UNIVERSIDADE ESTADUAL PAULISTA
"JÚLIO DE MESQUITA FILHO"
Campus de São José do Rio Preto

Vania Silva Carvalho

Aproveitamento da casca de banana na elaboração de barras de cereais: avaliação dos compostos bioativos, características físicas e sensoriais

São José do Rio Preto/SP
2015

Vania Silva Carvalho

Aproveitamento da casca de banana na elaboração de barras de cereais: avaliação dos compostos bioativos, características físicas e sensoriais

Tese apresentada como parte dos requisitos para obtenção do título de Doutora em Engenharia e Ciência de Alimentos, junto ao Programa de Pós-Graduação em Engenharia e Ciência de Alimentos, Área de Concentração – Ciência e Tecnologia de Alimentos, do Instituto de Biociências, Letras e Ciências Exatas da Universidade Estadual Paulista “Júlio de Mesquita Filho”, Câmpus de São José do Rio Preto.

Orientadora: Profª. Drª. Ana Carolina Conti e Silva

São José do Rio Preto
2015

Carvalho, Vania Silva.
Aproveitamento da casca de banana na elaboração de barras de cereais : avaliação dos compostos bioativos, características físicas e sensoriais / Vania Silva Carvalho. -- São José do Rio Preto, 2015
116 f. : il., tabs.

Orientador: Ana Carolina Conti e Silva
Tese (doutorado) – Universidade Estadual Paulista "Júlio de Mesquita Filho", Instituto de Biociências, Letras e Ciências Exatas

1. Tecnologia de alimentos. 2. Alimentos - Análise. 3. Banana - Subprodutos. 4. Compostos bioativos. 5. Fenóis. 6. Antioxidantes. 7. Alimentos - Armazenamento. I. Conti-Silva, Ana Carolina. II. Universidade Estadual Paulista "Júlio de Mesquita Filho". Instituto de Biociências, Letras e Ciências Exatas. III. Título.

CDU – 664.07(083.74)

Ficha catalográfica elaborada pela Biblioteca do IBILCE
UNESP - Campus de São José do Rio Preto

Vania Silva Carvalho

Aproveitamento da casca de banana na elaboração de barras de cereais: avaliação dos compostos bioativos, características físicas e sensoriais

Tese apresentada como parte dos requisitos para obtenção do título de Doutora em Engenharia e Ciência de Alimentos, junto ao Programa de Pós-Graduação em Engenharia e Ciência de Alimentos, Área de Concentração – Ciência e Tecnologia de Alimentos, do Instituto de Biociências, Letras e Ciências Exatas da Universidade Estadual Paulista "Júlio de Mesquita Filho", Câmpus de São José do Rio Preto.

Banca Examinadora

Profª. Drª. Ana Carolina Conti e Silva
UNESP – São José do Rio Preto
Orientador

Profª. Drª. Natália Soares Janzantti
UNESP – São José do Rio Preto

Profª. Drª. Adriana Barbosa Santos
UNESP – São José do Rio Preto

Profª. Drª. Valéria Paula Rodrigues Minim
UFV – Viçosa

Profª. Drª. Vanessa Dias Capriles
UNIFESP – São Paulo

São José do Rio Preto/SP, 07 de agosto de 2015

Dedicatória

À Laura.

Agradecimentos

Agradeço a Deus por me amparar nos momentos difíceis, me dar força interior para superar as dificuldades, mostrar o caminho nas horas incertas e me suprir em todas as minhas necessidades.

À minha linda filha Laura Rocha Carvalho, que Deus me deu a graça de conceber. É por ela que escolhi este caminho e é ela que sempre me deu força para continuar lutando dia a dia para enfrentar todas as adversidades que me surgiram durante este trabalho. Por me acompanhar nas análises diurnas e noturnas; por suportar o ‘cheiro fedido’ do laboratório; por compreender que a mamãe estava trabalhando aos finais de semana; por entender que a mamãe não podia lhe dar toda a atenção desejada, pois estava escrevendo essas páginas. Filha, o meu amor por você é imensurável!

À minha mãe, Maria Divina da Silva Carvalho, principal responsável pela minha vida e a quem devo meu caráter.

Ao meu pai, Francisco das Chagas de Carvalho, que me ensinou ter disciplina no trabalho e a saber lutar pelos meus objetivos.

Aos meus queridos irmãos Silvia e Daniel que sempre me incentivaram nessa jornada e sempre me apoiaram, seja numa simples conversa ou tendo que me aguentar num final de semana inteiro.

A todos os meus sobrinhos Jordana, Sofia, Tales e Isadora, que mesmo não entendendo direito o que a Dindinha/Titia fazia, sabiam que não era fácil e mesmo assim ainda querem ser ‘cientistas’.

À minha segunda família de São José do Rio Preto, Alana, Patrícia, Michele, Natália Antunes, Tatiane Seni, Talita, Patrícia que me acolheram com tanto carinho e sempre me apoiaram com muito amor nas mais diversas situações.

À minha mais nova irmã e companheira Tatiane Ferreira da Silva, por todas nossas conversas, risos e choros, principalmente durante os tratamentos estatísticos. O doutorado vai acabar, mas nossa amizade apenas começou.

À minha orientadora Ana Carolina Conti e Silva, por me acolher desde o primeiro dia da minha jornada. Por ser sempre paciente, generosa, compreensiva e a mais completa profissional que já conheci. Você é o meu exemplo Ana, e espero ser pelo menos um terço da profissional que você é.

Às minhas amigas de apartamento, Adriana, Mara e Wanessa, grandes companheiras, que entre altos e baixos sempre nos ajudamos e apoiamos umas às outras.

A todos os queridos amigos do Ibilce, Cristhiane Cavallini, Eloi Silvestre, Márcia Scandiuzi (do CCI) que acolheram tão bem minha filha, Alex Santos (da pós-graduação) que sempre foi paciente comigo, Michele Fernanda, Ana Rita, Alíria (do Restaurante Universitário) que sempre tinham uma refeição caprichada para eu repor minhas energias.

Ao Alexandre por me fornecer as bananas tão prontamente sempre que eu precisava.

À minha mais nova família da cidade de Morrinhos/GO, Suzane, Dayana, Ana Paula, Ellen, Nayana. Vocês são a prova de que amigas verdadeiras existem!

À FAPESP e à Capes pelo apoio financeiro.

“Tenho a impressão de ter sido uma criança brincando à beira-mar, divertindo-me em descobrir uma pedrinha mais lisa ou uma conchinha mais bonita que as outras, enquanto o imenso oceano, na verdade, continua misterioso diante dos meus olhos.”

Isaac Newton

RESUMO

A casca de banana é um resíduo agroindustrial, rica do ponto de vista nutritivo e com potencial para utilização no desenvolvimento de um novo produto. Neste sentido, o objetivo geral deste trabalho foi estudar o efeito da adição da farinha da casca de banana na elaboração de barras de cereais. A metodologia de modelagem de misturas foi utilizada para investigar os efeitos da farinha da casca de banana, flocos de arroz e farinha de aveia na aceitação sensorial e características físicas das barras de cereais; as formulações mais e menos aceitas tiveram seus perfis sensoriais avaliados por meio de análise descritiva; e o armazenamento das barras de cereais foi estudado quanto aos compostos bioativos e propriedades de textura. Proporções equivalentes dos três componentes (farinha de casca de banana, flocos de arroz e farinha da aveia) e a interação binária de farinha de casca de banana e flocos de arroz resultaram em barras de cereais com um grau de aceitação na região de melhor resposta do diagrama triangular. Ainda, a farinha da casca de banana interagiu com flocos de arroz e a farinha de aveia, promovendo mudanças na cor, volume específico e adesividade das barras de cereais. O mapa de preferência externo mostrou que a barra de cereal com 50% de farinha de casca de banana e 50% de flocos de arroz e a barra de cereal com 17% de farinha de casca de banana/66% de flocos de arroz/17% de farinha de aveia foram caracterizadas pela aceitação pela aparência, textura, sabor e aceitação global, bem como maior volume específico, força de ruptura e dureza; a formulação com iguais proporções dos três ingredientes foi caracterizada pela aceitação pelo aroma e baixas intensidades de vermelho, amarelo e croma. A adição da farinha de casca de banana também mudou a intensidade dos termos descritores das barras de cereais, resultando em diferentes perfis sensoriais em relação à barra comercial. Barras com maior quantidade de farinha de casca de banana adicionada foram caracterizadas pela cor escura, aroma de banana e gosto amargo, enquanto que a barra com adição de menor quantidade de farinha de casca de banana foi caracterizada pela quantidade de flocos de arroz e crocância, pelo fato de possuir maior quantidade de flocos de arroz. A barra de cereal comercial foi caracterizada pela dureza, gosto doce, adesividade e sabor de aveia. Finalmente, durante o estudo do armazenamento das barras de cereais, a quantidade de compostos fenólicos, bem como a atividade antioxidante total pelos métodos ABTS e DPPH$^{\cdot}$ de algumas barras de cereais, reduziu do início ao final do estudo, embora tenha aumentado em outras formulações. Houve modificações nas propriedades de textura durante o armazenamento, com um incremento na força de ruptura no quarto mês e na dureza no nono mês. Este estudo mostrou ainda que as barras de cereais formuladas com farinha de casca de banana apresentaram maior força de ruptura no quarto mês, o que torna interessante seu consumo até o terceiro mês. Por outro lado, os teores de compostos fenólicos e atividade antioxidante diminuíram no sexto mês, com isso seu consumo se torna indicado até o quinto mês de armazenamento. Apesar das alterações, a análise de componentes principais mostrou que o tempo teve pouco efeito nas principais características das barras de cereais. Concluindo, a adição de farinha de casca de banana na elaboração de barras de cereais é viável do ponto de vista sensorial e contribui para a incorporação de compostos bioativos, agregando valor ao produto e diminuindo as perdas industriais.

Palavras-chave: *aceitação sensorial, textura, compostos fenólicos totais, atividade antioxidante total, análise descritiva, armazenamento.*

ABSTRACT

The banana peel is an agro-industrial residue, rich regarding to nutritive value and with potential to be used in the development of a new product. In this way, the objective of this work was to study the effect of addition of the banana peel flour in production of cereal bars. The mixture modeling methodology was used to investigate the effects of banana peel flour, rice flakes and oat flour on the sensory acceptability and physical characteristics of the cereal bars; the most and least accepted formulations had their sensory profiles evaluated through descriptive analysis; and the storage of the cereal bars was studied regarding to bioactive compounds and texture properties. Equivalent proportions of three components and binary mixtures of banana peel flour and rice flakes resulted in bars with liking degree in the region of higher response in the triangular diagrams. Yet, the interaction between banana peel flour with rice flakes or oat flour promoted changes to the color, specific volume and adhesiveness of the cereal bars. The external preference mapping showed that cereal bar with 50% of banana peel flour and 50% of rice flakes and the cereal bar with 17% of banana peel flour /66% of rice flakes/17% of oat flour were characterized by the acceptability by appearance, texture, flavor and overall acceptability, as well as greater specific volume, force of rupture and hardness; the formulation with equal proportions of the three ingredients was characterized by acceptability by the aroma, and low intensities of red, yellow and chroma. The addition of banana peel flour also changed the intensity of descriptive terms of the cereal bars, resulting in different sensory profiles in relation to the commercial bar. Cereal bars with higher quantities of banana peel flour were characterized by dark color, banana aroma and bitter taste, while cereal bar with lowest quantity of banana peel flour was characterized by amount of rice flakes and crispness, because it had lower quantity of rice flakes. The commercial cereal bar was characterized by hardness, sweet taste, adhesiveness and oat flavor. Finally, during the storage study of the cereal bars, the quantity of total phenolic compounds, as well as the total activity antioxidant by methods ABTS and DPPH in some cereal bars, was reduced from beginning to end of this study, although had increased in others formulations. The texture properties of the cereal bars were modified during storage study, with increment of force of rupture from the fourth month and of hardness from the ninth month. This study showed that cereal bars formulated with banana peel flour showed higher rupture force in the fourth month, which makes it interesting consumption until the third month. Moreover, the levels of phenolic compounds and antioxidant activity decreased in six month, it becomes consumption indicated by the fifth month of storage. However, the principal component analysis showed that time had a little effect on the principal characteristics of the cereal bars. Concluding, the addition of banana peel flour in formulations of cereal bars is feasible regarding to sensory aspects and it contributes to the incorporation of bioactive compounds, aggregating value to the product and reducing industrial losses.

Keywords: *sensory acceptability, texture, total phenolic compounds, total antioxidant activity, descriptive analysis, storage.*

SUMÁRIO

LISTA DE TABELAS

LISTA DE FIGURAS

CAPÍTULO 1

CAPÍTULO 2

CAPÍTULO 3

CAPÍTULO 4

1. INTRODUÇÃO GERAL

A banana é uma das frutas mais consumidas mundialmente, podendo ser destinada ao consumo direto e para a industrialização na forma de compotas, doces, geleias e sorvetes. No entanto, a sua casca constitui um resíduo gerado pela agroindústria sem finalidade industrial e, para valorizar a casca de banana, é indispensável o desenvolvimento de tecnologias que sejam capazes de utilizar racionalmente os resíduos gerados pelas indústrias alimentícias, contribuindo para o desenvolvimento sustentável do país.

Sabe-se que casca da banana é rica em fibras alimentares, proteínas, minerais, além de compostos bioativos com potencial antioxidante. Com isso, esse resíduo gerado pode ser utilizado pela indústria alimentícia e farmacêutica, como por exemplo a farinha da casca de maracujá, com a finalidade de agregar valor aos produtos.

O consumo de alimentos saudáveis é uma tendência no mundo todo e a barra de cereais está associada a isso, pois além de ser um produto prático, versátil e conveniente, pode ser preparado de forma a aumentar o seu valor nutritivo. Em um cotidiano em que as pessoas não dispõem de tempo para preparar alimentos nutricionalmente saudáveis, o crescimento do consumo deste tipo de alimento aumenta a cada ano. Neste sentido, a farinha da casca de banana torna-se um ingrediente em potencial para aplicação em barras de cereais.

Durante o preparo de alimentos, sabe-se que ocorrem interações entre os ingredientes que podem afetar suas propriedades físicas, químicas e sensoriais. Para que o controle dessas alterações ocorra de forma eficiente, garantido os melhores parâmetros físico-químicos e sensoriais, é fundamental para ciência de alimentos a utilização de técnicas de planejamento e análises estatísticas de forma a garantir um produto com as melhores caraterísticas. Além disso, alimentos sofrem diversas alterações durante seu armazenamento ao longo do tempo, sendo que algumas delas podem resultar em prejuízo no valor nutritivo e demais parâmetros de qualidade do produto.

Diante do exposto, um estudo utilizando a farinha de casca da banana na elaboração de barra de cereal, que é um produto de grande consumo e aceitação entre crianças e jovens, torna-se interessante do ponto de vista da saúde humana e da ciência e tecnologia de alimentos, já que poder-se-á valorizar os resíduos da indústria alimentícia na elaboração de um produto com valor agregado.

Assim, foram elaboradas diferentes formulações de barras de cereais contendo farinha de casca de banana por meio de modelagem de misturas, com o intuito de investigar o efeito dessa adição na aceitação sensorial e nas propriedades físicas das barras de cereais. O perfil sensorial de algumas barras de cereais foi caracterizado e foi avaliado, ainda, o efeito do armazenamento na estabilidade dos compostos fenólicos, atividade antioxidante e propriedades de textura das barras, com a finalidade de viabilizar a elaboração das barras de cereais com a adição de farinha de casca de banana e que sejam compatíveis com as barras de cereais existentes hoje no mercado.

2. OBJETIVOS

2.1. Objetivo geral

Aproveitar a casca de banana na elaboração de barras de cereais.

2.2. Objetivos específicos

Investigar o efeito da adição da farinha da casca de banana, flocos de arroz e farinha de aveia na aceitação sensorial e propriedades físicas das barras de cereais por meio da metodologia de modelagem de misturas (capítulo 2).

Caracterizar o perfil sensorial de diferentes formulações de barras de cereais por meio de análise descritiva (capítulo 3).

Estudar o efeito do tempo de armazenamento na estabilidade dos compostos fenólicos, atividade antioxidante total e parâmetros de textura das barras de cereais (capítulo 4).

CAPÍTULO 1

REVISÃO BIBLIOGRÁFICA

1. A banana

De acordo com FAO (2014), o Brasil ocupa o quinto lugar em produção de bananas, chegando a quase 7 milhões de toneladas/ano. No Brasil, é a segunda fruta em importância, o que pode ser comprovado pela produção anual (Tabela 1) (IBGE, 2012). As regiões de maior produção são Nordeste e Sudeste que juntas representam mais de 60% da produção total de bananas no país.

Tabela 1: Principais frutas produzidas no Brasil em 2012.

Frutas	Área (ha)	Produção (t)
Laranja	808.624	19.032.285
Banana	478.524	6.943.904
Uva	80.651	1.455.081
Abacaxi	90.833	3.176.593
Maçã	38.491	1.338.270
Demais Frutas	1.489.035	11.982.518

Fonte: IBGE (2012).

A maior parte da produção de bananas no Brasil destina-se ao mercado *in natura*, sendo que o volume de comercialização, de um modo geral, é bem distribuído ao longo do ano (IBGE, 2012).

As perdas pós-colheita são tidas como o principal agravante da bananicultura, atingindo volumes expressivos. Almeida e Silva (2008) constataram perdas de 3,25% em propriedades rurais, 1,66% no mercado livre do produtor e na faixa de 0 a 2,1% no mercado varejista. Em regiões mais quentes, como no Estado de Mato Grosso, essas perdas podem chegar a 42%, desde a climatização até o final da vida útil dos frutos (CAMPOS; VALENTE; PEREIRA, 2003).

Não se conhece, exatamente, o número de cultivares de bananas existentes no mundo, mas estima-se entre 100 a 300 (SANSOM, 1980). No Brasil as cultivares mais difundidas são a Prata, Pacovan, Prata Anã, Nanicão, Nanica e Grande Naine e, em menor escala, são plantadas as variedades Figo Cinza, Figo Vermelho, Ouro, Caru Verde e Caru Roxa (SILVA et al., 1999; SILVA; SANTOS-SEREJO; CORDEIRO, 2004).

Desde a década de noventa, a bananicultura mundial encontra-se baseada em um clone de banana do subgrupo Cavendish, a Grande Naine (JANICK, 1998). Esses cultivares são adequados tanto para a exportação do fruto *in natura* quanto para o processamento. Talvez esse seja um dos motivos que justifica o amplo cultivo dessa variedade (THOMPSOM, 1995). A banana Nanica, a mais disseminada das Cavendish, tem o porte mais baixo que as demais, com frutos delgados, longos, encurvados e de cor amarelo esverdeado.

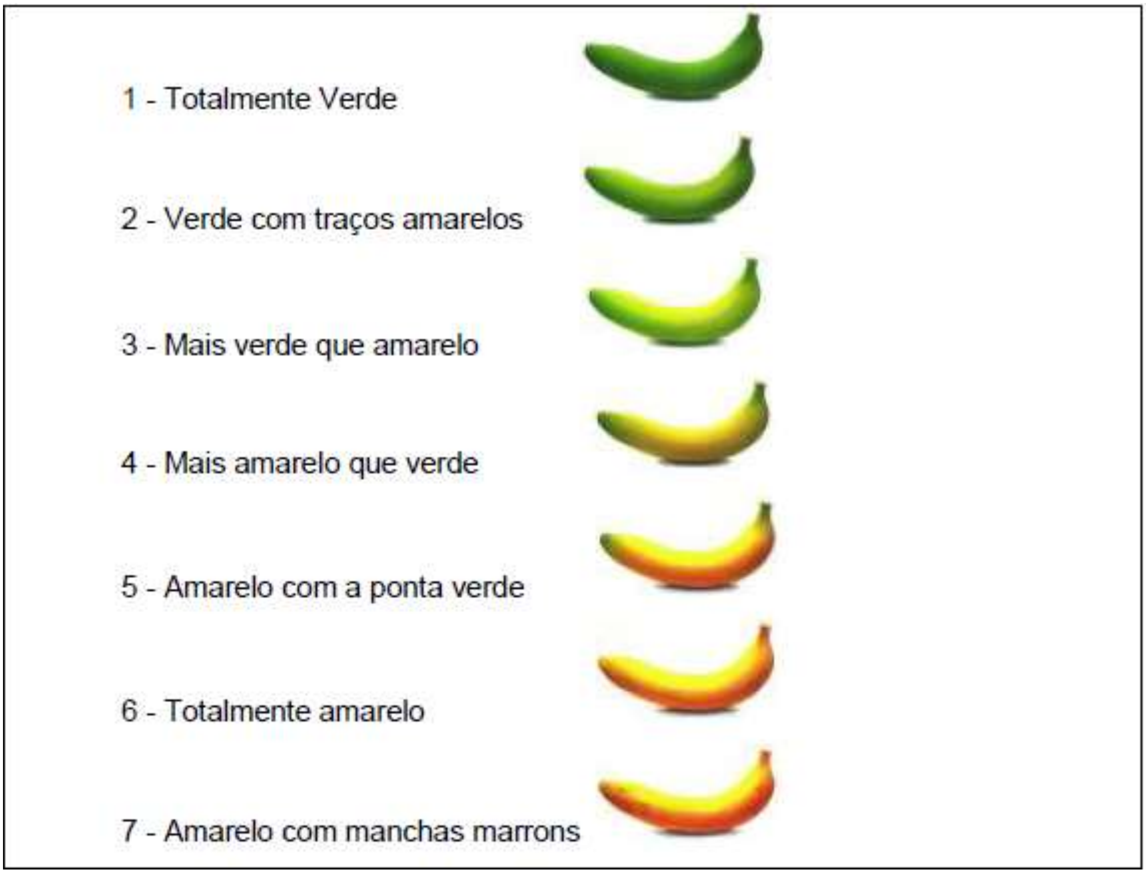
Não obstante as numerosas variedades de banana existentes no Brasil, levando-se em conta fatores como a preferência dos consumidores, produtividade, tolerância às pragas e doenças, resistência à seca e ao frio e porte, poucas cultivares apresentam potencial agroeconômico para fins comerciais (SILVA, et al., 1999). Assim, a EMBRAPA – Empresa Brasileira de Pecuária e Abastecimento, em parceria com outras instituições nacionais e internacionais, dispõe de um programa de melhoramento genético com o objetivo de obter vários genótipos resistentes às principais doenças com diferentes níveis de aceitação pelo consumidor (SILVA; PEREIRA; RODRIGUES, 2008; SILVA; SANTOS-SEREJO; CORDEIRO, 2004).

A maturação fisiológica corresponde àquela em que o fruto atingiu o seu tamanho e peso máximo, porém ainda não possui características desejáveis de comercialização. No entanto, evolui naturalmente para a maturação que o torna próprio para o consumo humano (MAIA et al., 2009). Dentre os frutos climatérios, a banana é um caso raro no que se refere à larga faixa de maturidade fisiológica em que pode ser colhida e induzida a amadurecer com excelente qualidade (FERNANDES; LEAL; SANCHES, 2010). Assim, a banana é colhida ainda verde (grau de maturação 1 – Figura 1) e induzida ao amadurecimento com excelente qualidade, o que faz com que a maturação comercial seja uma operação de rotina para essa espécie (WILLS et al., 1981). A banana colhida na maturidade fisiológica apresenta-se verde, com textura rígida, pobre em aromas e ácidos, baixo teor de açúcares e alto teor de amido e adstringência devido aos compostos fenólicos presentes na polpa (MEDINA; PEREIRA, 2004).

A indução da maturação é conhecida por climatização e tem por objetivo o controle do amadurecimento de grandes volumes de produção, a uniformização da coloração amarela e o aumento da longevidade dos frutos. O gás recomendado para essa finalidade é o etileno (SPOTO; GUTIERREZ, 2006; WENER, 1978). A climatização é feita em câmaras frigoríficas constando de exaustores, isolamento térmico, porta hermética, equipadas com controle de temperatura, umidade e concentração de gás (LICHTEMBERG; VILAS BOAS; DIAS, 2008).

Os graus de maturação dos frutos seguem a escala de maturação de Von Loeseck (1949) (Figura 1).

Figura 1: Escala de maturação de bananas.



Fonte: Von Loesecke (1949).

A maturação dos frutos envolve o aumento dos açúcares solúveis, a diminuição do amido e hemicelulose e uma suave queda no conteúdo de lipídeos e proteínas. Também ocorre a degradação da clorofila, síntese e aparecimento de carotenóides; o amaciamento da polpa devido à ação das enzimas protopectinases e pectinesterases e o desenvolvimento de aromas (MEDINA; PEREIRA 2004; MOHAPATRA et al., 2010).

Sendo a banana um fruto bastante produzido, consumido e com quantidades significativas de nutrientes, minerais e compostos bioativos, faz-se necessário um estudo do seu resíduo, a casca, como forma de valorizar o resíduo gerado pela agroindústria alimentícia no desenvolvimento de novos produtos.

2. A casca da banana

A casca da banana representa de 35 a 50% em peso da fruta madura, podendo ser utilizada em escala reduzida na forma direta, como em receitas, e na alimentação animal (TRAVAGLINI et al., 1993), mas geralmente é descartada (PACHECO-DEHALAYE et al., 2008). Considerando a casca da banana como 35% em peso da fruta madura, das 7 Mt de banana produzidas em 2012 no Brasil (IBGE, 2012), cerca de 2,5 Mt são referentes à casca da banana, sendo que sua maioria é destinada à alimentação animal a um preço baixo. Dessa forma, durante o processamento de produtos industrializados, a casca da banana se acumula como resíduo, causando sérios problemas ambientais (CHOOKLIN; MANEERAT; SAIMMARI, 2014).

A casca de banana é rica em fibras e diversos nutrientes, entre eles, minerais com atividade antioxidante como o magnésio, manganês e zinco (PEREIRA, 2007), que em associação com enzimas são denominados antioxidantes exogénos não enzimáticos (Halliwell & Gutteridge, 1985). O teor de alguns micronutrientes, como ferro e zinco, é maior na casca do que na polpa e, assim, a casca é considerada boa matéria-prima alimentícia (DAVEY et al., 2009; EMAGA et al., 2007; EMAGA et al., 2008). A casca da banana (base seca) também é rica em fibra alimentar total (43,2-49,7%), lipídios (3,8-11%), proteína (6-9%), amido (3,0%) e micronutrientes (K, P, Ca, Mg) (MOHAPATRA; MISHRA; SUTAR, 2010) e não foram encontrados trabalhos na literatura a respeito da presença de substâncias tóxicas na casca de banana.

A quantidade de compostos fenólicos presentes na casca de banana varia entre 0,90 a 3,0 g/100 g de matéria úmida (NGUYEN; KETSA; VAN DOOR, 2003), sendo que Someya et al (2002) identificaram galocatequina a uma concentração de 160 mg/100 g de matéria úmida. A casca de banana madura possui dopaminas e catecolaminas (KANAZAWA; SAKAKIBARA, 2000) e carotenóides, tais como o β-caroteno, α-caroteno e diferentes xantofilas, têm sido identificados na casca da banana (BORGES et al., 2014), bem como esteróis e triterpenos, tais como o β-sitosterol, estigmasterol e campesterol (GONZÁLEZ-MONTELONGO; LOBO; GONZÁLEZ, 2010; KNAPP; NICHOLAS, 1969).

Em trabalho realizado por Lee et al. (2010), ao desenvolverem geleia de casca de banana, foi observado o aumento do teor de compostos fenólicos e da capacidade antioxidante do produto final, devido ao rompimento da parede celular durante o processo de cocção. Assim, as cascas das frutas podem ser consideradas como alternativa de compostos bioativos, sendo necessário evitar seu desperdício.

Neste sentido, cascas de frutas e vegetais vêm sendo utilizadas no processamento de produtos tendo como finalidade o aproveitamento integral do alimento, bem como a incorporação de compostos bioativos naturais. Dentre esses produtos temos a barra de cereal que é considerado um alimento prático e conveniente quando se trata da ingestão de nutrientes.

3. Barras de cereais

O conceito de *snacks* saudáveis foi introduzido inicialmente nos Estados Unidos, na forma de barra de granola desenvolvida como um alimento matinal, e a legislação brasileira define os produtos de cerais aqueles obtidos a partir de partes comestíveis de cereais, podendo ser submetidos à processos de maceração, moagem, extração, tratamento térmico e/ou outros processos tecnológicos considerados seguros para a produção de alimentos (BRASIL, 2005).

Barras de cereais são alimentos nutritivos compostos por múltiplos ingredientes, incluindo cereais, frutas e açúcar. Existem diversos tipos de barras de cereais, entre elas estão as com alto teor proteico, alto teor de fibras e alto teor de calorias. Além disso, estão disponíveis outros tipos de barras como barras salgadas, com baixa caloria, barras dietéticas, com frutas e/ou castanhas, com flocos de arroz, com sementes, dentre outras (SARANTÓPOULOS; OLIVEIRA; CANAVESI, 2001). Elas também podem receber recheios ou coberturas, como de chocolate, e propriedades funcionais adicionadas, como prebióticos (LOBATO et al., 2012).

A mudança no estilo de vida da população, bem como seu interesse em alimentos saudáveis, estimula o interesse dos pesquisadores e da indústria alimentícia em desenvolver novas formulações e ingredientes de forma a aumentar o valor nutricional dos alimentos. Assim, outros tipos de barras de cereais são encontrados na literatura, como as com polpa de maçã, de marolo, de linhaça, com semente de uva, entre outras (DUTCKOSKY et al., 2006; LOBATO et al., 2012; LOVEDAY et al., 2009; OZILGEN, 2011; SILVA, et al., 2013; SUN-WATERHOUSE et al., 2010).

São ainda considerados alimentos práticos, convenientes e de fácil processamento e, dependendo dos ingredientes utilizados, podem ser comercializados por um baixo custo. Todavia, por ser de um processamento relativamente simples, a incorporação de altas quantidades de componentes funcionais pode se tornar difícil uma vez que ocorre a interação das características individuais desses componentes com outros ingredientes utilizados. Com isso, a incorporação desses componentes funcionais pode determinar as características sensoriais, tais como a textura e sabor, além de propriedades físicas do produto (LOBATO et al., 2012; SILVA et al., 2013).

A barra de cereal é um produto obtido da compactação de cereais. Três grupos de ingredientes compõem-na: sólidos (mistura de cereais, frutas secas e castanhas), ligantes (xarope de milho, mel, açúcar e seus substitutos, como edulcorantes, fibras e colágeno) e aromas como baunilha, banana, (PALLAVI et al., 2015; SARANTÓPOULOS; OLIVEIRA; CANAVESI, 2001), sendo que sua adição ocorre no final do processamento. Além disso, agentes estabilizantes, como a lecitina, também podem ser adicionados. Dentre os cereais utilizados, a aveia é a mais amplamente utilizada na formulação de barras de cereais, podendo ser utilizada na forma de farinha ou flocos. Segundo Karam, Groosmann e Silva (2001), a aveia destaca-se devido ao seu teor e qualidade proteica, predominância de ácidos graxos insaturados e composição de fibras alimentares. Os flocos ou farinha de cereais, dentre eles os flocos de arroz, também são bastante utilizados e podem alterar a aparência e a textura do produto final (KARAM; GROOSMANN; SILVA, 2001). Como as barras de cereais são alimentos multicomponentes é necessária a aplicação de um planejamento experimental baseado na modelagem de misturas.

4. Modelagem de misturas

Quando variáveis de mistura estão envolvidas em uma otimização, o resultado depende da proporção em que esses componentes se encontram e seus níveis não podem ser variados sem levar em conta os outros componentes. Em outras palavras, misturas são sistemas cujas propriedades dependem das proporções relativas dos seus componentes e não de suas concentrações (BARROS NETO et al, 2007; COSCIONE et al., 2005). Se uma proporção individual x_i é única, então a mistura é chamada pura, se forem dois, é chamada binária, e assim por diante (CORNELL, 2002).

O modelo mais simples para uma mistura de três componentes é o modelo aditivo ou linear, dado por:

$$Y_i = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \beta_3 X_3 + \varepsilon_i$$

onde Y_i é um valor experimental da resposta de interesse, β_0, β_1, β_2 e β_3 são os parâmetros do modelo e ε_i representa o erro aleatório asociado à determinação do valor de Y_i. Já o modelo quadrático é dado por:

$$Y = \beta_1 X_1 + \beta_2 X_2 + \beta_3 X_3 + \beta_{12} X_1 X_2 + \beta_{13} X_1 X_3 + \beta_{23} X_2 X_3 + \varepsilon_i$$

sendo que X_1, X_2, X_3 são componentes da mistura e $X_1+X_2+X_3 = 1$. E para o modelo cúbico especial tem-se a seguinte equação:

$$Y = \beta_1 X_1 + \beta_2 X_2 + \beta_3 X_3 + \beta_{12} X_1 X_2 + \beta_{13} X_1 X_3 + \beta_{23} X_2 X_3 + \beta_{123} X_1 X_2 X_3 + \varepsilon_i$$

A modelagem de misturas consiste em ajustar um modelo matemático polinomial a uma superfície de resposta obtida segundo um planejamento experimental específico, conhecido como planejamento estatístico de misturas. Neste tipo de delineamento, são utilizadas técnicas de análises para examinar o comportamento de superfícies de respostas quadráticas hiperdimensionais, com a finalidade de determinar a região ótima local e geral. Quando ocorre uma curvatura na superfície da mistura devido à não linearidade (frequentemente chamada sinergismo e antagonismo) da mistura entre os pares dos componentes, a equação polinomial canônica de grau dois ou mais é tida como representação da superfície. Se o sinal for positivo, os componentes são sinergísticos e se forem negativos eles são tidos como antagonísticos (CORNELL, 2002). Dessa forma, a modelagem de misturas tem grande importância industrial, sendo muito utilizado na obtenção de diversos produtos, como alimentos, fármacos e polímeros (COSCIONE et al., 2005), e diversos autores têm estudado o comportamento de misturas em diversos tipos de alimentos (BRAGA; CONTI-SILVA, 2015; FERREIRA, et al. 2014; MATSAKIDOU; MANTZOURIDOU; KIOSSEOGLOU, 2015).

Quando se trata do processamento de alimentos, ocorrem muitas alterações químicas nos ingredientes, entre elas, mudanças no comportamento dos compostos bioativos.

5. Compostos bioativos

Os compostos bioativos, representados principalmente pela vitamina C e polifenóis, tais como antocianinas, ácidos fenólicos, flavonóides e taninos, são conhecidos como antioxidantes naturais e, quando estão presentes nos alimentos, podem conferir, aos mesmos, propriedades de saúde (SZAJDEK; BOROWSKA, 2008).

Antioxidantes em sistemas biológicos têm múltiplas funções, as quais incluem proteção aos danos oxidativos nas principais vias de comunicação celular. A maior ação dos antioxidantes nas células é prevenir os danos causados pela ação de espécies reativas de oxigênio, tais como radical superóxido (O_2), radical hidroxil ($OH^{\cdot}$) e radical peroxil ($ROO^{\cdot}$) que são gerados nos organismos vivos durante o estresse oxidativo (KANNAN et al., 2013). Os radicais livres têm sido identificados como a causa de algumas doenças crônicas, entre elas o câncer.

Estudos epidemiológicos recentes sugerem que um consumo regular ou o seu aumento em frutas e vegetais pode auxiliar na redução do risco de doenças crônicas, e esses benefícios à saúde são atribuídos principalmente aos seus antioxidantes naturais e conteúdo de fibra dietética (LEE et al., 2003; SEERAM et al., 2005; SUN-WATERHOUSE et al., 2010).

Diversos métodos têm sido desenvolvidos para avaliar a capacidade antioxidante de extratos de plantas baseadas em diferentes mecanismos, entretanto, não existe uma metodologia padrão aceita universalmente (TSAO; DENG, 2004). Diferentes ensaios são aplicados ao investigar a atividade antioxidante, incluindo os métodos ORAC, Folin-Ciocalteu, por Trolox-equivalente (TEAC), 2,2-di(4-terc-octilfenil)-1-(picrilhidrazil) (DPPH) e poder antioxidante de redução férrica (FRAP) (APAK et al., 2013; CELLI; GHANEM; BROOKS, 2014). Esses diferentes métodos são aplicados para avaliar a atividade antioxidante de oxidantes biologicamente relevantes, incluindo o oxigênio singlete, ânion superóxido e radicais hidroxil (HUANG et al., 2005).

Compostos fenólicos são importantes na qualidade sensorial e nutritiva de frutas, hortaliças e outras plantas. São o de maior ocorrência no grupo dos fitoquímicos, além de serem muito importante fisiologicamente e morfologicamente para as plantas, pois possuem funções biológicas. Os fenóis podem atuar como fitoalexinas, pigmentos das plantas, antioxidantes e agentes protetores contra a luz ultravioleta

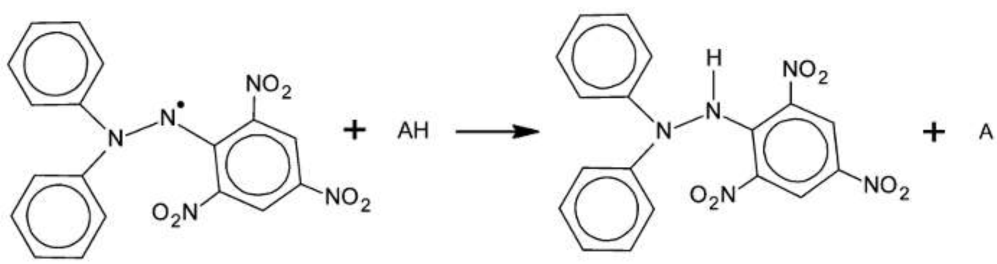
(UV), entre outros (NACZK; SHAHIDI, 2006; POPA et al., 2008). Essas propriedades bioativas fazem com que estes compostos desempenhem importante papel no crescimento das plantas e sua reprodução, proporcionando uma proteção eficaz contra os agentes patógenos, além de contribuir para as características de cor e sensoriais de frutas e hortaliças (ALASALVAR et al., 2001; IGNAT; VOLF; POPA, 2011).

Estudos científicos têm relatado que os fenóis naturais têm excelentes propriedades como conservantes dos alimentos, bem como tem um papel importante na proteção contra um número de distúrbios patológicos tais como aterosclerose, disfunção no cérebro e câncer (GORDON, 1996; VALENZUELA et al., 1992). Entretanto, esses compostos têm poucas aplicações industriais.

6. Atividade antioxidante total pelo método (DPPH·) 2,2-di(4-terc-octilfenil)-1-(picrilhidrazil)

O método do DPPH· é rápido, barato, conveniente além de ser preciso para avaliar a atividade antioxidante (BRAND-WILLIANS, et al., 1995; SHARMA; BHAT, 2009). Quando uma solução de DPPH· é misturada com um composto redutor, a sua cor muda de púrpura para amarelo, correspondente ao hidrazina (Figura 2). A capacidade de reduzir os antioxidantes por DPPH· pode ser avaliada por meio do monitoramento da diminuição da sua absorbância a 515-528 nm, com a formação do composto hidrazina e a presença de uma solução amarela (PYRZYNSKA; PEKAL, 2013).

Figura 2: Estrutura química do radical DDPH e sua reação com um captador de radicais livres indicado por AH.



2,2-difenil-1-picrilhidrazil **2,2,-difenil-1-picrilhidrazina**

Originalmente, acreditava-se que método do DPPH· envolvia a reação de transferência de hidrogênio, mas Foti et al., (2004) sugeriram um mecanismo diferente. A transferência inicial de elétrons ocorre muito rapidamente e a transferência subsequente de hidrogênio ocorre mais lentamente e isto depende da ligação de hidrogênio formada no solvente utilizado, como o metanol ou etanol.

A concentração de antioxidante necessária para diminuir a concentração inicial de DPPH· em 50% (denominada concentração de inibição IC_{50} ou concentração de eficiência EC_{50}) é também utilizada para a comparação das capacidades antioxidantes de diferentes compostos. O menor valor de EC_{50} indica uma maior capacidade antioxidante. Os valores de EC_{50} são expressos em diferentes unidades: em g de antioxidante por Kg de DPPH·, como µmol de um antioxidante ou em uma unidade de concentração como mg. L^{-1} (PYRZYNSKA; PEKAL, 2013).

7. Atividade antioxidante total pelo método ABTS

Neste método, o ABTS é oxidado pelo cátion deste radical, $ABTS^{\cdot+}$, o qual é intensamente colorido e a capacidade antioxidante é medida como a habilidade dos compostos teste em diminuir a cor, reagindo diretamente com o radical ABTS (GÜLÇIN, 2012). O cátion do radical ABTS constitui a base do método espectrofotométrico aplicado para medir a atividade antioxidante total de substâncias puras, misturas aquosas e bebidas (GÜLÇIN et al., 2009). A forma mais apropriada para a realização deste método é a técnica de descoloração, na qual o radical é gerado diretamente em sua forma estável pela reação com antioxidantes conhecidos (MILLER et al., 1993).

O $ABTS^{\cdot+}$ reage rapidamente com antioxidantes nos componentes alimentícios, normalmente com 30 minutos de reação. Esse método pode ainda ser usado sobre uma vasta gama de valores de pH e, dessa forma,, pode ser utilizado para estudar os efeitos do pH sobre os mecanismos antioxidantes. Além disso, o ABTS é solúvel em solventes aquosos e orgânicos e não é afetado pela força iônica. Assim, ele pode ser utilizado em variados meios para determinar a atividade antioxidante, tanto em extratos hidrofílicos e lipofílicos, além de fluidos corporais (AWIKA et al., 2003).

8. Textura

Textura é definida como uma manifestação sensorial da estrutura alimentar e a maneira pela qual esta estrutura reage às forças aplicadas, e representa a junção de todos os atributos mecânicos, geométricos e superficiais de um produto detectados através de receptores táteis, visuais e auditivos (SZCZESNIAK, 1963a). Além disso, a textura pode estar relacionada com a deformação, desintegração e o fluxo do alimento quando é aplicada uma força (BOURNE, 2002).

A textura pode ser medida através de testes instrumentais e sensoriais. Entre os testes instrumentais, tem-se o texturômetro, que imita as condições de mastigação e apresenta excelentes correlações com as avaliações sensoriais de textura (SZCZESNIAK, 1963b). Os métodos instrumentais têm ainda a vantagem de serem mais rápidos, práticos e mais baratos (KIM et al., 2009).

Métodos instrumentais têm sido desenvolvidos para medir as propriedades de textura de diversos produtos alimentícios, incluindo ervilhas congeladas, arroz, queijos, batatas, tomates processados, pescados e pães, onde os resultados são correlacionados com os dados sensoriais (KIM, et al., 2009). Além disso, uma grande variedade de métodos tem sido utilizada, os quais fornecem séries temporais de dados de deformação do produto, permitindo assim uma vasta gama de atributos de textura que podem ser calculados a partir de dados da força-tempo ou força-deslocamento (CHEN; OPARA, 2013).

Os perfis de textura são curvas que monitoram e registram eventuais características espaciais ou temporais das amostras durante as medições de textura dos alimentos. A Análise do Perfil de Textura (TPA) estabelece uma ‘ponte’ da medida objetiva à sensação subjetiva, tornando as características de textura dos alimentos mais previsível (CHEN; OPARA, 2013). A Análise do Perfil de Textura é um teste de dupla compressão, desenvolvido por Szczesniak e colaboradores (SZCZESNIAK; BRANT; FRIEDMAN, 1963), que tem sido usada como ‘padrão’ para a avaliação das características de textura de alimentos sólidos. O teste imita a mastigação e fornece uma série de parâmetros de textura, como dureza, coesividade, elasticidade, adesividade, mastigabilidade, dentre outros, que são relevantes para comparação com atributos de textura avaliados durante a mastigação (CHENG et al., 2014; KIM et al., 2009).

Loredo e Guerrero (2011) encontraram forte correlação positiva entre os parâmetros de adesividade, coesividade, dureza e fraturabilidade e a viscosidade sensorial para cinco alimentos (duas geleias, margarina, queijo e manteiga de amendoim), enquanto que Kim et al. (2009) encontraram correlações que variaram de 0,741 a 0,948 ao avaliarem barras de cereais.

9. Avaliação sensorial

A avaliação sensorial toma cada vez mais sua posição de importância dentro dos centros produtores e vendedores de alimentos. Nestes, o objetivo final dos trabalhos realizados nas áreas de desenvolvimento, produção e *marketing* é o consumidor, cuja avaliação se baseia, principalmente, na aceitabilidade e custos dos produtos (SANCHES; ZOCCHI, 2010).

A indústria alimentícia moderna utiliza a análise sensorial como ferramenta para a avaliação das características sensoriais dos produtos como componente essencial no desenvolvimento, manutenção, otimização, controle de qualidade e avaliação do potencial de mercado de um determinado alimento (MEILGAARD; CIVILLE; CARR, 2007; PIGGOT, 1995; STONE; SIDEL, 1993).

Os testes sensoriais são importantes por serem uma medida multidimensional integrada que possuem importantes vantagens, como serem capazes de identificar a presença ou ausência de diferenças perceptíveis, definirem características sensoriais importantes de um produto, serem capazes de detectar particularidades dificilmente detectadas por outros procedimentos analíticos, além de avaliarem se um produto é aceito pelo consumidor (MUNOZ; CIVILLE; CARR, 1992). Piggot (1995) acrescentou ainda que os testes sensoriais são usados para entender as reações do consumidor a um produto. O sucesso da aplicação dos testes sensoriais em problemas reais da indústria de alimentos e pesquisas depende da adequada correlação entre a utilização do método e a informação desejada ao final da sua aplicação, isto é, o objetivo a ser alcançado (PIGGOT, 1995).

As técnicas sensoriais podem ser divididas em testes discriminativos, afetivos e descritivos.

Os testes discriminativos determinam se duas ou mais amostras são diferentes, ou seja, se existem diferenças percebidas entre eles. Esses métodos são aplicados em amostras que têm componentes da formulação alterados ou processos diferentes. Essas pequenas diferenças podem ser percebidas pelo consumidor ou por uma equipe sensorial de pessoas treinadas na avaliação. Alguns exemplos de testes discriminativos são o duo-trio, triangular e R-index (SANTOS et al., 2005).

Nos testes afetivos, a proposta é avaliar a resposta pessoal (preferência e/ou aceitação) dos consumidores, habituais ou potenciais, em relação a um produto ou a características específicas do produto. Nos testes de aceitação, a escala hedônica é utilizada para indicar graus de aceitabilidade dos avaliadores (MEILGAARD; CIVILLE; CARR, 2007).

As técnicas descritivas são também chamadas de técnicas de perfis e são amplamente aplicadas para a caracterização de atributos sensoriais individuais, como perfil de sabor e perfil de textura, e de vários atributos simultaneamente, como a Análise Descritiva (AD). Os testes descritivos são utilizados para a obtenção da descrição detalhada do aroma, sabor e textura de alimentos e bebidas e também na área de pesquisa e desenvolvimento MEILGAARD; CIVILLE; CARR, 2007).

9.1. Métodos descritivos

O primeiro método descritivo proposto foi o Perfil de Sabor (CAUL, 1957) e todos os demais métodos descritivos desenvolvidos até hoje derivaram de alguma maneira deste método pioneiro (DUTCOSKY, 2011). Outros métodos que se destacam na análise sensorial descritiva são: o tradicional Perfil de Textura, por meio do qual é realizada a descrição completa da textura de um alimento, desde a primeira mordida até a completa mastigação, em termos de suas características mecânicas, geométricas, gordura e umidade (BRANDT et al., 1963); Análise Descritiva Quantitativa, que avalia todos os atributos sensoriais (aparência, aroma, sabor e textura) presentes no produto alimentício (STONE et al., 1974); Perfil Livre (*Free-Choice Profiling*), que se baseia no princípio de que as pessoas percebem as mesmas características nas amostras, mesmo que se expressem de forma diferente (WILLIANS; LANGRON, 1984); método Tempo-Intensidade, que envolve o monitoramento de determinados atributos e suas intensidades com o passar do tempo (MEILGAARD; CIVILLE; CARR, 2007); CATA (catch all that apply), no qual se utiliza avaliadores não treinados para descrever o perfil sensorial das amostras; e Perfil Descritivo Otimizado, no qual cada termo descritor é avaliado individualmente e as referências são apresentadas juntamente às amostras avaliadas (SILVA et al., 2012).

Quase todos os métodos descritivos requerem que os avaliadores tenham algum grau de treinamento. Com exceção do Perfil Livre e Perfil Descritivo Otimizado, os avaliadores são obrigados a ter um nível razoável de acuidade sensorial (MURRAY; DELAHUNT; BAXTER, 2001). Alguns autores proporam diferentes metodologias para a descrição rápida dos alimentos, onde os avaliadores passam por um rápido treinamento e utilizando referências, atingiram uma concordância com o painel treinado (RICHER et al., 2010, SILVA et al., 2012), tornando essas metodologias viáveis para a indústria de alimentos.

Segundo Meilgaard, Civille e Carr (2007), a seleção dos termos descritivos importantes e significativos de um alimento deve ser baseada em conhecimento técnico sobre o produto e nos princípios da percepção sensorial. De acordo com Stone e Sidel (1993), as vantagens da ADQ sobre outros métodos de avaliações são: (1) confiança no julgamento de uma equipe composta de 10 a 12 avaliadores treinados, ao invés de alguns poucos especialistas, (2) desenvolvimento de uma linguagem descritiva objetiva, mais próxima à linguagem do consumidor, (3) desenvolvimento consensual da terminologia descritiva a ser utilizada, o que implica em maior concordância de julgamentos entre os avaliadores e (4) os produtos são analisados ‘à cega’ em repetições por todos os participantes e, em seguida, os resultados são analisados estatisticamente.

O mapa de preferência é uma importante ferramenta utilizada para investigar os dados de testes afetivos através de métodos estatísticos multivariados, como a Análise de Componentes Principais (ACP) ou a Regressão dos Mínimos Quadrados Parciais (PLS-R) (HELGESEN; SOLHEIM; NAES, 1997). No mapa de preferência externo, a aceitação dos consumidores por determinados produtos pode ser correlacionada ao perfil sensorial dos mesmos, assim como às características físicas e químicas. Dessa forma, o mapa de preferência externo é identificado como vantajoso para os setores de *marketing* e de desenvolvimento de novos produtos, já que essa técnica revela as principais direções de preferência que separam os consumidores, com diferentes padrões de gosto, ligando-os às características físicas, químicas e até sensoriais do produto (VARELA; BELTRÁN; FISZMAN, 2014). Já o mapa de preferência interno permite a avaliação da preferência dos consumidores em relação ao conjunto, sendo que o mesmo pode complementar a análise de aceitação de um produto, explicando as preferências dos consumidores e tornando as informações obtidas mais valiosas (ROUSSEAU; ENIS; ROSSI, 2012). Diversos estudos têm sido realizados com sucesso utilizando essa técnica para vários produtos (BRAGA; CONTI-SILVA, 2015; PAIXÃO, et al., 2014; GOMES, et al., 2014; VIDAL, et al., 2014).

Referências bibliográficas

ALASALVAR, C.; GRIGOR, J. M.; ZHANG, D.; QUANTICK, P. C.; & SHAHIDI F. Comparison of volatiles, phenolics, sugars, antioxidant vitamins, and sensory quality of different colored carrot varieties. **Journal of Agricultural Food Chemistry**, Easton, v. 49, p. 1410–1416, 2001.

APAK, R.; GORINSTEIN, S.; BOHM, V.; SCHAICH, K. M.; ÖZYUREK, M.; & GUCLU, K. Methods of measurement and evaluation of natural antioxidant capacity/activity IUPAC technical report). **Pure and Applied Chemistry**, Oxford, v. 85, n. 5, p. 957–998, 2013.

AWIKA, J. M.; ROONEY, L. W.; WU, X.; PRIOR, R. L.; CISNEROS-ZEVALLOS, L. Screening methods to mesure antioxidant activity of sorghum (*Sorghum bicolor*) and sorghum products. **Journal of Agricultural and Food Chemistry,** Easton**,** v. 61, p. 6657-6662, 2003.

BRAGA, H.; CONTI-SILVA, A. C. Papaya néctar formullated with prebiotics: cheical characterization and sensory acceptability. **LWT – Food Science and Technology,** Georgia, v. 62, p. 854-860, 2015.

BRASIL. Ministério da Saúde. **Agência Nacional de Vigilância Sanitária**. Dispõe sobre o regulamento técnico para produtos de cereais, amidos farinhas e farelos devendo atender a Resolução- RDC nº 263, de 22 de setembro de 2005. Diário Oficial da República Federativa do Brasil; Brasília, 22 jun. 2005.

BARROS NETO, B. et al. **Como modelar misturas**. In: BARROS NETO, B.; SCARMINIO, I.S.; BRUNS, R. E. Como fazer experimentos. Campinas: Editora Unicamp, 2007, p. 363-417.

BORGES, C. V. et al. Characterisation of metabolic profile of banana genotypes, aiming at biofortified Musa spp. Cultivars**. Food Chemistry**, London, v. 145, p. 496-504, 2014.

BOURNE, M.C. **Food Texture and Viscosity: Concept and Measurement**, second ed. Academic Press, San Diego, p. 15, 2002.

BRAND-WILLIANS, W.; CUVELIER, M. E.; BERSET, C. Use of a free radical method to evaluate antioxidant activity. **Food Science and Technology**, Zurich, v. 28, n. 1, p. 25-30, 1995.

BRANDT, M. A.; SKINNER, E. Z.; COLEMAN, J. A. Texture profile method. **Journal of Food Science**, Chicago, v. 28, n. 4, p. 404-409, 1963.

CAMPOS, R.P.; VALENTE, J.P.; PEREIRA, W.E. Conservação pós-colheita de banana cv. Nanicão climatizada e comercializada em Cuiabá – MT e região. **Revista Brasileira de Fruticultura**, Cruz das Almas, v. 25, n. 1, p. 172-174, 2003.

CAUL, J. F. The profile method off flavor analysis. **Advances in Food Research**, New York, v. 7, p. 1-40, 1957.

CELLI, G. B.; GHANEM, A.; BROOKS, M. S. L. Haskap Berries (*Lonicera caerulea* L.)—a Critical Review of Antioxidant Capacity and Health-Related Studies for Potential Value-Added Products. **Food Bioprocess Technology,** New York, v. 7, p. 1541-1554, 2014.

CHEN, L., OPARA, U. L. Approaches to analysis and modeling texture in fresh and processed foods – A review. **Journal of Food Engineering,** Essex, v. 119, 497-507, 2013.

CHENG, J., SUN, D., HAN, Z., & ZENG, X. Texture and Structure Measurements and Analyses for Evaluation of Fish and Fillet. **Comprehensive Reviews in Food Science and Food Safety**, v.13, p. 52-61, 2014.

CHOOKLIN, C. S.; MANEERAT, S.; SAIMMAI, A. Utilization of banana peel as a novel substrate for biosurfactant production by *Halobacteriaceae archaeon* AS65. **Applied Biochemistry and Biotechnology**, Clifton, v. 173, p. 624-645, 2014.

CORNELL, J. A. **Experiments with mixtures: designs, models and analysis of mixture data.** Wiley series in probability and statistics: Canadá, 3rd. ed., 2002, 680p.

COSCIONE, A. R.; ANDRADE, J. C.; MAY, G. M. O modelamento estatístico de misturas: experimento tutorial usando voltametria de redissolução anódica. **Química Nova**, São Paulo, v. 28, n. 6, p. 1116-1122, 2005.

DAVEY, M. W.; DEN BERGH, I. V.; MARKHAM, R.; SWENNEN, R.; & KEULEMANS, J. Genetic variability in Musa fruit provitamin A carotenoid, lutein and mineral micronutrient contents. **Food Chemistry**, London, v. 115, p. 806–813, 2009.

DUTCOSKY, S. D. **Análise sensorial de alimentos.** 3. ed. rev. e ampl. Curitiba: Champagnat, 2011, 426p.

DUTCOSKY, S. D.; GROSSMANN, M. V. E.; SILVA, R. S. S. F.; & WELSCH, A. K. Combined sensory optimization of a prebiotic cereal product using multicomponent mixture experiments. **Food Chemistry**, London, v. 98, p. 630–638, 2006.

EMAGA, T. H.; ANDRIANAIO, R. H.; WATHELET, B.; TCHANGO, J. T. & PAQUOT, M. Effects of the stage of maturation and varieties on the chemical composition of banana and plantain peels. **Food Chemistry**, London, v. 103, p. 590-600, 2007.

EMAGA, T. H.; RONKARTt, S. N.; ROBERT, C.; WATHELET, B.; & PAQUOT, M. Characterization of pectins extracted from banana peels (Musa AAA) under different conditions using an experimental design. **Food Chemistry**, London, v. 108, p. 463–471, 2008.

FAO. <http://faostat3.fao.org/faostat-gateway/go/to/download/Q/QI/E> FAOSTAT. Statistical Database. Agricultural Data. Acessado em 03 de Junho, 2014.

FERNANDES, E. G.; LEAL, P. A. M.; SANCHES, J. Climatização e armazenamento refrigerado na qualidade pós-colheita de banana ‘nanicão’. **Bragantia**, Campinas, v. 69, n. 3, p. 735-744, 2010.

FERREIRA, S. M. et al., Infant dairy-cereal mixture for the preparation of a gluten free cream using enzymatically modified rice flow. **LWT – Food Science and Technology,** Georgia, v. 59, n. 2, p. 1033-1040, 2014.

FOTI, M. C.; DAQUINO, C.; GERACI, C. Electron-transfer reaction of cinnamic acids and their methyl esters with the DPPH(*) radical in alcoholic solutions. **Journal of Organometallic Chemistry**, Columbia, v. 69, n. 7, p. 2309-2314.

GOMES, C. L.; PFLANZER, S.B.; CRUZ, A. G.; FELÍCIO, P. E; BOLINI, H. M. A. Sensory descriptive profiling and consumer preferences of beef strip loin steaks. **Food Research International**, Barking, v. 59, p. 76-84, 2014.

GONZÁLEZ-MONTELONGO, R.; LOBO, M. G.; GONZÁLEZ, M. Antioxidant activity in banana peel extracts: testing extraction conditions and related bioactive compounds. **Food Chemistry**, London, v. 119, p. 1030-1039, 2010.

GORDON, M. H. Dietary antioxidants in disease prevention. **Natural Products Reports,** Glasgow, v. 265, p. 273, 1996.

GÜLÇIN, I.; ELIAS, R.; GEPDIREMEN, A.; TAOUBI, K.; KOKSAL, E. Antioxidant secoiridoids from fringe tree (*Chionanthus virginicus L.*), **Wood Science and Technology**, New York, v. 43, p. 195-212, 2009.

GÜLÇIN, I. Antioxidant activity of food constituints: na overview. **Archives of Toxicology,** New York, v. 86, p. 345-391, 2012.

HELGESEN, H.; SOLHEIM, R.; & NAES, T. Consumer preference mapping of dry fermented lamb sausages. **Food Quality and Preference**, Barking, v. 8, n.2, p.97–109, 1997.

HUANG, D.; OU, B.; & PRIOR, R. L. The chemistry behind antioxidant capacity assays. **Journal of Agricultural and Food Chemistry**, Easton, v. 53, n. 6, p. 1841–1856, 2005.

IGNAT, I.; VOLF, I.; POPA, V. I. A critical review of methods for characterisation of poliphenolyc compounds in fruits and vegetals. **Food Chemistry,** London, v. 126, p. 1821-1835, 2011.

IBGE - INSTITUTO BRASILEIRO DE GEOGRAFIA E ESTATÍSTICA. Produção Agrícola Municipal. <http://www.ibge.gov.br/home/estatistica/pesquisas/pesquisa_resultados.php?id_pesquisa=44N> Acessado em: 03 Junho, 2014.

JANICK, J. Fruit breeding in the 21st century. **Acta Horticulturae,** Hague, v. 490, p.1998.

KANAPP, F. F.; NICHOLAS, H. J. Sterols and triterpenes of banana peel. **Phytochemistry,** New York, v. 8, n. 1, p. 207-214, 1969.

KANAZAWA, K.; & SAKAKIBARA, H. High content of dopamine, a strong antioxidant, in Cavendish banana. **Journal of Agricultural and Food Chemistry**, Easton, v. 48, p. 844–848, 2000.

KANNAN, R. R. R.; ARUMUGAM, R.; THANGARADJOU. & ANANTHARAMAN, P. Phytochemical constituents, antioxidant properties and p-coumaric acid analysis insome seagrasses. **Food Research International**, Barking, v. 54, p. 1229-1236, 2013.

KARAM, L. B.; GROOSMANN, M. V. E.; SILVA, R. S. S. F. Misturas de farinha de aveia e amido de milho com alto teor de amilopectina para produção de *snacks*. **Ciência e Tecnologia de Alimentos**, Campinas, v. 21, n. 2, p. 158-163, 2001.

LEE, E.; YEOM, H.; HA, M.; BAE, D. Development of banana peel jelly and its antioxidant and textural properties. **Food Science and Biotechnology,** v. 19, n. 2, p. 449-455, 2010.

LEE, K.; KIM, Y.; KIM, D.; LEE, H.; & LEE, C. Major phenolics in Apple and their contribuition to the total antioxidant capacity. **Journal of Agricultural and Food Chemistry,** Easton, v. 51, p. 6516-6520, 2003.

LICHTEMBERG, L.A.; VILAS BOAS, E.V.B.; DIAS, M.S.C. Colheita e pós-colheita da banana. **Informe Agropecuário**, Belo Horizonte, v. 29, n. 245, p. 92-110, jul./ago 2008.

LOBATO, L. P.; PEREIRA, A. E. I. C.; LAZARETTI, M. M.; BARBOSA, D. S.; CARREIRA, C. M.; MANDARINO, J. M. G. & GROSSMANN, M. V. E. Snacks bars with high soy protein and isoflavone content for use in diets to control dyslipidaemia. **International Journal of Food Sciences and Nutrition**, Parma, v. 63, n. 1, p. 49-58, 2012.

LOREDO, A.B.G. & GUERRERO, S.N. Correlation between instrumental and sensory ratings by evaluation of some texture reference scales. **International Journal of Food Science and Technology**, Oxford, v. 46, p. 1977–1985, 2011.

LOVEDAY, S. M.; HINDMARSH, J. P.; CREAMER, L. K. & SINGH, H. Physicalchemical changes in a model protein bar during storage. **Food Research International**, Barking, v. 42, p. 798-806, 2009.

MAIA, G.A.; SOUSA, P.H.M.; LIMA, A.S.; CARVALHO, J.M.; FIGUEIREDO, R.W. **Processamento de frutas tropicais**. Fortaleza: Edições UFC, 2009.

MATSAKIDOU, A.; MANTZOURIDOU, F. T.; KIOSSEOGLOU, V. Optimization of water extraction of naturally emulsified oi from maize germ. **LWT – Food Science and Technology**, Georgia, v. 63, n. 1, p. 206-213, 2015.

MEDINA, V.M.; PEREIRA, M.E.C. Pós-colheita. In: BORGES, A.L.; SOUZA, L.S. (edit.). **O cultivo da bananeira**. Cruz das Almas: Embrapa Mandioca e Fruticultura Tropical, 2004. p. 209-231.

MEILGAARD, M.; CIVILLE, G. V.; CARR, B. T. **Sensory evaluation techniques**. 4 ed. New York: CRC, 2007. 448p.

MILLER, N. J.; RICE-EVANS, C. A.; DAVIS, M. J.; GOPINATHAN, V.; MILNER, A. A novel method for measuring antioxidant capacity and its application to monitoring the antioxidant status in premature neonates. **Clinical Science,** London, v. 84, p. 407-412, 1993.

MOHAPATRA, D.; MISHRA, S. & SUTAR, N. Banana and its by-product utilisation: an overview**. Journal of Scientific & Industrial Research***,* New Delhi, v. 69, p. 323-329, 2010.

MURRAY, J. M.; DELAHUNTY, C. M.; BAXTER, I. A. Descriptive sensory analysis: past, present and future. **Food Research International,** Barking, v. 34, n. 6, p. 461-471, 2001.

NACZK, M.; & SHAHIDI, F. Phenolics in cereals, fruits and vegetables: Occurrence, extraction and analysis. **Journal of Pharmaceutical and Biomedical Analysis**, Amsterdam, v. 41, p. 1523–1542, 2006.

NGUYEN, T. B. T.; KETSA, S.; & VAN DOORN,W. G. Relationship between browning and the activities of polyphenol oxidase and phenylalanine ammonia lyase in banana peel during low temperature storage. **Postharvest Biology and Technology**, Amsterdam, v. 30, p. 187–193, 2003.

OZILGEN, S. Influence of chemical composition and environmental conditions on the textural properties of dried fruit bars. **Czech Journal of Food Science**, Praha, v. 29, n. 5, p. 539-547.

PALLAVI, B. V.; CHETANA, R.; RAVI, R.; REDDY, S. Y. Moisture sorption curves of fruit and nut cereal bar prepared with sugar and sugar substitutes. **Journal of Food Science and Technology,** Oxford, v. 52, n. 3, p. 1663-1669, 2015.

PAIXÃO, J. A.; RODRIGUES, J. B.; ESMERINO, E. A.; CRUZ, A. G.; BOLINI, H. M. Influence of temperature and fat content on ideal sucrose concentration, sweetening power, and sweetness equivalence of different sweeteners in chocolate milk beverage. **Journal of Dairy Science**, Champaign, v. 97, n. 12, p.7344-7353, 2014.

PACHECO-DELAHAYE, E.; MALDONADO, R.; PÉREZ, E.; SCHROEDER, M. Production and characterization of unripe plantain (*Musa paradisiacal L.*) flours. **Interciencia**, Catanduva, v. 33, n.4, p. 290 – 296, 2008.

PEREIRA, M. C. A. **Efeito das farinhas da polpa e da casca de banana e do fermento de quefir nos níveis glicêmicos e lipidêmicos de ratos**. 2007. 132p. Tese (Doutorado em Ciência dos Alimentos) – Universidade Federal de Lavras, Lavras.

PIGOTT, J. R. Design questions in sensory and consumer science. **Food Quality and Preference,** Barking, v. 6, n. 4, p. 217-220, 1995.

POPA, V. I.; DUMITRU, M.; VOLF, I.; & ANGHEL, N. Lignin and polyphenols as allelochemicals. **Industrial Crops and Products**, Amsterdan, v. 27, p. 144–149, 2008.

PYRZYNSKA, K.; PEKAL, A. Application of free radical difenilpicrilhidrazil (DPPH) to estimate the antioxidant capacity of food samples. **Analytical Methods,** New York, v. 5, p. 4288-4295, 2013.

RICHTER, V. B.; ALMEIDA, T. C. A.; PRUDENCIO, S. H.; BENASSI, M. T. Proposing a racking desciptive sensory method. **Food Quality and Preference,** Barking, v. 21, n. 6, p. 611-620, 2010.

ROUSSEAU, B.; ENNIS, D. M.; ROSSI, F. Internal preference mapping and issue of satiety. **Food Quality and Preference,** Barking, v. 24, p. 67-74, 2012.

SAMSON, J.A. **Tropical Fruits**. London: William Clowes & Sons, 1980.

SANTOS, M. I. N.; NAKANO, A.; BABY, A. R.; VELASCOS, M. V. R. Análise sensorial: ferramenta para avaliar eficácia e benefício. **Cosmetic & Toiletries**, v. 17, n. 4, p. 52-55, 2005.

SARANTÓPOLUS, C. I. G. L.; OLIVEIRA, L. M.; CANAVESI, E**. Requisitos de conservação de alimentos em embalagens flexíveis**. Campinas, CETEA/ITAL 2001, 215 p.

SEERAM, N. P.; ADAMS, L. S.; HENNING, S. M.; NIU, Y. T.; ZHANG, Y. J.; NAIR, M. G. et al. In vitro antiproliferative, apoptotic and antioxidant activities of punicalagin, ellagic acid and a total pomegranate tannin extract are enhanced in combination with other polyphenols as found in pomegranate juice. **Journal Nutritional Biochemistry,** Stoneham, v. 16, p. 360-367, 2005.

SHARMA, O. P.; & BHAT, T. K. DPPH antioxidant assay revisited. **Food Chemistry**, London, v. 113, n. 4, p. 1202–1205, 2009.

SILVA, E. P.; SIQUEIRA, H. H.; LAGO, R. C.; ROSELL, C. M. & VILLAS BOAS, E. V. B. Developing fruit-based nutritious snack bars. **Journal of Science and Food Agriculture***,* Oxford, v. 94, p. 52-56, 2013.

SILVA, R. C. S. N.; MINIM, V. P. R.; SIMIQUELI, A. A.; MORAES, L. E. S.; GOMIDE, A. I.; MINIM, L. A. Optimized Descriptive Profile: A rapid methodology for sensory description. **Food Quality and Preference,** Barking, v. 24, p. 190-200, 2012.

SILVA, S. O.; ALVES, E.J.; SHEPHERD, K.; DANTAS, J.L.L. Cultivares. In: ALVES, E.J. (Org.). **A cultura da banana: aspectos técnicos, socioeconômicos e agroindustriais**. 2 ed. Brasília: Embrapa, 1999. p. 85-105.

SILVA, S. O.; SANTOS-SEREJO, J. A.; CORDEIRO, Z. J. M. **Variedades**. In: BORGES, A. L; SOUZA, L. S. (Org.). **O cultivo da bananeira**. Cruz das Almas: Embrapa Mandioca e Fruticultura, 2004, p. 45 - 58.

SILVA, S.O.; PEREIRA, L.V.; RODRIGUES, M.G.V. Variedades. **Informe Agropecuário**, Belo Horizonte, v. 29, n. 245, p. 78-83, jul./ago, 2008.

SOMEYA, S.; YOSHIKI, Y.; & OKUBO, K. Antioxidant compounds from bananas (Musa cavendish). **Food Chemistry**, London, v. 79, n. 3, p. 351–354, 2002.

SPOTO, H.F.; GUTIERREZ, A.S.D. Qualidade pós-colheita de frutas e hortaliças. In: OETTERER, M.; REGITANO D'ARCE, M.A.B.; SPOTO, M.H.F. **Fundamentos de ciência e tecnologia de alimentos**. Barueri: Manole, 2006. p. 403-452.

STONE, H.; SIDEL, J. Sensory evaluation practices. 2. ed. New York: Academic Press. 1993. 337 p.

STONE, H. et al. Sensory evaluation by quantitative descriptive analysis. **Food Technology**, Chicago, v. 28, n. 11, p. 24-34, 1974.

SUN-WATERHOUSE, D.; TEOH, A.; MASSAROTTO, C.; WIBISONO, R. & WADHWA, S. Comparative analysis of fruit-based functional snack bars. **Food Chemistry**, London, v. 119, p. 1369-1379, 2010.

SZCZESNIAK, A.S. Classification of textural characteristics. **Journal of Food Science,** Chicago, v. 28, p. 385–389, 1963a.

SZCZESNIAK, A.S. Objective measurements of food texture. **Journal of Food Science**, Chicago, v. 28, p. 410–420, 1963b.

SZCZESNIAK, A. S., BRANDT, M. A. and FRIEDMAN, H. H. Development of standard rating scales for mechanical parameters of texture and correlation between the objective and the sensory methods of texture evaluation. **Journal of Food Science**, Chicago, v. 28, p. 397–403, 1963.

THOMPSON, A.K. Banana processing. In: GOWEN, S. Bananas and plantains. In: GOWEN, S. **Bananas and plantains**. 1 ed. London: Chapman & Hall, 1995. p. 481-492.

TRAVAGLINI, D. A.; BLEINROTH, E. W.; LEITÃO, M. F. F. Banana-passa: princípios de secagem, conservação e produção industrial. Campinas: **Instituto de Tecnologia de Alimentos**, 1993, 73p. (Manual Técnico n. 12).

TSAO, R.; & DENG, Z. Separation procedures for naturally occurring antioxidant phytochemicals. **Journal of Chromatography B**, Amsterdam, v. 812, n. 1–2, 85–99, 2004.

VALENZUELA, A.; NIETO, S.; CASSELS, B. K.; & SPEISKY, H. Inhibitory effect ofboldine on fish oil oxidation. **Journal of American Oil Chemists Society**, Champaign, v. 68, p. 935-937, 1992.

VARELA, P.; BELTRÁN, J.; FISZMAN, S. An alternative way to uncover drivers of coffee liking: Preference. **Food Quality and Preference**, Barking, v. 32, part. B, p. 152-159, 2014.

VIDAL, L.; CADENA, R. S**.**; CORREA, S.; ABALOS, R. ; GOMEZ, B. ; GIMENEZ, A.; VARELA, P.; ARES, G. . Assessment of Global and Individual Reproducibility of Projective Mapping with Consumers. **Journal of Sensory Studies**, Manhattan, v. 29, p. 74-87, 2014.

VON LOESECKE, H.W. **Bananas: chemistry, physiology and technology**. New York: Interscience Publishers, 1949.

WERNER, R.A. **Frutas e hortaliças: como conservar**. Porto Alegre: Graposul, 1978.

WILLIANS, A. A.; LANGRON, S. P. The use of free-choice profiling for the evaluation of commercial ports. **Journal of the Science Food and Agriculture**, Oxford, v. 35, n. 5, p. 558-568, 1984.

WILLS, R.H.H.; LEE, T.H.; GRAHAM, D.; McGLASSON, W.D.; HALL, E.G. **Posthharvest: An introduction to the physiology and handling of fruit and vegetables**. London: The AVI, 1981.

CAPÍTULO 2

Bioactive compounds, physical characteristics and sensory acceptability of cereal bars produced with banana peel flour using the mixture modeling methodology

Abstract

The mixture design was used to investigate the effects of banana peel flour (BPF), rice flakes (RF) and oat flour (OF) on sensory acceptability and physical characteristics of cereal bars. Bioactive compounds of bars were also evaluated. Equivalent proportions of three components and binary mixtures of BPF and RF resulted in bars with liking degree in the region of higher response in the triangular diagrams. Interaction between BPF with RF or OF promoted changes to the color of bars; incorporation of only BPF reduced specific volume, and joint addition of BPF and OF increased adhesiveness of bars. Cereal bars with 50% BPF/50% RF and 17% BPF/66% RF/17% OF in the mixture can be considered to be the best formulations to be produced, regarding to sensory acceptability. Finally, banana peel flour contributed to incorporation of total phenolic compounds and total antioxidant activity in cereal bars, and thus allowed for development of products with aggregated functional property.

Keywords: agro-industrial residue; *Musa acuminate L., cv cavendshii;* rice flakes; oat flour; total antioxidant activity; external preference mapping.

1. Introduction

The feasibility of using agro-industrial residues and by-products in foods and incorporating them in human nutrition has been investigated by several authors (BABBAR et al., 2011; MOHAPATRA, MISHRA, SUTAR, 2010; PAIVA et al., 2012). Industrial waste includes seeds, bark, stems, and leaves, which largely contain a variety of biologically active species. These active species include antioxidant polyphenols, which have applications in the pharmaceutical and food industries (BUCIC´- KOJIC´ et al., 2009).

Banana is one of the most extensively consumed fruits in the world and represents approximately 40% of world fruit trade. The world production of bananas was 102 Mt in 2012, and Brazil was the fifth most important banana-producing country, with a total production of 6.9 Mt (FAO, 2014). The banana peel represents 30-40% of the total weight of the fruit. Consequently, the residue generated through traditional banana consumption is important and has a significant effect on the environment.

The banana peel is rich in minerals (EMAGA et al., 2008), and its quantity of the total dietary fiber reaches 43.2 to 49.7% (MOHAPATRA; MISHRA; SUTAR, 2010). In addition, Gonzalez-Montelogo, Gloria Lobo, & Gonzalez (2010) reported that banana peels contain large amounts of dopamine and l-dopamine, catecholamines, which have antioxidant activity. Therefore, the use of banana peels in food products is useful because of the peel’s nutritive value and also as an aid in reducing waste.

The substantial growth of the cereal bar market in recent decades is due to the development of innovative products that have been fortified with vitamins and minerals, as well as to the incorporation of bioactive compounds. In addition, consumers consider cereal bars to be healthy products (BOWER e WHITTEN, 2000; PALAZZOLO, 2003). Cereal bars have gained an acceptability in the consumers eyes as being “better for you,” because they are considered good in nutritional term and also because of their contribution of dietary fiber (DUTCOSKY et al., 2006).

Optimization techniques can be applied to a product in development in an attempt to find the ideal formulation for the desired products, or even to investigate how the independent variables affect one or some dependent variables. Thus, the mixture modeling methodology is suitable for food products that require a composition or a blend of key ingredients, since proportions of the ingredients in the mixture, and their levels, are dependent on each other, and the sum of all of the components is always 1 or 100% (HARE, 1974). In these cases, the ingredients are the independent variables or factors, and the objectives to be optimized or investigate are the dependent variables (CASTRO et al., 2003).

Therefore, we aimed to investigate the effect of the addition of the banana peel flour, rice flakes and oat flour in sensory acceptability and physical properties of the cereal bars, using the mixture modeling methodology.

2. Material and Methods

2.1. Material

Samples of the Cavendish variety of banana (*Musa acuminate L., cv cavendshii*), provided directly by the producer of São José do Rio Preto, SP, Brazil, were matured in an ethylene chamber while still at the production site. The bananas were then stored at the Laboratory of Sensory Analysis of the Food Engineering and Technology Department of the Institute of Biosciences, Literature and Exact Sciences of UNESP – Univ Estadual Paulista. The samples were stored in a cool, dry place until they reached the advanced stage of ripeness (when the peels had yellow and brown spots), stage of maturity in which most bananas are processed by the industry. The fruits were washed in running water and then the peel was separated from the pulp.

Approximately 2.2 kg of banana peels were arranged in trays provided with small perforations to facilitate the passage of hot air. Then the trays were placed in a Pasiani oven with air circulation (Classic Model Turbo 240).The oven was preheated (20 min) at 60 °C, according to Gonzaléz-Montelongo, Lobo and González (2010), and, the trays were then left inside overnight. The dried peels were crushed in a food process until the banana peel flour was obtained, and the flour was then stored in polypropylene plastic bags at room temperature and in the dark. After drying, 100 g of banana peel flour contained 6.8 g of moisture, 6.5 g protein, 2.2 g fat, 11.8 g of ash, 62.8 g of total dietary fiber (9.8 g of soluble fiber and 53 g of insoluble fibers) and 9.9 g of available carbohydrate (analyses performed at laboratory).

The banana pulp was used to obtain dried banana, which was used then in the formulation of cereal bars. Approximately 1.8 kg of banana pulp were cut longitudinally using stainless steel knives, and the pieces were placed on perforated trays and dried in a Pasiani oven with air circulation (Classic Model Turbo 240). After the oven was preheated (20 min) at 60 °C, the trays were left inside for 24 h.

The other ingredients used to prepare the cereal bars (rice flakes, oat flour, palm oil, maize glucose, and candied bananas) were purchased in a local market and only one brand of each product was purchased.

2.2. Experimental design

The simplex centroid design for three components was used in order to evaluate the individual and binary effects of banana peel flour, rice flakes and oat flour on the following dependent variables: sensory acceptability, such as appearance, aroma, texture, flavor, and overall acceptability, and the physical properties resulting from the texture, color, and specific volume of the cereal bars. Three replicates of the centroid point and three axial points were considered in the design, totalizing twelve formulations (Table 1) that were prepared at the same sequence presented in the table. The cereal bars can be seen at Anexo 1.

Table 1. Simplex centroid design for mixtures of banana peel flour (X_1), rice flakes (X_2) and oat flour (X_3) in the cereal bars.

formulation	component proportion[1]			proportion of each component in the cereal bar (g/100g)		
	X_1	X_2	X_3	banana peel flour	rice flakes	oat flour
1	1	0	0	42	0	0
2	0	1	0	0	42	0
3	0	0	1	0	0	42
4	0.5	0.5	0	21	21	0
5	0.5	0	0.5	21	0	21
6	0	0.5	0.5	0	21	21
7	0.33	0.33	0.33	14	14	14
8	0.33	0.33	0.33	14	14	14
9	0.33	0.33	0.33	14	14	14
10	0.66	0.17	0.17	27.72	7.14	7.14
11	0.17	0.66	0.17	7.14	27.72	7.14
12	0.17	0.17	0.66	7.14	7.14	27.72

[1]$X_1+X_2+X_3 = 1$ (equivalent to 100% of the mixture).

The rice flakes and oat flour were choosen for the model because they are ingredients that are commonly used in cereal bar production (RYLAND et al. 2010; SILVA et al. 2013). The highest level of each component represents 42 g/100 g of the total formulation of cereal bar (Table 1), what it corresponds to the quantity of dry ingredients in the cereal bars.

2.3. Cereal bar processing

The binders (30 g corn syrup, 18 g candied bananas, and 5 g palm oil) were heated to a boiling temperature and mixed. Subsequently, the dry ingredients (42 g of a mixture of banana peel flour, rice flakes and oat flour and 5 g dried banana), which had been previously mixed, were added to a mixture of the binders, and the mass was mixed using a scoop during 4 min. The resulting mass was spread in a stainless steel baking sheet that was 30 mm in height, and it was then baked in a Pasiani oven (Turbo Classic model 240); the oven was preheated (20 min) at 100 °C and the dough was cooked for 20 min. The resulting product was cooled at room temperature for 15 min. While still in the pan, the product was cut into bars of 31 ± 2 mm (width) x 63 ± 3 mm (length). The cereal bars were covered with film polyvinyl chloride (PVC) and stored at room temperature until the sensory analysis was performed 24 h later. The samples to be used for the physical, chemical and bioactive compounds analyses were vacuum packed and stored at room temperature and in the dark for 48 h after the bars were prepared.

2.4. Sensory acceptability of the cereal bars

The sensory analysis was performed at the Sensory Analysis Laboratory. This study was approved by the Research Ethics Committee of the Institute of Biosciences, Literature and Exact Sciences (Opinion Report 99.422; Anexo 2).

First, the consumers completed a questionnaire of demographic questions to specify their degree of liking and frequency of consumption of cereal bars in general.

The cereal bar formulations were then evaluated on sensory 9-point hedonic scales to measure sensory acceptability. The scales ranged from "dislike extremely" to "like extremely" (MEILGAARD; CIVILLE; CARR, 2007). The attributes of appearance, aroma, texture and flavor, and overall acceptability were the sensory parameters that were measured.

The test was conducted with sixty-seven consumers in individual booths, that proved all the samples, under white light, at a temperature of 22 ºC and in the morning and the afternoon. The samples were coded with three-digit random numbers and were presented in a monadic manner (MACFIE e BRATCHEL, 1989), and it was asked that consumers drink water between samples. Sensory analysis was performed divided in two sessions for each consumer because of the high number of samples.

2.5. Physical analyses of the cereal bars

The color of the cereal bars was analyzed using a Hunterlab colorimeter, Color Flex 45/0 model (Reston, USA), with D65 iluminant and a 10o observer and using the Spectra Magic Nx software (version CM-S100W 2.03.0006, Virginia, USA). The parameters L* (luminosity), a* (opposition between red and green), b* (opposition between yellow and blue), C* (chroma) and h (hue) were obtained.

The texture of the cereal bars was analysed through two tests using the TA.XT/Plus/50 texturometer (Stable Micro Systems, Godalming, England) and the Texture Exponent 32 software (Stable Micro Systems, Godalming, England) and with the following procedures:

1) Force of rupture: a three-point bending probe was used with a distance of 3.8 cm between the axles and a test speed of 1.0 $mm.s^{-1}$. For this test, three cereal bars that were 31 ± 2 mm (width) x 63 ± 3 mm (length) were cut completely and the maximum force, in Newton, was considered as the force of rupture;

2) Texture of Profile Analysis: ten cereal bar samples, cut into of 20 x 20-mm pieces with the aid of a stainless steel knife, were used in the test. The test conditions were as follows: a cylindrical aluminum probe that was 25 mm in diameter and which operated at a speed of 1.0 $mm.s^{-1}$; time of 5 s between the two compressions, and a compression of 50% of the height of the sample. The hardness, cohesiveness, springiness, adhesiveness and chewiness parameters were obtained (SZCZESNIAK, 2002). Fracturability was not obtained because it is not a texture parameter found in cereal bars.

Three entire cereal bars were weighed, and the length, width and height were measured with the aid of a digital caliper (Digimess IP54). The specific volume ($cm^3.g^{-1}$) of the bars was calculated using the following formula: specific volume = (height x length x width) / weight.

2.6. External preference mapping

The principal component analysis was applied using the Statistica 10.0 software (StatSoft Inc., Oklahoma, USA) in order to identify the correlations between sensory acceptability and physical characteristics of the cereal bars. The analysis resulted in an external preference mapping. For the mapping process, only the dependent variables that were influenced by the three components were considered (Table 2).

The average scores for sensory acceptability and the physical characteristics of the cereal bars were placed into the columns (variables), while the formulations were placed in the rows (cases). The formulation of the central point of the experimental design was calculated as the mean of formulations 7, 8 and 9. The data was standardized in the columns and analyzed using the correlation matrix without factor rotation. A percentage of explanation above 70% for the two first principal components indicates a strong correlation among the variables and that principal component analysis is an appropriate multivariate analysis for this data (MARDIA; KENT; BIBBY, 1979).

2.7. Analysis of bioactive compounds of banana peel flour and cereal bars

The bioactive compounds were analyzed to evaluate the banana peel flour and the cereal bars made with banana peel flour (formulations 1/4/5/7/10/11/12 in Table 1).

2.7.1. Extraction of antioxidants

The procedure developed by Rufino et al. (2010) was employed and, briefly, is as follows: fresh samples from the pre-testing stage were weighed in centrifuge tubes and the extract was obtained sequentially with 40 mL of methanol/water (50:50, v/v) in a magnetic stirrer at room temperature for 1 h. The tubes were centrifuged at 25,400g (BR4i multifunction, Chanteau-Gontier, France) for 15 min, and the supernatant was recovered. Then, 40 mL of acetone/water (70:30, v/v) were added to the residue at room temperature, extracted for 1 h in a magnetic stirrer and centrifuged. The methanol and acetone extracts were combined, made to reach 100 mL using distilled water, and then used to determine extract able polyphenol contents and antioxidant capacity.

2.7.2. Estimation of total phenolic content

The total phenolic content of the extract was determined using the colorimetric method with the Folin-Ciocalteu reagent according to an adapted version of the method used by Waterhouse (2002). The extracts (0.25 mL) were mixed with 0.25 mL of the Folin-Ciocalteu reagent, 0.25 mL of a sodium carbonate solution (7.5:92.5, v/v) and 2 mL of distilled water. After 30 min in a water bath at 37 °C, the absorbance of the sample was read at 750 nm in a spectrophotometer (Beckman Coulter DU 640, UV-vis, Fullerton, USA), and the results were expressed as mg of gallic acid equivalents per g of fresh weight (mg GAE. g^{-1}f.w.).

2.7.3. Total antioxidant activity measured by TEAC (Trolox equivalent antioxidant capacity)

The ABTS (2,2′-Azino-bis(3-ethylbenzothiazoline-6-sulfonic acid) radical was generated by the reaction of 5 mL of aqueous ABTS 7mM with 0.88μL of potassium persulphate (140 mM). The mixture was kept in the dark for 16 h and then diluted with ethanol until a solution with absorbance of 0.7 ± 0.05 at 734 nm was obtained (RUFINO et al., 2010). Next, 30 μL of either the sample or the trolox standard at 100 μM- 1500 μmol was added to 3 mL of diluted ABTS radical solution and the absorbance was recorded using a spectrophotometer after 6 min of reaction in the dark (Beckman Coulter DU 640, UV-vis, Fullerton, USA). The ethanolic solutions of known trolox concentrations were used for calibration, and the results were expressed as μmol trolox equivalent per g of fresh weight (μmol TE.g^{-1}f.w.).

2.8. Statistical analyses

The averages of the tests for each response variable were subjected to multiple regression analysis using the quadratic model $Y = \beta_1X_1 + \beta_2X_2 + \beta_3X_3 + \beta_{12}X_1X_2 + \beta_{13}X_1X_3 + \beta_{23}X_2X_3$, since there was not interaction among the three components for all the special cubic models. In the final equation of the model, only the coefficients with a significance level of 0.05 were considered. The quality of fit of the model was evaluated through an analysis of variance, and the regression was considered significant and without lack of fit at significance level of 0.05. Finally, the triangular diagrams for each dependent variable were generated. All of these analyses were performed using the Statistica 10.0 software (StatSoft Inc., Oklahoma, USA).

The Kruskal-Wallis (nonparametric ANOVA) followed by Dunn’s test were applied to compare the average of total phenolic compounds and antioxidant activity of the cereal bars, using the Statistica10.0 software (StatSoft Inc., Oklahoma, USA). A simple linear regression analysis was performed using the quantities of banana peel flour added to the cereal bar (independent variable) and the average total phenolic compounds and antioxidant activity (response variables), in software Microsoft Excel version 2013 (Microsoft Corporation, Santa Rosa, USA).

3. Results and Discussion

3.1. Sensory acceptability of the cereal bars

Of the sixty-seven consumers who participated in the sensory analysis, 58% were female, and 62.7% were from 18 to 25 years old (with a total variation from 17 to 56 years old). Their pre-test questionaires revealed that 54% considered themselves to be “very fond of cereal bars” and that 63% “consume a cereal bar at least once a week”.

The average sensory acceptability scores of the cereal bars ranged from 3.3 to 7.0 for appearance, from 4.9 to 6.8 for aroma, from 3.2 to 7.4 for texture, from 3.8 to 6.8 for flavor, and from 3.7 to 6.9 for overall acceptability (Anexo 3).

Each individual component had a significant effect, as did all of the binary interactions between components ($p \leq 0.05$), except for the interaction between banana peel flour and oat four when it was evaluated for its appearance; therefore, the significant coefficients were used in the equation of the model obtained (Table 2).

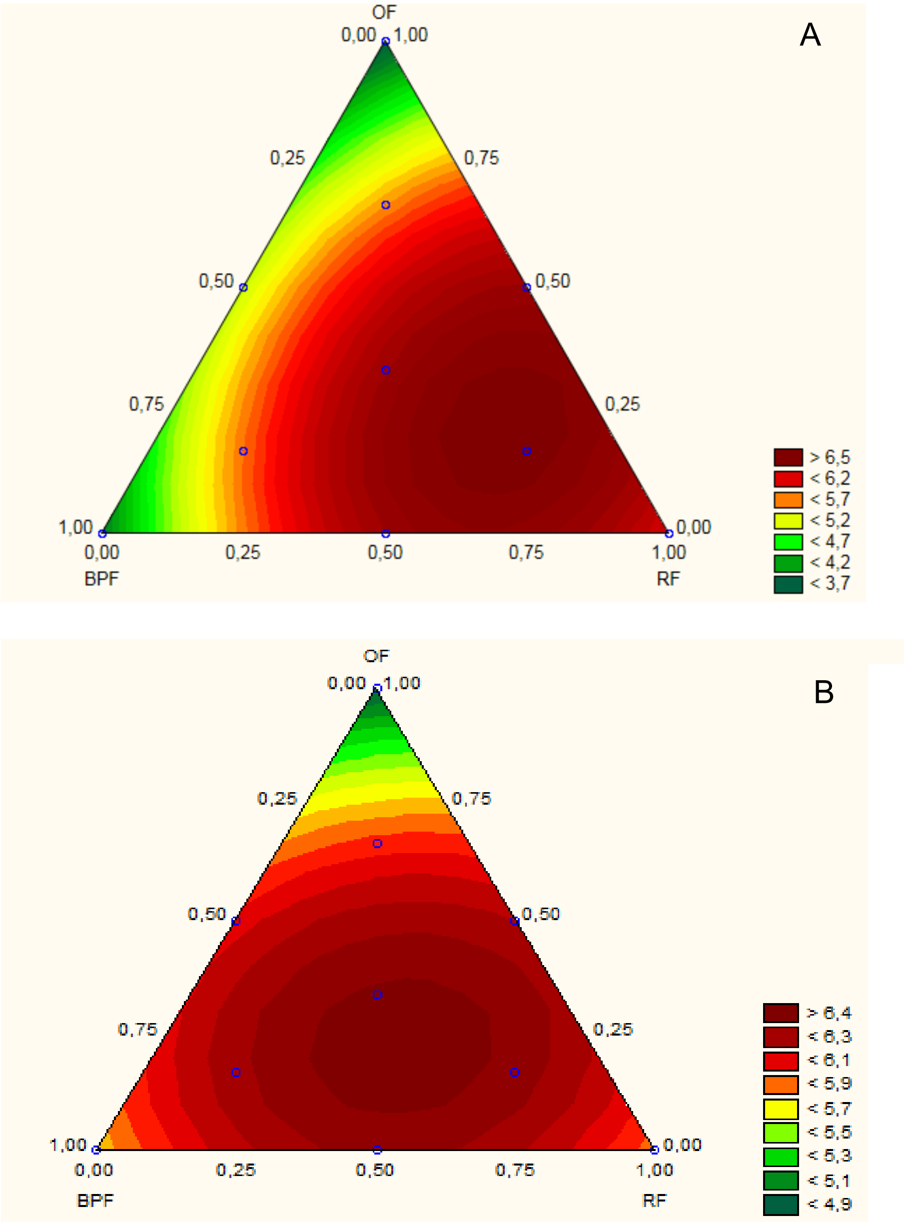
The models that explain the effects of the three components on the acceptability of appearance, texture, flavor, and overall acceptability are similar (Table 2); therefore, only the triangular diagram for the overall acceptability is presented, and the discussion is the same for the four dependent variables. An increasing in the proportion of rice flakes enhanced the liking by the appearance, texture, flavor, and overall acceptability of the cereal bars, while an increasing in the proportions of banana peel flour and oat flour, or a binary mixture of these two components, reduced the liking (Fig. 1A). However, equivalent proportions of the three components and the binary mixtures of banana peel flour/rice flakes and rice flakes/oat flour resulted in cereal bars with a degree of liking that was still in the region of greater response in the triangular diagram.

Table 2. Models and goodness of fit for the dependent variables of the cereal bars.

dependent variable	equation[1]	R^2 (%)	p-value	lack of fit
appearance acceptability	$Y_{ApA} = 4.24X_1 + 6.68X_2 + 3.32X_3 + 3.03X_1X_2 + 8.77X_2X_3$	98.3	<0.001	0.085
aroma acceptability	$Y_{ArA} = 5.72X_1 + 5.83X_2 + 4.86X_3 + 2.18X_1X_2 + 2.97X_1X_3 + 3.38X_2X_3$	84.4	0.003	0.777
texture acceptability	$Y_{TA} = 3.93X_1 + 6.67X_2 + 3.25X_3 + 6.51X_1X_2 + 5.40X_1X_3 + 7.47X_2X_3$	98.5	<0.001	0.089
flavor acceptability	$Y_{FA} = 3.79X_1 + 6.09X_2 + 4.04X_3 + 6.69X_1X_2 + 5.52X_1X_3 + 5.65X_2X_3$	97.4	<0.001	0.073
overall acceptability	$Y_{OA} = 3.94X_1 + 6.16X_2 + 3.63X_3 + 6.15X_1X_2 + 5.03X_1X_3 + 6.89X_2X_3$	99.6	<0.001	0.369
a* (red intensity)	$Y_{a*} = 2.53X_1 + 11.38X_2 + 8.79X_3 - 8.61X_1X_2 - 10.00X_1X_3$	95.1	<0.001	0.994
b* (yellow intensity)	$Y_{b*} = 2.51X_1 + 36.00X_2 + 30.28X_3 - 40.15X_1X_3$	91.6	<0.001	0.300
C* (color saturation)	$Y_{C*} = 3.17X_1 + 35.34X_2 + 29.56X_3 - 38.38X_1X_3$	92.1	<0.001	0.374
h (hue)	$Y_h = 40.07 X_1 + 70.78 X_2 + 72.95 X_3 + 57.25 X_1 X_2$	82.1	0.005	0.073
force of rupture (N)	$Y_{RF} = 0.85X_1 + 5.45X_2 + 0.56X_3 – 0.40X_1X_2 – 2.24X_1X_3 - 7.41X_2X_3$	81.9	0.005	0.217
hardness (N)	$Y_H = 10.51X_1 + 42.2X_2 - 1.23X_3 + 107.4X_1X_2 + 154.5X_1X_3 + 316.98X_2X_3$	69.5	0.025	0.548
adhesiveness (N.s)	$Y_A = 1.20X_1 + 0.50X_2 + 3.09X_3 + 7.8X_1X_2 + 13.27X_1X_3 + 9.90X_2X_3$	61.8	0.046	0.691
specific volume ($cm^3.g^{-1}$)	$Y_{SV} = 11.15X_1 + 21.27X_2 + 9.54X_3 + 6.30X_1X_2 + 2.0X_1X_3 – 11.4X_2X_3$	90.1	<0.001	0.722

[1] X_1 = banana peel flour, X_2 = rice flakes, X_3 = oat flour.

Fig. 1. Triangular diagrams for the overall acceptability (A) and aroma acceptability (B) of the cereal bars containing banana peel flour (BPF), rice flakes (RF) and oat flour (OF).



The cereal bar produced exclusively with banana peel flour was very dark visually and lacked the characteristic texture of cereal bars, while the cereal bar produced exclusively with oat flour was soft, sticky, and yellowish. The presence of rice flakes made the bars more similar to commercial cereal bars, since this ingredient is commonly used for this type of product (RYLAND et al, 2010; GARCIA et al, 2012; SILVA et al., 2013), and may have thus increased the cereal bars liking.

The positive effect of the mixture of the three components in the sensory acceptability may be related to the fact that cereal bars are formulated with a mixture of various dry ingredients, such as rice flakes, oats, dried fruit, and binders such as glucose syrup and honey (PADMASHREE et al., 2012;. SILVA et al., 2013). All of these findings suggest that banana peel flour is a potential ingredient to be used in cereal bars.

The addition of the three components resulted in a wide region of high liking approval for the aroma of the cereal bars (scores higher than 6 that means "like slightly"), regardless of their proportions. Only the increase in the proportion of oat flour reduced the liking score (Fig. 1B). The decomposition of unsaturated fatty acids is one of the unfavorable reactions that take place in oat flakes during heat processing, and it highly influences the formation of volatile compounds (KLENSPORF e JÉLEN, 2008). This change may have been perceived by the consumers.

3.2. Physical characteristics of the cereal bars

The average color scores of the cereal bars ranged from 17.9 to 46.1 for luminosity (L*), from 2.5 to 11.5 for red intensity (positive values for a*), from 2.5 to 35.7 for yellow intensity (positive values for b*), from 3.3 to 35.1 to color saturation (C*), and from 39.1 to 73.1 for hue (h) (Anexo 4).

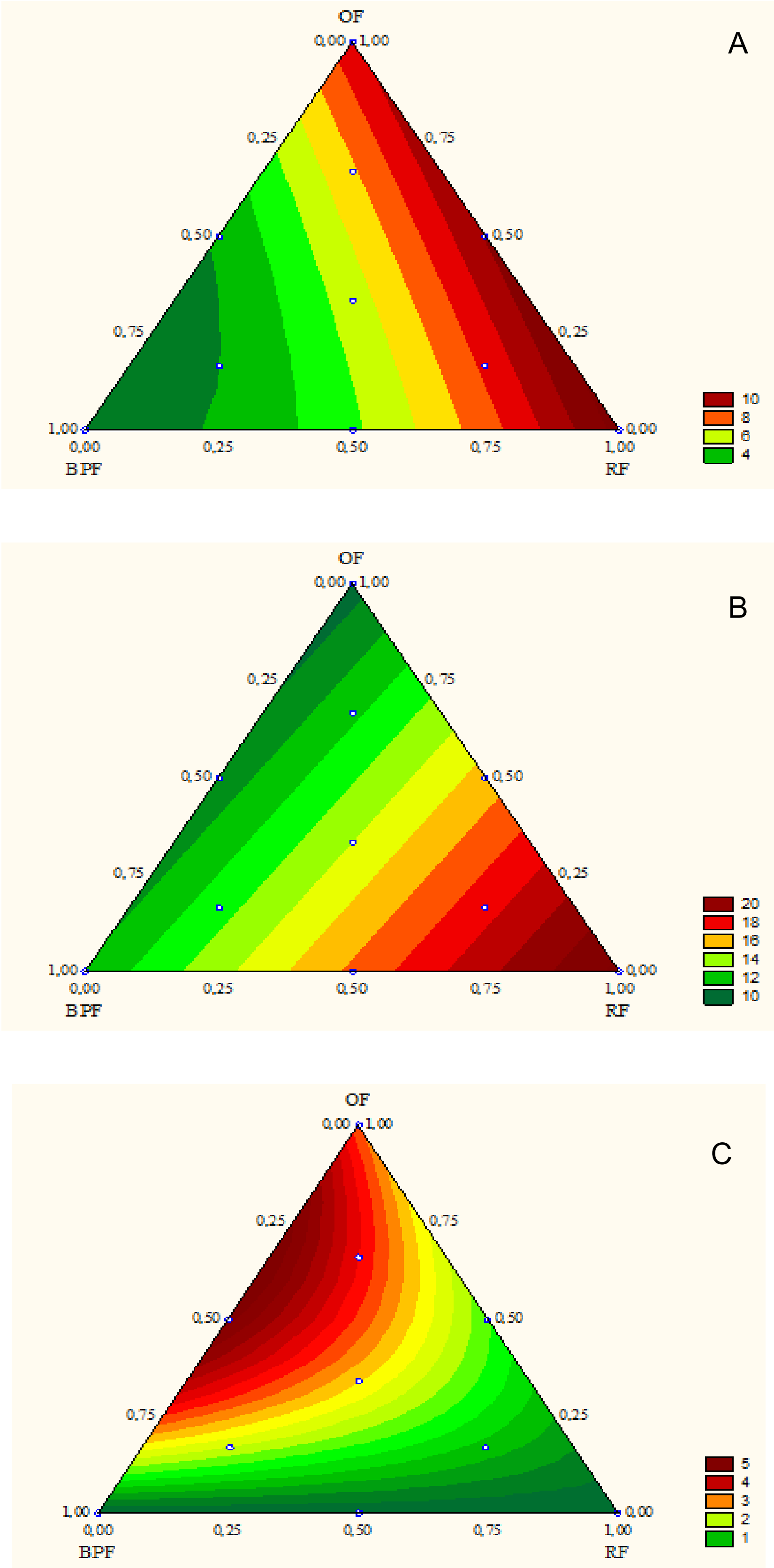
All of the isolated components affected only on red intensity and hue of the cereal bars, and the exclusive addition of banana peel flour did not affect yellow intensity or color saturation (Table 2). The banana peel flour interacted with the other two components only in the case of red intensity, and this interaction is antagonistic due to the negative signs of the equation coefficients, i. e., the increase in the quantities of rice flakes or oat flour, along with the reduction of banana peel flour, increases the red intensity of the cereal bars (Fig. 2A). Likewise, the increased incorporation of oat flour and the decrease in banana peel flour increased the yellow intensity and color saturation of the cereal bars (Table 2). Finally, the joint addition of banana peel flour and rice flakes results in a hue increase. The model for luminosity (L*) showed lack of fit ($p \leq 0.05$).

The average scores for the texture of the cereal bars ranged from 0.3 to 5.2 N for force of rupture, from 5.8 to 110.9 N for hardness, from 0.11 to 0.73 for cohesiveness, from 0.23 to 0.95 for springiness, from 0.9 to 6.6 N.s for adhesiveness, and from 0.6 to 12.3 N for chewiness. The means for the specific volume ranged from 9.6 to 20.8 $cm^3.g^{-1}$ (Anexo 5).

The isolated addition of banana peel flour influenced the specific volume of the cereal bars, but its combination with the oat flour influenced the adhesiveness of the bars (Table 2). The incorporation of banana peel flour reduced the specific volume (Fig. 2B), while the joint addition of banana peel flour and oat flour increased the adhesiveness of the bars (Fig. 2C). The model for cohesiveness had a lack of fit to ($p \leq 0.05$), whereas the models for springiness and chewiness were not significant ($p > 0.05$).

The banana peel flour, as described at item 2.1, had 62.8 g of total dietary fiber − a value much higher than those in rice flakes and oat flour, which the manufacturers declare to contain 4-6% and 13-15% of dietary fiber, respectively. The high fiber content may have caused the decrease in the specific volume and the increase in the adhesiveness of the cereal bars, since these effects were found in studies on other kinds of food products (WANG, ROSELL e BARBER, 2002; GOMEZ et al., 2003; VOLPINI-RAPINA, SOKEI e CONTI-SILVA, 2012). Another factor considered is the diversity of the geometry of the ingredients, mainly due to the rice flakes, resulting in different accommodation of the ingredients and consequently in different specific volume of the cereal bars.

Fig. 2. Triangular diagrams for the red intensity (A), specific volume (B) and adhesiveness (C) of the cereal bars containing banana peel flour (BPF), rice flakes (RF) and oat flour (OF).

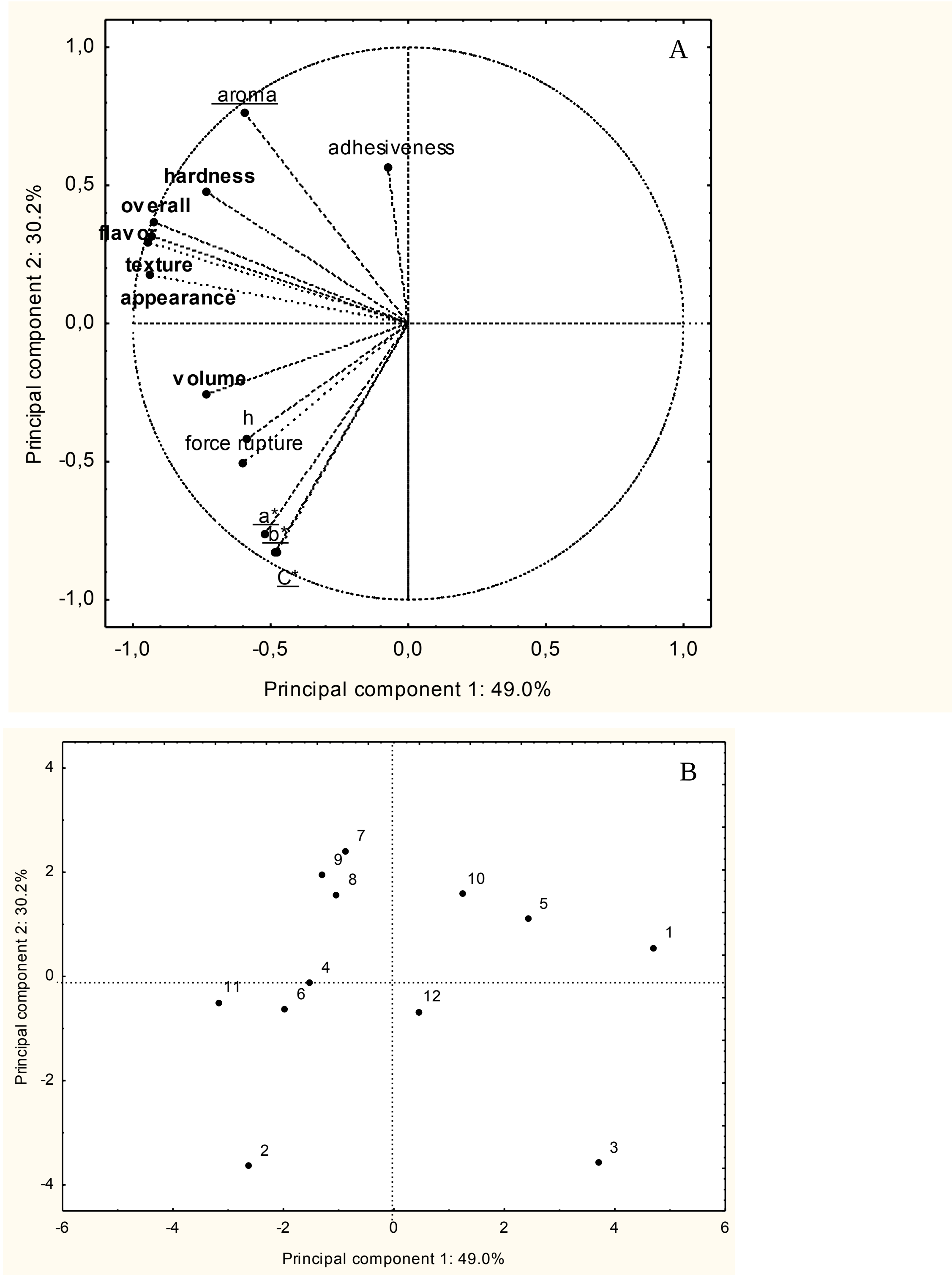


3.3. External preference mapping

The first principal component explained 49.0% of the data variation and the second principal component explained 30.2%, totalizing 79.2% of the total variation data (Fig. 3).

The first principal component is explained by the liking for appearance, texture, flavor, overall acceptability, specific volume and hardness (bold variables with factor charges ≥ 0.7 in the principal component 1), and all these variables are positively correlated (Fig. 3A). The formulations 4, 6 and 11 were characterized by the liking for appearance, texture and flavor and the overall acceptability, which is related to their higher specific volume and hardness (Fig. 3B). These cereal bars have a high amount of rice flakes (50, 50 and 66% in the mixture, respectively), which coincides with the results shown in the triangular diagram (Fig. 1A), although the cereal bars 4 and 11 also have banana peel flour in the formulation (50% and 17% in the mixture, respectively). Moreover, the cereal bars 1, 5 and 10, which are formulations with high amounts of banana flour (100%, 50% and 66% in the mixture, respectively), had low sensory liking (scores lower than 6 that means indifference and rejection), specific volume and hardness, since they are positioned in the opposite quadrant in relation to these characteristics (Fig. 3B).

Fig. 3. External preference mapping for the cereal bars (A - projection of the variables: bold variables correlate to principal component 1 and underlined variables correlate to principal component 2; B - projection of the formulations).



The second principal component is explained by the liking score for aroma and the color parameters a*, b* and C* (underlined variables with factor charges ≥ 0.7 in principal component 2), since color parameters are positively correlated among them, but negatively correlated with the aroma liking (Fig. 3A). Formulations 7, 8 and 9 (the center point of the experimental design) was characterized by a high aroma liking score and low red and yellow intensities and color saturation, while formulation 3, which incorporated only oat flour, was characterized by its low aroma liking (Fig. 3B). These results coincide with the triangular diagram for aroma (Fig. 1B). In addition, formulation 2 (100% rice flakes) was characterized by high red and yellow intensities and color saturation.

Combining the two statistical analyses used in this work, mixture modeling methodology and principal component analysis, it is possible to reach conclusions about different samples, which contains banana peel flour, and response variables. In general, the cereal bars with 17, 33.3 and 50% of banana peel flour in the mixture (formulations 11, 7/8/9 and 4, respectively) are located in regions of high sensory liking in the triangular diagrams (Fig. 1). The formulations 4 and 11 also can be considered as having high sensory liking for appearance, texture, flavor and overall according to external preference mapping (Fig. 3), while formulation 7/8/9 has high sensory liking for aroma. Therefore, the cereal bars with 50% banana peel flour/50% rice flakes (formulation 4) and 17% banana peel flour/66% rice flakes/17% oat flour (formulation 11) in the mixture of the three components can be considered to be the best formulations to produce regarding to sensory acceptability. Which makes these two ideals formulations technological point of view, because in them is the addition of up to 21 g of the banana peel flour. With this addition, it is possible to reduce the cost of cereal bars through substitution of cereals by banana peel flour, besides aggregating commercial value to the industrial waste.

3.4. Bioactive compounds from banana peel flour and cereal bars

The total phenolic compounds in the banana peel flour extract was 2.42 mg GAE. g-1f.w. (Table 3), different from the value of 3.8 mg GAE. g^{-1} f.w. of total phenolic compounds found in methanol extracts from bananas (BABBAR et al., 2011) and from values of 12 to 19 mg GAE. g^{-1} f.w. found in methanol extracts from two different banana varieties of banana, using different extraction times and temperatures (GONZALEZ-MONTELONGO et al., 2010).

Table 3. Bioactive compounds and antioxidant capacity in banana peel flour and in cereal bars formulated with banana peel flour.

	total phenolic content (mg GAE. g^{-1}f.w.)			total antioxidant activity (µmol TE.g^{-1}f.w.)		
	minimum	median	maximum	minimum	median	maximum
banana peel flour	2.38	2.43	2.44	1.05	1.06	1.10
formulation 1	4.16	4.18^{a}	4.20	3.34	3.37^{a}	3.52
formulation 4	1.75	1.75^{b}	1.77	1.40	1.45^{c}	1.52
formulation 5	2.12	2.14^{c}	2.17	1.91	1.97^{b}	2.00
formulation 7	1.87	1.92^{d}	1.98	1.00	1.16^{d}	1.16
formulation 10	2.33	2.37^{e}	2.43	2.09	2.14^{b}	2.21
formulation 11	1.38	1.41^{f}	1.44	1.07	1.08^{d}	1.17
formulation 12	0.86	0.87^{g}	0.88	0.55	0.58^{e}	0.68

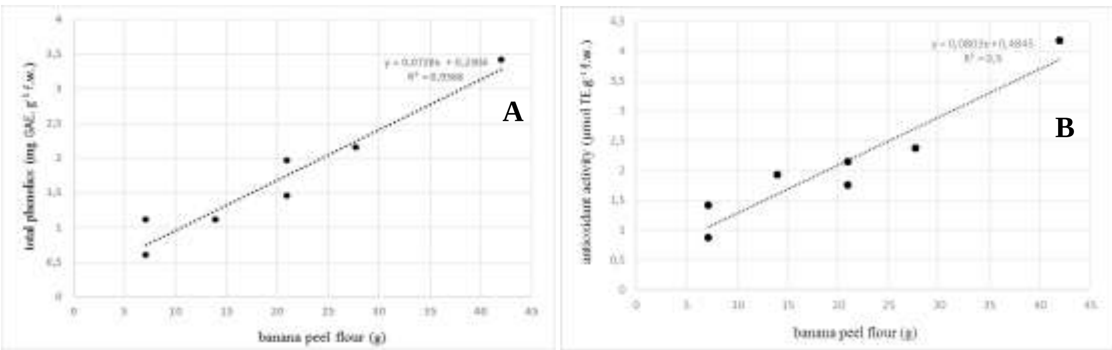
Different letters in the column indicate significantly different means according to Dunn´s test ($p \leq 0.05$).

Different extract concentrations and different procedures adopted for the analysis of total phenolic compounds, even when gallic acid is used as reference, are likely to result in different values (BABBAR et al., 2011). Formulation 1 had higher quantity of total phenolic compounds than banana peel flour, suggesting that this ingredient is not the only one responsible for the levels of total phenolic compounds, but the interaction among ingredients used in the preparation of cereal bars (SUN-WATERHOUSE et al., 2010; NOJARIT, GU e RYU, 2011).

The antioxidant capacity measured by ABTS, express in TEAC, in the case of banana peel flour was 1.07 μmol $TE.g^{-1}$f.w. (Table 3), different from value of 5.67 mg $TE.g^{-1}$d.w. found in another work, but these values depend on both the cultivar and the stage of ripeness of the fruit (BABBAR et al., 2011).

Total phenolic compounds were statistically different for all formulations, indicating that different proportions of banana peel flour addition confer different compositions of these compounds, whereas the antioxidant activity were statistically equal in formulations 5 and 10 and in formulations 7 and 11. Moreover, total phenolic compounds and antioxidant activity in extracts from the cereal bars are directly proportional to the amount of added banana peel flour (Fig. 4), and it is important to mention that the high fit of the data to the model obtained by regression analysis (R^2) indicates that Folin-Ciocalteu reagent did not reacted with ascorbic acid and reducing sugars, that may be present at the cereal bars (GEORGÉ et al., 2005).

Fig. 4. Total phenolic content (A) and total antioxidant activity (B) as a function of the amount of banana peel flour added to the cereal bars.



Anyway, the banana peel flour contributes to the insertion of total phenolic compounds and antioxidant activity in cereal bars, aggregating functional property to the products, since when an antioxidant substance is present at low concentration, it delays or inhibits significantly the substrate oxidation (KANNAN et al., 2013).

4. Conclusions

We conclude that it is feasible to produce cereal bars with banana peel flour. Equivalent proportions of the three components and the binary mixtures of banana peel flour and rice flakes result in cereal bars with degree of liking in the region of greater response in the triangular diagrams. The banana peel flour interacts with rice flakes and oat flour, promoting changes on the color of the cereal bars, while the incorporation of only banana peel flour reduces the specific volume and the joint addition of banana peel flour and oat flour increases the adhesiveness of the cereal bars. Regarding to sensory acceptability, cereal bars with 50% banana peel flour/50% rice flakes (formulation 4) and 17% banana peel flour/66% rice flakes/17% oat flour (formulation 11) in the mixture of the three components can be considered to be the best formulations to be produced. Finally, the banana peel flour contributes to the inclusion of total phenolic compounds and total antioxidant activity in cereal bars, and its use allows for the development of products with aggregated functional property, because it can reduce the cost of the product besides aggregating commercial value to a residue generated by the food industry.

Acknowldegements

The authors are grateful for the financial support from FAPESP (Fundação de Amparo à Pesquisa do Estado de São Paulo) (grant 2012/08852-3) and CAPES for the scholarship granted.

References

BABBAR, N.; OBEROI, H. S.; UPPAL, D. S.; PATIL, R. T. Total phenolic content and antioxidant capacity of extracts obtained from six important fruit residues. **Food Research International**, Barking, v. 44, p. 391-396, 2011.

BOWER, J. A.; WHITTEN, R. Sensory characteristics and consumer liking for cereal bar snack foods. **Journal of Sensory Studies**, Manhattan, v. 15, p. 327-345, 2000.

BUCIC´-KOJIC´, A.; PLANINIC´, M.; TOMAS, S.; JAKOBEK, L. & SERUGA, M. Influence of solvent and temperature on extraction of phenolic compounds from grape seed, antioxidant activity and colour of extract. **International Journal of Food Science and Technology,** Oxford, v. 44, p. 2394-2401, 2009.

CASTRO, I. A.; SILVA, R. S. F.; TIRAPEGUI, J.; BORSATO, D. & BONA, E. Simultaneous optimization of response variables in protein mixture formulation: constrained simplex method approach. **International Journal of Food Science and Technology,** Oxford, v. 38, p. 103-110, 2003.

DUTCOSKY, S.D. et al. Combined sensory optimization of a prebiotic cereal product using multicomponent mixture experiments. **Food Chemistry**, London, v. 98, n. 4, p. 630-638, 2006.

EMAGA, T. H.; ANDRIANAIO, R. H.; WATHELET, B.; TCHANGO, J. T. & PAQUOT, M. Effects of the stage of maturation and varieties on the chemical composition of banana and plantain peels. **Food Chemistry**, London, v. 103, p. 590-600, 2007.

FAO. (2014).<http://faostat3.fao.org/faostat-gateway/go/to/download/Q/QI/E> FAOSTAT. March 28, 2014.

GARCIA, M. C.; LOBATO, L. P.; BENASSI, M. T. & SOARES JÚNIOR, M. S. Application of roasted rice bran in cereal bars. **Ciência e Tecnologia de Alimentos,** Campinas, v. 32, p. 718-724, 2012.

GEORGÉ, S., et al. Rapid determination of poliphenols and vitamin C in plant-derivated products. **Journal of Agricultural and Food Chemistry**, Easton, v. 53, p. 1370-1373, 2005.

GOMEZ, M.; RONDA, F.; BLANCO, C.; CABALLERO, P. & APESTEGUIA, A. Effect of dietary fibre on dough rheology and bread quality. **European Food Research and Technology,** Berlin, v. 216, p. 51-56, 2003.

GONZALEZ-MONTELONGO, R.; LOBO, G. M. & GONZALEZ, M. Antioxidant activity in banana peel extracts: testing extraction conditions and related bioactive compounds. **Food Chemistry***,* London, v. 119, p. 1030-1039, 2010.

HARE, L. B. Mixture designs applied to food formulations. **Food Technology**, Chicago, v. 29, p. 50–62, 1974.

KANNAN, R. R. R.;ARUMUGAM, R.; THANGARADJOU, T. & ANANTHARAMAN, P. Phytochemical constituents, antioxidant properties and p-coumaric acid analysis insome seagrasses. **Food Research International**, Barking, v. 54, p. 1229-1236, 2013.

KLENSPORF, D.; JELÉN, H. H. Effect of heat treatment on the flavor of oat flakes. **Journal of Cereal Science**, London, v. 48, p. 656-661, 2008.

MACFIE, H. J.&BRATCHELL, N. Designs to balance the effect of order of presentation and first-order carry-over effects in hall tests. **Journal of Sensory Studies**, Manhattan, v. 4, p. 129-148, 1989.

MARDIA, K. V.; KENT, J. T. & BIBBY, J. M. **Multivariate analysis**. London: Academic Press, 1979

MEILGAARD, M.; CIVILLE, G. V. & CARR, B. T. **Sensory evaluation techniques** (4th ed.). Boca Raton: CRC Press, 2007.

MOHAPATRA, D.; MISHRA, S. & SUTAR, N. Banana and its by-product utilisation: an overview. **Journal of Scientific & Industrial Research**, New Delhi, v. 69, p. 323-329, 2010.

NORAJIT, K., GU, B., RYU, G. Effects on the addition of hemp power on the physicochemical properties and energy bar qualities of extruded rice. **Food Chemistry**, London, v. 129, p. 1919-1925, 2011.

PADMASHREE, A.; SHARMA, G. K.; SRIHARI, K. A.& BAWA, A. S. Development of shelf stable protein rich composite cereal bar. **Journal of Food Science and Technology**, Oxford, v. 44, p. 335-341, 2012.

PAIVA, A. P.; BARCELOS, M. F. P.; PEREIRA, J. A. R.; FERREIRA, E. B. & CIABOTTI, S. Characterization of food bars manufactured with agroindustrial by-products and waste. **Ciência e Agrotecnologia**, Lavras, v. 36, p. 333-340, 2012.

PALAZZOLO, G. Cereal Bars: There's not just for breakfast anymore. **Cereal Foods World**, v. 48, p. 70-72, 2003.

RUFINO, M. S. M.; ALVES, R. E.; BRITO, E. S.; PÉREZ-JIMÉNEZ, J.; SAURA-CALIXTO, F. & MANCINI-FILHO, J. Bioactive compounds and antioxidant capacities of 18 non-tradicional tropical fruits from Brazil. **Food Chemistry***,* London, v. 121, p. 996-1002, 2010.

RYLAND, D.;VAISEY-GENSER, M.;ARNTFIELD, S. D.& MALCOLMSON, L. J. Development of a nutritious acceptable snack bar using micronized flaked lentils. **Food Research International***,* Barking, v. 43, p. 642-649, 2010.

SILVA, E. P.; SIQUEIRA, H. H.; LAGO, R. C.; ROSELL, C. M. & VILLAS BOAS, E. V. B. Developing fruit-based nutritious snack bars. **Journal of Science and Food Agriculture***,* Oxford, v. 94, p. 52-56, 2013.

SUN-WATERHOUSE, D., TEOH, A., MASAROTTO, C. WIBISONO, R., WADHWA, S. Comparative analysis of fruit-based functional snack bars. **Food Chemistry**, London, v. 119, p. 1369-1379, 2010.

SZCZESNIAK, A. S. Texture is a sensory property. **Food Quality and Preference**, Barking, v. 13, p. 215-225, 2002.

VOLPINI-RAPINA, L. F.; SOKEI, F. R.; CONTI-SILVA, A. C. Sensory profile and preference mapping of orange cakes with addition of prebiotics inulin and oligofructose. **LWT - Food Science and Technology**, Georgia, v. 48, p. 37-42, 2012.

WANG, J.; ROSELL, C. M.; BARBER, C. B. Effect of the addition of different fibres on wheat dough performanceand bread quality. **Food Chemistry**, London, v. 79, p. 221-226, 2002.

WATERHOUSE, A. L. Polyphenolics: Determination of total phenolics. In R. E. Wrolstad (Ed.), **Current Protocols in Food Analytical Chemistry**. New York: John Wiley & Sons, 2002.

CAPÍTULO 3

Sensory profile of cereal bars formulated with banana peel flour

ABSTRACT

Cereal bars were prepared with different proportions of banana peel flour, rice flakes and oat flour, and had their sensory profiles evaluated through descriptive analysis and hedonic scale, respectively, in comparison to a commercial cereal bar. Cereal bars with intermediate and highest amounts of banana peel flour were characterized by banana aroma, dark color and bitter taste, while the cereal bar with lowest quantity of banana peel flour was described by amount of rice flakes and crispness. On the other hand, the commercial cereal bar was described by hardness, adhesiveness, sweet taste and oat flavor. Based on sensory studies, that the addition of the banana peel flour is feasible in the development of new sustainable food products with value-added.

Keywords: rice flakes, oat flour, external preference mapping, descriptive analysis.

1. Introduction

The banana peel is a household and industrial food waste discarded in large quantities in nature. It represents about 35% of the total fresh mass of ripe fruit (EMAGA et al., 2008) and there is not further involved in remarkable industrial applications (AURORE, PARFAIT, FAHRASMANE, 2009; QIU et al., 2010). Brazil was the second world producer of banana over the last two decades, accounting for overall production of 6.9 million tons per year (FAOSTAT, 2014). Around 53% of Brazilian production of banana is industrially processed, thus representing a potential generation of 1.4 million tons of banana peel waste (IBGE, 2012).

Bananas are one of the fruits most produced and consumed worldwide and the potential use of the peel would be of great relevance. Some researchers have revealed that the banana peel has compounds and nutrients important for food and for food industry. The banana peel is rich in dietary fiber, protein, essential amino acids, polyunsaturated fatty acids and potassium (EMAGA et al., 2007), besides bioactive compounds (GONZALEZ-MONTELONGO, GLORIA LOBO, GONZALEZ; 2010), which it may contribute to enhance the nutritive quality of several foods. Furthermore, the banana peel flour has high soluble fiber content, water holding capacity and swelling, low oil-holding capacities and could be used in fried products to provide a non-greasy sensation making it a potential ingredient for use in food products (JACOMETTI et al., 2015).

According to Freitas and Moretti (2006), the tendency to associate cereal bars with healthy food has already been remarked in food industry. Nevertheless, such food is not always beneficial once their amount in some essential nutrients is not as significant as recommended. In this way, the application of banana peel flour in cereal bars is interesting, because this ingredient is rich is dietary fiber and bioactive compounds.

However, it is well known that incorporation of agro-industrial by-products, besides the ingredients rich in dietary fibers, may cause changes on sensory characteristics of products. Therefore, we developed cereal bars containing banana peel flour, through variation of the ingredients rice flakes and oat flour, and we aimed to determine the sensory profile of the cereal bars, comparing with a commercial one.

2. Material and methods

2.1. Material

Samples of the Cavendish variety of banana (*Musa acuminate L., cv cavendshii*), provided directly by the producer, in São José do Rio Preto, SP, Brazil. Were matured in an ethylene chamber while still at the production site. The bananas were then stored at the Laboratory of Sensory Analysis of the Food Engineering and Technology Department of the Institute of Biosciences, Literature and Exact Sciences of São Paulo State University (UNESP). The samples were stored in a cool, dry place until they reached the advanced stage of ripeness (when the peels had yellow and brown spots). The fruits were washed in running water and the peel was then separated from the pulp.

Approximately 2.2 kg of banana peels were arranged in trays that had small perforations in order to facilitate the passage of hot air. The trays were then placed in a Pasiani oven with air circulation (Turbo 240 Classic Model). The oven was preheated for 20 min at 60 °C in according Gonzaléz-Montelongo, Lobo and González (2010) and, the trays were then left inside overnight. The dried peels were crushed in a food processor until the banana peel flour was obtained, and the flour was then stored in polypropylene plastic bags at room temperature and in the dark. After they were dried out, 100 g of banana peel flour contained 6.8 g of moisture, 6.5 g protein, 2.2 g fat, 11.8 g of ash, 62.8 g of total dietary fiber (9.8 g of soluble fiber and 53 g of insoluble fiber), and 9.9 g of available carbohydrates.

The banana fruit was used to obtain dried banana, which was then used in the formulation of cereal bars. Approximately 1.8 kg of banana pulp were cut longitudinally using stainless steel knives, and the pieces were placed on perforated trays and dried in a Pasiani oven with air circulation (Turbo 240 Classic Model). After the oven was preheated for 20 min at 60 °C, the trays were left inside for 24 h.

The other ingredients used to prepare the cereal bars (rice flakes, oat flour, palm oil, maize glucose, and candied bananas) were purchased in a local market, and only one brand of each product was purchased.

One commercial cereal bar, banana flavor, was purchased in local market (Carrefour Comércio e Indústria Ltda, São José do Rio Preto, Brazil) for comparison of the sensory profile and acceptability with the developed cereal bars. The list of the ingredients of this cereal bar is: rice flakes, corn flakes, maltodextrin, salt and malt extract, glucose syrup, honey, invert sugar, dyestuff and flavoring.

2.2. Cereal bar formulations

The cereal bar formulations investigated were the result of the mixture modeling methodology used in a previous study by this same research group. In the previous study, the simplex-centroid design for ternary mixtures was used in order to evaluate the effects of the interaction between the banana peel flour, rice flakes, and oat flour on the sensory acceptability and physical characteristics of the cereal bars. The highest level of each component represented 42 $g.100g^{-1}$ of the total formulation of each cereal bar. Four formulations (two with high acceptability by the consumers, and two with low acceptability; Table 1) were chosen to have their sensory profile described, in order to identify the sensory characteristics that describe these samples and that may be responsible in the influence of sensory acceptability.

Table 1. Proportions[1] of banana peel flour, rice flakes and oat flour in the cereal bar formulations.

formulation	Proportion of each component in the cereal bar ($g.100g^{-1}$)		
	banana peel flour	rice flakes	oat flour
1	7.14	27.72	7.14
2	14	14	14
3	21	21	0
4	27.72	7.14	7.14

[1]banana peel flour + rice flakes + oat flour = 42 g.

2.3. Cereal bar processing

The binders (30 g corn syrup, 18 g candied bananas, and 5 g palm oil) were heated to a boiling temperature and mixed. Next, the dry ingredients (42 g of a mixture of banana peel flour, rice flakes and oat flour and 5 g dried banana), which had been previously mixed, were added to a mixture of the binders, and the mass was mixed using a scoop during 4 min. The resulting mass was spread in a stainless steel baking sheet that was 30 mm in height, and it was then baked in a Tedesco oven (Turbo FTT 300 G Model); the oven was preheated for 20 min at 100 °C and the dough was cooked for 20 min. The resulting product was cooled at room temperature for 15 min. While still in the pan, the product was cut into bars of 31 ± 2 mm (width) x 63 ± 3 mm (length). The cereal bars were covered with polyvinyl chloride film (PVC) and stored at room temperature until the sensory analysis was performed 24 h later.

2.4. Descriptive analysis of the cereal bars

The descriptive analysis conduction was approved by the Research Ethics Committee of the Institute of Biosciences, Literature and Exact Sciences of UNESP (Opinion Report 948.487 – Anexo 2).

Panelists were recruited from the students of Instituto Federal Goiano – Campus Morrinhos and the descriptive analysis was based on an adaptation of Stone and Sidel (1993). Thirteen panelists, out of the 40 recruited, were preselected through a basic taste recognition (minimum of 6 correct responses in a total 8 solutions; MEILLGAARD; CIVILLE; CARR, 1999); odor recognition test (minimum of 3 correct responses in total 4 odors: vanilla, “banana passa”, oat and banana dry; MEILLGAARD; CIVILLE; CAR, 1999); and difference-from-control test to hardness parameter, due to its importance to cereal bars. The difference-from-control test was applied in three repetitions, using a scale of nine points ranging from “extremely less hard than standard” to “extremely harder than standard, and the panelists were preselected considering their capacity to discriminate samples ($p_{sample} \leq 0.50$) and capacity to reproduce judgments ($p_{repetition} > 0.05$) (ASTM, 1981; DAMÁSIO; COSTELL, 1991). Most of the thirteen panelists were female (61.5%), aged between 18 and 27 years (77%), who like cereal bars very much (84.6%) and consume cereal bars weekly (50%). Was used a structured scale of nine points where the parameter used is the hardness.

The sensory attributes were generated by the thirteen panelists, using a Kelly Repertory Grid method (MOSKOWITZ, 1983). After discussions to reach a consensus, the descriptive terms that were most important for characterizing the appearance, aroma, texture and flavor of the cereal bars were selected. The sensory panel also defined the attributes and the references for each of these (Fig. 1), besides the product evaluation form.

Fig. 1. Definitions and references for descriptive terms of the cereal bars.

	Definition	References
Appearance		
Amount of rice flakes	Amount of grain of the rice flakes identified on a 10g of portion	Low: Cereal bar, banana flavor (KELLOGS) High: 100% rice flakes (HARALD)
Dark color	Characteristic color of the cereal bar	Weak: Oat flakes (TAEQ) Strong: Prune (QUERO)
Aroma		
Banana aroma	Characteristic aroma of banana	Weak: Banana sweet creamy (ÁUREA) Strong: “Banana passa”
Flavor		
Banana flavor	Characteristic flavor of banana	Low: Banana sweet creamy (ÁUREA) High: “Banana passa”
Sweet taste	Intensity of the characteristic sweet taste associated with the presence of sugars	Low: Rice flakes (HARALD) High: Soft candy (ARCOR)
Oat flavor	Intensity of oat flavor	Low: Cereal bar, banana flavor (KELLOGS) High: Oat flakes (TAEQ)
Bitter taste	Intensity of bitter taste	Low: Mixture of rice flakes and 20% of glucose syrup High: Mixture of rice flakes, 20% of glucose syrup and 0.06% of caffeine
Texture		
Hardness	Force necessary to compress the sample between the teeth	Low: Candy bar, banana flavor (GOIANÃO) High: Hard candy (ERLAN)
Chewiness	Ease of chewing and dissolve the food in the mouth to be swallowed	Low: “Suspiro”, strawberry flavor (MARANATA) High: Caramel candy (ERLAN)
Crispness	Intensity of noise heard during mastication of the product	Low: Cereal bar, banana flavor (TAEQ) High: Breakfast cereal (CORN FLAKES)
Adhesiveness	Product’s ability to adhere to the tooth while chewing	Low: Cereal bar, banana flavor (NESTLÉ) High: Caramel candy (ARCOR)

After the training stage, which took seven sessions, the panelists were selected according to their capacity to discriminate samples ($p_{sample} \leq 0.50$), capacity to reproduce judgments ($p_{repetition} > 0.05$) and consensus with the panel (ASTM, 1981; DAMÁSIO e COSTELL, 1991), and all of the thirteen panelists were selected to conduct analysis on the sensory profile of the cereal bars.

The sensory analysis was performed in individual booths, under light and temperature at 22 °C. The cereal bars were presented on plastic plates coded with three-digit random numbers and were evaluated in three repetitions by the thirteen panellists. The sample presentation was balanced with complete blocks that were randomized and monadic and an unstructured linear intensity scale of 90 mm lenght was used for each descriptor (MACFIE; BRATCHEL, 1989).

2.5. Statistical analysis

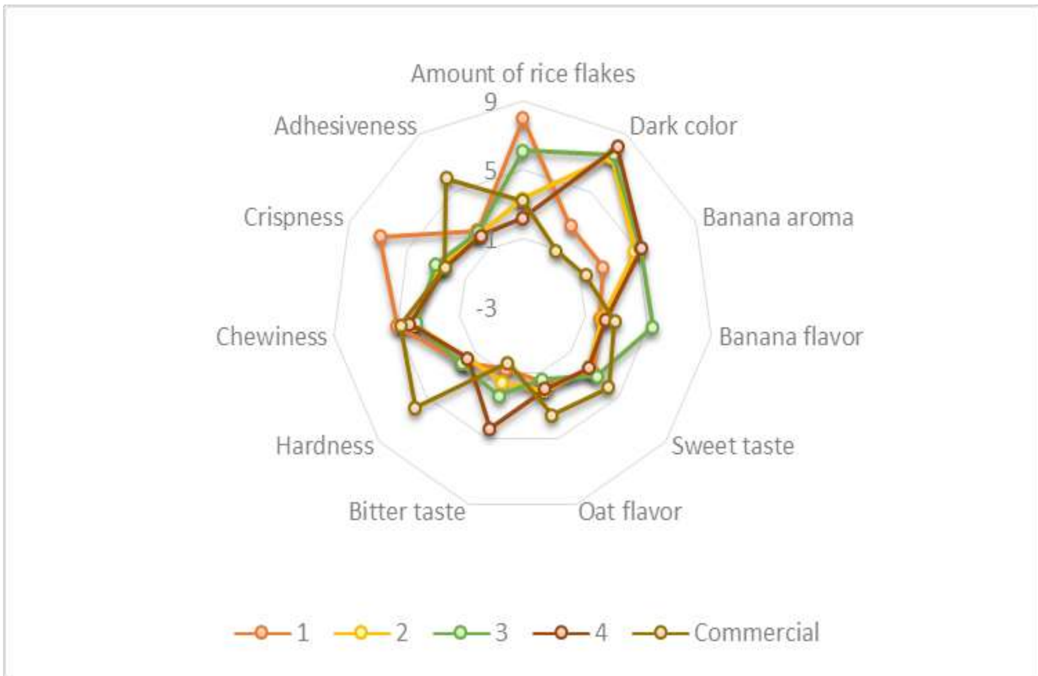
The means for the descriptive terms were compared using variance analysis followed by the Tukey test (significant difference when $p \leq 0.05$). Moreover, the principal component analysis was applied to the data of descriptive terms. In this way, the average scores of the descriptive terms were placed into the columns (variables) and the formulations were placed in the rows (cases). The data was standardized in the columns and analyzed using the correlation matrix without factor rotation. A percentage of explanation above 70% for the two first principal components indicates a strong correlation among the variables and that principal component analysis is an appropriate multivariate analysis for this data (MARDIA; KENT; BIBBY, 1979).

All statistical analyses were performed using the Statistica 10.0 software (StatSoft Inc., Oklahoma, USA).

3. Results and discussion

The formulation with lowest quantity of banana peel flour (formulation 1) stood out in amount of rice flakes, chewiness and crispness, while the formulation with highest quantity of banana peel flour (formulation 4) stood out in dark color, banana aroma and bitter taste (Fig. 2). Formulations 2 and 3, which have intermediate quantities of banana peel flour, stood out in dark color/banana aroma and dark color/banana aroma/banana flavor, respectively. On the other hand, the commercial bar stood out in sweet taste, oat flavor, hardness, chewiness and adhesiveness. The same results may be observed at Table 2.

Fig. 2. Spider-graph for sensory profile of the cereal bars.



The increase on the addition of banana peel flour increased the dark color of the cereal bars (Table 2), what may be explained by the Maillard's reaction that occurred during the production of banana peel flour, besides the enzymatic browning reaction. In the same way, slightly dark brown color was found in cereal bars prepared with sugar and sugar substitutes, although intensity of color brown decreased during storage of the cereal bars (PALLAVI et al., 2015). Moreover, cereal bars fortified with iron (NaFeEDTA and aminoquelato iron in the proportions of 45 to 60% of the recommended daily intake for adults, respectively) had the dark brown color identified as a descriptive term by panelists who participated of a descriptive quantitative analysis (SAMPAIO; FERREIRA; CANNIATTI, 2009), similar descriptive term found in this work.

The formulations 2, 3 and 4 had described as having similar intensities of banana aroma, while the formulation 1 had lower banana aroma, followed by the commercial bar (Table 2). Higher intensities of banana aroma in formulations 2, 3 and 4 may be due to the presence of banana peel flour in higher proportions in these formulations. However, the cereal bars did not show the same intensities of banana flavor as to banana aroma. The highest intensity of banana flavor was observed to formulation 3, and it was followed by formulation 2 and the commercial bar (Table 2). This may have happened because modifications on sugar composition of the cereal bars may affect the volatile compounds responsible for the aroma (HEENAN et al., 2012), and, probably, different quantities of glucose syrup were used for commercial cereal bar and the developed cereal bars.

Table 2. Intensity of the descriptive terms for the cereal bars (means ± SD, n = 39).

descriptive terms	formulations				commercial
	1	2	3	4	
amount of rice flakes	8.0±0.5^{a}	3.3±0.8^{c}	6.0±0.9^{b}	2.2±1.4^{d}	3.2±1.3^{c}
dark color	2.7±1.0^{c}	7.4±1.0^{b}	7.6±0.7^{ab}	8.1±0.5^{a}	0.9±0.6^{d}
banana aroma	2.6±0.6^{b}	4.8±0.6^{a}	5.2±0.8^{a}	5.2±0.6^{a}	1.4±0.8^{c}
banana flavor	1.9±0.8^{c}	3.1±0.6^{b}	5.2±0.6^{a}	2.3±0.6^{c}	3.0±0.4^{b}
sweet taste	2.9±0.5^{bc}	2.5±0.5^{c}	3.2±0.6^{b}	2.5±0.4^{c}	4.2±0.4^{a}
oat flavor	1.5±0.7^{bc}	2.1±0.6^{b}	1.4±0.8^{c}	2.0±1.1^{b}	3.6±0.6^{a}
bitter taste	0.8±0.7^{d}	1.6±1.0^{c}	2.4±0.7^{b}	4.4±1.0^{a}	0.4±0.2^{d}
hardness	1.9±0.4^{b}	1.6±0.4^{b}	2.1±0.6^{b}	1.6±0.3^{b}	6.0±1.0^{a}
chewiness	5.0±1.2^{a}	4.0±1.0^{b}	3.8±1,1^{b}	4.2±1.2^{b}	4,8±0.5^{a}
crispness	6.9±0.5^{a}	2.8±0.5^{c}	3.0±0.6^{bc}	2.4±0.6^{c}	2.4±0.9^{c}
adhesiveness	2.3±0.3^{b}	2.1±0.3^{b}	2.1±0.7^{b}	1.9±0.4^{b}	5.9±0.7^{a}

Different letters in the same line indicate different means ($p \leq 0.05$).

The commercial cereal bar had higher intensity of sweet taste than the other formulations, but all the formulations did not show the same intensity of sweet taste (Table 2), which implies that other ingredients (banana peel flour, rice flakes and oat flour) may have contributed to sweet taste. Some works show that “intensity of sweet taste” is not an obvious effect from the ingredients used in formulations: no difference on sweetness of cereal bars developed with sugar and sugar substitutes was found (Pallavi et al., 2015), in contrary of results found by Sampaio, Ferreira and Canniatti (2009), who observed differences on the sweet taste in cereal bars developed with addition of different quantities of NaFeEDTA and aminoquelato iron.

Intensities of oat flavor were higher for commercial cereal bar, but very similar among developed cereal bars (Table 2). Moreover, the average scores for oat flavor of the cereal bars was very lower than those found for “cereal flavor” of cereal bars fortified with iron (average scores ranging from 6.2 to 7 in an unstructured linear intensity scale of 100 mm length; SAMPAIO; FERREIRA; CANNIATTI, 2009).

Bitter taste was higher for developed cereal bars in relation to commercial cereal bar (Table 2). Moreover, it can be observed that formulations with high amounts of banana peel flour had higher intensities of bitter taste, descriptor that may be related to addition of banana peel flour. However, no relevant studies were found in literature for comparison with our results.

The hardness, chewiness and adhesiveness were higher for commercial cereal bar, while were similar for all cereal bars with banana peel flour, excepting chewiness of formulation 1 (Table 2). This was not expected, because addition of fibers ingredients influence texture of foods in general, enhancing hardness, chewiness and adhesiveness (DUTCOSKY, et al. 2006; VOLPINI-RAPINA; SOKEI; CONTI-SILVA, 2012). However, differences on the ingredient compositions between the commercial cereal bar and those with banana peel flour may also explain differences on texture. Higher chewiness was found to cereal bars prepared with sugar substitutes, descriptive term that had an important influence on the overall quality, i.e., lower overall quality scores were due to reduced chewiness (PALLAVI et al., 2015). Moreover, similar to this work, cereal bars developed with micronized flakes lentils had the adhesiveness values increased in relation to the product without micronized flakes (RYLAND et al., 2010).

The cereal bar 1 was characterized by amount of rice flakes and crispness, which was expected since this formulation was added of greatest amount of rice flakes. The rice flakes are obtained through extrusion process, process that causes changes on the molecular structure of the rice and on water absorption index and water solubility index (HAGENIMANA; DING; FANG, 2006), enhancing the sense of crispness in the product. Dutckosky et al. (2006) found greater crispiness in cereal bars with higher amount of oligofructose, and this descriptive term decreased with the addition of gum acacia.

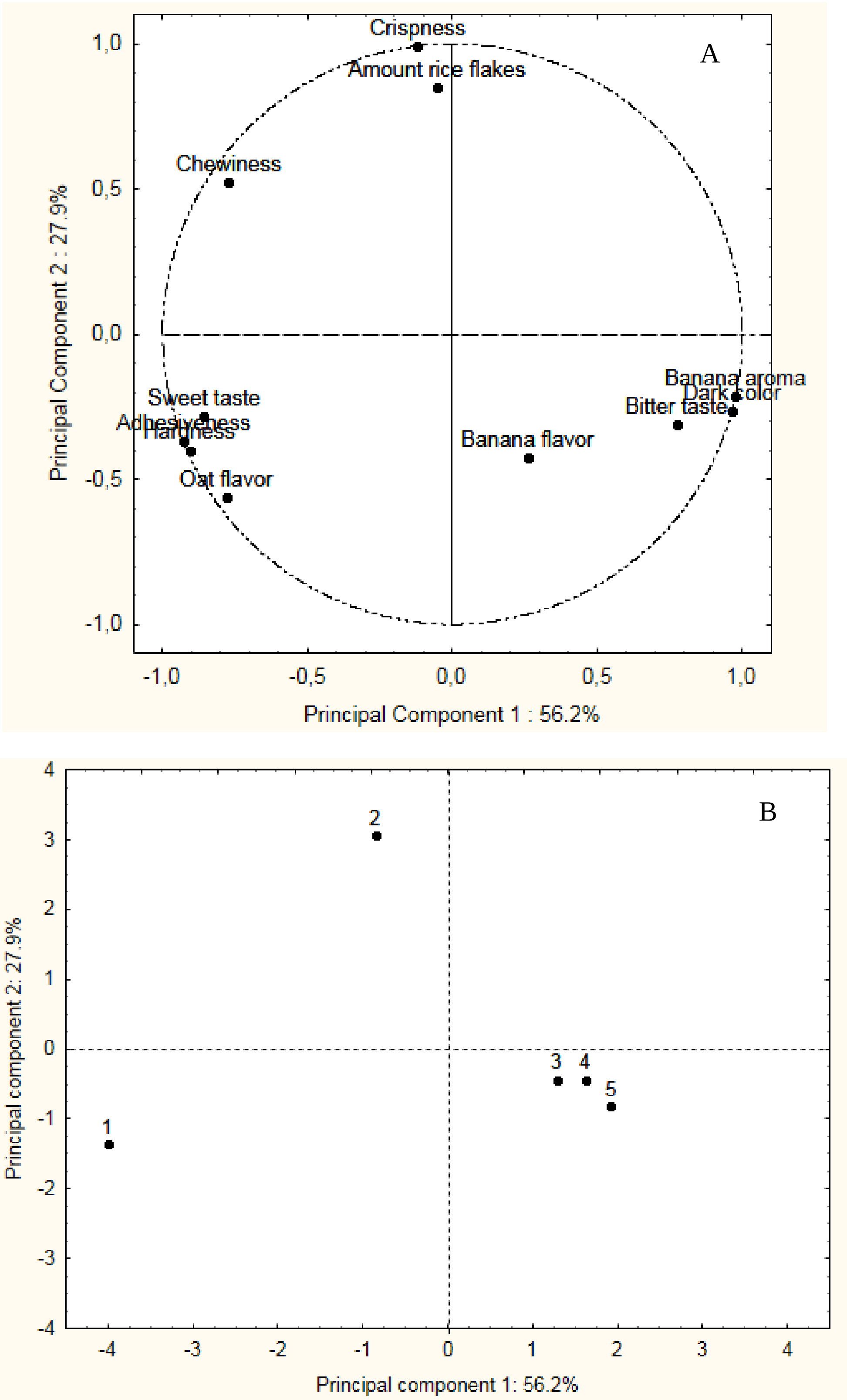
Principal component analysis showed that first and second principal components explained, respectively, 56.2 and 27.9% of the data variation (84.1% in total) (Fig. 3).

The first principal component is explained by “bitter taste, dark color and banana aroma” (factorial charges ≥ 0.7 in the principal component 1) and “oat flavor, hardness, adhesiveness, sweet taste and chewiness (factorial charges ≤ -0.7 in the principal component 1) (Fig. 3A). The hardness was correlated positively with intensities of oat flavor, adhesiveness, sweet taste and chewiness, but were correlated negatively with bitter taste, dark color and banana aroma. In this way, the cereal bars 2, 3 and 4, that have intermediate and highest quantities of banana peel flour (Table 1), were described by high intensities of bitter taste, dark color and banana aroma (Fig. 3B). Still in relation to these samples, they showed low intensities of oat flavor, hardness, adhesiveness, sweet taste and chewiness. In the same way, the commercial cereal bar was described by high intensities of oat flavor, hardness, adhesiveness and sweet taste, but low intensities of bitter taste, dark color and banana aroma. Similar results were found to cereal bars added of micronized flakes lentils, which had highest sour taste and fruit flavor, in contrast to a commercial bar, which was characterized by high degree of hardness (RYLAND et al., 2010).

The second component principal is explained by “amount of rice flakes and crispness” (factorial charges ≥ 0.7 in the principal component 2) (Fig. 3A), terms that described formulation 1 (Fig. 3B) that have higher proportion of rice flakes (Table 1).

The banana flavor did not contribute to any principal component, and, therefore, did not describe any cereal bar.

Fig. 3. External preference mapping to descriptive terms (A – projection of the variables; B – projection of the samples).



Considering the total dietary fiber found in the banana peel flour (62.8 g; item 2.1), we may estimate that 100 g of cereal bars, containing 7.14 and 14 g of banana peel flour, presents 4.48 and 8.79 g of total dietary fiber, respectively. According to Brazilian legislations, a food can be considered as “good source of dietary fiber” if contains 2.5 g of fiber per serving size (BRASIL, 2012) and a serving size for cereal bar is 30 g (BRASIL, 2003). Consequently, the cereal bar containing 14 g of banana peel flour can be considered “good source of dietary fiber”.

4. Conclusion

The addition of different proportions of banana peel flour, rice flakes and oat flour changes the intensities of descriptive terms of the cereal bars, besides resulting in different sensory profiles in relation to a commercial cereal bar. Cereal bars with intermediate and highest amounts of banana peel flour were characterized by banana aroma, dark color and bitter taste, while the cereal bar with lowest quantity of banana peel flour was described by amount of rice flakes and crispness, because it was also produced with higher proportion of rice flakes. On the other hand, the commercial cereal bar stood out in hardness, adhesiveness, sweet taste and oat flavor. Therefore, we can conclude, based on sensory studies, that the addition of the banana peel flour is feasible in the development of new sustainable food products.

Acknowldegements

The authors are grateful for the financial support from FAPESP (Fundação de Amparo à Pesquisa do Estado de São Paulo) (grant 2012/08852-3) and CAPES for the scholarship granted.

References

ASTM (American Society for Testing and Material). **Guidelines for the selection and training of sensory panel members.** ASTM Sp. Tech. Publ. nº 758, 1981.

AURORE, G.; PARFAIT, B.; FAHRASMANE, L. Bananas, raw materials for making processed food products. **Trends in Food Science & Technology**, Cambridge, v. 20, p. 78–91, 2009.

BRASIL. Ministério da Saúde. Agência Nacional de Vigilância Sanitária. Dispõe sobre o regulamento técnico de porções de alimentos embalados para fins de rotulagem nutricional devendo os valores atender a Resolução- RDC nº 359, de 23 de dezembro de 2003. Diário Oficial da República Federativa do Brasil; Brasília, 23 dez. 2003.

BRASIL. Ministério da Saúde. Agência Nacional de Vigilância Sanitária. Dispõe sobre alimentos com alegações de propriedades funcionais devendo os valores atender a Resolução- RDC nº 54, de 12 de novembro de 2012 quanto à informação nutricional complementar. Diário Oficial da República Federativa do Brasil; Brasília, 12 nov. 2012.]

DAMÁSIO, M. H.; COSTELL, E. Análisis sensorial descriptive: generación de descriptors y selección de catadores. **Revista de Agroquímica y Tecnología de Alimentos**, v. 31, p. 165-178, 1991.

DUTCOSKY, S.D. et al. Combined sensory optimization of a prebiotic cereal product using multicomponent mixture experiments. **Food Chemistry**, London, v. 98, n. 4, p. 630-638, 2006.

EMAGA, T. H.; ANDRIANAIO, R. H.; WATHELET, B.; TCHANGO, J. T.; PAQUOT, M. Effects of the stage of maturation and varieties on the chemical composition of banana and plantain peels. **Food Chemistry**, London, v. 103, p. 590-600, 2007.

EMAGA, T. H.; RONKART, S. N.; ROBERT, C.; WATHELET, B.; PAQUOT, M. Characterization of pectins extracted from banana peels (Musa AAA) under different conditions using an experimental design. **Food Chemistry**, London, v. 108, p. 463–471, 2008.

FAOSTAT. (2014). <http://faostat3.fao.org/faostat-gateway/go/to/download/Q/QI/E> FAOSTAT. Dezember 28, 2014.

FREITAS, D. G. C.; MORETTI, R. H. Caracterização e avaliação sensorial de barra de cereais. **Ciência e Tecnologia de Alimentos**, Campinas, v. 26, n. 2, p. 318-324, 2006.

GONZALEZ-MONTELONGO, R.; LOBO, G. M.; GONZALEZ, M. Antioxidant activity in banana peel extracts: testing extraction conditions and related bioactive compounds. **Food Chemistry***,* London, v. 119, p. 1030-1039, 2010.

HANGENIMANA, A.; DING, X.; FANG, T. Evaluation of rice flour modified by extrusion cooking. **Journal of Cereal Science**, London, v. 43, p. 38-46, 2006.

HEENAN, S.; SOUKOULIS, C.; SILCOCK, P.; FABRIS, A.; APREA, E.; CAPPELLIN, L.; MÄRK, T. D.; GASPERI, F.; BIASIOLI, F. PTR-TOF-MS monitoring of in vitro and in vivo flavor release in cereal bars with varying sugar composition. **Food Chemistry***,* London, v. 131, p. 477-484, 2012.

IBGE - Instituto Brasileiro de Geografia e Estatística. Produção Agrícola Municipal, 2012. Disponível em: <http://www.ibge.gov.br/home/estatistica/pesquisas/pesquisa_resultados.php?id_pesquisa=44N> Acessado em: 03 Junho, 2014.

JACOMETTI, G. A., MELLO, L. P. R. F., NASCIMENTO, P. H. A., SUEIRO, A. C., YAMASHITA, F., MALI, S. The physicochemical properties of fibrous residues from the agro industry. **LWT- Food Science and Technology**, Georgia, v. 62, p. 138-143, 2015.

JOHNSON, R. A.; WICHERN, D. W. **Applied multivariate statistical analysis** (3rd ed.) Engelwood Cliffs: Prentice Hall, 1992.

KRUSKAL, J. B.; WISH, M. **Multidimensional scaling**. Newbury Park: Sage., 1972.

MACFIE, H. J.; BRATCHELL, N. Designs to balance the effect of order of presentation and first-order carry-over effects in hall tests. **Journal of Sensory Studies**, Manhattan, v. 4, 1p. 29-148, 1989.

MARDIA, K. V.; KENT, J. T.; BIBBY, J. M. ***Multivariate analysis***. London: Academic Press, 1979.

MEILGAARD, M.; CIVILLE, G. V.; CARR, B. T. **Sensory evaluation techniques**. (3rd ed.). Boca Raton: CRC Press, 1999.

MOSKOWITZ, H. R. **Product testing and sensory evalution of foods**. Westport: Food & Nutrition Press, 1983.

PALLAVI, B. V.; CHETAVAN, R.; RAVI, R.; REDDY, S. Y. Moisture sorption curves of fruit and nut cereal bar prepared with sugar and sugar substitutes. **Journal of Food Science and Technology**, Oxford, v. 52, n. 3, p. 1663-1669, 2015.

QIU, L.; ZHAO, G.; WU, H.; JIANG, L.; LI, X.; LIU, J. Investigation of combined effects of independent variables on extraction of pectin from banana peel using response surface methodology. **Carbohydrate Polymers**, Virginia, v. 80, p. 326–331, 2010.

RYLAND, D.; VAISEY-GENSER, M.; ARNTFIELD, S. D.; MALCOLMSON. L. J. Development a nutritious acceptable snack bar using micronized flakes lentils. **Food Research International,** Barking, v. 43, n. 2, p. 642-649, 2010.

SAMPAIO, C. R. P.; FERREIRA, S. M. R.; CANNIATTI-BRAZACA, S. G. Perfil sensorial e aceitabilidade de barras de cereais fortificadas com ferro. **Alimentos e Nutrição**, Araraquara, v. 20, n. 1, p. 95-106, 2009.

STONE, H.; SIDEL, J. L. **Sensory evaluation practices**. (2nd ed.). San Diego: Academic Press, 1993.

VOLPINI-RAPINA, L. F.; SOKEI, F. R.; CONTI-SILVA, A. C. Sensory profile and preference mapping of orange cakes with addition of prebiotics inulin and oligofructose. **LWT - Food Science and Technology**, Georgia, v. 48, p. 37-42, 2012.

CAPÍTULO 4

Longitudinal study of storage of cereal bars formulated with banana peel flour: bioactive compounds and texture properties

Abstract

The storage of cereal bars formulated with banana peel flour was investigated to evaluate the bars' bioactive compounds and texture properties. The cereal bars were produced and stored during eleven months, under vacuum and protected from the light. In general, total phenolic compounds decreased during storage; although the total antioxidant activity (ABTS method) increased during the fifth month, it reduced during storage; and the total antioxidant activity (DPPH· method, EC_{50}) was not modified in many formulations, though it decreased in other formulations during storage period. The force of rupture began to increase in the fourth month, and hardness began to increase in the ninth month. A principal component analysis showed that time had little effect on the most important characteristics considered in description of the cereal bars. Finally, the presence of bioactive compounds in cereal bars depends on the addition of banana peel flour, which it contributes to the insertion of total phenolic compounds and total antioxidant activity in cereal bars, aggregating functional properties in these products.

Keywords: total phenolic compounds, DPPH·, ABTS, force of rupture, texture profile analysis.

1. Introduction

Because of the growing consumer demand for healthy, natural and convenient foods, attemps are being made to improve snack foods nutritional values by modifying their nutritive composition (BHASKARAN; HARDLEY, 2002; GRAY; ARMSTRONG; FARLEY, 2003). Cereal bars are a popular and convenient food and, therefore, would be an ideal food format to deliver fruit-derived phenolic antioxidants (SUN-WATERHOUSE et al., 2010).

Phenolics compounds, e.g., flavonoids and phenolics acids, belong to an important class of secondary metabolites and own recognized antioxidant activity (AMORIM et al., 2011). Antioxidant compounds neutralise free radicals and inhibit the initiation chain or interrupt the chain of propagation of oxidative reactions, converting free radicals into less harmful molecules and repairing the oxidative damage in human cells (BORGES et al., 2014). This class of compounds is also relevant to insertion in the elaboration of cereal bars.

The banana is one of the most extensively consumed fruits in the world and represents approximately 40% of the world fruit trade. World banana production was 102 Mt in 2012, and Brazil was the fifth most important banana-producing country with a total production of 6.9 Mt (FAO, 2014). The banana peel represents 30%-40% of the total weight of the fruit. It is rich in minerals (EMAGA et al., 2008), and its quantity of total dietary fiber reaches 43.2% to 49.7% (MOHAPATRA; MISHRA; SUTAR, 2010). In addition, Gonzalez-Montelogo, Gloria Lobo, & Gonzalez (2010) reported that banana peels contain large amounts of dopamine and l-dopamine, catecholamines that exhibit antioxidant activity. Moreover, the banana peel has from 3.1 to 380 mg GAE.g^{-1}, depending on the variety and ripeness, as well as on the type of phenolic compound extraction used (GONZÁLEZ-MONTELONGO; LOBO; GONZÁLEZ, 2010; REBELLO et al., 2014). Therefore, the use of banana peels in food products is beneficial because of the peel’s nutritive value, and their use is a way to reduce the residue generated through traditional banana consumption.

Many processed foods are multicomponent heterogeneous systems that are far from thermodynamic equilibrium (MEZZENGA, 2007), and there is often a considerable time between its manufacture and consumption, during which a product is transported and stored. During this storage time, multiple chemical, physical and biological reactions occur serially and simultaneously, and some of these reactions can cause negative effects on the nutritional quality of foods (LOVEDAY et al., 2009).

Likewise, the texture of cereal bars is affected along the shelf life (IMTIAZ; KUHN-SHERLOCK; CAMPBELL, 2012), which can cause losses for manufacturers of cereal bars. Ozilgen (2011) studied the behavior of cereal bars added of dried fruits, because the hardening of these ingredients caused complaints by consumers during storage, and at the same time that some dried fruits maintained the optimum quality of texture of the cereal bars, others dried fruit became harder during storage.

Since time can affect physical and chemical characteristics of foods, we aimed to study the shelf life of cereal bars formulated with banana peel flour regarding to bioactive compounds and texture properties.

2. Material and Methods

2.1. Material

Samples of the Cavendish variety of banana (*Musa acuminate L., cv cavendshii*), provided directly by the producer of São José do Rio Preto, SP, Brazil, were matured in an ethylene chamber while still at the production site. The bananas were then stored at the Laboratory of Sensory Analysis of the Food Engineering and Technology Department of the Institute of Biosciences, Literature and Exact Sciences of UNESP – Univ Estadual Paulista. The samples were stored in a cool, dry place until they reached the advanced stage of ripeness (when the peels had yellow and brown spots), it is at this stage of maturity that most bananas are processed. The fruits were washed in running water and then the peel was separated from the pulp.

Approximately 2.2 kg of banana peels were arranged in trays provided with small perforations to facilitate the passage of hot air. Then the trays were placed in a Pasiani oven with air circulation (Classic Model Turbo 240).The oven was preheated (20 min) at 60 °C in according Gonzaléz-Montelongo, Lobo and González (2010) and, the trays were then left inside overnight. The dried peels were crushed in a food process until the banana peel flour was obtained, and the flour was then stored in polypropylene plastic bags at room temperature and in the dark. After drying, 100 g of banana peel flour contained 6.8 g of moisture, 6.5 g protein, 2.2 g fat, 11.8 g of ash, 62.8 g of total dietary fiber (9.8 g of soluble fiber and 53 g of insoluble fibers) and 9.9 g of available carbohydrate (analyses performed at laboratory).

The banana pulp was used to obtain dried banana, which was used then in the formulation of cereal bars. Approximately 1.8 kg of banana pulp were cut longitudinally using stainless steel knives, and the pieces were placed on perforated trays and dried in a Pasiani oven with air circulation (Classic Model Turbo 240). After the oven was preheated (20 min) at 60 °C, the trays were left inside for 24 h.

The other ingredients used to prepare the cereal bars (rice flakes, oat flour, palm oil, maize glucose, and candied bananas) were purchased in a local market and only one brand of each product was purchased.

2.2. Cereal bar formulations and processing

Seven cereal bar formulations were investigated, resulting of the mixture modeling methodology used in a previous study by our research group (Table 1). In the previous study, the simplex-centroid design for ternary mixtures was used in order to evaluate the effects of the interaction between the banana peel flour, rice flakes, and oat flour on the sensory acceptability and physical characteristics of the cereal bars.

The binders (30 g corn syrup, 18 g candied bananas, and 5 g palm oil) were heated to a boiling temperature and mixed. Next, the dry ingredients (42 g of a mixture of banana peel flour, rice flakes and oat flour and 5 g dried banana), which had been previously mixed, were added to a mixture of the binders, and the mass was mixed using a scoop during 4 min. The resulting mass was spread in a stainless steel baking sheet that was 30 mm in height, and it was then baked in a Pasiani oven (Turbo 240 Classic Model); the oven was preheated for 20 min at 100 °C and the dough was cooked for 20 min. The resulting product was cooled at room temperature for 15 min. The product, still in the pan, was cut into bars of 31 ± 2 mm (width) x 63 ± 3 mm (length).

Table 1. Proportions[1] of banana peel flour, rice flakes and oat flour in the cereal bar formulations.

formulation	proportion of each component in the cereal bar (g/100 g)		
	banana peel flour	rice flakes	oat flour
1	42	0	0
2	21	21	0
3	21	0	21
4	14	14	14
5	27.72	7.14	7.14
6	7.14	27.72	7.14
7	7.14	7.14	27.72

[1]banana peel flour + rice flakes + oat flour = 42 g.

2.3. Longitudinal study of effects of cereal bars storage

The processed cereal bars were stored for eleven months and were evaluated monthly in order to examine their bioactive compounds and texture properties.

At zero time, three of the thirty-six cereal bars of each formulation that had been produced were evaluated. Three cereal bars of each formulation were then vacuum-packed into low-density polyethylene bags (LDPE), that were 195 mm (width) x 350 mm (length) x 10 µm (thick). A total of eleven bags of each formulation were packaged (one bag per month). The bags were kept in the dark at room temperature for eleven months; each month, one bag was randomly collected for analysis.

At zero time and after each bag was opened, the rupture force of the three types of cereal bars were evaluated (item 2.6); next, ten pieces of the cereal bars were cut for the texture profile analysis (item 2.6); and finally, the remaining pieces were used in the bioactive compound analysis (item 2.5.). Lights were maintained turned off during the bioactive compound analysis.

2.4. Analysis of bioactive compounds of cereal bars

2.4.1. Antioxidant extraction

The procedure employed was as follows: the extract of three fresh samples of each formulation from the pre-testing stage was obtained with 40 mL of methanol/water (50:50, v/v) in a magnetic stirrer at room temperature for 1 h. The samples were centrifuged at 25,400g (BR4i multifunction, Chanteau-Gontier, France) for 15 min, and the supernatant was recovered. Next, 40 mL of acetone/water (70:30, v/v) were added to the residue at room temperature, extracted for 1 h in a magnetic stirrer and centrifuged. The methanol and acetone extracts were combined, made to reach 100 mL using distilled water, and were then used to determine the quantity of total phenolic compounds and the antioxidant activity (RUFINO et al., 2010).

2.4.2. Estimation of total phenolic compounds

The quantity of total phenolic compounds of each extract was determined using the colorimetric method with the Folin-Ciocalteu reagent (WATERHOUSE, 2002) and results were expressed as mg of gallic acid equivalents per g of fresh weight (mg GAE. g^{-1}f.w.).

2.4.3. Total antioxidant activity measured using TEAC (Trolox Equivalent Antioxidant Capacity)

The ABTS [2,2′-Azino-bis(3-ethylbenzothiazoline-6-sulfonic acid)] radical was generated by the reaction of 5 mL of aqueous ABTS 7mM with 0.88μL of potassium persulphate (140 mM). The mixture was kept in the dark for 16 h and then diluted with ethanol until a solution with absorbance of 0.7 ± 0.05 at 734 nm was obtained (RUFINO et al., 2010). The ethanolic solutions of known Trolox concentrations were used for calibration, and the results were expressed as μmol of Trolox equivalent per g of fresh weight (μmol TE.g^{-1}f.w.).

2.4.4. Total antioxidant capacity measured using free radical scavenging via DPPH$^{\bullet}$

Free radical scavenging activity was measured in triplicate using the method described by Rufino et al. (2010), with modifications. A 0.06-mM solution of 2,2-di (4-

tert-octylphenil)-1-picrylhidrazyl ($DPPH^{\cdot}$) in methanol was prepared, and an aliquot of 100 µL of the antioxidant or the cereal bar extract solution was added to 3.9 mL of the $DPPH^{\cdot}$ solution. The antioxidant capacity was expressed as the concentration of the antioxidant present in the sample required to reduce the original amount of free radicals by 50% (EC_{50}), and the values were expressed as g of fruit per g of $DPPH^{\cdot}$ (g fruit.g^{-1} $DPPH^{\cdot}$).

2.5. Analysis of texture properties of cereal bars

Two analyses were employed to measure cereal bar texture, using the TA.XT Plus Texture Analyser (Stable Micro Systems, Godalming, England):

1) Force of rupture: a three-point bending probe was used with a distance of 3.8 cm between the axles and a test speed of 1.0 mm.s^{-1}. For this test, three cereal bars were cut completely, and the maximum force (in newtons) was considered as the force of rupture (KIM et al., 2009);

2) Texture Profile Analysis (TPA): ten cereal bar samples, cut into of 20-x-20-mm pieces with the aid of a stainless steel knife, were used in the test. A cylindrical aluminum probe that was 25 mm in diameter and which operated at a speed of 1.0 mm.s^{-1} was used; a time of 5 s was established between the two compressions; and the sample was compressed to 50% of its original height. The hardness, cohesiveness, springiness, adhesiveness, and chewiness parameters were obtained (SZCZESNIAK, 2002).

2.6. Statistical analyses

Analysis of variance at a significance level of 0.05 was applied with the factors “formulation” and “time” in order to investigate the influences of these factors on bioactive compounds and texture properties during the entire storage period of the cereal bars. Pearson’s correlation was also applied to discuss some results (significance level of 0.05).

Principal component analysis (PCA) was applied in order to identify correlations between the bioactive compounds and the physical properties of the cereal bars at both the beginning and the end of this storage study. Average quantities of bioactive compounds and of physical properties were placed in columns (variables), and the different formulations of the cereal bars were placed in rows (cases). The data was standardized before analysis. The PCA analysis was performed with a correlation matrix and without factor rotation.

All statistical analyses were performed using Statistica 10.0 software (StatSoft Inc., Oklahoma, USA).

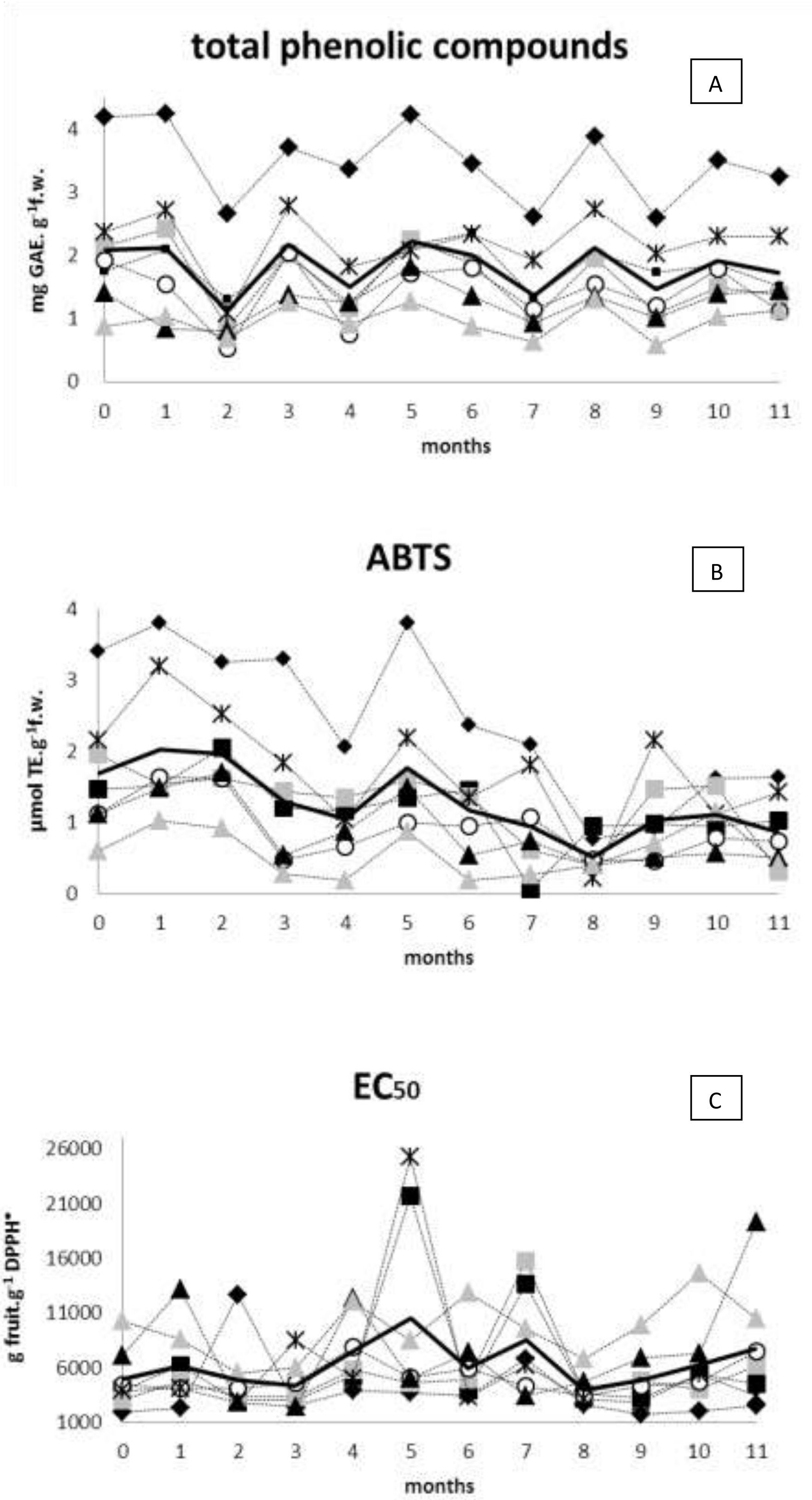
3. Results and Discussion

3.1. Bioactive compounds of cereal bars

The quantity of total phenolic compounds ranged from 4.19 to 0.87 mg GAE.g^{-1}f.w. in formulations 1 and 7, respectively, and at time zero (Fig. 1A). Sun-Waterhouse et al. (2010) found values ranging from 2.87 to 0.60 mg CtE.g^{-1} in cereal bars with inulin, phenolic extracts, and dietary fiber from apples, and similar values were also found in some raw fruits (RUFINO et al., 2010; IGNAT; VOLF; POPA, 2011; SOUZA et al., 2012). There was variation in the quantity of total phenolic compounds in all formulations during storage (Fig. 1A). In general, the variation profile of all of the formulations over the eleven-month period was similar to the average profile of the formulations as a group (bold line in Fig. 1A). Moreover, the “formulation” and “time” factors influenced the variation of total phenolic compounds in the cereal bars (both p-values were less than 0.001).

The total antioxidant activity was measured using the ABTS method. It ranged from 3.41 to 0.60 μmol TE.g^{-1}f.w. in formulations 1 and 7, respectively, at time zero (Fig. 1B). Yu et al. (2002) also found similar values: 2.32 to 3.22 μmol TE.g^{-1}f.w. in four samples of commercial cereal bars. During storage, a slight decrease in total antioxidant activity was observed until the fourth month; however, an increase in total antioxidant activity was observed in all of the formulations during the fifth month, with another subsequent reduction (Fig. 1B). This tendency was observed in almost all of the formulations, and also in the average profile of the formulations as a group (bold line in Fig. 1B). An increase in total antioxidant activity is usually considered to be a product of the Maillard reaction (KLIMCZAK et al., 2007), which may have occurred when the cereal bars were heated. The “formulation” and “time” factors influenced the variation in total antioxidant activity in the cereal bars (both p-values were less than 0.001).

Fig. 1. Total phenolic compounds (A), antioxidant activity by ABTS method (B) and antioxidant activity by DPPH method expressed in EC_{50} (C) of the cereal bars during storage study.



EC_{50} ranged from 1,858.68 to 10,244.05 g fruit.g^{-1} DPPH$^{\cdot}$ at time zero in formulations 1 and 7, respectively (Fig. 1C), and EC_{50} varied in all formulations during the storage period; however, this variation was influenced only by the "formulation" factor (p-value less than 0.001). The variation profile of the formulations over the eleven-month period differed from the average profile of the formulations as a group (bold line in Fig. 1C). EC_{50} value is defined as the concentration of antioxidant that causes a 50% decrease in DPPH· absorbance (CHEN; BERTI; FROLDI, 2013); thus, the higher the value, the lower the antioxidant activity.

Although formulations 2 and 3 contained the same quantity of banana peel flour (21 g/100 g), as did formulations 6 and 7 (7.14 g/ 100 g) (Table 1), the quantity of total phenolic compounds and total antioxidant activity differed between these samples in almost every month of storage (Fig. 1). This difference indicates that the other ingredients (rice flakes and oat flour) may have some effect on bioactive coumpounds, since they also exhibit antioxidant activity (KILCI; GOCMEN, 2014; WANYO; MEESO; SIRIAMORNPUN, 2014).

When measured using ABTS, formulation 1 (which included a higher quantity of banana peel flour) was found to have a higher quantity of total phenolic compounds, and formulations 6 and 7 (which included lower quantities of banana flour) had less total antioxidant activity. Additionally, formulation 1 had lower EC_{50} values, while formulations 6 and 7 had higher EC_{50} values (Fig. 1). Over the entire course of the storage period, the correlation coefficients between the quantities of banana peel flour and total phenolic compounds in the cereal bars ranged from 0.88 to 0.99 ($p \leq 0.05$). They ranged from 0.84 to 0.98 ($p \leq 0.05$) between the quantity of banana peel flour and the total antioxidant activity measured using the ABTS method (except for months 7 to 10, in which correlations were weak), and they ranged from -0.78 to -0.88 ($p \leq 0.05$) between the quantity of banana peel flour and EC_{50} values in some months (with weak correlations in other months). This finding indicates that the presence of bioactive compounds in cereal bars depended on the addition of banana peel flour, which contributes to total phenolic compounds and total antioxidant activity in cereal bars and which enhances the functional properties of the products.

A strong positive correlation was found between ABTS values and the quantity of total phenolic compounds from the beginning of the storage period ($r = 0.971$; $p \leq 0.05$) to the end of the storage period ($r = 0.874$; $p \leq 0.05$). This correlation occurs because phenolic compounds are the main precursors of total antioxidant activity (THAIPONG et al., 2006; FLOEGEL et al., 2011). There was a strong negative correlation between EC_{50} and the quantity of total phenolic compounds and between ABTS values and the quantity of total phenolic compounds at time zero (r = 0.806 and r = 0.802, respectively, p ≤ 0.05). Floegel et al. (2011) also found a strong correlation between the DPPH$^{\cdot}$ and ABTS methods in several fruits, but the correlation was positive since the authors expressed both antioxidant activities as mg of vitamin C. The correlation between the DPPH$^{\cdot}$ and ABTS methods decreased as the study progressed. This decrease likely occured as a result of interactions between free radicals and other components present in the cereal bars (SUN-WATERHOUSE et al., 2010).

3.2. Texture properties of cereal bars

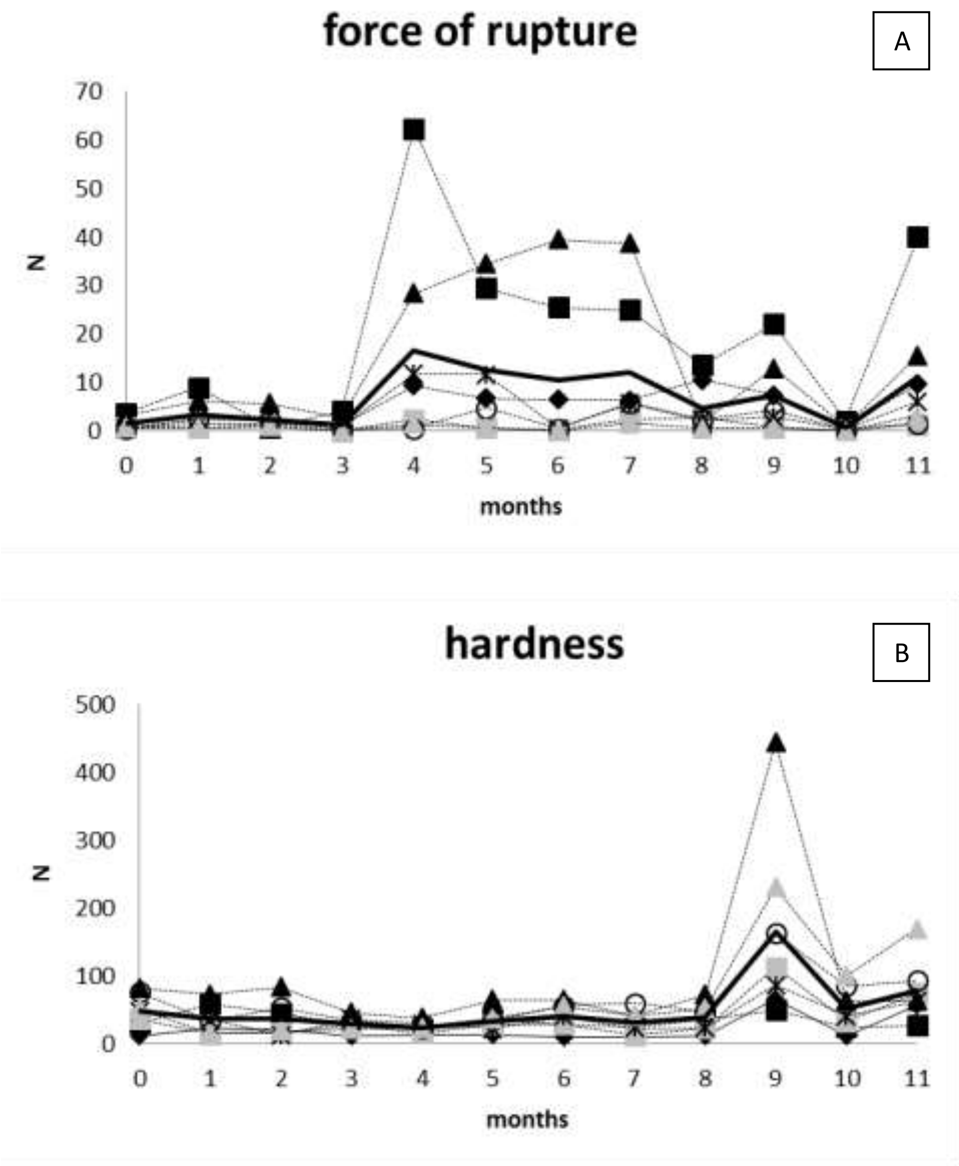
At beginning of the storage period, the average texture properties of the cereal bars ranged from 0.45 to 3.70 N for force of rupture, from 12.2 to 81.7 N for hardness, from 0.10 to 0.24 for cohesiveness, from 0.31 to 0.75 for springiness, from 1.85 to 6.50 N.s for adhesiveness, and from 1.01 to 10.16 N for chewiness. The "formulation" and "time" factors influenced only hardness, springiness, and the force of rupture (p-values less than 0.001).

The force of rupture began to increase in all of the samples in the fourth month (Fig. 2A), particularly formulations 2 and 6, which had higher proportions of rice flakes in the composition (Table 1). A higher force of rupture of cereal bars with rice flakes was not expected, because the rice flakes are voluminous, which makes compacting the cereal bars more difficult and which therefore is likely to reduce the force of rupture. Despite the increase in force of rupture values starting in the fourth month, the values in the tenth month were similar to those at zero time. Moreover, over the course of the eleven-month period, the variation profile of almost all of the formulations was similar to the average profile of the formulations as a group (bold line in Fig. 2A). It is important to note, however, that the opposite result occured in formulations 2 and 6 from the fourth month to the seventh month.

The hardness of the cereal bars changed less over time than the force of rupture values, though its increase was more apparent in the ninth month, especially in formulations 3, 4, 6 and 7 (Fig. 2B). These formulations had higher amounts of oat flour (Table 1), and the high capacity of oat to absorve water (SHARMA et al., 2014) may have led to the increased hardness of the cereal bars. The hardness of all formulations changed similarly over the elevent-month period, as did the average profile of all formulations.

Chemical and physical interactions among the ingredients in cereal bars can occur over time and begin to affect the taste and texture of the product. The shelf life of a cereal bar is substantially determined by its texture. Moreover, the time from manufacturing to consumption of the snack bars may be influencied by the lack of a thermodynamic equilibrium, which is common in heterogeneous multicomponent systems in processed foods (MEZZENGA, 2007; LOVEDAY et al., 2009; SUN-WATERHOUSE et al., 2010). Figure 2 helps to establish a cut-off point at the eighth month in terms of the texture properties, since, until this point, the hardness of the cereal bars is still similar to the beginning of the storage period, and the force the rupture is not significantly different from the initial values of some formulations.

Fig. 2. Texture properties of the cereal bars during storage study.



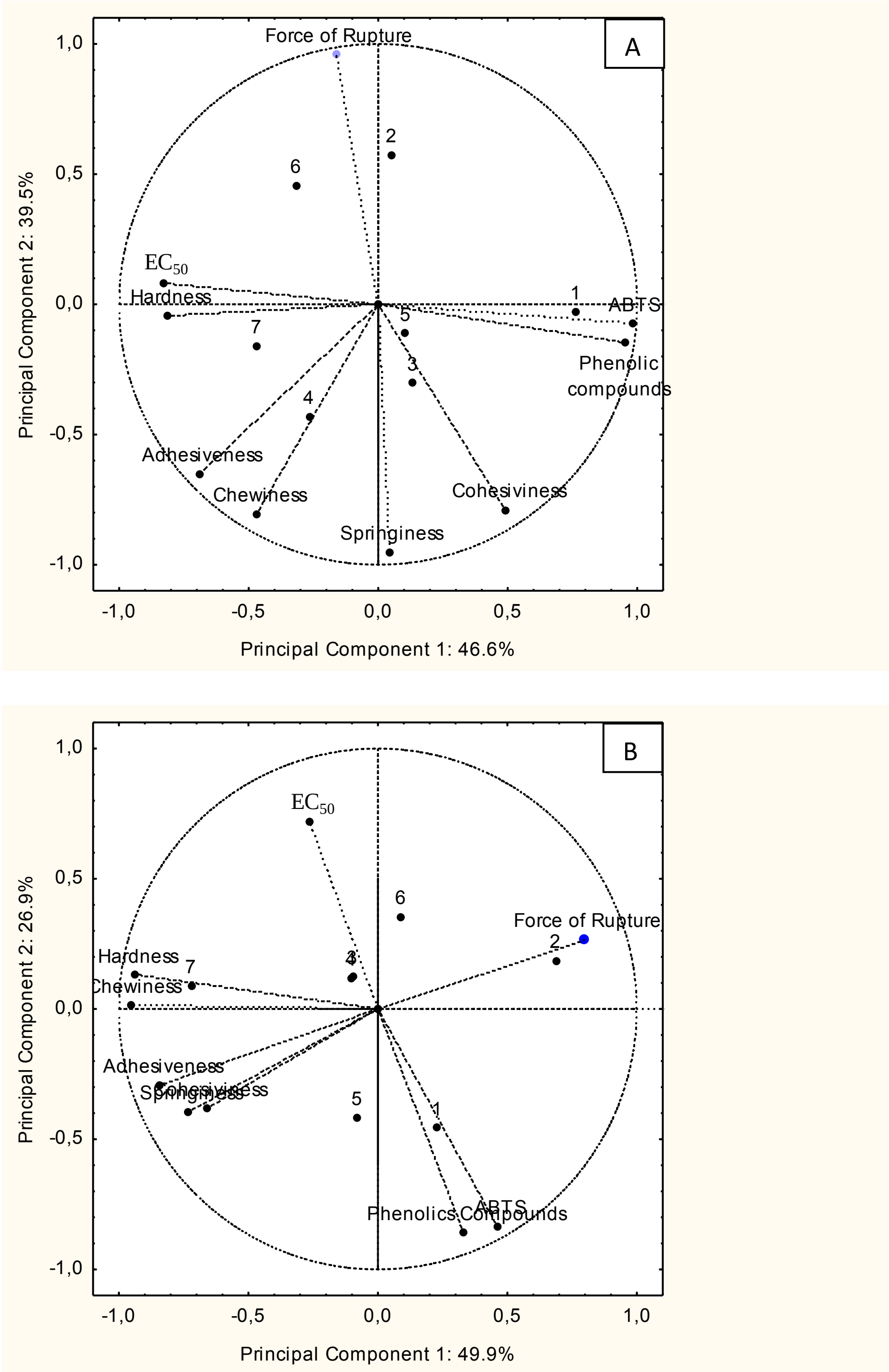
3.3 Description of the cereal bars through principal component analysis

When the data from the beginning of the storage period was considered, the first principal component explained 46.6% of the data variation and the second principal component explained 39.5%, totaling 86.1% of the data variation (Fig. 3A). The first principal component is explained by the antioxidant activity (which was measured using the ABTS method) and by total phenolics compounds; it was also explained by hardness, adhesiveness and EC_{50}. This result indicates that ABTS and total phenolic compounds themselves are positively correlated, but they are negatively correlated with hardness, adhesiveness and EC_{50}. The second principal component is explained by the force of rupture, as well as by springiness, chewiness and cohesiveness. As was noted in the case of principal component 1, springiness, chewiness and cohesiveness themselves are positively correlated, but they are negatively correlated with the force of rupture.

At beginning of the storage period, formulation 1 is described by a high quantity of total phenolic compounds and antioxidant activity, which was measured using the ABTS method, as well as by low values for EC_{50} and hardness (Fig. 3A). The description of formulation 7, however, was the opposite of formulation 1: it is described by a low quantity of total phenolic compounds and by antioxidant activity measured using the ABTS method, as well as by high values of EC_{50} and hardness.

Formulation 4 is described by high chewiness and a low force of rupture, and formulations 2 and 6 are described as the opposite: by a high force of rupture and low chewiness, springiness and cohesiveness.

Fig. 3. Principal Component Analysis for the cereal bars. (A) Beginning of shelf life study; (B) Ending of storage study.



When measured at the end of the storage period, the first principal component explained 49.9% of the data variation and the second principal component explained 26.9%, totaling 76.8% of the data variation (Fig. 3B). Principal component 1 is explained by force of rupture, which is negatively correlated with hardness, springiness, adhesiveness and chewiness. Principal component 2 is explained by the quantity of total phenolic compounds and the antioxidant activity measured using ABTS, which are negatively correlated with EC_{50}. Formulation 1 is still described by a high quantity of total phenolic compounds and the antioxidant activity measured using the ABTS method, as well as by low EC_{50} values. Low hardness, however, did not describe formulation 1 by the end of the storage period. Formulation 7 is also described in a slightly different manner, with high hardness and chewiness values and a low force of rupture. Formulation 2 also differed, with a high force of rupture and low adhesiveness, cohesiveness and springiness.

Although time was found to have an effect on the averages of many variables at the beginning and the end of the storage period, principal component analysis showed that time had little effect on the principal characteristics of the cereal bars: the formulations were described by almost the same variables at the beginning and at the end of the storage period.

4. Conclusion

Effects of time on phenolics compounds, antioxidant activity and texture properties were not the same for all formulations of cereal bars formulated with banana peel flour. The quantity of total phenolic compounds in some cereal bars decreased over the period of storage, though it increased in another formulation. Antioxidant activity, which was measured using the ABTS method, increased in the fifth month, but it then decreased until the last month. In addition, antioxidant activity decreased in almost all of the formulations over the course of the storage period. The antioxidant activity measured using the $DPPH^{\cdot}$ method was not modified in many formulations, though it decreased in some formulations. The texture properties of the cereal bars changed during storage, with an increased force of rupture starting in the fourth month and with increased hardness starting in the ninth month. Although time did affect total phenolic compounds, antioxidant activity and texture properties of cereal bars during storage, the principal component analysis showed that time had little effect on the most important characteristics used to describe cereal bars: the formulations were described by almost the same characteristics at the beginning and at the end of the storage period. Considering the parameters evaluated, we can observe that the cereal bar with the addition of banana peel flour can be consumed up to the third month of storage, due to the high increasing on the force of rupture at the fourth month, although studies about sensory acceptability should be performed to evaluate this increment. However, considering the bioactive compounds, consumption of the cereal bars can be done up to the fifth month, based on results for total phenolic compounds and total antioxidant activity measured through ABTS method. Finally, the presence of bioactive compounds in cereal bars depends on the addition of banana peel flour, which contributes to the insertion of total phenolic compounds and the antioxidant activity in cereal bars and therefore aggregates functional properties in the products.

Acknowldegements

The authors are grateful for the financial support from FAPESP (Fundação de Amparo à Pesquisa do Estado de São Paulo) (grant 2012/08852-3) and CAPES for the scholarship granted.

References

AMORIM, E. P., et al. Caracterização de acessos de bananeira com base na concentração de compostos funcionais. ***Ciência Rural**,* Santa Maria, v. 41, p. 592-598, 2011.

BERNO, N. D.; TEZZOTO-ULIANA, J. V.; DIAS, C. T. D.; KLUGG, R. A. Storage temperature and type of cut affect the biochemical and physiological characterists of fresh-cut purple onions. **Postharvest Biology and Technology***,* Amsterdan, v. 93, p. 91-96, 2014.

BHASKARAN, S.; HARDLEY, F. Buyer beliefs, attitudes and behavior: Foods with therapeutic claims. **Journal of Consumer Marketing***,* Florida, v. 19, p. 591-606, 2002.

BORGES, C. V.; AMORIM, V. B. O.; RAMLOV, F.; LEDO, C. A. S.; DONATO, M.; MARASHIN, M.;, AMORIM, E. P. Characterization of metabolic profile of banana genotypes aiming at biofortified *Musa* spp. cultivar. **Food Chemistry***,* London, v. 145, p. 496-504, 2014.

CHEN, Z.; BERTIN, R.; FROLDI, G. EC_{50} estimation of antioxidant activity in $DPPH^{\cdot}$ assay using several statistical programs. **Food Chemistry**, London, v. 138, p. 414-420, 2013.

EMAGA, T. H.; ANDRIANAIO, R. H.; WATHELET, B.; TCHANGO, J. T.; PAQUOT, M. Effects of the stage of maturation and varieties on the chemical composition of banana and plantain peels. **Food Chemistry**, London, v. 103, p. 590-600, 2007.

FAO. Disponível em:<http://faostat3.fao.org/faostat-gateway/go/to/download/Q/QI/E> FAOSTAT. Acessado em 28 de Março de 2014.

FLOEGEL, A.; KIM, D.; CHUNG, S.; KOO, S. I.; CHUN, O. K. Comparison of ABTS/$DPPH^{\cdot}$ assays to measure antioxidant capacity in popular antioxidant-rich US foods. **Journal of Food Composition and Analysis**, San Diego, v. 24, p. 1043-1048, 2011.

GRAY, J.; ARMSTRONG, G.; FARLEY, H. Oppontunities and constrains in the functional food market. **Nutrition and Food Science**, London, v. 33, p. 213-218, 2003.

GONZALEZ-MONTELONGO, R.; LOBO, G. M.; GONZALEZ, M. Antioxidant activity in banana peel extracts: testing extraction conditions and related bioactive compounds. **Food Chemistry**, London, v. 119, p. 1030-1039, 2010.

IMTIAZ, R. S.; KUHN-SHERLOCK, B.; CAMPBELL, M. Effect of dairy protein blends on texture of high proteins bars. **Journal of Texture Studies**, Malden, v. 43, p. 275-286, 2012.

KANNAN, R. R. R.; ARUMUGAM, R.; THANGARADJOU, T.; ANANTHARAMAN, P. Phytochemical constituents, antioxidant properties and p-coumaric acid analysis insome seagrasses. **Food Research International**, Barking, v. 54, p. 1229-1236, 2013.

KIM, E. H. J.; CORRIGAN, V. K.; HEDDERLEY, D. I.; MOTOI, L.; WILSON, A. J.; MORGENSTERN, M. P. Predicting the sensory texture of cereal snack bars using instrumental measurements. **Journal of Texture Studies**, Malden, v. 40, p. 457-481, 2009.

KILCI, A.; GOCMEN, D. Phenolic acid composition, antioxidant activity and phenolic content of tarhana supplemented with oat flour. **Food Chemistry**, London, v. 151, p. 547-553, 2014.

IGNAT, I.; VOLF, I.; POPA, V. I. A critical review of methods for characterisation of polyphenolic compounds in fruits and vegetables, **Food Chemistry**, London, v, 126, p. 1821-1835, 2011.

KLINCZAK, I.; MALECKA, M.; SCZLACHTA, M.; GLISZCZYNSKA-SWGIGLO, A. Effect of storage on the content of polyfhenols, vitamin C and antioxidant activity of orange juices. **Journal of Food Composition and Analysis**, San Diego, v. 20, n. 3-4, p. 313-322, 2007.

LEIGHTON, C. S., SCHÖNFELDT, H. C., & KRUGER, R. Quantitative descriptive sensory analysis of five different cultivars of sweet potato to determine sensory and texture profiles. **Journal of Sensory Studies**, Manhattan, v. 25, p. 2-18, 2010.

LOBATO, L. P. et al. Snacks bars with high soy protein and isoflavone content for use in diets to control dyslipidaemia. **International Journal of Food Sciences and Nutrition**, Basingstoke, v. 63, n. 1, p. 49-58, 2012.

LOVEDAY, S. M.; HINDMARSH, J. P.; CREAMER, L. K.; SINGH, H. Physicalchemical changes in a model protein bar during storage. **Food Research International**, Barking, v. 42, p. 798-806, 2009.

MARDIA, K. V.; KENT, J. T.; BIBBY, J. M. **Multivariate analysis**. London: Academic Press, 1979.

MENDES, N. S. R. et al. Oxidative stability of cereal bars made with fruit peels and baru nuts packaged in different types of packaging, **Food Science and Technology**, London, v. 33, n. 4, p. 730-736, 2013.

MEZZENGA, R. Equilibrium and non-equilibruim structures in complex foods systems. **Food Hydrocolloids**, Wrexham, v. 21, n. 5, p. 674-682, 2007.

MOHAPATRA, D.; MISHRA, S. & SUTAR, N. Banana and its by-product utilisation: an overview**. Journal of Scientific & Industrial Research***,* New Delhi, v. 69, p. 323-329, 2010.

REBELLO, L. P. G. et al. Flour of banana (*Musa* AAA) peel as a source of antioxidant phenolic compounds. **Food Research International**, Barking, v. 55, p. 397-403, 2014.

RUFINO, M. S. M. et al. Bioactive compounds and antioxidant capacities of 18 non-tradicional tropical fruits from Brazil. **Food Chemistry***,* London, v. 121, p. 996-1002, 2010.

RHAMAN, M. S. et al. Classification of commercial Omani halwa by physico-chemical properties and instrumental texture profile analysis, **Italian Journal of Food Science***,* Roma, v. 24, n. 3, p. 292-304, 2012.

SELCUK, N.; ERKAN, M. Changes in antioxidant activity and postharvest quality of sweet pomegranates cv. Hicrannar under modified atmosphere packaging. **Postharvest Biology and Technology***,* Amsterdan, v. 92, p. 29-36, 2014.

SHARMA, S.; KAUR, S.; DAR, B. N.; SINGH, B. Storage stability and quality assessment of processed cereal brans. **Journal and Food Science and Techonology***,* Oxford, v. 51, n. 3, p. 583-588, 2014.

SOUZA, V. R.; PEREIRA, P. A. P.; QUEIROZ, F.; BORGES, S. V.; CARNEIRO, J. D. S. Determination of bioactive compounds, antioxidant activity and chemical composition of Cerrado Brazilian fruits, **Food Chemistry***,* London, v. 134, p. 381-386, 2012.

SUN-WATERHOUSE, D.; TEOH, A.; MASSAROTTO, C.; WIBISONO, R.; WADHWA, S. Comparative analysis of fruit-based functional snack bars. **Food Chemistry***,* London, v. 119, p. 1369-1379, 2010.

SZCZESNIAK, A. S. Texture is a sensory property. **Food Quality and Preference**, Barking, v. 13, p. 215-225, 2012.

THAIPONG, K.; BOONPRAKOBA, U.; CROSBYB, K.; CISNEROS-ZEVALLOSC, L.; BYRNE, D. H. Comparison of ABTS, DPPH, FRAP, and ORAC assays for estimating antioxidant activity from guava fruit extracts, **Journal of Food Composition and Analysis***,* San Diego, v. 19, p. 669-675, 2006.

WANYO, P.; MEESO, N.; SIRIAMORNPUN, S. Effects of different treatments on the antioxidant properties and phenolic compounds of rice brand and rice husk. **Food Chemistry***,* London, v. 157, p. 457-463, 2014.

WATERHOUSE, A. L. Polyphenolics: Determination of total phenolics. In R. E. Wrolstad (Ed.), **Current Protocols in Food Analytical Chemistry**. New York: John Wiley & Sons, 2002.

YU, L.; PERRET, J.; DAVY, B.; WILSON, J.; MELBY, C. L. Antioxidants properties of cereal products. **Journal of Food Science***,* Chicago, v. 67, n. 7, p. 2600-2603, 2002.

ZIELINSKI, H.; DEL CASTILLO, M. D.; PRZYGODZKA, M.; CIESAROVA, Z.; KUKUROVA, K.; ZIELINSKA, D. Changes in chemical composition and antioxidatives properties of rye ginger cakes during their shelf-life. **Food Chemistry***,* London, v. 135, 2p. 965-2973, 2014.

3. CONCLUSÃO GERAL

Nesse trabalho foi avaliado o aproveitamento da casca da banana, um resíduo agroindustrial, na elaboração de barras de cereais por meio da metodologia de modelagem de misturas, bem como a avaliação de suas propriedades físicas, químicas e sensoriais.

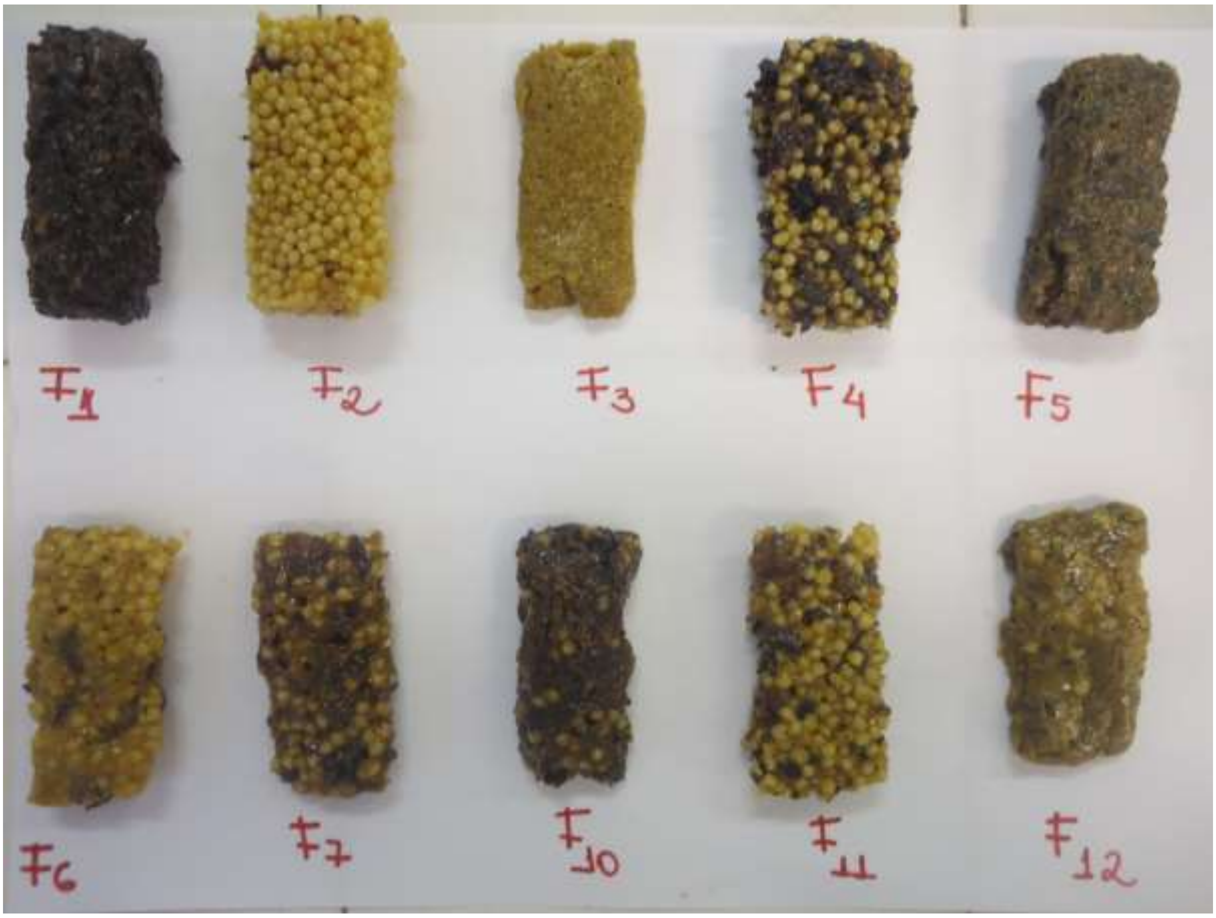
Proporções equivalentes dos três componentes que sofreram variação na modelagem de misturas (farinha de casca de banana, flocos de arroz e farinha da aveia) e a interação binária de farinha de casca de banana e flocos de arroz resultaram em barras de cereais com um grau de aceitação na região de melhor resposta do diagrama triangular. A farinha da casca de banana também interagiu com a farinha de aveia e flocos de arroz, promovendo mudanças na cor das barras de cereais e no volume específico. Em relação à aceitação sensorial, as barras que apresentaram a adição de 50% de farinha de casca de banana e 50% de flocos de arroz e as barras com 17% de farinha de casca de banana/66% de flocos de arroz/17% de farinha de aveia foram consideradas as formulações mais aceitas.

Ainda, as diferentes proporções de adição dos três componentes resultaram em mudanças nos perfis sensoriais das barras desenvolvidas e também em relação à uma barra de cereal comercial. Barras com maior quantidade de farinha de casca de banana adicionada foram caracterizadas pela cor escura, aroma de banana e gosto amargo, enquanto que barras com adição de menor quantidade de farinha de casca de banana foram caracterizadas pela quantidade de flocos de arroz e crocância, pelo fato de possuírem maior quantidade de flocos de arroz. Enquanto isso, a barra comercial foi caracterizada pela dureza, gosto doce, adesividade e sabor de aveia.

O estudo do armazenamento das barras de cereais ao longo de 11 meses mostrou que o tempo causa mudanças nas propriedades de texturas e compostos bioativos das barras de cereais formuladas com farinha de casca de banana. Os compostos fenólicos totais diminuíram em algumas amostras e em outras aumentaram ao longo do tempo. A atividade antioxidante avaliada pelo método ABTS aumentou até o nono mês e então teve uma diminuição no restante do período. Já pelo método DPPH$^{\cdot}$ não houve modificações em algumas formulações enquanto que para outras houve diminuição. Um aumento na força de ruptura das barras foi observado no início do quarto mês e a dureza aumentou no início do nono mês de armazenamento das barras de cereais. O estudo longitudinal do armazenamento mostrou que as barras de cereais formuladas com farinha de casca de banana apresentaram um aumento na força de ruptura no quarto mês, fazendo com que elas possam ser consumidas até o terceiro mês. Por outro lado, considerando os compostos bioativos presentes, o estudo mostrou a queda desses compostos no sexto mês, indicando seu consumo até o quinto mês de armazenamento. Pela análise de componentes principais verificou-se que as formulações foram descritas quase que pelas mesmas características do início e do final do período de armazenamento.

Finalmente, conclui-se que a elaboração de barras de cereais contendo farinha de casca de banana é viável do ponto de vista sensorial e importante para a saúde humana devido à incorporação de compostos bioativos e atividade antioxidante, favorecendo, também, a valorização deste resíduo agroindustrial por meio do desenvolvimento de um alimento sustentável.

ANEXO 1 – Barras de cereais elaboradas com farinha de casca de banana, farinha de aveia e flocos de arroz por meio de modelagem de misturas.



Legenda – formulações das barras de cereais com adição de farinha de casca de banana (FCB), flocos de arroz (FA) e farinha de aveia (FAv) nas seguintes proporções: F1 = 42 g FCB; F2 = 42 g FA; F3 = 42 g FAv; .F4 = 21 g FCB + 21 g FA; F5 = 21 g FCB + 21 g FAv; F6 = 21 g FA + 21 g FAv; F7 = 14 g FCB, FA, FAv; F10 = 27,72 g FCB + 7,14 FA + 7,14 g FAv; F11 = 7,14g FCB + 27,72 FA + 7,14 g FAv; F12 = 7,14 g FCB + 7,14 g FA + 27,72 FAv.

ANEXO 2 – Parecer do Comitê de Ética em Pesquisa.

INSTITUTO DE BIOCIÊNCIAS
LETRAS E CIÊNCIAS
EXATAS/CAMPUS DE SÃO

PROJETO DE PESQUISA

Título: Aproveitamento de resíduo industrial de casca de banana na elaboração de barras de cereais: compostos bioativos e aspectos sensoriais.

Área Temática:

Versão: 1

CAAE: 06697312.3.0000.5466

Pesquisador: VANIA SILVA CARVALHO MAGALHÃES

Instituição: Instituto de Biociências Letras e Ciências Exatas/ Campus de São José do Rio Pre

PARECER CONSUBSTANCIADO DO CEP

Número do Parecer: 99.422

Data da Relatoria: 10/09/2012

Apresentação do Projeto:

O processamento industrial de bananas gera uma grande quantidade de resíduos na forma de cascas, o que torna necessária sua utilização como forma de diminuir o impacto ambiental. Aliado a isso, o desenvolvimento de alimentos funcionais é uma oportunidade única para contribuir para a melhoria da qualidade dos alimentos e para a saúde e bem-estar do consumidor. A farinha de casca de banana, por ser rica em compostos bioativos, pode ser utilizada na elaboração de alimentos com alegação de propriedades funcionais, além de reduzir o impacto ambiental. A barra de cereal é um desses alimentos, pois ganhou a aceitação dos consumidores devido ao seu apelo funcional, como fornecimento de fibras alimentares e contribuição para uma dieta saudável. Além disso, o desenvolvimento de novos produtos está associado à aceitação sensorial e, também, a análise do perfil sensorial devido à incorporação de ingredientes diferentes dos tradicionais.

Objetivo da Pesquisa:

Objetivo geral
Aproveitar o resíduo industrial de casca de banana através de sua utilização na elaboração de barras de cereais.

Objetivos específicos
Avaliar a composição centesimal, os compostos fenólicos e a atividade antioxidante da casca de banana in natura e da farinha de casca de banana.
Elaborar barras de cereais contendo farinha de casca de banana através da metodologia de modelagem de misturas.
Avaliar as propriedades físicas das barras de cereais, como textura, cor e volume específico.
Caracterizar o perfil sensorial das barras de cereais através da Análise Descritiva Quantitativa.
Avaliar a aceitação sensorial e a intenção de compra das barras de cereais através de testes afetivos, além da construção de mapas de preferência.
Avaliar a composição centesimal, os compostos fenólicos e a atividade antioxidante das barras de cereais aceitas sensorialmente.

Avaliação dos Riscos e Benefícios:

A pesquisa oferecerá riscos mínimos à sua saúde, pois os produtos a serem experimentados são de consumo comum e de marcas comerciais, além daqueles que serão manipulados utilizando-se as Boas Práticas de Manipulação/Fabricação. Os benfícios são muitos considerando que barra de cereal a ser produzida com a farinha de casca de banana, por ser rica em compostos bioativos, pode ser

Endereço: CRISTOVAO COLOMBO 1897/99999
Bairro: JARDIM NAZARETH **CEP:** 15.054-000
UF: SP **Município:** SAO JOSE DO RIO PRETO
Telefone: (17)3221-2456 **Fax:** (17)3221-2500 **E-mail:** soraiaft@ibilce.unesp.br;

utilizada na elaboração de alimentos com alegação de propriedades funcionais, além de reduzir o impacto ambiental. Esta é um tipo de alimento que ganhou a aceitação dos consumidores devido ao seu apelo funcional, como fornecimento de fibras alimentares e contribuição para uma dieta saudável alé do fato que o desenvolvimento de alimentos funcionais é uma oportunidade única para contribuir para a melhoria da qualidade dos alimentos e para a saúde e bem-estar do consumidor.

Comentários e Considerações sobre a Pesquisa:

A pesquisa é relevante para a área além de contribuir para a melhoria da qualidade de um tipo de alimento de boa aceitação pela população, quer pelo baixo custo quer pela praticidade, de contribuir com uma dieta saudável e ainda mininizar impactos ambientais causados pela casca da banana. A introdução está muito bem referendada pela literatura, apresenta coerência entre os objetivos propostos e a metodologia.
O projeto está apresentado adequadamente, os objetivos estão claramente colocados, a metodologia a ser utilizada é adequada para os objetivos propostos, os riscos e/ou benefícios justificam a execução do projeto. Há infra-estrutura necessária para execução do projeto e concordância documentada da instituição em que será desenvolvida. Não foi apresentado, no projeto, o orçamento financeiro detalhado da pesquisa, porém foi apresentado o termo de outorga da FAPESP, agência à qual o projeto foi submetido e aprovado, que descreve os itens a serem financiados.
A descrição da casuística está adequada, os critérios para recrutamento ou seleção dos indivíduos são adequados, e ficou definido como será obtido o termo de consentimento e quem ficará responsável em obtê-lo.
O termo de consentimento apresentado contempla as informações sugeridas pelo CEP.
As medidas para proteção dos indivíduos quanto a qualquer risco eventual de saúde e monitoramento da coleta de dados pessoais ou familiais são adequadas para garantir a segurança dos indivíduos e confidencialidade dos dados
Não foi informado como os resultados serão divulgados
O orientador tem experiência em pesquisa relacionada com a temática do projeto e possui produção científica com regularidade, publicadas em veículos especializados.

Considerações sobre os Termos de apresentação obrigatória:

Todos os Termos de apresentação obrigatória foram apresentados e o TCLE está devidamente formulado.

Recomendações:

Nenhuma

Conclusões ou Pendências e Lista de Inadequações:

Aprovado

Situação do Parecer:

Aprovado

Necessita Apreciação da CONEP:

Não

Considerações Finais a critério do CEP:

Nada a acrescentar.

ANEXO 3 – Médias da aceitação sensorial (desvio-padrão; n = 67) pelas barras de cereais segundo os níveis de farinha de casca de banana (X_1), flocos de arroz (X_2) e aveia (X_3) na mistura.

Formulação	Proporção de cada componente na mistura			Aceitação				
	X_1	X_2	X_3	Aparência	Aroma	Textura	Sabor	Aceitação Global
1	1	0	0	4,3 (2,3)	5,7 (1,9)	3,9 (2,1)	3,8 (2,3)	3,9 (2,0)
2	0	1	0	6,5 (1,7)	5,8 (1,5)	6,7 (1,7)	6,1 (1,9)	6,2 (1,6)
3	0	0	1	3,3 (1,8)	4,9 (1,7)	3,2 (2,1)	4,1 (2,4)	3,6 (2,0)
4	0,50	0,50	0	6,1 (1,7)	6,2 (1,4)	6,8 (1,6)	6,6 (1,6)	6,5 (1,4)
5	0,50	0	0,50	4,2 (1,9)	6,0 (1,3)	4,8 (2,1)	5,4 (1,9)	5,0 (1,7)
6	0	0,50	0,50	7,0 (1,6)	6,2 (1,6)	6,8 (1,6)	6,5 (1,8)	6,6 (1,7)
7	0,33	0,33	0,33	6,2 (1,9)	6,8 (1,2)	6,7 (1,6)	6,8 (1,7)	6,6 (1,5)
8	0,33	0,33	0,33	6,2 (1,7)	6,4 (1,4)	6,7(1,6)	6,7 (1,7)	6,6 (1,5)
9	0,33	0,33	0,33	6,3 (1,5)	6,4 (1,4)	6,8 (1,4)	6,8 (1,6)	6,7 (1,4)
10	0,66	0,17	0,17	4,9 (1,9)	6,2 (1,6)	6,1 (1,6)	5,6 (2,2)	5,7 (1,8)
11	0,17	0,66	0,17	6,9 (1,3)	6,4 (1,3)	7,4 (1,1)	6,8 (1,4)	6,9 (1,3)
12	0,17	0,17	0,66	5,2 (1,8)	5,7 (1,5)	5,7 (2,0)	5,5 (2,0)	5,5 (1,8)

ANEXO 4 – Médias das variáveis de cor (desvio-padrão; n = 4) das barras de cereais segundo os níveis de farinha de casca de banana (X_1), flocos de arroz (X_2) e aveia (X_3) na mistura.

Formulação	Proporção de cada componente na mistura			Cor				
	X_1	X_2	X_3	L*	a*	b*	C*	h
1	1	0	0	17,9 (0,4)	2,5 (0,7)	2,5 (0,3)	3,2 (0,1)	39,1 (0,2)
2	0	1	0	46,1 (1,3)	11,5 (3,1)	35,7 (1,9)	35,1 (0,2)	70,1 (0,0)
3	0	0	1	37,1 (1,1)	8,8 (2,6)	26,8 (1,6)	28,7 (0,6)	70,9 (0,1)
4	0,50	0,50	0	30,9 (0,7)	4,7 (1,6)	16,2 (1,0)	15,5 (0,4)	72,5 (0,6)
5	0,50	0	0,50	20,4 (0,7)	2,9 (0,9)	6,3 (0,6)	6,4 (0,4)	62,8 (0,4)
6	0	0,50	0,50	35,4 (1,3)	9,8 (2,6)	26,7 (1,8)	26,7 (1,0)	67,3 (0,2)
7	0,33	0,33	0,33	26,9 (0,5)	4,2 (1,3)	9,8 (0,8)	9,9 (0,4)	64,2 (0,4)
8	0,33	0,33	0,33	27,0 (0,9)	6,1 (1,7)	13,0 (1,0)	13,3 (0,4)	61,8 (0,4)
9	0,33	0,33	0,33	26,5 (0,7)	6,0 (1,7)	13,9 (1,1)	14,1 (0,6)	64,0 (0,6)
10	0,33	0,33	0,33	23,2 (0,4)	3,1 (0,9)	6,1 (0,5)	6,3 (0,1)	60,4 (1,4)
11	0,66	0,17	0,17	36,3 (0,9)	7,9 (2,3)	25,4 (1,4)	24,8 (0,3)	71,1 (0,1)
12	0,17	0,66	0,17	27,3 (0,8)	6,8 (2,1)	24,8 (1,3)	24,1 (0,4)	73,1 (0,3)

ANEXO 5 – Médias da Análise do Perfil de Textura (desvio-padrão; n = 10), força de ruptura e volume específico (desvio-padrão; n = 3) das barras de cereais segundo os níveis de farinha de casca de banana (X_1), flocos de arroz (X_2) e aveia (X_3) na mistura.

Formulação	Proporção de cada componente na mistura			Análise do Perfil de Textura					Força de Ruptura (N)	Volume Específico ($cm^3.g^{-1}$)
	X_1	X_2	X_3	Dureza (N)	Adesividade (N.s)	Elasticidade	Coesividade	Mastigabilidade (N)		
1	1	0	0	15.7 (7.9)	-1.3 (1.0)	0.4 (0.3)	0.3 (0.3)	1.7 (1.1)	0.8 (0.1)	11.1 (1.0)
2	0	1	0	40.0 (20.3)	-0.8 (0.3)	0.2 (0.0)	0.6 (0.2)	0.6 (0.3)	5.2 (0.5)	20.7 (0.8)
3	0	0	1	5.7 (1.9)	-2.8 (1.1)	0.9 (0.1)	0.7 (0.1)	3.9 (1.5)	0.2 (0.1)	9.5 (0.5)
4	0,50	0,50	0	37.1 (23.1)	-2.5 (0.6)	0.3 (0.0)	0.1 (0.0)	1.4 (1.0)	3.7 (1.7)	15.2 (0.8)
5	0,50	0	0,50	36.2 (7.2)	-4.53 (1.1)	0.7 (0.2)	0.2 (0.4)	5.9 (1.6)	0.8 (0.1)	11.2 (0.8)
6	0	0,50	0,50	85.0 (20.7)	-3.5 (1.3)	0.3 (0.1)	0.1 (0.0)	3.2 (0.9)	0.7 (0.1)	12.4 (0.2)
7	0,33	0,33	0,33	74.3 (16.3)	-5.3 (2.2)	0.7 (0.3)	0.2 (0.0)	9.7 (4.6)	1.5 (0.8)	13.4 (1.1)
8	0,33	0,33	0,33	89.8 (17.9)	-3.9 (1.4)	0.6 (0.3)	0.1 (0.0)	8.0 (4.6)	0.4 (0.3)	14.2 (0.1)
9	0,33	0,33	0,33	110.8 (30.9)	-6.5 (1.6)	0.7 (0.2)	0.1 (0.0)	12.3 (4.5)	0.3 (0.4)	11.6 (0.3)
10	0,33	0,33	0,33	45.8 (14.9)	-4.1 (1.6)	0.4 (0.1)	0.2 (0.0)	4.0 (1.8)	0.6 (0.2)	13.4 (1.5)
11	0,66	0,17	0,17	98.0 (15.5)	-2.8 (1.0)	0.3 (0.2)	0.1 (0.0)	3.1 (2.1)	3.2 (0.7)	18.7 (2.5)
12	0,17	0,66	0,17	51.9 (11.1)	-6.5 (0.9)	0.5 (0.1)	0.2 (0.0)	5.0 (1.8)	0.8 (0.2)	10.9 (0.7)

ANEXO 6 – Parecer do Comitê de Ética em Pesquisa

INSTITUTO DE BIOCIÊNCIAS
LETRAS E CIÊNCIAS
EXATAS/CAMPUS DE SÃO

PARECER CONSUBSTANCIADO DO CEP

DADOS DO PROJETO DE PESQUISA

Título da Pesquisa: Aproveitamento de resíduo industrial de casca de banana na elaboração de barras de cereais: compostos bioativos e aspectos sensoriais.

Pesquisador: VANIA SILVA CARVALHO

Área Temática:

Versão: 3

CAAE: 06697312.3.0000.5466

Instituição Proponente: Instituto de Biociências Letras e Ciências Exatas/ Campus de São José do

Patrocinador Principal: FUNDACAO DE AMPARO A PESQUISA DO ESTADO DE SAO PAULO

DADOS DO PARECER

Número do Parecer: 948.487

Data da Relatoria: 01/02/2015

Apresentação do Projeto:

Trata-se de emenda em atendimento às solicitações do CEP por ocasião da última notificação

Objetivo da Pesquisa:

Os mesmos anteriormente relatados

Avaliação dos Riscos e Benefícios:

Os mesmos anteriormente relatados

Comentários e Considerações sobre a Pesquisa:

O CEP havia solicitado: - relatório das atividades desenvolvidas relativas ao período de 12/2013 a 10/2014.

- Justificativa para a transferência do local de desenvolvimento do projeto
- Projeto reformulado e;
- Anuência da orientadora, visto tratar-se de projeto de doutoramento

Considerações sobre os Termos de apresentação obrigatória:

Em conformidade

Recomendações:

Nada a relatar

Endereço: CRISTOVAO COLOMBO 2265
Bairro: JARDIM NAZARETH **CEP:** 15.054-000
UF: SP **Município:** SAO JOSE DO RIO PRETO
Telefone: (17)3221-2426 **Fax:** (17)3221-2500 **E-mail:** [illegible]

INSTITUTO DE BIOCIÊNCIAS
LETRAS E CIÊNCIAS
EXATAS/CAMPUS DE SÃO

Conclusões ou Pendências e Lista de Inadequações:

A pesquisadora apresentou justificativa para a transferência do local de desenvolvimento do projeto a saber: Instituto Federal Goiano, Campus Morrinhos, por ter sido aprovada em concurso público para o cargo de professor.

Apresentou o relatório das atividades do período de 12/2013 a 10/2014, tendo apresentado parte dos resultados em 3 congressos da área de atuação, os manuscritos, em inglês, de dois artigos para publicação em revista científica da área, sendo que, um já foi submetido e realização do exame de qualificação em setembro de 2014.

Embora não tendo apresentado nem o projeto reformulado nem a anuência da orientadora sobre a continuidade da orientação, depreende-se do cronograma original e dos resultados apresentados até o momento, que restam apenas a redação da tese e a sua defesa, conclui-se que a orientadora deve estar ciente e de acordo.

Situação do Parecer:

Aprovado

Necessita Apreciação da CONEP:

Não

Considerações Finais a critério do CEP:

O CEP aprova o parecer do relator.

SAO JOSE DO RIO PRETO, 09 de Fevereiro de 2015

Assinado por:
Claudia Regina Bonini Domingos
(Coordenador)