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INSTITUTO DE TECNOLOGIA
PROGRAMA DE PÓS-GRADUAÇÃO EM CIÊNCIA E TECNOLOGIA DE ALIMENTOS

TESE

Obtenção e caracterização de farinhas de rizomas e tubérculos de sistema orgânico de produção e suas potencialidades no desenvolvimento de alimentos para celíacos

Kamila de Oliveira do Nascimento

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UNIVERSIDADE FEDERAL RURAL DO RIO DE JANEIRO
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OBTENÇÃO E CARACTERIZAÇÃO DE FARINHAS DE RIZOMAS E TUBÉRCULOS DE SISTEMA ORGÂNICO DE PRODUÇÃO E SUAS POTENCIALIDADES NO DESENVOLVIMENTO DE ALIMENTOS PARA CELÍACOS

KAMILA DE OLIVEIRA DO NASCIMENTO

Sob a Orientação da Professora
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Tese submetida como requisito parcial para obtenção de grau do **Doutor em Ciências,** no Programa de Pós-Graduação em Ciência e Tecnologia de Alimentos, área de concentração em Ciências de Alimentos.

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"É muito melhor lançar-se em busca de conquistas grandiosas, mesmo expondo-se ao fracasso, do que alinhar-se com os pobres de espírito, que nem gozam muito, nem sofrem muito, porque vivem numa penumbra cinzenta, onde não conhecem nem vitória, nem derrota." (Theodore Roosevelt)

RESUMO

NASCIMENTO, Kamila de Oliveira do. **Obtenção e caracterização de farinhas de rizomas e tubérculos de sistema orgânico de produção e suas potencialidades no desenvolvimento de alimentos para celíacos**. 2015. 146p. Tese (Doutorado em Ciência e Tecnologia de Alimentos). Instituto de Tecnologia, Departamento de Tecnologia de Alimentos, Universidade Federal Rural do Rio de Janeiro, Seropédica, RJ, 2015.

No cenário brasileiro, a agricultura orgânica vem aumentando sua participação, com crescimento substancial da produção, da comercialização e do consumo de orgânicos. Sendo assim, o objetivo deste trabalho foi obter e caracterizar farinhas de rizomas e tubérculos de sistema orgânico de produção e suas potencialidades no desenvolvimento de alimentos para celíacos. As matérias-primas orgânicas (araruta *cv* comum e *cv* ovo de pata, taro *cv* Chinês e batatas doces: Rosinha de Verdan, Capivara e Alaranjada) foram obtidas na Fazendinha Agroecológica, Seropédica, RJ, no período de 2011 à 2014. As amostras já higienizadas foram descascadas e cortados em fatias. Logo após foram desintegradas em um processador e peneiradas. O produto peneirado foi disposto em tabuleiros e submetido à secagem em estufa com circulação e renovação de ar (65°C/24 h). As farinhas secas foram moídas e peneiradas até a obtenção de um pó fino. As olericolas analisadas, como o taro e a batata doce Rosinha *in natura* apresentaram níveis mais elevados de compostos fenólicos totais. Verificou-se que o principal ácido graxo poliinsaturado encontrado na batata doce Capivara (*in natura*) foi o ácido linoleico (C18:2 ω6). Além disso, os resultados obtidos para o perfil de fitosterol das olericulturas analisadas (araruta *cv* comum e *cv* ovo de pata, taro Chinês e batatas doces: Rosinha de Verdan, Capivara e Alaranjada), foram brassicasterol, campesterol, estigmasterol e β-sitosterol. Ambas as farinhas de ararutas (comum e ovo de pata), apresentaram elevada capacidade antioxidante em relação à fécula de taro. Para a farinha de taro foi observado um maior teor de cinzas, valor energético, fibra bruta e açúcares redutores. A farinha de taro apresentou maior capacidade de absorção de gordura que as ararutas ovo de pata e comum, além disso, os níveis de compostos fenólicos totais e capacidade antioxidante do taro foram significativos. O padrão de cristalinidade para as duas variedades de farinhas de ararutas e para o taro foi do tipo A. Para a farinha de batata doce alaranjada, verificou-se que esta apresentou maior valor energético total, cinzas, pH, acidez, açúcares redutores, açúcares não redutores e conteúdo de carotenoides totais do que as outras variedades (Capivara e Rosinha de Verdan). O β-caroteno (22.146,78 g/100 g db), foi o principal carotenoide da farinha de batata doce da variedade de polpa alaranjada analisada. Sendo que o tipo de cristalinidade para duas variedades de farinhas de batatas doces estudadas (Capivara e da batata doce de polpa alaranjada) foi do tipo A. Após os resultados do processamento, observou-se um maior rendimento para a obtenção de farinhas de batata doce Capivara (25,48 g/100g) e para a araruta ovo de pata (21,59 g/100g) respectivamente. Foi verificado pelo teste de aceitação e intenção de compra de biscoitos desenvolvidos com as farinhas orgânicas, que o biscoito de doce de batata Capivara foi o preferido pelos provadores não treinados. Assim, o desenvolvimento de produtos processados atraentes a partir destas farinhas orgânicas, desempenham um papel importante na sensibilização sobre o potencial e diversidade destas culturas. Diante do exposto, constatou-se que as amostras pesquisadas podem ser utilizadas como uma fonte viável de farinhas visando a sua utilização industrial e para diferentes aplicações. Além disso, a diversidade cultural da agricultura orgânica justifica o consumo e processamento destes alimentos isentos de glúten para a população em geral, bem como para os portadores da doença celíaca.

Palavras-chave: Batata doce, araruta, taro, farinhas, agricultura orgânica.

ABSTRACT

NASCIMENTO, Kamila de Oliveira do. **Obtaining and characterization of flours from rizhomes and tubers of organic system and its potential in the development of foods for coeliacs**. 2015. 146p. Thesis (Doctorate in Food Science and Technology). Institute of Technology, Department of Food Technology, Universidade Federal Rural do Rio de Janeiro, Seropédica, RJ, 2015.

In the Brazilian context, organic agriculture has increased its participation, with substantial growth in production, marketing and consumption of organic. Thus, the aim of this study was to obtain and characterize rhizomes flours and organic system of tuber production and its potential in the development of foods for coeliacs. The organic raw materials (arrowroot cv comum and cv ovo de pata, taro *cv* Chinese and sweet potatos: Rosinha de Verdan, Capivara and Orange fleshed) were obtained in Fazendinha Agroecology, Seropédica, RJ, in the period 2011 to 2014. The samples already sanitized were peeled and cut into slices. Soon after they were blown away in a processor and sifted. The sieved product was arranged on trays and dried in an oven with circulation and air exchange (65 °C/24 h). The dried flour were ground and sieved until obtaining a fine powder. The analyzed vegetable crops such as taro and sweet potato Rosinha in natura presented higher levels of phenolic compounds. It was found that the major polyunsaturated fatty acid found in the sweet potato Capivara (in kind) was linoleic acid (C18: 2 ω6). In addition, the results for the phytosterol profile of the analyzed olericulturas (arrowroot comum and ovo de pata, taro Chinese and sweet potatoes: Rosinha de Verdan, Capivara and Orange) were brassicasterol, campesterol, stigmasterol and β-sitosterol. Both ararutas flour (comum and ovo de pata) showed high antioxidant capacity compared to starch taro. For the taro flour was observed higher ash content, energy value, crude fiber and reducing sugars. Taro flour showed greater capacity for absorption of fat that ararutas ovo de pata, common, moreover, the levels of total phenolics and antioxidant capacity taro were significant. The pattern of crystallinity for the two varieties of ararutas flour and taro was type A. For the sweet potato flour orange fleshed, it was found that this had a higher total energy intake, ashes, pH, acidity, reducing sugars, sugars non-reducing and content of total carotenoids than the other varieties (Capivara and Rosinha de Verdan). The β-carotene (22,146.78 g / 100 g db) was the main carotenoid sweet potato flour analyzed variety of orange pulp. Since the type of crystallinity for two varieties of sweet potato flours studied (Capivara and Orange fleshed sweet potato) was type A. After the processing results was observed a higher yield to obtain sweet potato flour Capivara (25.48 g / 100g) and the arrowroot ovo de pata (21.59 g/100g) respectively. Verified by acceptance testing and intention of buying cookies developed with organic flours, the sweet potato Capivara biscuit was preferred by untrained tasters. Thus, the development of appealing products processed from these organic meals, play an important role in the awareness of the potential and diversity of these cultures. Given the above, it was found that the surveyed samples can be used as a viable source of flour aiming at its industrial use and for different applications. Furthermore, the cultural diversity of organic agriculture justifies the consumption and processing of gluten-free foods for the general population as well as for patients with celiac disease.

Key-words: Sweet potato, arrowroot, taro, flours, organic agriculture.

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Sumário

1. Introdução Geral e Justificativa

Nos últimos anos, as preocupações dos consumidores sobre a qualidade e segurança dos alimentos têm impulsionado a produção de alimentos orgânicos, que via de regra, tem seu consumo associado a benefícios à saúde humana, bem-estar animal e proteção ambiental. O sistema orgânico de produção agropecuária adota técnicas específicas como a otimização do uso dos recursos naturais e socioeconômicos disponíveis, respeitando a integridade cultural das comunidades rurais, tendo por objetivo a sustentabilidade econômica e ecológica (BRASIL, 2003). A exclusão de fertilizantes e pesticidas sintéticos contribui para que os alimentos produzidos por este tipo de cultivo sejam mais saudáveis do que os obtidos nos sistemas de cultivo convencionais (LOUARN et al., 2012).

O mercado mundial de alimentos orgânicos tem aumentado significativamente nos últimos anos. Sendo que o total de vendas de alimentos orgânicos somaram $15.2 bilhões em 1999, e subiu para $ 62.9 bilhões em 2011. A *Whole Foods*, uma cadeia de alimentos orgânicos, tem sido altamente bem sucedida já que "é a maior varejista do mundo" (DAUNFELDT e RUDHOLM, 2014). Em paralelo com os critérios de qualidade relacionados com o processo, tais como questões ambientais e o bem-estar animal, os critérios do produto como indicadores específicos para alimentos orgânicos, bem como sabor, nutrição e saúde, estão se tornando cada vez mais importantes (FUENTES et al., 2014).

De acordo com Santos et al., (2015) estima-se que haja no Brasil aproximadamente 1,5 milhão de hectares em produção orgânica, sem contar a produção extrativista orgânica na região Norte do Brasil. Estima-se que os pequenos e médios produtores de alimentos orgânicos, devem perfazer mais de 95% dos produtores orgânicos no Brasil. E ainda, o Brasil tem o maior mercado consumidor de orgânicos da América do Sul e este mercado está em crescimento, sendo considerado pelos principais importadores de orgânicos como os EUA, União Europeia e Japão, como o país de maior potencial de produção orgânica para exportação (SANTOS et al., 2015).

Dentre as culturas de interesse, destacam-se os rizomas e tubérculos, reconhecidamente fonte de amido, um polissacarídeo de armazenamento abundante nas plantas, importante para a dieta no fornecimento de carboidratos (BAIXAULI et al., 2008). A indústria de alimentos está interessada na utilização de farinhas de leguminosas para a melhoria da qualidade nutricional dos alimentos à base de cereais (VANNICE e RASMUSSEN, 2014). Portanto, farinhas obtidas a partir de fontes alternativas, como a batata doce, taro e ararutas e outros tubérculos, são potenciais substitutos da farinha de trigo, acrescentando variedade e funcionalidade ao produto (NJINTANG et al., 2008).

Dentre as culturas não convencionais que apresentam potencial para o fornecimento do farinhas ricas em amido, destacam-se a araruta (*Maranta arundinaceae*), a batata doce (*Ipomoea batatas* L.) e o taro (*Colocasia esculenta* (L.) Schott). O amido de araruta é um dos amidos nativos produzidos a partir do tubérculo de araruta (*Maranta arundinaceae*) com características únicas (WINARTI et al., 2014).

A araruta pode ser considerada como uma matéria-prima não-convencional para a extração de amido, sendo considerados como uma fonte potencial de amido. A araruta possui baixo teor de proteína, gordura, cinzas e composição de fibra, com dimensão de partícula entre 4 e 42 um e com uma temperatura de gelatinização entre 68 e 75 °C (VALÊNCIA et al., 2014). No Brasil, a araruta costumava ser cultivada por agricultores familiares tradicionais como os do Território do Recôncavo Baiano, mas nos últimos 50

anos, o seu cultivo tem sido quase extinto devido à concorrência de outras fontes de amido como mandioca, milho, aveia, cevada e trigo (MADINENI et al, 2012; SILVEIRA et al, 2013).

Os interesses na produção e na utilização de batata doce (*Ipomoea batatas* L.) estão aumentando nos últimos anos e o amido representa cerca de até 80% de sua matéria seca. Globalmente, a batata doce é a sexta cultura alimentar mais importante depois do arroz, trigo, batata, milho e mandioca, sendo também a quinta cultura alimentar mais importante nos países em desenvolvimento, desempenhando um papel crucial na segurança alimentar. Existem diversos benefícios para a saúde do consumo de batata doce, devido à presença de vários componentes funcionais, tais como fibras dietéticas, carotenoides, ácidos fenólicos, antocianinas, vitaminas e minerais (ABUKARI, SHANKLE e REDDY, 2015; ESAN et al., 2015; LEE et al., 2015; ZHU e WANG, 2014).

A batata doce alaranjada, por sua vez, representa uma fonte importante de β-caroteno, carboidrato, vitamina C, vitamina B6, cobre, potássio, ferro e fibra (TOYAMA, YOSHIMOTO e YAMAKAWA, 2006). Apresenta ainda inúmeros benefícios à saúde, incluindo ações antimutagenica, antioxidante, hepato-protetora e cardio-protetora, além dos efeitos antidiabéticos, que foram atribuídos a componentes fitoquímicos deste vegetal (ISHIGURO et al., 2012; GRACE, YOUSEF e GUSTAFSON, 2014). Dependendo da cor da polpa da batata doce, pode apresentar uma série de compostos bioativos, incluindo os carotenoides, antocianinas, ácidos fenólicos, outros flavonoides e vitamina C. A batata doce de polpa de alaranjada contém β-caroteno, responsável por conferir a atividade pró-vitamínica A, atividade que contribui para a prevenção de deficiências de vitamina A e cegueira noturna. Além dos carotenoides, a batata doce de polpa de alaranjada contém um perfil único de compostos fenólicos, tais como os ácidos hidroxicinâmicos, os quais representam os principais antioxidantes fenólicos na maioria dos cultivares de batata doce, disponíveis comercialmente (ESAN et al., 2015; GINTING e YULIFIANTI, 2015; GRACE, YOUSEF e GUSTAFSON, 2014; LAURIE et al., 2012).

O taro (*Colocasia esculenta* (L.) Schott) possui em média 70-80% de amido, com pequenos grânulos e, além de apresentar alta digestibilidade. Devido às pequenas dimensões de seus grânulos de amido (1-4 µm de diâmetro), o taro é altamente digerível e, como tal, tem sido utilizado em preparação de alimentos para lactentes e nas dietas de pessoas alérgicas a cereais e crianças sensíveis ao leite e outras aplicações industriais (NJINTANG et al, 2008; SIT et al, 2014; TEMESGEN, 2015). Além disso, o amido de taro é naturalmente isento de glúten e também pode ser indicado para úlcera péptica, doença inflamatória intestinal, doença celíaca entre outros (TEMESGEN, 2015).

Além da aplicação tecnológica no processamento de alimentos, as farinhas de araruta, batata doce e taro, por naturalmente não possuírem glúten, podem ser ingredientes estratégicos na elaboração de alimentos isentos desta proteína, voltados para portadores de doença celíaca (DC).

O glúten é comumente encontrado no trigo, centeio, cevada e aveia e apresenta propriedades aderentes e elásticas que são características tecnológicas importantes para produzir biscoitos, pão, bolos e outros produtos de panificação (MADEIRA et al., 2015; NASCIMENTO, BARBOSA e TAKEITI, 2012). Entretanto, as prolaminas do glúten são tóxicas para o paciente celíaco, caracterizando um processo inflamatório que envolve a mucosa do intestino delgado, levando a atrofia das vilosidades intestinais, má absorção de nutrientes e uma variedade de manifestações clínicas (HIRACAVA et al., 2015).

A DC pode ser considerada, mundialmente, como um problema de saúde pública, principalmente devido à elevada prevalência, frequente associação com morbidade variável e não-específica e em longo prazo, há probabilidade aumentada de aparecimento de complicações graves, incluindo câncer intestinal, osteoporose e infertilidade (SAINSBURY, MULLAN e SHARPE, 2013). Esta doença é uma afecção inflamatória crônica caracterizada por permanente intolerância ao glúten contido no trigo, centeio, cevada e aveia, torna-se necessário que a substituição desses ingredientes seja feita por outras fontes de alimentos que tragam benéficos a saúde, de forma a lhes propiciarem uma melhor qualidade de vida.

No entanto, a restrição absoluta de glúten é difícil e constitui um grande desafio para indústria de alimentos, uma vez que, os rizomas e tubérculos mencionados e seus derivados são matéria-prima para diversos tipos de produtos. Além disso, a farinha obtida do trigo apresenta em sua constituição o glúten, estando presente muitas vezes, em quantidades residuais nos alimentos disponíveis no mercado.

Portanto, o uso das farinhas orgânicas, além de estarem fundamentadas na produção de alimentos saudáveis, são importantes para o desenvolvimento de vários produtos alimentícios, além das propriedades nutricionais e compostos bioativos, presentes em cada uma delas. Sendo assim, o desenvolvimento de produtos com farinhas orgânicas torna-se viável. Além disso, enfatiza-se a diversidade de cultivares orgânicas no desenvolvimento e processamento dos alimentos.

2. Objetivos

2.1 Objetivo Geral

- Obter e caracterizar as farinhas de rizomas e tubérculos de sistema orgânico de produção e determinar suas potencialidades no desenvolvimento de alimentos para celíacos.

2.2 Objetivos Específicos

- Desenvolver e adaptar técnicas de processamento com vistas a desenvolver farinhas orgânicas e determinar a temperatura e tempo de secagem das farinhas orgânicas;
- Determinar a composição centesimal, o teor de minerais e a cor da araruta *cv* comum, araruta *cv* ovo de pata, batata doce *cv* Rosinha de Verdan, batata doce *cv* Capivara, batata doce *cv* cenoura e taro *cv* chinês *in natura* e nas farinhas orgânicas;
- Investigar o potencial antioxidante e os compostos fenólicos totais das amostras; Avaliar o perfil de carotenoides presentes no tubérculo e na farinha de batata doce *cv* cenoura;
- Determinar o perfil de ácidos graxos da batata doce *cv* Capivara *in natura* e avaliar a composição e os teores de fitosteróis nos rizomas e tubérculos orgânicos por cromatografia líquida;
- Investigar as características tecnológicas dos produtos orgânicos por meio do índice de solubilidade, índice de absorção de água, capacidade de absorção de gordura. Além de analisar os amidos por difração de raios X, pela microscopia eletrônica de varredura (MEV) e pelo analisador rápido de viscosidade (RVA);
- Avaliar as propriedades sensoriais dos produtos orgânicos elaborados com essas farinhas e analisar a aceitação desses produtos pelos consumidores e expandir a oferta de alimentos saudáveis, em benefício dos pacientes celíacos.

3. Estrutura da Tese

A Tese está organizada em sete capítulos de acordo com as etapas realizadas na pesquisa. Antes da apresentação dos capítulos dos resultados experimentais, foi estruturada uma Revisão de literatura (Capítulo I) que inclui os aspectos relacionados aos tubérculos e rizomas, à farinha, caracterização morfológica por microscopia eletrônica de varredura, viscosidade de pasta das farinhas, índice de solubilidade em água, índice de absorção de água e capacidade de absorção de gordura, perfil de cristalinidade da farinha por difração de raios-X, propriedades físico químicas, propriedades antioxidantes, alimentos orgânicos e doença celíaca. Cabe destacar, que parte desta Revisão referente aos temas de Certificação de alimentos orgânicos e de Doença Celíaca já se encontram publicados, conforme apresentado no Apêndice da Tese.

No Capítulo II realizou-se análise físico-química e bioativos de rizomas e tubérculos orgânicos.

As análises físico-químicas, antioxidante e propriedades reológicas de farinhas ararutas e taro orgânicas foram estudadas no Capítulo III.

Nos Capítulos IV foi investigado as propriedades físico-químicas, antioxidantes e reológicas de farinhas de batatas doces orgânicas.

No Capítulo V foram estudas as características físico-químicas dos tubérculos e das farinhas obtidas de batatas doces orgânicas. E no sexto e último Capítulo foram estudadas a qualidade microbiológica e a aceitação de *cookies* preparado com farinhas de batatas doces orgânicas.

Capítulo I

Revisão de Literatura

2. Revisão de Literatura

2.1 Alimentos Orgânicos

O consumidor está a cada dia mais preocupado com a qualidade dos alimentos que vão a sua mesa, seja pelas propriedades nutricionais, presença de resíduos tóxicos ou técnicas aplicadas durante o seu processamento. Neste cenário, as correntes de agricultura alternativa, dentre elas a agricultura orgânica, têm experimentado um expressivo aumento na demanda de seus produtos (NASCIMENTO et al., 2015).

Desde a introdução de alimentos orgânicos, suas vantagens e desvantagens têm sido muito debatidas. Os defensores enfatizam os benefícios da agricultura biológica, sob os aspectos econômicos, ambientais e para a saúde (YAZDANPANAH, FOROUZANI e HOJJATI, 2015).

O sistema orgânico de produção agropecuária adota técnicas específicas como a otimização do uso dos recursos naturais e socioeconômicos disponíveis, respeitando a integridade cultural das comunidades rurais, tendo por objetivo à sustentabilidade econômica e ecológica, a maximização dos benefícios sociais, a minimização da dependência de energia não renovável, empregando métodos culturais, biológicos e mecânicos, em contraposição ao uso de materiais sintéticos em qualquer fase de produção (BRASIL, 2003).

Segundo a Instrução Normativa 007/99 do Ministério do Abastecimento, Pecuária e Agricultura (MAPA) (BRASIL, 1999):

> *"o sistema orgânico de produção agropecuária e industrial visa à eliminação do emprego de agrotóxicos e outros insumos artificiais tóxicos, organismos geneticamente modificados (OGM)/transgênicos ou radiações ionizantes em qualquer fase do processo de produção, armazenamento e de consumo, e entre os mesmos privilegiando a preservação da saúde ambiental e humana, assegurando a transparência em todos os estágios da produção e da transformação".*

Desta forma, a produção orgânica (BRASIL, 2003):

- oferece produtos saudáveis isentos de contaminantes intencionais;
- preserva a diversidade biológica dos ecossistemas naturais e a recomposição ou incremento da diversidade biológica dos ecossistemas modificados em que se insere o sistema de produção;
- incrementa a atividade biológica do solo;
- promove o uso saudável do solo, da água e do ar;
- reduz ao mínimo todas as formas de contaminação desses elementos que possam resultar das práticas agrícolas;
- mantém ou incrementa a fertilidade do solo a longo prazo;
- recicla resíduos de origem orgânica, reduzindo ao mínimo o emprego de recursos não renováveis;
- baseia-se em recursos renováveis e em sistemas agrícolas organizados localmente;
- incentiva a integração entre os diferentes segmentos da cadeia produtiva e de consumo de produtos orgânicos e a regionalização da produção e comércio desses produtos;

- manipula os produtos agrícolas com base no uso de métodos de elaboração cuidadosos, com o propósito de manter a integridade orgânica e as qualidades vitais do produto em todas as etapas.

A indústria de alimentos orgânicos está crescendo continuamente em todo o mundo, com a Alemanha como um dos mercados de produtos orgânicos mais importantes da Europa (BRAVO et al., 2013). Dados estatísticos nos EUA indicam que o valor das vendas de varejo de alimentos orgânicos em 2012 foi de cerca de 28 bilhões de dólares, comparado a US$ 6 bilhões em 1999, enquanto o número de agricultores orgânicos aumentou a uma taxa de cerca de 12% ao ano. Assim, o sucesso futuro de qualquer programa orgânico vai depender de como ele é percebido pelo público e se os consumidores aceitam estes produtos (YAZDANPANAH, FOROUZANI e HOJJATI, 2015).

Segundo Marian et al. (2014) a atitude dos consumidores em relação aos alimentos orgânicos é geralmente positiva, com os benefícios normalmente associados ao sabor superior, o respeito pelo meio ambiente, a melhoria à saúde, segurança dos alimentos e um maior bem-estar animal. Entretanto, uma razão frequentemente relatada para não se comprar alimentos orgânicos, foi o preço, uma vez o valor que se paga a este tipo de produto é geralmente maior que ao produto de cultivo convencional.

Pesquisas mostram que a certificação tem sido prática crescente nos últimos anos e esteve vinculada ao aumento do comércio mundial desde a abertura crescente das economias nacionais, à valorização das economias locais e dos produtos de qualidade. Outros fatores cruciais na certificação de produtos agroecológicos e orgânicos é o crescimento substancial do comércio destes bens em nível mundial. Ainda que a produção de ecológicos e orgânicos seja pequena em relação à convencional, ela não é inexpressiva e as transações internacionais crescem significativamente (RADOMSKY, 2009).

Segundo Byé e Schmidt (2001) a construção de um sistema de reconhecimento da qualidade e/ou de autenticidade, que vem coroar a ênfase dada pela mídia à agricultura orgânica (AO) no Brasil, não se distancia de uma parte dos objetivos das macropolíticas anteriores. Os produtos da AO podem tornar-se, na verdade, um objeto de exportação. Ao certificar os produtos da agricultura orgânica, ele encoraja a criação de nichos em mercados protegidos. Ele favorece, entre os agricultores familiares, práticas alternativas às técnicas e às organizações implementadas para agro exportação. Ele constrói, enfim, por esse meio, um novo instrumento de desenvolvimento rural.

No caso da certificação de orgânicos, o organismo certificador tem a função de desenhar um método que seja capaz de minimizar o risco de fraude em um mercado de "bens de crença". Neste sentido, espera-se que o organismo certificador seja responsável perante a lei pelo cumprimento rigoroso do método apresentado a seu credenciador. Daí a importância dada à organização que executa este processo nas normas ISO que tratam da matéria (MEDAETS, 2003). A certificação orgânica tem uma longa tradição em muitos países europeus. Assim, a rotulagem dos produtos com logos de certificação orgânica é uma ferramenta para a sinalização aos consumidores e da garantia de que está comprando um produto que foi produzido de acordo com princípios orgânicos (JANSSEN e HAMM, 2012).

2.2 Rizomas e Tubérculos Orgânicos

Dentre as diversas culturas cultivadas sob o sistema orgânico de produção, destacam os rizomas e tubérculos.

Os tubérculos e rizomas são importantes fontes de carboidratos como fonte de energia e são utilizados como alimentos básicos em países tropicais e subtropicais. Estes produtos possuem componentes nutricionais importantes e benéficos. Destaca-se também que os tubérculos e raízes são isentos de glúten, e estes são uma fonte de carboidratos na forma de amido, que desempenha papel importante no estabelecimento das propriedades de textura de produtos como o macarrão entre outros. Portanto, a utilização de tubérculos no desenvolvimento de produtos como uma fonte de carboidratos, como o amido, isentos de glúten, pode auxiliar na redução da incidência de doença celíaca ou outras reações alérgicas (NJINTANG et al., 2008).

2.2.1 **Araruta** (*Maranta arundinaceae* L.)

A araruta (*Maranta arundinaceae* L.) é uma planta proveniente da América Latina e se encontra de forma nativa nas matas venezuelanas. O tamanho dos rizomas oscila entre 10 e 25cm, são de forma fusiforme, alongados e apresentam pequenos segmentos, separados entre si por leves estrangulamentos providos de escamas. Três são os cultivares de importância no Brasil, a creoula, a banana e a comum, que é a mais difundida comercialmente. A variedade comum é a que produz fécula de melhor qualidade. Seus rizomas são claros, em forma de fuso, cobertos por escamas e atingem até 30 centímetros dependendo da qualidade do solo, embora o tamanho normal varie de 10 a 25 centímetros (LEONEL, CEREDA e SARMENTO, 2002).

A creoula é originária das Antilhas (Ilhas Barbados e Saint Vincent), é uma planta de porte alto (superior a 1,0 m), com rizomas na superfície do solo, em touceiras, que precisam ser lavados várias vezes para perder a camada superficial, caso contrário produz fécula negra e de baixa qualidade. Apresenta florescimento abundante nas condições tropicais, sem contudo, haver formação de frutos e sementes (HEREDIA ZÁRATE e VIEIRA, 2005).

A araruta pode ser considerada como uma matéria-prima não convencional para a extração de amido, sendo considerados como uma fonte potencial de amido. A araruta possui baixo teor de proteína, gordura, cinzas e composição de fibra, com dimensão de partícula entre 4 e 42 um e com uma temperatura de gelatinização entre 68 e 75 °C (VALÊNCIA et al., 2014).

Possui um amido com boa digestibilidade, que não contém glúten e se encontra quase extinto no Brasil. No Recôncavo Baiano, a cultura vem sendo resgatada junto aos agricultores familiares, com o objetivo de incentivar o plantio, consumo e comercialização da fécula, que pode ser usada em várias receitas de alimentos. Apesar dos avanços e boas perspectivas, muitos desafios ainda precisam ser vencidos, como melhoria nas práticas de beneficiamento, criação de maquinários apropriados e organização dos agricultores. Além de reforçar a segurança alimentar, essa atividade contribui para a fixação das famílias no meio rural, aumentando as possibilidades de geração de emprego e renda (SILVEIRA et al., 2013).

Além disso, de acordo com Swadija, Padmanabhan e Vijay (2015) o amido de araruta pode ser usado para a preparação de vários produtos de panificação e na

preparação de refeições. O amido de araruta pode ser utilizado no tratamento de desordens intestinais, o que acrescenta valor medicinal ao produto. Há uma grande demanda para a fécula de araruta não só no mercado interno, mas também para exportação para os países do Golfo, principalmente, como um alimento para lactentes e inválidos.

A importância do amido de araruta está relacionada às características especiais de seu amido, o qual alcança preços elevados no mercado internacional. Sendo que a produção mundial da araruta é pequena, encontrando-se cultivos comerciais. A importância da araruta está muito relacionada com as características culinárias peculiares do seu amido. O preço alcançado pelo amido de araruta, no mercado internacional, é mais elevado que os similares, e é grande o interesse das indústrias do setor alimentício (LEONEL, OLIVEIRA e DUARTE-FILHO, 2005; MONTEIRO e PERESSIN, 2002).

Com relação à composição centesimal, Pérez, Lares e Gonzales, (1997) analisando os amido de araruta cultivados na Venezuela obtiveram 1,10% de proteína, 1,20% de matéria graxa, 0,57% de cinzas, 1,51% de fibras, 15,74% de carboidratos totais, 79,88% de umidade e pH 6,9.

Estudo realizado por Pérez e Lares (2005) avaliou algumas características químicas, minerais, funcional e propriedades reológicas da araruta, produzidas nos Andes venezuelanos. Observou que a araruta apresentou teor de fibra crua, gordura, e conteúdo de amilose altos ($p<0.05$), além de fósforo, sódio, potássio, magnésio, ferro, cálcio e zinco. Sendo que o conteúdo de fósforo, sódio, e potássio foram mais elevados.

2.2.2 Taro (*Colocasia esculenta*)

O taro (*Colocasia esculenta* (L.) Schott) é um dos tubérculos comestíveis mais amplamente cultivado em países tropicais e subtropicais. Em 2009, cerca de 11,3 milhões de toneladas métricas (MMT) de taro foram produzidos em todo o mundo. O rendimento médio mundial de taro foi de 6,2 toneladas/hectare (ZENG, LIU e LIU, 2014).

Embora esta cultura seja cultivada em muitas áreas do mundo, existe uma grande perda (cerca de 30%) durante o seu armazenamento. Transformando os tubérculos de taro em amido podem-se minimizar essas perdas e agregar valor ao produto (DAI et al., 2015). Seus tubérculos contém uma quantidade razoável de cálcio, fósforo, vitamina A e do grupo B, vitaminas. O teor de proteína e fibra dietética da parte comestível também são elevados em comparação a outras culturas de raízes e tubérculos (SIT et al., 2014).

A farinha de taro é muito utilizada no processamento de alimento infantil nos EUA, e na a obtenção de bolos, pão e vários alimentos em países como Philipinas, Colômbia, Brasil e Indonésia (ELISABETH, 2015). De acordo com Tagodoe e Nip, (1994) as farinhas de taro apresentaram baixo teor de gordura, proteína e cinzas, mas alto teor de amido e fibra alimentar total.

O taro foi reportado por apresentar de 70-80% de amido com pequenos grânulos e, por conseguinte, apresenta uma alta digestibilidade. Verificou ser viável a sua utilização na preparação de alimentos para lactentes e as dietas de pessoas alérgicas a cereais e crianças sensíveis ao leite e outras aplicações industriais (NJINTANG, SCHER e MBOFUNG, 2008; SIT et al., 2014; TEMESGEN, 2015). Além disso, o amido de taro é sem glúten e indicado para úlcera péptica, doenças crônicas de fígado, doença inflamatória intestinal e doenças da vesícula biliar (TEMESGEN, 2015).

O taro apresenta uma elevada perda de pós-colheita, devido ao seu elevado teor de umidade. Apesar de sua importância nutricional, industrial e para a saúde, não tem sido dada a devida atenção a pesquisas direcionadas ao taro, a fim de reforçar o seu potencial (NJINTANG, SCHER e MBOFUNG, 2008).

2.2.3 Batata Doce (*Ipoema batatas*)

A batata doce (*Ipomoea batatas* (L.) Lam.) pertence à família das Convolvuláceas, sendo uma das plantas alimentares mais antigas do Brasil. O cultivo da batata doce está distribuído por todo o país, o que se deve, além da riqueza nutricional, à capacidade de produção em solos fracos, à baixa incidência de pragas ou de doenças limitantes e à baixa exigência em manejo. A batata doce tem utilização culinária doméstica ou serve como matéria-prima para processos industriais, na obtenção de doces, farinhas, flocos e fécula. No Brasil, a utilização industrial da batata doce ainda é restrita, consumindo-se na forma cozida, principalmente na região Norte. Por ser uma raiz tuberosa com elevado teor de fécula, tem potencialidade de ser cultivada para fins industriais (ROESLER et al., 2008).

É uma das culturas econômicas mais importantes em muitos países tropicais e subtropicais da Ásia, África e América Latina (GUO et al., 2014). De acordo com os dados das Nações Unidas para Agricultura e Alimentação, a batata-doce é cultivada em 114 países, sendo que a China se destaca como o maior produtor do mundo, alcançando 77,3 milhões ton. / Ano e a Nigéria, com 34,0 milhões de ton. / Ano (FAOSTAT, 2015).

A contribuição da batata-doce em relação à saúde é reconhecido devido ao seu alto teor de nutrientes e prevenção de doenças, possuindo propriedades anticancerígenas e cardiovasculares. Quase todos as cultivares de batata-doce são excelentes fontes de vitamina C, B2, B6 e E, bem como fibras dietéticas, potássio, cobre, manganês e ferro, e estão baixo teor em gordura e colesterol (SHEKHAR et. Al., 2015).

Sendo que o principal componente da batata doce é o amido (66,8-78,5%) seguido pelos açúcares solúveis (8,2-15,3%), sacarose, glicose, frutose, maltose (LEONEL, OLIVEIRA e DUARTE-FILHO, 2005; OLIVEIRA et al., 2005). As fibras dietéticas insolúveis representam 6,17 a 7,69% do total de matéria seca (LEONEL, OLIVEIRA e DUARTE-FILHO, 2005).

Na indústria de alimentos, o amido é utilizado para melhorar as propriedades funcionais, sendo empregado em sopas, molhos de carne, como formador de gel em balas e pudins, estabilizante em molhos de salada, na elaboração de compostos farmacêuticos, na produção de resinas naturais e na elaboração de materiais termoplásticos biodegradáveis (OLIVEIRA et al., 2005).

De acordo com Nascimento (2006) a composição centesimal média da batata doce é de 70% de umidade, 28% de carboidratos, 2,6% de fibras, 1% de proteína, 0,9% de cinzas e traços de lipídios. Os teores médios de cálcio, magnésio, fósforo e potássio são de 21, 17, 36, 340 mg/100g, respectivamente.

A batata doce exibe muitas funções dietéticas benéficas e funcionais, como polifenólicos, antocianinas, β-caroteno, vitaminas e fibra, porém, apresenta baixo conteúdo de proteína (normalmente 4,5-7,0% em uma base seca). A presença de inibidores, como tripsina, diminui a digestibilidade da proteína em raízes armazenadas cruas. Ambas as cultivares diferem em relação ao conteúdo de proteína e na atividade inibidora de tripsina (TOYAMA, YOSHIMOTO e YAMAKAWA, 2006).

Iwe et al. (2001) avaliaram o teor de aminoácidos da farinha de batata doce e verificou que ela apresentou altos valores de ácido glutâmico, seguido ácido de ácido aspártico, leucina, entre outros, como prolina, arginina, lisina e valina.

Algumas variedades de batata doce, especialmente as variedades de batata-doce de polpa alaranjada, contêm quantidades significativas de β-caroteno, amido, fibra dietética, minerais, vitaminas (especialmente vitaminas C, B6 e folato), bem como antioxidantes, tais como os ácidos fenólicos, antocianinas, tocoferol e (WU, 2008). A batata doce de polpa alaranjada contém β-caroteno, responsável por conferir atividade pró-vitamina A, que contribui para a prevenção da catarata e degeneração macular relacionada à idade (AHMED, SORIFA e EUN, 2010a; PADMAJA, 2009).

A biofortificação da batata doce alaranjada está sendo utilizada com a intenção de controlar a deficiência de vitamina A em países em desenvolvimento. Isto devido ao fato do caroteno provitamina ser predominantemente encontrado na batata doce, além de ser mais biodisponível do que na cenoura. No Quênia ocidental, por exemplo, onde deficiência de vitamina A é um problema de saúde pública e a batata doce branca por ser uma comida secundária importante, a batata doce alaranjada foi introduzida na alimentação e seu consumo promoveu uma alimentação rica em vitamina A (HAGENIMANA et al., 2001).

O teor de β-caroteno encontrado em 28 variedades de batata doce dos Estados Unidos avaliados por Simonne et al., (1993) variou de traços a 190μg/g em base seca, sendo que oito das variedades apresentaram concentrações menores que 1μg/g, doze entre 1 e 50μg/g, seis entre 51 e 100μg/g, e apenas duas, mais do que 100 μg/g. Batatas doce de 11 diferentes estádios de maturação e origem, analisadas na Indonésia, apresentaram teor de β-caroteno de 58 ± 70μg/100g (HULSHOF et al., 1997). Os conteúdos de β-caroteno de 18 variedades de batatas com diferentes colorações de polpa, cultivadas no Havaí, variaram de 67 a 131 μg/g nas batatas doce de polpa laranja (7 variedades), de traços a 3μg/g nas de polpa amarela e branca (7 variedades) e de traços a 5μg/g nas de polpa roxa (4 variedades) (HUANG, TANUDJAJA e LUM, 1999). K'osambo et al., (1998) reportaram teores de carotenoides totais na faixa de traços a 88μg/g e teores de β-caroteno na faixa de traços a 80μg/g para 17 cultivares de batata doce cultivadas no Kenia.

Assim, o uso da batata doce, principalmente a de polpa alaranjada surge como alternativa de suplementação alimentar de vitamina A, devido à presença abundante de β-caroteno na mesma (RODRIGUEZ-AMAYA, 2004).

2.3 Farinhas

De acordo com a Legislação brasileira, farinhas são os produtos obtidos de partes comestíveis de uma ou mais espécies de cereais, leguminosas, frutas, sementes e rizomas, por moagem e outros processos tecnológicos considerados seguros para a produção de alimentos (BRASIL, 2005).

O tratamento térmico tem numerosas aplicações, é uma valiosa ferramenta para prolongar o prazo de validade dos alimentos processados na obtenção de farinhas, através da redução da atividade da enzima e da umidade (BUCSELLA et al., 2016).

Além disso, a farinha é um dos produtos intermédios propostos, porque é fácil de ser armazenada, pode ser produzida de um único produto tal como arroz, tapioca, ou composta de mistura de trigo com outro tubérculo ou cereal, além disso, a farinha pode ser fortificada. A vantagem do processamento de farinha é a sua flexibilidade para a

indústria de alimentos, com uma distribuição segura e economia no armazenamento. O desenvolvimento de vários produtos da agroindústria, como a farinha, em nível rural é esperado para melhorar a cada vez mais a mercadoria (ELISABETH, 2015).

As farinhas são, sem dúvida, o produto com amplas aplicações. Podem ser armazenadas por períodos de tempo variáveis, de preferência, armazenadas em sacos, em salas com refrigeração e escura. O produto possui uma vida de prateleira de 3 à 9 meses após a moagem, podendo chegar de 9-15 meses. Embora estes prazos possam ser úteis, o prazo de validade real pode ser maior ou menor dependendo da temperatura e umidade durante o armazenamento e as características exigidas do produto final pela indústria de farinhas (MELLADO-ORTEGA e HORNERO-MÉNDEZ, 2016).

Os tubérculos, raízes e caules são comumente convertidos em farinha para preservá-los. Estas farinhas são utilizadas como ingredientes e/ou auxiliares no processamento na indústria de alimentos, sendo que o principal constituinte dessas farinhas obtidas a partir de tubérculos, raízes e caules é amido. O amido é o principal carboidrato de raízes, variando de 73,7% a 84,9%. O uso desses amidos como condicionadores de massa na fabricação de pão, estabilizadores em sorvetes, e espessantes em sopas e molhos tem sido relevante (ZAIDUL et al., 2008).

Dentre as culturas não convencionais que apresentam potencial para o fornecimento do farinhas ricas em amido, destacam-se a araruta (*Maranta arundinaceae*), a batata doce (*Ipomoea batatas* L.) e o taro (*Colocasia esculenta* (L.) Schott). O amido de araruta é um dos amidos nativos produzidos a partir do tubérculo de araruta (*Maranta arundinaceae*) com características únicas (WINARTI et al., 2014).

O amido de araruta tem baixo teor de proteína, gordura, cinzas e de fibra (VALENCIA et al., 2014). De acordo com Swadija, Padmanabhan e Vijay (2015) o amido de araruta pode ser usado no desenvolvimento de vários produtos de panificação e na preparação de refeições.

As farinhas de batata doce de polpa alaranjada pode ser um produto alimentar com alto teor nutricional. As raízes frescas não podem ser armazenada durante mais de três meses sob temperatura ambiente. O processamento das raízes em farinhas pode estender a vida útil da batata doce por mais de três meses (AMAJOR et al., 2014).

De acordo com Menon, Padmaja e Sajeev (2015) a farinha de batata doce é menos onerosa do que o seu amido. Além disso, macarrão feito de amido tem baixo valor nutricional e funcional, uma vez que o amido é o ingrediente maioritário, ao contrário da farinha que tem um teor de fibra dietética de 2-3%.

Esta farinha pode ser utilizada como um agente espessante em sopa, molho, na fabricação de aperitivos, e produtos de panificação. A farinha de batata doce também pode servir como um substituto para farinhas de cereais, especialmente para os indivíduos diagnosticados com a doença celíaca. Pode também ser utilizada para melhorar os produtos alimentares através da cor, sabor, doçura natural, e suplementação de nutrientes (AHMED, AKTER e EUN, 2010b). Iwe et al. (2001) avaliaram o teor de aminoácidos da farinha de batata doce e verificou que ela apresentou altos valores de ácido glutâmico, seguido ácido de ácido aspártico, leucina, entre outros, como prolina, arginina, lisina e valina.

A farinha de taro é muito utilizada no processamento de alimento infantil nos EUA, e na a obtenção de bolos, pão e vários alimentos em países como Philipinas, Colômbia, Brasil e Indonésia (ELISABETH, 2015). De acordo com Tagodoe e Nip, (1994) as farinhas de taro apresentaram baixo teor de gordura, proteína e cinzas, mas alto teor de amido e fibra alimentar total.

A indústria de alimentos está interessada na utilização de farinhas de leguminosas para a melhoria da qualidade nutricional dos alimentos à base de cereais

(VANNICE e RASMUSSEN, 2014). Portanto, farinhas obtidas a partir de fontes alternativas, como a batata doce, taro e ararutas e outros tubérculos, são potenciais substitutos da farinha de trigo, acrescentando variedade e funcionalidade ao produto (NJINTANG et al., 2008).

2.4 Caracterização Morfológica por Microscopia Eletrônica Varredura (MEV)

Desde as primeiras descobertas do microscópio, pesquisadores têm examinado a microestrutura dos alimentos. No processamento ocorrem alterações na estrutura do alimento. Nos últimos anos, porém, o estudo da microestrutura de alimentos tem assumido uma importância crescente pelas indústrias de alimentos, visando criar novos produtos para satisfazer as demandas nutricionais e o consumidor (JAMES, 2009).

A microscopia eletrônica é uma das ferramentas mais utilizadas para avaliar a microestrutura de alimentos. A Microscopia Eletrônica de Varredura (MEV) foi recentemente aplicada à ciência dos alimentos para a análise de alimentos processados, fritos e produtos congelados, para a investigação de substâncias estranhas, como pedras, metais, sujidade e do solo, insetos e para a elucidação das interações entre o medicamento e o recipiente (TAGLIENTI et al., 2011).

O microscópio eletrônico de varredura fornece informações estruturais de uma amostra. As medições da massa podem ser realizadas rotineiramente sobre uma variedade de estruturas moleculares e supramoleculares utilizando feixes de elétrons (ENGEL e COLLIEX, 1993).

O desenvolvimento de novas técnicas de microscopia permite o estudo da morfologia e estrutura interna de grânulos de amido, sem a utilização de métodos de preparação de amostras complexas ou invasiva, abrindo, novas possibilidades para avaliação do produto (MIRA, VILLWOCK e PERSSON, 2007).

As características morfológicas de amidos provenientes de fontes diferentes de plantas variam de acordo com as práticas do genótipo e cultural. A variação no tamanho e forma dos grânulos de amido é atribuída à origem biológica, sendo que a morfologia dos grãos de amido depende da bioquímica do cloroplasto ou amiloplastos, como a fisiologia da planta. As estruturas granulares de amidos de batata, milho, arroz e trigo mostram variações significativas no tamanho e forma, quando visualizados por MEV (SINGH et al., 2003).

Os grânulos de amido de milho são em forma angulares, e os grãos de arroz em forma pentagonal e angulares. Por outro lado, os grânulos de amido de tipo B são esféricos ou em forma poligonal, que varia de 1 a 10µm de diâmetro (SINGH et al., 2003).

Zhang e Oates (1999) avaliaram os grânulos de amido de seis variedades de batata doces e verificaram que as mesmas foram morfologicamente semelhantes, sendo que os grânulos apresentaram forma arredonda ou oval, com dimensões características que variaram de 2,1-30,7 µm.

Srikaeo et al. (2006) investigaram as mudanças de microestrutura de amido em grãos de trigo mole e duro após o cozimento em panela de pressão por meio de um microscópio eletrônico de varredura e um microscópio de luz polarizada. As condições estudadas incluíram variação dos tempos de cozimento (20-120 min) à temperatura constante (120°C) e com temperaturas variáveis (110-140°C) para a constante de tempo (40 min). Este estudo mostrou que a MEV pode ser usada para observar os grânulos de amido em grão inteiro sem a necessidade de isolamento de amido. Embora, as imagens

de MEV não sejam tão claras como as realizadas na avaliação do amido isolado ou puro, eles forneceram padrões semelhantes. Observou-se que a MEV proporcionou uma visão clara das mudanças de grânulos de amido intactos em grãos de trigo cozidos.

2.5 Determinação da Viscosidade de Pasta de Farinhas

O conhecimento do comportamento reológico dos ingredientes alimentares (tais como a viscosidade de pasta de amidos) é importante para otimizar a aplicabilidade, estabilidade e propriedades sensoriais dos produtos finais (WANG et al., 2012).

As propriedades de pasta de amido são sensíveis ao calor e taxa de cisalhamento. O intumescimento dos grânulos de amido acima da temperatura de gelatinização abre e enfraquece a estrutura dos grânulos, resultando num aumento na viscosidade da pasta e causa danos durante o cisalhamento dos grânulos de amido. O grau de inchaço e a integridade dos grânulos estão diretamente relacionados com a viscosidade da pasta de amido (BHANDARI, SINGHAL e KALE, 2002).

Na indústria alimentar, a viscosidade alta, é uma grave limitação em amidos modificados em altas concentrações (LIU, HONG e GU, 2015). De acordo com Nascimento et al. (2007) os amidos nativos apresentam valores iniciais de viscosidade baixa, em consequência de serem insolúveis em água fria, enquanto, que os amidos termicamente tratados mostram um valor inicial de viscosidade elevado devido à tumescência irreversível dos grânulos de amido, devido ao seu grau de pré-gelatinização.

Perfis de viscosidade de pasta são ferramentas importantes para representar as propriedades funcionais do amido (SULAIMAN e DOLAN, 2013). Em muitas aplicações, o desempenho dos produtos de amido depende de suas propriedades funcionais, que são determinados em grande parte por suas características reológicas (NGUYEN, JENSEN e KRISTENSEN, 1998), sendo amplamente utilizada como ingrediente para melhora a textura de vários alimentos processados devido às propriedades de viscosidade de pastas do amido (WOKADALA, RAY e EMMAMBUX, 2012).

As propriedades de pasta constituem de base para a utilização de amido e de farinha na preparação de recheios, molhos, cremes e sobremesas lácteas e outros produtos, sendo que, farinhas com os maiores graus de gelatinização mostram um poder de espessamento maior em líquidos frios (MARTÍNEZ et al., 2015).

2.6 Determinação do Índice de Solubilidade em Água, Índice de Absorção de Água e Capacidade de Absorção de Gordura

A funcionalidade de um ingrediente está relacionada com suas características físico-químicas mais relevantes, que exercem grande influência nos processos de elaboração, estocagem, qualidade e aceitação de um alimento (CHAUD e SGARBIERI, 2006).

A aceitação de um ingrediente pela indústria de alimentos não está condicionada apenas às suas qualidades nutricionais, mas também, entre outros fatores, às suas propriedades funcionais que desempenham papéis decisivos. A solubilidade e absorção de água e a capacidade de absorção de gordura são propriedades funcionais importantes

nas formulações de alimentos como produtos cárneos, maionese, molhos, sopas e outros (WANG et al., 2001).

O índice de solubilidade em água está relacionado com a quantidade de sólidos solúveis, o qual é frequentemente é usado como uma indicação de degradação das moléculas de amido e dextrinização (GUHUA, ALI e BHATTACHARYA, 1998; DOGAN e KARWE, 2003). O aumento da solubilidade é atribuído à dispersão das moléculas de amilose e amilopectina como consequência da gelatinização, quando as condições são mais brandas, e à formação de compostos de baixo peso molecular, quando as condições são mais drásticas (COLONNA et al., 1984).

De acordo Carvalho, Ascheri e Vidal (2002) o Índice de Absorção de Água (IAA) está relacionado à disponibilidade de grupos hidrofílicos (–OH) em se ligar às moléculas de água e à capacidade de formação de gel das moléculas de amido. Somente os grânulos de amido gelatinizados absorvem água em temperatura ambiente e incham.

A absorção de água é uma propriedade importante em produtos de panificação, como bolo, pães e também em produtos cárneos (PORTE et al. 2011). A capacidade de absorção de água das farinhas desempenha um papel importante no processo de preparação de alimentos porque influencia outras propriedades funcionais e sensoriais. Além disso, o intervalo de aplicação de farinhas como ingredientes alimentares depende, em grande medida, na sua interação com água (SREERAMA et al., 2012).

A absorção de água é uma propriedade relevante para aplicações em produtos cárneos e de panificação, como pães e bolos (WANG et al., 2009). Segundo James e Sloan, (1984) valores altos de absorção de água são importantes para ajudar a manter a umidade desses produtos, pois permite a adição de maior quantidade de água aos mesmos, mantendo, assim, as características dos produtos frescos.

A capacidade de absorção de gordura tem grande importância na formulação de alimentos, podendo influenciar na ordem de adição dos ingredientes secos na mistura, além de ser usado para determinar os tempos de mistura utilizando uma distribuição uniforme do óleo ou gordura na mistura seca (NASCIMENTO e WANG, 2013).

A capacidade de absorção de gordura é uma propriedade funcional importante das farinhas (KINSELLA, 1976). De acordo com Sathe et al. (1982) a capacidade de absorção de gordura da farinha de leguminosas é muito importante para melhorar a textura e manter o sabor de produtos alimentícios.

Silva et al. (2008) analisaram o índice de absorção de água (IAA) em macarrões pré-cozidos por extrusão, elaborados a partir de farinha mista de arroz integral e milho e verificaram que variou de 2,06 a 6,18. De acordo com estes autores as massas comerciais apresentam em média um IAA de 2,06 e 3,13 g/g gel. De acordo com Leonel et al. (2006) os valores de IAA de produtos expandidos de inhame variaram de 6,5 a 16,4 g/g gel, sendo que a farinha de inhame não extrudada apresentou em média 3,03 g/g gel

Wang et al. (2009) verificara a capacidade de absorção de gordura (AG) das farinhas de trigo e soja (80:20) extrudadas e observaram que variou de 81,59% a 97,72%. Sendo que a absorção de gordura da farinha de trigo crua foi de 68,51.

Altos valores de absorção de gordura são interessantes em produtos como extensores de carnes, visando melhorar a sensação na boca, bem como o desenvolvimento de sopas, queijos processados e massas alimentícias (WANG et al., 2007).

2.7 Determinação do Perfil de Cristalinidade das Farinhas por Difração de Raios X

A difração de raios X é uma técnica que é largamente utilizada para estudar a estrutura do amido. As correntes paralelas moleculares no grânulo parecem ser arranjados com uma regularidade de estrutura que ultrapassa a de uma simples orientação molecular, uma vez que os grânulos de amido difratam raios-X. Em outras palavras, as cadeias paralelas ocasionalmente têm arranjos cristalinos em regiões locais de tamanho submicroscópico, que fazem com que difração de raios X de uma abordagem adequada para estudar o amido (DÜNDAR, TURAN e BLAUROCK, 2009).

A natureza cristalina do amido tem sido estabelecida por muitas décadas. De acordo com a sua estrutura cristalina, amidos nativos podem ser agrupados em três tipos: tipo A (amidos de cereais: milho, trigo, etc.), tipo B (frutas e tubérculos amidos: batata, etc.) (LIU et al., 2015). O padrão do tipo C (amidos de vagem: ervilha, etc.) é menos frequente, e encontrado em alguns legumes e rizomas (KUBO et al., 2008; WANG et al., 2008).

Os diferentes graus de ordem estrutural dos grânulos são responsáveis pelas propriedades de birrefringência e cristalinidade. A birrefringência óptica e as propriedades de difração de raios X fornecem uma ampla evidência de uma estrutura ordenada do grânulo de amido. Esta estrutura dos grânulos é constituída por camadas concêntricas que podem ser observadas em imagens de microscópio electrônico. A cristalinidade dos grânulos é descrita principalmente como uma função de dupla hélice formada pelos ramos de amilopectina, que varia entre 15 e 45% de cristalinidade. A estrutura cristalina é classificada de acordo com o seu perfil de um difratograma de raios-X. Padrões conhecidos como tipos A, B e C representam os ângulos de difração específicos causados pela dupla hélice das cadeias ramificada de amilopectina (ZAVAREZE e DIAS, 2011).

O padrão de cristalinidade é definido com base nos espaços interplanares e na intensidade relativa das linhas de difração de raios-X. A forma polimórfica do tipo C é considerada um arranjo intermediário entre os tipos A e B. O padrão A é uma característica dos amidos de cereais, padrão B é característico dos amidos de tubérculos, frutas e produtos com alto teor de amilose, como o amido de milho, e o padrão C é característico de amido de leguminosas. Amilose, quando complexado com compostos orgânicos, água ou iodo, pode aparecer como padrão tipo V (ZAVAREZE e DIAS, 2011).

De acordo com Cereda et al. (2002) o padrão do tipo A apresenta picos com mais intensidade em 2θ de 15, 17, 18 e 23° e do tipo B em 5,6; 15, 17, 19, 20, 22 e 23°. No entanto, para Hoover (2001) o padrão tipo B é típico de tubérculos e raízes e de amido é caracterizado por picos largos e menores e com duas reflexões principais centrados em 5,5 e 17° 2θ.

De acordo com Moura (2008) o padrão A apresenta picos fortes nos espaços interplanares de 5,8; 5,2 e 3,8º. Para o padrão B um pico forte está entre 15,8 e 16,0 16º, um pico com menor intensidade e mais largo a 5,9 2θ e outro a 5,2º, e um par de picos com intensidade de média a forte em 4,0-3,7º, sendo que o padrão C é semelhante ao padrão A e apresenta um pico a mais em 16º. Para Santos (2009) no padrão V os picos aparecem em 12,0; 6,8 e 4,4 Å, o pico de 4,4 Å é normalmente usado como a primeira indicação de que o complexo V está sendo formado.

O padrão de difração de raios-X para os amidos pode ser afetado pela condições de crescimento e maturidade da planta no momento da colheita. Estes efeitos podem ser mais prejudiciais para amidos do tipo C, porque eles são referidos como sendo uma

mistura de A e B do tipo polimorfos cristalinos. Amidos do tipo A contêm comprimentos de ramificação de cadeia média e mais curtas de amilopectina, ao passo que amidos do tipo B contêm comprimentos de ramificação de cadeia média mais longa. Os amidos do tipo C amidos, contêm amilopectina com longas ramificações e de cadeia curtas (MCPHERSON e JANE, 1999).

Sendo que a cristalinidade do amido afeta as propriedades físicas, mecânicas e tecnológicas de inúmeros produtos à base de amido, e é, portanto, relevante para o controle de qualidade do produto, desenvolvimento e processo. Em alimentos, a perda de cristalinidade nativa via gelatinização influencia as características aparentes de gelificação, viscosidade e formação de matriz, enquanto que o reordenamento do amido durante o processamento ou armazenamento do produto tem impacto na textura, estabilidade, qualidade, digestibilidade e na funcionalidade. Em aplicações farmacêuticas, amido pode ser utilizado como excipiente. Um certo grau de cristalinidade é desejado para o amido manter a liberação do fármaco específico e outras propriedades funcionais. Na formulação de comprimidos, por exemplo, alterações na cristalinidade podem ocorrer durante o processo de produção, tais como a secagem, o revestimento de granulação, moagem, compressão e devido à sua exposição ao *stress* mecânico, mudanças de temperatura, e os níveis de umidade diferentes. Amorfização ou transformação cristalina pode também ocorrer durante o armazenamento. As variações podem modificar propriedades tais como compressibilidade ou fluidez ou induzir mudanças na dissolução, solubilidade ou a biodisponibilidade do ingrediente ativo (MUTUNGI et al., 2012; VELASQUEZ et al., 2015).

Segundo Klauss (1997) a liberação controlada de fármaco ocorre quando um fármaco combinado com um polímero (natural ou sintético) é liberado de uma maneira pré-determinada. No processo de liberação do fármaco por intumescimento, as matrizes hidrofílicas absorvem água, liberando o fármaco da superfície da matriz polimérica e, consequentemente, sofrem intumescimento/relaxamento das cadeias poliméricas, formando uma camada gelatinosa de polímero (estado maleável). À medida que a água hidrata o núcleo seco, a camada exterior gelificada pode sofrer erosão por solubilização parcial ou total do polímero (erosão física). A penetração da água faz com que as cadeias do polímero se afastem, promovendo a difusão do fármaco.

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2.8 Caracterização Físico-química das Farinhas

As características físico-químicas, tecnológicas e sensoriais das matérias-primas e produtos processados são fatores importantes no planejamento, processamento, comercialização e consumo de produtos alimentícios. Sob os pontos de vista da nutrição e de saúde, o conhecimento da composição e funcionalidade dos alimentos forma o pilar da educação nutricional, adequando a ingestão de nutrientes ou componentes funcionais pelos indivíduos ou populações, visando a promoção e manutenção da saúde (BORGES et al., 2011).

Os carboidratos são a principal fonte de energia dos seres vivos. A glicose é usada como combustível pelas células, e o cérebro é quase inteiramente dependente dela para realizar as suas funções, incluindo o pensamento (SILVA e PALEZI, 2015).

Sendo que o amido é o principal carboidrato de reserva de energia sintetizado e armazenado em muitas partes de plantas e representa o segundo biopolímero mais abundante na terra, após a celulose. Desempenha um papel importante como material funcional para as indústrias tanto de alimentos como as demais indústrias, e serve como uma fonte essencial de energia para a alimentação humana e animal (SCHIRMER et al., 2013).

As proteínas de alto valor biológico e de melhor digestibilidade são encontradas em primeiro lugar no leite humano e depois nos produtos de origem animal (carnes em geral, leites e derivados e ovos). A dieta à base de vegetais também pode fornecer proteínas de boa qualidade, desde que contenha quantidade suficiente e combinação apropriada de vegetais (DIAS, FREIRE e FRANCESCHINI, 2010).

As proteínas são, talvez, o indicador mais sensível da qualidade dos alimentos. Isto não se aplica apenas à questão relevante de impedir a adulteração de alimentos e fraude, mas também pela apreciação dos ingredientes frescos, processamento e manuseamento correto, e armazenamento adequado (BONOMI et al., 2015).

Os lipídios possuem um papel fundamental na alimentação humana. Além de fornecerem calorias, agem como veículo para as vitaminas lipossolúveis, como A, D, E e K . Também são fontes de ácidos graxos essenciais como o linoleico, linolênico e araquidônico e contribuem para a palatabilidade dos alimentos (CASTRO et al., 2004).

A ingestão de lipídios tem sido o principal foco de recomendações dietéticas, com maior ênfase o impacto dos ácidos graxos na saúde. De acordo com a posição da *Academy of Nutrition and Dietetics*, a ingestão total de lipídios na dieta deve ser de 20% a 35% de energia, com um aumento do consumo de n-3, ácidos graxos poliinsaturados e ingestão limitada de gorduras saturadas e *trans* para a população adulta saudável (VANNICE e RASMUSSEN, 2014).

A fibra da dieta é definida como a parte não digerível do alimento vegetal a qual resiste à digestão e absorção intestinal, porém com fermentação completa ou parcial no intestino grosso. Podem ser classificadas em fibras solúveis e insolúveis. As fibras solúveis incluem as pectinas, gomas, mucilagens como *psillium*, um polissacarídeo viscoso. Entre as fibras insolúveis estão à celulose, as hemicelulose e a lignina (MONTEIRO e NASCIMENTO, 2014).

A FAO/OMS recomenda o consumo de no mínimo 25 g/dia na dieta a fim de auxiliar na prevenção do aparecimento de doenças crônicas relacionadas à dieta. Estudos epidemiológicos sugerem que as fibras dos cereais e produtos à base de grãos integrais são capazes de prevenir a obesidade e o ganho de peso, além de contribuírem na diminuição do risco de desenvolvimento de *diabetes Mellitus* (MELLO e LAAKSONEN, 2009).

A fibra dietética diminui o risco de *diabetes mellitus* tipo 2, doenças cardiovasculares e câncer do cólon, reduzindo a digestão e absorção de macronutrientes e diminuindo o contato tempo de carcinógenos dentro do lúmen intestinal. Além disso, o *Food and Drugs Administration (*FDA) aprovou alegações de saúde, apoiando o papel da fibra dietética na prevenção de câncer e doenças cardíacas (KACZMARCZYK, MILLER e FREUND, 2012).

O conteúdo em cinzas em um alimento representa o conteúdo total de minerais podendo, portanto, ser utilizado como medida geral da qualidade, e frequentemente é utilizado como critério na identificação de alimentos. O conteúdo em cinzas se torna importante para os alimentos ricos em certos minerais, o que implica em seu valor nutricional (KRUMREICH et al., 2013). Altos teores de cinzas nos alimentos indicam grandes quantidades de K, Na, Ca e Mg (BAMBI et al., 2010).

2.9 Determinação das Propriedades Antioxidantes de Farinhas

O estresse oxidativo é o resultado do desequilíbrio entre o sistema de defesa antioxidante e a formação de espécies reativas de oxigênio (EROS) (SUN et al., 2011). O dano oxidativo é considerado por desempenhar um papel central na ocorrência de várias doenças humanas, incluindo a doença de *Alzheimer*, doença de *Parkinson*, cancro, cataratas, aterosclerose, doenças cardiovasculares, entre outros (VALKO et al., 2007). Os antioxidantes eliminam as espécies reativas de oxigênio, como radical, radical hidroxila peróxido de hidrogênio e superóxido, resultando na inibição de iniciação e propagação de etapas, e prevenir ou retardar a oxidação. Portanto, muita atenção tem sido dada em busca de antioxidantes a partir de fontes naturais para prevenir o dano oxidativo (KHOLE et al., 2015; WU et al., 2015).

Particularmente as frutas e produtos hortícolas têm ganhado grande interesse entre os consumidores e pela comunidade científica, sobretudo em estudos epidemiológicos que indicam que consumo frequente de antioxidantes naturais está associado com um menor risco de doenças cardiovasculares e câncer. As atividades antioxidantes naturais das frutas e legumes estão relacionadas a três grandes grupos: vitaminas, compostos fenólicos e os carotenoides (THAIPONG et al., 2006).

Os carotenoides contribuem para a estabilidade dos alimentos, além disso, para atividade provitamina A, sendo que estes compostos possuem efeitos benéficos para a promoção da saúde (RODRIGUEZ-AMAYA, 2010). Como antioxidantes, os carotenoides desempenham importantes funções fisiológicas em animais e plantas. Nos seres humanos, certos carotenoides exercem efeitos protetores contra doenças cardiovasculares, certos tipos de câncer e doenças relacionadas com o envelhecimento (HANNOUFA e HOSSAIN, 2012).

A vitamina C é considerada o nutriente mais importante encontrada em alimentos cítricos, e é um componente solúvel em água importante antioxidante e um excelente agente redutor. O termo vitamina C não é utilizado apenas para o ácido ascórbico, mas também inclui todos os compostos que exibem a atividade biológica de ascorbato, tal como as suas formas oxidadas e ésteres. Embora o ácido ascórbico apresente uma elevada atividade antioxidante, os compostos fenólicos também têm sido considerado importantes contribuintes para a capacidade antioxidante total (SDIRI et al., 2012).

Os compostos fenólicos são os principais antioxidantes em leguminosas que desempenham um papel chave em limitar os efeitos de danos celulares e moleculares,

reduzindo espécies de oxigénio reativas envolvidas no desenvolvimento de muitas doenças e envelhecimento. Além da atividade antioxidante, estudos *in vitro* e em animais mostraram que os compostos fenólicos podem apresentar outros efeitos positivos tais como atividades antitumorais, anti-inflamatória, anti-hipertensiva, anti-ateroscleróticos e citotóxicos (LEE et al., 2013; DUEÑAS, 2015).

Huang, Chang e Shao (2006) observaram um conteúdo fenólico total para farinhas de batata doce variou 4,79-6,42 mg a 100 g^{-1} (b.s). Já a fécula de inhame analisada por Nascimento et al., (2013) apresentou 69.00±0,01 mg/100g de ácido gálico, 5,44 ± 0,03 Eq. µM. Trolox/g pelo método DPPH, 15,07 ± 0,46% de sequestro de radical livre e 1367,05 ± 0,07 µM de Sulfato Ferroso/g de amostra da atividade antioxidante pelo método FRAP.

Sendo que os antioxidantes são amplamente utilizados na indústria alimentar como potenciais inibidores da peroxidação lipídica (SCHERER e GODOY, 2009). Atuam eliminando os radicais livres e aumentando a vida de prateleira por retardar o processo de peroxidação lipídica, que é uma das principais razões para a deterioração de produtos alimentícios e farmacêuticos durante o processamento e armazenamento (GÜLÇIN, ELMASTAŞ e ABOUL-ENEIN, 2012).

Muitos antioxidantes sintéticos utilizados em alimentos, tais como hidroxianisol butilado e hidroxitolueno butilado, podem acumular-se no corpo, resultando em danos hepáticos e carcinogênese (VALENTÃO et al., 2002; LUO e FANG, 2008). Daí, a necessidade de identificar fontes alternativas naturais e seguras de alimentos antioxidantes, sendo que a busca de antioxidantes naturais, principalmente de origem vegetal, tem aumentado notavelmente nos últimos anos. Sendo que, os antioxidantes têm sido amplamente utilizados como aditivos alimentares para proporcionar proteção contra a degradação oxidativa de alimentos (GÜLÇIN, ELMASTAŞ e ABOUL-ENEIN, 2012).

Segundo Ventura et al., (2013) o desenvolvimento de produtos com propriedades funcionais, podem ser úteis para o tratamento de certas doenças. Além disso, os consumidores em todo o mundo estão mais conscientes sobre a relação entre hábitos alimentares e risco de doença. Assim, o desenvolvimento de novos alimentos para satisfazer as novas exigências do mercado torna-se relevante, principalmente para avaliar a qualidade e aceitação de alimentos com propriedades funcionais.

Por isso, o interesse por antioxidantes naturais tem aumentado consideravelmente nos últimos anos devido aos seus efeitos benéficos da prevenção e redução do risco de várias doenças (SIGER et al., 2012). Além disso, a aceitação do consumidor por produtos saudáveis também está relacionada com a qualidade e as propriedades sensoriais dos mesmos (BOROCHOV-NEORI et al., 2009).

2.10 Doença Celíaca

A doença celíaca (DC) é uma intolerância ao glúten, dependente de um processo imunológico. Pode aparecer durante a infância ou na vida de adulta, quando uma intolerância permanente para o glúten é desenvolvida (GRANATO e ELLENDERSEN, 2009).

O glúten é um polipeptídio existente no trigo (*Triticum aestivum*), centeio (*Secale cerale*), cevada (*Hordeum vulgare*) e aveia (*Avena sativa*). Seu efeito lesivo à mucosa intestinal na doença celíaca foi descrito por Dicke em 1950, na Holanda (NASCIMENTO e PORTE, 2006). O glúten constitui 90% das proteínas do endosperma

do grão do trigo, subdivide-se em duas frações de acordo com a solubilidade: glutenina e gliadina. A gliadina que geralmente corresponde 50% da quantidade total do glúten, é solúvel em etanol a 70%, enquanto que a glutenina é insolúvel em água e etanol a frio, e ligeiramente solúvel em etanol a quente. Essas duas proteínas combinadas possuem a propriedade de formar com a água uma substância elástica e aderente, insolúvel em água, que é o glúten, extremamente importante para tecnologia de panificação, pois é responsável pela textura da massa dos mesmos (NASCIMENTO, BARBOSA e TAKEITI, 2012).

Os pacientes celíacos não podem consumir glúten, pois até mesmo em uma mínima ingestão deste polipeptídeo pode causar danos intestinais (BONGIOVANNI et al., 2010). Os sintomas clássicos da doença celíaca incluem diarreia crônica, dores abdominais, distensão abdominal, baixo peso, estatura diminuída, vômitos e constipação (IŞIKAY, KOCAMAZ e SEZER, 2015) além de complicações à longo prazo como osteoporose, infertilidade e malignidade (BONGIOVANNI et al., 2010).

A mortalidade do paciente celíaco é aproximadamente duas vezes maior que da população geral, com um aumento que acontece predominantemente dentro do primeiro ano depois do diagnóstico. As mortes são principalmente devidas a malignidades com linfoma intestinal. Estudo feito por Cottone et al. (1999) em 228 adultos com DC de uma população mediterrânea mostrou 12 mortes, 12 tumores, 6 linfomas. O intervalo entre o diagnóstico de DC e a morte era de 4 anos. Sendo uma pesquisa realizada numa população sueca observou que 828 pacientes com DC morreram entre 1965-1994 com linfoma, câncer do intestino delgado, doenças autoimunes como artrite reumática, doença difusa de tecido conjuntivo, ou desordens alérgicas (como asma), inflamação intestinal, *diabetes mellitus*, desordens de deficiência imune, tuberculose, pneumonia e nefrites. Observa-se risco de mortalidade elevado para todas as causas de morte combinadas, sendo a maior parte, desordens caracterizadas por deficiência orgânica imune (KOTZE, 2009).

A DC apresenta várias formas clínicas e, nos últimos tempos, as mais comuns são as formas atípicas, cujos sintomas geralmente passam despercebidos. Dentre os principais sintomas, tem-se a anemia por deficiência de ferro, além de artrites, osteoporose, esterilidade, constipação intestinal, retardo no crescimento e hipoplasia do esmalte dentário. O diagnóstico da DC é desafiador, pois as formas clínicas da doença vêm se modificando e, cada vez mais, são latentes ou assintomáticas. Portanto, percebê-las exige o envolvimento, não somente do gastroenterologista, mas também, de vários outros profissionais da saúde (GUEVARA, 2002).

A co-existência da DC com outras doenças autoimunes, como o *diabetes mellitus* tipo 1, doença de Addison, lupus eritematoso sistêmico, artrite reumatoide, síndrome de Sjögren, hepatite autoimune, cirrose biliar primária e estomatite de repetição, tem sido relatada com frequencia, sugerem anormalidade intrínseca na regulação do sistema imune. A frequência da DC nos pacientes com doenças autoimunes da tireoide tem se mostrado de quatro a oito vezes maior do que na população geral ou em doadores de sangue (MELO et al., 2005).

Sendo que o diagnóstico da doença celíaca está baseado em testes sorológicos (antiendomisial, antigliadina e anticorpos de antitransglutaminase) e em mudanças histopatológicas características (as vilosidades se atrofiam, hiperplasia das criptas e células infiltradas inflamatórias) visto em biópsia de duodeno distal (CUMMINS et al., 2011). De acordo com os critérios da Sociedade Europeia e Latino-Americana, há a necessidade de realizar três biópsias, sendo que a primeira biópsia revela atrofia vilositária, a segunda logo após o tratamento que demonstra a recuperação das vilosidades e criptas e a terceira e última que mostra um dano induzido pela dieta com

glúten. Com a dieta sem glúten observa-se rapidamente uma diminuição da lesão da mucosa intestinal e da má-absorção de nutrientes com melhora sintomática (SIQUEIRA-NETO et al., 2004).

Considerando que o principal fator etiológico da doença celíaca é de natureza dietética, a adoção de práticas alimentares voltadas para a exclusão do glúten da dieta constitui medida profilática bastante eficaz. O seguimento de uma dieta sem glúten significa um desafio, uma vez que algumas situações favorecem a ingestão involuntária do mesmo. Entretanto, cabe particularmente ao profissional nutricionista elaborar e orientar a terapia dietética e corrigir *déficit* nutricionais, excluindo o glúten e seus derivados da dieta. A Acelbra também é uma entidade muito relevante no intercâmbio e esclarecimento a respeito da doença celíaca, no sentido de difundir importantes informações (NASCIMENTO, BARBOSA e TAKEITI 2012).

Assim, embora o mercado de produtos orgânicos ainda seja restrito quando comparado ao convencionais, observa-se uma crescente demanda mundial por esta categoria de alimentos, justificando o desenvolvimento de produtos orgânicos com vistas a contribuir para o benefício para a saúde, a atração por produtos novos, à moda e a procura por produtos mais saborosos e saudáveis.

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Capítulo II

Physicochemical and bioactive analysis of organic rhizomes and tubers from organic production system

Manuscrito em preparação

Physicochemical and bioactive compounds analysis of rhizomes and tubers from organic production system

Abstract

The aim of this study was to analyze the physicochemical and bioactive compounds analysis of rhizomes and tubers from organic production system [arrowroot (*Maranta arundinacea* L.): *ovo de pata* and *comum*, sweet potatos (*Ipomoea batatas* L.): *Rosinha de Verdan*, *Capivara* and *orange fleshed* and taro *Chinese* taro (*Colocasia esculenta* (L.) Schott)]. The rhizomes and tubers, cultivated from organic production system were obtained Integrated Agroecological Production (IAP) located at Seropédica, State of Rio de Janeiro, Brazil. The harvesting was carried out in the period from August of 2012 to June of 2014 and approximately 5 kg from each variety were used for each sampling. The rhizomes and tubers analyzed in this study showed good nutritional caracteristics, how: higher contents proteins, ash and crude fiber. The taro and sweet potato *Rosinha* presented higher levels of phenolic compounds. The major fatty acid founding sweet potato that contributed to the prevalence of polyunsaturated fatty was linoleic acid (C18:2 ω6). The results obtained for the phytosterol profile showed brassicasterol, campesterol, stigmasterol and β-sitosterol. The β-Carotene (10226.25 µg/100 g d.b) was the principal carotenoid of the *orange fleshed* sweet potato analyzed. Thus, the rhizomes and tubers analyzed showed nutritional features and bioactive compounds significant.

Keywords: Tuber, rhizomes, antioxidant capacity, fatty acid, β-carotene.

Análises físicoquímica e compostos bioativos de rizomas e tubérculos de sistema orgânico de produção

Resumo

O objetivo deste estudo foi analisar a físico-química e compostos bioativos análise dos rizomas e tubérculos de sistema orgânico de produção [araruta (*Maranta arundinacea* L.): *ovo de pata* e *comum*, batatas doces (*Ipomoea batatas* L.): *Rosinha de Verdan*, *Capiva*ra e de polpa alaranjada e Taro *Chinês* (Colocasia esculenta (L.) Schott)]. Os rizomas e tubérculos, cultivados a partir de sistema de produção orgânica foram obtidos do Sistema Integrado de Produção Agroecológica (IPA) localizado em Seropédica, Estado do Rio de Janeiro, Brasil. A colheita foi realizada no período de agosto de 2012 a junho de 2014 e aproximadamente 5 kg, de cada variedade foram usados para cada amostragem. Os rizomas e tubérculos analisados neste estudo mostraram boas caracteristicas nutricionais, como: maiores teores de proteínas, cinzas e fibra bruta. O taro e a batata-doce *Rosinha* apresentaram níveis mais elevados de compostos fenólicos. O principal ácido graxo da batata doce que contribuiu para a prevalência de ácido graxo poliinsaturado foi o ácido linoleico (C18:2 ω6). Os resultados obtidos para o perfil de fitosterol mostrou brassicasterol, campesterol, estigmasterol e sitosterol-β. O β-caroteno (10.226,25 g / 100 g db) foi o principal carotenóide da batata doce de polpa alaranjada analisado. Assim, verifica-se que os rizomas e tubérculos analisados apresentaram características nutricionais e compostos bioativos significativos.

Palavras-chave: Tuber, rizomas, capacidade antioxidante, ácido graxo, β-caroteno.

1. Introduction

Organic products have been increasingly popular because the concerns about environmental contamination and health benefits (Crecente-Campo et al., 2012). Consumer studies have shown that expectations concerning the health effects of organic food are essentially the strongest motives for consumers buying organic products (Huber et al., 2011).

Some sweet potato varieties, especially orange-fleshed sweet potato, contain significant amounts of β-carotene, starch, dietary fiber, minerals, vitamins (especially vitamins C, B6 and folate), as well as antioxidants, such as phenolic acids, anthocyanins, and tocopherol (Wu, 2008). The orange fleshed sweet potato contains β-carotene, responsible for conferring pro-vitamin A activity that contributes to the prevention of cataract and age-related macular degeneration (Ahmed, Sorifa, & Eun, 2010).

Moreover, it is well known that sweet potatoes presents a great potential to counter the malnutrition, thus research efforts have been recently intensified aiming the improvement of their production and processing, mainly as flour for use in beverage, alcohol, dye and bakery products, such as cookies, biscuits, muffins, noodles, breakfast foods and pies production (Ahmed, Akter, & Eun, 2010, Laurie et al., 2012 and Huang et al., 2013).

Maranta (*Maranta arundinacea* L.) can be considered as a non-conventional raw material for starch extraction. Among these, rhizomes of *Maranta* or arrowroot have been considered as a potential source of starch. *Maranta* is an herbaceous, perennial plant which have cylindrical rhizomes with high starch contends (17.2-18.9 w.b.%), being cultivated in the Caribbean islands, Southeast Asia, South America, Philippines and India. Some reports have document that the *Maranta* starch has low protein, fat, ash and fiber composition, with size particle between 4 and 42 μm and gelatinization temperature between 68 and 75 °C (Valencia et al., 2014).

Taro is a tropical tuber crop largely planted in many areas of the world. However, there is an average 30% taro loss during storage. Transforming tuber of taro in taro starch can minimise losses and add to the value the product (Dai et al., 2015). The tubers of taro contain reasonable amount of calcium, phosphorus, vitamin A and B group vitamins. The protein and dietary fiber content of the edible portion are also high as compared to other root and tuber crops (Sit et al., 2014).

Thus, the objective of this study was to analyze the physicochemical properties and bioactive compounds some olericulture.

2. Materials and Methods

2.1 Material and Sample preparation

Arrowroot, cultivars *ovo de pata* and *comum*, sweet potato (*Ipomoea batatas* (L.) Lam.), cultivars white (cv. *Capivara* and cv. *Rosinha de Verdan* and *orange fleshed* (cv. IAPAR 90) and taro cultivar *Chinese*, cultivated in organic production system in Seropédica, were supplied by Embrapa Agrobiology, Rio de Janeiro, Brazil (latitude 22º48'00" S, longitude 43°41'00" W and altitude of 33 meters). The harvest was carried out in the period from August of 2011 to June of 2012 and approximately 5 kg from each variety were used for each sampling.

The rhizomes and tubers were washed in tap water, sanitized into a 200 ppm solution of sodium hypochlorite for 15 minutes before analysis (Nascimento et al., 2013). Subsequently, the samples were peeled and crushed (Mini processador, Vicini, EPV-85, Rio de Janeiro, Brazil).

2.2 Physicochemical Properties

2.2.1 Chemical Composition and Physicochemical Properties

The proximate composition of each raw material was determined according to AOAC (2005) standards: moisture content (Method 925.09), total nitrogen (Method 2001.11, a conversion factor of 5.75 was used to convert total nitrogen to protein content), fat content (Method 945.38) and ash content (Method 923.03).

The crude fiber (Method 962.09; AOAC 2000), total titratable acidity (Method 942.15; AOAC (1997). The pH, hydrolysable carbohydrates, reducing and non-reducing carbohydrates by oxidation-reduction of Fehling's solution, according to the methodology described by IAL, (2008).

The total energetic value (TEV) was expressed in kilocalories (kcal.100g^{-1}) and was calculated considering Atwater conversion factors of 4 to kcal.g^{-1} to protein and carbohydrate and 9 kcal.g^{-1} to lipids (USDA, 2006). Calculated with the following formula: (carbohydrates × 4 kcal) + (protein × 4 kcal) + (fat × 9 kcal).

2.2.2 Colour Analysis

Colour was evaluated by the CIEL*ch system (Colour Quest XE - Hunter Lab, 2010, Virgínia, USA). CIEL*ch is a modification to the CIELAB scale which plots in polar coordinates rather than rectangular ones. The colour attributes lightness (L*), chroma (C) and hue angle (h) were measured four times on the surface of the sample. Measurements were performed using 25 mm viewing area aperture, D65 illuminant and

10° observer, according to CIE (Comission International de L'Eclairage) recommendations, using the equations below:

$$h* = \arctan\left(\frac{b*}{a*}\right) \quad (1)$$

The samples were placed on a white standard plate (L = 72.46, a = 5.09, and b = 14.71) and the L, a, and b color values were measured. L values range from 0 (black) to 100 (white); a values range from −80 (greenness) to 100 (redness); and b values range from −80 (blueness) to 70 (yellowness). All measurements were performed in four replicates. The whiteness index (WI) and yellowness index (YI) of sample was obtained by substituting the values of L*, a* and b* into the following equations according to the standard of CIE (Ghanbarzadeh, Almasi, & Entezami, 2010):

$$WI = 100 - \sqrt{[(100 - L)^2 + a^2 + b^2]} \quad (2)$$

$$YI = {}^{142.86b}/_{L} \quad (3)$$

2.3 Antioxidant Properties

2.3.1 Obtaining of Extracts

The extracts were obtained according to Swain and Hillis (1959) and Torres (2002) with minor modifications. 20 g of sample were diluted with ethanol (ACS) in volumetric flasks (100 mL). These solutions were subjected to magnetic stirrer at 25 °C for 1 h. Then, vacuum filtered using a sintered filter funnel (n. 3).

2.3.2 Determination of Total Phenolic Compounds

0.5 mL of each obtained extract was mixed to 7 mL of distilled water and 0.5 mL of Folin-Ciocalteu reagent, were mixed for 3 min. 2 mL of 20% Na_2CO_3 solution and heated to 100 °C for one minute in a temperature controlled water bath and cooled at the ambient condition in the dark (Singleton & Rossi Jr, 1965; Quettier-Deleu et al., 2000). The results were expressed in gallic acid equivalents (GAE; mg/100 g fresh mass) using a gallic acid (0.05 to 1.2 mg/mL) standard curve. All analysis were performed in triplicate.

2.3.3 DPPH Scavenging Activity

The antioxidant capacity was determined by the modified DPPH method (Brand-Williams, Cuvelier, & Berset, 1995), is based on the quantification of free radical-scavenging, with modifications. A methanol solution containing 0.06 mM DPPH was prepared. After adjusting the blank with methanol, an aliquot of 100 µL of samples extract was added to 3.9 mL of this solution. The absorbance was measured using an UV Spectrophotometer NEW 2000 (São Paulo, Brazil) at the 517 nm. The amount antioxidant capacity was expressed as µM of Trolox Equivalent per 100 g of sample (dry basis). The free radical-scavenging (%FRS) of each sample was calculated

according to Eq. 6. Where: A_c and A_A are absorbance values of blank and sample, respectively. All analysis was performed in triplicate.

$$\%FRS = \frac{(A_c - A_A) * 100}{A_c} \quad (5)$$

2.3.4 Method of Ferric Reducing Antioxidant Power (FRAP)

The antioxidant capacity of each sample was estimated by FRAP assay, following the procedure described by Rufino et al., (2010). Briefly, 2.7 mL of freshly prepared FRAP reagent (TPTZ, $FeCl_3$ and acetate buffer) at 37 °C was mixed with 90 μL of samples extracts and 270 μL of distilled water.Its was used blank containing FRAP reagent as reference, read at absorbance of 595 nm for 30 min. Aqueous solutions of known Fe (II) concentrations in the range of 100–1500 μM (Fe_2SO_4) were used for calibration.

2.4 Determination of Minerals

The determination of P, K, Ca, Mg, Cu, Fe, Mn and Zn was performed by nitric perchloric digestion and N sulfuric digestion of the method according to the methodology recommended by Tedesco (1995).

2.5 Chromatographic Analysis

2.5.1 Chemicals Reagents

Methanol, diethyl ether, t-Butyl-hydroquinone, ethanol and n-hexane were obtained from Merck (Darmstadt, Germany). Nonadecanoic methyl ester was from Sigma (St. Louis, MO, USA) and fatty acids standard mixtures were purchased from SupelcoTM 37 (FAME Mix 18919, Bellefonte, PA, USA). Phytosterol and other standards, were from Sigma Chemical Company (St. Luis, USA). The purities of the standards ranged from 95% to 99%. HPLC grade n-hexane and 2-propanol were obtained from Mscience (Darmstadt, Germany).

All used solvents were of chromatographic grade, including acetone, petroleum ether 35 - 60 ºC, methanol (MeOH), methyl *tert*-butyl ether (MTBE). The concentrations of β-carotene and α-carotene standards were determined spectrophotometrically using the $A^{1\%}_{1cm}$ value of 3450, 2592 and 2800, respectively, in petroleum ether. The standard purities were greater than 97 %.

2.5.2 Determination of Fatty Acids

The dry samples (150 mg) were converted into methyl esters by transesterification according to Huang et al. (2006). The fatty acids were determined using a gas chromatograph (Shimadzu GC 2010, Tokio, Japan), equipped with a split injector (1:50) and a flame ionization detector, and a workstation. The chromatographic separation was achieved on a fused silica CP-SIL 88 capillary column 50 m × 0.25 mm i.d., 0.20 µm film thickness (Chrompack, Middelburg, The Netherlands). The chromatographic conditions were temperature program was: initial temperature, 100 °C (5 minute) followed by 5 °C/minute up to 160 °C (zero minute), 8 ºC/minute up to 230 °C (12 minute); injector and detector temperatures were 250°C and 280 °C. The equipment used hydrogen as carrier gas at a flow rate of 1 mL/minute and nitrogen as the make-up gas at 30 mL/minute. Retention times of FAME standards were used to identify chromatographic peaks of the samples. The quantification was done by external standardization with a concentration range from 0.3 to 7 mg/mL.

2.5.3 Determination of Phytosterol

Phytosterol was extracted by direct saponification (2 g of the samples, 4 mL of a 50% aqueous solution of KOH and 6 mL of ethanol) at room temperature for 22 h in the dark. For the extraction of the unsaponifiable matter, 5 mL of distilled water and 10 mL of hexane were added to the samples, the mixture shaken; the hexane fraction was then separated (Saldanha et al., 2006).

The extraction with 10 mL of hexane was repeated three times (total of 4 extractions). Subsequently, the solution was dried in a rotary evaporator (Tecnalise, São Paulo, Brazil), the residue dissolved in 5 mL of hexane, transferred to a screw top flask, dried under N, diluted with 1 mL of mobile phase, filtered through a 22 mm filter (Millipore, Maryland, MD, USA) and injected in the HPLC system (Saldanha et al., 2006).

For HPLC, a Waters liquid chromatograph (Waters, Milford, MA, USA) equipped with on-line photodiode array detector (PDA) (Waters 2998) and refractive index (RID-Waters, 2414) detectors, rheodyne injector with a 20 µl loop, a tertiary solvent delivery system (Waters 600), oven heated column at 32 1C (CTO-3840) and software (Empower 2). The analytical column used was a Nova Pack CN HP 300 mm, 3.9 mm column, 4 mm (Waters, Milford, MA, USA). The mobile-phase was n-hexane: 2-propanol (97:3, v/v) at a flow rate of 1 mL/min and an analysistime of 30 min. The HPLC solvents were filtered through a 22 mm Millipore filter (Bedford, MA, USA) under vacuum prior to use. Quantification was done by external standardization, with a concentration range from 0.1 to 1.8 mg/mL.

2.6 Sample Extraction and Analysis β-carotene

2.6.1 Extration, Identification and Quantification of β-carotene and Isomers

Carotenoids extraction procedure was performed as described by Rodriguez-Amaya (2001) using limited light and controlled temperature to minimize degradation and isomerization of carotenoids. All analysis were performed in triplicate (n=3). Approximately 0.5 g of each matrix were weighed and then manually macerated in a porcelain grail with 3g of celite and 50 mL of acetone. The mixture was vacuum filtered on a glass funnel with sintered plate. The extraction procedure was repeated three or four times until the sample did not exhibit the characteristic color of carotenoids. Acetone extract was transferred quantitatively to a separatory funnel containing 50 mL of petroleum ether and washed, at least three times, with 300 mL ultrapure water. The ether extract was filtered through anhydrous sodium sulfate, collected in 100 mL volumetric flask and completed with petroleum ether. The level of total carotenoids in the samples extracts was determined by spectrophotometry at 450 nm, using a UV-1800 (Shimadzu, Tokyo, Japan). Carotenoids profile was determinate by taking an aliquot of 1 mL of the sample extract into an amber vial, which was dried under a N_2 stream and then dissolved with 100µL of acetone. Before HPLC analysis, the solution was vortex during 10 s.

2.6.2 HPLC Analysis

Profiles of the carotenoids were determined in an acetone extract by HPLC (Pacheco et al., 2012) using a Waters™ HPLC system, controlled by the Empower software program with the column oven at 33 ºC and photodiode array detector (PDA). Carotenoid separation was obtained in a C_{30} column (S-3 Carotenoid, 4.6 mm × 250 mm, YCM™) by a gradient elution of methanol and methyl *tert*-butyl ether. The elution started with a mix of 80 % methanol and 20 % methyl *tert*-butyl ether. At 0.5 min the ether concentration was increased to 25 %, at 15.00 min to 85 % and at 15.05 to 90 % ether. The ether concentration was maintained at 90 % until 16.50 min and then at 16.55 min returned to the initial condition (20 %), remaining constant up to the 28 min. The flow rate was 0.8 mL min^{-1} and the running time was 28 min. The injection volume of the samples was 15 µL. Carotenoids were identified based on their retention times and UV/Vis absorption spectra and compared to the retention times of the carotenoid standards.

2.7 Statistical Analysis

The results were verified by variance analysis (ANOVA). The chemical and physical tests were analyzed by variance and Tukey test at 5% of significance level for averages comparison.

3. Results and Discussion

3.1 Yield and Physicochemical Characterization

Table 1 presents the results of yield and physicochemical characterization of rhizomes and tubers organic ($p<0.05$).

Table 1. Physicochemical characterization of the organic rhizomes and tubers (n=6).

	Arrowroots		*Sweet potato*			*Taro*
Parameter (g/100g)	*Ovo de pata*	*Comum*	*Rosinha*	*Capivara*	*Orange-fleshed*	*Chinese*
Moisture	52.37±1.42^{d}	52.69±2.36^{d}	66.64±1.08^{c}	58.51±2.89^{d}	78.23±3.85^{b}	82.72±2.76^{a}
Protein	2.55±0.09^{ab}	2.62±0.12^{a}	1.40±0.07^{c}	2.35±0.51a^{b}	0.50±0.05^{d}	2.25±0.09^{b}
Fat	2.54±0.60^{b}	2.61±0.02^{b}	0.30±0.09^{d}	3.40±0.05^{a}	0.20±0.03^{d}	0.77±0.15^{c}
Ash	1.72±0.09^{a}	1.75±0.19^{a}	0.89±0.06^{b}	1.00±0.06^{b}	0.70±0.08^{c}	0.80±0.15^{bc}
Crude fiber	6.94±4.17^{b}	7.46±3.17^{a}	2.30±0.02^{c}	1.60±0.05^{d}	1.27±0.04^{e}	0.63±0.04^{f}
Hydrolysable carbohydrates	33.90±0.08^{a}	32.87±0.00^{c}	28.47±0.04^{d}	33.14±0.25^{b}	19.10±0.14^{e}	12.83±0.0^{f}
Reducing sugars	0.41±0.13^{d}	0.41±0.13^{d}	1.80±0.00^{b}	1.80±0.00^{b}	2.70±0.00^{a}	0.72±0.00^{c}
Non-reducing sugars	0.60±0.12^{e}	0.61±0.12^{e}	1.40±0.00^{c}	1.30±0.00^{d}	3.67±0.00^{b}	4.28±0.10^{a}
TEV (kcal)	172.70±0.02^{b}	169.53±0.30^{c}	134.98±2.00^{d}	184.96±0.04^{a}	105.68±0.01^{e}	79.25±0.0^{f}
Acidity (mg NaOH/100g)	7.79±0.14^{b}	8.45±0.14^{a}	5.80±0.14^{c}	4.90±0.28^{d}	2.86±0.29^{f}	3.20±0.29^{e}
pH	6.35±0.03^{c}	6.78±0.04^{a}	6.50±0.00^{b}	6.80±0.00^{a}	5.97±0.00^{d}	6.79±0.00^{a}

*Average ± RI= reliable interval for a statistical probability of 95%; Where same letter on the same line do not present significant differences ($p<0.05$) among each other. The results presented in Table corresponds to d.b. (dry basis); Each value is presented as mean ± standard deviation (n = 6); Means within each row with different letters (a–f) differ significantly ($p<0.05$); *d.b.: dry basis; TEV= total energy value; nd: no determined.

Arrowroot *comum* showed higher contents proteins, ash, crude fiber, pH and acidity, than the arrowroot *ovo de pata*, showing significant differences ($p<0.05$), however, lower moisture, fiber, hydrolysable carbohydrates and pH (Table 1). The arrowroot studied showed higher protein and ash content of two varieties arrowroot investigated, than that found by Pérez, Lares, and Gonzales (1997) who analyzed the rhizomes of arrowroot grown in Venezuela, which were 1.10% protein, 1.20% of fat matter, 0.57% ash, 1.51% crude fiber, 15.74% total carbohydrates, 79.88% moisture and pH 6.9.

The *orange fleshed* cultivar has shown moisture, reducing sugars and total carotenoid content ($p<0.05$), according to Table 1 and *Capivara* cultivar presented the higher total energy value, fat content and pH. Dincer et al. (2011) reported values of ash content 2.31% (d.b.) for 3 sweet potatoes cultivars from Turkey.

Fat content of sweet potato cultivars were 0.20 g/100g for *orange fleshed*, 0.30 g/100g for *Rosinha de Verdan* and 3.40 g/100g for *Capivara* and showed significant ($p<0.05$) differences between the cultivars (Table 1). As other roots and tubers, sweet potato is known for its low fat content. Mu, Tan, and Xue (2009) found 0.6% fat for sweet potatoes (d.b). Padonou, Mestres, & Nago (2005) reported fat content of cassava roots 0.53-0.65% (d.b).

There were significant differences ($p<0.05$) in hydrolysable carbohydrates content for sweet potatoes cultivars, ranging from 12.83 to 33.90 g/100g (d.b.) (Table 1). Total energy value (TEV) varied ($p<0.05$) among cultivars, and ranged from 79.25 to 184.96 kcal/100g, respectively. The *Capivara* presented higher levels of total carbohydrates content and fat and consequently, higher TEV than others cultivars (Table 1).

According Ji et al., (2015), starch (60.1% - 71.4%) is the most predominant nutrient component of four different color fleshed sweet potato samples followed by protein (4.86% - 6.53%), small amounts of fat (0.56% - 0.76%).

In sweet potato roots, starch is the main component, followed by simpler sugars as sucrose, glucose, fructose and maltose. In food industry, it is applied to enhance functional properties, as in soups, meat sauces, as formers in candies etc. (Stracke et al., 2009). According to Waramboi et al. (2011) the starch content is directly related to genotype and environmental settings in which the plant is cultivated, i.e. differences in soil, weather and other growing conditions. Waramboi et al. (2011) found for 25 sweet potatoes types from Papua New Guinean and Australia (30-58% of starch, d.b.). Kohyama and Nishinari (1992) obtained values ranging from 13.4 to 29.2% of starch content in different sweet potato roots.

The content fiber and non-reducing sugars of taro were higher (Tabel 1) than those found by Yeh et al. (2009) who verified for fresh yam tuber 71.46±0.34% water and 0.28±0.07% crude fat (d.b.) having 9.34±0.14% protein, 5.30±0.16% ash.

3.2 Colour Analysis

It is observed that taro was presented the lowest total color difference (Table 2).

Table 2. Colour analysis of the organic rhizomes and tubers (n=6).

	Arrowroots		*Sweet potato*			*Taro*
Parameter	*Ovo de pata*	*Comum*	*Rosinha*	*Capivara*	*Orange-fleshed*	*Chinese*
L	97.00±0.38^{a}	93.00±0.65^{b}	90.00±0.32^{c}	77.00±1.61^{e}	75.00±0.26^{f}	82.00±0.31^{d}
a*	0.10±0.01^{c}	-0.10±0.02^{d}	1.50±0.09^{b}	1.00±0.37^{b}	33.30±0.83^{a}	0.34±0.09^{c}
b*	7.90±0.21^{f}	11.00±0.52^{e}	13.60±0.37^{d}	24.80±0.03^{b}	36.00±0.98^{a}	16.50±0.85^{c}
C	7.90±0.21^{f}	11.00±0.52^{e}	13.70±0.38^{d}	24.80±0.02^{b}	44.00±0.31^{a}	16.50±0.85^{c}
h*	99.00±0.50^{cd}	100.00±0.13^{c}	107.00±0.68^{b}	120.00±0.68^{a}	58.00±0.30^{e}	98.00±0.82^{d}
WI	91.55±0.01^{a}	86.96±0.01^{b}	83.05±0.01^{c}	66.16±0.01^{e}	44.96±0.01^{f}	75.58±0.01^{d}
YI	9.28±0.00^{f}	16.90±0.00^{e}	21.59±0.00^{d}	46.01±0.00^{b}	68.57±0.00^{a}	28.74±0.00^{c}

Average ± RI= reliable interval for a statistical probability of 95%; Where same letter on the same line do not present significant differences ($p<0.05$) among each other. The results presented in Table corresponds to d.b. (dry basis); L (Luminosity); C (Chromaticity); h (Colour); b*(Chromaticity b - yellow-blue component); a*(Chromaticity a – green-red component); WI (whiteness index); YI (yellowness index); Each value is presented as mean ± standard deviation (n = 6); Means within each row with different letters (a–f) differ significantly ($p<0.05$); *d.b.: dry basis.

Arrowroot rhizome of *ovo de pata* presented a whiteness index (WI) higher and lower than yellowness index (YI) than other varieties of rhizomes and tubers. The sweet potato *orange fleshed* tuber showed higher a*, b*, C*, YI ($p<0.05$). Analyzing the color parameters h* was possible to realize that the *Capivara* tubers has a higher color purity (higher value of h*).

The intensity of yellow is dependent on the concentration of the beta-carotene pigment. Flesh colours of sweet potato have been related to its nutritional, taste and textural properties. The high +a and +b values recorded in some of the sweet potato cultivars, although advantageous in foods, may adversely affect starch quality since the extraction and leaching of the colour pigments result in discolouration of the starch granules (Aina et al., 2009).

These results were lower than found in samples of fresh cassava root with L* values ranging only from 55 to 85 were included. For a*, acceptable values ranged from 2 to 38, whereas for b* it was from 50 to 120 (Sánchez et al., 2014). Aina et al. (2009) found the colours of twenty-one Caribbean sweet potato cultivars that were lower (L = 60.8 to 84.0 and b* = 9.9 to 28.5) that present study, however, lower to parameter Chromaticity a* (a = −2.4 to 27.8).

3.3 Antioxidant Capacity

It is also observed that the greatest free radical-scavenging was of the *orange fresh* (79.00%±0.16) (Table 3).

Table 3. Antioxidant capacity of the organic rhizomes and tubers (n=6).

	Arrowroots		*Sweet potato*			*Taro*
Parameter	*Ovo de pata*	*Comum*	*Rosinha*	*Capivara*	*Orange-fleshed*	*Chinese*
Phenolic (mg/100g of gallic acid)	372.7±0.01^{d}	318.40±0.05^{e}	735.50±0.47^{b}	278.80±0.07^{f}	612.90±0.13^{c}	1005.60±1.76^{a}
Antioxidant capacity (µM Eq. Trolox/g)	10.09±0.15^{e}	5.00±0.06^{f}	18.04±0.17^{c}	10.35±0.22^{d}	23.92±0.38^{a}	20.09±0.00^{b}
%FRS	9.55±0.95^{c}	4.56±0.41^{f}	7.70±0.01^{d}	9.83±0.73^{b}	79.00±0.16^{a}	6.80±1.04^{e}
FRAP (µM Ferrous Sulfate/g of sample)	1260±0.40^{b}	1313.1±0.10^{a}	520.00±0.04^{d}	327.00±0.15^{e}	250.00±0.48^{f}	1140.00±0.17^{c}

*Average ± RI= reliable interval for a statistical probability of 95%; Where same letter on the same line do not present significant differences ($p<0.05$) among each other. The results presented in Table corresponds to d.b. (dry basis); FRS (Percent of free radical-scavenging); Eq. (Equivalent); µM (micromolar). Each value is presented as mean ± standard deviation (n = 6); Means within each row with different letters (a–f) differ significantly ($p<0.05$); *d.b.: dry basis.

The antioxidant capacity by DPPH method was the better in the sweet potato *orange fresh* (23.92±0.38 µM Eq. Trolox/g) and *Chinese taro* (20.09±0.00 µM Eq. Trolox/g).

However, it was observed that an arrowroot of *ovo comum* and *ovo de pata* showed higher antioxidant activity by FRAP method, compared with other varieties, showing significant differences ($p<0.05$). Differences were observed between the two radical scavenging assays (DPPH and FRAP). It appears that no linearity between the two different analysis methods, the principles and mechanisms for determining the antioxidant capacity in vitro are respectively different.

The DPPH method has the ability of the various antioxidants to donate an electron or hydrogen radical to the stable DPPH free radical and FRAP method compares antioxidants based on their ability to reduce ferric (Fe^{3+}) to ferrous (Fe^{2+}) ion

through the donation of an electron, with the resulting ferrous ion (Fe^{2+}) (Matins et al., 2013).

The studies by Grace et al. (2004) DPPH antioxidant activity in sweet potatos genotypes ranged from 8.47 to 0.28 μM Trolox/g DM. The high antioxidant activity can be attributable to the combination of high levels anthocyanin and phenolic acids in genotype sweet potato purple (7.43 - 8.47 μM Trolox/g db), compared to the orange (0.35 - 0.51 μM Trolox/g DM) and yellow-fleshed roots (0.35 - 0.56 μM Trolox/g db), however, these values were lower than the present study.

The FRA values of the 56 vegetable extracts (Chinese toon bud, loosestrife, perilla leaf, cowpea, caraway, lotus root, sweet potato leaf, soy bean (green), pepper leaf, and ginseng leaf) was of 60.9, 44.5, 25.44, 24.08, and 21.41 μM Ferrous Sulfate/g of sample (Deng et al., 2013). The DPPH radical scavenging capacity of methanolic extract from raw vegetables was found between 75 and 89% with the highest values observed in sweetpotato (89%) (Kunyanga et al., 2012).

Antioxidant activity was evaluated in sweet potato genotypes, as Trolox equivalent (DPPH), ranging from 1.3 to 4.6 mg g^{-1} db (Padda & Picha, 2008). Sreeramulu & Raghunath (2010) have investigated the antioxidant capacity in roots, tubers and vegetables consumed in India, and have observed that free radical scavenging activity ranged from 11.06 Trolox Equivalent to 125 mg 100g, and the antioxidant capacity was higher in root beet to the carrot.

3.4 Total Phenolic Compounds

The varieties of presented samples with a high content of phenolic compounds (278.80±0.07 to 1005.60±1.76 mg/100g of gallic acid), where the phenolics of organic *Chinese taro*, was bigger of that found by other samples. Verified that the total phenolic compounds in the *Capivara* was lower ($p<0.05$) than in other samples studied (Table 3).

The total phenolic contents of the sweet potato varieties Dakol, Emelda, Haponita, PSBSP and violet analyzed in the study by Rumbaoa, Cornago, & Geronimo, (2009) ranged from 192.7-1159.0 mg GAE/100 g dry sample. The total phenolic contents of cereals, legumes, oil seeds and vegetables ranged from 0.41 to 3.00 g/100 g of catechin/dry basis (Kunyanga et al., 2012). Total phenolic content, expressed in terms of chlorogenic acid equivalent, in different genotypes of sweet potato ranged from 1.4 to 4.7 mg g^{-1} dry weight (Padda & Picha, 2008).

The phytophenols often vary across the genotypes and are probably associated with genetic factors, which play a vital role in the formation of secondary metabolites (Teow et al., 2007). Padda and Picha (2007) have earlier reported a higher phenolic content in small-sized roots of potato than that of larger-sized roots. The decrease in phenolic content with the development of tubers in root crops has been attributed to a dilution effect resulting from tuber bulking.

3.5 Mineral Profile of the Organic Rhizomes and Tubers

Table 4 presents the results of mineral profile of the organic rhizomes and tubers.

Table 4. Mineral profile of the organic rhizomes and tubers.

	Arrowroots		**Sweet potato**			**Taro**
Parameter	*Ovo de pata*	*Comum*	*Rosinha*	*Capivara*	*Orange-fleshed*	*Chinese*
N (g kg^{-1})	19.76±0.03^{a}	6.38±0.04^{d}	4.60±0.01^{e}	6.50±0.01^{c}	3.95±0.01^{f}	11.90±0.01^{b}
P (g kg^{-1})	2.04±0.01^{c}	2.56±0.01^{b}	2.00±0.01^{d}	1.60±0.01^{e}	2.04±0.01^{c}	3.30±0.01^{a}
K (g kg^{-1})	3.09±0.04^{d}	3.31±0.01^{c}	3.80±0.01^{b}	2.50±0.01^{e}	5.82±0.01^{a}	5.80±0.01^{a}
Ca (g kg^{-1})	0.61±0.01^{f}	0.81±0.06^{c}	0.66±0.01^{e}	1.60±0.01^{a}	1.08±0.01^{b}	0.70±0.01^{d}
Mg (g kg^{-1})	1.12±0.01^{c}	1.47±0.03^{a}	0.44±0.01^{e}	1.30±0.01^{b}	0.73±0.01^{d}	0.40±0.01^{f}
Zn (mg kg^{-1})	15.47±0.01^{b}	14.68±0.01^{c}	3.60±0.01^{f}	70.60±0.01^{a}	4.60±0.01^{d}	4.00±0.01^{e}
Cu (mg kg^{-1})	31.41±0.01^{a}	5.60±0.01^{e}	11.60±0.01^{c}	29.00±0.01^{a}	22.85±0.01^{ab}	7.40±0.01^{d}
Fe (mg kg^{-1})	63.80±0.05^{b}	5.15±0.01^{d}	-	1110.00±0.01^{a}	4.36±0.01^{d}	13.40±0.01^{c}
Mn (mg kg^{-1})	6.16±0.01^{e}	6.38±0.01^{d}	16.30±0.01^{b}	13.00±0.01^{c}	22.2±0.01^{a}	2.80±0.01^{f}

All analyses were performed in triplicate and all data were presented as mean values ± standard deviations. The results presented in Table corresponds to d.b. (dry basis). N-Nitrogen; P-Phosphorus; K- Potassium; Ca- Calcium; Mg- Magnesium; Zn-Zinc; Cu-Copper; Fe-iron; Mn-Manganes.

In Table 4 it was observed that the organic *taro* showed better levels of potassium, phosphorus, calcium, magnesium, that found by Zhou et al. (2004). The tuber of organic taro in nature studied by these authors had on average, 2.26 g/100g potassium, 0.2 g/100g phosphorus, 0.2 g/100g calcium, 0.14 g/100g magnesium, 53.6 mg/kg iron, 29.2 mg/kg zinc, 10.6 mg/kg copper and 5.38 mg/kg manganese (Zhou et al., 2004).

Some studies of the mineral compositions of taro corms suggest that potassium is the more abundant mineral. Other abundant minerals include magnesium, phosphorus, and calcium. Data from the literature reveal that appreciable amounts of zinc are also present. From a nutritional standpoint, taro is rather low in iron and manganese. The nutritional composition of taro corms can vary widely and depends on the genotype, the growing conditions, and the interaction between the genotype and the environment, another factor is the age of a plant (Mergedus et al., 2015).

The sweet potato *Capivara* showed higher-levels of Ca, Zn, Cu and Fe. The most abundant microelement was iron (1110.00±0.01 mg kg^{-1}) followed by zinc (70.60±0.01 mg kg^{-1}) and Copper (29.00±0.01 mg kg^{-1}) which was significantly high ($p<0.05$) to sweet potato *Capivara* (Table 2). It was also observed that the *orange-fleshed* sweet potato showed higher-manganese values.

According to Sun et al. (2014), the most abundant microelement from sweet potato was Fe (average content of 8.15 mg/100 g dw), followed by Mn (average content of 4.10 mg/100 g sw), Zn (average content of 2.27 mg/100 g dw) and Cu (average content of 1.28 mg/100 g dry weight).

Even though heme iron from meat is more bioavailable than non-heme iron from vegetables, the intake of heme Fe/hemoglobin from red meat may increases the risk of colorectal cancer (Sun et al., 2014).

The American Institute of Medicine (2001) recommended a daily dietary Mn is of 1.8 - 2.3 mg and iron 8-18 mg to adults. Manganese is a trace element essential to all forms of life, serve both structural and enzymatic functions (Lemos & David, 2010). Mn deficiency in human beings is very rare because of its widespread presence in the human diet. A varied and balanced diet normally provides adequate amounts of this element. However, Mn deficiency has been related to skeletal abnormalities, alterations of reproductive function, osteoporosis, impaired growth and alterations of lipid and carbohydrate metabolism. The major sources of Mn in the diet are cereals and vegetables, but its Mn content varies considerably due to influence of the vegetable specie, Mn levels in soil, soil pH, and other factors (Cabrera-Vique & Bouzas, 2009).

The mineral content in fresh roots of 12 varieties ranged from 34 to 63 mg/100 g for calcium, 15 to 37 mg/100 g for magnesium, 28 to 51 mg/100 g for phosphorus, 191 to 334 mg/100 g for potassium, 0.73 to 1.26 mg/100 g for iron, and 0.51 to 0.69 mg/100 g for zinc. Variation within varieties over geographical sites could be ascribed to differences in soil mineral content and pH, or their interactions. The variation in nutritional content of sweet potato indicated here needs to be considered in varietal selection for different production sites and in calculating nutrient contribution of sweet potato toward dietary intake (Laurie et al., 2012).

Ash content represents the minerals of a food material. Calcium, phosphorus, magnesium, sodium, potassium, iron, zinc and copper have been identified as the main mineral constituents in sweet potato roots (Bouwkamp, 1985). Minerals such as iron, copper, zinc and manganese are essential, since they play an important role in biological systems (Taira et al., 2013). Mineral uptake (e.g., calcium) or addition (e.g., sodium) during processing can change the natural mineral composition of a product. Since nutrient content varies considerably by commodity, cultivar, and postharvest treatments (Rickman, Bruhn, & Barrett et al., 2007).

Some reasons for these discrepancies are the origin of the plant-food, different cultivars, variations in the mineral content in the soil and others (Lazarte et al., 2015).

3.6 Chromatographic Analysis

Gas chromatography analysis of the fatty acid methyl esters from fatty acids of sweet potato *Capivara* lipids revealed the presence of 7 fatty acids ($p<0.05$) (Table 5).

3.6.1 Fatty Acids

In Table 5, is observed the profile fatty acids of sweet potato *Capivara*. The results were obtained from the sample in g/100 g in dry basis.

Table 5. Fatty acids composition of sweet potato *Capivara*.

Sweet potato *Capivara*	
Fatty acid	**g/100g of oil (dry basis)**
Capric	1.10±0.11
Lauric	8.79±0.50
Palmitic 16:0	10.59±0.72
Stearic 18:0	1.50±0.05
Σ SFA	21.98±0.34
Margaroleic 17:1 ω7	2.82±0.18
Σ MUFA	2.82±0.18
Linoleic 18:2 ω 6	16.67±1.92
γ-Linolenic 18:3 ω6	11.21±1.57
Σ PUFA	27.88±1.74

Average ± RI= reliable interval for a statistical probability of 95%, according to the t-Student distribution; All results were expressed as mean standard deviation (n = 3); Where same letter on the same line do not present significant differences ($p<0.05$) among each other. The acronyms presented in Table corresponds to d.b. (dry basis); ∑SFA (total saturated fatty acids); ∑TFA (total fatty acids); ∑MUFA (total monounsaturated fatty acids); ∑PUFA (total polyunsaturated fatty acids).

The results in Table 5, showed that the tuber fresh sweet potato *Capivara* has significant levels of fatty acids. The major fatty acid found contributing to the prevalence of PUFA (Polyunsaturated Fatty Acids) was linoleic acid (C18:2 ω6) (16.67±1.92 g/100 g) and γ-Linolenic acid (18:3 ω6) (11.21±1.57 g/100 g).

Palmitic acid (C16:0) was the satured fatty acid most prevalent (10.59±0.72 g/100 g in dry basis). Levels have also been found, lauric acid also (C12:0) (8.79±0.50 g/100 g in dry basis), stearic acid (C18:0) (1.50±0.05 g/100 g) and capric acid (C10:0) (1.10±0.11 g/100 g) and margaroleic (C17:1) (2.82±0.18 g/100 g), in dry basis.

The content of oleic and linoleic acids, were the main fatty acids of potato tubers, came to 64.5% of all acids. Total lipids from non-genetically modified potato additionally contained higher amounts of palmitic and stearic, while polyunsaturated fatty acids were found in higher amounts in genetically modified potato (31.9% of total FAME) (Ramadan & Elsanhoty, 2012).

The fatty acid percentages in the sweet potato *Capivara*, decreased in the order of > PUFA (27.88±1.74 g/100 g) > SFA (21.98±0.34 g/100 g) and MUFA (2.82±0.18 g/100 g).

Fatty acids can no longer be viewed in general categories, such as saturated and unsaturated, because individual fatty acids within these categories have different influences on health status and disease risk. For example, whether the double bond is located on carbon number 3 or 6 (as in ω-3 and ω-6 PUFA) makes a remarkable difference in biological function (eg, vasoconstriction vs vasodilation). Therefore, understanding the breadth of information while delineating specifics about individual dietary fatty acids is essential (Vannice & Rasmussen, 2014).

Linoleic acid (LA) and alpha linolenic acid (ALA) belong to the n-6 and n-3 series of polyunsaturated fatty acids (PUFA), respectively. The PUFAs are n-3 and n-6, are considered essential dietary nutrients since they are not synthesized in the human body and are mostly obtained from the diet. Food sources of ALA and LA are most vegetable oils, cereals and walnuts (Russo, 2009).

3.6.2 Determination of Phytosterols

Table 6 presents the results of phytosterol contents of the organic rhizomes and tubers. The results were obtained from the sample in mg/ mL in dry basis.

Table 6. Phytosterol contents of the organic rhizomes and tubers.

	Arrowroots		**Sweet potato**			**Taro**
Parameter mg/ 100 g of oil (dry basis)	*Ovo de pata*	*Comum*	*Rosinha*	*Capivara*	*Orange-fleshed*	*Chinese*
Brassicasterol	3.68±0.01[a]	0.79±0.01[e]	3.62±0.01[a]	2.42±0.01b[b]	1.18±0.01[d]	1.74±0.01[c]
Campesterol	2.46±0.01[e]	3.07±0.01[c]	2.78±0.01[d]	30.22±0.56[a]	10.53±0.01[b]	0.77±0.01[f]
Stigmasterol	15.96±0.04[c]	11.67±0.67[e]	12.10±0.22[d]	6.87±0.22[f]	18.59±0.92[b]	21.82±0.04[a]
β-sitosterol	5.64±0.78[f]	7.94±0.01[d]	7.66±0.01[e]	8.47±0.01[c]	12.31±0.35[a]	10.99±0.01[b]
Total	27.74±0.79[d]	23.47±0.17[f]	26.16±0.06[e]	48.25±1.02[a]	42.61±0.23[b]	35.32±0.01[c]

Average ± RI= reliable interval for a statistical probability of 95%; All results were expressed as mean standard deviation (n = 3); Where same letter on the same line do not present significant differences ($p<0.05$) among each other. The results presented in Table corresponds to d.b. (dry basis).

The significant difference ($p<0.05$) among the samples was observed for the proportions of the measured phytosterol contents (Table 6). The results obtained for the phytosterol profile showed Brassicasterol (0.79±0.01 to 3.68±0.01 mg/100mL), Campesterol (0.77±0.01 to 30.22±0.56 mg/100 mL), Stigmasterol (6.87±0.22 to 21.82±0.04 mg/ 100 mL) and β-sitosterol (5.64±0.78 to 12.31±0.35 mg/ 100 mL) (Table 5).

The recommended daily intake of phytosterols to lower elevated low-density lipoprotein (LDL)-cholesterol is 2 g/day; higher intakes offer little additional benefit (Hovenkam et al., 2008).

Phytosterols (plant sterols) have been described as bioactive molecules. The nutritional role of these compounds to reduce circulating cholesterol levels in humans have been known since the 1950s. These compounds are an essential constituent of cell membranes that control both its fluidity and permeability. They are only available to humans through plant foods such as vegetable oils, nuts, seeds, cereals, legumes, fruits, and vegetables or industrial supplements from plant origin (Millán et al., 2015).

The average daily intake of plant sterols in Western countries ranges from 150 to 400 mg, depending on dietary habits and geographic region mainly by ingestion of vegetable oils, cereals, fruits and vegetables. Nevertheless, the amounts of plant sterols consumed daily are often not large enough to have significant cholesterol-lowering effects. A number of clinical trials have established that the consumption of 1.5–2.0 g/day of phytosterols can result in a 10-15% reduction in LDL cholesterol in as short as a three-week period in hyperlipidemic populations (Millán et al., 2015).

According to the results of this study, the phytosterol content in vegetables was high, and they also play an important role to increasing the phytosterols intake,

indicating that increased intake of vegetables with higher phytosterol contents helps increase the phytosterol levels (Table 6).

3.6.3 Analysis β-carotene and Isomers

In Fig. 1, it was verified the results of typical chromatogram in *orange fleshed* sweet potato.

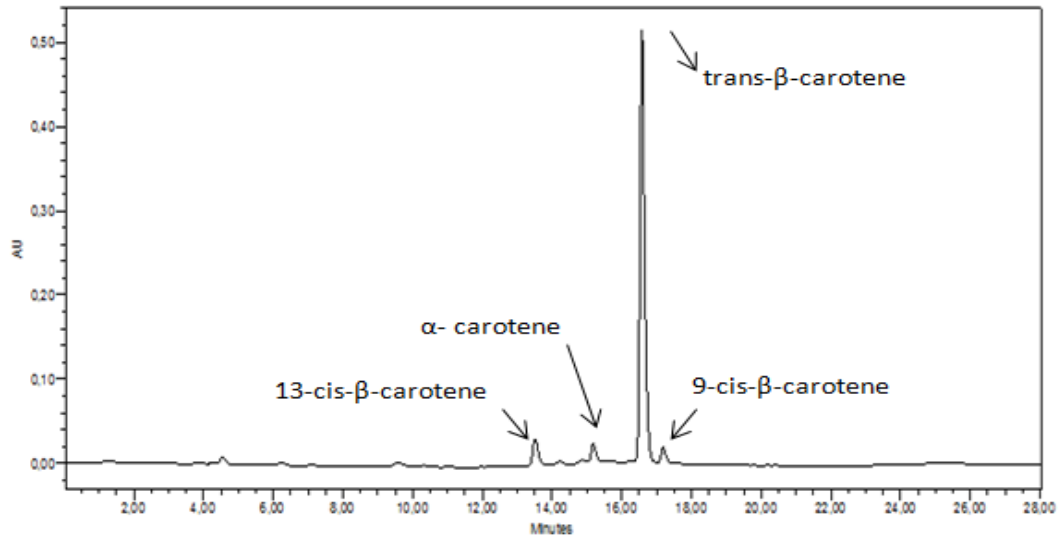

Fig. 1. Typical chromatogram in *orange fleshed* sweet potato tuber. 13 cis-β-carotene, α-carotene, β-carotene and 9 cis-β-carotene.

The obtained values of total carotenoids content for studied *orange fleshed* sweet potato (11209.36 µg/100 g of dry sample) were comparable to recognized sources of carotenoids (ex.: pumpkin and carrot).

Rodriguez-Amaya (2004) has found β-Carotene for different cultivars of pumpkins, values ranging from 80 to 29400 µg of this phytochemical per 100 g and to different cultivars carrot cultivars varied from 4600 to 10300 µg/100 g.

According to the results of this study, were observed that the β-Carotene (10226.25 µg/100 g of d.b), was the principal carotenoid of the *orange fleshed* sweet potato varieties analyzed, but the amounts of α-carotene (647.75 µg/100 g of d.b), 9 cis-β-carotene (139.66 µg/100 g of d.b), and 13 cis-β-carotene (195.70 µg/100 g of d.b), was significant (Fig. 1).

Nearly all of the β-carotene in sweet potato is in the trans configuration, which a beneficial characteristic as the trans isomer has double the provitamin A activity than the cis isomers (Van Jaarsveld et al., 2006).

The value of the present study (Fig. 1) was better than the values reported by Donado-Pestana et al. (2012) several sweet potato cultivars showed high levels of carotenoids (7910-12850 µg/100 g d.b) and it was showed that the all-trans-β-carotene had a quantitative predominance in raw roots. And bigger then found by Shih, Kuo, & Chiang (2009) for two different cultivars (430 and 833 µg/ 100g) of orange-fleshed roots. Ukpabi and Ekeledo (2009) and Tomlins et al. (2012) have found lower values,

ranging from 3870 to 5970 µg of β-carotene and 120 to 21600 µg of β-carotene per 100 g of root samples, respectively. Grace et al. (2014) presented concentrations of β-carotene and total carotenoids of 25330 and 28190 µg/100 g (d.b.), respectively in the freshly harvested *orange fleshed* roots (Covington genotype).

High content of trans-β-carotene was found in fresh roots of sweet potato cultivars produced at four agro-geographical production sites in South Africa. Resisto, Khano, Purple Sunset and W-119 with trans-β-carotene values ranging from 16456 to 10464 µg/100 g (Laurie et al., 2015).

The US Institute of Medicine (IOM, 2001) derived new conversion factors for estimating the amount of retinol activity equivalents (RAE) obtained from provitamin A carotenoids in foods , where 1 RAE = 1 µg retinol, 12 µg β-carotene, 24 µg α-carotene, or 24 µg β-cryptoxanthin.

From this study, the pro-vitamin A orange fleshed sweet potato which includes α-carotene and β-carotene will be the recommendation nutrient intake for men and women age from 19 to 50 years old is 900 µg EAR per day and for children for 4–8 year-old is 400 µg EAR (IOM, 2001).

The RE value that can be obtained from 100g of dry weight *orange fleshed* sweet potato is around 1704.36 µg of RE/100g of β-carotene and 852.18 µg of EAR/100g of β-carotene. And α-carotene the RE value that can be obtained from 100g of dry weight *orange fleshed* sweet potato is around 54.00 µg of RE and 27.00 µg of EAR/100g.

Retention of β-carotene in sweet potato during cooking has been shown to be between 70% and 95% (Rautenbach et al., 2010 and Van Jaarsveld et al., 2006).

A portion of 120 g fresh *orange-fleshed* sweet potato, when cooked (assuming 85% retention) will provide > 100% EAR, sufficient for the daily needs nutrients intake for men and women age from 19 to 50 years old and 60 g will provide > 100% of the recommended dietary allowance (RDA) of vitamin A for 4–8 year-old children (IOM (2001) and Laurie, Van Jaarsveld et al (2006) and Rautenbach et al., 2010).

Studies reviewed by Rodriguez-Amaya, Nutti, and Carvalho (2011) indicate that the carotenoid compositions of sweet potato roots vary widely between varieties and crops.

Rodriguez-Amaya (2001) has also reported the carotenoid composition of foods and found that are affected by factors such as cultivar or variety; part of the plant consumed; stage of maturity; climate or geographic site of production; harvesting and postharvest handling; processing and storage. The author indicates that greater exposure to sun light and elevated temperatures heighten carotenoid biosynthesis in these fruits.

In orange and yellow fleshed sweet potato, the colour is due to the presence of carotenoids, of which β-carotene is the most abundant. Some of the carotenoids, the provitamin A carotenoids, are vitamin A precursors, since they are absorbed and converted into vitamin A in the human body. β-Carotene is the major contributor to the vitamin A content of orange-fleshed and yellow-fleshed sweet potato. In many low-income countries, the largest contribution of vitamin A intake, up to 82% of the total vitamin A intake, comes from the provitamin A carotenoids in plant-based foods (Kidmose et al., 2007).

Thus the consumption of carotenoid-rich foods, such as fruits and vegetables, has been associated with a decrease of the risk of developing certain types of cancer and other degenerative and chronic diseases due to their important in vivo biological actions, in most cases related to their antioxidant and free-radical scavenging properties. In addition, some of these pigments (mainly β-carotene, α-carotene, and β-cryptoxanthin) have provitamin A activity (Hornero-Méndez & Mínguez-Mosquera, 2007).

4 Conclusion

The rhizomes and tubers analyzed in this study had good nutritional characteristics. The taro and sweet potato *Rosinha* were presented higher levels of phenolic compounds, however, the orange sweet potato showed the largest kidnapping of free radical and antioxidant activity by DPPH method. Have the two varieties of arrowroot, were the ones that have higher levels of antioxidant capacity by FRAP method. However, both rhizomes and tubers analyzed showed a significant antioxidant capacity. Arrowroot rhizome of *ovo de pata* presented a whiteness index and the taro was presented the lowest total color difference.

The organic *taro* showed better levels of K, P and Zn and the tuber *Capivara* was Ca, Zn, Cu and Fe. The major fatty acid found sweet potato *Capivara* was palmitic, lauric acid and also linoleic acid. The phytosterol content in vegetables was high, and they also play an important role, indicating that increased intake of vegetables with higher phytosterol contents helps increase the phytosterol intake.

Were observed that the β-Carotene was the principal carotenoid of the *orange fleshed* sweet potato analyzed, but the amounts of α-carotene 9 cis-β-carotene and 13 cis-β-carotene was comparatively substantial. Also a biofortification of *orange fleshed* sweet potato provides a feasible means of reaching malnourished rural populations who may have limited access to diverse diets, supplements, and commercially fortified foods. Furthermore rhizomes and tubers analyzed showed nutritional features and bioactive compounds significant.

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Capítulo III

Physicochemical, antioxidant and rheological properties of organic arrowroot and taro flours

Manuscrito em Preparação

Physicochemical, antioxidant and rheological properties of Brazilian organic arrowroots and taro flours

Abstract

The aim of this study was to analyse the rheological, physicochemical, and antioxidant properties in flours from two cultivars of organic arrowroot (*Maranta arundinacea* L.) *ovo de pata* and *comum* and taro *Chinese* (*Colocasia esculenta* (L.) Schott).). Based on the results obtained, that the best drying temperature chosen to obtain the starches was the temperature of 65 °C for 24h. It was observed a greater yield for the cultivar *ovo de pata* provided flour with higher yield (21.59±0.01 g/100g) and yield of 15.34 g/100g for organic taro flour. Taro presented high energy, ash content, crude fiber and reducing sugars than found arrowroot *ovo de pata* and *comum* flours. Flour from arrowroot *ovo de pata* presented higher water absorption index and lower fat absorption capacity that taro flour. Arrowroot flour *ovo de pata* presented a higher whiteness index and lower than yellowness index that arrowroot *comum*. The total phenolic compounds (380.00±0.01 mg/100g of gallic acid), were higher in arrowroot *ovo de pata* and both cultivar of arrowroot (*comum* and *ovo de pata*) provided flours with high antioxidant capacity that observed to the taro *Chinese*. Moreover, the levels of antioxidant capacity by FRAP of taro flour were significant (1277.00±0.07 µM Ferrous Sulfate/g of sample), but lower than arrowroot flour of *ovo de pata*. The arrowroot *comum* had a low crystallinity, however, similar to the pattern shown by the arrowroot *ovo de pata* and taro *Chinese*. Regarding the pattern of crystallinity of both arrowroots and taro flours showed standard type A. The difference folder temperature arrowroot *ovo de pata* to the arrowroot *comum* was only 4 °C, it is suggested that in relation to the initial temperature of repulping the *comum* variety presents gels at low temperature that arrowroot *ovo de pata* and less than taro *Chinese*. Thus, the results of investigation suggest the arrowroots and taro may be used for food industry and by consumers as a viable source of flour, with good nutritional, technological and antioxidant properties.

Keywords: Maranta arundinacea; Taro; Organic food; Rhizomes; Rheology; Chemical composition.

Propriedades físico-químicas, antioxidantes e reológicas de farinhas brasileiras de ararutas e taro orgânicas

Resumo

O objetivo deste estudo foi analisar as propriedades físico-químicas, antioxidantes e reológicas de farinhas brasileiras de duas cultivares de araruta orgânica (*Maranta arundinacea* L.) *ovo de pata* e *Comum* e taro *cv Chinês* (*Colocasia esculenta* (L.) Schott). Com base nos resultados obtidos, a melhor temperatura de secagem escolhida para obter as farinhas foi a temperatura de 65 °C durante 24h. Foi observado um maior rendimento de farinha para a cultivar da araruta *ovo de pata*, com maior rendimento (21,59 ± 0,01 g/100g) e um rendimento de 15,34 g/100g para a farinha de taro orgânica. A farinha de taro apresentou alto valor energético, teor de cinzas, fibra bruta e açúcares redutores do que o encontrado para as farinhas de *ararutas comum* e *ovo de pata*. A farinha de araruta *ovo de pata* apresentou um índice maior de absorção de água e menor capacidade de absorção de gordura que a farinha de taro. A farinha de araruta *ovo de pata* apresentou maior índice de brancura e menor índice de amarelecimento que a araruta *Comum*. Os compostos fenólicos totais (380,00 ± 0,01 mg/100g de ácido gálico), foram maiores na farinha de araruta *ovo de pata* e ambas as cultivares de ararutas (*Comum* e *Ovo de pata*) apresentaram capacidade antioxidante maior do que o observado para a farinha de taro *Chinês*. Além disso, a capacidade antioxidante pelo método de FRAP da farinha de taro foram significativas (1277,00 ± 0,07 uM Sulfato Ferroso / g de amostra), contudo menor que a farinha de araruta *ovo de pata*. A araruta *comum* apresentou uma cristalinidade baixa, no entanto, semelhante ao padrão mostrado pela araruta *ovo de pata* e taro *Chinês*. Quanto ao padrão de cristalinidade de ambas as farinhas de ararutas e taro mostrou do tipo A. A diferença temperatura de pasta da araruta ovo de pata para a araruta comum foi de apenas 4ºC a mais, sugere-se que em relação à temperatura inicial de formação de pasta a variedade comum apresenta géis a baixa temperatura que a araruta ovo de pata e muito menor que o taro. Assim, os resultados sugerem que as ararutas e o taro podem ser usados pela indústria de alimentos e pelos consumidores, como uma fonte viável de farinha, com boas propriedades nutricionais, tecnológicas e antioxidantes.

Palavras-chave: *Maranta arundinacea*; Taro; Alimento orgânico; Rizomas; Reologia; Composição química.

1. Introduction

The global organic food market has increased dramatically in recent years. Total organic food sales amounted to $15.2 billion in 1999, and rose to $62.9 billion in 2011. Whole Foods, a chain that only carries organic food, has been highly successful since the world′s largest retailer, Wal-Mart has introduced organic food in their super-centers (Daunfeldt & Rudholm, 2014). In parallel to the process-related quality criteria such as environmental issues and animal welfare, product criteria such as taste, nutrition and health, as well as organic specific indicators are becoming more and more important (Fuentes et al., 2014).

Specifically, organic food is considered to be more environmentally friendly, which benefits everyone, because, unlike conventional food, it is produced without using harmful chemical fertilizers, herbicides, and pesticides, which contribute to air, water, and soil pollution (Kareklas, Carlson & Muehling, 2014).

Maranta (*Maranta arundinacea* L) can be considered as a non-conventional raw material for starch. *Maranta* is an herbaceous, perennial plant which have cylindrical rhizomes with high starch contends (17.2-18.9 w.b.%), being cultivated in the Caribbean islands, Southeast Asia, South America, Philippines and India. Some reports have document that the *Maranta* starch has low protein, fat, ash and fiber composition, with size particle between 4 and 42 μm and gelatinization temperature between 68 and 75 °C (Valencia et al., 2014).

However, *Maranta* starch has received less attention despite its enormous potential in food applications. In Brazil, the arrowroot used to be cultivated by traditional family farmers as those from Territory of Recôncavo Baiano, but in the last 50 years, its cultivation has been almost reaching the extinction due to competition from other starch sources as cassava, maize, oats, barley and wheat (Madineni et al., 2012; Silveira et al., 2013).

Moreover, according to Swadija, Padmanabhan, & Vijay (2015) the starch arrowroot is used for the preparation of various bakery products, as a base for face powder, in the preparation meals and as a base for tablets, where rapid disintegration is desirable. The starch possesses demulscent and anti-diarrhoeal properties and is used in the treatment of intestinal disorders, which adds medicinal value the product. There is great demand for arrowroot starch not only in the domestic market but also for export to Gulf countries mainly as a food for infants and invalids.

Taro (*Colocasia esculenta* (L.) Schott) is one of the most widely cultivated edible tubers in tropical and subtropical countries. In 2009, about 11.3 million metric tonnes (MMT) of taro were produced worldwide. The global average yield of taro is 6.2 tonnes/hectare, but yields vary according to region (Zeng, Liu, & Liu, 2014).

Although this crop is largely cultivated in many areas of the world, there is a great loss (around 30%) during its storage. Transforming tuber of taro in to starch can minimize these losses and add value to the product (Dai et al., 2015). Their tubers contain reasonable amount of calcium, phosphorus, vitamin A- and B-group vitamins. The protein and dietary fiber content of the edible portion are also high as compared to other root and tuber crops (Sit et al., 2014).

Taro has been reported to have 70-80% starch with small granules and, therefore, presents a highly digestibility. It has been verified its use in the preparation of infant foods and the diets of people allergic to cereals and children sensitive to milk and other industrial applications (Njintang et al., 2008; Sit et al., 2014; Temesgen, 2015). Moreover, starch is gluten free and indicated for peptic ulcer and pancreatic patients;

chronic livers, inflammatory bowel and gall bladder diseases (Temesgen, 2015). However, it has a high postharvest loss due to its high moisture content. Despite its nutritional, industrial and health importance, taro has not gained sufficient attention research in order to enhance its potential (Njintang et al., 2008).

This work will show the present knowledge on the composition, structure, physicochemical properties of flours with a view to providing suggestions for needed research to improve the utilization of these flours in the food industry. Convective drying is a very common technique used for preparing flour based materials because of its low cost and available equipment furthermore, it is relatively rapid drying process.

Thus, the goal of this paper was to develop and adapt processing techniques in order to develop organic meals, and determine the temperature and time of drying the same. To study the physicochemical, antioxidant capacity and rheological properties of flours from two different varieties of organic arrowroots and taro cultivated in Brazil.

2 Materials and Methods

2.1 Material and Sample preparation

The arrowroot rhizomes cultivars *ovo de pata* and *comum* and taro cultivars *Chinese* were cultivated in organic production system in Seropédica, supplied by Embrapa Agrobiology, Rio de Janeiro, Brazil (latitude 22º48'00" S, longitude 43°41'00" W and altitude of 33 meters). The harvest was carried out in the period from August of 2011 to June of 2012 and approximately 5 kg from each variety were used for each sampling.

2.2 Flour production and Yield

The arrowroot of cultivars *ovo de pata* and *comum* and cv. *Chinese* taro, were washed in current water and sanitized in sodium hypochlorite (200 ppm) for 15 minutes. The samples was peeled, sliced (2 cm thickness), blender Oster (Osterizer Classic Blender 4093, Oster Beehive, Miami, USA) with 1 liter of water for 1 kg sample and sieved (200 µm). The samples were placed on a tray and dryed in oven with air circulation (Solab SL 102, São Paulo, Brazil) and speed, with an accuracy of ± 0.5 °C, with temperature control of 35 °C, 45 °C, 55 °C and 65 °C with three replicates (Takeiti, 2008) the distance 100 mm between the trays.

The samples were subjected to temperatures above and drying at intervals of predetermined time (every 15 minutes during the first two hours of the process, 30 minutes for the next two hours and 1 hour in the other) weighing of samples was performed using an analytical balance until dynamic equilibrium between the sample and air drying was achieved. Each experiment for obtaining the organic flour was performed in triplicate.

After drying, aiming to assess the product yield, samples were weighed out on a semi-analytical balance (Gehaka, AG 2000, São Paulo, Brazil). The dry material was ground on hammer mill 3100 (Perten Instruments, Huddinge, Sweden) to obtain a fine flour.

The obtained flours were sealed in laminated bags in order to prevent moisture absorption and stored in a freezer (-20 ºC) until further analysis.

2.2.1 Yield of Organic Flours

Flours yield (SY) was calculated according to Equation 1 (Waramboi et al., 2013).

$$SY(\%) = \left(\frac{W_f}{W_{fr}} \right) * 100 \quad (1)$$

Where:
W_f= weight of solids in flours;
W_{fr} = weight of solids in rhizomes and tubers.

2.3 Physicochemical Properties

2.3.1 Chemical Composition

The proximate composition of each raw material was determined according to AOAC (2005) standards: moisture content (Method 925.09), total nitrogen (Method 2001.11, a conversion factor of 5.75 was used to convert total nitrogen to protein content), fat content (Method 945.38) and ash content (Method 923.03).

The crude fiber (Method 962.09; AOAC 2000), total titratable acidity (Method 942.15; AOAC (1997). The pH, hydrolysable carbohydrates, reducing and non-reducing carbohydrates by oxidation-reduction of Fehling's solution, according to the methodology described by IAL, (2008).

The total energetic value (TEV) was expressed in kilocalories (kcal.100g^{-1}) and was calculated considering Atwater conversion factors of 4 to kcal.g^{-1} to protein and carbohydrate and 9 kcal.g^{-1} to lipids (USDA, 2006). Calculated with the following formula: (carbohydrates × 4 kcal) + (protein × 4 kcal) + (fat × 9 kcal).

2.3.2 Water Activity (A_w)

The water activity of the samples was measured using the Aqualab Lite (Decagon Devices, Pullman, Washington, USA) by Diniz, Figueiredo, & Queiroz (2003).

2.3.3 Colour Analysis

Colour was evaluated by the CIEL*ch system (Colour Quest XE - Hunter Lab, 2010, Virgínia, USA). CIEL*ch is a modification to the CIELAB scale which plots in polar coordinates rather than rectangular ones. The colour attributes lightness (L*), chroma (C) and hue angle (h) were measured four times on the surface of the sample. Measurements were performed using 25 mm viewing area aperture, D65 illuminant and 10° observer, according to CIE (Comission International de L'Eclairage) recommendations, using the equations below:

$$h* = \arctan \begin{pmatrix} b* \\ a* \end{pmatrix} \quad (2)$$

The samples were placed on a white standard plate (L = 72.46, a = 5.09, and b = 14.71) and the L, a, and b color values were measured. L values range from 0 (black) to 100 (white); a values range from −80 (greenness) to 100 (redness); and b values range from −80 (blueness) to 70 (yellowness). All measurements were performed in four replicates. The whiteness index (WI) and yellowness index (YI) of sample was obtained by substituting the values of L*, a* and b* into the following equations according to the standard of CIE (Ghanbarzadeh, Almasi, & Entezami, 2010):

$WI = 100 - \sqrt{[(100 - L)^2 + a^2 + b^2]}$ (3)

$YI = {}^{142.86b}/_{L}$ (4)

2.3.4 Water Absorption Index (WAI, Water Solubility Index (WSI) and Fat Absorption Capacity (FAC)

The WAI and WSI of the samples were analysed according to the procedure described by Anderson, Conway, Pfeifer, & Griffin (1969). Briefly, a sample of 1.0 g was mixed (manually with the aid of a glass rod) with 10 mL of distilled water, and centrifuged (NEW Model NI 1813, Piracicaba, São Paulo, Brazil). The suspension was placed in a petridish and dried at 105 ºC for 4 h to obtain the dry solids weight and the wet sediment was weighed. Were determined as: WSI = (weight of dry solids in supernatant (g/g)/weight of dry sample) / 100; WAI = weight of wet sediment/ (weight of the dry sample-weight of the dry solids).

The FAC was determined according to Dench et al. (1981). 0.5 g mixed (manually with the aid of a glass rod) into centrifuge tubes and added with 3 mL of soybean oil, and mixed (manually with the aid of a glass rod) for 30 s., then allowed to stand for 30 min. After a holding period of 30 min, the tubes were centrifuged ((NEW Model NI 1813, Piracicaba, São Paulo, Brazil) for 25 min at 3000 rpm. Excess oil was drained and the tube inverted for 30 min. Triplicate determinations were carried out and the water and fat absorption capacities were expressed as g of oil retained per 100 g of sample.

2.4 Antioxidant Properties

2.4.1 Obtaining of Extracts

The extracts were obtained according to Swain and Hillis (1959) and Torres (2002) with minor modifications. 20 g of sample were diluted with ethanol (ACS) in volumetric flasks (100 mL). These solutions were subjected to magnetic stirrer at 25 °C for 1 h. Then, vacuum filtered using a sintered filter funnel (n. 3).

2.4.2 Determination of Total Phenolic Compounds

0.5 mL of each obtained extract was mixed to 7 mL of distilled water and 0.5 mL of Folin-Ciocalteu reagent, were mixed for 3 min. 2 mL of 20% Na_2CO_3 solution and heated to 100 °C for one minute in a temperature controlled water bath and cooled at the ambient condition in the dark (Singleton & Rossi Jr, 1965; Quettier-Deleu et al., 2000). The results were expressed in gallic acid equivalents (GAE; mg/100 g fresh

mass) using a gallic acid (0.05 to 1.2 mg/mL) standard curve. All analysis were performed in triplicate.

2.4.3 DPPH Scavenging Activity

The antioxidant capacity was determined by the modified DPPH method (Brand-Williams, Cuvelier, & Berset, 1995), is based on the quantification of free radical-scavenging, with modifications. A methanol solution containing 0.06 mM DPPH was prepared. After adjusting the blank with methanol, an aliquot of 100 μL of samples extract was added to 3.9 mL of this solution. The absorbance was measured using an UV Spectrophotometer NEW 2000 (São Paulo, Brazil) at the 517 nm. The amount antioxidant capacity was expressed as μM of Trolox Equivalent per 100 g of sample (dry basis). The free radical-scavenging (%FRS) of each sample was calculated according to Eq. 6. Where: A_c and A_A are absorbance values of blank and sample, respectively. All analysis was performed in triplicate.

$$\%FRS = \frac{(A_c - A_A) * 100}{A_c} \quad (4)$$

2.4.4 Method of Ferric Reducing Antioxidant Power (FRAP)

The antioxidant capacity of each sample was estimated by FRAP assay, following the procedure described by Rufino et al., (2010). Briefly, 2.7 mL of freshly prepared FRAP reagent (TPTZ, $FeCl_3$ and acetate buffer) at 37 °C was mixed with 90 μL of samples extracts and 270 μL of distilled water.Its was used blank containing FRAP reagent as reference, read at absorbance of 595 nm for 30 min. Aqueous solutions of known Fe (II) concentrations in the range of 100–1500 μM (Fe_2SO_4) were used for calibration.

2.5 Morphological Properties

The visualization of the microstructure of flours was performed in a benchtop scanning electron microscope TM 3000 (Hitachi, Tokyo, Japan). The previously dried samples were placed on a metallic stub with self-adhesive conducting carbom tape and scanned at 15 kV.

2.6 Standard Starch Crystallinity Determination by X-ray Diffractometry

The determination of the x-ray diffraction profile was carried out in a D2 Phaser x-ray diffractor (Bruker AXS, Rheinfelden Germany) equipped with copper tube operated at 30 kV and 10 mA, producing CuKα radiation with 0,154 nm wavelength. Samples were scanned from 2 to 32° (2θ) at a rate of 0.15°/min, a step size of 0.02°, a divergence slit width of 0.6 mm, a scatter slit width of 0.6 mm and a receiving slit width of 0.2 mm. Diffrac.Suite EVA-XRD version 1.1 software (Bruker AXS, Rheinfelden Germany) was used to analyze the diffractograms.X-ray diffraction of starches were analyzed using X-ray diffractometer D2-Phaser (Bruker, Karlsruhe, Germany) and operating with Cu radiation (wavelength 1.506 Å) at a 8 sec scan time, a step of 0.02, being fed with voltage 30 kV and current of 10 mA. Each material was placed in an

acrylic-sample holder (approximately 1 g) and the diffraction angle of the scanning region was 2-32º (2-theta).

2.7 Paste Properties

The paste viscosity of flours, was used the methodology described Duarte et al. (2009) dupliccate. A Rapid Visco Analyser (RVA, Newport Scientific PTY LTD., Sidney, Australia) was used to measure the paste viscosity of samples as a function of temperature. 3 g of starch (14% of water content, wb), was added to 25 g distilled water and this was loaded into the RVA. The time-temperature profile included initially mixing and holding the specimen with the paddles rotating at 160 rpm at 50 °C for 4 min (to investigate the cold-swelling peak), heating to 95 ºC at a constant rate of 14 ºC/min, holding at 95 °C for 3 min, and then cooling to 25 °C in 5 min at the same rate. The readings from the paste curve generated were cold viscosity (CV) (maximum viscosity reading at 25 °C), peak viscosity at 95 °C (PV) (first viscosity reading data when the temperature reached 95 °C), breakdown viscosity and setback viscosity.

2.8 Statistical Analysis

The results were verified by variance analysis (ANOVA). The chemical and physical tests were analysed by variance and Tukey test at 5% of significance level for averages comparison.

3 Results and Discussion

Figure 1 are shown the drying curves of organic flours.

3.1 Drying Curves of Organic Flours

Moisture losses during drying processes of flours organic are shown in Figure 1.

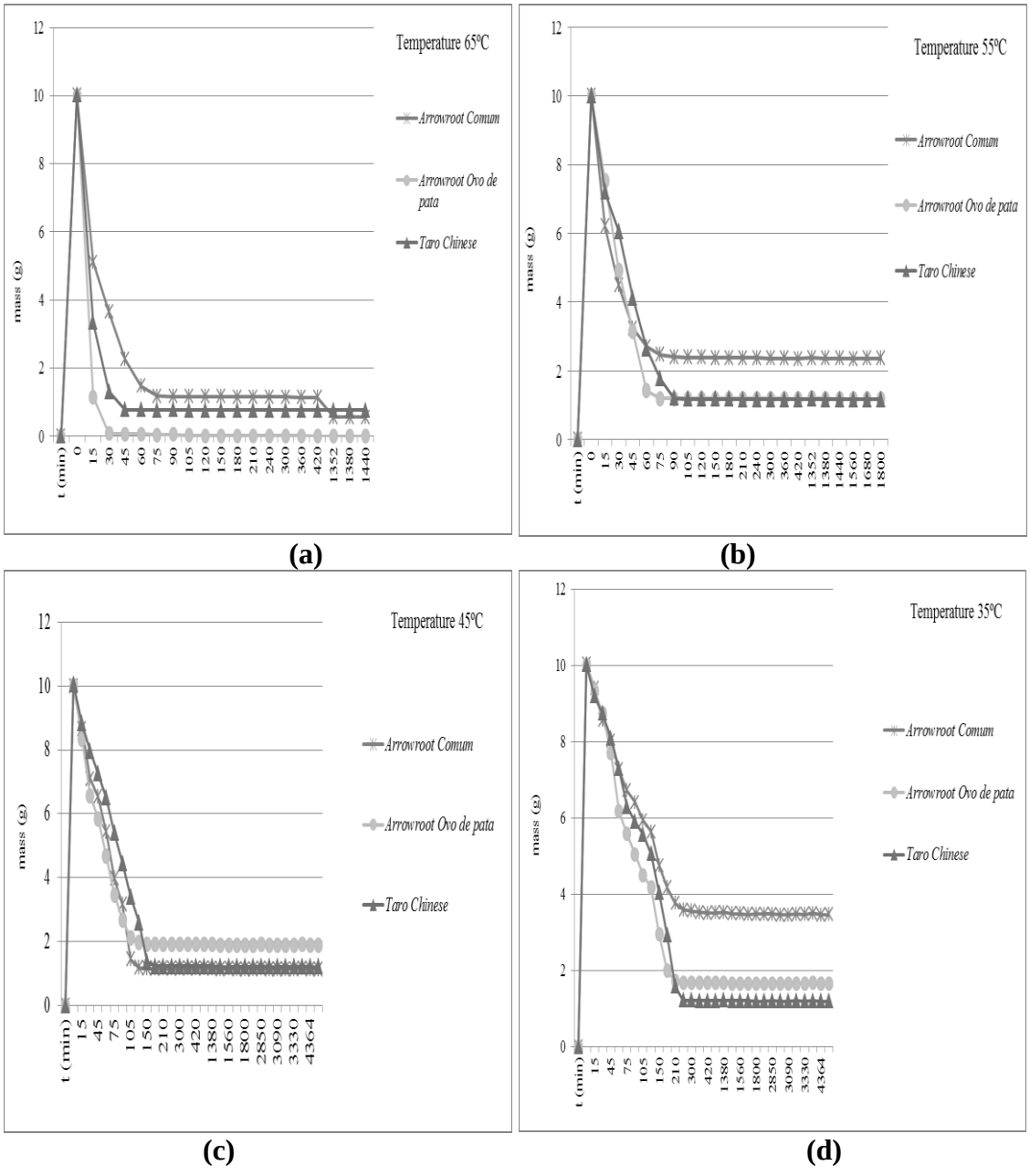

Fig. 1. Drying conditions flours obtained in an organic system at 35 ºC (a), 45 ºC (b), 55 ºC (c) and 65 ºC (d).

Moisture losses during drying processes of flours organic are shown in Figure 1. It appears that the largest loss of water were taken at higher temperatures (55 ºC and 65 ºC) for both organic flours. To achieve the equilibrium moisture content of the samples at 65 °C, 1400 minutes (~24 hours) were necessary, since using the temperature of 55 °C needed 1800 minutes. However, at temperatures of 35 °C and 45 °C took 4470 minutes and even then, there was an increase in bulk volume, which characterizes the absorption of water by some samples. It is also observed that the drying temperature to 35 °C caused a noticeable pinkish in arrowroot *comum* and *taro* flours (Figure 1). Therefore, the drying temperature used in order to obtain flour, was based on shorter time and higher drying temperature. Thus, it is important to identify different alternative flour sources with wide variability in flours properties.

These results are in accordance to those found by Koyuncu et al. (2004). The authors also showed that temperature is the most important drying parameter affecting the total drying time and the consumed energy, where time and the heat energy decrease with increasing temperatures. Besides, drying in the range 50-60 °C was found to be least energy consuming.

According Correia, Leitão, and Beirão-da-Costa, (2009) the free water evaporation rate was lower when the drying temperature was lower. Moisture losses during drying processes, was observed. Increasing temperature increased the amount of water released from the product.

Drying or dehydration is a simple procedure and is oftentimes less expensive than other food conservation techniques, and is therefore frequently used to give products with additional benefits, such as longer shelf life and easier transportation and commercialization. However, drying may alter color and taste, and can also cause nutrient loss due to oxygen and relatively high temperature exposure, especially when carried out using conventional hot air processes (Lago-Vanzela et al., 2013).

3.2 Yield and Physicochemical Characterization

Table 1 presents the results of yield and physicochemical characterization of organic arrowroot and taro flours ($p<0.05$).

Table 1. Yield and physicochemical characterization of the organic arrowroot and taro flours (n=3).

	Arrowroot		Taro
g/100g	*Ovo de pata*	*Comum*	*Chinese*
Moisture	11.80±1.16[b]	14.30±0.25[a]	6.11±0.01[c]
Protein	2.20±0.36[a]	1.00±0.11[b]	0.87±0.68[c]
Ash	3.00±0.05[b]	3.00±0.08[b]	4.02±0.47[a]
Fat	0.40±0.11[a]	0.10±0.07[c]	0.27±0.87[b]
Crude fiber	0.49±0.01[c]	0.66±0.08[b]	2.31±0.24[a]
Hydrolysable carbohydrates	78.00±0.32[b]	80.00±1.87[a]	67.95±0.33[c]
Yield of flour	21.59±0.01[a]	13.34±0.01[c]	15.34±0.07[b]
Reducing sugars	2.83±0.13[b]	1.30±0.00[c]	5.07±0.17[a]
Non-reducing sugars	7.41±0.20[a]	5.70±0.08[c]	6.86±0.01[b]
TEV (kcal)	365.36±0.00[a]	360.90±0.00[b]	325.43±0.01[c]
pH	6.17±0.00[b]	6.40±0.00[a]	6.22±0.07
Acidity (mg NaOH/100g)	7.22±0.28[a]	4.80±0.29[b]	1.97±0.29[c]
A_w	0.396±0.01[a]	0.300±0.02[c]	0.330±0.01[b]

*Average ± RI= reliable interval for a statistical probability of 95%; ** A_w= Water Activity; Where same letter on the same line do not present significant differences ($p<0.05$) among each other. The results presented in table corresponds to d.b. (dry basis); Where same letter on the same line do not present significant differences ($p<0.05$) among each other. TEV= total energy value; nd: no determined.

The results of processing the laboratory level showed a good yield of 21.59±0.01 g/100g (w/w) for arrowroot *ovo de pata* and 13.34±0.01 g/100g for arrowroot *comum* flours (Table 1). Whereas *ovo de pata* flours presented similar results compared to Leonel, Cereda & Sarmento (2002) who obtained a yield of 21 g/100g arrowroot starches.

The flours extraction yield obtained for taro *Chinese* (15.34 g/100g, w/w) was greater than those reported by Pérez, Schultz, & Delahaye, (2005), who obtained a yield of 10-12 g/100g for taro and by Ascheri (2010), who obtained 13.96 g/100g for yam starch.

There were significant differences ($p<0.05$) hydrolysable carbohydrates content for arrowroot cultivars, ranging from 78 to 80 g/100g (d.b.) (Table 1). For arrowroot, carbohydrate is the main component, followed by simpler sugars as sucrose, glucose, fructose and maltose.

Arrowroot flour from *ovo de pata* showed higher contents energy, ash, fat content, proteins, acidity, non-reducing sugars and reducing sugars than the from cultivate *comum*, showing significant differences ($p<0.05$), however, lower moisture, fiber, carbohydrate and pH (Table 1). The verified in the present were higher than those reported for Pérez & Lares (2005) for conventional arrowroot starch. In related to fat content, the starch from *ovo de pata* presented similar trend (0.40 g/100g), but the *comum* cultivate provided lower value (Table 1) than reported for Pérez & Lares (2005).

However, both organic flours showed better results regarding nutritional values found by Leonel, Cereda & Sarmento (2002) reported to arrowroot starch 12.8 g/100g of moisture, 0.18 g/100g of ash, 0.11 g/100g of lipids, 0.10 g/100g of proteins, 84.33 g/100g of starch, 1.0 g/100g of fiber e 0.17 g/100g of total sugar (dry basis). This nutritional quality poode is related to the organic system of farming techniques.

Also known that the chemical composition results of arrowroots flours (Table 1) of this study was greater than analysed by Erdman (1986) for two cultivates of arrowroot starch produced in Georgia has found that they presented 0.12 to 0.27 g/100g of protein and 0.36 to 0.28 g/100g of lipids (dry basis).

The values *Maranta* starch found in this study was higher than the results by Madineni et al. (2012) 8.1±1.2 g/100g of moisture, 1.5±0.20 g/100g of ash, 1.0±0.09 g/100g lipids, 0.8±0.01 g/100g protein and 81.60±0.24 g/100g of *Maranta* starch.

The organic taro flour showed higher fiber, ash and fat, but lower protein contents than those found to taro flour analyzed by Tattiyakul, Asavasaksakul, & Pradipasena, (2006) that presented 97.1-98% carbohydrate, 0.9-1.7 g protein /100 g, 0.3-0.7 g fiber/100 g, 0.2-0.3 g ash/100 g and 0.1-0.2 g fat /100 g in dry weight basis.

The values found in present study were similar than those results obtained by Mbofung et al. (2006) noted for taro flour: crude proteins ranges between 2.7 and 5.4%; available carbohydrate 33.3-77.8%; crude fibre 0.3-3.8%; ash 3.5-5.7% and crude starch 41.2-64.4% in dry weight basis.

On the other hand, the taro flour observed average protein content of 0.87 g/100 g was generally very smaller to values reported by other authors.

Nwokocha & Williams (2011) have evaluated the proximate composition of conventional yam starch. These authors obtained lower values of moisture (11.91±0.00 g/100g), ash (0.15±0.01 g/100g), protein (0.69±0.02 g/100g) and similar lipids content (0.29±0.01 g/100g).

It appears from the present study that the organic yam flour generally showed better nutritional values than that found by other authors and can associated with cultivation practices of the organic product, since the comparison of the present study was based on samples grown by conventional agriculture.

3.3 Water Activity (A_w)

The water activity from the arrowroot *ovo de pata* flour (A_w=0.396±0.01) was lower than the *comum* flour (A_w=0.300±0.02) (Table 1). The water activity of from taro flours *Chinese* (0.330±0.01) were same than the found by Tortoe, Johnson, and Nyarko (2009) where the ranges of water activity for the different plantain flours were 0.27-0.39 aw. Water activity is therefore an important parameter controlling the behaviour of intermediate and low moisture food during processing and storage, with particular emphasis on its effect on the rates of degradation reactions.

Water availability for chemical and biological reactions in foods has been historically described by the concept of "water activity" (A_w). The relationship between water activity and the rates of chemical and enzymatic reactions in the "food stability map" is still widely used as a tool by the food industry (Reid, 2007).

3.4 Colour Analysis

Table 2 presents the results of colour analysis of organic arrowroot and taro flours ($p<0.05$).

Table 2. Colour analysis of organic arrowroot and taro flours (n=3).

	Arrowroot		Taro
Parameter*	*Ovo de pata*	*Comum*	*Chinese*
L	97.00±0.38[a]	93.00±0.65[b]	79.34±0.50[c]
a*	0.10±0.01[b]	-0.10±0.02[c]	1.26±0.17[a]
b*	7.90±0.21[b]	11.00±0.52[a]	6.33±0.07[c]
C	7.90±0.21[b]	11.00±0.52[a]	6.45±0.17[c]
h*	99.00±0.50[b]	100.00±0.13[a]	73.62±0.35[c]
WI	91.55±0.00[a]	83.03±0.00[c]	89.46±0.01[b]
YI	11.63±0.00[b]	16.90±0.00[a]	11.39±0.50[c]

Average ± RI= reliable interval for a statistical probability of 95%; Where same letter on the same line do not present significant differences ($p<0.05$) among each other. L (Luminosity); C (Chromaticity); h (Colour); b*(Chromaticity b - yellow-blue component); a*(Chromaticity a – green-red component); WI (whiteness index); YI (yellowness index); Where same letter on the same line do not present significant differences ($p<0.05$) among each other.

Analysing the colour parameters L*, a*, b*, h* and C* was possible to realize that the arrowroots *comum* flour has a darker colour (lower L* value), more saturated (higher value of C*), more yellow (higher b* value) and a higher colour purity (higher value of h*) compared with *ovo de pata* flour. The chromaticity coordinate a* of *ovo de pata* was greater than *comum* flours (Table 2).

Arrowroot flour variety *ovo de pata* presented a higher whiteness index (WI) and lower than yellowness index (YI) *comum*, which shows its lighter shade. Where *comum* flour showed higher YI, justifying the staining of the same, which appears more yellowish (Chromaticity b* bigger). Thus, verified that arrowroot *ovo de pata* flour presenting a colour lighter than arrowroot *comum*.

However, Hsu et al. (2003) analysing the yams flours, found that it had presented L* from 87.44±0.13 to 89.00±0.04.

Flours from taro *Chinese* has had a clearest colour (higher L* value), less saturated (low value of C*), less yellow (lower b* value) and a higher colour purity (higher value of h*), compared to other taro flour evaluated by other authors. The chromaticity coordinate a* of taro flours, higher colour purity, the chromaticity coordinate a* of taro flour was low on the grounds that there was no change to red (Table 2).

According to Torbica, Hadnađev, and Hadnađev (2012) the colour of the flour is also significantly affected by the botanical source of the feedstock, since flour analyzed by this authors had the lowest lightness (L*) values and whiteness index (WI). Rice flour expressed the highest value WI almost white. Where, rice flour showed 88.55, 84.55 wheat flour and other flour showed whiteness index values of 86.52, respectively. Ghanbarzadeh, Almasi, and Entezami, (2010) investigated the effect films of starch/modified carboxy methyl cellulose and found that the resulting increase in b* values, YI, the values of L* (brightness) and whiteness index (WI).

3.5 Water Absorption Index (WAI), Water Solubility Index (WSI) and Fat Absorption Capacity (FAC)

Table 3 presents the results of Water Absorption Index (WAI), Water Solubility Index (WSI) and Fat Absorption Capacity (FAC) of organic arrowroots and taro flours ($p<0.05$).

Table 3. Water Absorption Index, Water Solubility Index and Fat Absorption Capacity of organic arrowroot and taro flours (n=3).

	Arrowroot		Taro
	Ovo de pata	*Comum*	*Chinese*
Water absorption index (WAI) (%)	2.61 ± 0.15^{a}	2.14 ± 0.02^{c}	2.42 ± 0.02^{b}
Water solubility index (WSI) (%)	13.50 ± 0.30^{b}	18.86 ± 0.32^{a}	12.62 ± 1.60^{c}
Fat absorption capacity (FAC) (%)	86.00 ± 0.01^{b}	84.00 ± 0.18^{c}	89.13 ± 0.71^{a}

*Average ± RI= reliable interval for a statistical probability of 95%, according to the t-Student distribution; Where same letter on the same line do not present significant differences ($p<0.05$) among each other. The results presented in table corresponds to d.b. (dry basis); Where same letter on the same line do not present significant differences ($p<0.05$) among each other.

Arrowroot flour variety *ovo de pata* presented water absorption index (WAI) and fat absorption capacity was higher of *comum* flour ($p<0.05$), however, showed water solubility index (WSI) lower than arrowroot *comum* (Table 3).

The results of present study were higher when compared to the water absorption index of arrowroot native starch, found by Jyothi, Sheriff, & Sajeev (2009). They found that the water absorption index, 1.81 g gel/g dry sample, water solubility index and oil absorption index, 1.16% and 0.60 g/g, respectively. However, were lower in comparison arrowroot starch extrudates: water absorption index, 6.52 to 8.85 g gel/g dry sample, water solubility index, 15.92% to 41.31%, and oil absorption index, 0.50 to 1.70 g/g (Jyothi, Sheriff, & Sajeev, 2009).

The values found in present study were similar than those results obtained by Singh et al., (2003), to water absorption index (WAI), water solubility index (WSI) of potato flour (6.56% to 5.50% and 10.18% to 11.40%) for corn (3.85% and 7.90%), for respectively.

Flour from taro *Chinese* showed low levels of water absorption and water solubility (WSI), however, a greater capacity to absorb fat (Table 3). Silva et al. (2008) analyzed the water absorption index (WAI) in pre-cooked pastas by extrusion made from flour mixed rice and corn, and found that ranged from 2.06 to 6.18. According to these authors, pre-cooked pastas trade have an average IAA 2.06 and 3.13 g / g gel.

Leonel et al. (2006) analyzed the water absorption index (WAI) in yam expanded and verified that products showed WAI of 6.5 to 16.4 g / g gel, whereas the non-extruded yam flour showed an average of 3.03 g/g gel. Thus, the starch obtained in the present study can be used in the development of pasta, like noodles.

Water absorption capacity of flours plays an important role in the food preparation process because it influences other functional and sensory properties. Furthermore, the range of application of flours as food ingredients is greatly dependent on their interaction with water (Sreerama et al., 2012).

Absorption of fat from soybeans and wheat flour (80:20) extruded with different screw rotation speeds ranged from 81.59% to 97.72% respectively (Wang et al., 2009). In the present study, the taro starch showed similar results to fat absorption capacity of

wheat and soybean meal (80:20) and extruded flour wheat studied by Wang et al. (2009). According to Sathe et al. (1982), the ability of fat absorption legume flour is very important to improve the texture of the mouth, and maintaining the flavor of food products.

3.6 Total Phenolic Compounds and Antioxidant Capacity

Table 4 presents the results of total phenolic compounds and antioxidant capacity of organic arrowroot and taro flours ($p<0.05$).

Table 4. Total Phenolic Compounds and antioxidant capacity of organic arrowroot and taro flours (n=3).

	Arrowroot		Taro
	Ovo de pata	*Comum*	*Chinese*
Phenolic (mg/100g of gallic acid)	380.50±0.03[a]	376.60±1.17[b]	65.42±0.01[c]
Antioxidant capacity (µM Eq. Trolox/g)	5.49±0.44[a]	5.49±0.40[a]	5.08±0.03[b]
%FRS	13.73±0.57[b]	13.83±0.68[b]	14.09±0.46[a]
FRAP (µM Ferrous Sulfate/g of sample)	4470.00±0.01[a]	1009.00±0.06[c]	1277±0.07[b]

*Average ± RI= reliable interval for a statistical probability of 95%. Where same letter on the same line do not present significant differences ($p<0.05$) among each other. The results presented in table corresponds to d.b. (dry basis); %FRS (Percent of free radical-scavenging); Eq. (Equivalent); µM (micromolar). Where same letter on the same line do not present significant differences ($p<0.05$) among each other.

Verified that the total phenolic compounds in the arrowroot *comum* flour was lower ($p<0.05$) than in *ovo de pata* flour and higher that taro *Chinese* flour, whereas the values for total phenolic compounds found in the organic flours were greater than found by Ahmed, Akter, & Eun (2010) who had verified for sweet potato flour a total phenolic compounds content from 5.24 to 10.44 mg/100g of gallic acid. Verified that the total phenolic compounds in the flour from taro *Chinese* was significant, compared taro flour evaluated by other authors, whereas the values for total phenolic compounds found in the organic flour taro were greater than found by Farombi, Britton, and Emerole (2000) for yam flour (22 to 60 mg/100g Catechin equivalent).

The values of antioxidant capacity evaluated by DPPH method were the same for both arrowroot flours varieties, not showing significant differences ($p<0.05$) among each other. However, it was observed that flour from *ovo de pata* showed higher antioxidant capacity by FRAP method.

The antioxidant capacity of taro flour was higher than those found by Ragaee, Abdel- Aal, and Noaman (2006), who studied hard and soft wheat flour and obtained 4.3±0.17 and 4.7±0.17 µM of Trolox Eq./g of sample, respectively.

Yu et al. (2004) have analysed the antioxidant properties of the wheat flour cultivated in different places and have observed that the wheat flour showed a antioxidant capacity, causing human nutrition improvement if ingested. Lavelli et al. (2009) have studied the antioxidant capacity of different varieties of integral wheat flour, which ranged from 949 to 867 g/g by the DPPH method for *T. Turgidum* and *T. aestivum* varieties, respectively, whereas the antioxidant capacity of *T. Monococcum* was higher than *T. turgidum* and *T. aestivum*.

Lavelli et al. (2009) have studied the phenolic compounds content in different whole flours from two especies of wheat and observed values that varied between 0.49 µmol and 0.98 µmol Eq. gallic acid/kg for *T. turgidum* samples and values from 0.60 to 0.84µmol Eq. de gallic acid/kg for *T. aestivum*. Vaher et al. (2010) have determined the content of total phenols in the bran, flour and whole grains from different species of wheat, cultivated in organic and conventional conditions. The total phenolic content was higher in the brain (1258-3157 µg/g), followed by the whole grains (168-459 µg /g) and lower in the flour (44-140 µg/g).

Differences were observed between the two radical scavenging assays (DPPH and FRAP). It appears that no linearity between the two different analysis methods, the principles and mechanisms for determining the antioxidant capacity in vitro are respectively different.

The DPPH method has the ability of the various antioxidants to donate an electron or hydrogen radical to the stable DPPH free radical. And FRAP method compares antioxidants based on their ability to reduce ferric (Fe^{3+}) to ferrous (Fe^{2+}) ion through the donation of an electron, with the resulting ferrous ion (Fe^{2+}) (Martins et al., 2013).

3.7 Scanning Electron Microscopy

The starch granules from arrowroot *ovo de pata*, arrowroot *comum* and taro Chinese were analysed by Scanning Electron Microscopy (SEM) and they are presented in Figure 2.

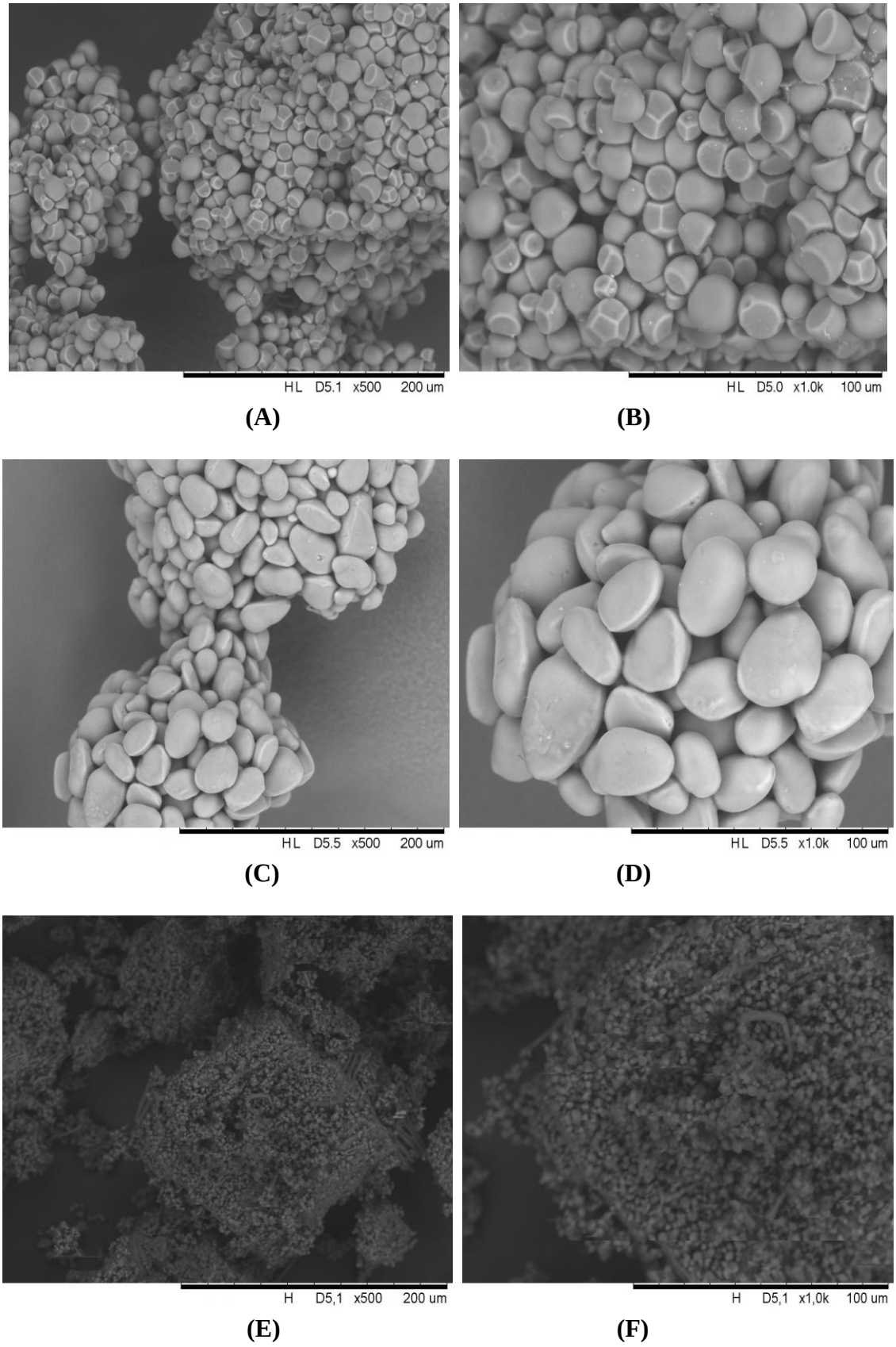

Fig. 2. Scanning electron micrographs (SEM) of starches of arrowroot *ovo de pata* (A and B), *comum* (C and D) and taro (E and F) with a zoom of 500x and 1.0kx.

The starch granules of arrowroot *ovo de pata* presented rounded circular shape and size varying from 11.8 to 19.2 µm. On the hand, the granules of arrowroot c*omum* presented oval circular shape and size varying from 4.31 to 36 µm. The starch granules of taro *Chinese* presented polygonal and irregular shapes with diameters between 1 and 5 µm.

Erdman (1986), analysing the starch granules of by electronic microscopy, showed granules with an oval and circular shape with size distribution varying between 14.52±0.56 µm and 10.05±0.32 µm. For the variety Tifton GA and the variety São Vicente, the average size of the granules were 16.62±0.78 µm and 12.42±0.62 µm.
Cereda et al. (2002) have found on the literature the smallest starch granules in taioba and cará (2 to 5µm) and the biggest in biri and yams (25 to 50 µm).

The results are in accordance that found by Agama-Acevedo et al. (2011), with granule size between 1 and 5 µm, in which the clearly showed taro starch, a mixture of shapes, such as spherical or dome-shaped and split, oval, polygonal, and irregular.

According Zeng, Liu, and Liu (2014) the granules of taro starch of several varieties ranged in size from 3.70 to 10.50 µm, with an average granule size of 6.54 ± 2.23 µm. Sizes and shapes of starch granules might influence the physicochemical and functional characteristics, because larger granules develop a high paste viscosity (Agama-Acevedo et al., 2011).

Native starches are used in food and non-food applications, in which starch properties such as viscosity, retrogradation, solubility, gelation, gel appearance and texture are the main criteria for choosing an appropriate starch for a certain end-use (Arns et al., 2015).

3.8 X-ray Diffractograms

It was observed from the Figure 3 the x-ray diffractogram of the arrowroot *ovo de pata* and *comum* and taro *Chinese* flours.

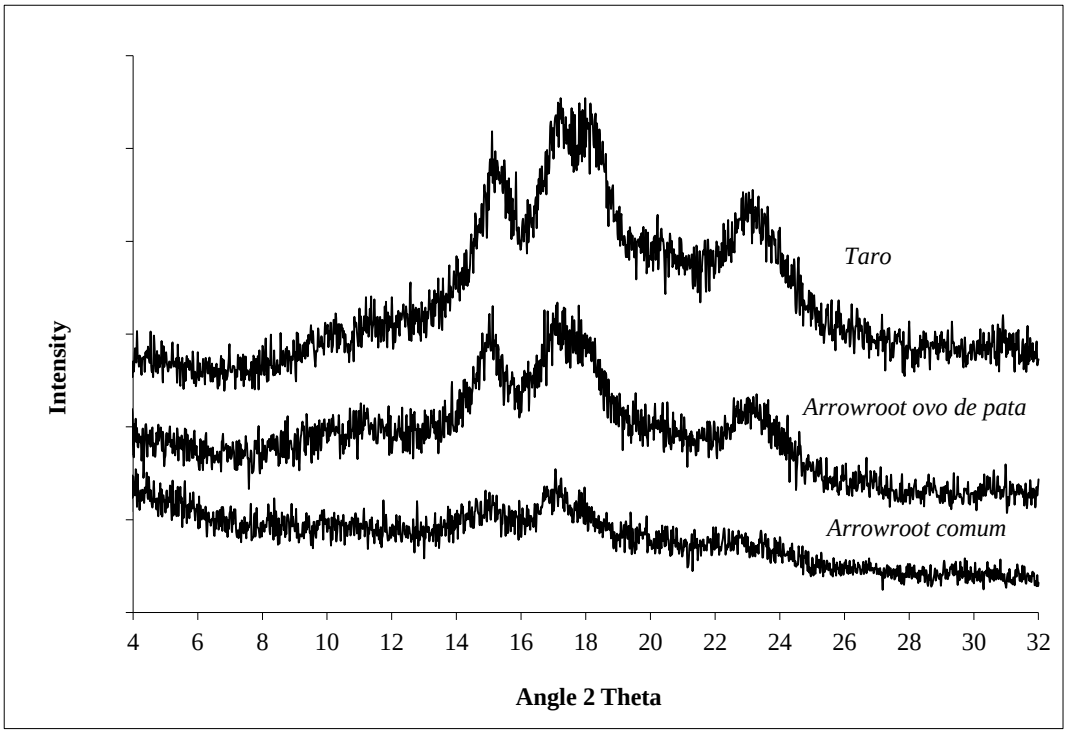

Fig.3. X-ray diffractograms of the arrowroot flours *ovo de pata, comum* and taro.

The crystallinity standard presented by arrowroot *ovo de pata, comum* and *Taro* flours has shown peaks intensity at 2θ of 15, 17, 18 and 22 (Fig. 3). Since the arrowroot *comum* had a low crystallinity, however, similar to the pattern shown by the arrowroot *ovo de pata* and taro *Chinese*. Regarding the pattern of crystallinity of both arrowroots and taro flours showed standard type A.

In accordance with Cereda et al. (2002) the type A standard has presented peaks with more intensity at 2θ of 15, 17, 18 and 23 and the B type at 5.6; 15, 17, 19, 20, 22 e 23. According to Thomas & Atwell (1999), the type A standard is characteristic of some starch tubers, roots, fruits, corn with high amylose content and downgraded starch.

However, for Hoover (2001), the type B standard is typical from starch tubers and roots and is characterized by peaks that are both broad and weak and with two main reflections centered at 5.5 and 17 °2θ.

According to Nwokocha and Williams (2011), X-ray diffraction characteristics of white yam starch gave strong peaks at 5.8, 15.52, 17.4, 19.88, 23.0 and 23.72. The degree of crystallinity estimated for white yam was 37.30%.

When a crystal is irradiated with X-ray, the rays divide themselves in order to create a distinct standard for the crystal structure. This technique is used to study the crystalline nature of the starch (Fig. 3). Through this method is possible to identify three general patterns of X-ray diffractograms in active starch, the pattern A, B and C.

X-ray diffraction patterns can be used to differentiate between native starches and it also detects changes in crystallinity brought about by physical or chemical treatment of granular starch (Shariffa et al., 2009).

The physicochemical properties of starch and its application in food industry are affected by its structure, such as relative crystallinity, the ratio of amylose to amylopectin, surface morphology of starch granule and the particle diameters of granules (Liu et al., 2011). Starch crystallinity affects the physical, mechanical, and technological properties of numerous starch-based products, and is therefore relevant

for product development, quality and process control. In foods, loss of native crystallinity via gelatinization influences apparent viscosity, gelation and matrix forming characteristics, whereas reordering of the starch during processing or storage has impact product texture, stability, quality, digestibility and functionality (Mutungi et al., 2012).

3.9 Paste Viscosity

The RVA pasting curve of flours from arrowroot cultivars *ovo de pata* and *comum* and taro *Chinese* are displayed in Fig. 4.

The *Chinese* taro flour showed the biggest initial paste viscosity temperature, which could be associated with the presence of other components in the flour such as soluble and insoluble fibers. According to Kaur, Kaushal, & Sandhu, (2013), the functional properties of the taro flours are provided not only by protein, but also by the complex carbohydrates and other components such as pectins and mucilages. The high viscosity of taro starches makes them very useful in food applications where high thickening power is desired as well as the small particle size being useful for bread or noodle production.

By comparing the temperature of initial paste viscosity of arrowroot *Ovo de pata* flour (76.96 °C) was higher than the commercial cassava starch (61.48 °C) (Chandanasree, Gul, & Riar, 2016) and to commercial corn starch of 71 ºC (Krueger et al., 1987).

Verified that temperature of initial paste viscosity of arrowroot *ovo de pata* was higher (76.96 °C) than the starches potato (67.3 ºC), cassava (67.4 ºC), rice (71.3ºC) and sweet potato (75.2 ºC) (Srichuwong et al., 2005).

The difference between the initial paste viscosity of arrowroot *Ovo de pata* and arrowroot *comum* flours was 4 °C. This may suggest that the starch granules of arrowroot *ovo de pata* present higher internal forces that keep the starch bind than *comum* cultivar starch granules, since the chemical composition of both arrowroots does not show consistent differences that would attribute the difference to it.

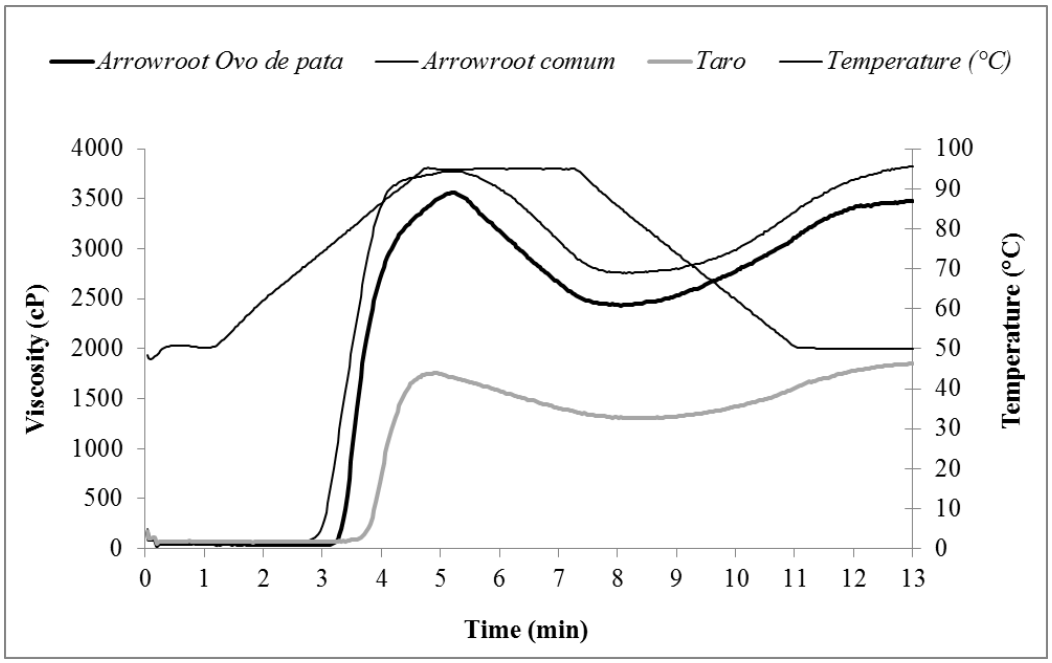

Fig.4. Paste viscosity profile of organic arrowroots, cultivars "ovo de pata" and "comum" and taro flours.

In the Table 5 are presented the readings of the paste profile arrowroot and taro flours.

Table 5. Pasting characteristics of organic arrowroots and taro flours (n=3).

	Arrowroot		Taro
(cP)	*Ovo de pata*	*Comum*	*Chinese*
Pasting temperature	76.96±0.02^{b}	72.60±0.12^{c}	82.60±0.14^{a}
Maximum peak viscosity (Max V.)	3551.50±0.03^{b}	3773.50±0.03^{a}	1744.50±0.03^{c}
Minimum viscosity (Min V.)	2678.50±0.01^{b}	3095.50±0.07^{a}	1414.00±0.01^{c}
Breakdown viscosity (BD)	873.00±0.01^{a}	678.00±0.00^{b}	330.00±0.01^{c}
Final viscosity	3464.00±0.01^{b}	3816.50±0.04^{a}	1845.00±0.01^{c}
Set back viscosity	748.00±0.00^{a}	660.50±0.56^{b}	421.00±0.00^{c}

cP= centipoises; Means in the rows with different are significantly different at $p< 0.05$. All analyzes were performed in druplicate.

The flour from arrowroot *comum* presented maximum, minimum, final and set back viscosities bigger than others cultivars. The breakdown viscosity and set back viscosity was bigger to *ovo de pata* flour (Table 5).

Pepe et al., (2015), observed that the gelatinization temperature range of arrowroot starch varied from 62.4 to 76.2 ºC. The native arrowroot starch was found to have a higher pasting temperature and lower pasting viscosities when compared to other root starches, such as Peruvian carrot and cassava starches. High pasting temperatures and low viscosities suggest the presence of strong bonding forces within the granule.

According to Peroni, Rocha, & Franco, (2006), the pasting temperature varied from 67.4 °C for cassava to 95 °C for ginger starch. Cassava, arrowroot and sweet potato starches displayed similar viscosity profiles, with low pasting temperature (67.4, 71.7 and 72.4 °C, respectively), relatively high peak viscosity and low set back.

To Chandanasree, Gul, & Riar, (2016), the heat treatment (dry heating of starch) resulted in significant changes in cassava starch gelatinization behavior. When starch without gums was heated, gelatinization temperature decreased from 61.48 °C in unheated samples to 60.49 °C with increase in heating time from 2 h to 4 h. This may be due to structural disruption of starch granules upon heating.

4 Conclusion

Based on the results obtained, that the best drying temperature chosen to obtain the flours was the temperature of 65 °C for 24h. The organic arrowroot flour from *ovo de pata* showed higher contents of energy, ash, lipid content, proteins, acidity, non-reducing sugars and reducing sugars, however, lower fiber, starch and pH that *comum*. The taro flour presented high values of ash content, crude fiber and reducing sugars than arrowroots flours. The results of processing the laboratory level showed a good yield to starch taro than by found another authors.

The water activity of the organic flours was appropriate to its preservation for boths flours.Water absorption index, water solubility index and fat absorption capacity arrowroots and taro flours significant values that contribute to the quality of food. It is noted that the arrowroot *comum* flour colour showed to be darker and more yellow than *comum*. The arrowroot *ovo de pata* presented phenolic compounds content superior than *comum*, nevertheless a similar antioxidant capacity. Analyzing the colour parameter of the taro flour, verified that has a less saturated and yellow and a higher purity colour.

The arrowroot *ovo de pata* provides a starch with circular and rounded granules, whereas *comum* presented an oval shape. The taro granules of this study presented polygonal, irregular shapes and very small. Regarding the pattern of crystallinity of both arrowroots and taro flours showed standard type A. The difference folder temperature arrowroot *ovo de pata* to the arrowroot *comum* was only 4 °C, it is suggested that in relation to the initial temperature of repulping the *comum* variety presents gels at low temperature that arrowroot *ovo de pata* and less than taro *Chinese*.

Thus, the results of investigation suggest the arrowroots and taro may be used for food industry and by consumers as a viable source of flour, with good nutritional, technological and antioxidant properties.

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Capítulo IV

Physicochemical characterization, antioxidant capacity and rheological properties of sweet potato flours obtained in organic system

Manuscrito em preparação

Physicochemical characterization, antioxidant capacity and rheological properties of sweet potato flours obtained in organic system

Abstract

The aim of this study was to analyze physicochemical characterization, antioxidant capacity and rheological properties of sweet potato (*Ipomoea batatas* L.) flours obtained in organic system. The sweet potato *Orange flashed* sweet potato flours showed bigger total energy value, ash, pH, acidity, reducing sugars, no reducing sugars, antioxidant capacity and total carotenoid content than others varieties. The β-Carotene (22146.78 µg/100 g of d.b), was the principal carotenoid of the *Orange fleshed* sweet potato flour varietie analyzed. Degree of crystallinity estimated for two varieties *Capivara* and *Orange flashed* sweet potato flours showed standard type A. The levels of starches crystallinity across the cultivars was of 34.60% of *Capivara* and 33.70% of *Orange fleshed*. As widely acknowledged, *Orange fleshed* sweet potato flours of cultivars are a rich source of carotenoids (provitamin A), and, if properly processed for maximum carotenoid retention, its products will be valuable for carotenoid intake, combatting vitamin A deficiency and other associated health benefits.

Keywords: Flour, sweet potato, antioxidant capacity, β-carotene.

Caracterização físico-química, capacidade antioxidante e propriedades reológicas de farinhas de batatas doces obtidas em sistema orgânico

Resumo

O objetivo deste estudo foi analisar a caracterização físico-química, capacidade antioxidante e propriedades reológicas de farinhas de batatas doces (*Ipomoea batatas* L.) obtidas em sistema orgânico. A farinha de batata doce alaranjada apresentou maior valor energético total, cinzas, pH, acidez, açúcares redutores, açúcares não redutores, capacidade antioxidante e conteúdo de carotenóides totais do que as outras variedades. O β-caroteno (22.146,78 g/100 g de db), foi o principal carotenóide da farinha de batata doce de polpa alaranjada analisada. O grau de cristalinidade estimado para o amido das farinhas das duas variedades de batata doce, *Capivara* e de polpa alaranjada foi do tipo A. Os padrões de cristalinidades do amido de batata doce *Capivara* foram de 34,60% e 33,70% para a variedade de polpa alaranjada. Como amplamente reconhecido, a farinha da cultivar de batata doce alaranjada é uma rica fonte de carotenóides (provitamina A), e, se processada adequadamente para a retenção máxima de carotenóides, seus produtos serão importantes para a ingestão de carotenóides, visando combater a deficiência, além de outros benefícios para a saúde.

Palavras-chave: Farinha, batata doce, capacidade antioxidante, β-caroteno.

1. Introduction

The organic market has recently increased considerably, and is widely regarded as one of the biggest growth markets in the food industry. Organic foods are generally perceived as more nutritious, as well as healthier, safer, and more environmentally friendly. Previous studies indicated that consumers are more likely to pay a premium for the superior quality and taste of organic foods, as well as their certified "safeness" (Teng & Wang, 2015).

Sweet potato is one of the most important economic crops in many tropical and subtropical countries in Asia, Africa, and Latin America (Guo et al., 2014). According to the United Nations Food and Agriculture Organization data, the sweet potatoes is cultivated in 114 countries, the China stands out as the world's largest producer reaching 77.3 million ton./year and the Nigeria with 34.0 million ton./year (Faostat, 2015).

Contribution of sweet potato towards health is acknowledged due to high nutrient content and its anti-carcinogenic and cardiovascular disease preventing properties. Almost all cultivars of sweet potato are excellent source of vitamin C, B2, B6 and E, as well as dietary fibre, potassium, copper, manganese and iron, and are low in fat and cholesterol (Shekhar et. al., 2015).

Some sweet potato varieties, especially orange fleshed sweet potato varieties, contain significant amounts of β-carotene, starch, dietary fiber, minerals, vitamins (especially vitamins C, B6 and folate), as well as antioxidants, such as phenolic acids, anthocyanins, and tocopherol (Wu, 2008). The orange fleshed sweet potato contains β-carotene, responsible for conferring pro-vitamin A activity that contributes to the prevention of cataract and age-related macular degeneration (Ahmed, Akter, & Eun, 2010a).

Moreover, it is well known that sweet potato presents a great potential to counter the malnutrition, thus research efforts have been recently intensified aiming the improvement of their production and processing, mainly as flour for use in beverage, alcohol, dye and bakery products, such as cookies, biscuits, muffins, noodles, breakfast foods and pies production (Ahmed, Akter, & Eun, 2010a; Laurie et al., 2012; Huang et al., 2013).

Sweet potato flour can easily be promoted as a substitute for wheat flour in sweet baked products and can also be used for its high carotenoid content. However, the price of the sweetpotato flour must be competitive with wheat flour and be of good quality (Van, 2000).

Thus, it is important to identify different alternative of flours sources with wide variability in properties. This work will show the present knowledge on the composition, structure, physicochemical properties of tuber and rhizomes of flours, with a view to providing suggestions for needed research to improve the utilization of these flours in the food industry. Thus, the objective of this study was to analyze physicochemical characterization, antioxidant capacity and rheological properties of sweet potato flours obtained in organic system.

2 Materials and Methods

2.1 Material and Sample preparation

The tubers by sweet potato (*Ipomoea batatas* (L.) Lam.), white cultivars white (cv. *Capivara* and cv. *Rosinha de Verdan* and *Orange fleshed* (cv. IAPAR 90) cultivated in a organic production system in Seropédica, were supplied by Embrapa Agrobiology, Rio de Janeiro, Brazil (latitude 22º48'00" S, longitude 43°41'00" W and altitude of 33 meters). The harvesting was carried out in the period from August of 2012 to June of 2014 and approximately 5 kg from each variety were used for each sampling

2.2 Flour production and Yield

The sweet potato (*Ipomoea batatas* (L.) Lam.), white (cv. *Capivara* and cv. *Rosinha de Verdan* and *orange fleshed* cv. IAPAR 90) tubers were washed in current water and sanitized in sodium hypochlorite (200 ppm) for 15 minutes. The samples was peeled, sliced (2 cm thickness), blender Oster (Osterizer Classic Blender 4093, Oster Beehive, Miami, USA) with 1 liter of water for 1 kg sample and sieved (200 µm). The samples were placed on a tray and dryed in oven with air circulation (Solab SL 102, São Paulo, Brazil) and speed, with an accuracy of ± 0.5 °C, with temperature control of 35 °C, 45 °C, 55 °C and 65 °C with three replicates (Takeiti, 2008) the distance 100 mm between the trays.

The samples were subjected to temperatures above and drying at intervals of predetermined time (every 15 minutes during the first two hours of the process, 30 minutes for the next two hours and 1 hour in the other) weighing of samples was performed using an analytical balance until dynamic equilibrium between the sample and air drying was achieved. Each experiment for obtaining the organic flour was performed in triplicate.

After drying, aiming to assess the product yield, samples were weighed out on a semi-analytical balance (Gehaka, AG 2000, São Paulo, Brazil). The dry material was ground on hammer mill 3100 (Perten Instruments, Huddinge, Sweden) to obtain a fine flour.

The obtained flours were sealed in laminated bags in order to prevent moisture absorption and stored in a freezer (-20 ºC) until further analysis.

2.2.1 Yield of Organic Flours

Flours yield (SY) was calculated according to Equation 1 (Waramboi et al., 2013).

$$SY(\%) = \left(\frac{W_f}{W_{fr}} \right) * 100 \quad (1)$$

Where:
W_f= weight of solids in flours;
W_{fr} = weight of solids in rhizomes and tubers.

2.3 Physicochemical Properties

2.3.1 Chemical Composition and Physicochemical Properties

The proximate composition of each raw material was determined according to AOAC (2005) standards: moisture content (Method 925.09), total nitrogen (Method 2001.11, a conversion factor of 5.75 was used to convert total nitrogen to protein content), fat content (Method 945.38) and ash content (Method 923.03).

The crude fiber (Method 962.09; AOAC 2000), total titratable acidity (Method 942.15; AOAC (1997). The pH, hydrolysable carbohydrates, reducing and non-reducing carbohydrates by oxidation-reduction of Fehling's solution, according to the methodology described by IAL, (2008).

The total energetic value (TEV) was expressed in kilocalories (kcal.100g^{-1}) and was calculated considering Atwater conversion factors of 4 to kcal.g^{-1} to protein and carbohydrate and 9 kcal.g^{-1} to lipids (USDA, 2006). Calculated with the following formula: (carbohydrates × 4 kcal) + (protein × 4 kcal) + (fat × 9 kcal).

2.3.2 Water Activity (A_w)

The water activity of the samples was measured using the Aqualab Lite (Decagon Devices, Pullman, Washington, USA) by Diniz, Figueiredo, & Queiroz (2003).

2.3.3 Colour Analysis

Colour was evaluated by the CIEL*ch system (Colour Quest XE - Hunter Lab, 2010, Virgínia, USA). CIEL*ch is a modification to the CIELAB scale which plots in polar coordinates rather than rectangular ones. The colour attributes lightness (L*), chroma (C) and hue angle (h) were measured four times on the surface of the sample. Measurements were performed using 25 mm viewing area aperture, D65 illuminant and 10° observer, according to CIE (Comission International de L'Eclairage) recommendations, using the equations below:

$$h* = \arctan\left(\frac{b*}{a*}\right) \qquad (2)$$

The samples were placed on a white standard plate (L = 72.46, a = 5.09, and b = 14.71) and the L, a, and b color values were measured. L values range from 0 (black) to 100 (white); a values range from −80 (greenness) to 100 (redness); and b values range from −80 (blueness) to 70 (yellowness). All measurements were performed in four replicates. The whiteness index (WI) and yellowness index (YI) of sample was obtained by substituting the values of L*, a* and b* into the following equations according to the standard of CIE (Ghanbarzadeh, Almasi, & Entezami, 2010):

$$WI = 100 - \sqrt{[(100 - L)^2 + a^2 + b^2]} \qquad (3)$$

$$YI = {142.86b}/{L} \qquad (4)$$

2.3.4 Water Absorption Index (WAI, Water Solubility Index (WSI) and Fat Absorption Capacity (FAC)

The WAI and WSI of the samples were analysed according to the procedure described by Anderson, Conway, Pfeifer, & Griffin (1969). Briefly, a sample of 1.0 g was mixed (manually with the aid of a glass rod) with 10 mL of distilled water, and centrifuged (NEW Model NI 1813, Piracicaba, São Paulo, Brazil). The suspension was placed in a petridish and dried at 105 ºC for 4 h to obtain the dry solids weight and the wet sediment was weighed. Were determined as: WSI = (weight of dry solids in supernatant (g/g)/weight of dry sample) / 100; WAI = weight of wet sediment/ (weight of the dry sample-weight of the dry solids).

The FAC was determined according to Dench et al. (1981). 0.5 g mixed (manually with the aid of a glass rod) into centrifuge tubes and added with 3 mL of soybean oil, and mixed (manually with the aid of a glass rod) for 30 s., then allowed to stand for 30 min. After a holding period of 30 min, the tubes were centrifuged ((NEW Model NI 1813, Piracicaba, São Paulo, Brazil) for 25 min at 3000 rpm. Excess oil was drained and the tube inverted for 30 min. Triplicate determinations were carried out and the water and fat absorption capacities were expressed as g of oil retained per 100 g of sample.

2.4 Antioxidant Properties

2.4.1 Obtaining of Extracts

The extracts were obtained according to Swain and Hillis (1959) and Torres (2002) with minor modifications. 20 g of sample were diluted with ethanol (ACS) in volumetric flasks (100 mL). These solutions were subjected to magnetic stirrer at 25 °C for 1 h. Then, vacuum filtered using a sintered filter funnel (n. 3).

2.4.2 Determination of Total Phenolic Compounds

0.5 mL of each obtained extract was mixed to 7 mL of distilled water and 0.5 mL of Folin-Ciocalteu reagent, were mixed for 3 min. 2 mL of 20% Na_2CO_3 solution and heated to 100 °C for one minute in a temperature controlled water bath and cooled at the ambient condition in the dark (Singleton & Rossi Jr, 1965; Quettier-Deleu et al., 2000). The results were expressed in gallic acid equivalents (GAE; mg/100 g fresh mass) using a gallic acid (0.05 to 1.2 mg/mL) standard curve. All analysis were performed in triplicate.

2.4.3 DPPH Scavenging Activity

The antioxidant capacity was determined by the modified DPPH method (Brand-Williams, Cuvelier, & Berset, 1995), is based on the quantification of free radical-scavenging, with modifications. A methanol solution containing 0.06 mM DPPH was prepared. After adjusting the blank with methanol, an aliquot of 100 μL of samples extract was added to 3.9 mL of this solution. The absorbance was measured using an UV Spectrophotometer NEW 2000 (São Paulo, Brazil) at the 517 nm. The amount antioxidant capacity was expressed as μM of Trolox Equivalent per 100 g of sample (dry basis). The free radical-scavenging (%FRS) of each sample was calculated according to Eq. 6. Where: A_c and A_A are absorbance values of blank and sample, respectively. All analysis was performed in triplicate.

$$\%FRS = \frac{(A_c - A_A) * 100}{A_c} \quad (5)$$

2.4.4 Method of Ferric Reducing Antioxidant Power (FRAP)

The antioxidant capacity of each sample was estimated by FRAP assay, following the procedure described by Rufino et al., (2010). Briefly, 2.7 mL of freshly prepared FRAP reagent (TPTZ, $FeCl_3$ and acetate buffer) at 37 °C was mixed with 90 μL of samples extracts and 270 μL of distilled water.Its was used blank containing FRAP reagent as reference, read at absorbance of 595 nm for 30 min. Aqueous solutions of known Fe (II) concentrations in the range of 100–1500 μM (Fe_2SO_4) were used for calibration.

2.5 Determination of Minerals

The determination of P, K, Ca, Mg, Cu, Fe, Mn and Zn was performed by nitric perchloric digestion and N sulfuric digestion of the method according to the methodology recommended by Tedesco (1995).

2.6 Sample Extraction and Analysis β-carotene

2.6.1 Chemical Reagents

All used solvents were of chromatographic grade, including acetone, petroleum ether 35-60 ºC, methanol (MeOH), methyl *tert*-butyl ether (MTBE). The concentrations of β-carotene and α-carotene standards were determined spectrophotometrically using the $A^{1\%}_{1cm}$ value of 3450, 2592 and 2800, respectively, in petroleum ether. The standard purities were greater than 97 %.

2.6.2 Extration, Identification and Quantification of β-carotene and Isomers

Carotenoids extraction procedure was performed as described by Rodriguez-Amaya (2001) using limited light and controlled temperature to minimize degradation and isomerization of carotenoids. All analysis were performed in triplicate (n=3). Approximately 0.5 g of each matrix were weighed and then manually macerated in a porcelain grail with 3g of celite and 50 mL of acetone. The mixture was vacuum filtered on a glass funnel with sintered plate. The extraction procedure was repeated three or four times until the sample did not exhibit the characteristic color of carotenoids. Acetone extract was transferred quantitatively to a separatory funnel containing 50 mL of petroleum ether and washed, at least three times, with 300 mL ultrapure water. The ether extract was filtered through anhydrous sodium sulfate, collected in 100 mL volumetric flask and completed with petroleum ether. The level of total carotenoids in the samples extracts was determined by spectrophotometry at 450 nm, using a UV-1800 (Shimadzu, Tokyo, Japan). Carotenoids profile was determinate by taking an aliquot of 1 mL of the sample extract into an amber vial, which was dried under a N_2 stream and then dissolved with 100µL of acetone. Before HPLC analysis, the solution was vortex during 10 s.

2.6.3 HPLC Analysis

Profiles of the carotenoids were determined in an acetone extract by HPLC (Pacheco et al., 2012) using a Waters™ HPLC system, controlled by the Empower software program with the column oven at 33 ºC and photodiode array detector (PDA). Carotenoid separation was obtained in a C_{30} column (S-3 Carotenoid, 4.6 mm × 250 mm, YCM™) by a gradient elution of methanol and methyl *tert*-butyl ether. The elution started with a mix of 80 % methanol and 20 % methyl *tert*-butyl ether. At 0.5 min the ether concentration was increased to 25 %, at 15.00 min to 85 % and at 15.05 to 90 % ether. The ether concentration was maintained at 90 % until 16.50 min and then at 16.55 min returned to the initial condition (20 %), remaining constant up to the 28 min. The flow rate was 0.8 mL min^{-1} and the running time was 28 min. The injection volume of the samples was 15 µL. Carotenoids were identified based on their retention times and UV/Vis absorption spectra and compared to the retention times of the carotenoid standards.

2.7 Morphological Properties

The visualization of the microstructure of flours was performed in a benchtop scanning electron microscope TM 3000 (Hitachi, Tokyo, Japan). The previously dried samples were placed on a metallic stub with self-adhesive conducting carbom tape and scanned at 15 kV.

2.8 Standard Starch Crystallinity Determination by X-ray Diffractometry

The determination of the x-ray diffraction profile was carried out in a D2 Phaser x-ray diffractor (Bruker AXS, Rheinfelden Germany) equipped with copper tube operated at 30 kV and 10 mA, producing CuKα radiation with 0,154 nm wavelength. Samples were scanned from 2 to 32° (2θ) at a rate of 0.15°/min, a step size of 0.02°, a divergence slit width of 0.6 mm, a scatter slit width of 0.6 mm and a receiving slit width of 0.2 mm. Diffrac.Suite EVA-XRD version 1.1 software (Bruker AXS, Rheinfelden Germany) was used to analyze the diffractograms.X-ray diffraction of starches were analyzed using X-ray diffractometer D2-Phaser (Bruker, Karlsruhe, Germany) and operating with Cu radiation (wavelength 1.506 Å) at a 8 sec scan time, a step of 0.02, being fed with voltage 30 kV and current of 10 mA. Each material was placed in an acrylic-sample holder (approximately 1 g) and the diffraction angle of the scanning region was 2-32º (2-theta).

2.9 Paste Properties

The paste viscosity of flours, was used the methodology described Duarte et al. (2009) dupliccate. A Rapid Visco Analyser (RVA, Newport Scientific PTY LTD., Sidney, Australia) was used to measure the paste viscosity of samples as a function of temperature. 3 g of starch (14% of water content, wb), was added to 25 g distilled water and this was loaded into the RVA. The time-temperature profile included initially mixing and holding the specimen with the paddles rotating at 160 rpm at 50 °C for 4 min (to investigate the cold-swelling peak), heating to 95 ºC at a constant rate of 14 ºC/min, holding at 95 °C for 3 min, and then cooling to 25 °C in 5 min at the same rate. The readings from the paste curve generated were cold viscosity (CV) (maximum viscosity reading at 25 °C), peak viscosity at 95 °C (PV) (first viscosity reading data when the temperature reached 95 °C), breakdown viscosity and setback viscosity.

2.10 Statistical Analysis

The results were verified by variance analysis (ANOVA). The chemical and physical tests were analysed by variance and Tukey test at 5% of significance level for averages comparison.

3 Results and Discussion

Figure 1 are shown the drying curves of organic sweet potato flours.

3.1 Drying Curves of Organic Flours

Moisture losses during drying processes of flours organic are shown in Figure 1.

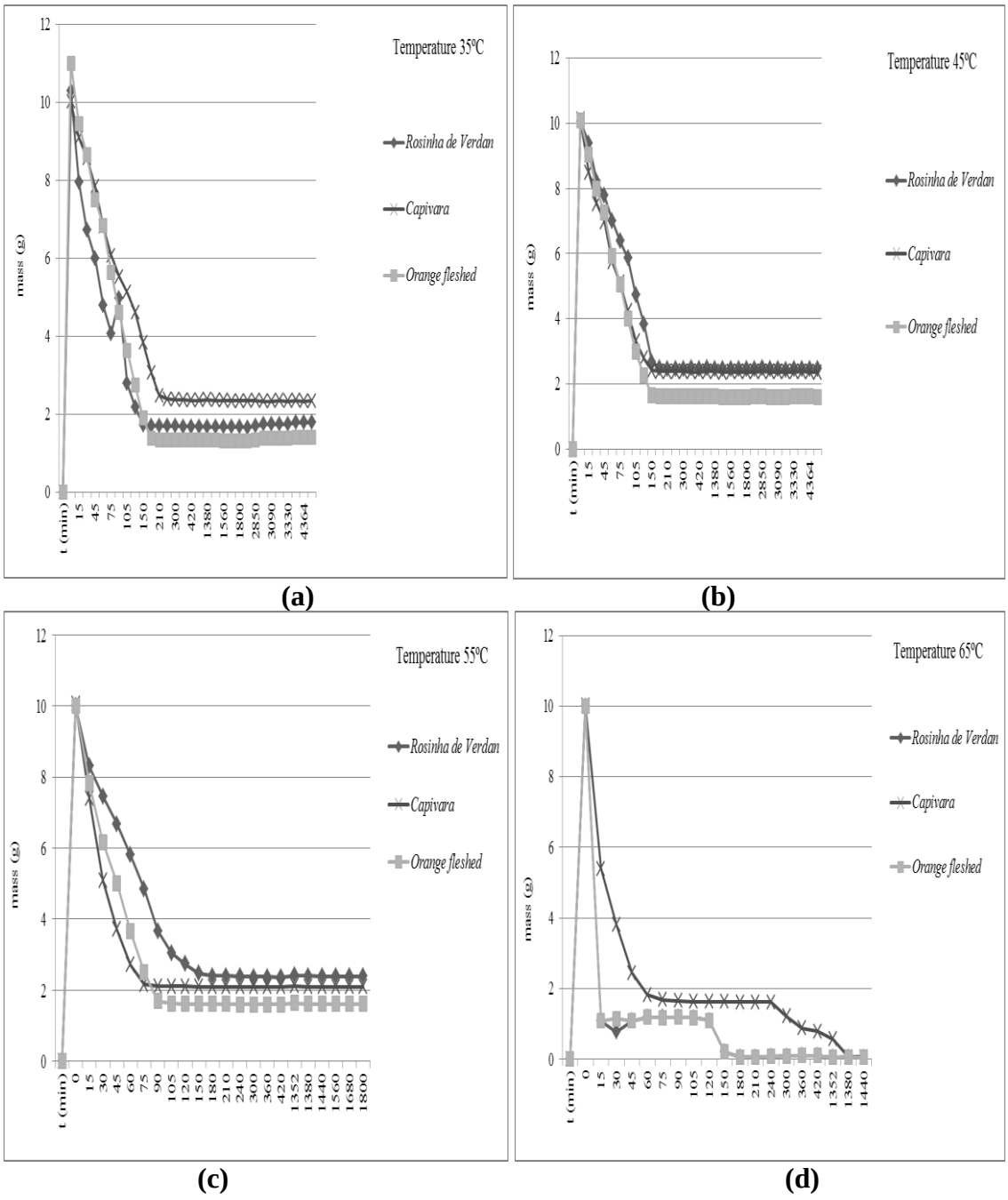


Fig. 1. Drying conditions flours obtained in an organic system at 35 ºC (a), 45 ºC (b), 55 ºC (c) and 65 ºC (d).

Moisture losses during drying processes of flours organic are shown in Figure 1. It appears that the largest loss of water were taken at higher temperatures (55 ºC and 65 ºC) for both organic flours. To achieve the equilibrium moisture content of the samples at 65 °C, 1400 minutes (~24 hours) were necessary, since using the temperature of 55 °C needed 1800 minutes. However, at temperatures of 35 °C and 45 °C took 4470 minutes and even then, there was an increase in bulk volume, which characterizes the absorption of water by some samples (Figure 1). Therefore, the drying temperature used in order to obtain flour, was based on shorter time and higher drying temperature. Thus, it is important to identify different alternative flour sources with wide variability in flours properties.

These results are in accordance to those found by Koyuncu et al. (2004). The authors also showed that temperature is the most important drying parameter affecting the total drying time and the consumed energy, where time and the heat energy decrease with increasing temperatures. Besides, drying in the range 50-60 °C was found to be least energy consuming.

Drying is probably the oldest method of food preservation and it is one of the most common processes used to improve food stability. Drying preserves foods by removing enough moisture from food and reduces microbiological activity and minimizes physical and chemical changes during storage to prevent decay and spoilage (Zarein, Samadi, & Ghobadian, 2015).

3.2 Yield and Physicochemical Characterization

The physicochemical analysis of organic sweet potato flours are presented in Table 1.

Table 1. Yield and physicochemical characterization of organic sweet potato flours (n=3).

	Sweet potato flours		
(g/100g)	*Rosinha*	*Capivara*	*Orange fleshed*
Moisture	6.15±1.01^{c}	8.18±0.86^{a}	6.90 ±2.82^{b}
Protein	1.35±0.05^{a}	0.28±0.00^{c}	0.41±0.45^{b}
Fat	0.11±0.06^{c}	0.66±0.09^{a}	0.41±0.34^{b}
Ash	2.06±0.27^{b}	1.41±0.15^{c}	2.43±0.19^{a}
Crude fiber	2.32±0.03^{b}	1.53±0.07^{c}	2.58±0.03^{a}
Hydrolysable carbohydrates	76.13±0.00^{b}	79.55±0.00^{a}	72.20±0.77^{c}
Yield of flour	21.31±0.01^{b}	25.31±0.24^{a}	18.31±0.30^{c}
Reducing sugars	6.35±0.00^{a}	0.53±0.00^{c}	5.57±0.00^{b}
Non-reducing sugars	5.53±0.89^{c}	7.86±0.00^{b}	9.50±0.00^{a}
TEV (kcal)	358.43±0.01^{a}	358.82±0.01^{a}	354.41±0.01^{b}
pH	5.34±0.00^{b}	5.23±0.00^{c}	6.21±0.00^{a}
Acidity (mg NaOH/100g)	3.28±0.29^{b}	2.26±0.29^{c}	4.56±0.29^{a}
A_w	0.391±0.01^{a}	0.317±0.00^{c}	0.323±0.00^{b}

*Average ± RI= reliable interval for a statistical probability of 95%, Where same letter on the same line do not present; Each value is presented as mean ± standard deviation (n = 3); Means within each row with different letters (a–c) differ significantly ($p<0.05$); *d.b.: dry basis; TEV= total energy value; nd: no determined.

The results of processing the laboratory level showed a good yield of 25.31 g/100g (w/w) for organic sweet potato flours cultivars *Capivara* and *Rosinha de Verdan* (21.31 g/100g (w/w) ($p<0.05$) (Table 1). The results was bigger that obtained by Dansby and Bovell-Benjamin (2003), was found to sweet potato flour production a yield of 15% (w/w).

Specific cultivars provide different flour yields and it is known that the physicochemical and functional properties of sweet potato flour are important for their selection in value added products development. Therefore, the tuber type has been used as a criterion in order to optimize the processing conditions according to specific flour applications (Waramboi, Gidley, & Sopade, 2013).

There was significant differences ($p<0.05$) in hydrolysable carbohydrates for sweet potato cultivars *Rosinha de Verdan*, *Capivara* and *Orange fleshed* (d.b.) (Table 1). The values reported here are in agreement with literature reports. Yadav et al., (2006), reported for the sweet potato flour, the total carbohydrates ranged from 73.0 to 73.8 g / 100g.

The *Orange fleshed* sweet potato flour showed bigger total energy value, ash, fiber, pH, acidity, no reducing sugars and total carotenoid content than other varieties. However, the *Rosinha de Verdan* flour showed higher levels of protein and reducing sugars.

Comparing these values was similar than found by to *Orange fleshed* sweet potato flour analized by Amajor et al (2014). The respective values for fat content (0.85±0.00% and 1.75±0.00 %), ash content (2.04±0.00% and 2.40±0.42%) and crude fibre content (2.90±0.28% and 2.67±0.00%) in dry basis.

Sweet potato flour can easily be promoted as a substitute for wheat flour in sweet baked products and can also be used for its high carotenoid content. However, the price of the sweetpotato flour must be competitive with wheat flour and be of good quality (Van, 2000).

Yadav et al. (2006), evaluated the proximate composition of various sweet potato flours (native, drum dried and hot air-dried), and found protein (6.3-6.6 g/100g), ash (1.0-1.3 g/100g), fat (1.0-1.1 g/100g), total dietary fiber (17.2-17.6 g/100g) and total carbohydrates (73-73.8 g/100g) in dry basis. However the protein and total fiber found by these authors is bigger that found in the present study.

3.3 Water Activity (A_w)

The water activity level in food is of practical importance as it controls the onset and severity of mould spoilage. It is commonly observed that foods most likely to show rapid deterioration due to biological and chemical changes are usually those with high water content (Abdullah, Nawawi, & Othman, 2000). It should be noted that the flours has low water activity is therefore less subject to deterioration.

The water activity of sweets potato flours (Table 1) were same than the found by Tortoe, Johnson, and Nyarko (2009) where the ranges of water activity for the different plantain flours were 0.27-0.39 A_w.

Pathogenic bacteria cannot grow below a water activity of 0.85, although halophilic bacteria can grow at A_w as low as 0.75, whereas yeasts and molds are more tolerant to reduced water activity, but usually no growth occurs below a water activity of about 0.6 (Rahman, 2010). Some species of xerophilic spoilage molds and osmophilic yeasts can grow at A_w 0.60 to 0.70, but the minimum a_w for mycotoxin

production by molds is 0.80, with the majority not producing mycotoxins at A_w, 0.85 (Beuchat et al., 2013).

Water activity affects microbial growth, shelf-life, texture, aroma and smell, moisture migration, caking, clumping and colour of foods. Flours generally have a low water activity level and as such keep much longer (Njintang & Mbofung, 2003). Water activity is therefore an important parameter controlling the behaviour of intermediate and low moisture food during processing and storage, with particular emphasis on its effect on the rates of degradation reactions (Tortoe, Johnson, & Nyarko, 2009).

3.4 Colour Analysis

Table 2 presents the results of colour analysis of organic sweet potato flours.

Table 2. Colour analysis of organic sweet potato flour (n=3).

	Sweet potato flours		
Parameter	*Rosinha*	*Capivara*	*Orange fleshed*
L	76.85±0.01[a]	76.62±0.32[b]	73.32±0.18[c]
a*	0.72±0.06[b]	0.45±0.01[c]	7.74±0.09[a]
b*	8.16±0.27[b]	8.16±0.16[b]	15.58±0.22[a]
C	8.19±0.27[c]	8.31±0.17[b]	17.39±0.23[a]
h	62.59±0.18[b]	78.90±0.24[a]	58.42±0.19[c]
WI	75.45±0.01[a]	75.23±0.01[b]	68.15±0.01[c]
YI	15.17±0.01[c]	15.21±0.01[b]	30.35±0.01[a]

Average ± RI= reliable interval for a statistical probability of 95%; Where same letter on the same line do not present significant differences ($p<0.05$) among each other. The results presented in Table corresponds to d.b. (dry basis); L (Luminosity); C (Chromaticity); h (Colour); b*(Chromaticity b - yellow-blue component); a*(Chromaticity a – green-red component); WI (whiteness index); YI (yellowness index); Each value is presented as mean ± standard deviation (n = 3); Means within each row with different letters (a–c) differ significantly ($p<0.05$); *d.b.: dry basis.

Analyzing the colour parameters L*, a*, b*, h* and C* was possible to realize that the sweet potato flours cultivars *Rosinha de Verdan and Capivara* have a light colour (higher L* value), less saturated (low value of C*), less yellow (lower b* value) and a higher colour purity (higher value of h*) compared with *Orange-fleshed* sweet potato flour ($p<0.05$) (Table 2). The chromaticity coordinate a* value sweet potato *Orange fleshed* flour was greater than sweet potatoes flours of *Rosinha de Verdan* and *Capivara*. *Rosinha de Verdan* flour showed a high whiteness index (WI) and low yellowing index (YI), suggesting that the sample was more whites (chromaticity b* smaller and smaller YI). However, the *Orange fleshed* sweet potato flour showed high yellowing index (YI) ($p<0.05$) (Table 1).

The native potato starch showed the L* value 97.693, a* value is −0.096, b-value 0.933 and angle hue 95.874. The native sweet potato starch, 'L*' value (94.007) was lower than that of the native potato and taro starch samples analyzed by Pamodrao and Riar (2014).

3.5 Water Absorption Index (WAI), Water Solubility Index (WSI) and Fat Absorption Capacity (FAC)

Table 3 presents the results of water absorption index, water solubility index and fat absorption capacity of organic sweet potato flours.

Table 3. Water absorption index, water solubility index and fat absorption capacity of organic sweet potato flours (n=3).

	Sweet potato flours		
	Rosinha	*Capivara*	*Orange fleshed*
Water absorption index (WAI) (%)	2.44±0.09 [a]	2.47±0.02 [a]	2.42±0.03 [a]
Water solubility index (WSI) (%)	19.78±1.59[a]	12.80±0.13[c]	15.62±1.37[b]
Fat absorption capacity (FAC) (%)	124.92±0.01[b]	125.01±0.00[a]	120.63±0.87[c]

*Average ± RI= reliable interval for a statistical probability of 95%; Where same letter on the same line do not present significant differences ($p<0.05$) among each other. The results presented in Table corresponds to d.b. (dry basis); Each value is presented as mean ± standard deviation (n = 3); Means within each row with different letters (a–c) differ significantly ($p<0.05$); *d.b.: dry basis.

The lower water absorption index (WAI) was similar for both of sweet potato flours. The water solubility index was high to sweet potato flour of *Rosinha de Verdan* however, fat absorption capacity index (WSI) minor than sweet potato flours of *Capivara* ($p<0.05$) (Table 3), however, the both flours presented high WSI.

The values found in present study were similar than those results obtained by Singh et al., (2003), to Water absorption index (WAI), water solubility index (WSI) of potato flour (6.56% to 5.50% and 10.18% to 11.40%) for corn (3.85% and 7.90%), for respectively.

The water capacity of the rice flours ranged from 122.64 to 143.35% (db) and the water capacity of rice starches varied from 93.73% to 106.64%. The satrch exhibited highest and lowest swelling power, respectively at 60 °C (Falade & Christopher, 2015).

The lower water absorption capacity could be attributed to the presence of lower amount of hydrophilic constituents in it (Akubor & Badifu, 2004). Water absorption capacity of flours plays an important role in the food preparation process because it influences other functional and sensory properties. Furthermore, the range of application of flours as food ingredients is dependent, to a large extent, on their interaction with water (Sreerama et al., 2012). Thus, water absorption index is an important processing parameter and has implications for viscosity. It is also essential in bulking and consistency of products, as well as in baking application (Niba et al., 2002).

Oil absorption capacity of the rice flours ranged from 59.97 to 72.98% (db) and the water capacity of rice starches varied from 112.55% to 151.48% (Falade & Christopher, 2015).

Oil absorption capacity, the amount of oil absorbed by gram of sample, is an important characteristic in food formulations since they improve the satiety, flavour and mouthfeel of foods (Odoemelam, 2005; Omosulis et al., 2011). Thus, the high oil absorption capacity of the sweet potato flours these study could be useful in cold meat industry, second Mao and Hua, (2012), particularly for sausages, where the protein usually bridge the fat/oil and water in order to obtain high quality products.

3.6 Antioxidant Properties

Table 4, are presented the results from the analyzed the phenolic compounds and antioxidant activity of sweet potato flours obtained in organic system.

Table 4. Analyzed the phenolic compounds and antioxidant capacivity of sweet potato flours (n=3).

	Sweet potato flours		
	Rosinha	*Capivara*	*Orange fleshed*
Phenolic (mg/100g of gallic acid)	53.78±0.01[b]	18.43±0.00[c]	136.58±0.01[a]
Antioxidant capacity µM Eq. Trolox/g	5.43±0.02[b]	5.47±0.06[b]	6.92±0.15[a]
%FRS	19.24±0.34[b]	20.13±0.20[b]	38.79±2.06[a]
FRAP (µM Ferrous Sulfate/g of sample)	2130.63±0.02[a]	1548.08±0.03[b]	850.87±0.03[c]

*Average ± RI= reliable interval for a statistical probability of 95%; Where same letter on the same line do not present significant differences ($p<0.05$) among each other. The results presented in Table corresponds to d.b. (dry basis); FRS (Percent of free radical-scavenging); Eq. (Equivalent); µM (micromolar). Each value is presented as mean ± standard deviation (n = 3); Means within each row with different letters (a–c) differ significantly ($p<0.05$); *d.b.: dry basis.

It is observed that the sweet potato flour of *Orange fleshed* presented bigger phenolic content that the *Capivara* and of *Rosinha de Verdan*. However, the *Rosinha de Verdan* presented higher antioxidant capacity by FRAP that variety *Capivara* and *Orange fleshed* (Table 4).

Differences were observed between the two radical scavenging assays (DPPH and FRAP). It appears that no linearity between the two different analysis methods, the principles and mechanisms for determining the antioxidant capacity in vitro are respectively different.

The DPPH method has the ability of the various antioxidants to donate an electron or hydrogen radical to the stable DPPH free radical. And FRAP method compares antioxidants based on their ability to reduce ferric (Fe^{3+}) to ferrous (Fe^{2+}) ion through the donation of an electron, with the resulting ferrous ion (Fe^{2+}) (Martins et al., 2013).

However, the values of phenolic compounds found in sweet potato flours of *Orange fleshed* and *Rosinha de Verdan* variety higher than those found by Rumbaoa, Cornago and Geronimo (2009), which found that the phenolic content in the samples of potato ranged from 34.4 to 50.0 that mg/100g Eq. gallic acid per mg. Huang, Chang and Shao, (2006), observed a total phenolic content in raw sweet potato flours ranging from 4.79 to 6.42 mg to 100 g^{-1} dry matter, and less than total phenols in dry steam flours that were between 10.13 and 80.78 mg. For each genotype, of sweet potato, the phenolic content of the dry flour was vapor bigger than the raw meal.

3.7 Minerals Profile

Table 5 presents the results of Mineral profile of the organic of sweet potato flours.

Table 5. Mineral profile of the organic of sweet potato flours (n=3).

	Sweet Potato flours		
	Rosinha	*Capivara*	*Orange fleshed*
N (g kg^{-1})	2.80±0.01^{c}	3.37±0.00^{b}	3.70±0.01^{a}
P (g kg^{-1})	0.93±0.01^{b}	0.82±0.01^{c}	1.30±0.01^{a}
K (g kg^{-1})	2.24±0.01^{a}	1.64±0.01^{b}	1.20±0.00^{c}
Ca (g kg^{-1})	0.91±0.01^{c}	7.55±0.01^{a}	1.76±0.01^{b}
Mg (g kg^{-1})	0.49±0.01^{c}	1.19±0.01^{a}	0.93±0.01^{b}
Zn (mg kg^{-1})	8.03±0.01^{c}	32.58±0.01^{a}	13.51±0.02^{b}
Cu (mg kg^{-1})	61.84±0.01^{a}	6.19±0.00^{c}	11.20±0.01^{b}
Fe (mg kg^{-1})	-	430.20±0.01^{a}	10.18±0.01^{b}
Mn (mg kg^{-1})	4.48±0.01^{b}	4.19±0.01^{c}	6.29±0.03^{a}

All analyses were performed in triplicate and all data were presented as mean values ± standard deviations. The results presented in Table corresponds to d.b. (dry basis). N-Nitrogen; P- Phosphorus; K-Potassium; Ca- Calcium; Mg- Magnesium; Zn-Zinc; Cu-Copper; Fe-iron; Mn- Manganes.

The *Orange fleshed* sweet potato flour showed better nitrogen values, phosphorus and manganese (6.29±0.03 mg kg^{-1}), however, it was found that the sweet potato *Rosinha de Verdan* had a higher content of copper (61.84±0.01 mg kg^{-1}) (Table 5).

The most abundant microelement was iron (430.20±0.01 mg kg^{-1}) followed by zinc (32.58±0.01 mg kg^{-1}) which was significantly higher ($p<0.05$) that sweet potato flours *Capivara* (Table 5).

The sweet potato flours of the present study showed higher mineral contents of Zn, Fe and P that sweet potato starch analyzed by Deng et al. (2013), which found Zn (13.75 mg/kg), Fe (4.79 mg/kg), Ca (140.75 mg/kg), Mg (26.27 mg/kg), Al (22.65 mg/kg), K (4.46 mg/kg) and P (0.014%) in dry basis.

The potassium (960 mg solids) was the major mineral reported by Waramboi et al. (2011) in orange sweet potato flour from Papua New Guinea and Australia.

More than 60% of the world's population is iron (Fe) deficient and 30% is zinc (Zn) deficient. Other micronutrient deficiencies, mainly calcium (Ca) and magnesium (Mg) are also prevalent (Amarakoon, McPhee, & Thavarajah, 2012).

Minerals in food are essential inorganic elements required for the regulation of metabolic processes and structural function as the main components of bones and teeth (Obinna-Echem, Beal, & Kuri, 2015). Potatoes are an excellent source of mineral, generally is not rich in Ca, but can be a valuable source of trace elements, such as Se and I, if fertilized appropriately (Kärenlampi & White, 2009).

3.8 Analysis β-carotene and Isomers

In Figure 2, it was verified the results of typical chromatogram in *Orange fleshed* sweet potato flour.

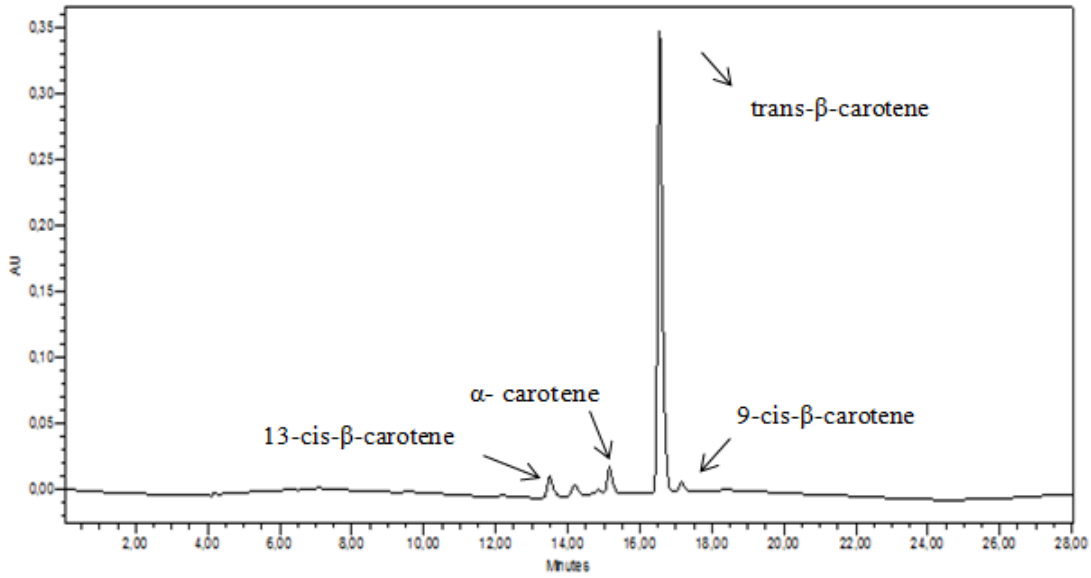


Fig. 2. Typical chromatogram in *Orange fleshed* sweet potato flour 13 cis-β-carotene, α-carotene, β-carotene and 9 cis-β-carotene.

The obtained values of total carotenoids to *Orange fleshed* sweet potato flour was 24998.71 µg/100 g of dry sample. According to the results of this study, were observed that the β-Carotene 22146.78 µg/100 g of d.b, was the principal carotenoid found in the *Orange fleshed* sweet potato flour analyzed, but the amounts of α-carotene (1204.55 µg/100 g of d.b), 9 cis-β-carotene (377.60 µg/100 g of d.b), and 13 cis-β-carotene (1269.78 µg/100 g of d.b), was comparatively substantial (Figure 2). The cis isomers were detected in small quantities in the carotenoid profiles of the orange sweet potato starch and the 13-cis forms were more evident than 9-cis forms. Ahmed, Akter and Eun (2010b) found the β-carotene content in sweet potato flours ranged that from 26.8 to 37.9 µg /100 g wet weight basis.

Since there are double bonds in the carbon chain, carotenoids are susceptible to some reactions such as oxidation and isomerisation (cis-trans) during food processing and storage, especially due to light, heat, acids, and oxygen; thus causing loss of colour and reduction of biological activity. Though pro-vitamin A carotenoid degradation takes place during drying, there was a concentration of carotenoids in the products as a consequence of water removal.

The US Institute of Medicine (IOM, 2001) derived new conversion factors for estimating the amount of retinol activity equivalents (RAE) obtained from provitamin A carotenoids in foods , where 1 RAE = 1 µg retinol, 12 µg β-carotene, 24 µg α-carotene, or 24 µg β-cryptoxanthin.

From this study, the pro-vitamin A *Orange fleshed* sweet potato flour which includes α-carotene and β-carotene will be the recommendation nutrient intake for men and women age from 19 to 50 years old is 900 µg EAR and for children for 4–8 year-old is 400 µg RAE per day (IOM, 2001).

From this study, the RE value that can be obtained from 100g of dry weight *Orange fleshed* sweet potato flour is around 3691.13 µg of RE /100g of β-carotene and 1845.56 µg of RAE/100g of β-carotene. And α-carotene the RE value that can be obtained from 100g of dry weight *Orange fleshed* sweet potato flour is around 100.38 µg of RE and µg 50.19 of RAE/100g.

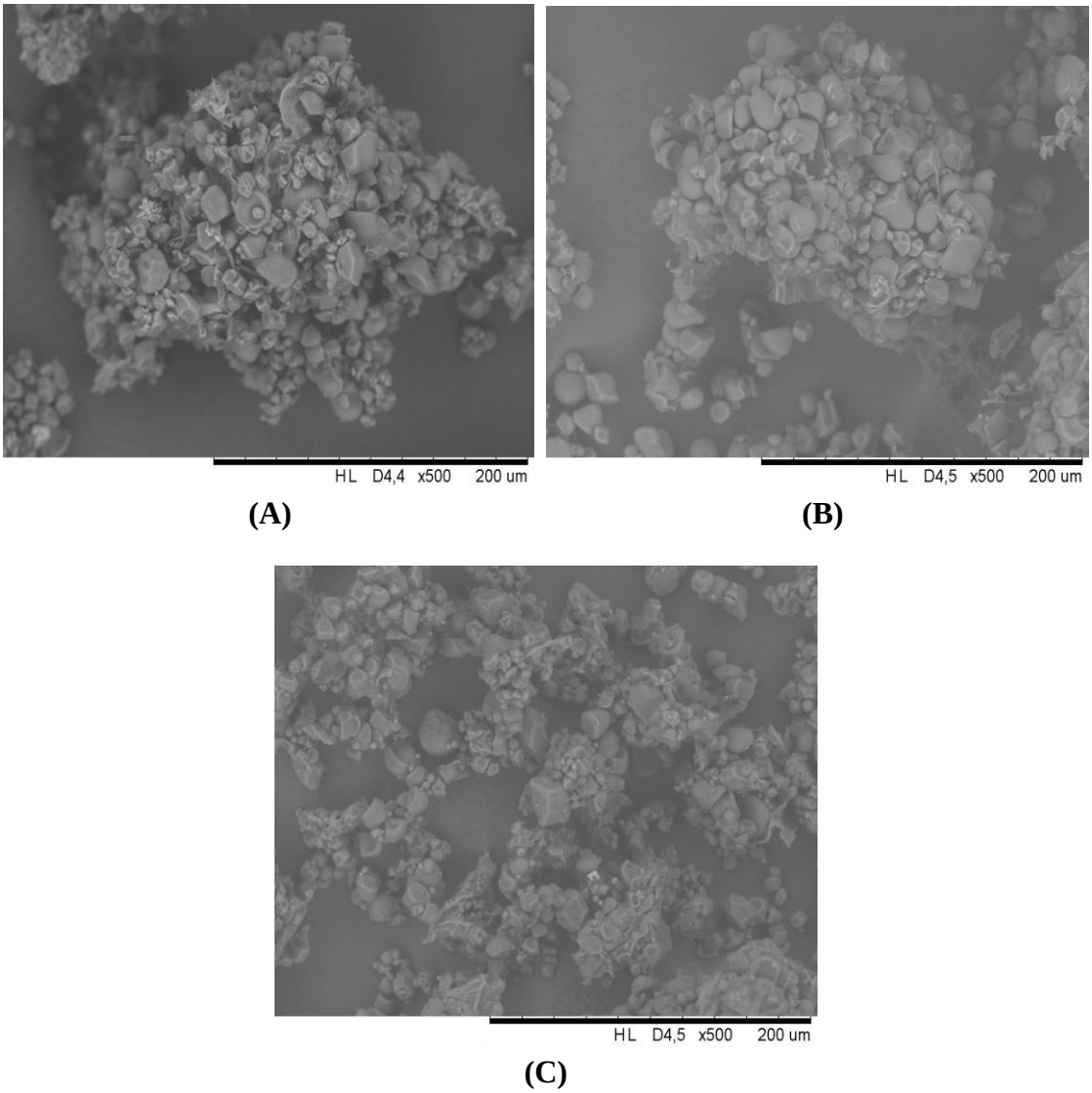
From this result, it can be concluded that 46.25 g dry weight of *Orange fleshed*

sweet potato flour can provide 100% retinol activity equivalents (RAE) which is sufficient for the daily needs nutrients intake for men and women age from 19 to 50 years old and 21 g will provide > 100% of the recommended dietary allowance (RDA) of vitamin A for 4–8 year-old children (IOM, 2001).

Carotenoids are among the most valuable food constituents in terms of food quality and human health effects. The principal carotenoids found in foods are β-carotene, α-carotene, β-cryptoxanthin, lycopene, lutein, and zeaxanthin. The *Orange fleshed* sweet potato (OFSP), varieties with considerable amounts of β-carotene are available. The use of carotenoid-rich biofortified flours in a variety of products has been shown to be technologically feasible (Rodriguez-Amaya, Nutti, & Carvalho, 2011).

3.9 Scanning Electron Microscopy

The starches granules of sweet potato were analyzed by Scanning Electron Microscopy (SEM) and they are presented in Figure 3.



(A) **(B)**

(C)

Fig. 3. Scanning electron micrographs (SEM) of starches of sweet potato *Rosinha de Verdan* (A) *Capivara* (B) and *Orange fleshed* (C) with a zoom of 500x.

The sizes of sweet potato starches granules ranged from 2 to 42 μm. Sweet potato starch granules are of a similar size of cassava and maize starch but are smaller than potato which have a large range of granular size. Sweet potato starch granules may be smooth, oval spherical, oval round, round polygonal or polygonal with different sizes (Tan, Li, & Tan, 2009).

Sizes and shapes of starch granules might influence the physicochemical and functional characteristics, because larger granules develop a high paste viscosity (Agama-Acevedo et al., 2011). Native starches are used in food and non-food applications, in which starch properties such as viscosity, retrogradation, solubility, gelation, gel appearance and texture are the main criteria for choosing an appropriate starch for a certain end-use (Arns et al., 2015).

3.10 X-ray Diffractograms

It was observed in the Figure 4 the x-ray diffractograms of the sweet potato flours. When a crystal is irradiated with X-ray, the rays divide themselves in order to create a distinct standard for the crystal structure. This technique is used to study the crystalline nature of the starch.

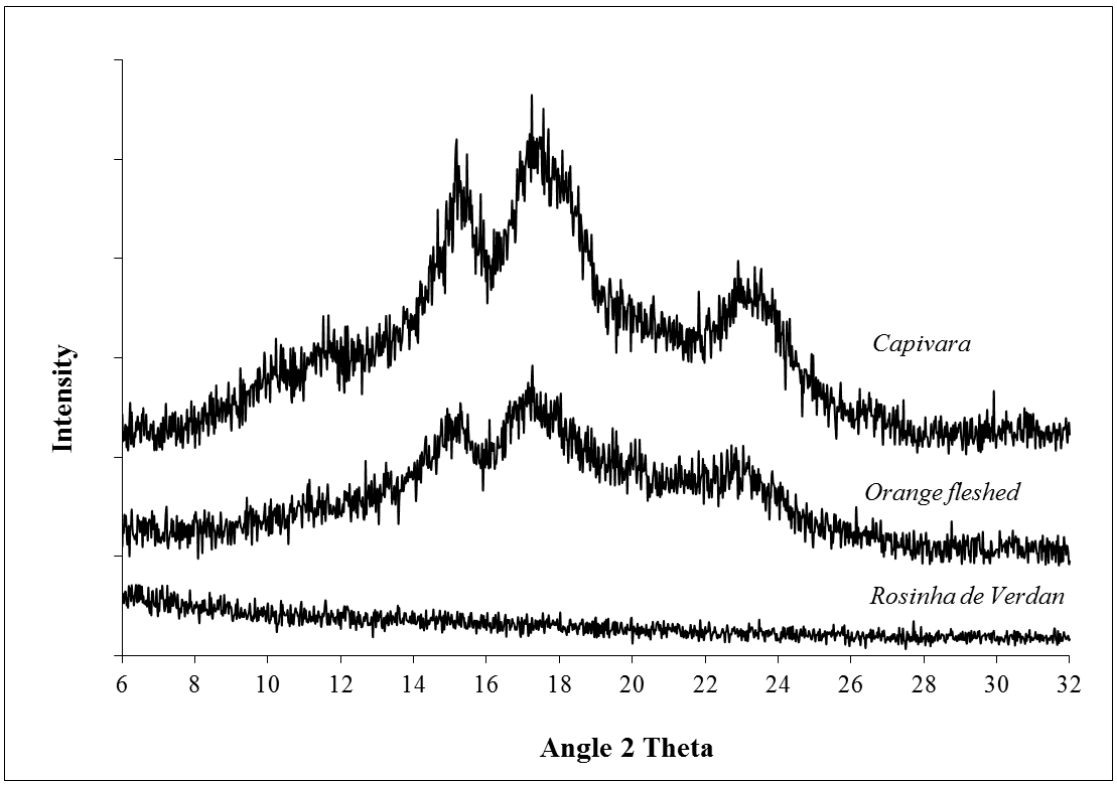


Fig. 4. X-ray diffractograms of the sweet potatos flours.

Six intense diffraction peaks to *Capivara* and *Orange fleshed* (15.0°, 17.0°, 18.0°, 22.0° and 23.0°) were clearly observed in the X-ray diffractograms. The *Rosinha de Verdan* showed no crystallinity.

Degree of crystallinity estimated for two varieties *Capivara* and *Orange fleshed* sweet potatoes showed standard type A, however.

The levels of starch crystallinity across the cultivars was of 34.60% of *Capivara* and 33.70% of *Orange fleshed.*

X-ray diffraction patterns can be used to differentiate between native starches and it also detects changes in crystallinity brought about by physical or chemical treatment of granular starch (Shariffa et al., 2009).

Typical X-ray diffractograms found by Waramboi et al. (2011) indicate that the sweet potato cultivars exhibited type-A crystalline pattern with four distinct intensities; 15.0°, 17.0°, 17.9° and 22.8°, 2-theta angles. The levels of starch crystallinity ranged from 30% to 39% across the cultivars.

According to Shariffa et al. (2009), both hydrolyzed heat-treated and hydrolyzed native tapioca and sweet potato starch exhibited typical A-type patterns with strong peaks at 2θ about 15°, 17°, 18° and 23° for tapioca and 15°, 17°, 22° and 23° for sweet potato.

Four intense diffraction peaks at 5.3°, 14.9°, 17.4°, and 21.8°, clearly observed in the X-ray diffractogram of sweet potato starches are characteristic of C-type starch analyzed by Li et al. (2015). The absolute crystallinity for this starch sweet potato analyzed by Tan, Li and Tan (2009), was 38%. Type A starches tend to have higher levels of crystallinity (33-45%) and higher gelatinization temperature.

The X-ray diffraction pattern for many starches is affected by sample preparation and by growth conditions and maturity of the parent plant at the time of harvest (Mcpherson & Jane, 1999). The A-type crystal pattern has amylopectin molecules with shorter chains. As result, A-type crystals tend to be more resistant to enzymatic digestion than B-type crystals (Copeland et al., 2009). In addition, B-type crystallites have been observed to start melting at much lower temperatures (e.g., 70–80 °C) than those required by A-type crystallites (e.g., 90-110 °C) (Parada & Aguilera, 2012).

Starch crystallinity affects the physical, mechanical, and technological properties of numerous starch-based products, and is therefore relevant for product development, quality and process control. In foods, loss of native crystallinity via gelatinization influences apparent viscosity, gelation and matrix forming characteristics, whereas reordering of the starch during processing or storage has impact product texture, stability, quality, digestibility and functionality (Mutungi et al., 2012).

3.11 Paste Viscosity

The paste viscosity properties of sweet potato flours was shown in Table 6 and Fig. 5.

The *Orange fleshed* sweet potato flour showed the highest temperature, however the *Rosinha de Verdan* variety had lower pulp temperature from *Capivara* and *Orange fleshed* varieties. This would be related to the proportion of lower starch, in addition, the low concentration of carbohydrate (76.13±0.00 g / 100 g) *Rosinha de Verdan*, may have contributed to the low initial viscosity.

By comparing the temperature of initial paste viscosity of *Orange fleshed* sweet potato flour with than the verified that temperature was higher than the starches potato (67.3 ºC), cassava (67.4 ºC), rice (71.3ºC), elephant yam (81.6 ºC), corn (82.0 ºC) and water yam (83.2 °C) (Srichuwong et al., 2005). And higher than the starches sweet potato (75.2 ºC) analyzed by Srichuwong et al., (2005). Similar results were found by

Soison et al., (2015) where the temperature initial of viscosity of varieties of sweet potato starches ranged from 76.4 ºC to 85 ºC.

Verified that temperature of initial paste viscosity of *Orange fleshed* sweet potato flour was higher (89.60 °C) than the commercial cassava starch (61.48 °C) (Chandanasree, Gul, & Riar, 2016) and to commercial corn starch of 71 ºC (Krueger et al., 1987).

Table 6. Pasting characteristics of organic sweet potato flours (n=3).

	Sweet potato flours		
(cP)	*Rosinha*	*Capivara*	*Orange fleshed*
Pasting temperature	75.50±0.01^{c}	78.90±0.14^{b}	89.60±0.12^{a}
Maximum peak viscosity (Max V.)	470.00±0.02^{c}	1601.50±0.04^{a}	632.00±0.00^{b}
Minimum viscosity (Min V.)	435.00±0.02^{c}	1396.00±0.03^{a}	566.00±0.05^{b}
Breakdown viscosity (BD)	35.00±0.01^{c}	205.50±0.10^{a}	66.00±0.03^{b}
Final viscosity	661.00±0.03^{c}	2250.50±0.87^{a}	781.00±0.01^{b}
Set back viscosity	199.00±0.04^{c}	1676.50±0.03^{a}	212.50±0.01^{b}

cP= centipoises; Means in the rows with different are significantly different at $p< 0.05$. All analyzes were performed in quadruplicate.

The flour from sweet potato *Capivara* presented maximum, minimum, final and set back viscosities bigger than others cultivars. The breakdown viscosity was bigger to *Capivara* sweet potato flour (Table 6).

According Kaur and Singh, (2005) the hot paste viscosity which is the minimum viscosity value measuring the ability of paste to withstand breakdown during cooling ranged between 598.33 cP to 832.00 cP for different chickpea.

According to Peroni, Rocha, and Franco, (2006), the pasting temperature varied from 67.4 °C for cassava to 95 °C for ginger starch. Cassava, arrowroot and sweet potato starches displayed similar viscosity profiles, with low pasting temperature (67.4, 71.7 and 72.4 °C, respectively), relatively high peak viscosity and low set back.

The lower breakdown viscosities were found in composite flours, as compared with the wheat flour. This may be due to restricted swelling of the starch granules, which increased the tendency of the hydrophilic chain of the fiber in composite flours to bind with hydrogen bonds of the water, causing a decrease in available water for starch granules. The breakdown viscosity also decreases as increase in soybean flour level in composite flour. It can be regarded with the susceptibility of protein to heat damage (Devi & Haripriya, 2012).

The RVA profile of the organic sweet potato flourss (Fig. 5) has shown alterations at the granules viscosity, according to time and temperature.

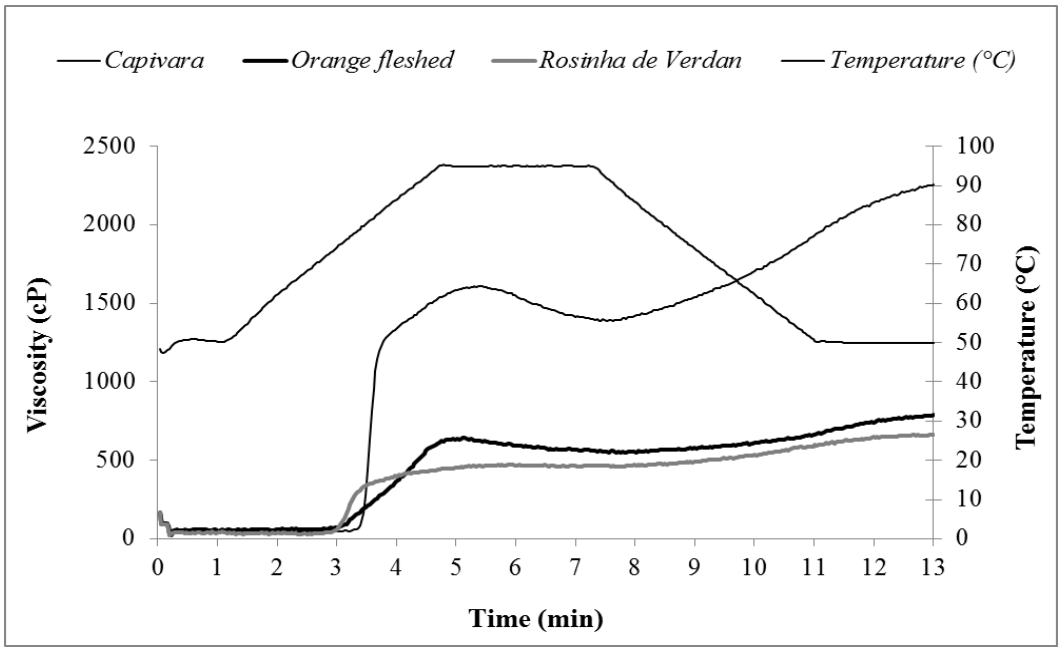


Fig. 5. Paste viscosity profile of organic sweet potatoes flours.

The final viscosity indicated the re-association of starch granules during cooling time after gelatinization and the formation of gel network (Ortega-Ojeda et al., 2004).

The lower breakdown and final viscosity increase in of sweet potato flours indicated the ability of the flour to form a viscous paste or gel after cooking and cooling as well as the resistance of the paste to shear stress during stirring.

Final viscosity (indicates the ability of the material to form a viscous paste) and setback (measure of retrogradation tendency or syneresis of flours upon cooling of cooked flour pastes) (Kaur & Singh, 2005).

4 Conclusion

It can be concluded that the sweet potato flours have major economic importance due not only to its high yield but also to its functionality and technological profile when compared to to other sources such as yam, corn among others.

Orange fleshed sweet potato flour was a rich source of carotenoids (provitamin A), and, if properly processed for maximum carotenoid retention, its products will be valuable for carotenoid intake, combatting vitamin A deficiency and other associated health benefits. This study also showed variation in mineral content in sweet potato flours between varieties. It is important to note that development and utilization of such functional and nutritional products can be used to improve the nutritional status of the population, which can impart health benefits by preventing degenerative diseases.

Moreover, the pasting and functional properties of the flours, especially of the sweet potato *Capivara*, indicated that the flour could be used as a desirable food ingredient in starch-based foods. Therefore, the potential supply of sweet potato flours is large and cheap.

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Capítulo V

Physicochemical characteristics of tubers and flours from organic sweet potato roots

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PHYSICOCHEMICAL CHARACTERISTICS OF TUBERS AND FLOURS FROM ORGANIC SWEET POTATO[1]

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ABSTRACT - This work aimed to determine chemical composition, nutritional aspects and morphological characteristic of tubers from sweet potato roots (*Ipomoea batatas* L.) of cultivars Rosinha de Verdan, Capivara and orange-fleshed produced under the organic system. The chemical composition of flours from sweet potato (SP) roots was different among cultivars. The starch content for sweet potato cultivars ranged from 26-33 % (d. b.), and the starch content of roots ranged from 12.48-27.63 % (d.b.). The flour yield ob- tained for sweet potato flour processing was higher in Rosinha de Verdan (25.40%). While, the orange-fleshed roots presented 3182 µg of β-carotene/100 g. The processing condition modified the starch granular characteristics of the flours and reduced 31% the carotene content and vitamin A value of the orange-fleshed flour. The orange-fleshed flour presented higher levels of carbohydrate, starch and total energy value (TEV) than others white-fleshed flour. The consumption of serving size of orange-fleshed roots and flour provided higher provitamin A require-ments for children.

Key-words: *Ipomoea Batatas.* Organic food. Processing.

CARACTERÍSTICAS FÍSICO-QUÍMICAS DOS TUBÉRCULOS E DAS FARINHAS OBTIDAS DE BATATAS DOCES ORGÂNICAS

RESUMO - Este trabalho teve como objetivo determinar a composição química, os aspectos nutricionais e as características morfológicas dos tubérculos e das farinhas de batatas doces (*Ipomoea batatas* L.) das cultivares Rosinha de Verdan, Capivara e de polpa alaranjada obtidas no sistema orgânico. A composição química das batatas doces (BD) variou entre as cultivares estudadas. O teor de amido das raízes de batata doce estudadas variou entre 26 e 33 % (d.b.). O maior rendimento de processo foi verificado para farinha da cultivar Rosinha de Verdan (25,40%) e do teor de amido das raízes variou de 12,48 a 27,63% (d.b.). Enquanto que, a batatas doces de polpa alaranjada apresentou 3182 mg de β-caroteno por 100 g (d.b.). A condição de processamento alterou as carac-terísticas morfológicas do amido das farinhas e reduziu em 31% o teor de carotenoides e de vitamina A da farinha de polpa de laranja. Dentre as farinhas estudadas, a de polpa alaranjada foi a que apresentou maior quantidade de carboidratos, amido e valor energético. O consumo de uma porção das raízes e das farinhas de batatas doce alaranjada forneceu elevada quantidadede vitamina A, tendo como base a Ingestão diária recomen-dada (IDR) para crianças.

Palavras-chave: *Ipomoea Batatas.* Alimentos orgânicos. Processamento.

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INTRODUCTION

The sweet potato crop is highly adaptable and tolerates high temperatures, low soil fertility and drought. It is a short season crop, provides food on marginal soils and degraded. Recognizing the great potential of the crop of sweet potatoes in combating malnutrition and food security has resulted in intensified research efforts in recent decades to improve their production and consumption (QUEIROGA et al., 2007; LAURIE et al., 2013).

According to the United Nations Food and Agriculture Organization data, the sweet potato is cultivated in 114 countries, with China stands out as the world's largest producer reaching 75.362 million ton./year (FAOSTAT, 2012).

Moreover, it is known that sweet potatoes presents a great potential against malnutrition and research efforts have been recently intensified aiming the improvement of their production and processing (LAURIE et al., 2012), mainly as flour for use in beverage, alcohol, dye and bakery products, such as cookies, biscuits, muffins, noodles, breakfast foods and pies production (AHMED; AKTER; EUN, 2010; HUANG et al., 2013).

Therefore, flour processing from sweet potato provides an alternative to the difficulties associated with storage and transport of the raw roots (DANSBY; BOVELL-BENJAMIN, 2003) and can create new economic and employment activities for farmers and rural households, and can add nutritional value to food systems (BOVELL-BENJAMIN, 2007).

The sweet potato has been reported to have numerous health benefits, which have been attributed to the sweet potato phytochemical constituents. It has long been known that the orange-fleshed sweet potato contains β-carotene, responsible for conferring pro-vitamin A activity that contributes to the prevention of cataract and age-related macular degeneration (AHMED; SORIFA; EUN, 2010).

Besides acting as antioxidants, carotenoids, anthocyanins and phenolic compounds also provide sweet potatoes with their distinctive flesh colours (TEOW et al., 2007; JUNG et al., 2011; KIM et al., 2011; RAMESH et al., 2011). Hence, utilization of sweet potato for its nutritive value and as a source of natural food antioxidant, presents an opportunity to increase its consumption (RUMBAOA et al., 2009).

During the past decade, organic food sales and farmland have grown rapidly worldwide. The organic production system aims at environmental sustainability, economically feasible and socially fair food production, maintaining human beings in connection with nature (JANZANTTI; SANTOS; MONTEIRO, 2014).

According to Organics Brazil Project, which brings together companies that export products and organic inputs, the incomes from exportation of organic products by Brazil exceeded US$ 129.5 million in 2012. The overall organic market grew 40% in 2010, and the domestic sales increase has been expected in the next years, due to new rules for Bra-zilian organic production. All this, leads the organic agriculture to an increasing internal demand im-pelled by the crescent number of customers who are in search of healthier, tastier and environment-friendly food.

This promising scenario for organic foods has also been verified around the world, whe-re consumers are willing to pay more for these types of products (ORGANICS BRAZIL, 2011; 2013; SILVA et al., 2011). It is noteworthy that to date no studies in the literature on sweet potatoes grown in Organic System and its impact on the physicochemical characteristics of the roots. Here, the chemical composition, nutritional aspects and morphological characteristics of white-(Capivara and Rosinha de Verdan) and orange-fleshed sweet potatoes (roots and flours) from organic production system were evaluated.

MATERIAL AND METHODS

Samples

About 5 kg of each cultivar of sweet potato roots (*Ipomoea batatas* (L.) Lam.), white (cv. Capivara and cv. Rosinha de Verdan) and orange-fleshed (cv. IAPAR 90) were randomly harvested (September 2011 and 2012) from organic production systems at the Integrated Agroecological Production System (IAPS), located at Seropédica, Rio de Janei-ro, Brazil (latitude 22º48'00" S, longitude 43°41'00" W and altitude of 33 meters). The IAPS is the result of an Institutional agreement between Brazilian Agricultural Research Corporation (EMBRAPA), Federal Rural University of Rio de Janeiro (UFRRJ) and Rio de Janeiro State Agricultural Research Institute (PESAGRO-Rio).

The preparation of the soil for cultivation consisted of disking followed by windrowing with micro tractor and rotary hoe. The planting is done at a spacing of 80 cm between ridges and 20 cm be-tween plants. The climate is characterized by fre-quent rainfall and high temperatures in summer; mild and dry

winter. The annual temperature and rainfall averages are 24 °C and 1.250 mm, resectively.

Flour Processing

The roots were washed in tap water, sanitized into a 200 ppm solution of sodium hypochlorite for 15 minutes and blotted with absorbent paper (NASCIMENTO et al., 2013). Subsequently, the sweet potatoes were peeled, sliced (3 cm height) and boiled in hot water for 20 minutes (after, dipped in cold water). Thereafter, the samples were placed on trays and subjected to drying in a forced-air circulation oven (SOLAB, mod 102 SL, Piracicaba/SP) at 65 °C for 24 hours, according to Leonel, Jackey and Cereda (1998). Finally, the flours were obtained in a mill (Perten model 3100, Huddington, Sweden) and sieved until obtaining a fine powder, which were put into laminated packaging in order to prevent moisture absorption, and stored in a freezer (-20ºC) until chemical analysis.

Flour Yield

Flour solids yield (FY) was calculated according to Equation 1 (Waramboi et al., 2011).

$$FY(\%) = \left(\frac{W_f}{W_{fr}} \right) * 100 \qquad (1)$$

Where:

W_f= weight of solids in flour;
W_{fr} = weight of solids in roots

Chemical composition

Moisture, protein, fat, ashes content and starch of roots and flour were determined in dry basis (d.b.) according to the methodology described by AOAC (2010). Total carbohydrates percentages (%TC) were estimated by difference (Equation 2):

$$\%TC = 100\% - (\%moisture + \%proteins + \%fat + \%ashes) \qquad (2)$$

The total energy value (TEV) of the roots and flours was estimated considering the conversion factors of 4 kcal g^{-1} for protein or carbohydrate and 9 kcal g^{-1} for fat (AOAC, 2010).

Total carotenoid content

The total carotenoid content (TCC) of roots and flour was determined according to Rodriguez-Amaya (2004):

$$TCC(\mu g/100 g_{DW}) = \frac{Abs * V * 10^6}{Abs_{1cm(1)} * 10^2 * m_{DW}} * 100 \qquad (3)$$

Where:
Abs = spectrophotometer absorbance read at 449 nm;
V= volumetric flask content (25 mL);
m_{DW}= sample dry weight (g);
$A_{1cm(1\%)}$= 2592 (absorption coefficient, obtained into a spectrophotometer cuvette with a 1^{-cm} light path regarding β-carotene at a given wavelength).

Scanning electron microscopy (SEM)

The observation of the morphology of flours granules was performed in a scanning electron microscope Benchtop TM 3000 (Hitachi, Tokyo, Japan), coupled to Energy Dispersive Spectroscopy (EDS) (EDS (Quantax), Karlsruhe, Germany, 2010).

Nutritional aspects

The serving size of sweet potato roots (130 g) and flours (30 g) based on a 2,000 calories diet were determined according to Food and Drugs Administration (FDA, 2013). The provitamin A values (root and flour), percentage contribution towards vitamin A requirements and serving size needed to provide 100% of the vitamin requirements were determined according to the recommendations of Dietary Reference Intake (DRI) of American Institute of Medicine (IOM, 2010) considering new retinol activity equivalent (RAE) for dietary β-carotene.

Statistical analysis

All analyses were performed in triplicate and all data were presented as mean values ± standard deviations. The results were analyzed by variance and Tukey test at 5% of significance level for averages comparison.

RESULTS AND DISCUSSION

Chemical composition of roots and flours

Table 1 shows that chemical composition of sweet potato roots were significantly different ($p < 0.05$) among the different cultivars.

The orange-fleshed cultivar has shown influence on ash content ($p<0.05$), to Table 1 and Capivara cultivar presented the higher ash content varying from 0.85 to 1.29% (d.b) according for different cultivars of sweet potatoes, Kohyama and Nishinari (1992) reported ash content values ranging from 2.13 to 2.62% (d.b). Dincer et al. (2011) reported values of ash content 2.31% (d.b.) for 3 sweet potatoes cultivars from Turkey. Since ash content represents the mineral content of a food material, it has been identified calcium, phosphorus, magnesium, sodium, potassium, iron, zinc and copper as the main mineral constituents in sweet potato roots (BOUWKAMP, 1985). Minerals such as iron, copper, zinc and manganese are essential, since they play an important role in biological systems (JUNSEI et al., 2013). Mineral uptake (e.g., calcium) or addition (e.g., sodium) during processing can change the natural mineral composition of a product. Sodium concerns in canned food can be addressed by choosing products with no salt added. Since nutrient content varies considerably by commodity, cultivar, and postharvest treatments, inclusion of a wide variety of fruits and vegetables in the diet is encouraged (RICKMAN; BRUHN; BARRETT, 2007).

Fat content of sweet potato cultivars varied between 0.19 (orange-fleshed), 0.34 (Rosinha de Verdan) and 4.50% (Capivara) and showed significant ($p < 0.05$) differences between the cultivars (Table 1). As other roots and tubers, sweet potato is known for its low fat content. Mu, Tan and Xue (2009) found 0.6% fat for sweet potatoes. Ishida et al. (2000) analyzed the lipid content of two cultivars of sweet potatoes, which ranged from 0.20 to 0.33 g/100 g (d.b). Padonou, Mestres and Nago (2005) reported fat content of cassava roots 0.53-0.65% (d.b).

Table 1. Chemical composition of the organic roots sweet potatoes from different cultivar.

(%)*	Roots		
	Capivara	Rosinha de Verdan	Orange-fleshed
Moisture	50.58±2.89[b]	63.00±1.08[a]	61.46±1.30[b]
Ash	1.29±0.02[a]	1.07 ±0.06[b]	0.85±0.08[c]
Fat	4.50±0.05[a]	0.34±0.09[b]	0.19±0.03[c]
Proteins	2.53±0.51[a]	1.76±0.07[b]	0.58±0.08[c]
TC	33.29±0.95[b]	32.75±1.43[c]	35.92±0.05[a]
TEV (kcal)	183.78±2.00[a]	141.11 ±4.00[c]	149.06±0.01[b]
Starch	28.47±0.04[b]	33.14±0.25[a]	26.34±0.14[c]
Crude Fiber	7.81±0.00[a]	1.08±±0.00[b]	1.00±0.00[b]
TCC (µg/100 g)	Nd	Nd	3182±9.00[b]

Each value is presented as mean ± standard deviation (n = 3); Means within each row with different superscript lower case letters (a–c) differ significantly ($p<0.05$); *d.b.: dry basis; TC=total carbohydrates; TEV= total energy value; TCC=Total Carotenoid Content; nd: no determined.

The total carbohydrates (TC) content and total energy value (TEV) varied ($p<0.05$) among cultivars, and ranged from 32 to 35 (%) and 141 to 183 Kcal/100 g, respectively. The Capivara presented higher levels of TC and fat, and consequently, higher TEV than others cultivars (Table 1).

In sweet potato roots, starch is the main component, followed by simpler sugars as sucrose, glucose, fructose and maltose. In food industry, it is applied to enhance functional properties, as in soups, meat sauces, as formers in candies etc. (STRACKE et al., 2009).

According to Waramboi et al. (2011) the starch content is directly related to genotype and environmental settings in which the plant is cultivated, i.e. differences in soil, weather and other growing conditions.

There were significant differences ($p<0.05$) in starch content for sweet potatos cultivars, ranging from 26 to 33% (d.b.) (Table 1). The obtained values were lower than thatobtained by Liu et al. (2013) for twenty different samples of sweet potato from Papua New Guinea (47-80% of starch, d. b.) and Waramboi et al.(2011) for 25 sweet potatoes

types from Papua New Guinean and Australia (30-58% of starch, d.b.). On the other hand, Kohyama and Nishinari (1992) obtained values ranging from 13.4 to 29.2% of starch content in different sweet potato roots.

Grace et al. (2014) affirmed that the carotenoid content varies on cultivar and growing environment. In present study, it was observed 3182 µg of β-carotene per 100 grams of orange-fleshed roots. Fonseca et al. (2008) studied orange fleshed cultivar (IAPAR 69) from organic system production and found 10,120 µg per 100 g (d.b.), calculated in β-carotene equivalent. This value was higher than those reported by Shih, Kuo and Chiang (2009) for two different cultivars (430 and 833 µg/ 100 g) of orange-fleshed roots. On the other hand, Ukpabi and Ekeledo (2009) and Tomlins et al. (2012) have found higher values, ranging from 3870 to 5970 µg of β-carotene and 120 to 21600 µg of β-carotene per 100 g of root samples, respectively. Grace et al. (2014) presented concentrations of β-carotene and total carotenoids of 25330 and 28190 µg/100 g (d.b.), respectively in the freshly harvested orange-fleshed roots (Covington genotype). In other study (DONADO-PESTANA et al., 2012), several sweet potato cultivars showed high levels of carotenoids (7910-12850 µg/100 g d.b) and it was showed that the all-trans-β-carotene had a quantitative predominance in raw roots.

The obtained values of β-carotene content for studied root (3182 µg/100 g) were comparable to recognized sources of carotenoids (ex.: pumpkin and carrot). Rodriguez-Amaya (2004) has found values ranging from 104 to 2350 µg of this phytochemical per 100 g of different cultivars of pumpkin.

Rodriguez-Amaya (2001) has also reported the carotenoid composition of foods are affected by factors such as cultivar or variety; part of the plant consumed; stage of maturity; climate or geographic site of production; harvesting and postharvest handling; processing and storage. The author indicates that greater exposure to sunlight and elevated temperatures heighten carotenoid biosynthesis in these fruits. On the other hand, Fonseca et al. (2008) reported no influence of cropping system (organic or conventional) on total carotenoids content.

In the Table 2, it is presented the chemical composition of sweet potatoes flours from different cultivars. The statistical analysis revealed differences ($p<0.05$) among cultivars.

The overall yield obtained for sweet potato processing was higher ($p < 0.05$) in Rosinha de Verdan (25.40%) than those found in orange-fleshed (22.40%) and Capivara (18.10%). The results of mass balance during flour production provided a yield of 15% (w/w), which is in accordance with the results obtained by Dansby and Bovell-Benjamin (2003). Specific cultivars provide different flour yields and it is known that the physicochemical and functional properties of sweet potato flour are important for their selection in value added products development, therefore, the root type has been used as a criterion in order to optimize the processing conditions according to specific flour applications (WARAMBOI; GIDLEY; SOPADE, 2013).

It was observed that the cultivar had no influence ($p < 0.05$) on ash (0.76-0.81%, d.b.) and fat (0.10-0.14%, d.b.) contents of different obtained flours (Table 2).

Table 2. Yield and chemical composition of the organic sweet potatoes flour from different cultivars.

(%)*	Flours		
	Capivara	Rosinha de Verdan	Orange-fleshed
Yield	18.10^{c}	25.40^{a}	22.40^{b}
Moisture	10.44 ± 0.62^{b}	13.42 ± 2.35^{a}	7.05 ± 0.16^{c}
Ash	0.81 ± 0.21^{a}	0.76 ± 0.37^{a}	0.80 ± 0.09^{a}
Fat	0.10 ± 0.01^{a}	0.10 ± 0.02^{a}	0.14 ± 0.04^{a}
Proteins	0.99 ± 0.10^{a}	0.67 ± 0.86^{b}	0.13 ± 0.05^{c}
TC	73.43 ± 1.45^{a}	67.41 ± 0.18^{b}	63.74 ± 0.32^{c}
TEV (kcal)	298.58 ± 2.00^{a}	273.22 ± 2.00^{b}	256.74 ± 1.00^{c}
Starch	12.48 ± 0.47^{c}	16.73 ± 0.15^{b}	27.63 ± 0.77^{a}
Crude Fiber	1.75 ± 0.00^{a}	$0.92\pm\pm0.00^{b}$	0.51 ± 0.00^{c}
TCC (µg/100 g)	nd	nd	2195±0.08

Each value is presented as mean ± standard deviation (n = 3); Means within each row with different superscript lower case letters (a–c) differ significantly ($p<0.05$); *d.b.: dry basis; TC=total carbohydrates; TEV= total energy value; TCC=Total Carotenoid Content; nd: no determined.

There were significant differences ($p < 0.05$) in starch content for sweet potatoes cultivars, ranging from 12.48 to 27.63% (d.b.) (Table 1). These losses can be accounted for starch degradation by amylase activity, at the beginning of the process (DAMIR, 1989). Furthermore, the flour processing steps cooked on boiling water for 20 minutes and drying at 65 °C/25 hours caused a decrease in starch content but an increase in reducing sugar content (DAMIR, 1989; WARAMBOI et al., 2011).

Drying at 40 °C causes a decrease in sweet potato sucrose content and increases in glucose, fructose and maltose which partly compensate for the loss in sucrose (TAMATE; BRADBURY, 1985).

The carotenoid content of the orange-fleshed flour is presented in Table 2 and similar result was reported by Waramboi, Gidley and Sopade (2013) for extruded and non-extruded sweet potato flours (2300-35500 µg/100 g solids).

It was observed significant effects of the flour processing on the carotenoid content of orange-fleshed cultivar (about 31%). Many researchers have found similar results during flour processing of orange-fleshed sweet potatoes, because the heat-processing methods generally reduce the carotenoid content as a result of the vulnerability of these compounds to degradation and isomeration by heat (DONADO-PESTANA et al., 2012; WARAMBOI et al., 2013).

Donado-Pestana et al. (2012) reported the orange-fleshed sweet potato submitted to different heat treatments resulted in a significant decrease in the sweet potato carotenoids content and processing of flour presented the greatest losses of major carotenoids (~45%), following boiled (25%) and roasted (8%).

It should be noted that drying or dehydration is a simple procedure and is oftentimes less expen-sive than other food conservation techniques. Therefore, it is frequently used to give products additional benefits, such as longer shelf life and easier transportation and commercialization.

However, drying may alter color and taste, and can also cause nutrient loss due to oxygen and relatively high temperature exposure, especially when carried out using conven-tional hot air processes (Lago-Vanzela et al., 2013).

This justifies the difference in the nutrient content of the roots of organic sweet potatoes and flour ob-tained in this study.

Morphological properties of sweet potato roots and flours

Considerable structural differences were observed in Scanning Electron Micrographs (SEM) (Fig. 1 a-c) and flours (Fig. 1 d-f). Most of the starch granules flours are oval, although they present round, spherical, polygonal and also irregular shapes, it is in accordance with Antonio et al. (2011). For studied cultivars, the raw starch granules are round, spherical and presented 10-36 µm size, predominantly in the range of 18 µm.

This result is in agreement with Leonel (2007) that reported the starch granules in the sweet potato presented circular shapes and polyhedral, and distribution of different sizes concentrated in the range of 12 to 20 µm. Leonel et al. (2004) reported that sweet potato starch granules presented circular and polygonal shapes, with the maximum diameter varying from 45 to 52 µm and the minimum diameter between 6 and 8 µm, whilst Yadav et al. (2006) showed that the starch granules were spherical with a size varying from 4 to 26 µm.

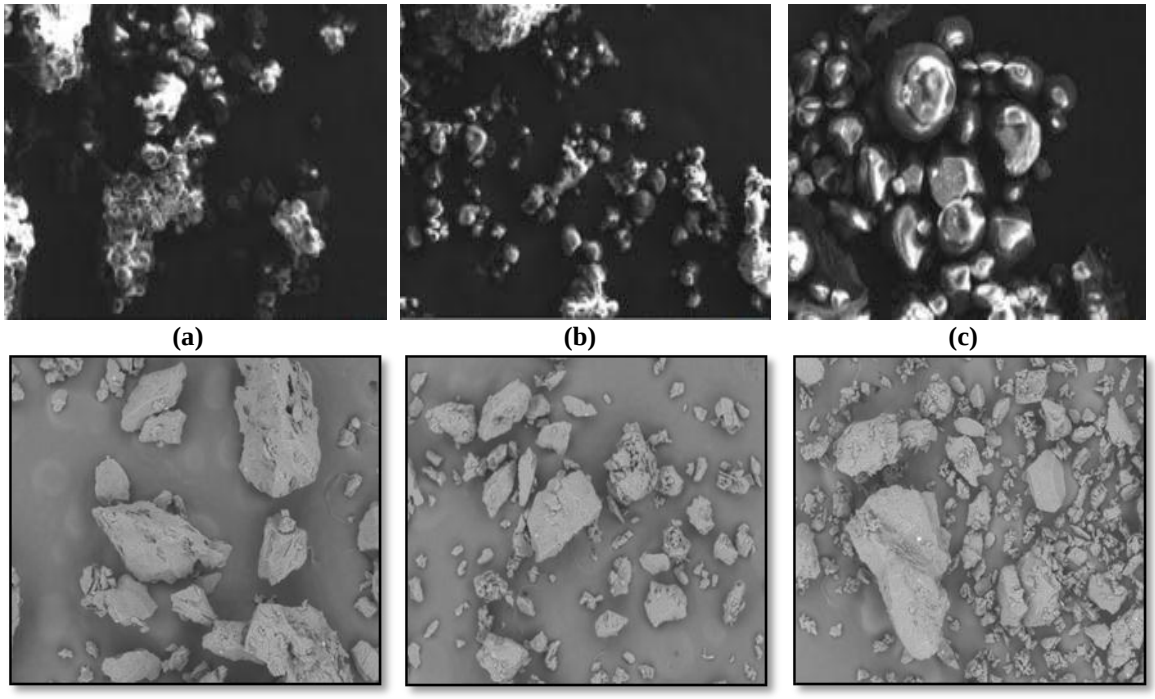

Figure 1. Scanning electron micrographs (SEM) of structural characteristics of the starch sweet potato cultivars Capivari (a), "Rosinha de Verdan" (b) and Orange-fleshed (c) with an increase of 8.5 x 300X observed in SEM. The flour Capivara (d), "Rosinha de Verdan" (e) and Orange-fleshed (f) with an increase of 5.0 x 100X observed in SEM.

The sweet potatoes flours showed modified starches without granular characteristics (Figure 1 d-f), which could be attributed flour processing steps cooked on boiling water for 20 minutes and drying at 65 °C/24 hours that contributed to the changes and starch gelatinization (LAI et al., 2011). Similar result was reported by Yadav et al. (2006 and 2007) and Antonio et al. (2011).

The thorough departure from the structure of starch can is assigned to the high level of gelatinization due to heat treatment and also for grinding (PINEDA-GÓMEZ et al., 2012). Yadav et al. (2006) studied the changes in characteristics of sweet potato flour prepared by different drying techniques and observed which, the disruption of the granules indicated complete gelatinization of starch in both drying processes. These authors reported that release of amylose during thermal treatment would have resulted in hollowness of the modified starch granules, where by the granules appear to be broken open, which may be responsible for better hydration of processed starches. The inner portion of some granules appears terraced or step shaped that confirms the layered internal structure of starch granule.

It is well known that the solubility of starch in water is directly related to solution temperature. However, when a dispersion of starch is performed at high temperatures, beyond the gelatinization temperature, starch granules swell up to many times their original size. This effect enhances viscosity and gelling properties upon cooling, promoting the use of starch as a thickening agent in food products (AHMED; SORIFA; EUN, 2010). The absorption of water by amorphous regions within the granules destabilizes their crystalline structure, resulting in loss of birefringence, which is one definition of gelatinization.

Upon continuous heating, granules tend to swell to greater extents, and the crystallites melt resulting in an increasing molecular motion that eventually leads to complete separation of amylose and amylopectin. A proper understanding of starch phase transitions or gelatinization is extremely important in food processing operations (WEI et al., 2011).

Food processing can be thought of as altering the naturally occurring structure and composition of food materials and historically these changes, particularly in structure, have been considered at a macroscopic scale. In recent years, though, the study of the *micro*structure of food has been verified worldwide, manufactures create new products to satisfy nutritional demands and consumer enjoyment (JAMES, 2009).

Nutritional aspects of sweet potatoes roots and flours

The orange fleshed sweet potato flours showed significant ($p<0.05$) lower vitamin A values than sweet potato roots (Table 3), which could be attributed loss of carotenoid content during processing.

The recommended dietary allowance (RDA) for children considering 1 to 3 and 4 to 8 years old is 300 µg RAE/day and 400 µg RAE/day, respectively (IOM, 2010) The consumption of serving size (130 g) roots provide 115% of the pro vitamin A requirements for children of the 1-3 years old and 86% for 4-8 years old, while the 30 grams of flour provide 18 % of the pro vitamin A requirements for children of 1-3 years old and 13.7 % for 4-8 years old (Table 3).

Table 3. The root and flour sweet potato pro vitamin A value, percentage contribution towards vitamin A requirements and serving size needed to provide 100% of the vitamin requirements.

Sweet potato	Pro Vitamin A (µg RAE 100 g^{-1})	Pro Vitamin A (µg RAE)/ Serving size*	Amount needed to provide 100% RDA	
			1-3 y	4-8 y
Roots	265.17 ±0.09[a]	4136.6[a]	114.9[a]	86.2[a]
Flour	182.91±0.08[b]	658.5[b]	18.3[b]	13.7[b]

d.b.: Dry basis duplicate determinations; Pro Vitamin A value in µg RAE (Retinol Activity Equivalents) was calculated by dividing the total β-carotene (µg) content by 12, assuming 12 µg trans-β-carotene = 1 µg Retinol = 1 µg RAE (IOM, 2010); * Serving size: roots = 130g and flour= 30 g (USDA, 2010); RDA: Recommended Dietary Allowance (IOM, 2010).

In addition, the incorporation of orange sweet potatoes for feeding children aged 1-3 years, may contribute to the increase in serum retinol concentrations, decreasing marginally deficient in vitamin A. Vitamin A deficiency (VAD) is a serious problem in developing countries where it is estimated that 190 million preschool age children and 19.1 million pregnant women are VAD (retinol < 70 µmol). Vitamin A deficiency is an entirely preventable condition, but continues to result in 670,000 deaths and 250,000-500,000 cases of blindness in children (YI et al., 2014).

Bio-fortified sweet potato is an extremely rich source of pro vitamin A that has been shown to be effective to improve the Vitamin A status for children (WILLIAMS et al., 2013).

Burri (2011) in a recent review concluded that higher vitamin A is to be expected with orange-fleshed sweet potato and that this could prevent Vitamin A deficiency in many food-deficit countries, if orange-fleshed sweet potatoes were substituted for white, cream, yellow or purple-fleshed sweet potatoes. This is because variety is by far the most important factor influencing the concentration of β-carotene and also because of the effectiveness of sweet potato on Vitamin A deficiency prevention.

CONCLUSION

The chemical composition of sweet potatoes (SP) root and flour were different among cultivars. The flour processing affects the starch granular characteristics and reduced in 31% the total carotenoid content and, therefore, vitamin A value in orange-fleshed sweet potato flour. The flour from orange-fleshed roots showed higher levels of carbohydrate, starch and total energy value (TEV) than others white-fleshed flour and 30 g sweet potato flour provide 18 % of the vitamin A requirements for children of one to three years old and 13.7 % for four to eight years old.

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Capítulo VI

Aceptación sensorial y calidad microbiológica de galletas preparadas con almidones de patatas dulces orgánicas

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SENSORY ACCEPTANCE AND CAKE MICROBIOLOGICAL QUALITY PREPARED WITH ORGANIC SWEET POTATOES STARCH

Kamila de Oliveira do Nascimento; Isabela Pereira Reis; Flávia de Floriani Pozza Rebello; Maria Ivone Martins Jacintho Barbosa

Resumen

El objetivo deste trabajo fue analizar la aceptación sensorial y la calidad microbiológica de galletas preparadas con patatas dulces orgánicas. Fueron realizados análisis de Coliformes a 45ºC, *Salmonella sp* y Staphylococcus coagulase y testes de aceptación y la intención de compra de galletas desarrollados con almidones orgánicos (Capivara, Rosinha de Verdan y Zanahoria). Las galletas se analizaron de acuerdo con los padrones microbiológicos establecidos por la ley. El teste de aceptación e intención de la compra se observa que la galleta dulce de patata cv Capivara fue el más preferido por los catadores. Se concluye que las galletas orgánicas presentan características microbiológicas adecuadas y se considera una buena opción tecnológica y con óptimas propiedades nutricionales para las explotaciones familiares.

Palabras clave: Agricultura Orgánica; panificación; patatas dulces.

Resumo

O objetivo deste trabalho foi analisar a aceitação sensorial e a qualidade microbiológica de biscoitos de batatas doces orgânicos. Foram realizadas análises de Coliformes a 45ºC, *Salmonella sp* e Staphylococcus coagulase e teste de aceitação e intenção de compra dos biscoitos desenvolvidos com féculas orgânicas (Capivara, Rosinha de Verdan e Cenoura). Os biscoitos analisados estavam de acordo com os padrões microbiológicos estabelecidos pela legislação. Pelo teste de aceitação e intenção de compra observa-se que o biscoito de batata doce *cv* Capivara foi o mais preferido pelos provadores. Conclui-se que os biscoitos orgânicos apresentaram características microbiológicas adequadas, sendo considerado uma boa opção tecnológica e com boas propriedades nutricionais para a agricultura familiar.

Palavras-chave: Agricultura orgânica; panificação; batata doce.

Introducción

El consumidores cada día más preocupado con la calidad de los alimentos que van a su mesa, o por las propiedades nutricionales, la presencia de residuos tóxicos o técnicas aplicadas durante su procesamiento. En este escenario, la agricultura alternativa actual, entre ellos, la agricultura ecológica, ha experimentado un aumento significativo en la demanda de sus productos.

Así, dentro de la agricultura familiar, la producción de alimentos orgánicos se ha demostrado como una ventaja para los pequeños agricultores, que ya representan aproximadamente 90000 productores orgánicos. Esta práctica se ha vuelto cada vez más social, el reconocimiento político y científico en todo el mundo que se basa en la aplicación de las estrategias agroecológicas a través del uso de insumos locales, aumentando el valor añadido y proporcionando una cadena de comercialización más justa (MELO et al., 2012).

Los mayores beneficios para la salud, la innovación, incluso la moda y la demanda de productos más sabrosos son algunos factores que sumados a los problemas nutricionales y ambientales explican esta tendencia en el mercado de alimentos orgánicos (ROITNER-SCHOBESBERGER, 2008). Algunos autores afirmam que los alimentos orgánicos tienen en su composición nutrientes superior a los alimentos convencionales (DANGOUR, 2009; NASCIMENTO et al., 2012). Según Lairon (2010) y Lairon y Huber (2014) los productos vegetales orgánicos contienen más materia seca y minerales (principalmente Fe ++ y Mg ++); contienen más micronutrientes antioxidantes, tales como fenoles y ácido salicílico, para los productos orgánicos de origen animal, y contiene ácidos grasos poliinsaturados más que los convencionales.

La patata dulce (*Ipomoea batatas* L.) es uno de los cultivos económicos más importantes del mundo. Se cultiva ampliamente en todo el mundo y ocupa el quinto lugar como cultivo de alimentos en los países en desarrollo después del arroz, el trigo, el maíz y la yuca (HUANG et al., 2013). Su cultura es muy adaptable y soporta altas temperaturas, la baja fertilidad de los suelos y la sequía (LAURIE et al., 2013).

Los flavonoides tienen un importante antioxidante mediante la eliminación de los radicales libres. Por lo tanto, los aspectos médicos y bioquímicos de los flavonoides han recibido una atención creciente (WU et al., 2015).

Nascimento et al. (2013) evaluaron el teor de compuestos fenólicos, la actividad antioxidante y carotenoides totales del almidón de patata dulce *cv* Zanahoria orgánica y encontraron 146,34±0,01 mg/100g ácido gálico de compuestos fenólicos, 1079,83±0,03 Eq. a 1000 µM de sulfato ferroso/g de muestra por el método de FRAP y 29,5±0,03 mg/100g de carotenoides totales. En uno otro análisis hecha por Nascimento et al. (2014) estes autores obtuvieron para el almidón de patata dulce *cv* Capivara 20,25 mg/100 g de ácido gálico para compuestos fenólicos, y 1701,80±0,03 µM de sulfato ferroso/g de muestra (FRAP). Puesto que el almidón de patata dulce *cv* Rosinha de Verdan presentó contenido de fenólicos igual a 57,30±0,01 mg/100g de ácido gálico e actividad antioxidante de 2270,72±0,02 µM de sulfato ferroso/ g de muestra por el método de FRAP.

Por lo tanto, con el fin de exigir a la industria alimentaria para el desarrollo de nuevos productos, centrándose el consolidado mercado de galletas y el interés de los consumidores en productos de alto valor añadido, el objetivo de este estudio fue analizar la aceptación sensorial y la calidad microbiológica de las galletas preparadas com patatas dulces orgánicos como una opción tecnológica para la agricultura familiar.

Materiales y Métodos

Procesamiento de las Muestras y Obtención de los Almidones de Patatas Dulces Orgánicas

Cerca de 5 kg de cada cultivar de los tubérculos de patata dulce (*Ipomoea batatas* (L.) Lam.), variedades Capivara, Rosinha de Verdan y Zanahoria (cv. IAPAR 90) adaptados a lo sistema de producción orgánico (SOP), se obtuvieron de La Fazendinha Agroecologica, Seropédica-RJ. Las plantas se cosecharon al azar, de agosto a diciembre de 2013. Se lavaron las muestras, desinfectadas con una solución de hipoclorito de sodio de 50 ppm, pelado y en rodajas (2 cm de espesor). Poco después fueron soplado en un procesador de (Osterizer Blender Classic®) y se tamizó a través de 200 de malla, con la apertura de 0,250mm y 0,075 mm respectivamente. El retenido se disponen en bandejas y se sometió a secado en un horno con circulación y el intercambio de aire (SL Solab® 102), una temperatura de 65 °C durante 24 horas. El almidón seco se muele en un molino Perten 3100 y se tamiza para obtener un polvo fino (NASCIMENTO, TAKEITI y BARBOSA, 2012).

Elaboración de las Galletas Orgánicas

Las galletas se procesaron en el Laboratorio de la Universidad Federal Rural de Río de Janeiro (UFRRJ), utilizando (70 g) de almidones de batatas orgánicas: cv Rosinha de Verdan, cv Capivara y cv Zanahoria, mantequilla (50 g), azúcar cristal (20 g), de azúcar moreno (20 g), sal (~1 g), huevo (1 ud.), la esencia de vainilla (al gusto) (materias primas orgánicas). El bicarbonato de sodio utilizado no era orgánico (~1 g). Sin embargo, fue en el plazo hasta el 5% permitido por la ley para los productos no orgánicos en la composición.
Las masas de las galletas de tres variedades de batatas se procesaron en una batidora eléctrica (Arno®) por separado. Inicialmente se añadió a la mantequilla, el azúcar, la sal y la esencia y se mezcló. Se añadieron inmediatamente después de que el huevo, azúcar morena y bicarbonato de sodio se mezclaron a baja velocidad (n. 2) por tres minutos. Posteriormente se añadió a cada formulación el almidón de patata Dulce *cv* Rosinha de Verdan, *cv* Capivara y *cv* Zanahoria orgánicos. Cada masa se mezcló por separado a la misma velocidad durante dos minutos. Después de cada amasado se dividió en pequeñas porciones, extendida con el rodillo de madera y formado con la ayuda de la forma circular. Las galletas orgánicas se cocieron a 180 °C variando el tiempo de cocción de acuerdo con cada formulación estándar (~8 minutos en el horno). De esta manera, logramos evitar reacciones adversas en productos como el pardeamiento excesivo y regusto amargo. Con la excepción de bicarbonato, otras materias primas fueron certificados orgánica.

Ensayos Microbiológicos

La evaluación microbiológica se basó en la resolución - RDC nº 12, que define el Reglamento Técnico para los estándares microbiológicos para los alimentos (BRASIL, 2001). Analisis de coliformes a 45 °C se realizaron, y también *Salmonella sp.* y Staphylococcus coagulasa positiva en el Laboratorio de Microbiología del Departamento de Tecnología de los Alimentos UFRRJ.

Avaliación del Comité de Ética en Búsqueda (CEB)

Esta investigación fue sometido al Comité de Ética en la Búsqueda UFRRJ (COMEP-UFRRJ) y aprobado (Protocolo 313/2013). Después de la aprobación se realizaron pruebas sensoriales.

Análisis Sensorial

Para el análisis sensorial fue la aceptación de la prueba utilizada, según Stone y Sidel (2004). Se evaluó el grado de aceptación como gustó o no en cada formulación preparada, utilizando la escala hedónica de 9 puntos (1 = muy malo; 9 = excelente). La prueba sensorial se realizó en el Laboratorio de Análisis Sensorial de UFRRJ y el panel sensorial fue formado por 50 participantes, entre estudiantes y empleados UFRRJ entre 18 y 68 años. La aparición de cada formulación fue juzgado en un diseño de bloque aleatorizado y sabor características completas, sabor y textura de la forma monádico. Los catadores evaluaron la aparición de formulaciones listas fondo blanco plato, estará con número de tres dígitos, iluminado por la luz natural en cabinas individuales. También se llevó a cabo la prueba de la intención de compra para evaluar la preferencia del consumidor.

Análisis Estadístico

Para el análisis estadístico se utilizó el Diseño Completamente al Azar (DCA). Las diferencias estadísticas entre las muestras se comprobaron mediante análisis de varianza y comparación de medias mediante la prueba de Tukey al 5% de probabilidad.

Resultados y Discusión

Se observó que las muestras estaban en conformidad con las normas microbiológicas fijadas por la ley, presentando para ambas muestras, la ausencia de Staphylococcus coagulasa positiva y *Salmonella sp.* en 25 g de la muestra, y el resultado <3,0 NMP/g para coliformes totales de hasta 45 °C.

La Tabla 1 muestra la preferencia de galletas, de tres variedades de patatas dulces orgánicos.

Las puntuaciones medias para el análisis sensorial (Tabla 1) muestran que la galleta hecha de cv Capivara fue la más aceptada por los catadores en relación a los atributos de apariencia, color, aroma, sabor y textura, que difieren significativamente ($p<0,05$) de galletas dulce patata *cv* Rosinha de Verdan y *cv* Zanahoria.

Rodrigues, Caliari y Asquieri (2011) evaluaron la aceptabilidad de galletas, de los diferentes niveles de harina de yuca seca y se dio cuenta de que tenían buena aceptación por la apariencia, sabor y textura.

Tabla 1. Aceptación de las galletas preparadas con tres variedades de patatas dulces orgánicas.

Galletas de Patatas Dulces Orgánicas					
Atributos	cv Rosinha	cv Capivara	cv Zanahoria	D.M.S.*	C.V.*
Apariencia	6,82[b]	7,62[a]	6,40[c]	0,008	0,05
Color	6,98[b]	7,46[a]	6,52[c]	0,008	0,05
Aroma	6,96[b]	7,10[a]	5,88[c]	0,017	0,06
Sabor	6,34[b]	7,04[a]	4,50[c]	0,017	0,07
Textura	6,68[b]	7,16[a]	5,66[c]	0,009	0,03

* Letras diferentes en la misma fila indican diferencias significativas según prueba Tukey a nivel de significación del 5%. D.M.S. (Diferencia Mínima Significativa); C.V. (coeficiente de variación).

Silva et al. (2009) evaluaron la aceptación de las galletas preparadas con la pre-cocido a 15% de granos de café molido y arroz, y la mezcla consistió mayor preferencia por aroma y textura en comparación con los de 20%.

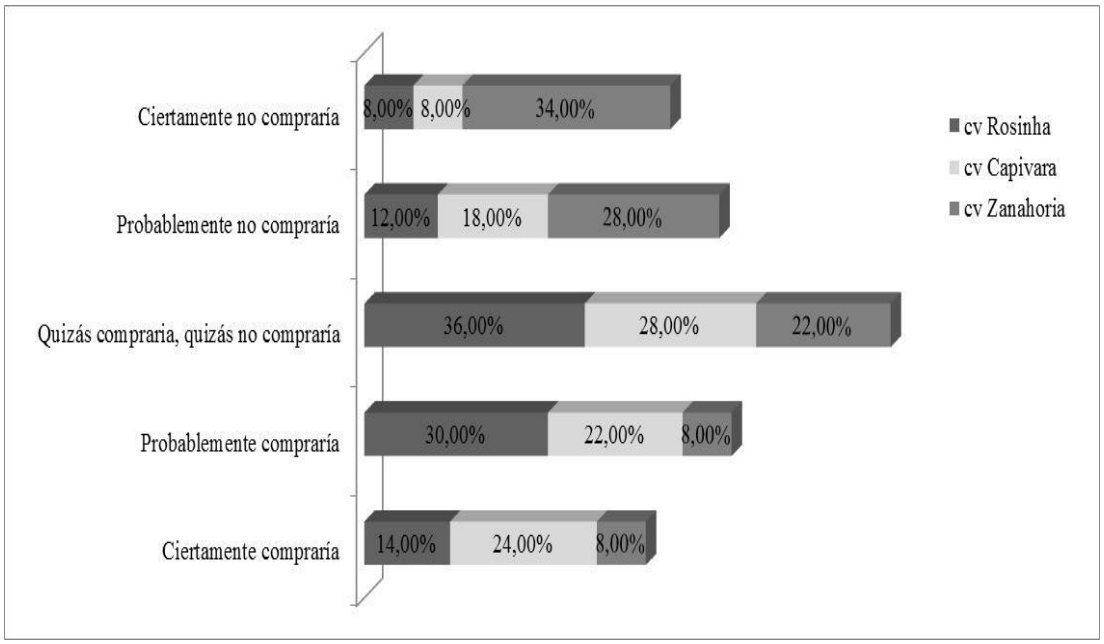

Figura 1. Intención de compra de las galletas orgánicas.

Por la prueba intención de compra, parece que el 46% de los consumidores compra ciertamente las galletas de batata, siendo la realizada con patata dulce *cv* Capivara la más preferida. Donde el 60% de los consumidores que pueden comprar galletas orgánicas.

Vieira et al. (2010) encontraron que la prueba de la intención de compra de galletas hecgas com harina mezclada con un 10 y 15% de almidón de yuca, se encontró que el 71% de los catadores ciertamente comprarón y el 67% probablemente comprarón. Para las formulaciones sin almidón y 5% de almidón, estas puntuaciones fueron 29% y 42%, respectivamente.

Conclusión

Se concluye que los parámetros de calidad adoptadas en la preparación de galletas orgánicas muestran la importancia de las Buenas Prácticas de Manufactura en la producción y el procesamiento de estos alimentos. Las galletas orgânicas hechas con almidones orgánicos de patatas en este estudio tenían características microbiológicas adecuadas y aceptación sensorial buena, convirtiéndose así en una gran alternativa a utilizar en lugar de harina de trigo, por sus propiedades funcionales, también el aumento de la demanda de productos de la granja familiar.

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Conclusão Geral

Observou-se que as amostras de ararutas, taro e batatas doces analisadas possuem grande importância econômica devido não só ao seu perfil nutricional, mas também pelas funcionalidades das suas farinhas e pelo perfil tecnológico das mesmas, quando comparado com outras fontes de farinhas, tais como inhame, milho, mandioca entre outros. As olericolas analisadas, como o taro e a batata doce Rosinha *in natura* apresentaram níveis mais elevados de compostos fenólicos totais. Verificou-se que o principal ácido graxo poliinsaturado encontrado na batata doce Capivara (*in natura*) foi o ácido linoleico (C18:2 ω6). Além disso, os resultados obtidos para o perfil de fitosterol das olericulturas analisadas (araruta *cv* comum e *cv* ovo de pata, taro Chinês e batatas doces: Rosinha de Verdan, Capivara e Alaranjada), foram brassicasterol, campesterol, estigmasterol e β-sitosterol. Em relação às farinhas de ararutas (comum e ovo de pata), verificou-se que ambas as cultivares apresentaram elevada capacidade antioxidante em relação à farinha de taro. Para a farinha de taro foi observado um maior teor de cinzas, valor energético, fibra bruta e açúcares redutores que o encontrado nas farinhas de araturas. A farinha de taro apresentou maior capacidade de absorção de gordura que as ararutas ovo de pata e comum, além disso, os níveis de compostos fenólicos totais e capacidade antioxidante do taro foram significativos. O padrão de cristalinidade para as duas variedades de farinhas de ararutas e para o taro foi do tipo A. Observou-se que o taro *Chinese* foi o que apresentou maior temperatura de pasta, o que pode está associado à presença de goma ou fibras (hemicelulose), observado pela composição química dessa farinha.

Para a farinhas de batata doce alaranjada, verificou-se que esta apresentou maior valor energético total, cinzas, pH, acidez, açúcares redutores, açúcares não redutores e conteúdo de carotenoides totais e capacidade antioxidante do que as outras variedades pesquisadas (Capivara e Rosinha de Verdan). O β-caroteno (22.146,78 g/100 g db), foi o principal carotenoide do variedade de farinha de batata doce de polpa alaranjada analisada. Sendo que o padrão de cristalinidade para as duas variedades de farinhas de batatas doces estudadas (Capivara e da batata doce de polpa alaranjada) foi do tipo A. A batata doce alaranjada foi o que apresentou maior temperatura de pasta, sendo que as farinhas de batatas doces podem ser utilizadas em preparações de molhos ou sopas.

Após os resultados do processamento, observou-se um maior rendimento para a obtenção de farinhas de batata doce Capivara (25,48 g/100g) e para a araruta ovo de pata (21,59 g/100g) respectivamente.

Foi verificado pelo teste de aceitação e intenção de compra de biscoitos desenvolvidos com as farinhas orgânicas, que o biscoito de doce de batata Capivara foi o preferido pelos provadores não treinados.

Assim, o desenvolvimento de produtos processados atraentes a partir destas farinhas orgânicas, desempenham um papel importante na sensibilização sobre o potencial e diversidade destas culturas. Uma vez que no Brasil a produção de trigo não atende a demanda interna, e consequentemente, tem sido dependente de trigo importado para o fabrico de produtos de panificação. Por estes motivos, esta pesquisa incidiu sobre a obtenção de farinha de rizomas de ararutas e tubérculos de batatas doces e taro, a partir de culturas locais visando à substituição do trigo.

Diante do exposto, constatou-se que as amostras pesquisadas podem ser utilizadas como uma fonte viável de farinhas visando a sua utilização industrial e para diferentes aplicações. As amostras analisadas, como amplamente reconhecidas, são importantes fontes de compostos bioativos, como compostos fenólicos, carotenoides,

ácidos graxos essenciais e fitosteróis. Torna-se viável o desenvolvimento e utilização de tais produtos com boas propriedades funcionais e nutricionais podendo ser utilizados para melhorar o estado nutricional da população, conferirindo benefícios para a saúde. Além disso, a diversidade cultural da agricultura orgânica justifica o consumo e processamento destes alimentos isentos de glúten para a população em geral, bem como para os portadores da doença celíaca.

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APÊNDICES

APÊNDICE 1. Fluxograma de Obtenção das Farinhas Orgânicas e Rendimento

As amostras foram lavadas, higienizadas, descascadas e cortados em fatias (2 cm espessura), logo após foram desintegradas em 1 litro de água destilada em um processador (*Osterizer Blender Classic)* por 5 minutos e peneiradas em peneiras de 200 *µm*. O produto foi disposto em tabuleiros e submetido à secagem em estufa com circulação e renovação de ar SL 102 da *Solab*, á uma temperatura de 65°C por 24 horas.

Após a secagem, as amostras foram moídas em um moinho *Perten* 3100 e peneiradas até a obtenção de um pó fino. Após a secagem das farinhas, foi feita a pesagem (DST 15-DM/P, Triunfo) para avaliar o rendimento do produto.

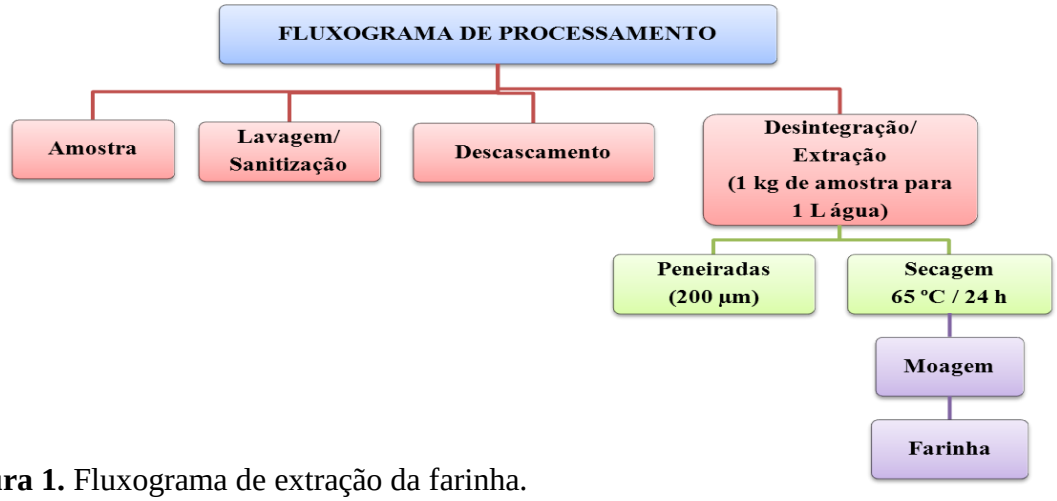

Figura 1. Fluxograma de extração da farinha.
Fonte: Adaptado de ERDMAN, (1986); HSU et al., (2003); LEONEL (2002).

As farinhas foram envasadas em embalagens laminadas para prevenir absorção de umidade e armazenadas em um congelador (-20ºC) até ser usado para testes adicionais. O rendimento (R) foi determinado de acordo com a equação abaixo:

$$R = \frac{PB}{PS} * 100$$

Equação (1)
Onde:
R= Rendimento
PB = Peso Bruto da amostra *in natura*
PS = Peso da amostra Seca

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APÊNDICE 2. Parecer do Comitê de Ética na Pesquisa da UFRRJ/ COMEP.

SERVIÇO PÚBLICO FEDERAL
UNIVERSIDADE FEDERAL RURAL DO RIO DE JANEIRO
PRÓ-REITORIA DE PESQUISA E PÓS-GRADUAÇÃO
COMISSÃO DE ÉTICA NA PESQUISA DA UFRRJ / COMEP

Protocolo Nº 313/2013

PARECER

O Projeto de Pesquisa intitulado "*Obtenção, caracterização e avaliação sensorial de féculas orgânicas e suas potencialidades no desenvolvimento de alimentos para celíacos*", sob a responsabilidade da Profa. Dra. Maria Ivone M. J. Barbosa do Departamento de Tecnologia de Alimentos do Instituto de Tecnologia, processo 23083.000129/2013-73, atende os princípios éticos e está de acordo com a Resolução 196/96 que regulamenta os procedimentos de pesquisa envolvendo seres humanos.

UFRRJ, 08/03/2013

Profa. Dra. Aurea Echevarria Neves Lima
Pró-reitora de Pesquisa e Pós-graduação

APÊNDICE 3. Certificado de Análise Microbiológica do Biscoito de Batata doce Rosinha de Verdan.

SERVIÇO PÚBLICO FEDERAL
UNIVERSIDADE FEDERAL RURAL DO RIO DE JANEIRO
LABORATÓRIO ANALÍTICO DE ALIMENTOS E BEBIDAS

CERTIFICADO DE ANÁLISE

Data do recebimento: -------			
Produto: Biscoito de batata doce rosinha de verdan.		Marca: -------	
Data de fab. ----	Data de val. ------	Lote: -------	
Local da coleta: ------		Temperatura da amostra: ambiente.	
Fabricante: --------		Solicitante: Kamila de Oliveira do Nascimento.	
Orientador: Professora Maria Ivone.		CEP: -------	Tel: --------
CNPJ: ------		Inscrição Estadual: -------	
Responsável pela Empresa: -------		Coletor: -------	

RESULTADOS

ANÁLISES REALIZADAS	RESULTADOS OBTIDOS
Coliformes termotolerantes NMP/g	<3,0 est.
Estafilococos coag. Positiva UFC/g	$<1,0 \times 10^2$ est.
Salmonela SP Ausência em 25g.	Ausente

Seropédica, 11 de dezembro de 2012.

ESTES RESULTADOS REFEREM-SE EXCLUSIVAMENTE A AMOSTRA ACIMA CARACTERIZADA.

Dra. Rosa Helena Luchese
Coordenadora Técnica

LAAB-RURAL DTA/IT/UFRRJ Rodovia BR465 Km7 Campus Universitário
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Elaboração: Elizângela dos Santos Cardoso. 01 de 01

APÊNDICE 4. Certificado de Análise Microbiológica do Biscoito de Batata doce Capivara.

SERVIÇO PÚBLICO FEDERAL
UNIVERSIDADE FEDERAL RURAL DO RIO DE JANEIRO
LABORATÓRIO ANALÍTICO DE ALIMENTOS E BEBIDAS

CERTIFICADO DE ANÁLISE

Data do recebimento: -------			
Produto: Biscoito de batata doce Capivara		Marca: -------	
Data de fab. ----	Data de val. ------	Lote: -------	
Local da coleta: ------		Temperatura da amostra: ambiente.	
Fabricante: --------		Solicitante: Kamila de Oliveira do Nascimento.	
Orientador: Professora Maria Ivone.		CEP: -------	Tel: --------
CNPJ: ------		Inscrição Estadual: -------	
Responsável pela Empresa: -------		Coletor: -------	

RESULTADOS

ANÁLISES REALIZADAS	RESULTADOS OBTIDOS
Coliformes termotolerantes NMP/g	<3,0 est.
Estafilococos coag. Positiva NMP/g	<1,0 x 10^2 est.
Salmonela SP Ausência em 25g.	Ausente

Seropédica, 11 de dezembro de 2012.

ESTES RESULTADOS REFEREM-SE EXCLUSIVAMENTE A AMOSTRA ACIMA CARACTERIZADA.

Dra. Rosa Helena Luchese
Coordenadora Técnica

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Elaboração: Elizângela dos Santos Cardoso. 01 de 01

APÊNDICE 5. Certificado de Análise Microbiológica do Biscoito de Batata doce cenoura.

SERVIÇO PÚBLICO FEDERAL
UNIVERSIDADE FEDERAL RURAL DO RIO DE JANEIRO
LABORATÓRIO ANALÍTICO DE ALIMENTOS E BEBIDAS

CERTIFICADO DE ANÁLISE

Data do recebimento: -------	
Produto: Biscoito de batata doce cenoura.	Marca: -------
Data de fab. ---- Data de val. ------	Lote: -------
Local da coleta: ------	Temperatura da amostra: ambiente.
Fabricante: --------	Solicitante: Kamila de Oliveira do Nascimento.
Orientador: Professora Maria Ivone.	CEP: ------- Tel: --------
CNPJ: ------	Inscrição Estadual: -------
Responsável pela Empresa: -------	Coletor: -------

RESULTADOS

ANÁLISES REALIZADAS	RESULTADOS OBTIDOS
Coliformes termotolerantes NMP/g	<3,0 est.
Estafilococos coag. Positiva UFC/g	$<1,0 \times 10^2$ est.
Salmonela sp Ausência em 25g.	Ausente

Seropédica, 11 de dezembro de 2012.

ESTES RESULTADOS REFEREM-SE EXCLUSIVAMENTE A AMOSTRA ACIMA CARACTERIZADA.

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APÊNDICE 6. Artigo Publicado na Revista Acta Tcnológica: A Importância do Estímulo à Certificação de Produtos Orgânicos.

ALIMENTOS

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http://portaldeperiodicos.ifma.edu.br/

A importância do estímulo à certificação de produtos orgânicos.

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RESUMO

A procura por parte dos consumidores por produtos mais saudáveis, com menos resíduos químicos e com certificados de procedência, faz da agricultura orgânica uma opção muito viável. Embora o mercado de produtos orgânicos ainda seja pequeno, se comparado ao mercado de alimentos convencionais, observa-se crescente demanda mundial por esta categoria de alimentos. Sendo assim, explicitar a importância da certificação de produtos orgânicos no Brasil em tempos de globalização se faz extremamente relevante, pois o consumo deste segmento está cada vez mais em ascensão. A certificação é a garantia da procedência e da qualidade orgânica de um alimento natural ou processado. O agricultor ganha um diferencial de mercado ao oferecer produtos de melhor qualidade e mais valorizados, estabelecendo uma relação de confiança com o consumidor. Já o consumidor tem a garantia de um alimento sem contaminação química, cuja produção respeita o meio ambiente e o trabalhador. Além disso, o selo de certificação de um alimento orgânico fornece ao consumidor mais do que a garantia de estar levando para a casa um produto isento de contaminação química. Concluiu-se que a certificação orgânica é um fator importante e decisivo para conquistar maior credibilidade dos consumidores, além de conferir maior transparência às práticas e aos princípios utilizados na produção orgânica.Registros de 3.214 pesos de bovinos da raça Nelore, nascidos de 1976 a 2006 em fazendas localizadas nos Estados

Termos para indexação: alimentos orgânicos - agricultura orgânica - mercado.

Certification of organic products: why it is important.

ABSTRACT

The demand by consumers for healthier products, with less chemical wastes and certificate of origin, turns organic agriculture a very viable option. Although the market for organic products is still small, if compared to the conventional food market, it is observed that the demand for this kind of food is growing worldwide. Thus, the understanding of why the certification of organic products in Brazil is important in times of globalization is extremely relevant because the consumption of organic food is increasingly rising. The certification is the guarantee of origin and quality of natural or processed organic food. The farmer gets differential earnings in the market by offering products of best quality and most valued, establishing a relationship of trust with the consumer. The consumer gets the guarantee of a food with no

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APÊNDICE 7. Artigo Publicado na Saúde em Revista: Doença Celíaca: Sintomas, Diagnóstico e Tratamento Nutricional.

Doença Celíaca: Sintomas, Diagnóstico e Tratamento Nutricional

Celiac Disease: Symptoms, Diagnosis and Nutritional Treatment

RESUMO A doença celíaca é uma intolerância sensível ao glúten a qual depende de um processo imunológico. Ela pode aparecer durante na infância ou a vida adulta, quando uma intolerância permanente ao glúten é desenvolvida. O índice de mortalidade no mundo em virtude dessa doença é aproximadamente duas vezes maior que o da mortalidade por outras causas, com um aumento que acontece predominantemente no primeiro ano depois do diagnóstico da enfermidade. A morte ocorre principalmente devido à presença de malignidades com linfoma intestinal. Pacientes com doença cèlíaca apresentam sintomas como diarréia, anorexia, desnutrição, distensão abdominal e perda de peso. A doença pode estar associada a inúmeras outras, tais como dermatite herpetiformis, osteoporose, epilepsia e diabetes mellitus tipo 1. No Brasil, a incidência é de um caso para cada 681 pessoas em todo o país. O diagnóstico é baseado nas características clínicas, testes sorológicos de anticorpos específicos e biópsia intestinal. O tratamento dos pacientes celíacos consiste na exclusão do glúten da dieta deles por toda a vida, corrigindo os diferentes graus de desnutrição, anorexia, desidratação, intolerâncias alimentares, carências de vitaminas e minerais. Considerando que o principal fator etiológico da doença celíaca é de natureza dietética, a adoção de práticas alimentares voltadas para a exclusão do glúten da dieta constitui medida profilática bastante eficaz. Assim, cabe particularmente ao profissional nutricionista elaborar e orientar a terapia dietética do paciente celíaco e corrigir deficit nutricionais, excluindo o glúten e derivados da sua dieta.

Palavras-chave: DOENÇA CELÍACA, OSTEOPOROSE, EPILEPSIA E DIABETES MELLITUS.

ABSTRACT Celiac disease is a sensitive intolerance to gluten which depends on an immunological process and can appear during the childhood or adult life, when a permanent intolerance to the gluten is developed. mortality rate is approximately two times higher than other cases, appearing frequently in the first year after diagnosis. The death happens mainly due to the presence of malice's with intestinal lymphoma. Patient with disease celiac they present symptoms as diarrhea, anorexia, malnutrition, abdominal distention and weight loss. Besides, celiac disease can be associated the countless ones other, such as dermatitis herpetyforms, osteoporosis, epilepsy and diabetes mellitus type 1. In Brazil, the incidence is one case per 681 people. The diagnosis is based on the clinical characteristics, tests serological of specific antibodies and intestinal biopsy. The treatment consists of gluten free diet that correct different malnutrition degrees, anorexia, dehydration, food intolerances, and vitamins/minerals deficiencies. Considering that the main etiological factor of CD is dietary origin, the adoption of food habits such as gluten free diet constitutes an effective prophylaxis. In conclusion, nutritionists should elaborate a dietary therapy in order to correct nutritional deficits, excluding definitively gluten and derivates of diet.

Keywords: CELIAC DISEASE, OSTEOPOROSIS, EPILEPSY AND DIABETES MELLITUS.

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