al., 2009).

OHC corresponds to the amount of oil which is retained in the product after the application of an external force, such as centrifugation (Borchani et al. 2012). The oil retention capacity values were relatively low, ranging from 2.5 to 3.9 g oil / g of sample in dry basis, considering the results of three fruits. The results were very close between all treatments. Borchani et al. (2012) studied the drying of date waste at different drying temperatures and did not observe much influence of the temperature in the OHC parameter.

Values of OHC found by authors who also studied fruit wastes are among the following ranges: about 2.00 to 3.50 g/g for the alcohol insoluble residue of dried orange peels (Garau et al. 2007), similar to the values obtained in this study; about 3.00 to 6.50 g/g for alcohol insoluble residue of dried orange peel (Garau et al. 2007), values higher than those of the present study; and from 0.6 to 1.81 g /g in concentrated grape, lemon, orange, and apple waste fibers (Figuerola et al. 2005), values below the values obtained for the uvaia, grumixama and cambuci wastes.

The solubility index ranged from 23.5% to 39% for grumixama waste, 15.6% to 26.8% for uvaia waste and 20.8% to 40% for cambuci waste. As expected, for the three fruits, the highest values were related to treatments without centrifugation. These results can be explained by the fact that part of the soluble compounds have been removed along with the water left in the centrifugation of the residue.

The hygroscopicity assay shows the ability of a material to absorb moisture from the environment. For the three fruits, the residues dried under different conditions differed significantly from each other. The treatments with previous centrifugation showed lower values than treatments without centrifugation. The fruit soluble components are represented, among others, by large amounts of low molecular weight sugars, such as glucose, fructose and sucrose and organic acids (Adhikari & Howes 2002, Tonon et al. 2008). The removal of soluble and hygroscopic components such as low molecular weight sugars (Jaya & Das 2004) in the centrifugation process may be related with lower hygroscopicity values obtained for the waste with prior centrifugation. In addition, an increase in hygroscopicity was observed for the dried product in assays with higher temperatures. In this case, mostly, the by-products dried at higher temperatures reached lower final moisture values (Table 1). This tendency is consistent with the one verified by Tonon et al. (2011) for dried acai by spray drying.

Apparent density, specific volume and bulk density results are presented at Table 4.

Table 4. Apparent density (AD), Specific volume (SV), bulk density (BD) results for the by-products of three types of fruit processed at 40, 60 and 80 °C (centrifuged and not centrifuged)

Fruit	Assay	BD (g/mL)	AD (g/mL)	SV (mL/g)
Grumixama	40NC	0.45 ± 0.01^{c}	0.593 ± 0.004^{c}	1.69 ± 0.01^{b}
	40C	0.508 ± 0.007^{a}	0.75 ± 0.01^{a}	1.33 ± 0.02^{d}
	60NC	0.443 ± 0.006^{c}	0.575 ± 0.006^{c}	1.74± 0.02^{a}
	60C	0.469 ± 0.006^{b}	0.646 ± 0.004^{b}	1.55 ± 0.01^{c}
	80NC	0.508 ± 0.002^{a}	0.647 ± 0.005^{b}	1.55 ± 0.01^{c}
	80C	0.482 ± 0.002^{b}	0.6415 ± 0.0003^{b}	1.559 ± 0.001^{c}
Uvaia	40NC	0.460 ± 0.001 ^{cd}	0.62 ± 0.01 ^{d}	1.62 ± 0.04 ^{a}
	40C	0.480 ± 0.001 ^{ab}	0.67 ± 0.01 ^{bc}	1.50 ± 0.03 ^{b}
	60NC	0.450 ± 0.002 ^{d}	0.64 ± 0.01 ^{cd}	1.57 ± 0.03 ^{a}
	60C	0.47 ± 0.01 ^{bc}	0.698 ± 0.005 ^{ab}	1.43 ± 0.01 ^{bc}
	80NC	0.445 ± 0.006 ^{d}	0.620 ± 0.004 ^{d}	1.61 ± 0.01 ^{a}
	80C	0.496 ± 0.008 ^{a}	0.73 ± 0.02 ^{a}	1.379 ± 0.04 ^{c}
Cambuci	40NC	0.474 ± 0.006 ^{a}	0.66 ± 0.01 ^{a}	1.51 ± 0.02 ^{a}
	40C	0.41 ± 0.02 ^{bc}	0.628 ± 0.005 ^{a}	1.59 ± 0.01 ^{a}
	60NC	0.420 ± 0.009 ^{b}	0.641 ± 0.008 ^{a}	1.56 ± 0.02 ^{a}
	60C	0.431 ± 0.009 ^{b}	0.65 ± 0.02 ^{a}	1.54 ± 0.04 ^{a}
	80NC	0.48 ± 0.01 ^{a}	0.66 ± 0.02 ^{a}	1.52 ± 0.04 ^{a}
	80C	0.386 ± 0.002 ^{c}	0.65 ± 0.02 ^{a}	1.53 ± 0.06 ^{a}

Values in the same column having the same letter for each fruit are not significantly different at a confidence level of 95%. Conditions = 40, 60 and 80 °C without prior centrifugation (40NC, 60NC and 80NC) and 40, 60 and 80 °C with prior centrifugation (40C, 60C and 80C).

The bulk density of a powder is the ratio of the mass of the sample without being compressed and its volume, considering the contribution of the empty space between the particles. Thus, it is a property that depends on the density of the powder and the spatial arrangement of the particles in the powder layer (WORLD HEALTH

ORGANIZATION, 2012). By-products from the three studied fruits showed variation in the bulk density values due to the treatment they were submitted to. The bulk density of grumixama residues ranged from 0.443 (60NC) to 0.508 g/mL (40C and 80NC). For uvaia, the variation was from 0.445 (80NC) to 0.496 g/mL (80C) and for cambuci, values varied between 0.386 (80C) and 0.48 g/mL (80NC). The bulk density values found for grumixama, uvaia and cambuci were below the values found by Ahmed et al. (2013) for date fibers (0.22 to 0.26 g/mL).

The apparent density is a real density with increased value, obtained after mechanical compaction of powder (World Health Organization, 2012). The fruit that had minor differences in apparent density between the different drying conditions was cambuci, with no significant difference between treatments. For the other fruits, the parameter varied with the different drying conditions: between 0.575 (60NC) and 0.75 g/mL (40C) for grumixama and between 0.620 (80NC) and 0.73 g/mL (80C) for uvaia. Basanta et al (2014) found apparent density values ranging from 0.34 to 0.578 g/mL for cherry fruit residues, slightly below the values from the present study.

The specific volume is the inverse of apparent density and, according to Tukey's test at 5% significance level there was no difference between cambuci by-products treatments, with values ranging between 1.51 (40NC), and 1.59 mL/g (40C). The values of this property to the grumixama by-products ranged from 1.33 (40C) to 1.74 mL / g (60NC) and between 1.379 (80C) and 1.62 (40NC) for uvaia waste. All the values were below the values found by Basanta et al. (2014) for cherry fruit residues (1.73 to 2.99 mL/g).

Total phenolic content, total anthocyanins and antioxidant activity results can be seen in Table 5.

Table 5. Total phenolic content (TPC), total anthocyanins (TA) and antioxidant activity for grumixama, uvaia, cambuci and their fractions, processed at 40, 60 and 80 °C (centrifuged and not centrifuged).

				Antioxidant activity		
Fruit	**Assay**	**TPC mg GAE/g**	**TA mg cyanidin-3-glucoside eq/g**	**ABTS µmol TE/g**	**FRAP mmol Fe_2So_4/100g**	**ORAC µmol TE/g**
Grumixama	40NC	110 ± 2^{d}	15.6 ± 0.9^{de}	863 ± 33^{b}	238 ± 8^{ab}	934 ± 43^{c}
	40C	129 ± 1^{a}	20.5 ± 0.8^{c}	1068 ± 52^{a}	248 ± 8^{a}	1072 ± 54^{a}
	60NC	92 ± 2^{e}	17 ± 1^{d}	685 ± 32^{c}	183 ± 8^{c}	815 ± 41^{d}
	60C	121 ± 2^{b}	22.1 ± 0.8^{bc}	824 ± 22^{b}	231 ± 9^{b}	882 ± 78^{bc}
	80NC	86 ± 2^{f}	13.8 ± 0.8^{e}	630 ± 31^{c}	167 ± 7^{d}	764 ± 39^{d}
	80C	119 ± 2^{c}	24.2 ± 0.6^{b}	825 ± 23^{b}	233 ± 7^{b}	948 ± 54^{c}
	f	57 ± 1^{g}	8.0 ± 0.2^{f}	489 ± 46^{d}	153 ± 5^{e}	507 ± 24^{e}
	p	26.6 ± 0.7^{h}	3.64 ± 0.05^{g}	239 ± 14^{e}	72 ± 2^{f}	179 ± 14^{f}
	bp	129.4 ± 0.7^{a}	26 ± 1^{a}	1041 ± 39^{a}	248 ± 7^{a}	1037 ± 64^{ab}
Uvaia	40NC	32 ± 1^{c}		313 ± 15^{c}	64 ± 3^{b}	255 ± 9^{bc}
	40C	37 ± 1		349 ± 12^{a}	73 ± 2^{a}	273 ± 18^{b}
	60NC	32 ± 1^{c}		315 ± 13^{c}	64 ± 2^{b}	243 ± 12^{c}
	60C	34 ± 1^{b}		357 ± 14^{a}	72 ± 2^{a}	256 ± 13^{bc}
	80NC	30.5 ± 0.9^{c}		320 ± 14^{bc}	66 ± 3^{b}	269 ± 10^{bc}
	80C	35.0 ± 0.8^{b}		316 ± 8^{c}	74 ± 2^{a}	265 ± 23^{bc}

	f	23.9 ± 0.7^{d}	191 ± 3^{d}	44 ± 2^{c}	201 ± 14^{d}
	p	19.9 ± 0.9^{e}	189 ± 1^{d}	37.9 ± 0.6^{d}	147 ± 17^{e}
	bp	38 ± 2^{a}	339 ± 8^{ab}	70.6 ± 0.8^{a}	323 ± 16^{a}
Cambuci	40NC	38.4 ± 0.8^{f}	307 ± 13^{e}	78 ± 3^{ef}	217 ± 12^{e}
	40C	43 ± 1^{c}	340 ± 14^{cd}	89 ± 6^{d}	265 ± 8^{d}
	60NC	36 ± 1^{g}	277 ± 16^{f}	73 ± 5^{f}	286 ± 17^{cd}
	60C	44 ± 2^{c}	352 ± 14^{c}	93 ± 3^{cd}	306 ± 23^{bc}
	80NC	41 ± 1^{d}	314 ± 11^{e}	90 ± 5^{d}	313 ± 14^{b}
	80C	48 ± 1^{b}	375 ± 12^{b}	105 ± 7^{b}	330 ± 9^{ab}
	f	40 ± 1^{de}	326 ± 12^{de}	97 ± 4^{c}	157 ± 11^{f}
	p	39 ± 1^{ef}	305 ± 12^{e}	85 ± 3^{de}	112 ± 11^{g}
	bp	63 ± 1^{a}	557 ± 18^{a}	145 ± 4^{a}	349 ± 9^{a}

Values in the same column having the same letter for each fruit are not significantly different at a confidence level of 95%. f=freeze-dried fruit. p=freeze dried pulp. bp=freeze dried by-product. Conditions = 40, 60 and 80 °C without prior centrifugation (40NC, 60NC and 80NC) and 40, 60 and 80 °C with prior centrifugation (40C, 60C and 80C). Results in dry basis.

Among the three studied fruits, grumixama presented the highest total phenolic content, followed by cambuci and uvaia. Total phenolic content values ranged between 19.9 mg GAE/g (uvaia pulp) and 38 mg GAE/g (uvaia by-product) for uvaia, 26.6 mg GAE/g (grumixama pulp) and 129.4 mg GAE/g (grumixama by-product) for grumixama and 36 mg GAE/g (cambuci 60NC) and 63 mg GAE/g (cambuci by-product) for cambuci. In addition, for the three fruits, among fruit, pulp and by-product fractions, the by-product presented the highest and pulp presented the lowest total phenolic content. Uvaia fruit TPC was close to the value found by Rufino et al. (2010) (1930 mg GAE/100g db).

Hot air drying of the by-products and the different drying conditions affected total phenolic content. For grumixama and uvaia, the drying condition that presented the highest TPC was 40C, while for cambuci, it was 80C. For each fruit, the conditions that lead to a product with the lowest TPC were 80NC (grumixama), 40NC, 60NC and 80NC (uvaia) and 60NC (cambuci). Comparing to the freeze dried by-product, for uvaia, grumixama and cambuci, the dried by-products presented TPC 2 to 20%, 0.2 to 34% and 25 to 42% lower, respectively. For the three fruits, when comparing same temperature assays, those with previous centrifugation led to lower drying times and presented higher values of total phenolic compounds.

Besides TPC, grumixama also presented the highest antioxidant activity levels considering all tested methodologies (FRAP, ORAC and ABTS), followed by cambuci and uvaia. ABTS values ranged from 189 µmol trolox/g (uvaia pulp) to 1068 µmol trolox/g (grumixama 40C). FRAP results ranged between 37.9 mmol/100g (uvaia pulp) and 248 mmol/100g (grumixama 40C). Furthermore, comparing fruit, pulp and by-product fractions, the by-products presented the highest and pulps presented the lowest total antioxidant capacity. Rufino et al. (2010) evaluated uvaia fruit antioxidant activity and the values were really close to those obtained in the present study (ABTS = 182 µmol Trolox/g db and FRAP = 408 µmol Fe_2SO_4/g db). Cambuci fruit and pulp ORAC values are comparable to that obtained by Gonçalves et al. (2010) (about 100 µmol Trolox/g db) . Grumixama fruit ABTS value was up to twice the value found for crude extract of grumixama fruit by Flores et al. (2012) (about 0.5 mmol trolox/g db). It is important to consider that the bioactive compounds extraction method was different from the one used in the present study.

Some factors can impact on antioxidant properties of fruits, such as soil, climate, species, cultivars and irrigation.

Antioxidant activity was different for the different hot air drying conditions. For grumixama, the highest antioxidant activity values were obtained for 40C (ABTS), 40NC and 40C (FRAP) and 40C (ORAC). For uvaia, the highest antioxidant activity values were obtained for 40C and 60C (ABTS) and 40C, 60C and 80C (FRAP). For ORAC assay, there was no difference among the uvaia by-product drying treatments. For cambuci, ABTS highest value was obtained for 80C, FRAP highest value was obtained for 80C and ORAC highest value was obtained for 80C, 80NC and 60C.

The anthocyanin content was measured for grumixama fruit, pulp and by-products, which presents red/purple color. Comparing fruit, pulp and by-product, the by-product concentrates most part of the anthocyanins. The anthocyanins content differed significantly in the final dried product depending on the drying conditions, which involves both time and temperature that the product is exposed. Product exposure to temperature for extended periods may affect the quality of the product, leading to degradation of functional compounds (Yılmaz et al. 2015). Comparing the hot air dried by-product under different conditions with the freeze dried by-product, it was possible to observe that 52 to 92% of total anthocyanin content remained in hot air dried by-product. The by-products that passed through the previous centrifugation step, which resulted in shorter drying times, presented higher total anthocyanins results.

Figure 2 presents Pearson's correlation coefficient between the tested antioxidant activity methods and total phenolic content. Equally FRAP, ORAC and ABTS presented strong positive correlation (close to 1) with total phenolic content. Müller et al. (2010) also found strong correlation between antioxidant activity (FRAP, ORAC and ABTS) and total phenolic content when evaluating puree, concentrate and juice from different fruits.

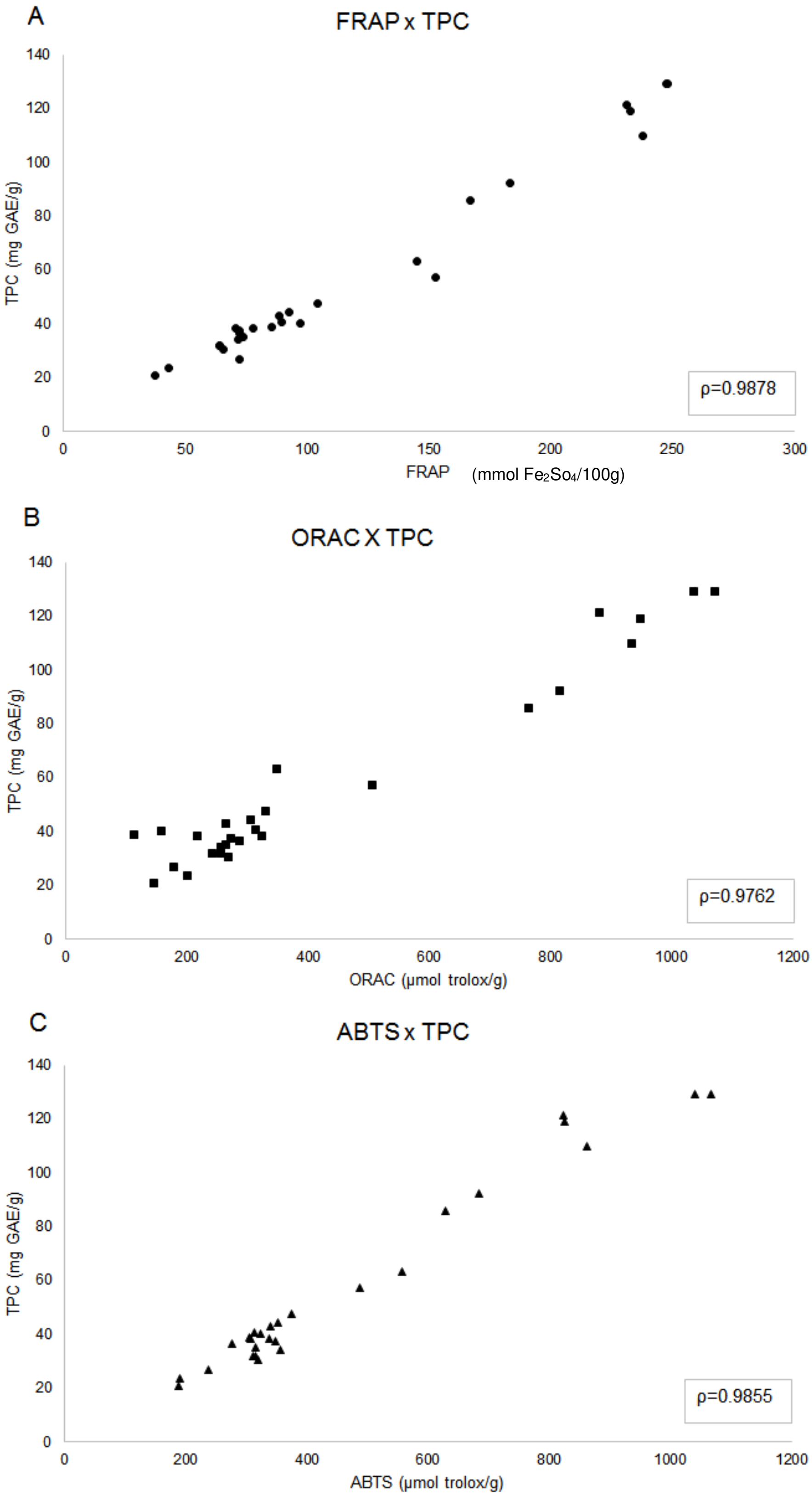

Figure 2. Correlation (Pearson) of antioxidant capacity (A-FRAP, B-ORAC, C-ABTS) and total phenolic content

Table 6. Quantity of organic acids (mg/g db) present in pulp, by-product, dried by-product with highest TPC and fruit fractions for grumixama, uvaia, cambuci

		Organic Acid Quantity (mg/g d.b.)			
Sample	**Fruit**	**Tartaric**	**Malic**	**Citric**	**Ascorbic**
f	Grumixama	2.2 ± 0.1^{bc}	6.0 ± 0.7^{a}	57 ± 3^{b}	Nd
p	Grumixama	3.0 ± 0.2^{a}	7 ± 1^{a}	68.6 ± 0.7^{a}	Nd
bp	Grumixama	2.9 ± 0.4^{ab}	4.1 ± 0.1^{b}	42.1 ± 0.5^{c}	Nd
40C	Grumixama	2.0 ± 0.4^{c}	2.1 ± 0.1^{c}	21.0 ± 0.3^{d}	Nd
f	Uvaia	Nd	148 ± 3^{b}	Nd	8.3 ± 0.2^{a}
p	Uvaia	Nd	166 ± 6^{a}	Nd	7.7 ± 0.3^{a}
bp	Uvaia	Nd	86.3 ± 0.8^{c}	Nd	5.26 ± 0.04^{b}
40C	Uvaia	Nd	35.1 ± 0.5^{d}	Nd	Nd
f	Cambuci	11.2 ± 0.4^{a}	19.4 ± 0.5^{b}	59 ± 2^{b}	2.6 ± 0.1^{b}
p	Cambuci	12.0 ± 0.5^{a}	29.8 ± 0.3^{a}	74.9 ± 0.5^{a}	3.5 ± 0.2^{a}
bp	Cambuci	8.5 ± 0.2^{b}	13.7 ± 0.3^{c}	42.4 ± 0.6^{c}	1.0 ± 0.1^{c}
80C	Cambuci	7.2 ± 0.2^{c}	6.53 ± 0.05^{d}	24.3 ± 0.3^{d}	Nd

Values in the same column having the same letter for each fruit are not significantly different at a confidence level of 95%. f = freeze dried fruit, p = freeze dried pulp; bp = freeze dried by-product, 40C = dried by-product at 40 °C with centrifugation and 80C = dried by-product at 80 °C with centrifugation. Nd= not detected

Table 6 presents the quantity of organic acids evaluated in the freeze dried fruit, pulp and by-products and in the hot air dried by-product. The major acid was citric for grumixama and cambuci and malic for uvaia. Cambuci presented all four analyzed acids, while grumixama presented tartaric, malic and citric acids and uvaia presented only malic and ascorbic acids.

For the three fruits, it was possible to observe that the concentration of organic acids was lower in the by-product fraction. Some factors may be responsible for the degradation of ascorbic acid (vitamin C) in the product, such as pH, temperature, light, enzymes, oxygen, and metallic catalysers. Depending on hot air drying conditions and exposure time, the loss of vitamin C can be high (Santos & Silva 2008). Ascorbic acid was not present in any of fractions of grumixama and did not stand conventional drying for uvaia and cambuci by-products. Asami et al. (2003) evaluated the content of vitamin C in strawberry dried by freeze drying and air drying. The freeze drying results were 2.7 times higher than air drying results. FAO's Recommended Nutrient Intakes (RNIs) for vitamin C varies according to the group. For adults, the vitamin C RNI is 45 mg/day. Considering the fresh matter, 100 g of uvaia pulp, uvaia fruit, cambuci pulp or cambuci fruit per day would be sufficient to supply FAO's Recommended Nutrient Intakes (RNIs) for vitamin C.

4 Conclusions

The results showed that grumixama, uvaia and cambuci by-products have important compounds to human nutrition such as dietary fiber and bioactive compounds and can be a potential ingredient to be used by food industries. The by-product fraction presented higher fiber and bioactive compounds amounts when compared to the fruit and pulp fractions. Different drying conditions may influence the physical characteristics and the content of bioactive compounds and antioxidant capacity of dried by-products. All the processing conditions evaluated led to products that may still be considered a source of bioactive compounds, despite a decrease in by-products' antioxidant activity was observed after drying. The by-product drying is relatively simple and could be used by small industries and rural producers, for example, providing positive socio-economic and environmental implications to the results of this research.

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CAPÍTULO 5

Fruit by-product based confectionery: antioxidant capacity and sensory characteristics evaluated by CATA questions and acceptance test

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Fruit by-product based confectionery: antioxidant capacity and sensory characteristics evaluated by CATA questions and acceptance test

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Abstract

Fruit industries generates high amounts of solid by-products that can still have interesting features to human nutrition and could be used by other food industries. The aim of the present study was to evaluate the sensory acceptability of confectionery products made with pulp and by-products from Brazilian native fruits by consumers and to verify the characteristics that describe the products by check all that apply (CATA) questions. At least 120 consumers evaluated fruit bar formulations and chocolate or cupulate panned confectionery made from cambuci, uvaia or grumixama, all Atlantic Forest native fruits. Among the fruit bars, mostly, formulations containing the fruit pulp were preferred by consumers. CATA results suggests a positive influence of attributes such as “fruit aroma”, “practical” and “pleasant aftertaste” and a negative influence of attributes such as “bitter”, “bitter aftertaste” and “bad aftertaste” on fruit bar acceptance by the consumers. The acceptance of the panned confectionery was, among other features, related to the chocolate flavor.

Keywords: native fruits, fruit bars, chocolate, fruit by-products

1 Introduction

Due to the health appeal, the consumption of fruits and vegetables by the population is increasing (ORREGO; SALGADO; BOTERO, 2014). Brazil is the third largest fruit producer in the world, with a huge variety of species considered non-conventional, that presents taste and other unique characteristics and are less commercialized than other fruits. These species present great potential to be explored by industries, since consumers are each time more curious and interested about these products and new flavors and it can be an opportunity to local producers (ALMEIDA et al., 2011; WATANABE; OLIVEIRA, 2014). Among the non-conventional fruits that are used for frozen pulp production, there are cambuci (*Campomanesia phaea*), grumixama (*Eugenia brasiliensis* Lam.) and uvaia (*Eugenia pyriformis*), all native from Brazilian Atlantic Forest.

Fruits, in general, are perishable and seasonal which leads to the need to apply methods for conservation, for example, the production of frozen pulp by facilitating the marketing, transportation and product supply during the year (INFANTE et al., 2013). However, this type of industry generates a huge amount of organic waste, which is basically composed of bagasse, peels and fruit seeds. These by-products can be used as animal feed in some cases or can be simply disposed in land fields (KOSMALA et al., 2010; OSZMIANSKI; WOJDY; LACHOWICZ, 2016). Some industries use them for ethanol and biogas, and medications (DJILAS; CANADANOVIC-BRUNET; CETKOVIC, 2009; REDONDO-CUENCA; VILLANUEVA-SUÁREZ; MATEOS-APARICIO, 2008). Nevertheless, these products can best be used as ingredients for the food industry due to their high nutritional value and other interesting compounds, as antioxidants, fibers, phenolic compounds, anthocyanins. Thus, various examples of food products formulations added by by-products in order to improve the nutritional value are reported in literature, such as bread (MILDNER-SZKUDLARZ et al., 2011), yogurt and salad dressing (TSENG; ZHAO, 2013), meat products (BISWAS et al., 2015; SÁYAGO-AYERDI; BRENES; GOÑI, 2009), among others.

In addition to these products, confectionery products are undergoing constant transformation. There is a tendency of replacement of dyes and artificial flavors by adding fruit pulp or fruit concentrates, for example (CASTILHO et al., 2014). However, the use of fruit pulp leads to increased cost of the product to the consumer and by-products can be a cheaper alternative ingredient aggregating nutritional value to confectionery products (LAUFENBERG; KUNZ; NYSTROEM, 2003).

Some confectionery products which can be produced with by-products are fruit bars and chocolate panned confectioneries. Fruit bars can be considered snacks, generally produced from the fruit edible part and other ingredients. They can have other nomenclatures, such as fruit leathers and fruit rolls (PHIMPHARIAN et al., 2011). Although fruit bars or fruit leathers, as well as other processed fruit products, are considered for some people as not equivalent to the fresh fruit, they are interesting convenient products (ORREGO; SALGADO; BOTERO, 2014). The pan coating with chocolate is accomplished by the application of various successive layers of melted chocolate on the centers and subsequent cooling to promote solidification (AEBI, 2009). An alternative to the use of chocolate is the “cupulate”, obtained from cupuassu (*Theobroma grandiflorum*) residue (cupuassu seeds that are subjected to the same processing steps carried out with cocoa to produce chocolate). After harvesting, the seeds are separated from the fruit and fermented with the pulp layer covering the seeds. After fermentation, the seeds are dried and then roasted and ground. The mixture of this ground seeds with cupuassu butter and sugar form the cupulate (DE OLIVEIRA et al., 2004). This product was developed by CPATU (Agroforestry Research Center East Amazonia) / EMBRAPA in 1986. It has a lower cost of production and may lead to products such as milk, white, dark and semi dark cupulate (LANNES; MEDEIROS; AMARAL, 2002).

Few studies were found about the addition of by-products in confectionery formulations (CAPPA; LAVELLI; MARIOTTI, 2014). However, it is important to know the sensory characteristics and acceptance of products made from by-products, because the bitterness and astringency of bagasse and peels may cause the rejection by the consumers.

In order to evaluate sensory characteristics new descriptive analysis methods can be used as alternatives to conventional descriptive tests (VALENTIN et al., 2012; VARELA; ARES, 2012). Among the categories of quick descriptive tests, there is the “verbal-based methods”, as Check all that apply (CATA) questions. This method is a fast sensory test in which the assessors are asked to inform all the terms that are related to the sample from a list (ARES et al., 2015). Many products have been evaluated with CATA questions, as ice cream (DOOLEY; LEE; MEULLENET, 2010), milk desserts (BRUZZONE et al., 2015), meat products (JORGE et al., 2015) and fruit fillings made with different hydrocolloids (AGUDELO; VARELA; FISZMAN, 2015). CATA method was reviewed by Meyners and Castura (2014).

The aim of the present work was to develop confectionery products (fruit bars and chocolate or cupulate panned confectioneries) using fruit by-products and evaluate their acceptance by consumers and sensory characteristics by CATA questions.

2 Material and methods

2.1 Material

In order to produce the confectionery products, the following ingredients were used:

- Fruit leather: fresh grumixama (Eugenia brasiliensis Lam.), uvaia (Eugenia pyriformis) and cambuci (Campomanesiaphaea) pulps and by-products (Sítio do Bello, Paraibuna, São Paulo, Brazil); dried grumixama, uvaia and cambuci by-product; pectin (GENU® D Slow Set Confectionery, CP Kelco); sucrose (União, purchased in Campinas local market, São Paulo, Brazil); glucose syrup (Glucogill40DE, Cargill).
- Fruit and chocolate/cupulate panned confectionery: dried grumixama, uvaia and cambuci by-product (Sítio do Bello, Paraibuna, São Paulo, Brazil); pectin (GENU® D Slow Set Confectionery, CP Kelco); sucrose (União, purchased in Campinas local market); glucose syrup (Glucogill 40DE, Cargill); liquor and deodorized cocoa butter (Barry Callebaut); icing sugar (Glaçúcar, purchased in Campinas local market, São Paulo, Brazil); fermented and dried cupuassu beans (CUPUAMA).
- Chemical Reagents: Folin-Ciocalteau (Dinamica), gallic acid (Sigma-Aldrich), trolox 6-hydroxy-2,5,7,8-tetramethylchroman-2-carboxylic acid (Sigma-Aldrich), fluorescein (Sigma-Aldrich); 2,2'-Azobis(2-amidinopropane) dihydrochloride (Sigma-Aldrich).

2.2 Obtaining the dry fruit by-products

The by-products were centrifuged to remove the water and dried in conventional oven with air circulation and renovation (Pilot Plant of Fruit, Vegetables, Coffee, Cocoa, Sugary and Beverage Products, Department of Food Technology, School of Food Engineering, Unicamp). The by-product was disposed in thin layers in perforated trays (0.3 x 0.3 cm). Drying parameters were defined in previous studies in order to prevent bioactive compounds degradation. Uvaia and grumixama by-products were dried at 40 °C and cambuci by-product was dried at 80 °C, until constant sample weight. Grumixama and uvaia residues had the seeds separated and discarded after drying. Then, the remaining part was milled in a multi-use mill (Tecnal TE at 631/2) and IKA Labortechnik A10 mill. Cambuci residue was grinded immediately after drying. The dried grinded powders were separated by particle size with sieves, resulting in two products to be further used in fruit bars production: small particles with less than 0.25 mm and large particles with 1.19 to 1.68 mm. They were stored in vacuum packaging (Metalized polyethylene terephthalate 17g/m² + white polystyrene 100 g/m²), at -18 ° C until use.

2.3 Fruit bar production

Fruit bars were formulated from pulp (P); pulp + wet by-product (PWB); wet by-product (WB); pulp + large particle size dried by-product (PLDB); large particle size dried by-product (LDB); pulp + small particle size dried by-product (PSDB); small particle size dried by-product (SDB), sugar, glucose syrup and pectin. The formulations for grumixama (G), cambuci (C) and uvaia (U) are presented in Table 1.

Table 1. Fruit bars formulations for the three fruits, in percentage

Formulation	Fruit	Fruit pulp	Wet by-product	Dried by-product	Water	Sugar	Glucose syrup	Pectin	Citric acid
P	G	76.00	-	-	2.70	9.00	9.00	3.00	0.30
PWB	G	40.10	33.30	-	1.44	10.50	10.50	4.00	0.16
WB	G	-	37.50	-	37.64	10.90	10.90	2.90	0.16
PLDB	G	74.90	-	3.70	-	7.00	7.00	4.40	0.30
LDB	G	-	-	11.40	74.40	6.70	6.70	0.80	-
PSDB	G	74.90	-	3.70	2.70	7.00	7.00	4.40	3.00
SDB	G	-	-	3.70	71.35	11.70	11.70	1.40	0.15
P	U	53.15	-	-	-	22.38	22.38	2.10	-
PWB	U	39.90	19.69	-	-	19.42	19.42	1.57	-
WB	U	-	37.50	-	37.60	11.00	11.00	3.00	-
PLDB	U	56.85	-	2.75	-	19.12	19.12	2.16	-
LDB	U	-	-	11.40	64.20	11.70	11.70	0.80	-

PSDB	U	56.85	-	2.75	0.00	19.12	19.12	2.16	-
SDB	U	-	-	3.70	71.50	11.70	11.70	1.40	-
P	C	53.48	-	-	-	25.23	19.17	2.12	-
PWB	C	40.22	19.86	-	-	22.18	16.13	1.61	-
WB	C	-	37.50	-	35.90	14.00	9.70	2.90	-
PLDB	C	56.80	-	2.80	-	22.00	16.00	2.20	-
LDB	C	-	-	11.50	63.10	14.00	10.00	1.40	-
PSDB	C	56.80	-	2.80	-	22.00	16.00	2.20	-
SDB	C	-	0.00	3.70	71.20	14.00	9.70	1.40	-

Grumixama (G), cambuci (C) and uvaia (U). Pulp (P); pulp + wet by-product (PWB); wet by-product (WB); pulp + large particle size dried by-product (PLDB); large particle size dried by-product (LDB); pulp + small particle size dried by-product (PSDB); small particle size dried by-product (SDB). Small sized dried by-product = below 0.25 mm. Large sized dried by-product = between 1.19 and 1.68 mm.

For each formulation a methodology was performed, as described below.

- P: pulp, citric acid, glucose syrup and sugar were mixed and concentrated to 35 °Brix. In this stage, pectin was added and the mixture was concentrated until 50 °Brix.

- PLDB and PSDB: pulp, citric acid, glucose syrup and sugar were mixed and concentrated to 35 °Brix. In this stage, pectin was added and the mixture was concentrated until 40-45 °Brix. The dried by-product was added and mixed until the mixture was homogeneous.

- LDB and SDB: water, citric acid, glucose syrup and sugar were mixed and concentrated to 35 °Brix. In this stage, pectin was added and the mixture was concentrated until 50 °Brix. The dried by-product was added and mixed until the mixture was homogeneous.

- WB and PWB: the wet by-product was previously grind with water or pulp. Glucose syrup and sugar were added and the mixture was concentrated to 35 °Brix. In this stage, pectin was added and the mixture was concentrated until 40-45 °Brix.

The formulations were disposed in PVC molds with approximate dimensions of 2.5 cm (width), 12 cm (length) e 0.8 cm (height). After about one hour, fruit bars were removed from the mold, disposed in stainless steel perforated trays (0.3 x 0.3 cm) and dried at 60 °C in pilot scale conventional oven with air circulation at 0.4 m/s, measured with an anemometer (Lutron – AM 4202, Taiwan) positioned in the air entrance in the drying chamber. Fruit leathers were dried until water activity lower than 0.80, for 4 h to 9 h.

2.4 Fruit and chocolate or cupulate panned confectionery production

2.4.1 Cupulate and chocolate coating production

Chocolate and cupulate processing followed the methodology of Cohen et al. (2004). For cupulate, the fermented and dried cupuassu beans were roasted in pilot roaster (JAF INOX, Brazil) and then broken in a mill (ICMA). The shell was removed and the roasted nibs were milled and then refined with sugar in a roll mill with three rolls (PILON), internally cooled with water. In the case of chocolate, cocoa liquor was mixed with sugar and then refined with sugar in a roll mill with three rolls (Draiswerke GMBH). The following steps were the same for both chocolate and cupulate. After the refining, the next step was the conching when cocoa or cupuassu butter and the emulsifiers soybean lecithin and polyglycerol polyricinoleate were added. The conching was divided into two steps: (1) plastic conching, during four hours performed in a homogenizer equipment fitted with double jacket for heating using water heating bath at 60 °C. The equipment also has two perpendicular to each other mixers which rotate in opposite directions.; (2) liquid conching, performed in a JAF Inox conche during 12 hours. Cupulate formulation was made from 48.6% of *nibs*/liquor, 49.2% of sugar, 1.4% of cupuassu butter, 0.4% of polyglycerol polyricinoleate and 0.4% of soy lecithin. Chocolate formulation was made from 39.5% of *nibs*/liquor, 49.2% of sugar, 10.5% of cupuassu butter, 0.4% of polyglycerol polyricinoleate and 0.4% of soy lecithin.

2.4.2 Centers

Fruit centers were prepared from the fruit leather formulation SDB. The formulation was concentrated up to 60 °Brix, the by-product was added and the mixture was placed in silicone molds (1x1x1 cm). Once the cubes were firm, they were removed from the mold and dried on perforated trays (mesh 0.3x0.3cm) in oven with air circulation with 0.4 m/s of velocity, at 60 °C, until the water activity was below 0.6, for about 8 h.

2.4.3 Panned confectionery

- Sealing: The fruit cores were sealed with acacia gum solution (40% of acacia gum and 60% of water) by applying layers of acacia gum solution and water to coat all the centers in a coater (N-10, JHM Máquinas, with a 27.4 cm diameter vat). This step was repeated at least three times. The sealed centers were kept for at least 12 hours at room temperature in dry environment;

- Coating with chocolate or cupulate: chocolate or cupulate were heated and maintained at 35 °C. The centers were covered with chocolate with the coater in movement in a room with temperature of 10 to 20 °C. The coating was crystallized on the surface of the centers through the cores movement. This coating step was repeated until the mass was 2.5 times the initial mass of the centers. The coated products stand for at least 12 hours in cool place at room temperature.

- Brightness: brightness solution was prepared with acacia gum (46.67%), water (26.67%) and sucrose (26.67%). The panned confectioneries were covered with the solution and dried, with the coater in movement. This step was repeated for at least 3 times. In the last layer, the coater was kept in movement with the products inside for 30 minutes. The final products stand in a cool place for at least 12 hours.

Moisture content of both fruit bars and panned confectioneries was determined in vacuum oven at 70°C, method 920.151 (AOAC, 2006).

Figure 1 shows the developed fruit bars and panned confectionery.

Figure 1. Confectionery products formulated

Fruit bars: Pulp (P); pulp + wet by-product (PWB); wet by-product (WB); pulp + large sized dried by-product (PLDB); large sized dried by-product (LDB); pulp + small sized dried by-product (PSDB); small sized dried by-product (SDB). Panned confectioneries: CHO_C (chocolate and cambuci); CUP_C (cupulate and cambuci); CHO_G (chocolate and grumixama); CUP_G (cupulate and grumixama); CHO_U (chocolate and uvaia); CUP_U (cupulate and uvaia). Small sized dried by-product = below 0.25 mm. Large sized dried by-product = between 1.19 and 1.68 mm.

2.5 Bioactive compounds evaluation

2.5.1 Extraction

To determine total phenolic content, total anthocyanins and antioxidant capacity of the developed confectionery products, ethanolic extracts were obtained, following methodology of HAMINIUK et al. (2011). The samples (2 to 9 g) were extracted with 40mL of a 40% ethanol solution for one hour with agitation in a stirring table (120 bpm). After the extraction, they were centrifuged at 1535 x g and the supernatant filtered with Whatman n°1 filter paper. The extracts were kept at -18 °C until use. The extraction for each sample was performed in triplicate.

2.5.2 Total phenolic content

The determination of the total phenolic content followed the methodology proposed by SINGLETON and ROSSI (1965) and described by HAMINIUK et al. (2011), by using the Folin-Ciocalteu reagent with gallic acid as standard. 100 µL extract was added to 5 mL of distilled water. Then 500 µL of Folin-Ciocalteu reagent was added to the mixture and, after 3 minutes, 1.5 mL of 15% sodium carbonate was added. After completing the volume to a final volume of 10 mL, the mixture was kept in the dark and at room temperature for 2 hours. After this period, the absorbance was measured by spectrophotometer Beckman model DU-70 at 765 nm. The results were expressed as gallic acid equivalents per gram (dry basis).

2.5.3 Total Anthocyanins

Total anthocyanins assay was performed to the confectionery products made from grumixama. The assay followed methodology of CHAOVANALIKIT & WROLSTAD (2004), that uses pH differential methodology. The extracts were mixed with buffer at pH 1.0 or 4.5, in a proper proportion and had their absorbance measured in a spectrophotometer (Beckman DU-70 model), at two absorbances: 510 and 700 nm. The absorbance and the concentration of monomeric anthocyanins were calculated by equations 1 and 2, respectively:

$$A = (A_{510} - A_{700})_{pH\ 1.0} - (A_{510} - A_{700})_{pH\ 4.5} \qquad (1)$$

$$\text{monomeric anthocyanin pigments } (\text{mg}/L) = \frac{A\ x\ MW\ x\ DF\ x\ 1000}{\varepsilon\ x\ 1} \qquad (2)$$

A was the previously calculated absorbance (Equation 1), MW is the molecular weight of cyaniding-3-glucoside (449.2 g/mol), DF is the dilution factor and ε is the extinction coefficient of cyaniding-3-glucoside (26900 L/cm*mol). The results were presented in mg of cyaniding-3-glucoside equivalents /g of dry sample.

2.5.4 Antioxidant capacity

The extracts had the antioxidant capacity determined using Oxygen Radicals Absorption Capacity (ORAC) methodology, which was performed according to methodology described by DÁVALOS & CARMEN GÓMEZ-CORDOVÉS (2004). The results were expressed as micromoles of Trolox equivalent per g of sample in dry basis (µmol of TE/g).

2.6 Total dietary fiber

Total dietary fiber determination followed method 958.29 of AOAC (2006).

2.7 Sensory evaluation

Consumer tests were applied at the State University of Campinas, using standard rooms. For fruit leathers, three sensory tests were applied: one for grumixama formulations, one for uvaia and another for cambuci. For chocolate or cupulate and fruits panned confectioneries, one sensory test was performed. One hundred and twenty four (58% female and 42% male), one hundred and twenty six (62% female and 38% male) and one hundred and twenty three (63% female and 37% male) consumers participated of the study for grumixama, uvaia and cambuci fruit leathers, respectively. One hundred and twenty (61% female and 39% male) consumers participated of the panned confectionery sensory analysis. Samples were presented to the assessors at room temperature, one at a time, in random sequence, following complete blocks design (Macfie, 1989). This test was conducted with the approval of the ethics committee of the State University of Campinas (protocol numbers: 34473514.4.0000.5404 and 47862015.4.0000.5404).

2.7.1 Acceptance test

Sensory tests were performed to evaluate the acceptability of the final product through structured hedonic scale of 9 points: extremely disliked (1); disliked very much (2), disliked moderately (3), slightly disliked (4), nor liked or disliked (5), liked slightly (6), liked moderately (7), liked very much (8), extremely liked (9). For fruit leather, the assessors evaluated the appearance, taste, aroma, texture (hardness and ease of chewing) and overall liking. For chocolate or cupulate and fruit panned confectioneries, the evaluated characteristics were the same except for texture.

2.7.2 Check all that apply method (CATA)

To perform CATA method each of the assessors was invited to select from a list all the terms that described each sample. CATA attributes were selected based on literature (RAMOS, 2015; AGUDELO; VARELA; FISZMAN, 2015) and on the open discussion with fruit bars and panned confectionery consumers and specialists, which evaluated the developed products. The terms used for each sensory test are presented in Table 2, including sensory attributes (aroma, texture and taste) and attributes that measured attitude. The attributes were randomized between assessors and products (ARES; JAEGER, 2013; ARES et al., 2015).

Table 2. Check all that apply attributes that were used in the sensory analysis of each fruit bars (grumixama, uvaia and cambuci) and panned confectionery.

Product	Attibutes
Grumixama fruit bar	Acid, bad aftertaste, bitter, bitter aftertaste, fruit aroma, hard to bite, healthy, high antioxidant content , high fiber content , it can be eaten anytime, pleasant aftertaste, practical, sandy, soft texture, sweet
Uvaia fruit bar	Acid, bad aftertaste, bitter, bitter aftertaste, fruit aroma, hard to bite,

	healthy, heterogeneous appearance, high antioxidant content, high fiber content, homogeneous appearance, it can be eaten anytime, pleasant aftertaste, practical, sandy, soft texture, sweet
Cambuci fruit bar	Acid, bad aftertaste, bitter, bitter aftertaste, floral flavor, fruity aroma, fruity flavor, hard to bite, healthy, heterogeneous appearance, high antioxidants content, high fiber content, homogeneous appearance, it can be eaten anytime, pleasant aftertaste, pleasant aroma, pleasant color, practical, sandy, soft texture, sweet, unpleasant color
Panned confectionery	Acid, astringent taste, attractive color, bad aftertaste, bitter, bitter aftertaste, caramel flavor, chocolate flavor, coffee flavor, cover detaches of the core, cover does not release of the core, crumbly, earthy taste, fat taste, firm to the bite (but not hard), floral taste, fruity aroma, fruity flavor, glossy, hard to bite, healthy, heterogeneous appearance, high antioxidant content, high fiber content, homogeneous appearance, it can be eaten anytime, it takes to melt in the mouth, little sweet, melts in hand, melts in the mouth well, melts well and quickly disappears in the mouth, not attractive color, opaque, pleasant

	aftertaste, pleasant aroma, practical, sandy texture, smooth / creamy texture, soft, sour taste, sticky, sweet taste, unpleasant aroma

2.8 Statistical analysis

Antioxidant capacity, total phenolic content, total anthocyanins and acceptance data was analyzed by ANOVA and Tukey's test ($p<0.05$).

For the overall liking of the samples, a principal component analysis was carried out in order to obtain a preference map showing the consumers preference results in the first two dimensions.

CATA question data was analyzed by Cochran's Q test, comparing products independently for each attribute. A multiple factor analysis (MFA) was also performed using the contingency table of citations for CATA questions and preference data (AGUDELO; VARELA; FISZMAN, 2015).

A penalty-lift analysis was performed in order to make a correlation between CATA data and overall liking (MEYNERS; CASTURA; CARR, 2013).

Pearson's correlation was performed for ORAC and TPC and for ORAC and total anthocyanin data (MULLER at al., 2010).

3 Results and discussion

3.1 Total phenolic content (TPC), antioxidant capacity and anthocyanin content

The results for TPC, antioxidant capacity and total anthocyanins of the fruit bars and panned confectioneries are presented in Tables 3 and 4, respectively.

Table 3. Antioxidant activity (AC), total phenolic content (TPC), total anthocyanin (TA) and sensory evaluation acceptance test results for fruit bars made from different native fruits

Product	**Fruit**	**TPC (mg GAE/g)**	**AA (µmol trolox/g)**	**TA (mg cyanidin-3-glucoside equivalent/g)**	**Sensory Attributes**					
					Appearance	**Aroma**	**Flavor**	**Hardness**	**Chewiness**	**Overall liking**
LDB	G	24.7 ± 0.7^{a}	565 ± 21^{a}	5.6 ± 0.6^{a}	6.2 ± 2.2^{ab}	5.3 ± 1.9^{ab}	3.6 ± 2.0^{c}	5.4 ± 1.9^{bc}	5.3 ± 2.3^{b}	4.4 ± 1.8^{b}
P	G	4.33 ± 0.07^{e}	86 ± 9^{f}	0.09 ± 0.01^{e}	6.4 ± 1.6^{ab}	5.7 ± 1.3^{a}	5.7 ± 1.9^{a}	6.1 ± 1.8^{ab}	6.3 ± 1.9^{a}	5.9 ± 1.8^{a}
PLDB	G	11.8 ± 0.5^{c}	241 ± 26^{d}	1.9 ± 0.2^{d}	5.2 ± 2.0^{c}	5.5 ± 1.3^{ab}	4.4 ± 2.0^{b}	4.9 ± 2.1^{cd}	5.0 ± 2.1^{bc}	4.7 ± 1.8^{b}
PSDB	G	12.9 ± 0.5^{b}	278 ± 14^{c}	2.16 ± 0.03^{cd}	5.8 ± 1.8^{bc}	5.5 ± 1.4^{ab}	4.4 ± 2.1^{b}	4.4 ± 1.9^{d}	4.7 ± 2.1^{bc}	4.5 ± 1.9^{b}
PWB	G	12.8 ± 0.4^{b}	270 ± 15^{cd}	3.12 ± 0.07^{bc}	4.1 ± 2.0^{d}	5.1 ± 1.5^{ab}	5.0 ± 2.0^{ab}	4.6 ± 2.2^{d}	4.7 ± 2.0^{bc}	4.7 ± 1.9^{b}
SDB	G	9.1 ± 0.2^{d}	132 ± 5^{e}	1.48 ± 0.06^{d}	6.7 ± 1.7^{a}	5.6 ± 1.4^{ab}	5.1 ± 2.2^{ab}	6.4 ± 1.8^{a}	6.8 ± 1.8^{a}	5.7 ± 2.1^{a}
WB	G	13.2 ± 0.6^{b}	320 ± 18^{b}	3.6 ± 0.3^{b}	3.5 ± 1.9^{d}	5.0 ± 1.4^{b}	5.1 ± 2.0^{ab}	4.3 ± 2.1^{d}	4.4 ± 2.0^{c}	4.6 ± 1.8^{b}
LDB	U	5.1 ± 0.2^{a}	39 ± 2^{a}		5.7 ± 2.0^{b}	5.8 ± 1.3^{cd}	5.3 ± 2.0^{b}	5.7 ± 1.9^{c}	5.5 ± 2.0^{d}	5.4 ± 1.6^{c}
P	U	1.24 ± 0.04^{g}	18 ± 1^{e}		6.9 ± 1.7^{a}	6.6 ± 1.5^{a}	6.9 ± 1.5^{a}	7.1 ± 1.4^{a}	7.3 ± 1.4^{ab}	7.0 ± 1.3^{a}
PLDB	U	1.92 ± 0.08^{f}	23 ± 1^{d}		6.4 ± 1.8^{a}	6.6 ± 1.3^{a}	6.9 ± 1.5^{a}	7.1 ± 1.3^{a}	7.3 ± 1.4^{ab}	7.0 ± 1.2^{a}
PSDB	U	2.23 ± 0.06^{e}	23 ± 1^{d}		6.7 ± 1.6^{a}	6.5 ± 1.2^{a}	6.7 ± 1.6^{a}	7.1 ±1.3^{a}	7.5 ± 1.2^{a}	6.9 ± 1.2^{ab}
PWB	U	2.57 ± 0.05^{d}	28 ± 1^{c}		5.4 ± 1.9^{b}	6.3 ± 1.3^{ab}	6.3 ± 1.8^{a}	6.5 ± 1.7^{ab}	6.8 ± 1.7^{bc}	6.4 ± 1.6^{b}
SDB	U	3.2 ± 0.1^{c}	31 ± 2^{bc}		6.7 ± 1.5^{a}	5.9 ± 1.4^{bc}	5.4 ± 1.9^{b}	6.0 ± 1.9^{bc}	6.5 ± 1.7^{c}	5.7 ± 1.6^{c}
WB	U	3.85 ± 0.06^{b}	31.0 ± 0.6^{b}		3.5 ± 1.8^{c}	5.4 ± 1.5^{d}	4.4 ± 2.0^{c}	3.3 ± 1.7^{d}	3.6 ± 1.9^{e}	4.0 ± 1.8^{d}
LDB	C	11.3 ± 0.5^{a}	92 ± 6^{a}		4.4 ± 2.2^{c}	5.6 ± 1.6^{c}	3.6 ± 2.1^{d}	4.9 ± 2.0^{c}	5.0 ± 2.2^{d}	4.0 ± 1.9^{d}
P	C	3.8 ± 0.2^{e}	25 ± 2^{e}		7.1 ± 1.5^{a}	6.7 ± 1.3^{a}	7.3 ± 1.5^{a}	7.3 ± 1.3^{a}	7.7 ± 1.1^{a}	7.3± 1.4^{a}

PLDB	C	6.9 ± 0.2^{c}	58 ± 5^{d}	6.3 ± 1.9^{b}	6.5 ± 1.4^{ab}	5.9 ± 2.0^{b}	6.9 ± 1.6^{a}	7.2 ± 1.6^{ab}	6.3 ± 1.8^{b}
PSDB	C	7.2 ± 0.2^{c}	61 ± 4^{d}	6.6 ± 1.7^{ab}	6.5 ± 1.5^{ab}	5.8 ± 2.0^{b}	6.7 ± 1.5^{ab}	6.9 ± 1.6^{bc}	6.1 ± 1.7^{bc}
PWB	C	7.0 ± 0.3^{c}	69 ± 3	5.9 ± 1.7^{b}	6.4 ± 1.4^{ab}	5.9 ± 2.0^{b}	6.9 ± 1.5^{a}	7.1 ± 1.4^{ab}	6.2 ± 1.7^{bc}
SDB	C	5.4 ± 0.2^{d}	76 ± 3^{b}	4.4 ± 2.2^{c}	5.6 ± 1.6^{c}	3.6 ± 2.1^{d}	4.9 ± 2.0^{c}	5.0 ± 2.2^{d}	4.0 ± 1.9^{d}
WB	C	10.6 ± 0.4^{b}	82 ± 4^{b}	4.7 ± 2.0^{c}	6.0 ± 1.4^{bc}	4.1 ± 2.0^{d}	4.0 ± 2.1^{d}	4.5 ± 2.1^{d}	4.2 ± 2.0^{d}

Values in the same column having the same letter for each fruit are not significantly different at a confidence level of 95%. Pulp (P); pulp + wet by-product (PWB); wet by-product (WB); pulp + large sized dried by-product (PLDB); large sized dried by-product (LDB); pulp + small sized dried by-product (PSDB); small sized dried by-product (SDB); grumixama (G), cambuci (C) and uvaia (U). Small sized dried by-product = below 0.25 mm. Large sized dried by-product = 1.19 - 1.68 mm. Results in dry basis.

Table 4. Antioxidant activity (AC), total phenolic content (TPC), total anthocyanin (TA) and sensory acceptance test results for panned confectioneries

Formulation	TPC (mg GAE/g)	AA (µmol trolox/g)	TA (mg cyanidin-3-glucoside equivalent/g) *	Sensory Attributes				
				Appearance	Aroma	Flavor	Texture	Overall liking
CHO_C	6.5 ± 0.3^{b}	183 ± 18^{b}	-	7.4 ± 1.6 ^{a}	6.9 ± 1.7 ^{a}	6.0 ± 2.2 ^{cd}	6.4 ± 1.8 ^{ab}	6.2 ± 2.0 ^{bc}
CUP_C	3.0 ± 0.1^{e}	140 ± 10^{c}	-	7.7 ± 1.4 ^{a}	6.5 ± 1.6 ^{a}	5.6 ± 1.9 ^{d}	6.2 ± 1.7 ^{ab}	5.9 ± 1.9 ^{c}
CHO_G	8.5 ± 0.4^{a}	304 ± 27^{a}	0.7 ± 0.1 ^{a}	7.6 ± 1.3 ^{a}	7.0 ± 1.5 ^{a}	6.7 ± 1.8 ^{ab}	6.6 ± 1.7 ^{a}	6.8 ± 1.6 ^{ab}
CUP_G	4.7 ± 0.2^{d}	204 ± 28^{b}	0.53 ± 0.05 ^{a}	7.8 ± 1.2 ^{a}	6.7 ± 1.7 ^{a}	6.3 ± 1.9 ^{abc}	6.5 ± 1.7 ^{ab}	6.4 ± 1.7 ^{abc}
CHO_U	5.1 ± 0.2^{c}	122 ± 9^{c}	-	7.5 ± 1.4 ^{a}	6.9 ± 1.7 ^{a}	7.0 ± 1.7 ^{a}	6.5 ± 1.8 ^{ab}	6.9 ± 1.6 ^{a}
CUP_U	2.2 ± 0.2^{f}	92 ± 13^{d}	-	7.7 ± 1.3 ^{a}	6.7 ± 1.5 ^{a}	6.1 ± 1.9 ^{bcd}	5.9 ± 2.0 ^{b}	6.2 ± 1.8 ^{bc}

Values in the same column having the same letter are not significantly different at a confidence level of 95%. CHO_C (chocolate and cambuci); CUP_C (cupulate and cambuci); CHO_G (chocolate and grumixama); CUP_G (cupulate and grumixama); CHO_U (chocolate and uvaia); CUP_U (cupulate and uvaia).
* evaluated just in grumixama because it is not present in cambuci and uvaia.

Tables 3 and 4 present the results for total phenolic content of fruit bars and panned confectioneries, respectively. The results differed according to the different formulations. In addition, by the analysis of the results it was possible to visualize the differences between fruits. We observed a growing range of levels: the lowest values occurred for uvaia products, intermediate values are relative to cambuci products, and higher values refer to the formulations with grumixama.

For the three fruits, the fruit bar with the maximum total phenolic content was LDB and fruit bar with minimum total phenolic content was P. The intervals of this study expressed in mg gallic acid / g dry basis are 4.33 to 24.7 (grumixama); 1.24 to 5.1 (uvaia); and from 3.8 to 11.3 (cambuci).

Regarding the TPC of panned confectioneries, all samples differed significantly of each other, suggesting that in addition to the differences between the fruit, the coating also influences the results. The biggest TPC content was found for grumixama CHO (8.5 ± 0.4 mg gallic acid / g dry sample), and the lowest for uvaia CUP (2.2 ± 0.2 mg gallic acid / g dry sample). It is worth noting that the chocolate and cupulate formulations also contribute for the antioxidant capacity and phenolic compounds of the product. It is also possible to observe that products with chocolate had approximately twice the TPC found for cupulate products. The values found for grumixama, uvaia and cambuci fruit bars were, respectively, 9.1, 3.2 and 5.4 mg GAE/ g dry sample. In the case of uvaia, adding the coating increased TPC content. For grumixama and cambuci, the chocolate coating increased TPC content, but cupulate coating lead to a lower TPC. A possible explanation for this observation is that cupulate coating used in this study may have less TPC content than the chocolate. Thus, the application of cupulate to a fruit by-product based core increases the proportion of coating mass in comparison to the core mass, decreasing the TPC content in comparison to the product without the coating (fruit bar). Furthermore, the core was produced in a different format (cubes) and was dried until water activity lower than 0.6, facts that might also contribute to the different results when comparing to the fruit bars.

HAMINIUK et al. (2011) studied the total phenolic content of ethanolic extracts of Brazilian native fruits, including the three used in our study. The levels found by the author in mg GAE / 100 mL were 56.873 ± 3.150, 37.340 ± 1.410 and 341.400 ± 19.078 for grumixama, uvaia and cambuci pulps, respectively.

Considering that the fruit pulp is the current commercialized product in the market, we can make a comparison between the TPC and dietary fiber of the developed confectionery products and the TPC and dietary fiber of the fruit pulps, using the quantities present in a serving size as reference. To calculate the values, the serving size of the pulps and confectionery products was 100 g and 20g, respectively. The calculated TPC values by serving size is showed in Figure 2. For grumixama, a serving size of 20 g of fruit bars have from 30% (P) to 178% (LDB) of TPC from 100 g of grumixama pulp. For cambuci, 20 g of fruit bars have from 25% (P) to 74% (LDB) of the TPC from 100 g of cambuci pulp. For uvaia, 20 g of fruit bars have from 17% (P) to 72% (LDB) of the TPC from 100 g of uvaia pulp. For panned confectionery, 20 g of the products have from 25% (CUP_C) to 89% (CHO_U) of the TPC of respective fruit pulp (serving size 100 g). It is important to emphasize that the chocolate and cupulate coverage of panned confectionery also contribute to the TPC.

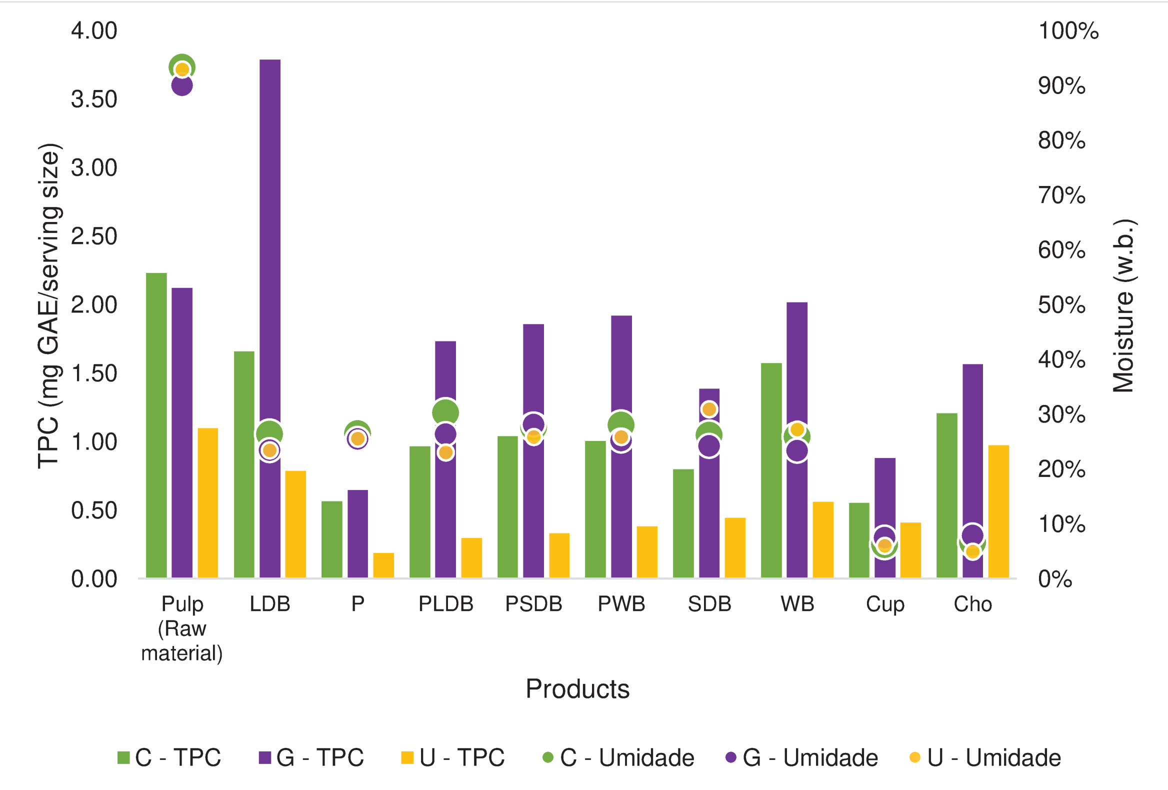

Figure 2. TPC of confectionery products and fruit pulps, wet basis.

Large sized dried by-product (LDB); Pulp (P); pulp + large sized dried by-product (PLDB); pulp + small sized dried by-product (PSDB); pulp + wet by-product (PWB); small sized dried by-product (SDB); wet by-product (WB); chocolate (Cho) and cupulate (Cup) panned confectioneries. grumixama (G), cambuci (C) and uvaia (U);Small sized dried by-product = below 0.25 mm. Large sized dried by-product = 1.19 - 1.68 mm.

The antioxidant capacity of the products was evaluated by ORAC. The results of the ORAC analysis revealed a similar tendency for total phenolic content. Comparing the fruit bars formulations of the same fruit, for the three fruits, the highest antioxidant capacity occurred to LDB and the lowest to P formulations. Comparing the fruits, grumixama presented the highest antioxidant values while uvaia presented the lowest. Fruit bars antioxidant results varied from 86 to 565 µmol trolox/ g dry sample (grumixama), 18 to 39 µmol trolox/ g dry sample (uvaia) and 25 to 92 µmol trolox/ g dry sample (cambuci).

For panned confectioneries, the antioxidant capacity of cambuci covered with chocolate and grumixama covered with cupulate were not significantly different between each other. Cambuci covered with cupulate and uvaia covered with chocolate were statistically similar to each other. The highest ORAC value was found to grumixama covered with chocolate (304 ± 27 µmol trolox/ g dry sample), and the lowest was found to uvaia covered with cupulate (92 ± 13 µmol trolox / g dry sample). For all fruits, chocolate-panned confectioneries presented higher antioxidant capacity than the cupulate ones.

Pearson’s correlation coefficient was calculated to ORAC and TPC data. A high positive correlation was found (0.8543).

In relation to anthocyanins, evaluated just for grumixama fruit bars, the formulations were statistically different when compared to each other. The values varied between 0.09 (P) to 5.6 (LDB) mg cyanidin-3-glucoside equivalent/g. Evaluating the results for panned confectioneries, the coverage used (chocolate or cupulate) did not lead to significant difference between the samples. Because chocolate and cupulate coverages contributed to antioxidant capacity but did not contribute to total anthocyanin content, only grumixama fruit bar results were used to calculate the correlation between ORAC and total anthocyanin. Pearson’s correlation coefficient was positive: 0.96.

3.2 Fiber content

The fiber content (dry basis) of the pulps and by-products was evaluated (Table 5) and used to estimate the fiber content of the developed fruit bars. As long as for TPC evaluation, fiber content was calculated in the products and compared to the pulps considering the products’ serving size (Figure 3).

Table 5. Fiber content of fruit by-products and pulps (dry basis)

Raw material	**Fiber (g/100g)**
Cambuci by-product	49.0 ±0.7
Cambuci pulp	24.3 ±0.4
Grumixama by-product	39.7 ±0.4
Grumixama pulp	13.6 ±0.1
Uvaia by-product	52 ±2
Uvaia pulp	11.7 ±0.2

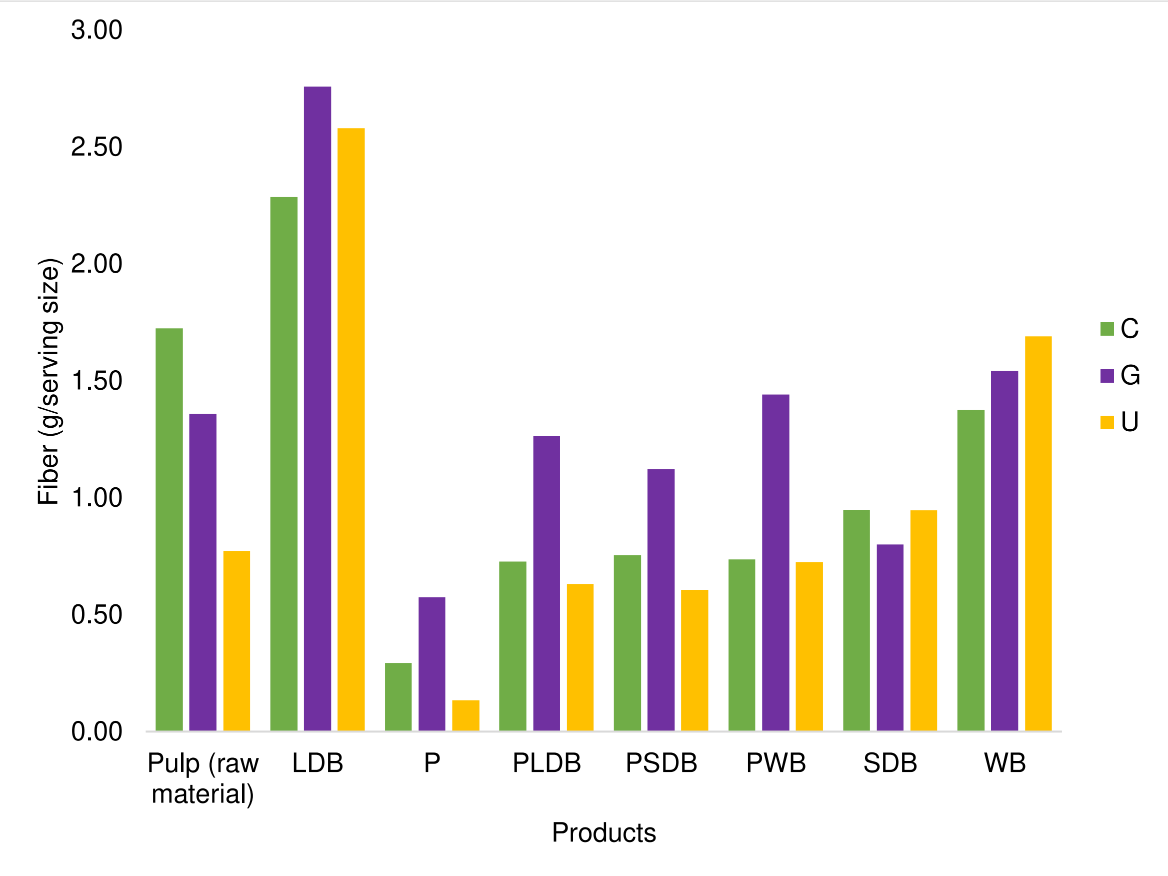

Figure 3. Dietary fiber of fruit bars and fruit pulps, wet basis.

Pulp = raw material. Fruit bars: Large sized dried by-product (LDB); Pulp (P); pulp + large sized dried by-product (PLDB); pulp + small sized dried by-product (PSDB); pulp + wet by-product (PWB); small sized dried by-product (SDB); wet by-product (WB); grumixama (G), cambuci (C) and uvaia (U). Small sized dried by-product = below 0.25 mm. Large sized dried by-product = between 1.19 - 1.68 mm.

Calculated fiber results showed that fruit bars presented from 0.13 (P) to 2.58 (LDB), 0.57 (P) to 2.76 (LDB) and 0.29 (P) to 2.29 (LDB) grams of fibers per serving size (20 g of fruit bar, wet basis), for uvaia, grumixama and cambuci, respectively. In order to compare fruit bars fiber results, we used the pulp fiber quantity in a serving size (100 g of pulp, wet basis) as reference. The fiber present in a serving size of 20 g of fruit bars was up to 334% (LDB, uvaia), 203% (LDB, grumixama) and 132% (LDB, cambuci) of the quantity of fiber of a serving size of 100 g of the respective fruit pulp.

3.3 Sensory Analysis

3.3.1 Test of acceptance with consumers

The results of the sensory evaluation of the fruit bars (acceptance) are presented in Table 3 and of the panned confectionery in Table 4.

In general, the samples of grumixama fruit bar, P and SDB were the formulations that presented the highest acceptance scores considering the majority of the attributes. For uvaia fruit bar, P, PSDB and PLDB were the samples that presented the highest acceptance scores. Among cambuci fruit bars, the highest scores for all attributes occurred for formulation P. On the other hand, the less accepted formulations were PWB, WB, PLDB, LDB and PSDB (grumixama), SDB and LDB (uvaia) and LDB, WB and SDB (cambuci). These results indicate it would be interesting to associate the use of by-products with other better-accepted products such as pulp.

The highest overall liking score was near to 6 for grumixama bars, while for cambuci and uvaia, the highest scores were near to 7. Considering the form of the by-product in the formulations, the use of the large dried by-product or the wet by-product (without the association with pulp) was not attractive to the consumers for all fruits.

In order to verify the possibility of applying the fruit residue in other confectionery and match the taste of fruit waste with other ingredients, the formulations of fruit bar that contained only the small dried by-product (SDB) were chosen. Cores were developed from these formulations and were panned with cupulate or chocolate.

In relation to appearance and aroma, the panned confectioneries did not differ ($p > 0.05$). Considering the results of same fruits for the taste attribute, only uvaia presented a statistical significant difference between cupulate and chocolate formulations, being CHO_U the sample with the best evaluation. Considering the overall liking of panned confectioneries, there were significant differences between the samples. Overall liking scores ranged between 5.9 and 6.9. CUP_G, CHO_G and CHO_U were the samples that showed the highest overall liking scores. SDB overall liking scores for grumixama, uvaia and cambuci were, respectively, 5.7, 5.7 and 5.6. In that manner, we could suggest that there was a good association of the by-product based centers and the chocolate or cupulate coverage.

An internal preference map was constructed in order to show the individual preference of each consumer for grumixama, uvaia and cambuci fruit bars and panned confectioneries. The maps for each product are shown in Figure 4.

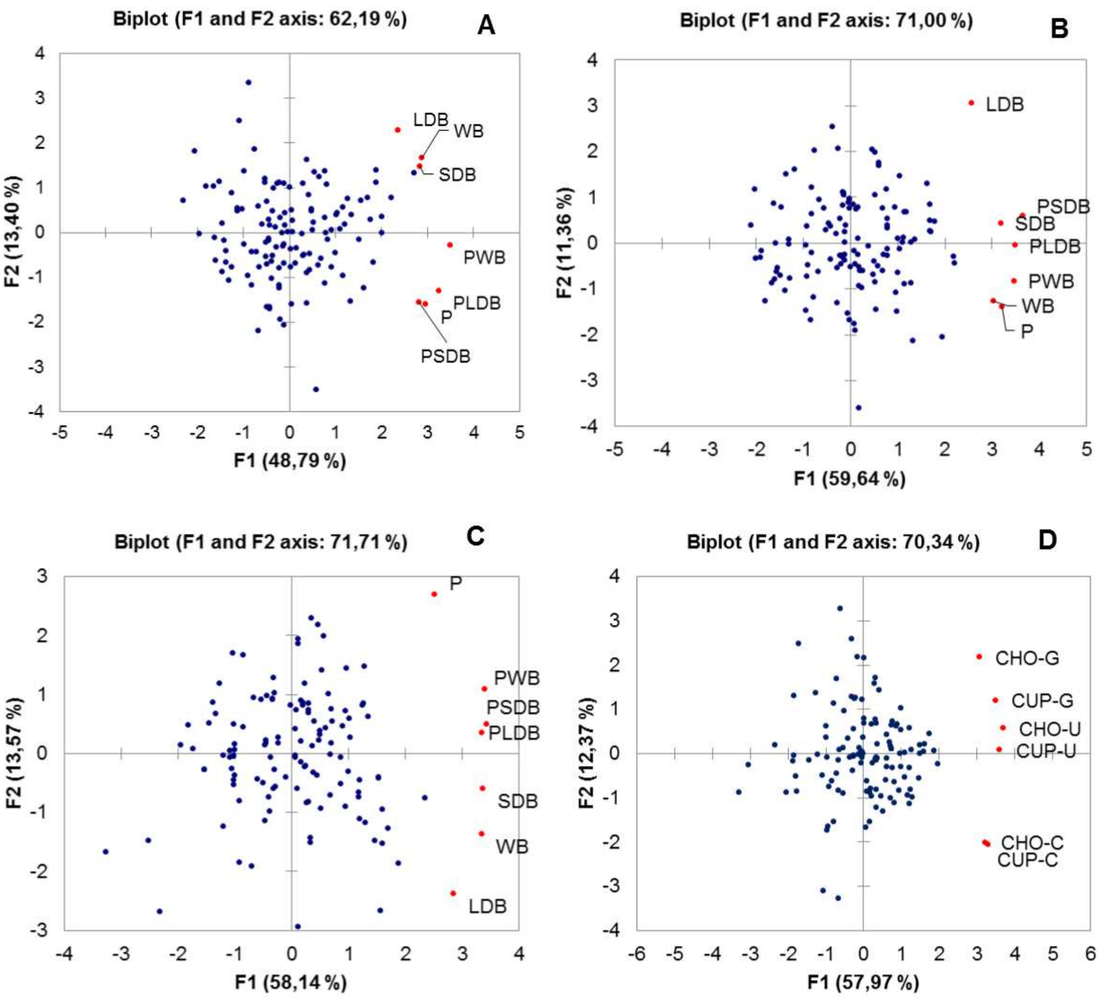

Figure 4. Internal preference map. A-Uvaia fruit bar. B-Grumixama fruit bar. C-Cambuci fruit bar. D-Panned confectioneries

Large sized dried by-product (LDB); Pulp (P); pulp + large sized dried by-product (PLDB); pulp + small sized dried by-product (PSDB); pulp + wet by-product (PWB); small sized dried by-product (SDB); wet by-product (WB); chocolate (Cho) and cupulate (Cup) panned confectioneries. grumixama (G), cambuci (C) and uvaia (U); .Small sized dried by-product: below 0.25 mm. Large sized dried by-product: between 1.19 and 1.68 mm.

The first two dimensions F1 and F2 presented in the maps represents 71.00%, 62.19%, 71.71% and 70.34% of overall liking results for grumixama fruit bar, uvaia fruit bar, cambuci fruit bar and panned confectioneries, respectively. For all maps, the first dimension F1 explained the majority of the results: 59.64, 48.79, 58.14 and 57.97 for grumixama fruit bar, uvaia fruit bar, cambuci fruit bar and panned confectioneries, respectively. We can observe that the consumers are distributed quite uniformly in dimensions F1 and F2 for the four plots, while all samples are concentrated in the positive side of the F1 axis. Apparently, F2 was the axis that distinguished the samples' acceptance. For uvaia and grumixama fruit bars, the most accepted samples were positioned in the negative part of F2 axis and for cambuci fruit bar and panned confectioneries, the positive part of F2 axis was related to better accepted products.

3.3.2 CATA

Table 5 presents the frequencies (in percentage) of citation of the CATA terms by the consumers. The terms that presented 20% or less of frequency of citation for all samples were no longer considered for CATA data evaluation (CRUZ et al., 2013). For grumixama, uvaia and cambuci fruit bars, no terms were eliminated. For panned confectioneries, on the other hand, 26 of the 42 presented terms were considered. The eliminated terms in the product's evaluation were: *acid*, *astringent taste, caramel flavor, coffee flavor, earthy taste, fat taste, healthy, heterogeneous appearance, high antioxidant content, It takes to melt in the mouth, melts in the hand, melts well and quickly disappears in the mouth, not attractive color, opaque, smooth / creamy texture, unpleasant aroma*.

Table 5. Frequency (%) of citation of each of the terms of the CATA for samples of fruit bar and panned confectionery produced with cambuci, grumixama and uvaia by-products.

Terms of the CATA Analysis	FRUIT BAR: Frequency of responses (%)								Terms of the CATA Analysis	PANNED CONFECTIONERY: Frequency of responses (%)					
	Fruit	P	PWB	WB	PLDB	LDB	PSDB	SDB		CHO-U	CHO-G	CHO-C	CUP-U	CUP-G	CUP-C
Acid	U	51^{c}	54^{c}	23^{a}	42^{bc}	32^{ab}	51^{c}	26ª	Acid	5	8	19	9	13	20
bad aftertaste	U	4^{a}	17^{bc}	31^{c}	6^{a}	25^{bc}	11^{ab}	24^{bc}	adstringent taste	3	18	12	3	15	13
Bitter	U	5^{ab}	13^{abc}	28^{c}	4^{a}	17^{bc}	6^{ab}	21^{c}	attractive color	38^{a}	41^{a}	27^{a}	40^{a}	41^{a}	38ª
bitter aftertaste	U	3^{a}	10^{abcd}	24^{d}	6^{ab}	18^{bcd}	7^{abc}	18^{cd}	bad aftertaste	6^{a}	20^{bc}	24^{bc}	15^{ab}	20^{bc}	31^{c}
fruit aroma	U	61^{cd}	60^{cd}	31^{a}	67^{d}	41^{ab}	55^{bcd}	44^{abc}	bitter	12^{a}	27^{b}	16^{ab}	8^{a}	18^{ab}	12ª
hard to bite	U	2^{a}	17^{b}	79^{c}	2^{a}	11^{ab}	3^{a}	10^{ab}	bitter aftertaste	16^{a}	36^{b}	22^{ab}	14^{a}	28^{ab}	21^{ab}
Healthy	U	47^{abc}	56^{c}	33^{a}	56^{bc}	48^{abc}	50^{bc}	40^{ab}	caramel flavor	3	4	2	6	5	5
heterogeneous appearance	U	14^{b}	58^{c}	59^{c}	58^{c}	62^{c}	5^{ab}	2ª	chocolate flavor	65^{c}	64^{bc}	44^{a}	42^{a}	48^{ab}	34ª
high antioxidant contente	U	16^{a}	21^{a}	15^{a}	21^{a}	16^{a}	19^{a}	14ª	coffee flavor	8	8	8	18	17	10
high fiber contente	U	13a	45^{cd}	51^{d}	56^{d}	82^{e}	21^{ab}	34^{bc}	coverage detaches of the core	35^{b}	23^{ab}	18^{a}	23^{ab}	13^{a}	20ª
homogeneous appearance	U	67^{b}	20^{a}	14^{a}	17^{a}	13^{a}	79^{b}	75^{b}	coverage does not release of the core	17^{a}	22^{a}	20^{a}	24^{a}	28^{a}	24ª
it can be eaten anytime	U	56^{c}	48^{bc}	29^{a}	50^{bc}	40^{abc}	46^{bc}	37^{ab}	crumbly	26^{b}	10^{a}	14^{ab}	8^{a}	8^{a}	7ª
pleasant aftertaste	U	59^{b}	48^{b}	18^{a}	57^{b}	21^{a}	48^{b}	29ª	earthy taste	9	11	11	8	12	18
practical	U	48^{b}	46^{b}	25^{a}	42^{b}	38^{b}	46^{b}	44^{b}	fat taste	5	3	2	8	8	9
Sandy	U	2^{a}	19^{b}	24^{bc}	36^{cd}	85^{e}	10^{ab}	51^{d}	firm to the bite (but not hard)	53^{a}	54^{a}	53^{a}	52^{a}	44^{a}	45ª

soft texture	U	55^{c}	26^{b}	2^{a}	48^{c}	8^{a}	56^{c}	26^{b}
Sweet	U	54^{d}	36^{c}	9^{a}	48^{cd}	19^{ab}	56^{d}	33^{bc}
Acid	C	52^{bc}	67^{cd}	57^{bcd}	72^{d}	48^{ab}	72^{d}	32^{a}
bad aftertaste	C	2^{a}	28^{b}	62^{c}	24^{b}	68^{c}	20^{b}	53^{c}
Bitter	C	2^{a}	19^{b}	58^{d}	20^{b}	62^{d}	24^{bc}	40^{c}
bitter aftertaste	C	2^{a}	22^{b}	43^{cd}	24^{b}	53^{d}	24^{b}	32^{bc}
floral flavor	C	11^{a}	34^{c}	26^{bd}	24^{abc}	34^{c}	18^{ab}	30^{bc}
fruit flavor	C	74^{e}	49^{cd}	27^{ab}	60^{de}	20^{a}	49^{cd}	38^{bc}
Fruit aroma	C	60^{d}	46^{bcd}	25^{a}	47^{cd}	24^{a}	42^{bc}	30^{ab}
hard to bite	C	2^{ab}	1^{a}	68^{d}	2^{ab}	22^{c}	9^{abc}	11^{bc}
Healthy	C	38^{ab}	36^{ab}	27^{a}	45^{b}	33^{ab}	34^{ab}	35^{ab}
heterogeneous appearance	C	8^{a}	47b	43^{b}	44^{b}	49^{b}	4^{a}	2^{a}
high antioxidants content	C	16^{a}	19^{a}	22^{a}	22^{a}	23^{a}	18^{a}	17^{a}
high fiber content	C	17^{a}	51^{cd}	48^{c}	54^{cd}	67^{d}	25^{ab}	33^{b}
homogeneous appearance	C	63^{b}	12^{a}	11^{a}	21^{a}	12^{a}	63^{b}	67^{b}
	C	48^{c}	38^{bc}	28^{ab}	36^{abc}	24^{a}	36^{abc}	31^{ab}
it can be eaten anytime								
pleasant aftertaste	C	49^{c}	28^{b}	7^{a}	28^{b}	5^{a}	28^{b}	16^{ab}
pleasant aroma	C	41^{c}	33^{bc}	15a	39^{c}	13^{a}	36^{bc}	23^{ab}
pleasant color	C	61^{c}	23^{b}	5^{a}	28^{b}	7^{a}	32^{b}	18^{b}
Practical	C	50^{d}	37^{bcd}	27^{ab}	39^{bcd}	24^{a}	41^{cd}	34^{abc}
Sandy	C	5^{a}	37^{c}	38^{c}	46^{c}	82^{d}	19^{b}	46^{c}
soft texture	C	52^{d}	38^{cd}	3^{a}	43^{cd}	7^{a}	28^{bc}	23^{b}
Sweet	C	63^{d}	20^{bc}	8^{ab}	24^{c}	5^{a}	24^{c}	30^{c}
unpleasant color	C	9^{a}	27^{b}	54^{c}	24^{ab}	53^{c}	25^{b}	28^{b}

floral flavor	9^{a}	8^{a}	33^{c}	11^{ab}	6^{a}	23^{bc}
fruity aroma	24^{a}	23^{a}	33^{a}	21^{a}	21^{a}	30^{a}
fruity flavor	46^{a}	47^{a}	61^{a}	51^{a}	43^{a}	53^{a}
Glossy	18^{a}	23^{a}	20^{a}	15^{a}	14^{a}	18^{a}
hard to bite	21^{b}	8^{ab}	6^{a}	15^{ab}	7^{a}	7^{a}
Healthy	15	17	17	15	13	18
heterogeneous appearance	8	7	4	4	8	7
high antioxidant content	8	8	7	3	7	6
high fiber contente	16	16	12	18	13	20
homogeneous appearance	38^{a}	33^{a}	33^{a}	31^{a}	31^{a}	34^{a}
it can be eaten anytime	38^{a}	33^{a}	28^{a}	31^{a}	28^{a}	28^{a}
it takes to melt in the mouth	10	9	11	13	14	13
little sweet	13^{a}	18^{a}	24^{a}	17^{a}	19^{a}	23^{a}
melts in hand	4	6	6	3	3	3
melts in the mouth well	21^{a}	20^{a}	17^{a}	18^{a}	19^{a}	15^{a}
melts well and quickly disappears						
in the mouth	18	12	9	13	12	13
not attractive color	7	4	4	7	2	3
Opaque	13	17	13	14	18	11
pleasant aftertaste	44^{b}	23^{a}	27^{a}	32^{ab}	18^{a}	21^{a}
pleasant aroma	34^{a}	32^{a}	26^{a}	31^{a}	21^{a}	20^{a}
Practical	30^{a}	33^{a}	27^{a}	25^{a}	29^{a}	24^{a}
sandy texture	17^{a}	13^{a}	9^{a}	23^{a}	21^{a}	20^{a}
smooth / creamy texture	13	13	12	16	16	20
Soft	26^{a}	38^{a}	30^{a}	31^{a}	33^{a}	41^{a}

Acid	G	51^{d}	27^{bc}	10^{a}	38^{cd}	13^{ab}	45^{d}	15^{ab}	sticky	26^{a}	21^{a}	25^{a}	33^{a}	24^{a}	24^{a}
bad aftertaste	G	27^{a}	35^{ab}	32^{ab}	46^{bc}	71^{d}	53^{c}	48^{bc}	sweet taste	53^{b}	43^{ab}	37^{ab}	45^{ab}	43^{ab}	30^{a}
Bitter	G	27^{a}	43^{abc}	33^{ab}	47^{bc}	55^{c}	59^{c}	49^{bc}	unpleasant aroma	2	2	5	1	1	3
bitter aftertaste	G	27^{a}	44^{b}	35^{ab}	52^{b}	72^{c}	52^{b}	50^{b}							
fruit aroma	G	49^{b}	34^{ab}	31^{a}	35^{ab}	28^{a}	28^{a}	31^{a}							
hard to bite	G	19^{b}	57^{cd}	57^{d}	40^{c}	6^{a}	53^{cd}	6^{a}							
Healthy	G	43^{b}	40^{ab}	44^{b}	37^{ab}	27^{a}	34^{ab}	43^{b}							
high antioxidant content	G	24^{a}	27^{a}	19^{a}	23^{a}	19^{a}	25^{a}	25^{a}							
high fiber content	G	27^{a}	44^{c}	50^{cd}	44^{bc}	64^{d}	28^{ab}	27^{a}							
it can be eaten anytime	G	45^{b}	35^{ab}	35^{ab}	33^{a}	25^{a}	29^{a}	34^{ab}							
pleasant aftertaste	G	37^{c}	19^{b}	23^{bc}	13^{ab}	6^{a}	11^{ab}	20^{b}							
Practical	G	46^{b}	37^{ab}	35^{ab}	39^{ab}	26^{a}	31^{ab}	42^{b}							
Sandy	G	4^{a}	13^{abc}	17^{bcd}	27^{cd}	69^{e}	10^{ab}	31^{d}							
soft texture	G	20^{b}	7^{a}	6^{a}	6^{a}	24^{b}	4^{a}	29^{b}							
Sweet	G	35^{d}	19^{bc}	21^{cd}	7^{ab}	4^{a}	6^{a}	25^{cd}							

Large sized dried by-product (LDB); Pulp (P); pulp + large sized dried by-product (PLDB); pulp + small sized dried by-product (PSDB); pulp + wet by-product (PWB); small sized dried by-product (SDB); wet by-product (WB); chocolate (Cho) and cupulate (Cup) panned confectioneries. grumixama (G), cambuci (C) and uvaia (U); Small sized dried by-product = below 0.25 mm. Large sized dried by-product = between 1.19 and 1.68 mm. Products sharing the same letter(s) do not differ significantly (p≤0.05) for each attribute by Cochran's test. Attributes without letters were not evaluate by Cochran's test

For cambuci fruit bars, the terms most frequently cited in CATA (above 40% for the majority of the samples) were *fruit flavor*, *acid* and *fruit aroma*. For uvaia, these terms were *fruit aroma*, *practical*, *healthy*, *it can be eaten anytime*, *acid*, *heterogeneous appearance*, *high fiber content* and *pleasant aftertaste*. For grumixama, the most checked terms were *hard to bite*, *bitter*, *bitter aftertaste*, *bad aftertaste*, *healthy* and *high fiber content*.

For panned confectioneries, in general, the main terms that were selected by the judges were *chocolate flavor*, *fruit flavor*, *firm to bite (but not hard)*, *attractive color* and *sweet taste*, all with 40% of frequency for the majority of the evaluated samples. These terms can be more related to the core (like *fruit flavor*), to the coverage (like *chocolate flavor*) or both (like *firm to bite*). Although chocolate and cupulate have different flavor, 44% of the consumers checked "chocolate flavor" for CUP_U, for example.

Non-parametric Cochran's test revealed significant differences for almost all CATA parameters sensory evaluated in uvaia, grumixama and cambuci fruit bars. For these three sensory tests, the only parameter that did not differ among samples was *high antioxidant content*. P, PLDB and PSDB were the formulations that presented the highest overall liking scores among uvaia fruit bars. According to Cochran's test, they presented characteristics such as higher fruit aroma, lower bad and bitter aftertaste, lower bitterness, softer texture, higher sweetness, higher pleasant aftertaste, lower bitter aftertaste and higher acidity.

In the case of grumixama bar, the two samples with highest overall liking scores (P and SDB) presented characteristics such as softer texture and higher sweetness. However, they differed in some characteristics. P was harder to bite, presented higher fruit aroma, lower bitter aftertaste, lower bitterness, lower sandiness, higher pleasant aftertaste and higher acidity.

For cambuci, the sample with the highest overall liking scores (P) in comparison to the other samples presented characteristics such as not hard to bite, lower fiber content, higher fruit aroma, lower unpleasant color, lower bad aftertaste, lower bitterness, lower sandiness, higher soft texture, higher pleasant color, higher sweetness, higher pleasant aftertaste, intermediary acidity, lower bitter aftertaste, higher fruity flavor and lower floral flavor.

The Cochran's test for panned confectioneries showed that characteristics such as *fruit aroma*, *sticky*, *it can be eaten anytime*, *fruit flavor*, *sandy texture*, *melts* *well in mouth*, *soft*, *glossy*, *attractive color*, *practical*, *pleasant aroma*, *homogeneous*, *little sweet*, *coverage detaches of the core* and *firm to bite* did not differ among samples.

TARANCÓN et al. (2015) used CATA questions to evaluate healthier fats in biscuits and the consumers were also able to differ the samples with CATA descriptors. Figure 5 presents Multiple factor analysis of CATA data.

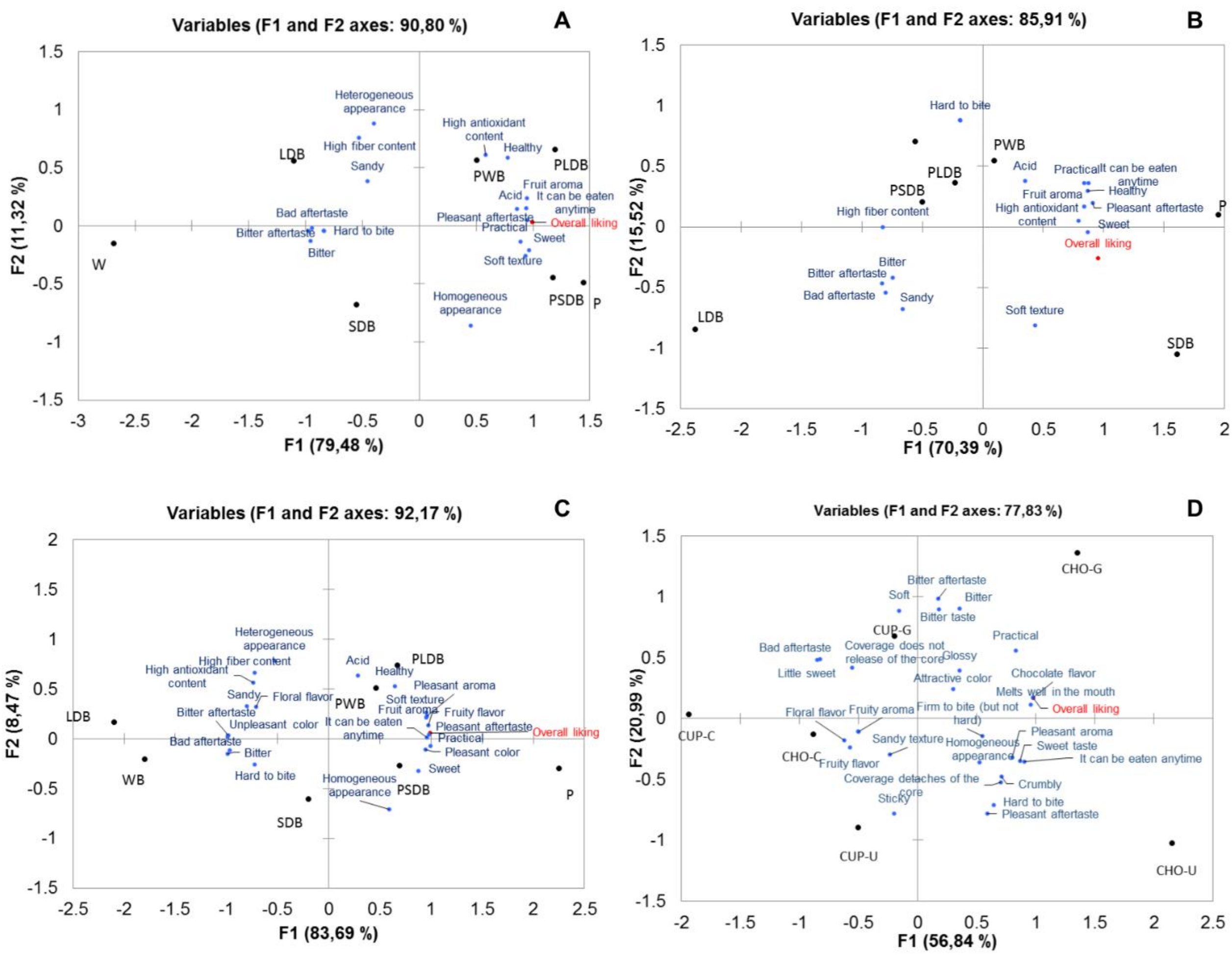

Figure 5. Multiple factor analysis. A-Uvaia fruit bar. B-Grumixama fruit bar. C-Cambuci fruit bar. D-Panned confectioneries.

Large sized dried by-product (LDB); Pulp (P); pulp + large sized dried by-product (PLDB); pulp + small sized dried by-product (PSDB); pulp + wet by-product (PWB); small sized dried by-product (SDB); wet by-product (WB); chocolate (Cho) and cupulate (Cup) panned confectioneries. grumixama (G), cambuci (C) and uvaia (U); .Small sized dried by-product is the by-product with particle size below 0.25 mm. Large sized dried by-product is the by-product with particle size between 1.19 and 1.68 mm.

F1 and F2 axes in MFA explained 90.80% of the uvaia fruit bars CATA and overall liking data, being F1 responsible for 79.48%. The formulations with pulp (P, PLDB, PSDB, PWB) were all positioned in the positive side of F1 axis in the plot, where the overall liking is also positioned. Acceptability is also close to characteristics such as *practical*, *fruit aroma*, *sweet*, *acid* and *soft texture*. On the other hand, samples without pulp (SDB, LDB and WB) were positioned in the negative part of F1 axis, being close to characteristics such as *bitter*, *bitter aftertaste*, *hard to bite* and *bad aftertaste*.

For grumixama fruit bars, F1 and F2 axes in MFA explained 85.91% of CATA and overall liking data, being F1 responsible for 70.39%. The higher acceptability occurred for P, SDB and PWB samples, matching with *sweet*, *pleasant aftertaste*, *high antioxidant content*, *fruit aroma* and *practical*. On the other hand, PLDB, PSDB, WB and LDB were in the opposite side of acceptability and near to features such as *bitter*, *bitter aftertaste*, *bad aftertaste*, *sandy* and *high fiber content*.

Cambuci data was 92.17% explained by F1 and F2 axes in MFA plot, being F1 responsible for 83.69%. Comparable to uvaia, the formulations with pulp and the overall liking are positioned in the positive side of F1 axis and the other formulations are in the negative side. Furthermore, acceptability is near to features like *fruity flavor*, *pleasant aftertaste*, *practical*, *pleasant color* and *sweet*.

For panned confectioneries, F1 and F2 together explained less the data: 77.83%, divided into 56.84% for F1 and 20.99% for F2. The closest characteristic to overall liking is *chocolate flavor*. The flavor attributed to the final product by the coverage lead to a more interesting product to the consumers.

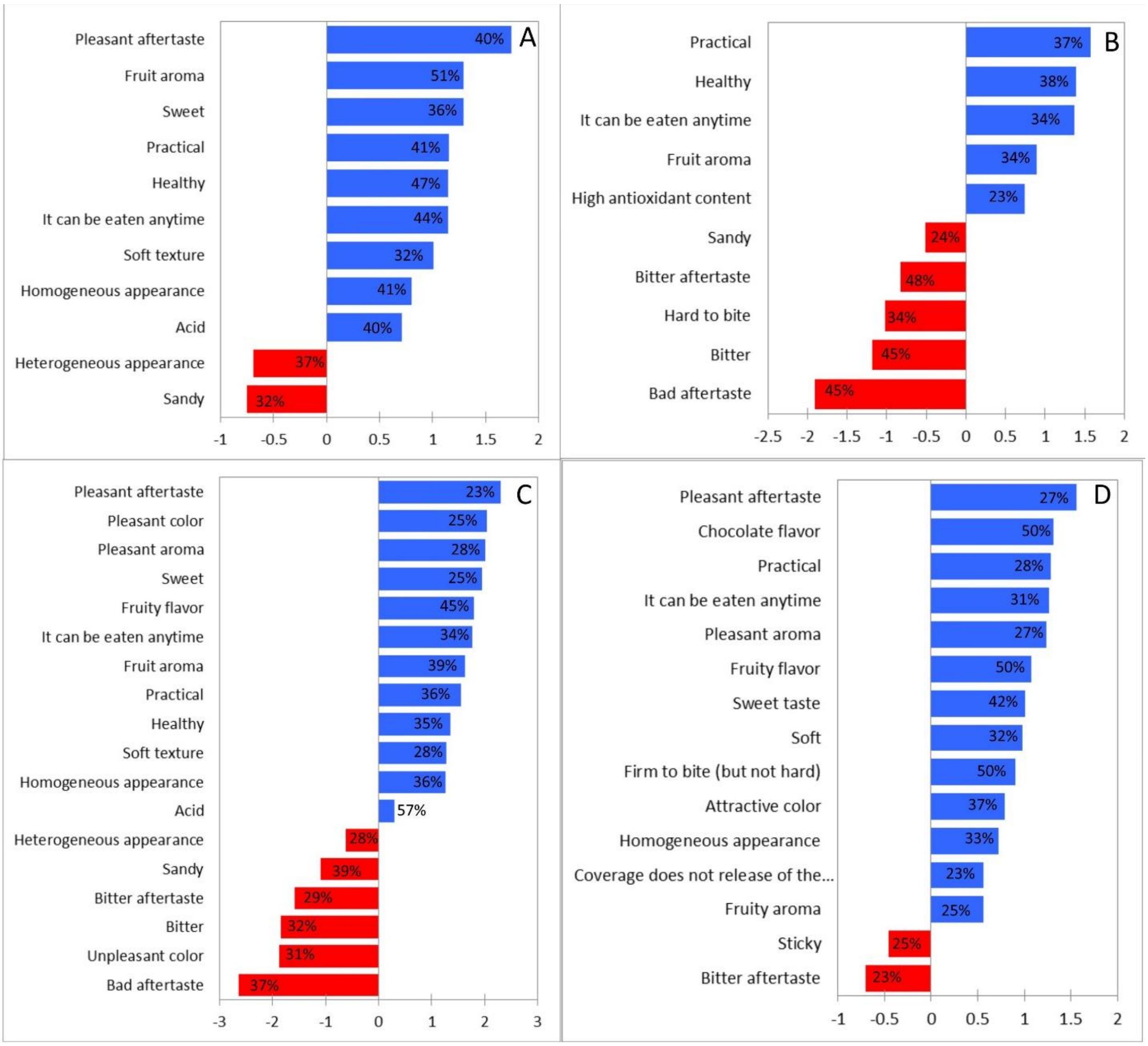

Figure 6. Penalty-lift analysis of CATA data for all products by fruit. A-uvaia fruit bar. B-grumixama fruit bar. C-cambuci fruit bar. D-panned confectionery. Percentage number represent the frequency of observations in which the attribute was used to characterize the product.

For each product, a penalty lift analysis was performed in order to correlate acceptance and CATA data and to verify the CATA attributes that contributed positively or negatively to the overall liking. The attributes in the positive part of x-axis represent a positive influence in the acceptance data while the attributes in the negative part of x-axis represents a negative influence in the acceptance data. The x values represents the effect of the attribute in the averages (Figure 6).

For uvaia fruit leathers, the attributes that negatively influenced the acceptance data were *heterogeneous appearance* and *sandy*. The attributes that positively contributed to the acceptance were *pleasant aftertaste, fruit aroma, sweet, practical, healthy, it can be eaten anytime, soft texture, homogeneous appearance and acid*. *Pleasant aftertaste* was the attribute with the highest positive effect in the acceptance average (1.7), being cited in 40% of the observations.

It can be eaten anytime, *healthy*, *fruit aroma*, *high antioxidant content* and *practical* were the attributes that positively contributed to overall liking and *bad aftertaste*, *bitter*, *hard to bite*, *sandy* and *bitter aftertaste* were the attributes that negatively influenced the acceptance for grumixama fruit bars. *Practical* was the attribute with the highest positive effect in the acceptance average (1.6), being cited in 37% of the observations. *Bad aftertaste* was the attribute with the highest negative effect in acceptance average (-1.9), being highly cited (45% of the observations)

For cambuci fruit bars, CATA descriptors that negatively influenced were *heterogeneous appearance*, *sandy*, *bitter aftertaste*, *bitter*, *unpleasant color* and *bad aftertaste*. The attributes that positively influenced were *pleasant aftertaste, pleasant color, pleasant aroma, sweet, fruit flavor, it can be eaten anytime, fruit aroma, practical, healthy, soft texture, homogeneous appearance and acid*. Pleasant aftertaste had the highest positive effect in overall liking average (2.3) and was cited in 23% of the observations. *Bad aftertaste* had the highest negative effect in overall liking average (-2.6) and was cited in 37% of the observations.

For panned confectioneries, the attributes that negatively contributed to the acceptance were *sticky* and *bitter aftertaste*. In addition, the attributes that positively contributed were *pleasant aftertaste, chocolate flavor, practical, it can be eaten anytime, pleasant aroma, fruit flavor, sweet taste, soft, firm to bite (but not hard), attractive color, homogeneous appearance, coverage does not release of the core* and *fruit aroma*. *Pleasant aftertaste* was the attribute that presented the highest positive effect in acceptance average (1.6) and was cited in 27% of the observations. *Chocolate flavor* presented the second highest positive influence on the acceptance average (1.3) and was cited in 50% of the observations.

4 Conclusion

TPC and antioxidant capacity presented a high Pearson correlation coefficient. Pulp and fruit by-product can be source of phenolic compounds and antioxidant capacity to confectionery products.

Considering the acceptance among the fruit bars, uvaia and cambuci presented a higher potential than grumixama. CATA questions were a good tool to understand consumer's perceptions about the products. In association with the overall liking, it was possible to suppose which attributes contributed positively or negatively to the acceptance scores. In a general view, characteristics such as *bitter*, *bitter aftertaste*, *bad aftertaste* and *sandy* negatively influenced the acceptance and characteristics such as *fruit aroma*, *it can be eaten anytime, pleasant aftertaste* and *practical* lead to a better acceptance of some of the products.

Nevertheless, for all fruits, improvements can be done, such as changing the proportion of pulp/by-product or associating with other products. These changes should be able to reduce the perception of bad or bitter aftertastes by the consumers. The use of the fruit bar formulation with the small dried by-product in order to obtain fruit based cores to produce chocolate/cupulate panned confectionery was a good alternative to improve the sensory acceptance.

Briefly, the results express the market potential of fruit bars and panned confectioneries made from Brazilian native fruit pulp and by-products, being an alternative to add value to the residue generated by the fruit processing chain.

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CAPÍTULO 6

Fruit pulp and by-product based jelly candies: bioactive compounds and sensory evaluation

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Fruit pulp and by-product based jelly candies: bioactive compounds and sensory evaluation

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Abstract

Consumers are increasingly concerned about the health and consumption of healthier products. Under this situation, there is a tendency to reduce or replace the use of artificial colorants and flavors of various products such as confectionery. The use of fruit pulp or by-product is an opportunity to use natural ingredients to the product. The aim of the present study was to apply the pulp and by-products of three Brazilian native fruits (grumixama, uvaia and cambuci) to produce healthier jelly candies. The content of the bioactive compounds (total phenolic content and total anthocyanin), total antioxidant capacity, as well as the sensory characteristics (acceptance test and Check all that apply methodology) were evaluated. Jelly candies made from by-product had a higher total phenolic content and antioxidant capacity than those made with pulp. However, in a general view, pulp formulations were better accepted than those with by-product. The better-evaluated samples were related to features like sweet, fruit aroma and pleasant aftertaste. By-product formulations were related to features like bitter and bitter aftertaste.

1 Introduction

Tropical fruits have a prominent role in the Brazilian agricultural production, thanks to factors such as the vast size of the country and tropical climate that favor this type of cultivation. The country is the third largest fresh fruit producer (FAO, 2016), and this activity contributes to 25% of the total agricultural production value (BARRETO; BENASSI; MERCADANTE, 2009). Fruits can be consumed in various forms and are extensively used in the production of frozen pulps and other fruit products, but can also be utilized for the dairy industry, ice cream, candy etc.(KUSKOSKI et al., 2006). Currently, many specific native fruits have been explored, as well as their products. Among them, some Atlantic Forest native fruits can be highlighted, such as uvaia (*Eugenia pyriformis*), cambuci (*Campomanesia phaea*) and grumixama (*Eugenia brasiliensis Lam.*).

The frozen pulp industry generates a lot of waste, consisting mostly of peel, seeds and bagasse. It is estimated that these residues account for up to 65 to 70% of the weight of the raw material and can lead to environmental problems in case of an improper disposal (LOUSADA JUNIOR et al., 2006). The residues may still have compounds that can be interesting to human nutrition, such as nutrients, bioactive compounds and fibers.

Fiber presence in nutrition have been related to some health benefits, such as ability to regulate bodily functions in order to help protect against diseases such as hypertension, diabetes, cancer, osteoporosis and coronary artery disease (SOUZA, et al., 2003). In addition to help in bowel function, foods enriched with fibers also have influence on the reduction of plasma cholesterol and increase the level of the hormone cholecystokinin, resulting in a decreased absorption of glucose and fat (SLAVIN, 2005; KENDALL; ESFEHANI; JENKINS, 2010).

Other important class of compounds present in the fruit by-products are the polyphenols. Some of them are studied for their health benefits such as reducing the risk of developing diseases such as cancer, Alzheimer's disease, cataracts, and Parkinson. These characteristics are due to the antioxidant capacity and ability to capture free radicals that these compounds have, retarding or inhibiting oxidation of DNA, proteins and lipids (AYALA-ZAVALA et al., 2011).

As fruit wastes are a low-cost product and generally have in their composition a considerable amount of fiber and bioactive compounds, it seems interesting to use them in the formulation of other food products, to increase the fiber and antioxidant content of the final product. The direct use of by-products in food products can be interesting either to minimize losses and to add value to the developed products. Many authors have studied ways of using solid waste generated by the fruit industry in other industries (ethanol, biogas, pharmaceuticals, animal feed, etc.) or in the food industry. Some examples of the possible uses in the food industries are: use of apple pomace for cake formulation (SUDHA; BASKARAN; LEELAVATHI, 2007), jam formulation using passion fruit peel (DIAS et al., 2011), use of apple pomace in wheat flour supplementation (KTENIOUDAKI; O'SHEA; GALLAGHER, 2013), among other applications. One segment where these fruit by-products could also be used is in confectionery products.

Jelly candies are confectionery products with low cooking periods and high moisture content (20%) comparing with hard and chewy candies, for example. The texture is provided by the gelling agent used, as arabic gum, agar, gelatin, pectin and starches (QUEIROZ, 1999; SWEETMAKER 1981; KATZ ET WIENEN, 1991). Consumers are looking forward to reduce or replace the use of artificial colors and flavors of various products such as confectionery. Their concern about health and consumption of healthier products is getting higher nowadays. The use of fruit pulp or by-product is an opportunity to add a natural ingredient to the product. Few studies about using fruit pulp or residues in confectionery products have been found. Silva et al. (2016) have studied different processed açaí pulps in chewy candies production. Cappa, Lavelli, & Mariotti (2014) have used grape skin to enrich fruit candies.

This project aims at studying the viability of the application of the waste generated from the production of frozen pulp from fruits typical of the Atlantic Forest (cambuci, uvaia and grumixama) in jelly candies, as long as evaluating the final product's total phenolic compounds, antioxidant capacity and sensory characteristics by acceptance tests and check all that apply questions.

2 Material and Methods

2.1 Material

In order to produce the jelly candies, the following ingredients were used: dried grumixama, uvaia and cambuci by-product, pectin (GENU® D Slow Set Confectionery, CP Kelco); sucrose (União, purchased in Campinas local market, São Paulo, Brazil); glucose syrup (Glucogill 40DE, Cargill); agar (Mix, purchased in Campinas local market, São Paulo, Brazil); gelatin (250H8, Rousselot); arabic gum (Instantgum BB, Nexira); sodium citrate (Cargill). The analysis were carried out using the following material: Reagents: Folin-Ciocalteau (Dinamica), gallic acid (Sigma-Aldrich), trolox 6-hydroxy-2,5,7,8-tetramethylchroman-2-carboxylic acid (Sigma-Aldrich), fluorescein (Sigma-Aldrich); 2,2'-Azobis(2-amidinopropane) dihydrochloride (Sigma-Aldrich).

2.2 Processing

2.2.1 Obtaining the dry fruit residues

The by-products of grumixama, uvaia and cambuci were obtained from a native fruit producer (Sítio do Bello, Paraibuna, São Paulo, Brazil). They were previously centrifuged, removing the water, and then hot air dried at air velocity of 0.4m/s in a conventional dryer with air circulation and renovation (Pilot Plant of Fruit, Vegetables, Coffee, Cocoa, Sugary and Beverage Products, Department of Food Technology, Faculty of Food Engineering, Unicamp). For the drying procedure, the centrifuged by-product was disposed in thin layers in perforated trays (0.3 x 0.3cm). Drying parameters were defined in an earlier study. Uvaia and grumixama by-products were dried at 40 °C and cambuci by-product was dried at 80 °C, until constant sample weight. For cambuci, the next step was milling the dried by-product in a multi-use mill

(Tecnal TE at 631/2) and in a IKA Labortechnik A10 mill. Grumixama and uvaia residues, however, had an additional step, that involved the separation of the seeds. The separated peel and bagasse were then milled. The by-products were milled until less than 0.25mm and were stored in vacuum packaging (Metalized polyethylene terephthalate 17g/m² + white polystyrene 100 g/m²), at -18 °C until use.

2.2.2 Jelly candy production

Jelly candies were formulated from pulp or by-product and pectin (JC-PP and JC-PB); agar (JC-AP and JC-AB); agar and pectin (JC-APP and JC-APB); gelatin (JC-GP and JC-GB); gelatin and arabic gum (JC-GAGP and JC-GAGB). Besides fruit (pulp or by-product) and the jellying agent, all formulations presented sucrose, glucose syrup and sodium citrate. The formulations for grumixama (G), cambuci (C) and uvaia (U) are presented in Table 1.

Table 1. Formulations for jelly candies produced from pulp or by-product of grumixama (G), uvaia (U) and cambuci (C) in percentage

Formulation	Fruit	Pulp	Sucrose	Glucose syrup	Water	Sodium citrate	Agar	Pectin	Arabic gum	Gelatin	Dried by-product	Citric Acid
JC-APP	G	30.00	24.00	28.00	13.90	0.10	3.00	1.00	-	-	-	-
JC-GP	G	30.00	26.00	30.00	4.70	0.30	-	-	-	9.00	-	-
JC-PP	G	29.97	20.98	24.98	22.38	0.10	-	1.50	-	-	-	0.10
JC-GAGP	G	10.30	26.00	30.00	16.75	0.30	-	-	8.40	8.25	-	-
JC-APB	G	-	25.84	29.82	34.69	0.10	2.98	0.99	-	-	4.97	0.60
JC-GB	G	-	26.00	30.00	27.90	0.10	-	-	-	11.00	5.00	-
JC-PB	G	-	25.90	29.88	34.76	0.10	-	3.98	-	-	4.98	0.40
JC-GAGB	G	-	17.01	21.02	40.03	0.30	-	-	8.40	8.25	4.99	-
JC-AB	G	-	26.00	30.00	34.90	0.10	4.00	-	-	-	5.00	-
JC-AP	G	30.00	34.20	19.00	14.00	0.30	2.50	-	-	-	-	-
JC-APP	U	30.00	24.00	28.00	13.90	0.10	3.00	1.00	-	-	-	-
JC-GP	U	30.00	26.00	30.00	4.70	0.30	-	-	-	9.00	-	-
JC-PP	U	30.00	21.00	25.00	22.40	0.10	-	1.50	-	-	-	-
JC-GAGP	U	10.30	26.00	30.00	16.75	0.30	-	-	8.40	8.25	-	-
JC-APB	U	-	26.00	30.00	34.90	0.10	3.00	1.00	-	-	5.00	-

JC-GB	U	-	26.00	30.00	27.90	0.10	-	-	-	11.00	5.00	-	-
JC-PB	U	-	26.00	30.00	34.90	0.10	-	4.00	-	-	5.00	-	
JC-GAGB	U	-	26.00	30.00	22.05	0.30	-	-	8.40	8.25	5.00	-	
JC-AB	U	-	26.00	30.00	36.40	0.10	2.50	-	-	-	5.00	-	
JC-AP	U	30.00	34.20	19.00	14.00	0.30	2.50	-	-	-	-	-	
JC-APP	C	30.00	24.00	28.00	12.90	0.10	3.00	1.00	-	-	-	-	
JC-GP	C	30.00	26.00	30.00	4.70	0.30	-	-	-	9.00	-	-	
JC-PP	C	30.00	21.00	25.00	22.40	0.10	-	1.50	-	-	-	-	
JC-GAGP	C	10.30	26.00	30.00	16.75	0.30	-	-	8.40	8.25	-	-	
JC-APB	C	-	26.00	30.00	34.90	0.10	3.00	1.00	-	-	5.00	-	
JC-GB	C	-	26.00	30.00	29.90	0.10	-	-	-	9.00	5.00	-	
JC-PB	C	-	26.00	30.00	34.90	0.10	-	4.00	-	-	5.00	-	
JC-GAGB	C	-	26.00	30.00	22.05	0.30	-	-	8.40	8.25	5.00	-	
JC-AB	C	-	26.00	30.00	36.40	0.10	2.50	-	-	-	5.00	-	
JC-AP	C	30.00	34.20	19.00	14.00	0.30	2.50	-	-	-	-	-	

Jelly candies with pulp (JC-PP) or by-product (JC-PB) with pectin, pulp (JC-AP) or by-product (JC-AB) with agar; pulp (JC-APP) or by-product (JC-APB) with agar and pectin; pulp (JC-GP) or by-product (JC-GB) with gelatin, pulp (JC-GAGP) or by-product (JC-GAGB) with gelatin and arabic gum

The different jelly candies formulations were produced according to different methodologies, as described below, in Figure 1.

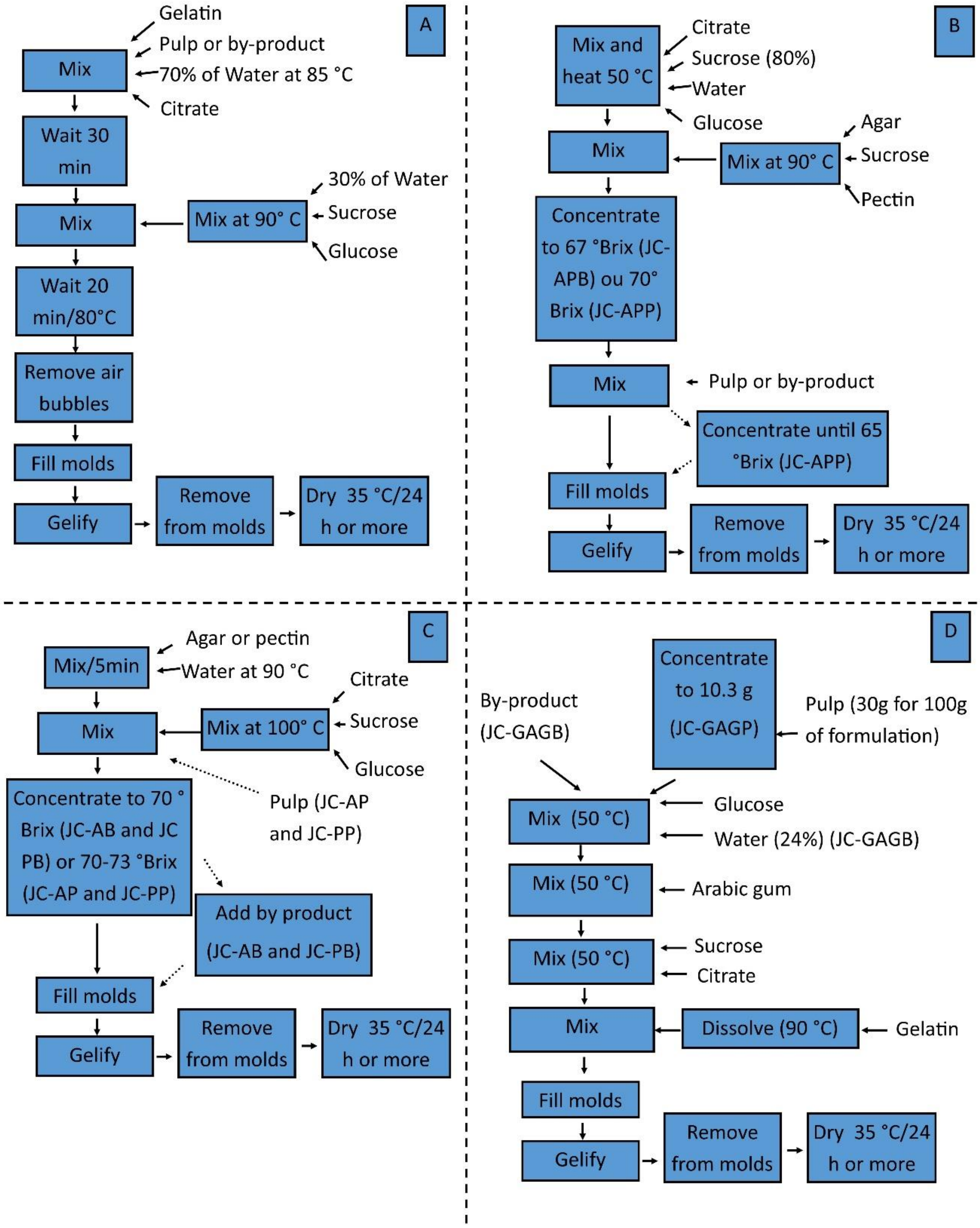

Figure 1. Production of jelly candies.

A – JC-GP and JC-GB. B – JC- APP and JC-APB. C – JC-PP, JC-PB, JC-AP and JC-AB. D – JC-GAGP and JC-GAGB. Jelly candies with pulp (JC-PP) or by-product (JC-PB) with pectin, pulp (JC-AP) or by-product (JC-AB) with agar; pulp (JC-APP) or by-product (JC-APB) with agar and pectin; pulp (JC-GP) or by-product (JC-GB) with gelatin, pulp (JC-GAGP) or by-product (JC-GAGB) with gelatin and arabic gum

Jelly candies were dried at 35 °C until water activity was lower than 0.75. Figure 2 presents the developed jelly candies.

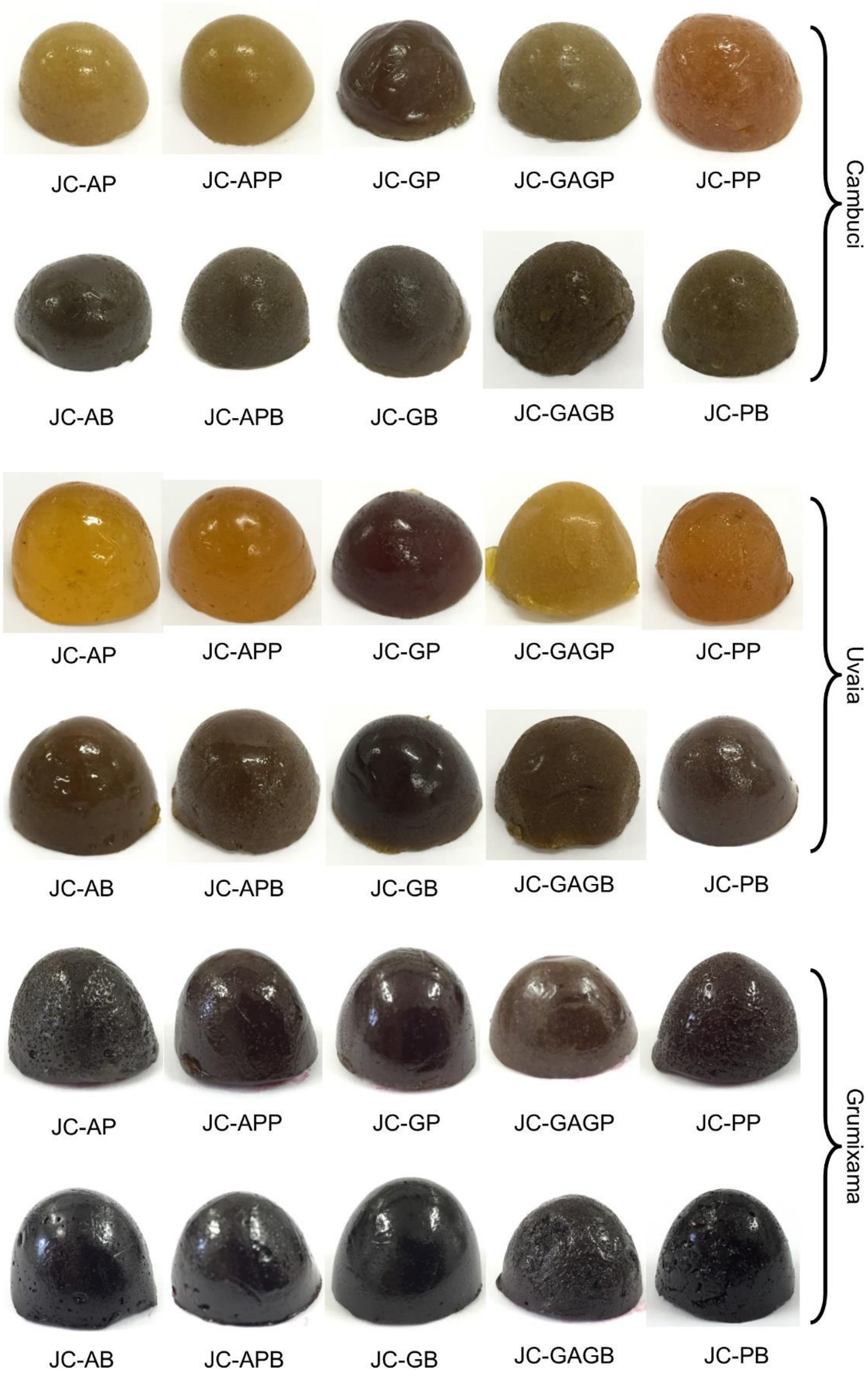

Figure 2. Jelly candies with pulp or by-product and pectin (JC-PP and JC-PB); agar (JC-AP and JC-AB); agar and pectin (JC-APP and JC-APB); gelatin (JC-GP and JC-GB); gelatin and arabic gum (JC-GAGP and JC-GAGB)

Moisture content of jelly candies was determined in vacuum oven at 70°C, according to method 920.151 (AOAC, 2006).

2.3 Chemical and physico-chemical analysis

2.3.1 Total phenolic content (TPC), total anthocyanins and antioxidant capacity

The analysis of the bioactive compounds was performed according to HAMINIUK et al. (2011). An ethanolic extract was used to determine total phenolic content, total anthocyanins and antioxidant capacity of the developed jelly candies. Jelly candies (2.4 to 12 g) were extracted with 40mL of a 40% ethanol solution for one hour. After the extraction, the mixture was centrifuged at 1535 x g and the supernatant was filtered with filter paper (Whatman n°1). The extracts were kept at -18 °C until use. The extraction for each sample was performed in triplicate.

The total phenolic content was quantified using Folin-Ciocalteu reagent according to the method proposed by SINGLETON AND ROSSI (1965) and described by HAMINIUK et al. (2011). 100 µL extract was added to 5 mL of distilled water. After that, 500 µL of Folin-Ciocalteu reagent was added to the mixture. 3 minutes later, 1.5 mL of 15% sodium carbonate was added. The final volume was completed up to 10 mL with distilled water and the mixture was kept in the dark at room temperature for 2 hours for the reactions to complete. The absorbance was measured by using a spectrophotometer Beckman DU-70 model at 765 nm. A gallic acid curve was used as standard for the calculation. The results were expressed as gallic acid equivalents (GAE) per gram (dry basis).

The antioxidant capacity assay was performed through ORAC, as described by DÁVALOS & GÓMEZ-CORDOVÉS (2004). The results were expressed as micromoles of Trolox equivalent per g of sample in dry basis (µmol TE/g).

Grumixama formulations were evaluated for their total anthocyanins assay, by pH differential methodology (CHAOVANALIKIT & WROLSTAD, 2004). The extracts were mixed with buffer at pH 1.0 or 4.5, in a proper proportion and had their absorbance measured in a spectrophotometer (Beckman DU-70 model), at two absorbance values: 510 and 700 nm. The absorbance and the concentration of monomeric anthocyanins were calculated by the equations 1 and 2, respectively.

$$A = (A_{510} - A_{700})_{pH\,1.0} - (A_{510} - A_{700})_{pH\,4.5} \qquad (1)$$

$$\text{monomeric anthocyanin pigments (mg}/L) = \frac{A\,x\,MW\,x\,DF\,x\,1000}{\varepsilon\,x\,1} \qquad (2)$$

Where: A was the previously calculated absorbance (Equation 1), MW is the molecular weight of cyanidin 3 glucoside (449.2 g/mol), DF is the dilution factor and ε is the extinction coefficient of cyanidin 3 glucoside (26900 L/cm*mol). The final total anthocyanins results were expressed in mg of cyanidin 3 glucoside equivalents /g of dry sample.

2.3.2 Total dietary fiber

Total dietary fiber determination followed method 958.29 of AOAC (2006).

2.4 Sensory Evaluation (Consumer Tests)

Consumer tests were conducted with the approval of the ethics committee of the State University of Campinas (protocol number 34473514.4.0000.5404). Sensory tests used standard cabins. Three sensory tests were applied, one for each of the three fruits. One hundred and twenty two, one hundred and twenty four and one hundred and twenty four consumers participated of the study for grumixama, uvaia and cambuci jelly candies, respectively. Samples were presented to the consumers in random sequence following complete blocks design (MACFIE; BRATCHELL, 1989). They were presented at room temperature, one at a time.

2.4.1 Acceptance test

Sensory tests of acceptance were performed to evaluate the consumers' preference for the jelly candies. A hedonic scale was used, from 1 to 9: extremely disliked (1); disliked very much (2), disliked moderately (3), slightly disliked (4), not liked or disliked (5), liked slightly (6), liked moderately (7), liked a lot (8), extremely liked (9). The evaluated parameters were: aroma, taste, easy to chew, stickiness and overall liking.

2.4.1 Check all that apply (CATA)

To perform CATA method, the assessors selected from a list all the terms that described each sample. The terms used for each fruit test are presented in Table 2. The attributes were randomized between assessors and products (ARES; JAEGER, 2013; ARES et al., 2015). CATA attributes selection was based on literature (RAMOS, 2015; AGUDELO; VARELA; FISZMAN, 2015) and on the open discussion with jelly candied consumers and specialists, which evaluated the developed products.

Table 2. Check all that apply questions that were used in the sensory analysis of each jelly candy (grumixama, uvaia and cambuci)

Product	CATA terms
Grumixama jelly candy	Hard to bite, high fiber content, fruit aroma, bad aftertaste, firm to bite, healthy, bitter, sandy, stick, it can be eaten anytime, sweet, pleasant aftertaste, high antioxidant content, practical, bitter aftertaste, acid
Uvaia jelly candy	Easy to chew, high fiber content, fruit aroma, bad aftertaste, firm to bite, healthy, bitter, sandy, sticky, it can be eaten anytime, sweet, pleasant aftertaste, high antioxidant content, practical, bitter aftertaste, fruity flavor, acid
Cambuci jelly candy	Acid, bad aftertaste, bitter, bitter aftertaste, easy to chew, firm to bite, floral flavor, fruit flavor, fruit aroma, healthy, high antioxidant content, high fiber content, it can be eaten anytime, pleasant aftertaste, pleasant aroma, practical, sandy, sticky, sweet

2.5 Statistical analysis

ANOVA and Tukey's test ($p<0.05$) were used in order to analyze antioxidant capacity, total phenolic content, total anthocyanins and acceptance data. A principal component analysis was carried out in order to obtain a preference map from overall liking of the samples showing the consumers preference results in the first two dimensions.

Check all that apply results were analyzed by Cochran's Q test, comparing products independently for each attribute. Furthermore, a multiple factor analysis (MFA) was also performed using the contingency table of citations for CATA questions and preference data (AGUDELO et al., 2015; CRUZ et al, 2013). A penalty-lift analysis was performed in order to make a correlation between CATA data and overall liking (MEYNERS; CASTURA; CARR, 2013).

3 Results and discussion

Table 3 presents the results for TPC, antioxidant capacity and total anthocyanins of all developed jelly candies.

Table 3. Antioxidant activity (AA), total phenolic content (TPC), total anthocyanin (TA) and acceptance results for jelly candies produced from pulp or by-product of grumixama (G), uvaia (U) and cambuci (C).

		Chemical Analysis *			Sensory analysis				
Formulation	**Fruit**	**TPC (mg GAE/g)**	**AA (µmol trolox/g)**	**TA (mg cyanidin-3-glucoside eq/g) ****	**Aroma**	**Taste**	**Chewiness**	**Stickness**	**Overall liking**
JC-APP	G	0.85 ± 0.06^{e}	14.2 ± 0.9^{g}	0.03 ± 0.00^{f}	5.5 ± 1.3^{abc}	4.8 ± 2.1 ^{bc}	6.7 ± 1.6 ^{a}	6.5 ± 1.7 ^{a}	5.5 ± 1.8 ^{bc}
JC-GP	G	1.24 ± 0.07^{de}	18 ± 1^{fg}	0.31 ± 0.02^{e}	5.1 ± 1.2^{bc}	5.3 ± 1.7 ^{b}	3.2 ± 1.8 ^{e}	5.3 ± 2.2 ^{b}	4.9 ± 1.9 ^{bcd}
JC-PP	G	1.18 ± 0.03^{de}	22 ± 2^{efg}	0.01 ± 0.00^{f}	5.9 ± 1.3^{a}	6.7 ± 1.9 ^{a}	6.7 ± 1.6 ^{a}	5.8 ± 1.8 ^{ab}	6.5 ± 1.7 ^{a}
JC-GAGP	G	1.47 ± 0.06^{d}	31 ± 2^{e}	0.25 ± 0.01^{e}	5.5 ± 1.5 ^{ab}	5.4 ± 1.8 ^{b}	5.8 ± 1.9 ^{b}	5.6 ± 1.9 ^{b}	5.6 ± 1.7 ^{b}
JC-APB	G	6.5 ± 0.5^{b}	132 ± 4^{ab}	1.77 ± 0.05^{b}	5.1 ± 1.3 ^{bc}	3.8 ± 2.4 ^{de}	5.5 ± 1.9 ^{bc}	5.6 ± 1.9 ^{b}	4.2 ± 2.1 ^{de}
JC-GB	G	4.8 ± 0.3	79 ± 8^{d}	0.76 ± 0.04^{d}	5.0 ± 1.4 ^{c}	4.2 ± 1.8 ^{cd}	3.4 ± 1.8 ^{e}	5.3 ± 1.9 ^{b}	4.1 ± 1.8 ^{e}
JC-PB	G	6.5 ± 0.2^{b}	128 ± 9^{b}	2.20 ± 0.08^{a}	5.2 ± 1.1 ^{bc}	5.0 ± 2.0 ^{bc}	4.8 ± 2.0 ^{cd}	5.2 ± 1.8 ^{b}	4.8 ± 1.7 ^{cd}
JC-GAGB	G	5.2 ± 0.3^{c}	110 ± 9^{c}	1.09 ± 0.05^{c}	5.4 ± 1.1 ^{bc}	5.1 ± 1.6 ^{b}	6.6 ± 1.5 ^{a}	5.7 ± 1.8 ^{b}	5.3 ± 1.7 ^{bc}
JC-AB	G	6.9 ± 0.4^{a}	137 ± 11^{a}	2.14 ± 0.04^{a}	5.0 ± 1.2 ^{bc}	3.2 ± 1.8 ^{e}	4.4 ± 2.0 ^{d}	5.5 ± 2.0 ^{b}	3.6 ± 1.9 ^{e}
JC-AP	G	1.03 ± 0.05^{de}	24 ± 1^{ef}	0.01 ± 0.00^{f}	6.0 ± 1.4 ^{a}	6.2 ± 2.0 ^{a}	6.8 ± 1.7 ^{a}	6.0 ± 1.7 ^{ab}	6.3 ± 1.7 ^{a}
JC-APP	U	0.64 ± 0.05^{f}	10.3 ± 0.6^{d}	-	6.5 ± 1.6 ^{a}	5.8 ± 1.9 ^{bc}	6.7 ± 1.6 ^{bc}	6.2 ± 1.7 ^{ab}	6.1 ± 1.6 ^{b}
JC-GP	U	1.6 ± 0.2^{c}	16.5 ± 0.5^{ab}	-	5.6 ± 1.6 ^{b}	5.6 ± 1.7 ^{c}	4.0 ± 2.1 ^{f}	5.1 ± 2.2 ^{de}	5.0 ± 1.8 ^{c}
JC-PP	U	0.9 ± 0.1^{de}	11 ± 1^{d}	-	6.7 ± 1.6 ^{a}	6.9 ± 1.8 ^{a}	7.5 ± 1.3 ^{a}	6.6 ± 1.6 ^{a}	7.0 ± 1.4 ^{a}
JC-GAGP	U	0.73 ± 0.05^{ef}	14 ± 1^{c}	-	5.5 ± 1.7 ^{b}	5.4 ± 1.7 ^{c}	4.3 ± 2.0 ^{f}	5.0 ± 2.1 ^{de}	4.9 ± 1.8 ^{c}
JC-APB	U	1.77 ± 0.06^{b}	15.0 ± 0.4^{bc}	-	5.1 ± 1.5 ^{bc}	4.3 ± 2.2 ^{de}	6.2 ± 1.9 ^{cd}	5.3 ± 2.0 ^{cde}	4.8 ± 2.0 ^{c}
JC-GB	U	1.73 ± 0.08^{bc}	17.9 ± 0.6^{a}	-	4.8 ± 1.3 ^{c}	4.3 ± 1.8 ^{e}	2.6 ± 1.5 ^{g}	4.9 ± 2.1 ^{de}	3.8 ± 1.6 ^{d}

JC-PB	U	2.0 ± 0.2^{a}	17.8 ± 0.4^{a}	-	5.4 ± 1.3 $^{b c}$	5.3 ± 2.1 ^{c}	5.6 ± 1.9 ^{de}	5.7 ± 1.8 ^{bcd}	5.3 ± 1.8 ^{c}
JC-GAGB	U	1.0 ± 0.1^{d}	15.4 ± 0.6^{bc}	-	5.0 ± 1.4 ^{bc}	5.1 ± 1.8 ^{cd}	5.1 ± 1.9 ^{e}	4.7 ± 1.9 ^{e}	4.8 ± 1.6 ^{c}
JC-AB	U	1.6 ± 0.1^{bc}	14 ± 1^{c}	-	5.2 ± 1.4 ^{bc}	4.4 ± 2.1 ^{de}	6.3 ± 1.9 ^{cd}	6.1 ± 2.0 ^{abc}	4.8 ± 1.9 ^{c}
JC-AP	U	0.58 ± 0.02^{f}	8 ± 1^{e}	-	6.5 ± 1.5 ^{a}	6.4 ± 1.8 ^{ab}	7.3 ± 1.3 ^{ab}	6.8 ± 1.6 ^{a}	6.6 ± 1.5 ^{ab}
JC-APP	C	1.04 ± 0.05^{e}	14 ± 1^{d}	-	6.2 ± 1.5 ^{ab}	5.9 ± 2.1 ^{bc}	6.7 ± 1.5 ^{ab}	6.5 ± 1.7 ^{a}	6.1 ± 1.8 ^{bc}
JC-GP	C	1.12 ± 0.07^{e}	16 ± 1^{c}	-	5.5 ± 1.5 ^{cd}	5.2 ± 1.6 ^{c}	3.1 ± 1.9 ^{g}	5.4 ± 2.2 ^{b}	4.7 ± 1.6 ^{d}
JC-PP	C	2.7 ± 0.1^{b}	16.9 ± 0.9^{c}	-	6.5 ± 1.4 ^{a}	6.8 ± 1.9 ^{a}	7.3 ± 1.6 ^{a}	6.9 ± 1.7 ^{a}	6.9 ± 1.6 ^{a}
JC-GAGP	C	1.16 ± 0.06^{e}	11.1 ± 0.7^{e}	-	5.7 ± 1.6 ^{bc}	5.5 ± 1.7 ^{c}	5.4 ± 1.9 ^{d}	5.1 ± 2.0 ^{bc}	5.5 ± 1.6 ^{c}
JC-APB	C	2.01 ± 0.07^{d}	24.7 ± 0.4^{a}	-	5.0 ± 1.3 ^{d}	4.0 ± 2.2 ^{d}	5.6 ± 2.0 ^{cd}	5.0 ± 2.2 ^{bc}	4.1 ± 2.0 ^{d}
JC-GB	C	1.2 ± 0.2^{e}	25 ± 1^{a}	-	5.0 ± 1.4 ^{d}	4.4 ± 1.9 ^{d}	3.8 ± 2.1 $^{f g}$	5.4 ± 2.1 ^{b}	4.4 ± 1.7 ^{d}
JC-PB	C	2.93 ± 0.09^{a}	23 ± 1^{ab}	-	5.1 ± 1.2 ^{d}	3.9 ± 2.0 ^{d}	4.9 ± 2.0 ^{de}	5.5 ± 2.0 ^{b}	4.1 ± 1.8 ^{d}
JC-GAGB	C	1.16 ± 0.06^{e}	22 ± 1^{b}	-	5.1 ± 1.4 ^{cd}	4.0 ± 1.9 ^{d}	4.5 ± 2.1 ^{ef}	4.4 ± 2.0 ^{c}	4.2 ± 1.8 ^{d}
JC-AB	C	2.19 ± 0.07^{c}	21 ±2^{b}	-	5.2 ± 1.4 ^{cd}	4.2 ± 2.2 ^{d}	6.2± 2.1 ^{bc}	5.5 ± 2.2 ^{b}	4.5 ± 2.0 ^{d}
JC-AP	C	1.15 ± 0.06^{e}	15.1 ± 0.6^{cd}	-	6.6 ± 1.3 ^{a}	6.6 ± 1.6 ^{ab}	6.9 ± 1.5 ^{ab}	7.0 ± 1.5 ^{a}	6.7 ± 1.4 ^{ab}

Values in the same column having the same letter for each fruit are not significantly different at a confidence level of 95%. Jelly candies with pulp (JC-PP) or by-product (JC-PB) with pectin, pulp (JC-AP) or by-product (JC-AB) with agar; pulp (JC-APP) or by-product (JC-APB) with agar and pectin; pulp (JC-GP) or by-product (JC-GB) with gelatin, pulp (JC-GAGP) or by-product (JC-GAGB) with gelatin and arabic gum

*Dry basis

** evaluated just for grumixama because in uvaia and cambuci it is no present

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3.1 Total phenolic content, antioxidant capacity and total anthocyanins

In relation to the total phenolic compounds of the jelly candies, the results varied for the different formulations. Values ranged between 0.85 (APP - agar and pectin and pulp) and 6.9 mg of gallic acid / g dry sample (AB - agar and by-product) for grumixama. For uvaia, the variation was between 0.58 (AP - agar and pulp) and 1.77 mg of gallic acid / g dry sample (APB - agar and pectin and by-product). For cambuci, the values ranged from 1.04 (APP - agar and pectin and pulp) to 2.93 mg of gallic acid / g dry sample (PB - pectin and by-product). Generally, jelly candies made from pulp had a lower content of phenolic compounds than those made with the by-product.

Comparing TPC values of jelly candies made of the same hydrocolloid, but one with by-product and the other with pulp, by-product formulations' TPC was up to 7.66, 2.81 and 1.93 times the pulp formulations' TPC for grumixama, uvaia and cambuci, respectively.

The fruit pulp is the current commercialized product in the market. We can make a comparison between the TPC of the jelly candies and the TPC of the fruit pulps, considering the serving size of each of the products, in wet basis. For the fruit pulps the serving size was 100 g and for jelly candies the serving size was 20g. The comparison is showed in Figure 3. For grumixama, a serving size of 20 g of jelly candies presented TPC from 6% (JC-APP) to 53% (JC-AB) of the TPC of a serving size of 100g of grumixama pulp. For cambuci, 20 g of jelly candies presented TPC from 7% (JC-APP) to 21% (JC-PB) of the TPC from 100 g of cambuci pulp. For uvaia, 20 g of jelly candies, presented TPC from 9% (JC-AP) to 28% (JC-PB) of the TPC from 100 g of uvaia pulp.

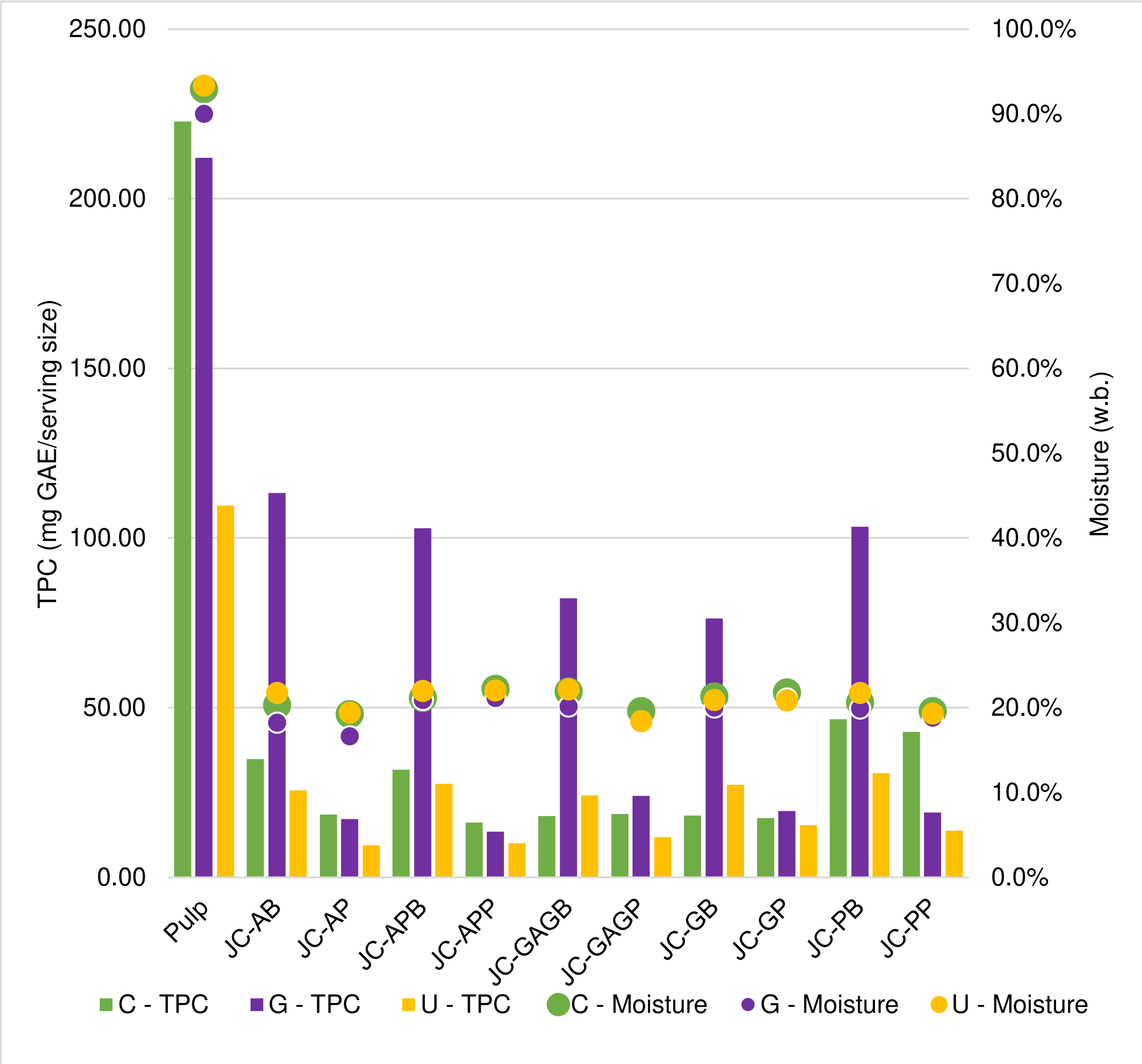

Figure 3. TPC and moisture of confectionery products and fruit pulps, by serving size.

Pulp = raw material. Jelly candies with pulp (JC-PP) or by-product (JC-PB) with pectin, pulp (JC-AP) or by-product (JC-AB) with agar; pulp (JC-APP) or by-product (JC-APB) with agar and pectin; pulp (JC-GP) or by-product (JC-GB) with gelatin, pulp (JC-GAGP) or by-product (JC-GAGB) with gelatin and arabic gum. Pulp serving size = 100 g (wet basis). Jelly candies serving size = 20 g (wet basis)

Because grumixama was the only between the studied fruits with red/purple color, only their products had their total anthocyanins analyzed. The values for the different formulations were statistically different. Total anthocyanins for formulations produced with by-products were considerably higher than the values for formulations made of pulp. The obtained values ranged between 0.01 (JC-AP and JC-PP) to 2.20 (JC-PB) mg cyanidin-3-glucoside equivalent/g. Cappa et al. (2014) studied fruit candies enriched with grape skin. They also noted a higher total anthocyanin content for formulations added with the by-product, since anthocyanins are naturally present in grape skin.

Regarding the antioxidant capacity of the jelly candy extracts, the results ranged between 14.2 (JC-APP) and 137 (JC-AB) µmol TE/g, 8 (JC-AP) and 17.9 (JC-GB) µmol TE/g and 11.1 (JC-GAGP) and 25 (JC-GB) µmol TE/g for grumixama, uvaia and cambuci jelly candies, respectively. In a general view, when comparing same fruit and hydrocolloid products, by-product based jelly candies presented higher antioxidant capacity than pulp based products, except for uvaia JC-GP and JC-GB, cambuci JC-GP and JC-GB and JC-GAGB and JC-GAGP, which the pairs were not statistically different ($p<0.05$). Cappa et al (2014) also observed higher antioxidant capacity for candies produced with by-product.

3.2 Fiber content

The fiber content (dry basis) of the raw material (pulps and by-products) was evaluated (Table 4).

Table 4. Fiber content of fruit by-products and pulps (dry basis)

Raw material	Fiber (g/100g)
Cambuci by-product	48.97 ±0.72
Cambuci pulp	24.32 ±0.37
Grumixama by-product	39.70 ±0.36
Grumixama pulp	13.55 ±0.12
Uvaia by-product	52.18 ±1.80
Uvaia pulp	11.70 ±0.16

The fiber content results for the raw material (Table 4) and the fiber of the hydrocolloid were used to calculate the fiber content of the jelly candies (arabic gum, pectin and agar were considered to have 100% of fiber, in dry basis). The fiber content of the jelly candies was calculated in the products in wet basis, by serving size (20 g, wet basis) and compared to the fiber content of the pulps serving size (100 g, wet basis) (Figure 4). For grumixama jelly candies, the fiber content of the 20 g serving size was from 8% (GP) to 205% (GAGB) of the total fiber of a 100 g serving size of grumixama pulp. For cambuci jelly candies, the fiber content of 20 g is from 8% (GP) to 128% (GAGB) of the total fiber of 100 g of cambuci pulp. Finally, for uvaia jelly candies, the fiber content of 20 g is from 8% (GP) to 286% (GAGB) of the total fiber of 100 g of uvaia pulp.

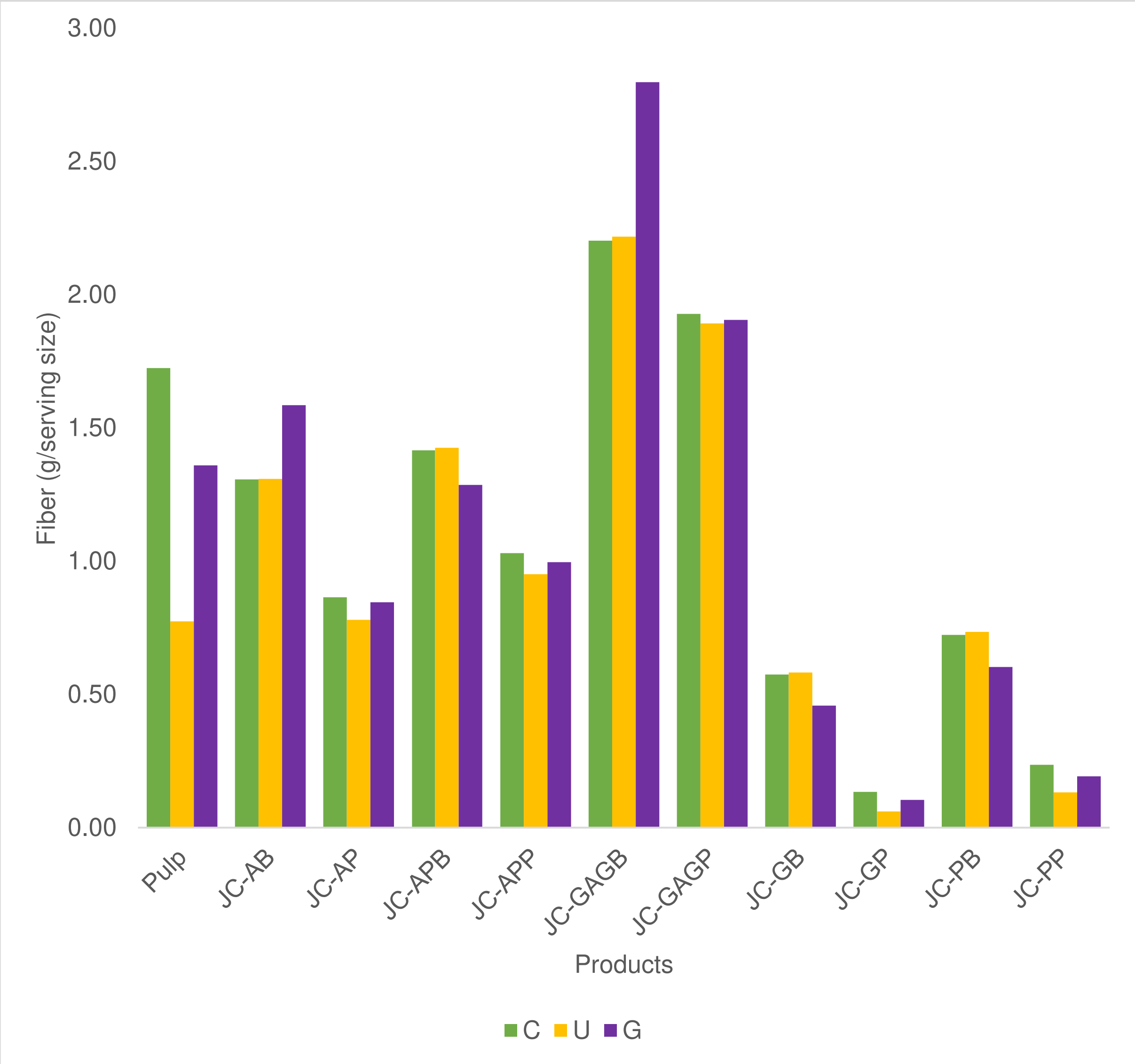

Figure 4. Dietary fiber content of fruit bars and fruit pulps, wet basis.

Pulp = raw material. Jelly candies with pulp (JC-PP) or by-product (JC-PB) with pectin, pulp (JC-AP) or by-product (JC-AB) with agar; pulp (JC-APP) or by-product (JC-APB) with agar and pectin; pulp (JC-GP) or by-product (JC-GB) with gelatin, pulp (JC-GAGP) or by-product (JC-GAGB) with gelatin and arabic gum. Pulp serving size = 100 g (wet basis). Jelly candies serving size = 20 g (wet basis)

3.3 Sensory evaluation

3.3.1 Test of acceptance

The results for the sensory analysis are presented in Table 3.

Considering the aroma of the samples, grumixama scores were around 5. Uvaia and cambuci scores were a little higher, ranging from 4.8 to 6.7 and 5.5 to 6.6, respectively. For all fruits the combination of gelatin and by-product resulted in lower aroma scores, while the combination of pectin and pulp resulted in the highest aroma scores.

Analyzing the taste scores, for all fruits, formulations were statistically different and the values ranged from 3.2 to 6.7, 4.3 to 6.9 and 3.9 to 6.8, for grumixama, uvaia and cambuci, respectively. For all fruits, the association of pectin and pulp resulted in the highest taste scores. For grumixama, JC_AB and JC_APB had the lowest taste scores. For uvaia, the lowest scores were from JC_APB, JC_GB, and AB samples. Moreover, for cambuci, all samples with by-product in the formulation received the lowest taste scores: JC_AB, JC_GAGB, JC_PB, JC_GB and JC_APB.

Regarding the texture of the jelly candies, for the three studied fruits, all samples made from gelatin, both pulp and by-product based, presented the lowest easy to chew scores. For the three fruits, JC_APP and JC_PP were the samples with the highest easy to chew scores. Stickiness values ranged from 5.2 (JC_PB) to 6.5 (JC_APP), 4.7 (JC_GAGB) to 6.8 (JC_AP), 4.4 (JC_GAGB) to 7.0 (JC_AP) for grumixama, uvaia and cambuci, respectively.

In terms of overall liking of grumixama jelly candies, the highest scores for pulp formulations were 6.5 (JC_PP) and 6.3 (JC_AP). Grumixama by-product jelly candy with the highest overall liking score was JC_GAGB, with 5.3. For uvaia jelly candies, the most accepted among the formulations with pulp were JC_PP and JC_AP, with scores of 7.0 and 6.7, respectively. In addition, the most accepted among the formulations with uvaia residue was JC_PB, with score of 5.3. The best accepted cambuci pulp jelly candies were JC_PP and JC_AP, with 6.9 and 6.7 scores, respectively, while all cambuci by-product based products were not statistically different ($p<0.05$). For grumixama, overall liking values ranged between 3.6 and 6.5. For uvaia, the values ranged between 3.8 and 7.0. In addition, for cambuci, the values ranged between 4.1 and 6.9.

With the results of sensory tests, it was possible to build preference mapping in relation to the attribute "overall liking" for each fruit, represented by Figure

5. The first two dimensions F1 and F2 presented in the maps represents 55.66%, 61.56% and 57.97%of overall liking results for grumixama, uvaia and cambuci jelly candies, respectively. For all maps, the first dimension F1 explained the majority of the results: 41.49, 44.14 and 45.26% for grumixama, uvaia and cambuci jelly candies, respectively. For three fruits, samples were all positioned in the positive part of F1 axis, while consumers were uniformly distributed in the four quarters of the map. In general it was possible to note that for grumixama and uvaia, the most accepted samples were positioned in the negative part of F2 axis and for cambuci, in the positive part.

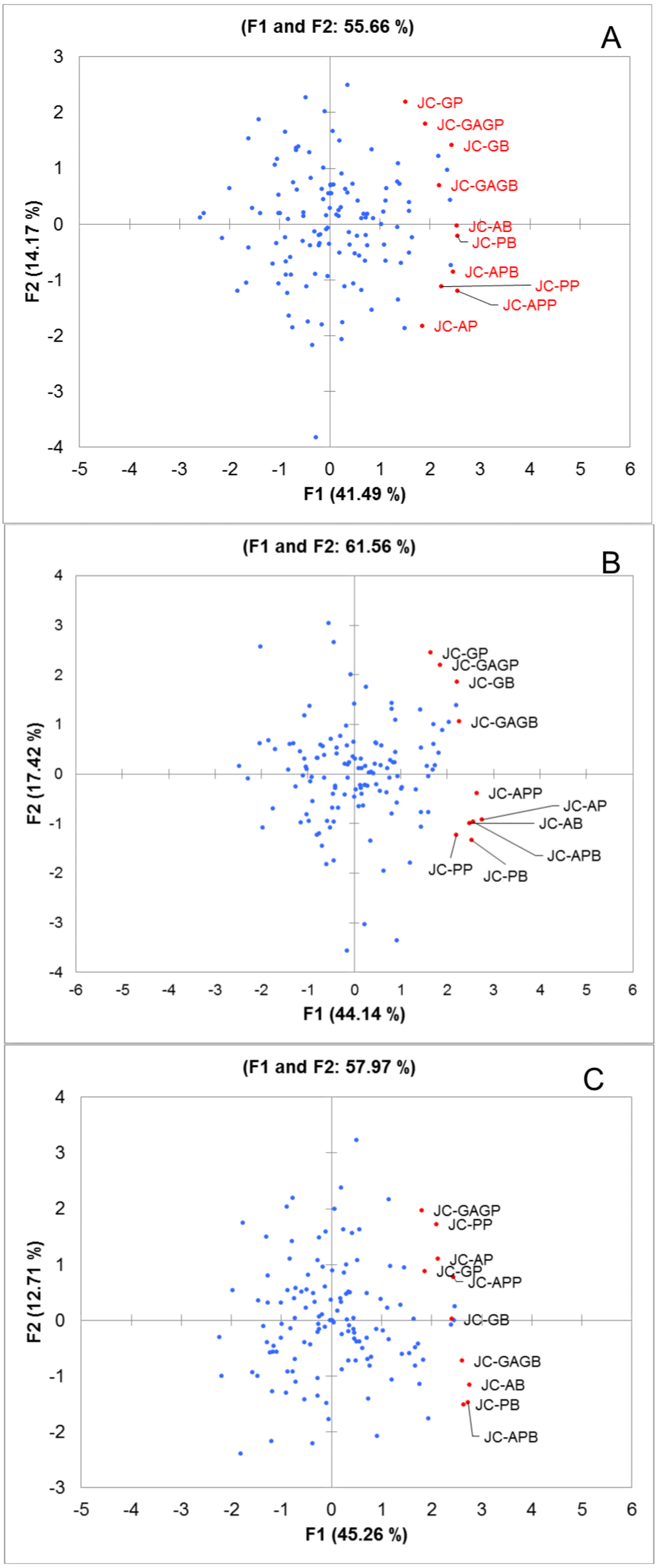

Figure 5. Internal preference map of jelly candies sensory evaluated: A-Grumixama, B-Uvaia, C-Cambuci.

3.3.2 CATA

Check all that apply (CATA) is a verbal based method where the consumers were invited to check in a list of attributes those related to each tested sample. Analyzing CATA results, the terms that appeared for each product were summarized and the frequency of citation was calculated (Table 5).

Table 5. Frequency of CATA attributes citation (%) for uvaia (U), grumixama (G) and cambuci (C)

Attributes	Frequency of responses for each formulation (%)										
	Fruit	JC-AB	JC-AP	JC-APB	JC-APP	JC-GAGB	JC-GAGP	JC-GB	JC-GP	JC-PB	JC-PP
Hard to bite	G	51^{d}	7^{ab}	6^{ab}	2^{a}	7^{ab}	20^{bc}	77^{e}	61^{de}	39^{cd}	2^{a}
High fiber content	G	27^{c}	11^{ab}	26^{bc}	18^{abc}	16^{abc}	15^{abc}	28^{c}	10^{a}	25^{abc}	12^{abc}
Fruit aroma	G	7^{a}	45^{c}	11^{a}	33^{bc}	11^{a}	21^{ab}	8^{a}	21^{ab}	17^{a}	36^{bc}
Bad aftertaste	G	75^{f}	12^{ab}	66^{f}	37^{cd}	36^{cd}	27^{bcd}	59^{ef}	8^{a}	45^{de}	20^{abc}
Firm to bite	G	42^{ab}	61^{bcd}	34^{a}	38^{a}	35^{a}	65^{cd}	43^{ab}	68^{d}	45^{abc}	48^{abcd}
Healthy	G	13^{a}	30^{b}	20^{ab}	25^{ab}	25^{ab}	24^{ab}	14^{a}	20^{ab}	23^{ab}	30^{b}
Bitter	G	48^{e}	10^{ab}	49^{e}	20^{bc}	30^{cd}	20^{bc}	42^{de}	6^{a}	39^{cde}	11^{ab}
Sandy	G	48^{d}	2^{a}	48^{d}	25^{bc}	18^{b}	3^{a}	20^{bc}	0^{a}	cd^{38}	4^{a}
Sticky	G	6^{a}	34^{cd}	15^{ab}	20^{abc}	45^{d}	34^{cd}	18^{abc}	34^{cd}	21^{bc}	41^{d}
It can be eaten anytime	G	8^{ab}	30^{d}	11^{abc}	23^{bcd}	21^{bcd}	24^{cd}	7^{a}	20^{bcd}	13^{abc}	30^{d}
Sweet	G	12^{a}	68^{c}	16^{a}	42^{b}	24^{ab}	40^{b}	11^{a}	41^{b}	20^{a}	67^{c}
Pleasant aftertaste	G	3^{a}	54^{f}	10^{ab}	28^{cd}	21^{bcd}	30^{cde}	8^{ab}	41^{def}	18^{bc}	47^{ef}
High antioxidant content	G	8	7	11	7	10	7	9	8	13	11
Practical	G	10^{a}	23^{bcd}	11^{ab}	25^{cd}	19^{abcd}	19^{abcd}	9^{a}	17^{abcd}	12^{abc}	30^{d}

Bitter aftertaste	G	53^{e}	6^{ab}	48^{e}	17^{bc}	41de	26^{cd}	45^{e}	2^{a}	49^{e}	21^{c}
Acid	G	2^{a}	3^{a}	27^{c}	8^{ab}	2^{a}	6^{a}	7^{ab}	1^{a}	20^{bc}	20^{bc}
Easy to chew	U	64^{ef}	81^{fg}	60de	73^{efg}	28^{bc}	15^{ab}	4^{a}	16^{b}	42^{cd}	86^{g}
High fiber content	U	37^{c}	10^{a}	38^{c}	10^{a}	36^{bc}	19^{ab}	41^{c}	14^{a}	44^{c}	8^{a}
Fruit aroma	U	24^{ab}	68^{d}	25^{ab}	64^{d}	26^{ab}	40^{bc}	17^{a}	43^{c}	35^{bc}	71^{d}
Bad aftertaste	U	40de	10^{a}	49^{e}	20^{abc}	32^{cde}	14^{ab}	30^{bcd}	21^{abcd}	25^{bcd}	8^{a}
Firm to bite	U	30^{ab}	44^{bc}	15^{a}	46^{bc}	46^{bc}	69de	83^{e}	73de	60^{cd}	29^{ab}
Healthy	U	33^{a}	34^{a}	25^{a}	35^{a}	28^{a}	26^{a}	28^{a}	25^{a}	30^{a}	35^{a}
Bitter	U	20^{d}	6^{abc}	21^{d}	8^{abcd}	19^{cd}	4^{ab}	21^{d}	3^{a}	15^{bcd}	8^{abcd}
Sandy	U	56^{e}	5^{ab}	65^{e}	6^{ab}	31^{cd}	4^{a}	18^{bc}	2^{a}	35^{d}	2^{a}
Sticky	U	7^{a}	10a	30^{bc}	17^{ab}	61^{d}	61^{d}	27^{bc}	44^{cd}	27^{bc}	25^{bc}
It can be eaten anytime	U	27^{ab}	53d	25^{a}	47^{cd}	30^{abc}	34^{abc}	25^{a}	38^{abcd}	41^{bcd}	53^{d}
Sweet	U	36^{ab}	64d	42^{bc}	48^{bcd}	40^{abc}	46bcd	23^{a}	48^{bcd}	46^{bcd}	60^{cd}
Pleasant aftertaste	U	23ab	45^{cd}	19^{a}	38^{bcd}	21^{ab}	31^{abc}	22^{ab}	32^{abc}	28^{abc}	56^{d}
Practical	U	27^{ab}	47^{c}	25^{a}	42^{bc}	27^{ab}	33^{abc}	24^{a}	31^{abc}	33^{abc}	44^{c}
High antioxidant content	U	14	12	12	9	13	7	12	10	17	10
Bitter aftertaste	U	23^{c}	6^{ab}	20^{bc}	9^{abc}	19^{bc}	4^{a}	14^{abc}	6^{ab}	20^{bc}	2^{a}
Fruity flavor	U	42^{ab}	75^{d}	42^{abc}	61^{cd}	39^{ab}	35^{a}	26^{a}	61^{cd}	56^{bc}	78^{d}
Acid	U	3^{a}	21^{bc}	5^{a}	29^{c}	3^{a}	4^{a}	4^{a}	4^{a}	9^{ab}	51^{d}
Easy to chew	C	63^{cd}	84^{e}	46^{bc}	76de	15^{a}	40^{b}	14^{a}	7^{a}	34^{b}	85^{e}
High fiber content	C	31^{bcd}	15^{ab}	33^{cd}	18^{abc}	28^{bcd}	18^{abcd}	25^{abcd}	12^{a}	35^{d}	15^{ab}
Fruit flavor	C	35^{abc}	83^{d}	33^{ab}	75^{d}	26^{a}	54^{c}	30^{ab}	48^{bc}	33^{ab}	81^{d}
Fruit aroma	C	14^{a}	52^{cd}	20^{ab}	50^{cd}	17^{a}	35^{bc}	22^{ab}	28^{ab}	15^{a}	63^{d}

Bad aftertaste	C	55^{bc}	9^{a}	58^{bc}	18^{a}	66^{c}	13^{a}	46^{b}	13a	64^{bc}	6^{a}
Firm to bite	C	11^{a}	29^{bc}	30^{bc}	41^{cd}	54^{d}	61^{de}	79^{ef}	88^{f}	49^{d}	14^{ab}
Healthy	C	24^{ab}	34^{bc}	20^{ab}	34^{bc}	13^{a}	27^{abc}	20^{ab}	21^{ab}	24^{abc}	39^{c}
Floral flavor	C	28^{bcd}	13^{ab}	33^{cd}	11^{a}	40^{d}	12^{ab}	33^{cd}	12^{ab}	37^{d}	15^{abc}
Bitter	C	37^{b}	2^{a}	43^{b}	6^{a}	54^{b}	7^{a}	40^{b}	4^{a}	41^{b}	6^{a}
Sandy	C	54^{c}	7^{ab}	52c	8^{ab}	23^{b}	11^{ab}	9^{ab}	1^{a}	52^{c}	11^{ab}
Sticky	C	33^{de}	9^{a}	29^{bcde}	15^{abc}	53^{f}	46^{ef}	25^{bcd}	31^{cde}	20^{abcd}	12^{ab}
It can be eaten anytime	C	20^{ab}	43^{d}	20^{ab}	33^{bcd}	15^{a}	26^{abc}	21^{ab}	28^{abcd}	19^{ab}	40^{cd}
Pleasant aroma	C	10^{a}	50^{d}	8^{a}	35^{cd}	11^{a}	26^{bc}	7^{a}	17^{ab}	8^{a}	46^{d}
Sweet	C	22^{ab}	60^{d}	19^{ab}	50^{cd}	15^{a}	44^{cd}	15^{ab}	33^{bc}	15^{a}	59^{d}
Pleasant aftertaste	C	11^{ab}	36^{cd}	12^{ab}	37^{cd}	7^{a}	25^{bc}	12^{ab}	21^{abc}	8^{a}	46^{d}
High antioxidant content	C	11	9	13	9	11	8	13	7	14	8
Practical	C	22^{ab}	38^{c}	25^{abc}	29^{bc}	15^{a}	27^{abc}	26^{abc}	24^{ab}	22^{ab}	33^{bc}
Bitter aftertaste	C	35^{b}	5^{a}	35^{b}	10^{a}	44^{b}	7^{a}	35^{b}	4^{a}	46^{b}	5^{a}
Acid	C	15^{abc}	24^{bc}	14^{abc}	28^{cd}	12^{abc}	8^{a}	9^{ab}	8^{ab}	23^{bc}	39^{d}

Jelly candies with pulp (JC-PP) or by-product (JC-PB) with pectin, pulp (JC-AP) or by-product (JC-AB) with agar; pulp (JC-APP) or by-product (JC-APB) with agar and pectin; pulp (JC-GP) or by-product (JC-GB) with gelatin, pulp (JC-GAGP) or by-product (JC-GAGB) with gelatin and arabic gum. Products sharing the same letter(s) do not differ significantly ($p \leq 0.05$) for each attribute by Cochran's test. High antioxidant content was not evaluate by Cochran's test.

Terms that were cited with a frequency of 40% or higher were considered frequently cited by consumers. The most frequently cited terms for grumixama by-product based jelly candies were *hard to bite, bad aftertaste, firm to bite, bitter* and *sandy*, while for grumixama pulp based jelly candies some frequently cited terms were: *firm to bite, sweet* and *pleasant aftertaste*.

For uvaia, *fruit aroma* was highly cited for all pulp based products. *Firm to bite* was frequently cited for almost all products, except for JC-AB, JC-APB and JC-PP. *Easy to chew* was highly cited for JC-AB, JC-AP, JC-APB, JC-APP. JC-PB and

JC-PP. *Sweet* was highly cited for almost all products, except for JC-AB and JC-GB. Fruit flavor was frequently cited for JC-AB, JC-AP, JC-APB, JC-APP, JC-GP, JC-PB and JC-PP.

Moreover, for cambuci jelly candies, all pulp based products received high citation frequency for *fruit flavor* and all by-product based products received high citation frequency for bad aftertaste. *Easy to chew* was frequently cited for almost all products, except for JC-GAGB, JC-GB, JC-GP and JC-PB. *Sweet* was highly cited for all pulp based jelly candies, except for JC-GP. Bitter was highly cited for all by-product based jelly candies, except for JC-AB.

The only excluded term for further statistical analysis for all fruits was *high antioxidant content*, because it presented less than 20% of frequency of citation for all products (CRUZ et al., 2013). A contingency table with the other terms was used to evaluate CATA data by Multi factor analysis (MFA) and Penalty-lift analysis.

There were significant differences for all CATA parameters according to non-parametric Cochran's test for grumixama and cambuci jelly candies. In the case of uvaia, the only parameter that did not differ for the different jelly candy samples was *healthy.*

JC-PP and JC-AP were the samples with the highest overall liking scores among grumixama jelly candy samples. According to Cochran's test they were not hard to bite, presented high fruit aroma, low bitter aftertaste, were not bitter or sandy, were sticky and sweet and presented a pleasant aftertaste. JC-PP was perceived as more acid than JC-AP, which makes sense considering both products formulations.

For uvaia samples, the best accepted samples (JC-PP and JC-AP) were easy to chew, did not present high fiber content, presented high fruit aroma, did not present bad aftertaste, were not too firm to bite, were not bitter, sandy or sticky, were considered practical and to be eaten anytime, had a high pleasant aftertaste, did not present bitter aftertaste and had a high fruit flavor. JC-PP were highly acid.

Cambuci best accepted samples (JC-PP and JC-AP), considering Cochran's test results, were easy to chew, did not present high fiber content, presented high fruit flavor and aroma, did not have a bad or bitter aftertaste, were considered to be healthy, practical and to be eaten anytime, were not bitter, sandy or sticky and presented a pleasant aftertaste.

Figure 6 shows the Multi Factor Analysis (MFA) plots for the three fruit based jelly candies.

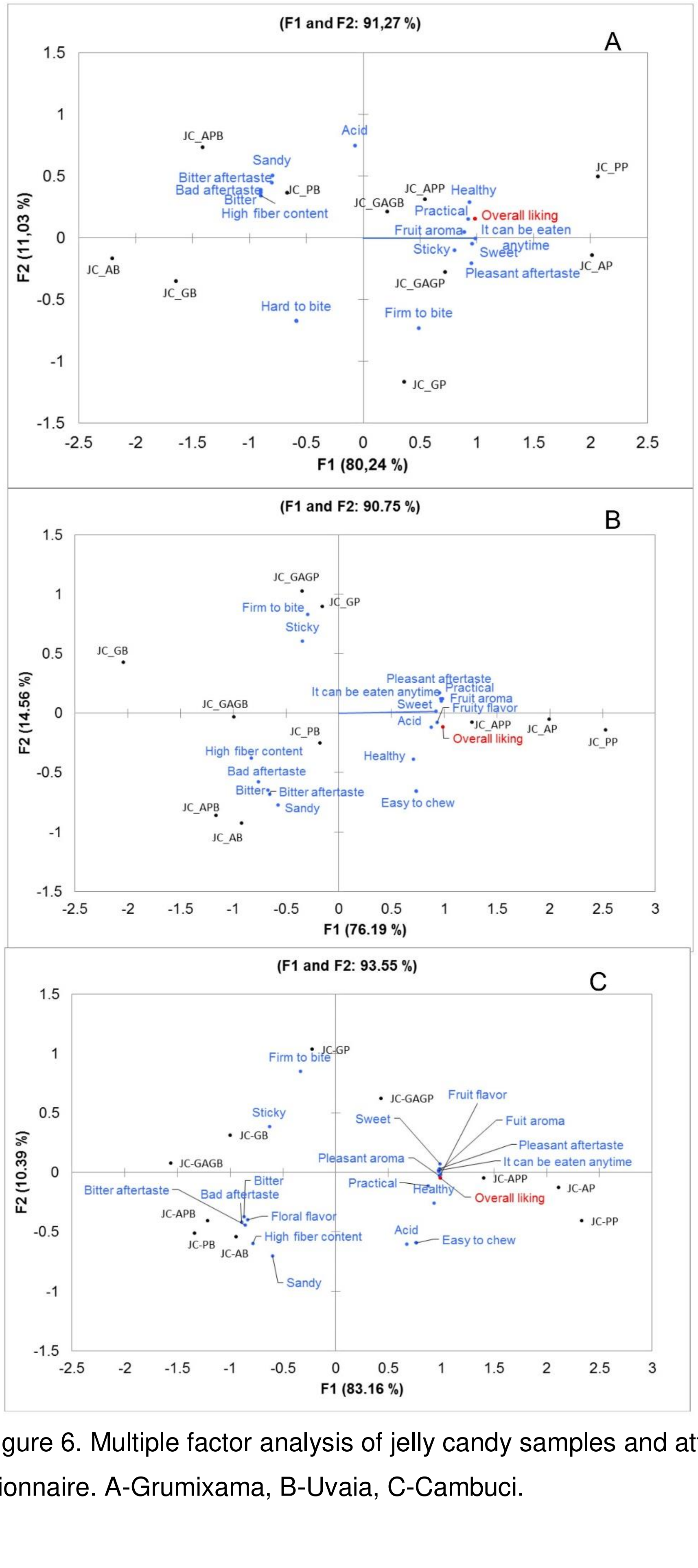

Figure 6. Multiple factor analysis of jelly candy samples and attributes from CATA questionnaire. A-Grumixama, B-Uvaia, C-Cambuci.

Analyzing the first factor F1 in MFA plots, for the three fruits, the major part of pulp based samples are positioned in the right side, being related to F1 axis positive values, while by-product based samples are positioned in the left side of F1 axis, being related to F1 axis negative values.

For grumixama, F1 and F2 axes explained together 91.27% of CATA data in MFA plot, being F1 responsible for 80.24%. According to the plot, by-product based samples were positioned near to features like sandy, bitter aftertaste, bad aftertaste, bitter and high fiber content. Pulp based samples, however, were positioned near to features like practical, healthy, sweet, it ca be eaten anytime, pleasant aftertaste, fruit aroma and sticky.

For uvaia, the first two axes explained 90.75% of the results and F1 represented 76.19% and F2 represented 14.56%. As long as for grumixama by-product samples, uvaia by-product based jelly candies were positioned near to characteristics such as sandy, bitter aftertaste, bad aftertaste, bitter and high fiber content. Among uvaia pulp based jelly candies, JC-GAGP and JC-GP were slightly in the negative par of F1 axis and were near to characteristics such as firm to bite and sticky. The other pulp based samples were near to features like acid, sweet, fruit aroma, fruit flavor and pleasant aftertaste.

For cambuci, MFA of the two first factors explained 93.55% of data variability. Similar to the other fruits, cambuci by-product based formulations were related to characteristics such as sandy, bitter aftertaste, bad aftertaste, bitter and high fiber content. These samples were also near to floral flavor. JC-GP was the only pulp based formulation slightly positioned in the left side of F1 axis in MFA plot and was near to firm to bite. The other pulp based formulations were near to healthy, acid, easy to chew, practical, pleasant aroma, pleasant aftertaste, fruit aroma and fruit flavor.

Overall liking was analyzed in MFA as supplementary data and for the three fruits was positioned in the right side of F1 axis, near to most part of pulp based samples and close to characteristics as fruit flavor, sweet, pleasant aroma, pleasant aftertaste and fruit aroma.

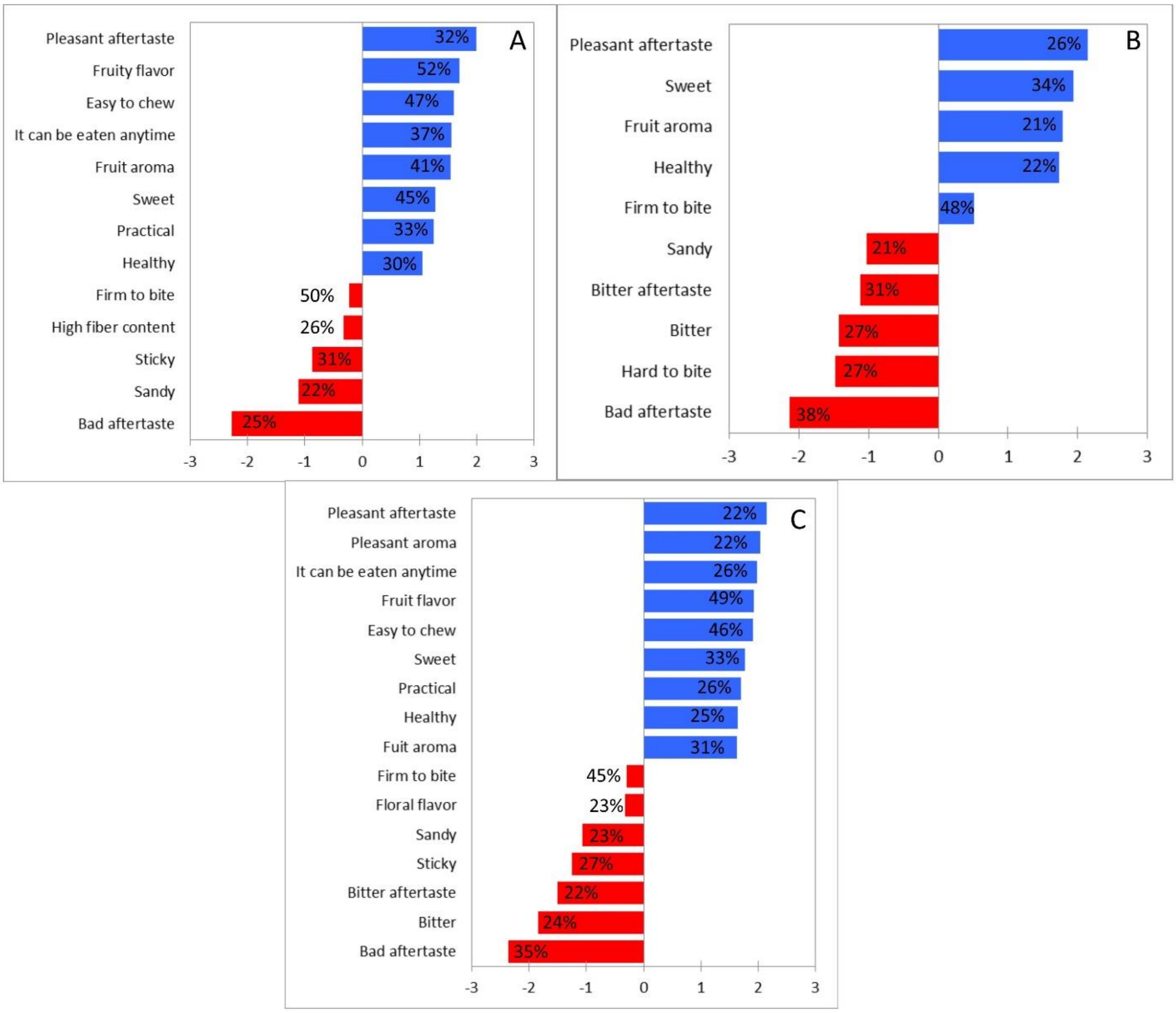

Figure 7. Penalty-lift analysis of CATA data for all jelly candies by fruit. A-Uvaia, B-Grumixama, C-Cambuci. Percentage number represent the observations in which the attribute was used to characterize the product.

Penalty-lift analysis was used in CATA data in order to verify which CATA attributes contributed positively or negatively for overall liking of the samples. Characteristics that are positioned in the positive part of x-axis positively contributed to overall liking while characteristics positioned in the negative part, negatively contributed to overall liking. Figure 7 shows the positive and negative contribution of each attribute. In addition, x-axis present the effect on acceptance average for each attribute. Each attribute is also followed by the percentage of observations in which the attribute was cited.

For grumixama formulations, *pleasant aftertaste, sweet, fruit aroma, healthy* and *firm to bite* were the attributes that positively influenced the overall liking. *Sandy, bitter aftertaste, bitter, hard to bite* and *bad aftertaste* were the attributes that negatively influenced the overall liking. *Pleasant aftertaste* and *sweet* were the attributes that presented highest positive effect on the acceptance average (2.1 and 1.9, respectively). These attributes were cited in 26% (*pleasant aftertaste*) and 34% (*sweet*) of grumixama jelly candies observations. *Bad aftertaste* was the characteristic that presented higher negative influence on the liking average (-2.1) and was cited in 38% of the observations for grumixama jelly candies.

For uvaia samples, the positive characteristics were *pleasant aftertaste, fruit flavor, easy to chew, it can be eaten anytime, fruit aroma, sweet, practical* and *healthy*, while the negative characteristics were *firm to bite, high fiber content, sticky, sandy* and *bad aftertaste. Pleasant aftertaste* was the attribute the attribute that presented highest positive effect on acceptance average (2.0) and was cited in 32% of the observations for cambuci jelly candies. Attributes like *fruit flavor*, *easy to chew, fruit aroma and sweet* were cited in a huge number of observations (above 40%). Bad aftertaste was the characteristic that presented higher negative influence on the liking average (-2.3) and was cited in 25% of the observations for uvaia jelly candies

For cambuci samples, the attributes that provided a positive impact on overall liking were *pleasant aftertaste, pleasant aroma, it can be eaten anytime, fruit flavor, easy to chew, sweet, practical, healthy, and fruit aroma.* Attributes such as *firm to bite, floral flavor, sandy, sticky, bitter aftertaste, bitter and bad aftertaste* provided a negative impact on overall liking. *Pleasant aftertaste* was the attribute the attribute that presented highest positive effect on acceptance average (2.1) and was cited in 21% of the observations for cambuci jelly candies. Attributes like *fruit flavor* and *easy to chew* were cited in a huge number of observations (above 40%) and positively contributed to the acceptance average. Bad aftertaste was the characteristic that presented higher negative influence on the liking average (-2.4) and was cited in 35% of the observations for cambuci jelly candies.

4 Conclusion

The use of native fruit pulp and by-products in jelly candies was viable. Grumixama, uvaia and cambuci pulp based jelly candies have a great potential. Hydrocolloids such as pectin and agar gave more interesting sensory evaluations than the others. The by-product use, however, is still a sensory challenge. Pulp based samples provided higher acceptability for all tested fruits.

In order to apply these three native fruit by-products in jelly candies, reformulations should be made to result in a better consumer's acceptance. By-products formulations received lower scores and were related to features like bitter, bitter aftertaste and bad aftertaste. New products could be developed by reducing the amount of by-product or incorporating the fruit pulp, since pulp formulations were better accepted by consumers.

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DISCUSSÃO GERAL

Com relação à secagem dos subprodutos do processamento de cambuci, grumixama e uvaia, as curvas de secagem (razão de umidade *versus* tempo) demonstraram que quanto maior a temperatura de secagem, menores foram os tempos. Além da secagem convencional a 40, 60 e 80 °C, foi testada a adição de um processo prévio de eliminação da água através da centrifugação do resíduo. Após o processo, o resíduo foi seco conforme os demais ensaios. A adição desta etapa de centrifugação teve o objetivo de preservar a qualidade e os compostos bioativos presentes no resíduo. Conforme esperado, a retirada da água permitiu reduzir o tempo de exposição do resíduo às temperaturas de secagem, além possibilitar uma redução na energia de secagem. Sugere-se que um estudo posterior com aumento de escala seja feito para de fato comparar a economia de energia decorrente do processo de centrifugação

O tempo de secagem para os resíduos de uvaia variou entre 330 e 1110 min (80C e 40NC, respectivamente). Os resíduos de grumixama apresentaram menores tempos de secagem: entre 255 e 870 min (80C e 40NC, respectivamente). Já os resíduos de cambuci apresentaram tempos de secagem entre 225 e 1410 min (80C e 40NC, respectivamente). Comparando ensaios de secagem na mesma temperatura, para o resíduo de uvaia, os tempos de secagem foram reduzidos em 24,5%, 16,7% e 21,4% para os ensaios centrifugados nas temperaturas de 40, 60 e 80 °C, respectivamente. Para o resíduo de grumixama, os tempos foram reduzidos em 24%, 31% e 15% para ensaios a 40, 60 e 80 °C, respectivamente. Já para o resíduo de cambuci, foram observadas as maiores reduções no tempo de secagem para ensaios na mesma temperatura: 54% (40 °C), 47% (60 °C) e 44% (80 °C).

Para os ensaios com centrifugação prévia, a diferença no tempo de secagem entre 40 °C e 80 °C foi de 63%, 61% e 66% para uvaia, grumixama e cambuci, respectivamente. Em relação aos ensaios sem centrifugação prévia, a tendência foi semelhante: 64%, 66% e 72% para uvaia, grumixama e cambuci, respectivamente.

Com a adição da etapa de centrifugação prévia para a secagem dos resíduos de grumixama e uvaia, os ensaios a 80 °C sem centrifugação apresentaram tempo de secagem próximo aos ensaios a 60 °C com centrifugação.

A taxa de secagem, para todas as frutas e condições estudadas, não foi constante e, conforme esperado, diminuiu na medida em que o produto era seco. Temperaturas menores apresentaram menores taxas de secagem quando comparadas a temperaturas mais altas. Além disso, ao comparar ensaios da mesma fruta na mesma temperatura, os ensaios com centrifugação prévia apresentaram menores taxas de secagem.

Quanto à modelagem matemática dos dados experimentais de razão de secagem (MR) *versus* tempo, de forma geral, praticamente todos os modelos utilizados apresentaram bom ajuste aos dados (valores altos de R^2 e valores baixos de χ^2 e RMSE), com destaque para o modelo *Midilli*. O único modelo testado que apresentou um ajuste inferior aos demais foi o *Wang and Singh*. Os modelos *Midilli, Logarithmic, Page, Modified Page, Henderson and Pabis* e *Weibull* podem ser usados para descrever a cinética de secagem dos resíduos de cambuci, uvaia e grumixama.

Conforme esperado, a difusividade efetiva foi maior para os tratamentos com temperaturas mais altas. A centrifugação prévia, para todas as temperaturas resultou em um aumento na difusividade. Os resultados encontrados para as três frutas estão de acordo com o esperado para produtos agrícolas: 10^{-12} a 10^{-8} m^2/s (DO NASCIMENTO et al., 2016). Além da temperatura, o tipo de equipamento de secagem, a estrutura e forma do produto a ser seco, o teor de umidade inicial e outras condições de secagem podem influenciar nos valores de difusividade (DOYMAZ, 2017).

Para a avaliação da cor, para os três resíduos estudados, a secagem por liofilização foi utilizada para a obtenção das amostras controle. Sendo assim, em comparação ao resíduo liofilizado, no caso das três frutas estudadas houve mudança considerável na cor do produto seco em todas as condições de secagem avaliadas.

Para todas as condições de secagem e para as três frutas, houve uma redução no parâmetro de luminosidade (L) após a secagem, indicativo de escurecimento da amostra. No caso da uvaia, houve diminuição da cor amarela e um aumento da cor vermelha. Para o cambuci, houve aumento das cores amarela e vermelha. E para a grumixama, houve redução nas cores amarela e vermelha com a secagem. Entre as três frutas estudadas, os resíduos de cambuci foram os que apresentaram maior diferença total de cor (ΔE) quando comparados ao resíduo liofilizado da respectiva fruta. De maneira geral, para as três frutas, os resíduos que passaram por centrifugação prévia, apresentaram menor diferença total de cor que os resíduos que foram diretamente secos.

De maneira geral, os resíduos secos em diferentes condições apresentaram diferentes teores de fenólicos totais e capacidade antioxidante para as três frutas. Não foi encontrada na literatura a avaliação dos compostos fenólicos dos resíduos do processamento de cambuci, grumixama e uvaia.

Comparando os resultados obtidos para as frações das frutas (polpa, resíduo e fruto), para as três frutas, o resíduo apresentou os maiores teores de compostos fenólicos totais e capacidade antioxidante e a polpa os menores. Por exemplo, o teor de compostos fenólicos totais presentes no resíduo foi 1,9; 4,9 e 1,7 vezes maior que o encontrado na polpa de uvaia, grumixama e cambuci, em base seca, respectivamente.

Para os resíduos secos das três frutas, foi possível verificar que a adição da etapa prévia de centrifugação do resíduo úmido trouxe resultados positivos na retenção de compostos fenólicos totais nas três temperaturas estudadas. Tal retenção pode ser relacionada à retirada de parte da água pela centrifugação e consequente redução do tempo de secagem. Para a grumixama, por exemplo, o resíduo seco sem centrifugação prévia apresentou teor de compostos fenólicos totais 15,1%, 23,8% e 28,0% menores que o resíduo seco com centrifugação prévia para os ensaios a 40, 60 e 80 °C, respectivamente. Comparando os teores de compostos fenólicos totais dos resíduos de uvaia secos com o controle (resíduo liofilizado), houve uma redução de 3% (40C) a 21% (80NC), sendo que a condição 40C não apresentou diferença significativa em relação ao controle ($p<0,05$). Já para a grumixama, o resíduo foi, entre as três frutas estudadas, aquele que apresentou maior quantidade de compostos fenólicos totais. Assim como no caso da uvaia, 40C foi a condição de secagem com maior retenção dos compostos fenólicos totais, não diferindo do controle ($p<0,05$). As reduções do teor de compostos fenólicos totais com a secagem variaram de 0,2% (40C) a 33,8% (80NC) em comparação ao controle. Foi possível verificar que temperaturas mais altas resultaram em maiores perdas nos compostos fenólicos totais. No caso do cambuci, comparando com as outras duas frutas estudadas, o produto seco apresentou a maior perda de compostos fenólicos na secagem. Houve redução de 24,9% (80C) a 42,4% (60NC) em relação ao controle. Diferentemente das secagens das outras duas frutas, o tratamento 80C foi o que apresentou maior retenção de compostos fenólicos totais no resíduo de cambuci. Apesar da alta temperatura (80 °C), o tempo de secagem foi curto. O teor de compostos bioativos no produto pode ser afetado tanto pelo tempo quanto pela temperatura de exposição e isso pode variar de fruta para fruta dependendo dos tipos de compostos fenólicos presentes. Para o cambuci, tempos de exposição mais longos a temperaturas mais baixas resultaram em maiores perdas.

Deve-se destacar que apesar da ocorrência de perdas nos teores de compostos fenólicos totais para a maioria das condições de secagem estudadas, ainda há presença significativa destes compostos nos produtos secos. É interessante a utilização desses resíduos na formulação de outros alimentos, trazendo a possibilidade de adicionar esses compostos fenólicos a outros produtos destinados à alimentação humana.

A quantidade de fibras presentes nos resíduos estudados foi de 3,4 a 4,7 vezes a quantidade de fibras presente nas polpas. Mesmo em menor quantidade, as polpas das frutas estudadas também apresentaram fibras em sua composição. Tanto a polpa como o resíduo podem contribuir com fibras nos produtos em que são utilizados como matéria-prima.

Quanto aos teores de ácidos orgânicos avaliados na polpa, fruta, resíduo e resíduo seco, o resíduo e o resíduo seco apresentaram as menores quantidades. Entre os ácidos avaliados na uvaia, estavam presentes o málico e o ascórbico. O cambuci apresentou todos os ácidos estudados (ascórbico, málico, cítrico e tartárico). Já a grumixama apresentou o tartárico, o málico e o cítrico. A vitamina C (ácido ascórbico) já não estava inicialmente presente no resíduo de grumixama. No entanto, para uvaia e cambuci, verificou-se que houve degradação da vitamina C após a secagem do resíduo. O ácido ascórbico não foi detectado nos resíduos secos.

A utilização da polpa e/ou resíduo seco ou úmido de cambuci, uvaia e grumixama em produtos destinados à alimentação humana é uma oportunidade de trazer novos sabores e, no caso da utilização dos resíduos, também agregar valor a um subproduto usualmente pouco aproveitado. A área de confeitos é interessante para aplicação dessas frutas e são muito escassos os estudos na área envolvendo o aproveitamento de resíduos gerados na cadeia produtiva de frutas. A utilização do resíduo e/ou da polpa das frutas pode ser interessante para conferir aroma e cor naturais aos confeitos. Na utilização proposta a própria fruta foi responsável por conferir sabor e cor aos produtos. Além disso, a introdução de polpa e/ou resíduos em confeitos permitiu a incorporação de compostos de interesse à alimentação humana como fibras e compostos bioativos. A elaboração dos confeitos (barra de fruta, confeito drageado e balas de goma) a base de polpa e/ou resíduo do processamento de cambuci, uvaia e grumixama mostrou-se tecnologicamente viável.

Comparando as diferentes frutas utilizadas, a avaliação da barra de fruta e balas de goma, conforme esperado, revelou produtos com compostos fenólicos totais e capacidade antioxidante maiores para aqueles formulados com grumixama, seguido dos produtos elaborados com cambuci e dos produtos elaborados com uvaia. No caso dos confeitos drageados, além da fruta, a cobertura também exerceu influência no resultado de compostos fenólicos totais e capacidade antioxidante, sendo que a cobertura de chocolate contribuiu mais que a de cupulate.

Em relação às formulações de barra de fruta, no caso das três frutas, aquela que apresentou maior capacidade antioxidante e compostos fenólicos totais foi a LDB (formulação com resíduo seco de menor tamanho de partícula), enquanto a P (formulação com polpa) foi a que resultou nos menores valores. As formulações LDB apresentaram compostos fenólicos totais 4,1; 5,7 e 3 vezes maiores que as formulações P e capacidade antioxidante 2,2; 6,6 e 3,7 vezes maior que as formulações P para uvaia, grumixama e cambuci, respectivamente. As barras de fruta apresentaram de 1,24 a 5,13 mg GAE/g bs, 4,33 a 24,32 mg GAE/g bs e 3,82 a 11,25 mg GAE/g bs para uvaia, grumixama e cambuci, respectivamente. Para todas as barras o menor valor foi para a formulação P e o maior para a LDB.

Para as balas de goma, de maneira geral, as formulações com resíduo apresentaram valores superiores àqueles das balas produzidas com polpa. As formulações com resíduo apresentaram compostos fenólicos totais até 3,4; 8,1 e 2,8 vezes maiores que as formulações com polpa e capacidade antioxidante até 2,1; 9,6 e 2,2 vezes maior que as formulações com polpa para uvaia, grumixama e cambuci, respectivamente. As balas apresentaram de 0,58 a 1,96 mg GAE/g bs, 0,95 a 6,92 mg GAE/g bs e 1,04 a 2,93 mg GAE/g bs para uvaia, grumixama e cambuci, respectivamente.

Comparando os compostos fenólicos totais nas balas (em base úmida) com a polpa das frutas (em base úmida), que é o produto normalmente consumido pela população, as balas de polpa apresentaram compostos fenólicos totais até 0,6 (JC-GP), 0,6 (JC-GAGP) e 0,89 (JC-PP) vezes a quantidade de compostos fenólicos totais da polpa para uvaia, grumixama e cambuci, respectivamente. Já as balas de resíduos apresentaram compostos fenólicos totais até 1,3 (JC-PB), 2,7 (JC-AB) e 0,9 (JC-PB) vezes a quantidade de compostos fenólicos totais da polpa para uvaia, grumixama e cambuci, respectivamente.

Comparando os compostos fenólicos totais nas barras de fruta com a polpa das frutas, em base úmida, as barras da formulação LDB apresentaram compostos fenólicos totais até 3,4, 8,4 e 3,5 vezes maiores que a quantidade de compostos fenólicos totais da polpa para uvaia, grumixama e cambuci, respectivamente. Já as barras de formulação P apresentaram compostos fenólicos totais até 0,8, 1,4 e 1,2 vezes a quantidade de compostos fenólicos totais da polpa para uvaia, grumixama e cambuci, respectivamente.

Os confeitos drageados, por sua vez, apresentaram de 2,16 (CUP_U) a 8,48 mg GAE/g bs (CHO_G). Comparando os compostos fenólicos totais nos confeitos drageados com a polpa das frutas, em base úmida, os drageados de chocolate apresentaram compostos fenólicos totais até 4.4 vezes maiores (CHO_U) que a polpa da respectiva fruta. Já os drageados com cupulate apresentaram compostos fenólicos totais até 2 vezes maiores (CUP_G) que a da polpa da respectiva fruta.

Considerando a quantidade de fibras presente nas matérias-primas utilizadas na produção das balas e barras, foi calculada a quantidade de fibras presente em cada um dos produtos finais. As balas desenvolvidas apresentaram até 10,86% de fibras (JC_GAGB, cambuci) (base úmida). Já as barras apresentaram até 13% de fibras (LDB, grumixama) (base úmida) em sua composição. Para fins comparativos, tomou-se como referência a quantidade de fibras presente nas polpas das frutas (base úmida). As polpas apresentaram quantidades de fibra de 0,77%, 1,36% e 1,73% para uvaia, grumixama e cambuci, respectivamente. Entre as balas de polpa ou resíduo, respectivamente, a quantidade de fibras foi até 10,9 vezes (JC_GAGP, uvaia) e 13,6 vezes (JC_GAGB, uvaia) maior que a quantidade de fibras da polpa da respectiva fruta. No caso das barras, a quantidade de fibras foi até 15,8 vezes (LDB, uvaia) maior que a quantidade de fibras da respectiva polpa.

Por fim, a análise sensorial realizada nos confeitos mostrou a aceitação destes produtos pelos consumidores. As balas de goma, de forma geral, apresentaram valores de impressão global e sabor superiores para as balas produzidas com polpa e valores inferiores para as balas produzidas com resíduo. Para as três frutas, as balas com maior aceitação foram produzidas com polpa e pectina ou polpa, ágar e pectina.

As barras de grumixama, entre as três frutas, apresentaram valores inferiores de aceitação global. As formulações com maior aceitação foram P e SDB. As barras de uvaia com maiores notas de aceitação foram P, PSDB e PLDB. E a barra de cambuci preferida pelo consumidor foi a P. Os drageados, que tinham como núcleo a formulação SDB de cada uma das frutas, apresentaram bons valores de aceitação global, principalmente quando comparados às barras de frutas SDB. Tanto os drageados cobertos com chocolate como os cobertos com cupulate tiveram boa aceitação do consumidor.

Através da análise dos dados de CATA e também da análise de penalidades, foi possível ter uma ideia dos atributos que contribuíram positivamente ou negativamente para a aceitação do produto.

De forma geral, para as barras de fruta e balas de goma, atributos de sabor e textura como *amargo*, *amargor residual*, *sabor residual ruim* e *duro ao morder*, *arenoso* e *sabor floral* influenciaram negativamente na aceitação dos produtos. Características como *doce*, *sabor frutado*, *sabor residual agradável*, *ácido*, *textura macia*, *pode ser consumido a qualquer momento* e *prático* tiveram influência positiva. Tais características podem ser utilizadas como referência para o desenvolvimento ou melhoria das balas e barras de cambuci, uvaia e grumixama.

Para os confeitos drageados, o atributo *sabor de chocolate* exerceu influência positiva na aceitação dos produtos. A produção de confeitos drageados a base de resíduos de cambuci, uvaia e grumixama é uma oportunidade de utilização desses subprodutos, que agregaram compostos de interesse como compostos fenólicos e fibras aos produtos, além de características sensoriais da fruta. A utilização do cupulate no lugar do chocolate na cobertura dos drageados também é promissora, sendo que 34 a 48% dos provadores marcaram *sabor de chocolate* como uma característica dos produtos drageados com cupulate.

CONCLUSÃO GERAL

Os resíduos das frutas estudadas, em comparação à polpa e aos frutos, apresentam grande quantidade de compostos bioativos e fibras. Junto à questão de saudabilidade, cada vez mais recorrente, além da possibilidade de minimizar desperdícios pela indústria de frutas, aproveitar esses resíduos em produtos alimentícios é uma opção interessante, que pode permitir agregar valor a um subproduto que muitas vezes é descartado. As diferentes condições de secagem foram avaliadas e foi selecionada aquela que minimizasse as perdas dos principais compostos bioativos nos subprodutos secos. Ao mesmo tempo, a simplicidade do processo de secagem estudado torna a aplicação com devidas adequações viável a pequenos e médios produtores de polpa de frutas. O processo prévio de centrifugação do resíduo, etapa simples e de baixo custo adicionado ao processo, se mostrou adequado para reduzir o tempo de secagem. Trata-se de uma etapa a mais, porém possível de ser adicionada ao processo. A aplicação das polpas das frutas e dos respectivos subprodutos em confeitos se mostrou viável tecnicamente. Por meio da análise sensorial dos confeitos, foi possível verificar que os consumidores apreciam características como doce, sabor residual agradável, sabor e aroma frutados. A utilização dos resíduos ainda é um desafio, sendo associada muitas vezes a características como sabor residual ruim ou amargo. A utilização dos resíduos como centros nos confeitos drageados com chocolate e cupulate se mostrou uma boa alternativa para o aproveitamento destes resíduos em um produto de maior valor agregado. Num âmbito mais amplo, espera-se que, a partir da conclusão da pesquisa em questão, haja um estímulo aos pequenos e médios produtores de frutas nativas da Mata Atlântica para a industrialização do excedente de produção não comercializado *in natura*, seja pela obtenção de polpa ou outros produtos, com aproveitamento integral, inclusive dos resíduos gerados, possibilitando o reflorestamento com as árvores destes frutos em mais áreas anteriormente devastadas.

PERSPECTIVAS DE CONTINUIDADE OU DESDOBRAMENTO DO TRABALHO

Tendo em vista os resultados obtidos no presente estudo, algumas sugestões de trabalhos futuros podem ser levantadas:

- Aprimoramento das formulações desenvolvidas para melhoria da aceitação sensorial das balas de goma por meio de variações nas concentrações de polpa e resíduo;

- Substituição da sacarose e do xarope de glucose dos confeitos desenvolvidos (barra de fruta, balas de goma e confeito drageado) por edulcorantes e/ou polióis, a fim de tornar mais amplo o potencial público consumidor do produto, atingindo consumidores com restrição à ingestão de açúcares. Ou, ainda, a utilização de sucos ou polpas de outras frutas como fonte de açúcar, como, por exemplo, o suco de maçã, com o objetivo de adoçá-los naturalmente;

- Potencial aplicação de resíduos de outras frutas em confeitos;

- Estudo de formas de separação das sementes e do bagaço/casca.

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ANEXO 1

TERMO DE CONSENTIMENTO LIVRE E ESCLARECIDO

Caracterização de compostos bioativos e estudo da secagem de subprodutos de frutas nativas da Mata Atlântica

Nome do responsável: Kazumi Kawasaki Ramos

CAAE: 34473514.4.0000.5404

Você está sendo convidado(a) a participar como voluntário de um estudo. Este documento, chamado Termo de Consentimento Livre e Esclarecido, visa assegurar seus direitos como participante e é elaborado em duas vias, uma que deverá ficar com você e outra com o pesquisador. Após a leitura com calma e atenção, caso concorde em fazer parte do estudo, assine no final deste documento.

Justificativa e objetivos:

A utilização de frutas e seus produtos na alimentação humana tem sido associada a diversos benefícios à saúde. O Brasil conta com uma grande diversidade de espécies frutíferas, muitas delas ainda pouco conhecidas. No entanto, existe um movimento de busca do consumidor por novos produtos e novos sabores, o que pode impulsionar o mercado de frutas nativas, além gerar maiores oportunidades para pequenos produtores. As indústrias processadoras de polpa de frutas geram grandes quantidades de cascas e bagaço, por conta disso existe interesse em aproveitá-los. Uma forma de agregar valor a esses subprodutos, uma vez que ainda podem ser ricos em compostos de interesse, é a sua utilização em produtos destinados à alimentação humana, como os confeitos.

O objetivo do presente projeto é a utilização das polpas e subprodutos de frutas nativas da Mata Atlântica para desenvolver confeitos (balas a partir de diferentes agentes gelificantes e estruturado de fruta a base de pectina), avaliando a sua aceitação sensorial.

Procedimentos:

Cada participante irá realizar a análise em cabines individuais, receberá dez diferentes amostras de confeito para degustação. As balas e estruturados de fruta foram elaborados na Planta Piloto do Laboratório de Frutas e Hortaliças (DTA/FEA/Unicamp), podendo conter os seguintes ingredientes (comuns em confeitos): açúcar, frutas (uvaia, grumixama ou cambuci), pectina, amido de milho, goma acácia, pectina, gelatina, ágar, citrato de sódio e xarope de glicose. As amostras serão servidas e provadas individualmente e, entre as amostras, você receberá água filtrada para lavagem da cavidade oral. Você deverá preencher uma ficha de avaliação para cada amostra, de acordo com a sua percepção sensorial de cada uma destas. O procedimento terá uma duração total de aproximadamente 10 minutos.

Desconfortos e riscos:

Será considerado como critério de exclusão do voluntário: Apresentar alergia, intolerância ou restrição a um ou mais componentes das formulações que serão analisadas. As frutas envolvidas no presente estudo são frutas não convencionais e não conhecidas por grande da população, sendo mais consumidas na região de Mata Atlântica (onde a população local tem maior acesso a essas frutas). Cabe ressaltar que há sempre a possibilidade de apresentar uma alergia não previamente conhecida. Se você tiver algum problema relacionado diretamente à sua participação no estudo, você será encaminhado para o serviço de emergência disponível no Hospital das Clínicas, Rua Vital Brasil, 251, Campinas - SP. Cabe ressaltar que o consumo excessivo de açúcar pode ser prejudicial à saúde, podendo estar relacionado a doenças como diabetes e obesidade. Sendo assim, sugere-se que o consumo dos confeitos não seja feito de maneira abusiva. Ao provar a amostra, não é necessário ingerir a amostra inteira. Você pode ingerir somente o suficiente para realizar a avaliação.

Serão considerados como critérios de inclusão para a participação do voluntário: Ter idade mínima de 18 anos e máxima de 50 anos; Ser aluno ou funcionário da Unicamp; Ser consumidor e gostar de balas e confeitos e assinar o termo de consentimento livre e esclarecido.

O voluntário durante o projeto terá toda a liberdade para questionamento de qualquer dúvida e esclarecimento sobre a pesquisa a ser realizada bem como poderá deixar de participar da pesquisa a qualquer tempo, sem prejuízos. Também não haverá nenhuma forma de reembolso de dinheiro, já que com a participação na pesquisa o voluntário não terá gastos.

Benefícios:

Não haverá benefício direto ao participante. Sua participação como voluntário auxiliará, em termos de conhecimento e retorno social na geração de conhecimento que permitirá o desenvolvimento sustentável da indústria processadora de polpa de fruta, com foco no pequeno produtor. Cabe informar que não haverá ressarcimento financeiro ao participante da pesquisa, já que com a participação na pesquisa o voluntário não terá nenhum gasto.

Sigilo e privacidade:

Sua identidade será mantida em sigilo e nenhuma informação será fornecida a outras pessoas que não façam parte da equipe da pesquisa.

Contato:

Em caso de dúvidas sobre o estudo, você poderá entrar em contato com a pesquisadora Kazumi Kawasaki Ramos; Laboratório de Frutas e Hortaliças - Faculdade de Engenharia de Alimentos - FEA/UNICAMP; Rua Monteiro Lobato, 80, Distrito de Barão Geraldo, Campinas – SP, CEP: 13083-862; E-mail: kazumiramos@gmail.com / kaka@fea.unicamp.br. Telefone: (19) 3521-4006.
Em caso de denúncias ou reclamações sobre sua participação e sobre questões éticas do estudo, você pode entrar em contato com a secretaria do Comitê de Ética em Pesquisa (CEP) da UNICAMP: Rua: Tessália Vieira de Camargo, 126; CEP 13083-887 Campinas – SP; telefone (19) 3521-8936; fax (19) 3521-7187; e-mail: cep@fcm.unicamp.br

Consentimento livre e esclarecido:

Após ter sido esclarecido(a) sobre a natureza da pesquisa, seus objetivos, métodos, benefícios previstos, potenciais riscos e o incômodo que esta possa acarretar, aceito participar:

Nome do(a) participante: ________________________ Data: ____/_____/______.
(Assinatura do participante ou nome e assinatura do seu responsável LEGAL)

Responsabilidade do Pesquisador:

Asseguro ter cumprido as exigências da resolução 466/2012 CNS/MS e complementares na elaboração do protocolo e na obtenção deste Termo de Consentimento Livre e Esclarecido. Asseguro, também, ter explicado e fornecido uma cópia deste documento ao participante. Informo que o estudo foi aprovado pelo CEP perante o qual o projeto foi apresentado. Comprometo-me a utilizar o material e os dados obtidos nesta pesquisa exclusivamente para as finalidades previstas neste documento ou conforme o consentimento dado pelo participante.

____Data: ____/_____/______.
(Assinatura do pesquisador)

ANEXO 2

TERMO DE CONSENTIMENTO LIVRE E ESCLARECIDO

Aproveitamento de subprodutos do processamento de polpa de frutas nativas da Mata Atlântica e Amazônia em produtos drageados

Nome do responsável: Matheus Henrique Mariz de Avelar
Número do CAAE: 47862015.4.0000.5404

Você está sendo convidado a participar como voluntário de uma pesquisa. Este documento, chamado Termo de Consentimento Livre e Esclarecido, visa assegurar seus direitos como participante e é elaborado em duas vias, uma que deverá ficar com você e outra com o pesquisador.

Por favor, leia com atenção e calma, aproveitando para esclarecer suas dúvidas. Se houver perguntas antes ou mesmo depois de assiná-lo, você poderá esclarecê-las com o pesquisador. Se preferir, pode levar este Termo para casa e consultar seus familiares ou outras pessoas antes de decidir participar. Se você não quiser participar ou retirar sua autorização, a qualquer momento, não haverá nenhum tipo de penalização ou prejuízo.

Justificativa e objetivos:

A incorporação de frutas em confeitos pode ser uma alternativa potencial para as indústrias de confeitos atenderem à crescente demanda dos consumidores por produtos mais saudáveis e com melhor qualidade nutricional e sensorial. Além da polpa, vários estudos científicos têm demonstrado que os resíduos gerados no processamento das frutas têm potencial aplicação como ingrediente funcional em vários alimentos. O aproveitamento dos resíduos de frutas pode representar a recuperação de nutrientes, compostos bioativos de interesse e fibras, além de permitir a redução no custo de produção e no tratamento de resíduos nas indústrias. A elaboração de confeitos com subprodutos do processamento de frutas é uma tecnologia pouco explorada, mas que apresenta potencial aplicação industrial.

Em vista disso, esse projeto tem como objetivo avaliar a aplicação de subprodutos de frutas em confeitos drageados e realizar a avaliação sensorial dos produtos desenvolvidos.

Procedimentos:

Participando do estudo você está sendo convidado a: realizar a análise em cabines individuais e receber diferentes amostras de confeitos drageados para degustação. Os drageados foram elaborados na Planta Piloto de Frutas e Hortaliças (DTA/FEA/Unicamp), podendo conter os seguintes ingredientes (comuns em confeitos): açúcar, cereal matinal, frutas (uvaia, grumixama ou cambuci), pectina, amido de milho, goma acácia, citrato de sódio, chocolate, cupulate (similar ao chocolate elaborado com sementes de cupuaçu), cera de abelha, cera de carnaúba, e xarope de glicose. As amostras serão servidas e provadas individualmente e, entre as amostras, você receberá água filtrada para lavagem da cavidade oral. Você deverá preencher uma ficha de avaliação para cada amostra, de acordo com a sua percepção sensorial. O procedimento terá uma duração total de aproximadamente 10 minutos.

Desconfortos e riscos:

Você **não** deve participar deste estudo se: Apresentar alergia, intolerância ou restrição a um ou mais componentes das formulações que serão analisadas. As frutas envolvidas no presente estudo são frutas não convencionais e pouco conhecidas por grande da população, sendo mais consumidas em regiões de Mata Atlântica e Amazônia (onde a população local tem maior acesso a essas frutas). Cabe ressaltar que há sempre a possibilidade de apresentar uma alergia não previamente conhecida. Se você tiver algum problema relacionado diretamente à sua participação no estudo, você será encaminhado para o serviço de emergência disponível no Hospital das Clínicas, Rua Vital Brasil, 251, Campinas - SP. Cabe ressaltar que o consumo excessivo de açúcar pode ser prejudicial à saúde, podendo estar relacionado a doenças como diabetes e obesidade. Sendo assim, sugere-se que o consumo dos confeitos não seja feito de maneira abusiva. Ao provar a amostra, não é necessário ingeri-la inteira. Você pode ingerir somente o suficiente para realizar a avaliação.

Serão considerados como critérios de inclusão para a participação do voluntário: Ter idade mínima de 18 anos e máxima de 50 anos; Ser aluno ou funcionário da Unicamp;

Ser consumidor e gostar de confeitos e assinar o termo de consentimento livre e esclarecido.
O voluntário durante o projeto terá toda a liberdade para questionamento de qualquer dúvida e esclarecimento sobre a pesquisa a ser realizada bem como poderá deixar de participar da pesquisa a qualquer tempo, sem prejuízos. Também não haverá nenhuma forma de reembolso de dinheiro, já que com a participação na pesquisa o voluntário não terá gastos.

Benefícios:
Não haverá benefício direto ao participante. Sua participação como voluntário auxiliará na geração de conhecimento e retorno social que poderá permitir a inovação e o desenvolvimento sustentável da indústria processadora de polpa de fruta e de confeitos.

Sigilo e privacidade:
Sua identidade será mantida em sigilo e nenhuma informação será fornecida a outras pessoas que não façam parte da equipe da pesquisa.

Ressarcimento:
Não haverá ressarcimento financeiro ao participante da pesquisa, já que não é previsto gasto do voluntário com a participação na pesquisa.

Contato:
Em caso de dúvidas sobre o estudo, você poderá entrar em contato com o pesquisador Matheus Henrique Mariz de Avelar; Laboratório de Frutas e Hortaliças - Faculdade de Engenharia de Alimentos - FEA/UNICAMP; Rua Monteiro Lobato, 80, Distrito de Barão Geraldo, Campinas – SP, CEP: 13083-862; E-mail: Matheus.hmavelar@yahoo.com.br. Telefone: (19) 3521-4006.
Em caso de denúncias ou reclamações sobre sua participação e sobre questões éticas do estudo, você pode entrar em contato com a secretaria do Comitê de Ética em Pesquisa (CEP) da UNICAMP das 08:30hs às 13:30hs e das 13:00hs as 17:00hs na Rua: Tessália Vieira de Camargo, 126; CEP 13083-887 Campinas – SP; telefone (19) 3521-8936; fax (19) 3521-7187; e-mail: cep@fcm.unicamp.br

Consentimento livre e esclarecido:

Após ter sido esclarecido(a) sobre a natureza da pesquisa, seus objetivos, métodos, benefícios previstos, potenciais riscos e o incômodo que esta possa acarretar, aceito participar:

Nome do(a) participante:

____

____Data: ____/_____/______.

(Assinatura do participante ou nome e assinatura do seu responsável LEGAL)

Responsabilidade do Pesquisador:

Asseguro ter cumprido as exigências da resolução 466/2012 CNS/MS e complementares na elaboração do protocolo e na obtenção deste Termo de Consentimento Livre e Esclarecido. Asseguro, também, ter explicado e fornecido uma cópia deste documento ao participante. Informo que o estudo foi aprovado pelo CEP perante o qual o projeto foi apresentado. Comprometo-me a utilizar o material e os dados obtidos nesta pesquisa exclusivamente para as finalidades previstas neste documento ou conforme o consentimento dado pelo participante.

____Data: ____/_____/______.

(Assinatura do pesquisador)

ANEXO 3

Não disponibilidade do sistema de cadastro no Sistema Nacional de Gestão do Patrimônio Genético