UNIVERSIDADE ESTADUAL PAULISTA
"JÚLIO DE MESQUITA FILHO"
Campus de Botucatu

FCA
Faculdade de Ciências Agronômicas
UNESP | BOTUCATU

LETÍCIA SILVA PEREIRA BASÍLIO

BATATA-DOCE COLORIDA NÃO-COMERCIAL: AGREGAÇÃO DE VALOR, CARACTERIZAÇÃO BIOATIVA E DESENVOLVIMENTO DE SUCO MISTO

Botucatu

2022

LETÍCIA SILVA PEREIRA BASÍLIO

BATATA-DOCE COLORIDA NÃO-COMERCIAL: AGREGAÇÃO DE VALOR, CARACTERIZAÇÃO BIOATIVA E DESENVOLVIMENTO DE SUCO MISTO

Tese apresentada à Faculdade de Ciências Agronômicas da Unesp Câmpus de Botucatu, para obtenção do título de Doutor em Agronomia (Horticultura).

Orientadora: Drª Giuseppina Pace Pereira Lima

Coorientador: Dr Marco Antonio Tecchio

Botucatu

2022

B312b

Basílio, Letícia Silva Pereira
Batata-doce colorida não-comercial: agregação de valor, caracterização bioativa e desenvolvimento de suco misto / Letícia Silva Pereira Basílio. -- Botucatu, 2022
119 p.

Tese (doutorado) - Universidade Estadual Paulista (Unesp), Faculdade de Ciências Agronômicas, Botucatu
Orientadora: Giuseppina Pace Pereira Lima
Coorientador: Marco Antonio Tecchio

1. Postharvest technology. 2. Horticultural products. 3. Plant bioactive compounds. I. Título.

Sistema de geração automática de fichas catalográficas da Unesp. Biblioteca da Faculdade de Ciências Agronômicas, Botucatu. Dados fornecidos pelo autor(a).

Essa ficha não pode ser modificada.

UNIVERSIDADE ESTADUAL PAULISTA

Câmpus de Botucatu

CERTIFICADO DE APROVAÇÃO

TÍTULO DA TESE: BATATA-DOCE COLORIDA NÃO COMERCIAL: AGREGAÇÃO DE VALOR, CARACTERIZAÇÃO BIOATIVA E DESENVOLVIMENTO DE SUCO MISTO

AUTORA: LETÍCIA SILVA PEREIRA BASÍLIO
ORIENTADORA: GIUSEPPINA PACE PEREIRA LIMA
COORIENTADORA: MAÍRA RODRIGUES ULIANA
COORIENTADOR: MARCO ANTONIO TECCHIO

Aprovada como parte das exigências para obtenção do Título de Doutora em AGRONOMIA (HORTICULTURA), pela Comissão Examinadora:

Prof.ª Dr.ª GIUSEPPINA PACE PEREIRA LIMA (Participaçao Virtual)
Ciencias Quimicas e Biologicas / Instituto de Biociencias de Botucatu UNESP

Prof. Dr. FÁBIO VIANELLO (Participaçao Virtual)
Biomedicina Comparata e Alimentazione / Università Degli Studi di Padova

Prof. Dr. ADRIANO DO NASCIMENTO SIMÕES (Participaçao Virtual)
Fisiologia e Tecnologia Pós-Colheita / Universidade Federal Rural de Pernambuco

Prof. Dr. IGOR OTÁVIO MINATEL (Participaçao Virtual)
Coordenadoria do Curso de Biomedicina / UniFSP - Avaré-SP

Prof. Dr. PABLO FORLAN VARGAS (Participaçao Virtual)
Departamento de Agronomia / UNESP - Câmpus de Registro/SP

Botucatu, 06 de maio de 2022

AGRADECIMENTOS

Agradeço a Deus, a Nossa Senhora (principalmente sob o título de Nossa Senhora Aparecida) e aos anjos e santos, que muito ouviram (e ouvirão).

Agradeço os meus queridos pais pelo apoio e confiança incondicional, desde sempre, para sempre. À minha irmã, por tudo que é para mim. Aos meus sogros e cunhado, por acompanharem sempre com muita torcida e carinho os meus caminhos.

Aos amigos e parentes que mesmo quando distantes, se fazem presente de coração e oração.

O presente trabalho foi realizado com apoio da Coordenação de Aperfeiçoamento de Pessoal de Nível Superior - Brasil (CAPES) - Código de Financiamento 001.

Ao CNPQ – Conselho Nacional de Desenvolvimento Científico e Tecnológico, pela bolsa de estudos concedida (n° 201218/2020-8).

À Profª Drª Giuseppina Lima, minha orientadora, agradeço por ser a pedra angular de cada palavra aqui redigida. Agradeço ainda a amizade e 'chicotadas'. Levarei para a vida inteira!

Aos colegas e amigos do Laboratório de Bioquímica Vegetal, agradeço a paciência e parceria.

Agradeço ao Prof. Dr. Marco Antonio Tecchio e ao seu grupo de alunos ("povo da uva") pelo período de aprendizado e ajuda mútua.

Aos professores e funcionários da FCA e IB, que fizeram este trabalho possível.

Ao Prof. Dr. Pablo Vargas e ao seu grupo de alunos, ao Sr. João Navarro e aos funcionários e professores do CERAT, por me auxiliarem com tanta bondade e prontidão no transporte e aquisição de minhas amostras.

A tutti gli amici del "laboratorio 45", del Prof. Dr. Fabio Vianello. Quello che ho appreso ha attraversato il mare, così come la mia gratitudine per tutto ciò che ho ricevuto. Evviva!

Ao meu marido e filha, que são sal e luz de minha vida. Que me fazem querer ir sempre além todas as manhãs. Só nós sabemos o gosto (ora doce, ora amargo) de tudo isso.

A mim, pela perseverança na semeadura e humildade na colheita. Respira, pois muito ainda virá!

RESUMO

A batata-doce (*Ipomoea batatas* L.) é uma planta perene de raiz tuberosa, considerada uma cultura de importância econômica e social em diversos países devido ao alto rendimento e ampla adaptabilidade. Possui alto valor nutricional, com excelentes teores de carboidratos, açúcares, minerais, aminoácidos (proteína), vitaminas, fibra alimentar e forte atividade antioxidante, pode ser consumida de várias formas. É uma cultura que faz jus ao crescente interesse da população em alimentos de qualidade nutricional e nutracêutica. Os refugos da produção e resíduos gerados podem ser usados para elaboração de subprodutos, agregando valor à produção, incluindo alto potencial como matéria-prima em segmentos industriais distintos. Neste trabalho estudamos os compostos bioativos e atividade antioxidantes de genótipos de batata-doce de polpa colorida, da colheita à elaboração de produtos. No primeiro capítulo observamos a presença destes compostos em polpas, casca e polpas + cascas dos genótipos 'BRS Amélia', 'CPNH 1365', 'CPNH 1358','JNRX1', 'JNRX2 e 'JNRX7', além de avaliar as características físico-químicas das diferentes partes das raízes antes e após cozimento. Concluímos que a casca, geralmente descartada, pode ser uma fonte potencial de compostos bioativos. No segundo capítulo propomos a elaboração de um suco misto de batata-doce de polpa roxa ('JNRX12') com uvas híbridas ('Bordô', 'BRS Cora' e 'BRS Violeta') para a utilização das raízes fora do padrão. Além de apreciado sensorialmente, os sucos mistos apresentaram teores interessantes de compostos fenólicos, com destaque para antocianinas e aminas biogências e aminoácidos promotores da saúde. No terceiro capítulo avaliamos o perfil fitoquímico e potencial antioxidante dos genótipos de batata-doce de polpa colorida crus e quando submetidos ao cozimento por fervura, vapor, micro-ondas, forno convencional com e sem proteção de papel alumínio. Observamos que a variabilidade genética está ligada à extração e liberação dos compostos da matriz vegetal. A cocção em água fervente, comuns nos lares, não foi interessante pois reteve os compostos hidrossolúveis. Maior teor de fitoquímicos foram vistos em batatas-doces alaranjadas cozidas em micro-ondas e forno com ou sem proteção de papel alumínio. Em genótipos de polpa roxa, o uso de vapor, micro-ondas e forno com proteção de papel alumínio como tratamento térmico mostrou-se a melhor opção, pois apresentou maiores níveis de aminas benéficas, polifenóis e atividade antioxidante. Esperamos

que este estudo contribuía na divulgação das propriedades funcionais e bioativas de raízes fora do padrão de batatas-doces de polpa colorida e seu potencial para elaboração de produtos e derivados, incentivando seu plantio e consumo.

Palavras-chave: *Ipomoea batatas* (L); uvas híbridas; tratamentos térmicos; suco mistos; antioxidantes.

ABSTRACT

Sweet potato (*Ipomoea batatas* L.) is a perennial plant with tuberous roots, considered a crop of economic and social importance in several countries due to its high yield and wide adaptability. It has high nutritional value, with excellent levels of carbohydrates, sugars, minerals, amino acids (protein), vitamins, dietary fiber and strong antioxidant activity. Sweet potatoes can be eaten in a variety of ways. The waste products and generated residues can be used for the elaboration of by-products, in diversified products adding value to the production, including high potential as raw material in different industrial segments. It is a culture that lives up to the growing interest of the population in foods of nutritional and nutraceutical quality. In this work, we studied the bioactive compounds and antioxidant activity of colored-fleshed sweet potato genotypes, from harvest to product elaboration. In the first chapter we observed the presence of these compounds in pulp, peel and pulp + peel of the genotypes 'BRS Amélia', 'CPNH 1365', 'CPNH 1358', 'JNRX1', 'JNRX2 and 'JNRX7', in addition to evaluating the physical characteristics -chemistry of the different parts of the roots before and after cooking. We conclude that the bark, usually discarded, can be a potential source of bioactive compounds. In the second chapter we propose the elaboration of a mixed juice of sweet potato with purple pulp ('JNRX12') with hybrid grapes ('Bordô', 'BRS Cora' and 'BRS Violeta') for the use of non-standard roots. In addition to being sensorially appreciated, the mixed juices showed interesting levels of phenolic compounds, especially anthocyanins and biogenic amines and health-promoting amino acids. In the third chapter, we evaluated the phytochemical profile and antioxidant potential of genotypes of sweet potato with colored pulp raw and when submitted to boiling, steam, microwave, conventional oven with and without aluminum foil protection. We observed that genetic variability is linked to the extraction and release of compounds from the plant matrix. Cooking in boiling water, common in homes, was not interesting because it retained the water-soluble compounds. Higher content of phytochemicals were seen in orange sweet potatoes cooked in a microwave and oven with or without foil protection. In purple pulp genotypes, the use of steam, microwave and oven with aluminum foil protection as heat treatment proved to be the best option, as it presented higher levels of beneficial amines, polyphenols and antioxidant activity. We hope that this study contributed to the dissemination of the functional and bioactive properties of non-standard colored pulp sweet potatoes and

their potential for the elaboration of products and derivatives, encouraging their planting and consumption.

Key words: *Ipomoea batatas* (L); hybrid grapes; heat treatments; mixed juice; antioxidants.

SUMÁRIO

INTRODUÇÃO GERAL[1]

A batata-doce (*Ipomoea batatas* (L).) é a planta dicotiledônea, também conhecida como batata-da-terra, batata-da-ilha, jatica e jetica. São encontradas variedades distintas desta raiz, sendo classificada de acordo com o formato, tamanho, cor, precocidade, cor de folhas e flores. Já a classificação de acordo com a coloração das raízes, esta é realizada com base na cor da casca (epiderme) e da polpa, como batatas-doces de cores brancas, amarelas, laranjas, vermelhas e roxas (Sanchez et al., 2020).

Dentre as hortaliças, a batata-doce tem papel de destaque na agricultura, além de grande importância econômica e social. É uma cultura capaz de ser conduzida em pequena e grande escala, com elevada capacidade produtiva (Andrade Júnior et al., 2012; Amaro et al., 2019). É uma hortaliça amplamente consumida no Brasil e em outros países por ser uma fonte nutritiva de fácil aquisição, promotora da saúde humana.

A batata-doce é utilizada ainda na alimentação animal e nas indústrias de alimentos, fármacos, tecidos, papel e cosméticos como matéria prima, além de ser utilizada na produção de combustíveis (Silva Júnior et al., 2020; Andrade Júnior et al., 2012; Lafia et al., 2020). Quando utilizado o refugo das safras, existe um apelo ecológico e sustentável interessante para empresas e consumidores.

A batata-doce (*Ipomoea batatas* (L.) Lam.) (Convolvulaceae) é uma cultura que se destaca no cenário produtivo de tuberosas amiláceas (i. e. mandioca, açafrão, araruta, biri, jacatupé, inhame, mandioquinha-salsa, taro, taioba) por possuir um ciclo produtivo curto, baixo investimento de implementação em campo, capacidade de crescer e se desenvolver em sistemas agrícolas e facilidade de plantio (Oloniyo et al., 2021). Trata-se de uma cultura com grande importância social e econômica, devido a características como rusticidade e ampla adaptação climática, o que permite o seu cultivo em menor tempo e com elevada capacidade de produção (Aguirre et al., 2020).

A batata-doce é cultivada majoritariamente em áreas tropicais e subtropicais e é considerada cultura primária e fonte nutricional acessível à população, tanto rural, como

[1] Publicada em formato de capítulo de livro intitulado "**PLURALIDADE DA BATATA-DOCE DO CAMPO À MESA: UMA REVISÃO NARRATIVA**".

Disponível em: https://www.editoracientifica.org/articles/code/220107403 DOI 10.37885/220107403

urbana (Galvão et al., 2021). A alta capacidade de produzir alimento/ biomassa de qualidade, com baixo custo e sustentável, tornam a batata-doce particularmente interessante como opção para a agricultura familiar, incluindo assentamentos como: quilombos, aldeias indígenas e comunidades caiçaras (Vargas et al., 2018)).

Não existe no meio científico um consenso quanto ao centro de origem dessa espécie, entretanto, o mais aceito é a América Central e Norte da América do Sul, tornando seu cultivo restrito em regiões mais frias (Embrapa, 2021). O plantio ocorre a partir da seleção ou aquisição de ramas de qualidade, devendo priorizar materiais que foram submetidos a processos de limpeza viral (Figura 1) e obtidos com antecedência a data de plantio. Existem diferentes sistemas de plantio como leiras/camalhões, canteiros ou montículos, sendo o cultivo em leiras (Figura 2) o mais utilizado, com distribuição e plantio manual das ramas (Embrapa, 2021).

Figura 1. Mudas de batata-doce livre de vírus sendo produzida em telados (A). Mudas livre de vírus preparadas para o transporte e plantio (B).

Fonte: João Navarro, 2022

Figura 2. Plantio das ramas de batata-doce (A). Área de cultivo de batata-doce em leiras (B).

Fonte: Elaborado pelos autores

Para a batata-doce, os espaçamentos para o plantio podem variar, devendo levar-se em consideração a região onde será realizado e as condições climáticas da época do plantio. A colheita pode ser realizada de forma mecânica (Figura 3), semimecânica (Figura 4) ou manual e deve ser realizada de forma cuidadosa, evitando-se ao máximo a ocorrência de danos mecânicos e garantindo qualidade na vida útil pós-colheita (Embrapa, 2021)

Figura 3. Colheita mecanizada de batata-doce. Trator opera o equipamento de arrasto (A) fazendo a retirada das raízes do solo (B) e depósito das raízes em engradados (C).

Fonte: Elaborado pelos autores

Figura 4. Colheita semimecanizada. Equipamento retira as raízes do solo (A), que são coletadas (B) e depositas em caixas plásticas (C).

Fonte: Elaborado pelos autores

Dentre as culturas mais importantes do mundo, a batata-doce encontra-se em sexto lugar, além de ser a quinta cultura alimentar mais essencial em países em desenvolvimento, depois apenas do arroz, trigo, milho e mandioca (Hayati & Anhar, 2019). A produção mundial estimada em 2020 foi de 89 milhões de toneladas, em área plantada estimada de 7 milhões de hectares (FAO, 2021). O continente asiático é

responsável por 62,6% da produção mundial e a China o maior representante, com produção estimada de 49 milhões de toneladas. O continente africano vem em sequência, com alta produtividade em países como Malawi (6.918.420 t), Tanzânia (4.435.063 t) e Nigéria (3.867.871 t) (FAO, 2021). No Brasil, o cultivo da batata-doce apresenta destaque de produção nas regiões Nordeste, Sul e Sudeste. Os principais estados produtores são Rio Grande do Sul, São Paulo, Ceará, Paraná, Sergipe, Rio Grande do Norte, Pernambuco, Paraíba e Alagoas (Embrapa, 2021). O Brasil ocupa o 15º lugar como produtor mundial, com produtividade média de 14,5 t ha-1 e é o maior país produtor na América Latina (FAO, 2021).

O Brasil, comparado aos grandes centros produtores, ainda apresenta baixa produtividade no cultivo de batatas-doces. Isso se deve principalmente ao cultivo de variedades locais não selecionadas, ocorrendo um rendimento abaixo do potencial da cultura (Embrapa, 2021). Além disso, pode estar associada a fatores como o uso de sistema de plantio inadequado, baixa fertilidade natural do solo e o uso consecutivo de um mesmo material para o cultivo e propagação da batata-doce (Amaro et al, 2019; Otoboni et al., 2020). No entanto, programas de melhoramento nesta cultura estão cada vez mais empenhados em gerar novos materiais genéticos para o produtor, uma vez que a seleção e a disponibilização de cultivares de batata-doce podem aumentar o potencial produtivo e a qualidade das raízes (Vargas et al., 2017). As melhorias que novos genótipos trazem em campo refletem no mercado consumidor, baseado na oferta de um alimento produtivo, saudável e mais acessível à população de baixa renda (Embrapa, 2021). Atualmente constam 32 cultivares na lista de cultivares registradas no Ministério da Agricultura, Pecuária e Abastecimento – MAPA, no entanto, muitos destes acessos estão em desuso devido a vários fatores como a exigência de padronização, resistência a pragas e doenças e mecanização, abrindo espaço para a pesquisa e busca de genótipos com maior potencial agrícola (Embrapa, 2021).

Dentre as convolvuláceas, a batata-doce é a única espécie hexaplóide (2n = 6x = 90) e esta ploidia é responsável pela alta variabilidade presente em seus genótipos e cultivares. Esta variabilidade faz da batata-doce uma hortaliça única, uma vez que são encontrados raízes de diferentes cores de casca (branco, creme, amarelo, laranja, rosa e vermelho) e de polpa (branca, creme, laranja, amarelo e roxo) (Wang; Nie; Zhu, 2016). Quando apresentam polpas e cascas coloridas, as batatas-doces são consideradas alimentos eficazes para serem utilizadas em programas de biofortificação, visando a segurança alimentar e o aumento nutricional da cultura, a exemplo da cultivar de polpa

laranja ‘Beauregard’ (Laurie et al., 2015). Esta coloração geralmente é influenciada pelo nível de metabolitos (Wang; Nie; Zhu, 2016).

A composição nutricional de batatas-doces está ligada, dentre outros fatores, ao local de origem, tipo e a composição do solo e clima (HOU, Feina et al., 2020). No Brasil, o projeto de biofortificação é liderado pela Embrapa e conta com apoio do Fundo de pesquisa Embrapa/Monsanto e de programas internacionais denominados AgroSalud e HarvestPlus. O objetivo é disponibilizar aos agricultores e consumidores cultivares de batata-doce com teores mais elevados de micronutrientes (principalmente Fe e Zn), além de metabolitos secundários como β-caroteno e leva em consideração desde a produtividade no campo até a aceitação do consumidor (Embrapa, 2018). Quando questionados, produtores da região de Presidente Prudente – São Paulo relatam que comercializam, em sua maioria, cultivares de coloração de casca rosada e polpa branca ou creme (i.e., ‘Canadense’) e casca e polpa branca (i.e., ‘Coquinho’), apesar dos benefícios nutricionais e funcionais verificados em batatas doces coloridas, por ser culturalmente melhor aceita. Grande parte do que se planta é comercializado em grandes centros comerciais como o CEAGESP, seguido de mercados locais e feiras. Estes produtores também plantam outras culturas em consórcio, como gramíneas (i.e., cana-de-açúcar e milho) e hortaliças (i.e., mandioca, abóbora, berinjela e brássicas). Em outro levantamento, 2.031 pessoas de todas as federações nacionais confirmaram encontrar com maior facilidade batatas-doces de polpa branca nos mercados, com casca rosada ou branca. Contudo, percebe-se a mudança do mercado consumidor e a possibilidade de comercialização quando a maioria (64%) afirmou que independente do preço compraria batatas-doces de polpa colorida por possuírem maiores teores de substâncias que auxiliam em nossa saúde e bem-estar.

Batatas-doces alaranjadas e amarelas possuem carotenoides (principalmente o β-caroteno) que atuam como a molécula primária de pigmento, bem como fonte de provitamina A (pVACs) em nosso organismo (Bechoff et al., 2011; Tang; Cai; Xu, 2015). De forma geral, quando mais alaranjado a raiz, maior o teor de provitamínicos A (Simões et al., 2020; Basílio et al., 2020). Cabe ressaltar que, baixos níveis de vitamina A podem ocasionar deficiência ocular temporária ou permanente (Bovell-Benjamin, 2007), destacando a importância da ingestão de pVACs para a saúde humana. Em alguns países asiáticos, a exemplo de Bangladesh, existe um quadro preocupante de cegueira noturna entre crianças em idade pré-escolar e mulheres em idade reprodutiva, principalmente de origem rural. Além destes, mulheres grávidas, lactantes e mulheres

não grávidas/não lactantes também são susceptíveis a esta deficiência no país (Alam; Rana; Islam, 2016).

As batatas-doces roxas também são ricas em outros compostos bioativos, i.e., ácidos fenólicos, flavonoides e antocianinas (Basílio et al, 2020). Estes compostos estão diretamente relacionados à capacidade antioxidante destes alimentos, bem como, com outras propriedades benéficas à saúde (Albuquerque; Sampaio; Souza, 2019) e são influenciados por tratamentos e/ou processamentos realizados após a colheita.

Batatas-doces, a depender da composição e coloração, também são fontes de aminoácidos e aminas biogênicas, compostos que também possuem alta atividade antioxidante (Hou et al., 2020). Em vários estudos, são encontrados aminoácidos essenciais como isoleucina, leucina, lisina, metionina + cisteína, fenilalanina + tirosina, treonina, triptofano e valina, sendo a lisina e o triptofano os aminoácidos mais comuns em batatas-doces (Islam et al., 2016; Mu; Tan; Xue, 2009). A lisina desempenha papéis importantes no metabolismo humano, desde à sua associação com a vitamina C a formação de pró-colágeno até a regulação de ansiedade induzida por estresse (Smriga et al., 2004, 2007; Yang et al., 2021). O triptofano é essencial para regulação de sono, humor e cognição em humanos e é precursor de serotonina, melatonina e niacina (vitamina B3) no organismo (Silber; Schmitt, 2010). Aminas biogênicas são moléculas mono ou policatiônicas produzidas após a α-descarboxilação de aminoácidos em plantas e mamíferos (Diamante et al., 2019). Nas raízes de batata-doce podem ser encontradas as monoaminas serotonina, histamina e tiramina, as diaminas putrescina e cadaverina e as poliaminas espermina, espermidina e agmatina, variando de acordo com a composição da matriz celular (Islam et al., 2016).

Além da composição bioativa, estas raizes possuem alta porcentagem de água, alto valor nutritivo e são consideradas uma opção de baixo custo para o controle de diabetes tipo 2 e obesidade (Alam, 2021). Podem ser consideradas fontes de carboidratos digeríveis e não digeríveis (i.e., celulose e a hemicelulose). São ricas em açúcares simples como a sacarose, frutose e glicose oriundos da degradação do amido e responsável pelo sabor doce das raízes (Vidal et al, 2018). Possuem teores consideráveis de minerais como cálcio, ferro e potássio e estima-se que o consumo médio de 200 g de batatas-doces forneceria às crianças de 4 a 8 anos, mais de 28% e para gestantes, 20% da necessidade de magnésio diária (Vizzotto et al., 2018).

Embora outras partes como caule e folhas também tenham valor nutricional, as raízes de batata-doce são a parte comestível mais consumida. As cascas geralmente

são descartadas nos procedimentos domésticos e industriais, mas podem constituir fontes interessantes de fitoquímicos (Borges et al., 2019; Basílio et al., 2020). Folhas e raízes possuem alta capacidade antioxidante, antimicrobiana, anticancerígena, antidiabética, anti-ulcerogênica, anti-inflamatória, hepato e neuro protetiva, antiobesidade e promovem melhorias na saúde do intestino (Vidal et al., 2018; Alam, 2021).

Por muito tempo o potencial nutritivo das folhas de batata-doce foi ignorado, fazendo com que compusessem apenas a alimentação animal. No entanto, com o avanço do conhecimento, sabe-se que as folhas de batata-doce são fontes de minerais essenciais, vitaminas, polifenóis e carotenoides, incluindo luteína , mostrando-se uma solução barata e eficaz como alimento, principalmente em locais que enfrentam escassez constante de alimentos (Nguyen et al., 2021; Alam, 2021).

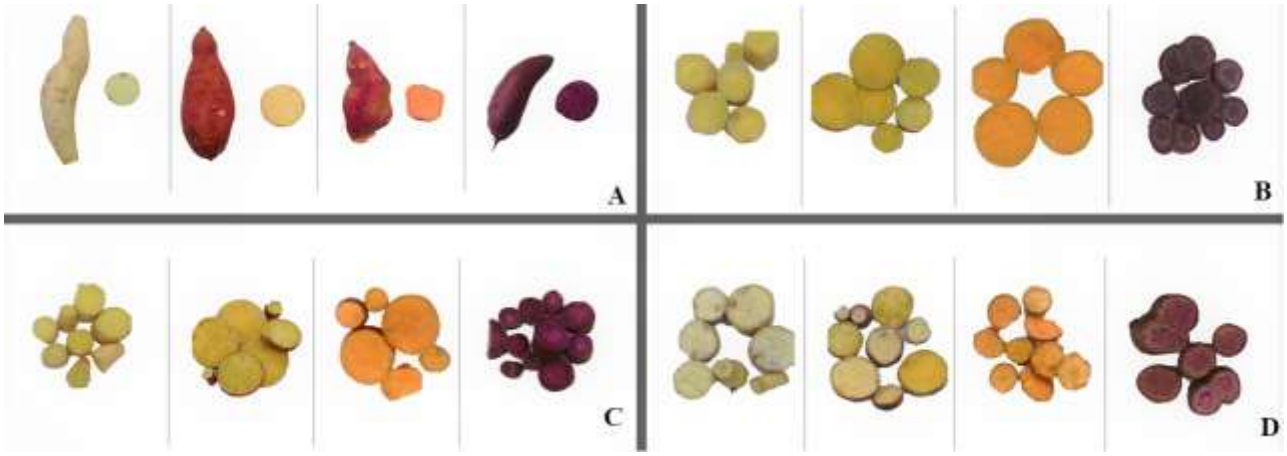
Em alguns países da África e Ásia, as folhas são consideradas como hortaliças folhosas e são fontes de proteínas, aminoácidos essenciais, vitaminas, minerais, antioxidantes e fibras dietéticas (Johnson; Pace, 2010). Estudos mostram que o consumo de folhas de batata-doce afeta o perfil lipídico sérico de humanos, reduzindo o risco de doenças cardiovasculares (Johnson; Pace, 2010). Folhas de batata-doce apresentam benefícios também como prevenção de problemas oculares, pois foi descrito níveis de luteína em folhas de batata-doce entre 19,01 e 28,85 mg/100 g (Wang et al., 2017) dependendo da cultivar. Polifenóis também são importantes compostos com atividade antioxidante e foi descrito que folhas de batata-doce podem conter de 2,73 a 12,46g / 100g (massa seca) (Sun, Mu, Xi, & Song, 2014; Sun, et al., 2014). Outros resultados de estudos com folhas de batata-doce demonstram que os polifenóis das folhas possuem atividade antioxidante (in vitro) duas vezes maior que o descrito para ácido ascórbico, polifenóis de chás e de sementes de uva (YU et al., 2017).

Na nutrição humana, as raízes tuberosas de batata-doce são geralmente consumidas após o processamento térmico, devido ao alto teor de compostos antinutricionais encontrados nas raízes cruas. Estes compostos naturais são encontrados em alimentos e estão comumente associados à redução da biodisponibilidade e bioacessibilidade de nutrientes e micronutrientes no organismo após o consumo (Haile & Getahun, 2018). Os efeitos negativos destas moléculas podem ser eliminados através de tratamento térmico, fermentação e/ou manipulação genética. (Jeyakumar & Lawrence, 2022). Em batatas-doces os antinutrientes podem variar de acordo com genótipo, tempo de colheita e armazenamento e os mais comuns nestes

tubérculos são oxalatos, taninos, fitatos, saponinas, alcalóides e cianeto de hidrogênio (Siener; Seidler; Hönow, 2020).

As batatas-doces toleram diferentes formas de cocção, podendo ser cozidas em vapor ou água, fritas, assadas e/ou incorporadas em receitas e produtos através de amidos e farinhas (Vidal et al., 2018; Carrera et al., 2021). O modo de preparo também pode mitigar antinutrientes. Em batatas-doces laranjas, o preparo em fritura diminui oxalatos e ácido fítico em comparação ao cozimento em água fervente. Contudo, os taninos foram menos presentes em raízes preparadas em ebulição do que nas fritas (Abong et al., 2020). Sabe-se que o preparo em forno aumenta o teor de matéria seca e cinzas, mas diminui o teor de fibra alimentar e proteína (Vidal et al., 2018). A fervura em água também aumenta a retenção de compostos fenólicos nas raízes, mas degrada a maioria desses fitoquímicos nas folhas (Abong et al.,2020). Alguns açucares como a maltose podem ser detectados apenas após o processamento térmico (Vidal et al., 2018). De acordo com a via de cocção utilizada, as batatas-doces possuem diferente biodisponibilidade de compostos benéficos à saúde como fenóis, flavonoides, carotenoides, vitaminas, aminoácidos, compostos voláteis, açúcares e minerais (Kourouma et al., 2019; Carrera et al., 2021). A presença desses compostos pode promover alterações na cor, aroma e textura (Figura 5), além de se tornarem mais palatáveis, mais doces e menos ácidas (Basílio et al., 2020; Hou et al., 2020). O tempo de cocção também é um fator a ser considerado para garantir maior teor de compostos promotores da saúde humana (Diamante et al., 2019; Kourouma et al., 2019).

Figura 5. Batatas-doces de polpas branca, amarela, laranja e roxa A) cruas, B) cozidas em água fervente, C) cozidas em micro-ondas e D) assadas em forno



Fonte: Elaborado pelos autores

Desse modo, nosso grupo de pesquisa realizou um questionário aplicado à consumidores em geral, para compor dados sobre consumo de batata-doce. Este questionário foi realizado em formulário on-line e aferimos alguns resultados interessantes: apenas 6,1% dos entrevistados não possuíam o hábito de consumir batata-doce e 21,7% consomem a hortaliça mais de uma vez por semana e a maioria afirma realizar o cozimento a partir da imersão em água em ebulição para o preparo e consumo de batatas-doces. Os voluntários afirmaram consumir raízes e caules tuberosos com frequência, sendo a batata-doce o quarto mais consumido, atrás da mandioca, cenoura e batata inglesa. Os produtos alimentícios, ou derivados, mais conhecidos foram doces (1260 pessoas), chips (1192 pessoas), produtos de panificação (pão – 848 pessoas; bolo – 565 pessoas) e massas (620 pessoas), embora alguns já tenham se deparado com produtos mais autênticos como cervejas, sucos e purês.

Em outros países latino-americanos, como o Peru, o consumo de batatas-doces coloridas é dado geralmente por meio de produtos de panificação e massas oriundos de farinhas de batatas-doces (CIP, 2018). No México, a tradição é utilizar as raízes em sobremesas como pudins, gelatinas, sorvetes e adicionadas de leite condensado ou mel (Sagapa, 2015). No Chile, são encontrados produtos industrializados, como chips de batata-doce coloridas. Em países africanos como Quênia, Nigéria e Uganda, as batatas-doces são geralmente consumidas fritas pela população urbana em grandes centros e desidratas em zonas rurais ou de interior (Ssali et al., 2021). Na Ásia, é comum o consumo das batatas-doces em salmouras ou fermentadas, além de serem utilizadas na incorporação de bebidas lácteas, como ocorre no Japão e Filipinas (El Sheikha; Ray, 2017).

A batata-doce é matéria-prima de alta qualidade em vários setores industriais, devido à variação genotípica. A indústria de alimentos á a grande responsável pelo escoamento dos tubérculos, sendo formulados vários produtos com batata-doce como produtos lácteos (i. e. iogurte, leite fermentado), macarrão, pão, bebidas alcoólicas e bebidas não alcoólicas (Alam, 2021). O amido é o principal subproduto extraído e equivale a aproximadamente 50%-80% da matéria seca da raiz (Wang et al., 2020). Com o avanço tecnológico, outras vantagens da batata-doce vêm sendo exploradas na indústria de alimentos como a capacidade de geleificação, devido a eficiência em retenção que evita que produtos absorvam gordura durante a fritura (Paula et al., 2021)

Além da indústria alimentícia, a batata-doce ganha cada dia mais espaço em outros setores. As raízes e folhas são utilizadas como fonte de compostos interessantes para suplementação e medicamentos na indústria farmacêutica (Vidal et al., 2018). Em um estudo em modelos animais, pomadas de batata-doce (cv. Brazlândia Branca) promoveram cicatrização de feridas cutâneas e preveniram ulceração gástrica induzida por etanol (Hermes et al., 2013). Na indústria química, o amido de batata-doce pode ser utilizado como carreador de antioxidantes e enzimas (Aina et al., 2012). O amido extraído de batata-doce tem potencial para produção de polímeros de base ecológica, interessante para indústria de embalagens, gerando baixo impacto econômico e ambiental (Vannini et al., 2021).

A utilização de raízes de batata-doce como corante natural é conhecida em alimentos mas se expande na indústria têxtil, garantindo segurança não só ao fabricante como ao usuário, fornecendo propriedades funcionais aos tecidos e tornando-se uma opção interessante aos indivíduos que prezam conceitos sustentáveis (Fazal-Ur-Rehman; Khosa, 2019). O amido de batata-doce pode ser valioso para indústria de cosméticos e decoração, sendo utilizado como revestimento natural (Wang et al., 2020).

O potencial na indústria energética é voltado à produção de biocombustível (etanol). O processo convencional de produção de bioetanol envolve a conversão do amido em açúcares fermentáveis, obtendo em alguns casos (cv. Duda) rendimento médio de aproximadamente 46 % superior ao obtido da cana-de-açúcar e 149% superior ao obtido através de milho, demonstrando a elevada relevância da sua utilização para este fim (Lareo; Ferrari, 2019).

Em todos os aspectos industriais, uma grande vantagem é a utilização de produtos de refugo que normalmente vão para o descarte. Produtores de Presidente Prudente, São Paulo, relatam alto índice de perda pós-colheita por defeitos de formação e tubérculos fora do padrão, danos leves que prejudicam somente as características visuais, sem comprometer a qualidade das raízes (Figura 6). A grande maioria destes produtores utiliza esse material para alimentação animal, além de descartar essas raízes e/ ou incorporá-las na lavoura para efeito de adubação verde.

Figura 6. Batatas-doces fora do padrão comercial

Fonte: Elaborado pelos autores

O desperdício é um problema mundial em todas as práticas agrícolas e impacta os setores economicamente, ambientalmente e socialmente (VIEIRA et al., 2021). Acredita-se que cerca de 14% dos alimentos produzidos no mundo sejam perdidos antes de chegar ao varejo (FAO, 2019). A utilização de produtos de refugo na indústria vai de encontro com o conceito de sustentabilidade, ajudando empresas a responderem a crescente pressão em se tornarem mais sustentáveis e ecológicas (Vieira et al., 2021). No setor alimentício, o possível uso de batatas-doces fora do padrão, mas com alta qualidade fitoquímica corresponde à segurança alimentar e nutricional, já que dá acesso a alimentos de qualidade e promotores da saúde de forma ambiental, cultural, econômica e socialmente sustentáveis (Maniglia, 2009). Esta prática abre fronteiras para a utilização da batata-doce na elaboração de novos produtos, minimizando o descarte pós-colheita.

CAPÍTULO 1

POTENTIAL OF COLORED SWEET POTATO GENOTYPES AS SOURCE OF BIOACTIVE COMPOUNDS[2]

Potencial de los genotipos de camote coloreado como fuente de compuestos bioactivos

Letícia Silva Pereira Basílio
São Paulo State University, Department of Chemistry and Biochemistry, Institute of Bioscience, 18618-970, Botucatu, São Paulo, Brazil. E-mail: l.pereira@unesp.br

Cristine Vanz Borges
São Paulo State University, Department of Chemistry and Biochemistry, Institute of Bioscience, 18618-970, Botucatu, São Paulo, Brazil. E-mail: cristine.vanzb@gmail.com

Pablo Forlan Vargas
São Paulo State University (UNESP), Campus of Registro, 11900-000, Registro, São Paulo, Brazil. E-mail: pablo.vargas@unesp.br

Adalton Mazetti Fernandes
São Paulo State University (UNESP), Center of Tropical Roots and Starches (CERAT), Av. Universitária, 3780, Lageado Experimental Farm, 18610-034 Botucatu, São Paulo, Brazil. Email: adalton.fernandes@unesp.br

João Pedro Corrêa de Camargo
São Paulo State University, Department of Chemistry and Biochemistry, Institute of Bioscience, 18618-970, Botucatu, São Paulo, Brazil. E-mail: joaoquimica1991@hotmail.com

Matheus Antonio Filiol Belin
São Paulo State University, Department of Chemistry and Biochemistry, Institute of Bioscience, 18618-970, Botucatu, São Paulo, Brazil. E-mail: belin.maf@gmail.com

Mariana Emy Haneda Ferrarini
São Paulo State University, Department of Chemistry and Biochemistry, Institute of Bioscience, 18618-970, Botucatu, São Paulo, Brazil. E-mail: mariana.ehf@gmail.com

Giuseppina Pace Pereira Lima
São Paulo State University, Department of Chemistry and Biochemistry, Institute of Bioscience, 18618-970, Botucatu, São Paulo, Brazil. E-mail: pace.lima@unesp.br

[2] Artigo publicado no Periódico Científico 'Revista Iberoamericana de Tecnología Postcosecha'. Disponível em: https://www.redalyc.org/journal/813/81365122010/

Key Words: *Ipomoea batatas*; carotenoids, phenolic compounds, antioxidants, boiling.

ABSTRACT: The aim of this work was to evaluate the bioactive composition and antioxidant capacity of fleshes, peels and fleshes + peels of six genotypes of raw colored sweet potatoes, in addition to determining the physical-chemical attributes of the samples of raw flesh + peel and after thermal treatment. Orange-fleshed sweet potatoes 'BRS Amélia', 'CPNH 1365' and 'CPNH 1358' and purple-fleshed sweet potatoes 'JN RX1', JN RX2 and 'JN RX7' were analyzed for the content of total phenolic compounds, total flavonoids, antioxidant capacity, total carotenoids (orange-fleshed genotypes) and total monomeric anthocyanins (purple-fleshed genotypes). Sweet potatoes were boiled in water for 12 minutes, separated in peel and flesh and analyzed after powdering in low temperature. Peel + flesh of orange-fleshed 'CNPH 1365' showed the highest levels of phenolic compounds (286.44 mg/100g) and total flavonoids (141.77 mg/100g). Peel + flesh of 'CPNH 1358' showed high levels of total carotenoids (11.21 mg/100g). Peel + flesh of purple sweet potato 'JN RX1' contains higher levels of total phenols (324.78 mg/100g) and 'JN RX2' showed the highest levels of flavonoids (160.17 mg/100g), as well as total anthocyanins (17.63 mg/100g). The 'JN RX7' peels also showed high anthocyanins content (15.64 mg/100g). After cooking, orange-fleshed sweet potatoes showed decreasing of titratable acidity levels and increasing of soluble solids, which contributed to higher ratio values. The thermal processing induced an increase in the ratio in purple-fleshed sweet, with the exception of 'JN RX7'. Our results show that colored sweet potatoes are potential sources of phytochemicals, demonstrating that the use of this tuber, especially the peels, in the food and pharmaceutical industries should be expanded.

Palabras clave: *Ipomoea batatas*; carotenoides, compuestos fenólicos, antioxidantes, cocción

RESUMEN: El objetivo de este trabajo fue evaluar la composición bioactiva y capacidad antioxidante de pulpas, cáscaras y pulpas + cáscaras de seis genotipos de camote coloreado crudo, además de determinar los atributos físico-químicos de las muestras de pulpa + cáscara crudas y después del tratamiento térmico. Se analizaron los camotes anaranjados 'BRS Amélia', 'CPNH 1365' y 'CPNH 1358' y los camotes morados 'JN RX1', JN RX2 y 'JN RX7' para determinar el contenido de compuestos fenólicos totales, flavonoides totales, capacidad antioxidante, carotenoides totales (genotipos de pulpa naranja) y antocianinas monoméricas totales (genotipos de pulpa púrpura). Los camotes se hirvieron en agua durante 12 minutos, se separaron en cáscaras y pulpa y se analizaron después de pulverizarlas a baja temperatura. La cáscara + pulpa del "CNPH 1365" de pulpa anaranjada mostró los niveles más altos de compuestos fenólicos (286.44 mg /100g) y flavonoides totales (141.77 mg /100g). La cáscara + pulpa de "CPNH 1358" mostró niveles altos de carotenoides totales (11.21 mg /100g). La cáscara + pulpa del

camote morado 'JN RX1' contiene niveles más altos de fenoles totales (324.78 mg/100g) y 'JN RX2' mostró los niveles más altos de flavonoides (160.17 mg/100g), así como antocianinas totales (17.63 mg/100g). Las cáscaras 'JN RX7' también mostraron un alto contenido de antocianinas (15.64 mg/100g). Después de la cocción, las batatas de pulpa anaranjada mostraron una disminución de los niveles de acidez titulable y un aumento de los sólidos solubles, lo que contribuyó a valores de proporción más altos. El procesamiento térmico indujo un aumento en lo *ratio* de camotes morados, con la excepción de "JN RX7". Nuestros resultados muestran que los camotes coloreadas son fuentes potenciales de fitoquímicos, demostrando que el uso de este tubérculo, especialmente las cáscaras, en las industrias alimentaria y farmacéutica debe expandirse.

1.1 - INTRODUCTION

Phenolic compounds and carotenoids are formed through reactions of plant secondary metabolism and are important to protect the cells and tissues against damage induced by biotic and abiotic stress (Borges *et al*., 2017). In the edible parts of plants (fruits, tubers, rhizomes, etc.), phenolic compounds contribute, in addition to protection, in the characteristics of texture, flavor, aroma, astringency and color (Maoka, 2020). The presence of these secondary metabolites becoming an interesting biomass for the exploitation of phenolic compounds and carotenoids, molecules considered free radical scavengers. Some authors report, for example, that these bioactive compounds, appear in higher levels around the cortex and or close to the peels (Islam *et al*., 2016; Jung *et al*., 2011).

In human nutrition, these phytochemicals are being researched due to their antioxidant properties with numerous health benefits and may present antibacterial, antitumor, antiviral, antimutagenic activity, as well as act as cardioprotective agents (Sagar *et al*., 2018). Studies also report that the consumption of food with significant amounts of these antioxidants may reduce the risk of developing degenerative diseases, such as cancer, and contributes to the delay of cellular aging (Lima *et al*., 2014; Minatel *et al*., 2017), emphasizing the importance of these compounds in human nutrition.

Even though they have great antioxidant potential, food peels are usually discarded, either for domestic consumption or in industry. Peel separation may induce deterioration of plant tissues and browning induced by enzymes, such as polyphenoloxidase and

peroxidase, which use phenolic compounds as substrate (Simões *et al*., 2020), damaging the quality of the final product.

A very interesting issue is the diversity of sweet potato tubers, with different colors of peel (white, cream, yellow, orange, pink and red) and flesh (white, cream, orange, yellow and purple). This coloration is generally influenced by the level of metabolites found in the tubers (Wang *et al*., 2018), e.g., orange sweet potatoes present β-carotene (carotenoid) as the majoritary compound (Van Jaarsveld *et al*., 2005); in contrast, purple sweet potatoes have in their chemical composition bioactive compounds such as phenolic acids, flavonoids and anthocyanins (De Albuquerque *et al*., 2019). The exploitation of this diversity, that is, the use of varieties which fleshes and peels with different contents of antioxidant compounds, might be explored by the food and pharmaceutical industries, adding value to the product and, concomitantly, increasing the income of the rural producer.

In recent surveys conducted by our group on the use of peels in tuberous foods (potatoes, sweet potatoes, beets, carrots, cassava, among others), 75.7% responded that they discarded this material, 11.6% that they consumed and 12.7% who reuse it for other purposes, such as animal feed and composting (unpublished data), demonstrating the need for studies aimed at the purpose of using this biomass. Most sweet potato consumption is domestic and, although it is a tuber with industrial potential, there is little visibility in the use of its by-products by the industry. The peel is an important by-product resulting from the processing of food and may be a potential source of bioactive compounds.

Thus, our objective was to determine the contents of total phenolic compounds, total carotenoids and *in vitro* antioxidant activity in raw and thermally processed samples of flesh, peel and flesh + peel of different colored sweet potatoes.

1.2 - MATERIAL AND METHODS

Purple-fleshed sweet potato genotypes 'JN RX1', 'JN RX2' and 'JN RX7' were purchased from a producer in the region of Presidente Prudente, São Paulo (latitude 22° 7′ 39″S, longitude 51° 23′ 8″ W and altitude 457 m). The orange-fleshed sweet potato genotypes 'BRS Amélia', 'CPNH 1365' and 'CPNH 1358' were grown in Botucatu , São Paulo (22 ° 52

' 47 ” S latitude, 48 ° 25 ' 12 ” W longitude and 810 m altitude), at the Center of Tropical Roots and Starches (CERAT).

After sanitizing the raw tubers, the peels were removed using a manual peeler. The extremities of the tubers were discarded and the flesh, peel and flesh + peel (whole tuber) were powdered in liquid nitrogen and stored at -20° C. In all genotypes, total phenolic compounds, total flavonoids and antioxidant capacity (DPPH and MDA) were analyzed. In the tubers 'BRS Amélia', 'CPNH 1365' and 'CPNH 1358' (orange flesh), the total carotenoids were also analyzed and in 'JN RX1', 'JN RX2' and 'JN RX7' (purple flesh), total anthocyanins monomeric were evaluated.

The total phenols content was analyzed using the reagent Folin Ciocalteu (Singleton & Rossi, 1965). Fresh samples were homogenized in MeOH: acetic acid: water (80:1:19 v/v/v) and submitted to an ultrasonic bath for 30 min and centrifugation at 6000 rpm, for 15 min (5° C). The supernatant was removed and placed in an amber glass container. The process was repeated, totaling two extractions and the supernatants were mixed for the analysis. The results were calculated from a standard curve and expressed in mg of gallic acid equivalent/100g.

The total flavonoids content was analyzed according to the method of Zhishen *et al*. (1999) adapted by Pękal and Pyrzynska (2014). Fresh samples were homogenized in MeOH: water (70:30, v/v), vortexed for 3 min, sonicated (20 min) and centrifuged (6000 rpm, 15 min, 5 °C). After the addition of sodium nitrite (5%) and homogenization, and after 30 min, aluminum chloride (2%) was added and the tubes were homogenized again. After 6 min, 0.5 ml of sodium hydroxide (1M) was added. The samples were read at 510 nm after 10 min. The results were expressed in mg rutin equivalent/100g.

The ability of the samples to reduce the DPPH radical (2,2-diphenyl-1-picrylhydrazyl) was assessed following the methodology of Brand-Williams *et al*. (1995). The samples were extracted in MeOH: acetic acid: water (80: 1: 19, v/v/v) and, for the reaction, 1 ml of sample was added to 3 ml ethyl alcohol and 0.3 ml DPPH reagent. After 30 minutes, the spectrophotometer (517 nm) was read and the absorbance of the samples correlated with the absorbance of the control (white) resulted in the percentage of free radical scavenging, which was then converted to mg of Trolox /100g.

Free malondialdehyde (MDA) was determined using the methodology described by Heath and Packer (1968). The samples were homogenized in 0.25% thiobarbituric acid, 10% trichloroacetic acid and 89.75% water. The material remained in a water bath

(90° C) for 60 min and was cooled in an ice bath. After centrifugation (6000 rpm, 5° C, 10 min), the samples were read in a spectrophotometer at wavelengths 560 nm and 600 nm. The results were expressed in nmol TBARS/g.

Total monomeric anthocyanins were determined using the differential pH method (Giusti and Wrolstad, 2001). Flesh, peel and flesh + peel samples were homogenized in MeOH: acetic acid: water (80:1:19 v/v/v), sonicated (20 min) and centrifuged (6000 rpm, 5° C, 15 min). The absorbance was measured at 510 and 700 nm, and the result was expressed in mg cyanidin-3-o-glycoside/100g.

The total carotenoids were analyzed according to Lichtenthaler (1987). Fresh samples were homogenized in acetone by sonication for 30 min. The extracts were centrifuged at 6000 rpm (15 min) and the absorbance was measured in a spectrophotometer at wavelengths of 661, 641 and 450 nm. The results were calculated and expressed in mg /100g of fresh weight.

The physical-chemical characteristics were carried out according to the methodology proposed by the Adolf Lutz Institute (2008) in the fleshes + peels of raw and cooked sweet potatoes. Orange-flesh and purple-flesh sweet potatoes were washed in running water, followed by sanitization in sodium hypochlorite (75%) for 10 minutes. The extremities of the tubers were discarded. Fleshes with peel was cut into slices (2 x 1 cm) and cooked in 500 ml of boiling water (100 ° C) for 12 minutes. The water was drained and after cooling, the samples were immediately evaluated. Total titratable acidity (TA) was determined in aqueous extract, using 1 g of the material homogenized in 10 ml of distilled water and titrated in 0.1 N NaOH. The results were expressed in percentage of citric acid/100g of fresh weight. The hydrogen potential (pH) was measured using a potentiometer (model Q Quimis - 400ª). The content of soluble solids (SS) in the samples was analyzed using a digital refractometer (Atago model, PAL-1), with results expressed in °Brix.

The analyzes were performed in triplicate and the data were submitted to analysis of variance (ANOVA), followed by Scott-Knott test (comparison of means) ($p < 0.05$), with the aid of the SISVAR program. Principal component analysis (PCA), cluster analysis (HCA) and correlation test were performed using the XLSTAT software (version 2017; Addinsoft, France).

1.3 - RESULTS AND DISCUSSION

In orange flesh potatoes ‘BRS Amélia’, ‘CPNH 1365’ and ‘CPNH 1358’ there was a significant variation in the levels of bioactive compounds, depending on the genotype and part analyzed (flesh, peel or flesh + peel). Sweet potato 'CPNH 1358' (orange-fleshed, Figure 1) presented the lowest levels of total phenolic compounds and total flavonoids (Table 1), either in the peel (163.39 and 76.63 mg/100g, respectively), in the flesh (185.37 and 86.25 mg/100g, respectively) or when using the whole tuber (flesh + peel) (178.65 and 81.76 mg/100g, respectively). In contrast, ‘CNPH 1365’ contains the highest levels of phenolic compounds and total flavonoids in the flesh and in the peel (286.44 and 141.77 mg/100g, respectively) (Table 1).

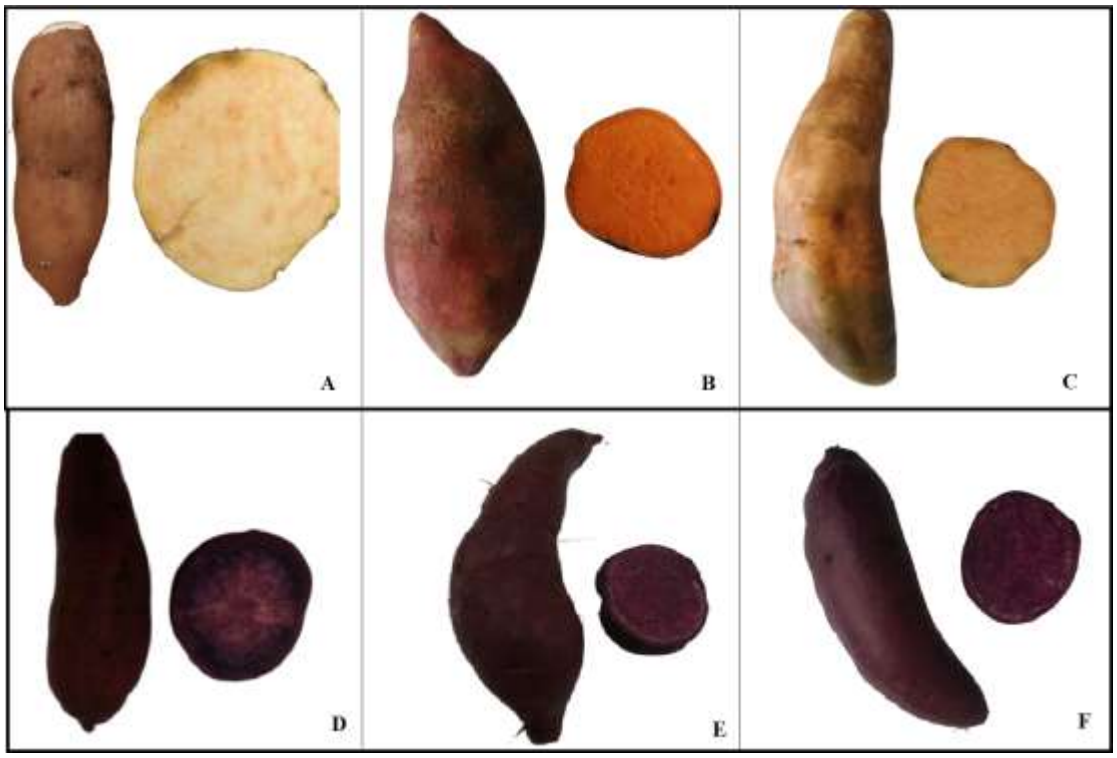


FIGURE 1

Colored fleshed sweet potatoes genotypes: A) ‘BRS Amélia’; B) ‘CPNH 1358’; C) ‘CPNH 1365’; D) ‘‘JN RX1’’; E)’JN RX2’ and F)’JN RX7’.

TABLE 1

Total phenolic compounds (TPC, mg/100g), total flavonoids (TF, mg/100g), total carotenoids (TC, mg/100g), antioxidant capacity by the DPPH (mg/100g) and MDA (nmol TBARS/g) methods in flesh + peel, peel and flesh of orange flesh sweet potatoes.

	TPC	**TF**	**TC**	**DPPH**	**MDA**
'BRS Amélia' FP	232.76±28.6 b	97.77±3.0 d	4.34±0.2 d	4.29±0.5 a	10.69±0.2 b
'BRS Amélia' P	246.39±1.0 b	127.86±0.4 b	4.50±0.1 d	4.48±0.4 a	6.22±0.2 e
'BRS Amélia' F	249.59±3.1 b	130.26±1.3 b	4.90±0.2 d	3.74±0.2 a	11.70±.2 a
'CPNH 1365' FP	286.44±1.52 a	141.77±1.9 a	8.93±0.1 c	4.32±0.5 a	8.13±0.2 d
'CPNH 1365' P	223.72±2.0 b	111.58±0.4 c	8.24±0.3 c	4.64±0.4 a	10.91±0.9 b
'CPNH 1365' F	269.32±3.8 a	131.01±2.7 b	9.02±0.1 c	2.85±0.2 b	4.37±0.3 f
'CPNH 1358' FP	178.65±0.06 c	81.76±1.6 e	11.21±0.2 a	2.79±0.2 b	8.61±0.4 d
'CPNH 1358' P	163.39±2.43 c	76.63±3.0 f	7.74±0.6 c	3.10±0.7 b	6.27±0.1 e
'CPNH 1358' F	185.37±3.1 c	86.25± 5.2 e	9.78±0.7 b	2.90±0.6 b	9,93±0.9 c

*Means followed by the same letter, in the column, do not differ statistically among themselves by Sckott-Knott test ($p \leq 0.05$).

** FP= flesh + peel; P = peel and F = flesh.

In orange-fleshed sweet potato (cv. Paraná), Simões *et al*. (2020) described higher amounts of flavonoids (approximately 30% more), when compared to the cream-fleshed sweet potatoes (cv. ESAM 1). In the present study, 'CPNH 1358' contains higher total carotenoids in the flesh + peel (11.21 mg/100g) and in the flesh (9.78 mg/100g), while the other genotypes do not show differences between the analyzed parts. The total carotenoids content did not show great variations when the three genotypes were analyzed, regardless of analyzing only the flesh (4.90 to 9.78 mg/100g), only the skin (4.50 to 8.24 mg/100g) or the whole tuber (flesh + peel) (4.34 to 11.21 mg/100g) (Table 1). Although the genotype 'CPNH 1358' presents low levels of total phenolics, it shows high levels of total carotenoids when the whole tuber is analyzed (flesh + peel), compared to the other genotypes. It is worth emphasizing that 'CPNH 1358' present the most accentuated orange color (Figure 1).

Orange-fleshed sweet potatoes contain carotenoids, mainly β-carotene in higher levels compared to α-carotene, both precursors of retinol (vitamin A) in the human body (Maoka, 2020; Simões *et al.,* 2020). The intense orange color in fruits (Borges *et al*., 2019), vegetables (Diamante *et al*., 2020) and tubers (Simões *et al*., 2020) is a phenotypic characteristic that is correlated with the presence of provitamin A, corroborating with the results found in the present work. Vitamin A deficiency mainly affects children and pregnant women, which can cause developmental delays, blindness, inefficiency in the immune system and, depending on the severity, death (Alam *et al*., 2020). Thus, the consumption of 'CNPH1358', as well as 'CNPH1365', may be a good option for reducing hypovitaminosis A, considered a worldwide public health problem (Alam *et al.*, 2020). It is worth mentioning that, in addition to provitamins, these pigments have antioxidant activity, reducing the effects promoted by free radicals and preventing a series of cardiovascular diseases (Kulczyński *et al*., 2017).

Aiming a grouping model of the different bioactive compounds analyzed in orange-fleshed sweet potato cultivars, principal component analysis (PCA) was applied (Figure 2). The PCA explained 80.27% of the data variance resulting from the analysis of the content of total phenols, total flavonoids and total carotenoids in orange-fleshed sweet potatoes (Figure 2). 'CNPH 1365' and 'BRS Amélia' contain the highest levels of (poly)phenols and show the highest antioxidant activities measured via DPPH, grouping into PC1 +, which explains 52.95% of the data variance. On the other hand, the 'CNPH 1358', which has the highest levels of carotenoids, showed less activity measured via DPPH and greater antioxidant capacity when analyzed by MDA (PC1-) method. Our results demonstrate the high antioxidant value of the peel, due to the presence of phenolic and carotenoid compounds, regardless of the method used. In the food industry, bio-waste sources of bioactive compounds are important in the incorporation of products such as natural dyes, improving the nutritional and functional quality of foods, demonstrating the potential for using this biomass (Martins and Ferreira, 2017).

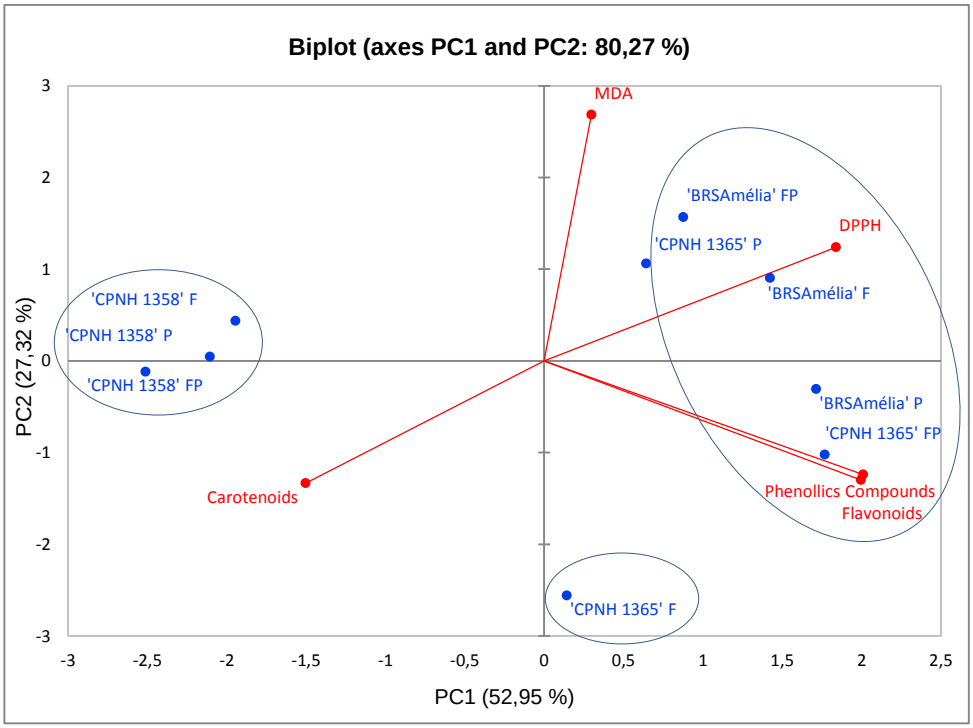


FIGURE 2

Two-dimensional projection and scores of the biochemical characteristics of total phenolic compounds, total flavonoids, total carotenoids, antioxidant activity DPPH and MDA in orange-fleshed sweet potatoes. The treatments are represented by the points, where F = flesh; P = peel and FP = flesh + peel.

In the hierarchical cluster analysis (HCA) (Figure 3), 'CNPH 1358' presented specific grouping in relation to the analyzed parts of the tuber, differing from 'BRS Amélia' and from ‘CNPH1365’. In addition, it is possible to highlight that both in 'CNPH 1358' and in 'CNPH 1365', the levels of the compounds were predominant in the fleshes, influencing the similarity.

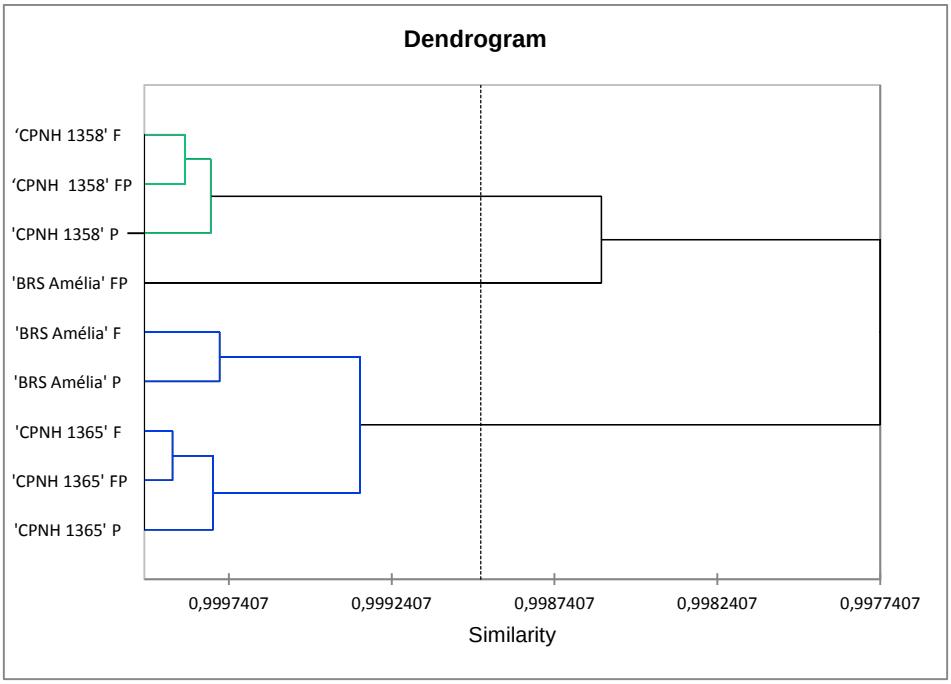


FIGURE 3

Hierarchical cluster analysis (HCA) of the biochemical characteristics of total phenolic compounds, total flavonoids, total carotenoids, antioxidant activity by DPPH and lipid peroxidation by MDA in orange-fleshed sweet potatoes. The treatments are represented by the points, where F = flesh; P = peel and FP = flesh + peel.

In the three genotypes of purple sweet potatoes, the presence of high levels of total phenolic compounds and total flavonoids in the peels is clear (Figure 1 and Table 2), with emphasis on the phenols content in 'JN RX1' (324.78 mg/100g) and flavonoids in 'JN RX2' (160.17 mg/100g). However, these genotypes showed the lowest levels of phenolic compounds (162.50 to 177.88 mg/100g). In this study, it is worth to point out that purple sweet potatoes contain higher contents of phenolic compounds, including flavonoids, compared to the orange-fleshed ones. Other studies have also demonstrated higher levels of phenolic compounds in purple-fleshed sweet potatoes (0.949 mg/g), compared to white-fleshed (0.003 mg/g) (Teow *et al*., 2007).

TABLE 2

Total phenolic compounds (TPC, mg/100g), total flavonoids (TF, mg/100g), total anthocyanins (TA, mg/100g), antioxidant capacity by the DPPH (mg/100g) and MDA (nmol TBARS/g) methods in flesh + peel, peel and flesh of purple flesh sweet potatoes.

	TPC	**TF**	**TA**	**DPPH**	**MDA**
‘‘JN RX1’’ FP	345.36±12.5 a	96.22±2.4 d	1.86±0.2 d	6.48±0.9 d	23.11±0.4 b
‘‘JN RX1’’ P	324.78±24.9 b	134.44±3.3 b	4.19±0.9 c	14.37±0.1 a	17.90±1.0 c
‘JN RX1’ F	165.70±6.5 e	92.04±12.2 d	1.4±+0.4 d	11.67±0.2 b	31.07±1.9 a
‘JN RX2’ FP	202.98±3.3 d	137.38±4.5 b	17.63±5.69 a	7.63±0.1 d	19.45±0.5 d
‘JN RX2’ P	285.12±13.7 c	160.17±5.27 a	5.13±0.71 c	9.51±0.3 c	15.77±0.2 f
‘JN RX2’ F	162.5±16.20 e	134.72±9.1 b	3.33±0.9 c	7.19±0.8 d	21.29±0.3 c
‘JN RX7’ FP	265.12±10.5 c	119.60±1.0 c	8.32±0.8 b	2.45±0.1 f	20.25±0.2 d
‘JN RX7’ P	319.77±13.81 b	138.07±5.8 b	15.64±2.1 a	5.26±0.1 e	13.40±0.3 f
‘JN RX7’ F	177.88±10.55 e	85.07±1.9 d	2.99±0.5 c	2.10±0.1 f	32.51±0.8 a

* Means followed by the same letter, in the column, do not differ statistically among themselves by the Sckott-Knott test ($p \leq 0.05$).

** FP= flesh + peel; P = peel and F = flesh

Purple sweet-potatoes containing abundant anthocyanins and several studies demonstrate their diverse biological activities, including scavenging reactive species (Cartier *et al*., 2017). 'JN RX1' (Table 2), which exhibits an intense purple color in the flesh, contains higher levels of anthocyanins in the peel (4.19 mg/100g), when compared to the other analyzed parts (Figure 1). However, when the comparison occurs between the genotypes, both 'JN RX2' and 'JN RX7' have higher levels of anthocyanins compared to 'JN RX1'. Anthocyanins are considered the most important phenolic group for the coloring of purple sweet potatoes (Salawu *et al*., 2015). Certainly, this flavonoid influenced the antioxidant activity, both by DPPH or MDA in ‘JN RX1’ and ‘JN RX7’, since phenolic compounds contribute to the ability to eliminate free radicals (Cartier *et al*., 2017). These results allow us to affirm that sweet potato peels, usually discarded by the consumer, might be used as a source of important bioactive agents - increasing the functional value, and may be an option for the food industry in the elaboration of by-products.

The principal component analysis was also applied to the purple sweet potato data. The two main components explain 83.63% of the data variance (Figure 4) and the results showed that there was no grouping between the genotypes in relation to the analyzed antioxidant compounds. In contrast, the fleshes were grouped in PC2- and this grouping was influenced by antioxidant activities, measured via MDA and DPPH.

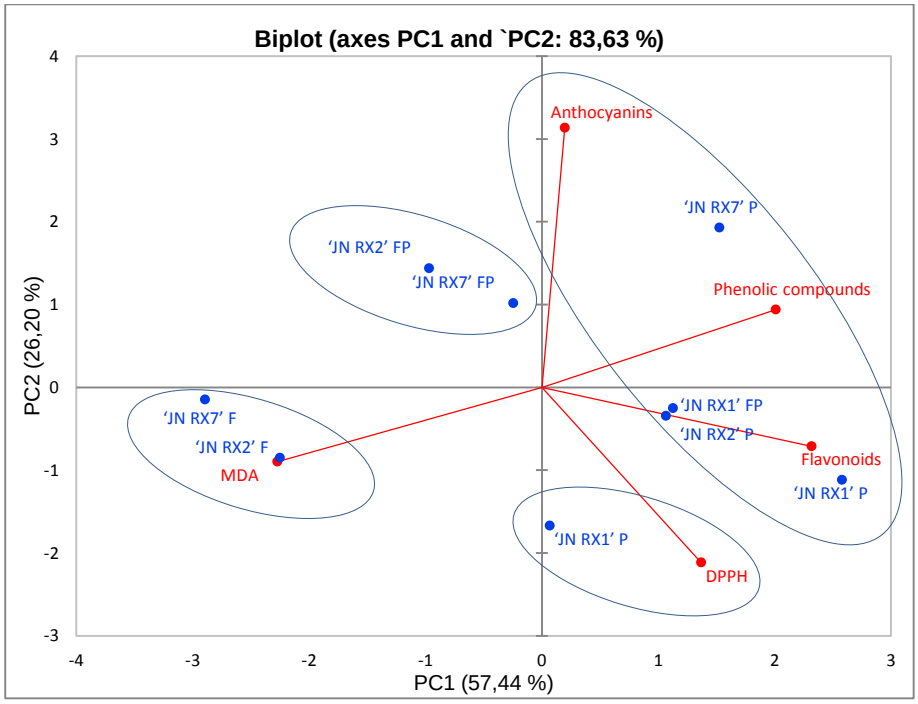


FIGURE 4

Two-dimensional projection and scores of biochemical characteristics, total phenolic compounds, total flavonoids, total anthocyanins, antioxidant activity by DPPH and lipid peroxidation by MDA in purple-fleshed sweet potatoes. The treatments are represented by the points, where F = flesh; P = peel and FP = flesh + peel.

The hierarchical cluster analysis (HCA) also demonstrates the grouping of 'JN RX2' and 'JN RX7' fleshes (Figure 5) and it is worth noting that both have the lowest levels of total phenolic compounds, reflecting the low antioxidant activity measured by DPPH and high by MDA. The peels of all purple flesh genotypes showed the highest values of phenols, flavonoids and anthocyanins and were grouped in PC1 +, with emphasis on 'JN RX 1' and 'JN RX 2', which show high similarity.

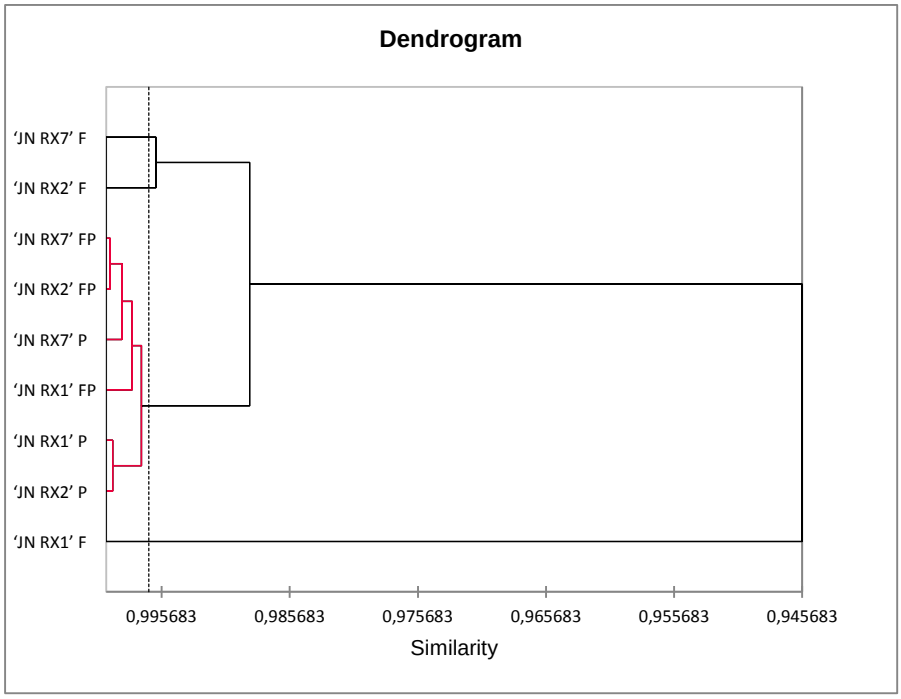


FIGURE 5

Dendrogram of biochemical characteristics, total phenolic compounds, total flavonoids, total anthocyanins, antioxidant activity by DPPH and lipid peroxidation by MDA in orange-fleshed sweet potatoes. The treatments are represented by the points, where F = flesh; P = peel and FP = flesh + peel.

Aiming at a physicochemical characterization of the orange and purple sweet potatoes, the tubers were cooked, which is the preferred form of consumption, and the physicochemical attributes were characterized (Table 3). There was an increase in pH in 'BRS Amélia' after cooking in water. In purple-fleshed sweet potatoes, there was a decrease in pH in 'JN RX1' and 'JN RX2' after thermal processing. The pH values found in the orange and purple genotypes cooked in water were higher than 6.0, however a lower pH (5.5) was detected in raw 'BRS Amélia'. pH values below 5.5 may indicate low quality, due to oxidation processes (De Oliveira *et al*., 2019). All genotypes (orange flesh and purple flesh) showed decreased titratable acidity in response to cooking, except for the purple-fleshed sweet potato 'JN RX2', which may be attributed to losses of organic acids to the cooking water (Ogliari *et al*., 2020), improving the taste and consequently increasing consumer acceptance. The titratable acidity contents detected in our study were lower than those described for other sweet potato genotypes (De Oliveira *et al*.,

2019) and can be attributed to cultivation factors, including abiotic factors, such as climate and fertilization.

TABLE 3

Physicochemical characteristics of raw and cooked orange-fleshed and purple-fleshed sweet potatoes: pH, soluble solids (°Brix), titratable acidity (% citric acid) and ratio (SS / TA).

Orange-fleshed sweet potatoes						
	'BRS Amélia'		**'CPNH 1365'**		**'CPNH 1358'**	
	Raw	**Cooked**	**Raw**	**Coooked**	**Raw**	**Cooked**
pH	5.52±0.18 d	6.29±0.01 c	6.90±,0.02 a	6.27±0.01 c	6.43±0.03 b	6.61±0.02 b
TA	0.20±0.02 a	0.14±0.01 c	0.25±0.04 a	0.18±0.01 b	0.22±0.01 a	0.16±0.01 b
SS	12.90± 0.07 c	14.20±0.20 b	12.87± 0.49 c	20.50±0.93 a	14.50±0.80 b	21.00±0.00 a
Ratio	66.16±5.97 b	100.08±7.57 a	52;27±8.19 b	112.32±9.58 a	65.28±7.57 b	127.99±4.33 a
Purple-fleshed sweet potatoes						
	''JN RX1''		**''JN RX2''**		**''JN RX7''**	
	Raw	**Cooked**	**Raw**	**Coooked**	**Raw**	**Cooked**
pH	6.47±0.03 a	6.35±0.02 b	6.49±0.04 a	6.37±0.01 b	6.36±0.01 b	6.31±0.02 b
TA	0.42±0.02 a	0.39±0.00 b	0.39±0.01 b	0.37±0.01 b	0.43±0.02 a	0.41±0.01 b
SS	15.27±0.16 c	17.77±0.22 b	14.77±0.29 c	20.67±1.09 a	15.37±0.09 c	14.63±0.31 c
Ratio	36.21±1.53 c	45.52±1.09 b	37.51±2.28 c	55.76±4.02 a	35.48±0.44 c	36.11±1.29 c

* Means followed by the same letter, in the line, do not differ statistically among themselves by the Sckott-Knott test (p≤ 0.05).

Cooking induced an increase in the content of soluble solids in all genotypes, except for the purple-fleshed sweet potato 'JN RX7' (Table 3). This increase may be due to the ease of extraction due to the rupture of the cell wall by the action of temperature (Borges *et al*., 2019; Lima *et al*., 2017). The increase in SS is important for consumer acceptance, due to the more sweet taste. Comparing the ratio between SS and TA (*ratio*), the orange genotypes show higher values, compared to the purple sweet potatoes, regardless of thermal processing. This result is very interesting, since the presence of sugars and acids

influences the taste and the acceptance of the product (Jayasena and Cameron, 2008). It is worth mentioning that cooking in water promoted an increase in the *ratio* in all genotypes, except 'JN RX7', which was a result influenced by the absence of significant variations in the content of soluble solids after the action of high temperature.

Principal component analysis was performed to verify the physicochemical characteristics after thermal processes (boiling) in the genotypes studied (Figures 6 e 7). In relation to orange-fleshed sweet potatoes (Figure 6), PC1 represents 61.28% of the total data variance, grouping the genotypes according to the thermal processing. PC1+ grouped the cooked genotypes ‘CPNH 1365’ e ‘CPNH 1358’, which showed the higher SS and ratio (Table 3) than raw orange-fleshed sweet potatoes (PC1+ and PC2+). These raw genotypes also presented the highest levels of carotenoids (Table 1), an potent free radical scavenger, which are also related with inhibit the development of cardiovascular diseases and mitigate the risk of metabolic diseases, such as diabetes (Kulczyński *et al*., 2017). In this way, ‘CPNH 1365’ show good characteristics physicochemical and antioxidants, which make them new genotypes interesting for consumption.

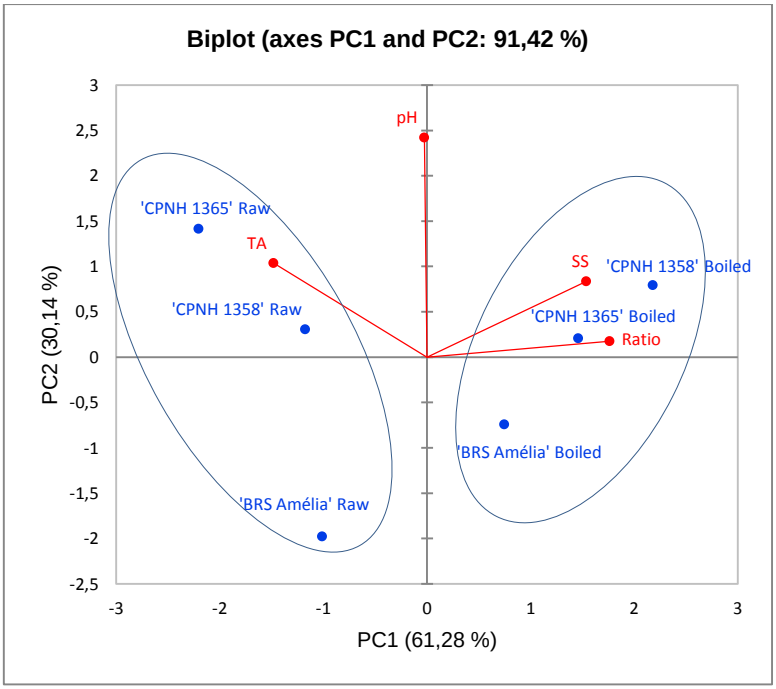


FIGURE 6

Two-dimensional projection and scores of physicochemical biochemical characteristics pH, soluble solids (°Brix), titratable acidity (% citric acid) and ratio (SS / TA), in raw and cooked orange-fleshed sweet potatoes.

The principal component analysis applied to the physicochemical analyses of purple-fleshed sweet potatoes explained 93.31% of analyzed data (Figure 7).

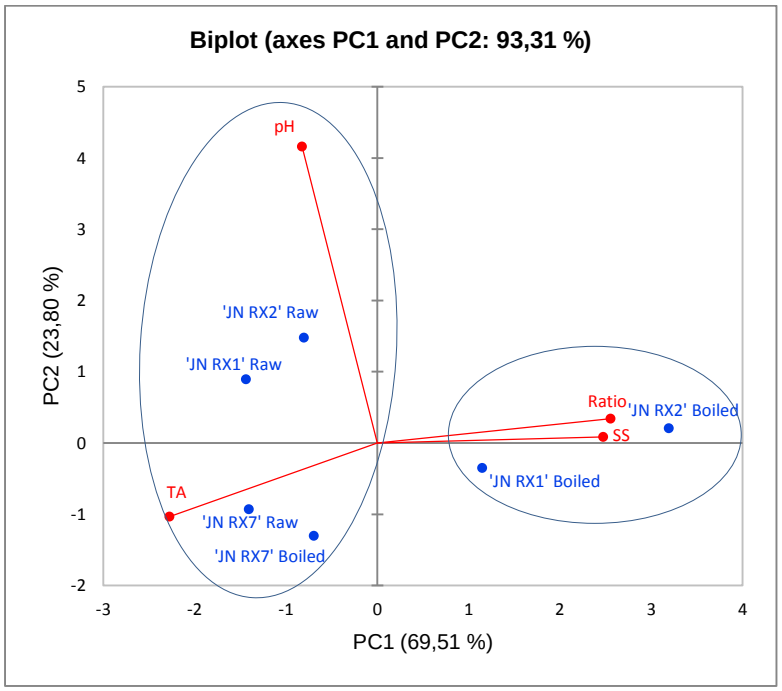


FIGURE 7

Two-dimensional projection and scores of physicochemical biochemical characteristics pH, soluble solids (°Brix), titratable acidity (% citric acid) and ratio (SS / TA), in raw and cooked purple-fleshed sweet potatoes.

PC1 explained 69.51% of the evaluated parameters. PC1+ grouped both boiled genotypes ‘JN RX1’ and ‘JN RX2’ with the highest content of SS and ratio, which have also higher pH (PC1-) compared with ‘JN RX7’. Although raw ‘JN RX1’ show the highest antioxidant activity measured by DPPH radical, it present lower levels of anthocyanin (Table 2) than ‘JN RX7’. It is worth mentioning the levels of SS, ratio and antioxidants in ‘JN RX2’, which may be an indication of the quality of this genotype for consumption.

1.4 - CONCLUSION

The bioactive compounds found in sweet potatoes are genotype-dependent and the color of the tubers is an interesting phenotypic characteristic for indicating the class and content of these phytochemicals in the different genotypes. In general, genotypes with orange coloration 'BRS Amélia', 'CPNH 1365' and 'CPNH 1358' are potential

sources of carotenoids and the more intense the color of the tuber (i.e., 'CPNH 1358'), the higher the levels of these provitamins A. Purple-fleshed sweet potatoes' JN RX1 ',' JN RX2 'and JN RX7', however, have high levels of phenolic compounds such as flavonoids (i.e., anthocyanins) and greater antioxidant capacity, mainly the peels, where the highest levels of these bioactives compunds are found. The orange sweet potato 'CPNH 1365' and the purple sweet potato 'JN RX2' have a higher content of bioactive compounds and high SS levels, emphasizing the potential of these genotypes for selection and their use as high quality food and source of compounds that promote human health. It should be noted that colored flesh sweet potatoes are potential sources of bioactive compounds, demonstrating the importance of expanding the use and enhancement of vegetables for use in the food and pharmaceutical industries, especially the peels, where the greatest content of these compounds are verified.

Acknowledgements

The authors gratefully acknowledge the financial support of Sao Paulo Research Foundation (FAPESP) for financial support of this work (grant number 2016/22665-2 and 2017/08032-0) and for scholarship provided by Coordenação de Aperfeiçoamento de Pessoal de Nível Superior (CAPES) to Letícia Silva Pereira Basílio (grant number 88882.433049/2019-01) and by Sao Paulo Research Foundation (FAPESP) to M.A.F. Belin (grant number 2019/26996-1) and National Council for Scientific and Technological Development (CNPq, Brazil) (grant number 307571/2019-0).

Literature

BASÍLIO, L. S. P. et al. Potential of colored sweet potato genotypes as source of bioactive compounds. **Revista Iberoamericana de Tecnología Postcosecha**, no. 21 (2), 2020. .

BASÍLIO, L. S. P.; VANZ BORGES, C.; MINATEL, I. O.; VARGAS, P. F.; TECCHIO, M. A.; VIANELLO, F.; LIMA, G. P. P. New beverage based on grapes and purple-fleshed sweet potatoes: Use of non-standard tubers. **Food Bioscience**, vol. 47, p. 101626, 2022. DOI https://doi.org/10.1016/j.fbio.2022.101626. Available at: https://www.sciencedirect.com/science/article/pii/S2212429222000852.

BASÍLIO, L.; SILVA, A. C.; MONTEIRO, G.; VARGAS, P.; VIANELLO, F.; LIMA, G. P. P. PLURALIDADE DA BATATA-DOCE DO CAMPO À MESA: UMA REVISÃO NARRATIVA. **OPEN SCIENCE RESEARCH I**. [*S. l.*: *s. n.*], 2022. p. 174–190.

BORGES, C. V.; BELIN, M. A. F.; AMORIM, E. P.; MINATEL, I. O.; MONTEIRO, G. C.; GOMEZ GOMEZ, H. A.; MONAR, G. R. S.; LIMA, G. P. P. Bioactive amines changes during the ripening and thermal processes of bananas and plantains. **Food Chemistry**, vol. 298, p. 125020, 2019. DOI https://doi.org/10.1016/j.foodchem.2019.125020. Available at: http://www.sciencedirect.com/science/article/pii/S0308814619311227.

BORGES, C. V; MARASCHIN, M.; COELHO, D. S.; LEONEL, M.; GOMEZ, H. A. G.; BELIN, M. A. F.; DIAMANTE, M. S.; AMORIM, E. P.; GIANETI, T.; CASTRO, G. R. Nutritional value and antioxidant compounds during the ripening and after domestic cooking of bananas and plantains. **Food Research International**, vol. 132, p. 109061, 2020. .

BRAND-WILLIAMS, W.; CUVELIER, M. E.; BERSET, C. Use of a free radical method to evaluate antioxidant activity. **LWT - Food Science and Technology**, vol. 28, no. 1, p. 25–30, Jan. 1995. https://doi.org/10.1016/S0023-6438(95)80008-5.

CARRERA, C.; ZELAYA-MEDINA, C. F.; CHINCHILLA, N.; FERREIRO-GONZÁLEZ, M.; BARBERO, G. F.; PALMA, M. How Different Cooking Methods Affect the Phenolic Composition of Sweet Potato for Human Consumption (Ipomea batata (L.) Lam). **Agronomy**, vol. 11, no. 8, p. 1636, 2021. .

CARRILLO, J. Á.; ZAFRILLA, M. P.; MARHUENDA, J. Cognitive Function and Consumption of Fruit and Vegetable Polyphenols in a Young Population: Is There a Relationship? **Foods**, vol. 8, no. 10, 2019. DOI 10.3390/foods8100507. Available at: https://www.mdpi.com/2304-8158/8/10/507.

CONIO, B.; MARTINO, M.; MAGIONCALDA, P.; ESCELSIOR, A.; INGLESE, M.; AMORE, M.; NORTHOFF, G. Opposite effects of dopamine and serotonin on resting-state networks: review and implications for psychiatric disorders. **Molecular Psychiatry**, vol. 25, no. 1, p. 82–93, 2020. DOI 10.1038/s41380-019-0406-4. Available at: https://doi.org/10.1038/s41380-019-0406-4.

DIAMANTE, M. S.; BORGES, C. V.; DA SILVA, M. B.; MINATEL, I. O.; CORRÊA, C. R.; GOMEZ GOMEZ, H. A.; LIMA, G. P. P. Bioactive Amines Screening in Four Genotypes of Thermally Processed Cauliflower. **Antioxidants**, vol. 8, no. 8, p. 311, 2019. .

DIAMANTE, M. S.; BORGES, C. V.; MINATEL, I. O.; JACOMINO, A. P.; BASÍLIO, L. S. P.; MONTEIRO, G. C.; CORREA, C. R.; DE OLIVEIRA, R. A.; LIMA, G. P. P. Domestic cooking practices influence the carotenoid and tocopherol content in colored cauliflower. **Food Chemistry**, vol. 340, p. 127901, 2021. .

GIUSTI, M. M.; WROLSTAD, R. E. Characterization and measurement of anthocyanins by UV-visible spectroscopy. **Current protocols in food analytical chemistry**, no. 1, p. F1-2, 2001. .

GOMEZ-GOMEZ, H. A.; MINATEL, I. O.; BORGES, C. V.; MARQUES, M. O. M.; DA SILVA, E. T.; MONTEIRO, G. C.; DA SILVA, M. J. R.; TECCHIO, M. A.; LIMA, G. P. P. Phenolic Compounds and Polyamines in Grape-Derived Beverages. **Journal of Agricultural Science**, vol. 10, no. 12, 2018. .

GOMEZ, H. A. G.; MARQUES, M. O. M.; BORGES, C. V.; MINATEL, I. O.; MONTEIRO, G. C.; RITSCHEL, P. S.; ZANUS, M. C.; DIAMANTE, M. S.; KLUGE, R. A.; LIMA, G. P. P. Biogenic Amines and the Antioxidant Capacity of Juice and Wine from Brazilian Hybrid Grapevines. **Plant Foods for Human Nutrition**, vol. 75, no. 2, 2020. https://doi.org/10.1007/s11130-020-00811-5.

HARDELAND, R.; PANDI-PERUMAL, S. R.; CARDINALI, D. P. Melatonin. **The international journal of biochemistry & cell biology**, Netherlands, vol. 38, no. 3, p. 313–316, Mar. 2006. https://doi.org/10.1016/j.biocel.2005.08.020.

HEATH, R. L.; PACKER, L. Photoperoxidation in isolated chloroplasts. **Archives of Biochemistry and Biophysics**, vol. 125, no. 1, p. 189–198, 1968. https://doi.org/10.1016/0003-9861(68)90654-1.

HENNEBERG, R.; OTUKI, M. F.; FURMAN, A. E. F.; HERMANN, P.; DO NASCIMENTO, A. J.; LEONART, M. S. S. Protective effect of flavonoids against reactive oxygen species production in sickle cell anemia patients treated with hydroxyurea. **Revista brasileira de hematologia e hemoterapia**, vol. 35, no. 1, p. 52–55, 2013. https://doi.org/10.5581/1516-8484.20130015.

HONG, K. H.; KOH, E. Effects of cooking methods on anthocyanins and total phenolics in purple-fleshed sweet potato. **Journal of Food Processing and Preservation**, vol. 40, no. 5, p. 1054–1063, 2016. .

HUMIA, B. V.; SANTOS, K. S.; SCHNEIDER, J. K.; LEAL, I. L.; DE ABREU BARRETO, G.; BATISTA, T.; MACHADO, B. A. S.; DRUZIAN, J. I.; KRAUSE, L. C.; DA COSTA MENDONÇA, M.; PADILHA, F. F. Physicochemical and sensory profile of Beauregard sweet potato beer. **Food Chemistry**, vol. 312, p. 126087, 2020. DOI https://doi.org/10.1016/j.foodchem.2019.126087. Available at: https://www.sciencedirect.com/science/article/pii/S0308814619322368.

KALAČ, P.; KRAUSOVÁ, P. A review of dietary polyamines: Formation, implications for growth and health and occurrence in foods. **Food Chemistry**, vol. 90, no. 1, p. 219–230, 2005. DOI https://doi.org/10.1016/j.foodchem.2004.03.044. Available at: https://www.sciencedirect.com/science/article/pii/S0308814604002961.

KURNIANINGSIH, N.; RATNAWATI, R.; NAZWAR, T. A.; ALI, M.; FATCHIYAH, F. The Behavioral Effect of Anthocyanin from Purple Sweet Potatoes on Prenatally Stressed Offspring Mice. **Systematic Reviews in Pharmacy**, vol. 11, no. 10, p. 482–490, 2020. .

LICHTENTHALER, H. K. [34] Chlorophylls and carotenoids: pigments of photosynthetic biomembranes. **Methods in enzymology**. [*S. l.*]: Elsevier, 1987. vol. 148, p. 350–382.

LIN, Y.; SHI, R.; WANG, X.; SHEN, H.-M. Luteolin, a flavonoid with potential for cancer prevention and therapy. **Current cancer drug targets**, vol. 8, no. 7, p. 634–646, 2008. .

MONTEIRO, G. C.; MINATEL, I. O.; JUNIOR, A. P.; GOMEZ-GOMEZ, H. A.; DE CAMARGO, J. P. C.; DIAMANTE, M. S.; BASÍLIO, L. S. P.; TECCHIO, M. A.; LIMA, G. P. P. Bioactive compounds and antioxidant capacity of grape pomace flours. **LWT**, vol. 135, p. 110053, 2020. .

NEGRI, S.; COMMISSO, M.; AVESANI, L.; GUZZO, F. The case of tryptamine and serotonin in plants: a mysterious precursor for an illustrious metabolite. **Journal of Experimental Botany**, vol. 72, no. 15, p. 5336–5355, 28 Jul. 2021. DOI 10.1093/jxb/erab220. Available at: https://doi.org/10.1093/jxb/erab220.

NGUYEN, H. C.; CHEN, C.-C.; LIN, K.-H.; CHAO, P.-Y.; LIN, H.-H.; HUANG, M.-Y. Bioactive compounds, antioxidants, and health benefits of sweet potato leaves. **Molecules**, vol. 26, no. 7, p. 1820, 2021. .

NICOLETTO, C.; VIANELLO, F.; SAMBO, P. Effect of different home-cooking methods on textural and nutritional properties of sweet potato genotypes grown in temperate climate conditions. **Journal of the Science of Food and Agriculture**, vol. 98, no. 2, p. 574–581, 2018. .

OLONIYO, R. O.; OMOBA, O. S.; AWOLU, O. O.; OLAGUNJU, A. I. Orange-fleshed sweet potatoes composite bread: A good carrier of beta (β)-carotene and antioxidant properties. **Journal of Food Biochemistry**, vol. 45, no. 3, p. e13423, 2021. .

PAPAGEORGIOU, M.; LAMBROPOULOU, D.; MORRISON, C.; KŁODZIŃSKA, E.; NAMIEŚNIK, J.; PŁOTKA-WASYLKA, J. Literature update of analytical methods for biogenic amines determination in food and beverages. **TrAC Trends in Analytical Chemistry**, vol. 98, p. 128–142, 2018. .

PĘKAL, A.; PYRZYNSKA, K. Evaluation of aluminium complexation reaction for

flavonoid content assay. **Food Analytical Methods**, vol. 7, no. 9, p. 1776–1782, 2014. .

POPOVA, M.; BANKOVA, V.; BUTOVSKA, D.; PETKOV, V.; NIKOLOVA-DAMYANOVA, B.; SABATINI, A. G.; MARCAZZAN, G. L.; BOGDANOV, S. Validated methods for the quantification of biologically active constituents of poplar-type propolis. **Phytochemical Analysis: An International Journal of Plant Chemical and Biochemical Techniques**, vol. 15, no. 4, p. 235–240, 2004. .

SIENER, R.; SEIDLER, A.; HÖNOW, R. Oxalate-rich foods. **Food Science and Technology**, vol. 41, p. 169–173, 2020. .

SILBER, B. Y.; SCHMITT, J. A. J. Effects of tryptophan loading on human cognition, mood, and sleep. **Neuroscience & biobehavioral reviews**, vol. 34, no. 3, p. 387–407, 2010. .

SIMOES, A. do N.; DE ALMEIDA, S. L.; BORGES, C. V.; FONSECA, K. S.; BARROS JUNIOR, A. P.; DE ALBUQUERQUE, J. R. T.; CORRÊA, C. R.; MINATEL, I. O.; MORAIS, M. A. dos S.; DIAMANTE, M. S. Delaying the harvest induces bioactive compounds and maintains the quality of sweet potatoes. **Journal of food biochemistry**, vol. 44, no. 8, p. e13322, 2020. .

SINGLETON, V.; ROSSI, J. R. Determination of tannins in wines. **J. Enology and viticulture**, vol. 6, no. 3, p. 114, 1965. .

CAPÍTULO 2

NEW BEVERAGE BASED ON GRAPES AND PURPLE-FLESHED SWEET POTATOES: USE OF NON-STANDARD TUBERS [3]

Letícia Silva Pereira Basílio[a], Cristine Vanz Borges[a], Igor Otavio Minatel[a], Pablo Forlan Vargas[b], Marco Antonio Tecchio[c], Fabio Vianello[d], Giuseppina Pace Pereira Lima[a]

[a] Department of Chemical and Biological Sciences, Institute of Biosciences, São Paulo State University, 18.618-000 Botucatu, São Paulo, Brazil
[b] Tropical Root and Starches Center, São Paulo State University, 18610-034 Botucatu, São Paulo, Brazil
[c] Department of Horticulture, School of Agriculture, São Paulo State University, 18.610-034 Botucatu, São Paulo, Brazil
[d] Department of Comparative Biomedicine and Food Science, University of Padova, 35020 Legnaro, Italy

Abstract

Grapes and sweet potatoes are two different plant species that have distinct bioactive composition and the use of both in a non-alcoholic mixed beverage may be an interesting source of phytochemicals. Physicochemical and sensory characteristics, profile of phenolic compounds and biogenic amines of mixed juices of grapes (‘BRS Violeta’, ‘BRS Cora’ and ‘Bordô’) and purple-fleshed sweet potato (‘JNRX12’) (0, 10 and 30%) were determined. The beverage with sweet potato had high antioxidant activity attributed to the phytochemical compounds (e.g. anthocyanins, gallic acid, catechin, tryptophan, melatonin, serotonin and dopamine). Low levels of unwanted amines (histamine, tyramine, putrescine and cadaverine) were detected, showing that their consumption is safe. Purple-fleshed sweet potato had high levels of desirable amines, mainly melatonin, making the addition of sweet potato attractive for enriching beverages. The color, texture and sensory aspects were similar in whole grape juice and in mixed juices. Juices from 'BRS Violeta', with or without sweet potato showed

[3] Artigo publicado no Periódico Científico ’Food Bioscience’

DOI: https://doi.org/10.1016/j.fbio.2022.101626

high levels of bioactive compounds but were the least appreciated. The overall appearance and aroma of juices elaborated from 'BRS Cora' or 'Bordô' grapes had similar acceptance, regardless of the addition of sweet potato. Beverages from 'BRS Cora' and 30% purple-fleshed sweet potato are the most interesting mixture due to tryptophan and melatonin contents. Mixed juices of grapes and sweet potatoes (10% and 30%) are viable options for the use of tubers outside the commercial standard, as they add interesting bioactive compounds to beverages and please the consumer.

Keywords: functional beverages, phenolic compounds, biogenic amines, quality index

2.1- Introduction

Foods rich in polyphenols and bioamines are important for promoting health and well-being. These molecules stand out due to their high antioxidant potential (Borges et al., 2019, 2020; Diamante et al., 2019; Gomez et al., 2020). Phenolic compounds, are increasingly exploited for their beneficial effects against various metabolic diseases, antimicrobial and anti-inflammatory (Dludla et al., 2019; Magalingam et al., 2015), and also widely used in the food industry for their ability to pigment (i.e., anthocyanins) (Giusti & Wrolstad, 2001; Monteiro et al., 2021). Biogenic amines, in addition to antioxidants, are involved in several physiological processes and some amines are considered health-promoting (e.g. dopamine, serotonin, melatonin, spermine and spermidine) and others, when consumed in excess, are commonly harmful, such as histamine, putrescine, cadaverine and tyramine. Furthermore, the intake of amino acids (e.g. tryptophan, agmatine and L-dopa) is also critical, since they are important amine precursors (Borges et al., 2019; Gomez et al., 2020).

In times of great stress, such as the current Covid-19 pandemic, maintaining a balanced diet is essential. This viral respiratory disease (SARS-CoV-2) is a global health problem (Gurunathan et al., 2021) and one of the solutions against this disease may be the use of bioactive molecules, which can be found in abundance in functional foods (Attademo & Bernardini, 2021; Messaoudi et al., 2021).

Sweet potatoes (*Ipomoea batatas* (L.)) are a source of phytochemicals considered important due to their beneficial effects when introduced into the diet (Basílio et al., 2020). Genotypes with purple skin and flesh stand out for being rich in flavonoids such as anthocyanins, responsible for the pigmentation, in addition to having antioxidant capacity superior to that of genotypes of other colorations (Magalingam et al., 2015). Grapes and derivatives (wines and juices) are also sources of antioxidant compounds. Some grape genotypes stand out for their high sugar content and juice color, such as ‘BRS Cora’ and ‘BRS Violeta’ (Lima et al., 2014). These genotypes may be used in the production of whole juices (varietals), or combined with traditional varieties, in order to improve quality (Gomez et al., 2020). In general, the more intense the color of the grape, the more interesting it becomes from a functional point of view, related to the phenolic compounds and antioxidant capacity (Monteiro et al., 2021).

One of the problems faced by gardeners around the world is the waste generated in the post-harvest (Galanakis, 2013). In relation to sweet potato, part of the tubers is usually discarded due to their bad formation, size and appearance. However, they are in perfect condition for human consumption since they are often free from injuries or hygiene problems. In addition, the use of this type of food contributes to reducing waste and may be a culturally, economically and socially sustainable option (Galanakis, 2013).

Unlike alcoholic beverages, the combination of grapes and sweet potatoes is intended to make a beverage less acidic and, consequently, more appreciated by people of all ages. Grapes are widely consumed and known for their high levels of phenolic compounds (Monteiro et al., 2021), including anthocyanins, which is also the major compound in purple-fleshed sweet potato (Gérard et al., 2019; Basilio et al., 2020), in addition to vitamins, dietary fibers, simple fermentable sugars, among other nutrients (Albuquerque et al., 2019). The elaboration of a new healthy mixed beverage with grapes and purple-fleshed sweet potato is source of several nutrients, including important bioactive compounds, without the addition of synthetic dye. The production of juices is a simple process and adds value to the by-products, even more when using waste vegetables. In addition, practical and innovative products such as mixed juices may also meet the nutritional needs of individuals who follow more restrictive diets, as occurs in flexitarianism and veganism. In this study, we characterized the physicochemical characteristics, identified and quantified the phytochemicals (phenolic compounds and biogenic amine profiles) and evaluated the antioxidant activity of whole ‘BRS Cora’, ‘BRS Violeta’ and ‘Bordô’ grape juices and in mixtures with ‘JNRX12’ sweet potatoes that were not able to be commercialized.

2.2 - Material and Methods

2.2.1. Experimental location, genotypes and juice processing

‘Bordô’, ‘BRS Cora’ and ‘BRS Violeta’ grapes were harvested in an experimental vineyard located in São Manuel, São Paulo, Brazil (22° 44′ 50″ S, 48° 34′ 00″ W and

765 m altitude). The purple-fleshed sweet potato ‘JNRX12’ was harvested in Presidente Prudente, São Paulo, Brazil (22° 7′ 39″ S, 51° 23′ 8″ W and 475 m altitude). The mixed juices were prepared by hot pressing. Grapes were destemmed and crushed in a manual crusher machine. No pectinase-based enzyme mixture was added. Maceration was performed in a water bath at 60 ± 2 °C for 1 h. The mixture with sweet potatoes (with skins) occurred in the juice maceration phase.

Sweet potatoes, mostly non-commercial standard, were sliced (3 mm thick) with the skin on and kept in boiling water for 3 min before being incorporated or not (whole grape juice) with grape must, in the proportions of 10% and 30% of sweet potatoes (w/w). Each mixed juice was prepared in a room with low luminosity. After maceration, the must was separated by draining and was lightly pressed. The juice was homogenized, bottled in amber glass bottles (215 mL capacity) and submitted to pasteurization at 80 °C for 3 min. The bottles were sealed, cooled, labeled and stored under refrigeration (6 ± 2 °C) for 1 week, ensuring complete stabilization.

2.2.2. Physicochemical and sensory analysis

Physicochemical analysis was carried out on all juices (IAL, 2008), as well as on purple-fleshed sweet potatoes after cooking. The pH was determined with a digital potentiometer (Quimis - Q- 400), the soluble solids (SS) (°Brix) through a digital refractometer (Atago, PAL-1) and the total acidity (TA) by titration of NaOH until the sample reached a pH equivalent to 8.2 and expressed as a percentage of tartaric acid. Color measurements were determined by UV-Vis spectrophotometry recording the absorbance at 420, 520 and 620 nm and expressed as color intensity (CI) (Glories, 1984).

$$\boldsymbol{CI} = \boldsymbol{A_{420}} + \boldsymbol{A_{520}} + \boldsymbol{A_{620}}$$

The browning index (BI) was evaluated (Muche, Speers, & Rupasinghe, 2018) according to the formula:

$$\boldsymbol{BI} = \boldsymbol{A_{420}}/\boldsymbol{A_{520}}$$

Sensory analysis (Research Ethics Council of São Paulo State University – UNESP; CAAE: 18570219.0.0000.5411) was performed with 65 untrained adult tasters, who evaluated the samples according to a standard method of subjective evaluation using a hedonic scale (Raupp et al., 2009). The socioeconomic profile of the participants was evaluated regarding age (18 – 60 years old), education and whether or not they had a smoking habit. To better perform the analysis, a randomized list of 15 types of mixed juice was drawn up using SAS® software. Thus, random samples were used, without replacement and without favoring any treatment. The attributes analyzed were color, aroma, flavor, body (structure) and global acceptance, using a seven-point hedonic scale, ranging from: disliked a lot (1) to liked a lot (7) (Meilgaarde, Civille, & Carr, 1999). In addition, the purchase intention for each sample was evaluated.

2.2.3. Biochemical analysis

2.2.3.1. Total phenolic compounds, total flavonoids, anthocyanin and antioxidant activity

The samples were diluted (1:10 v/v) in MeOH:acetic acid:water (80:1:19 v/v/v) for total phenolic compounds, total flavonoids and antioxidant activity (DPPH, FRAP, MDA and ABTS). The total phenolic compounds were analyzed using Folin–Ciocalteu

reagent (Singleton & Rossi, 1965) and the results were expressed in mg of gallic acid equivalent (mg GAE) per 100 mL.

The total flavonoid content was analyzed according to the method of Pękal & Pyrzynska (2014), with adaptations. Briefly, sodium nitrite solution (5%, w/v) was added to the extract and homogenized. After 5 min in a dark environment at room temperature, $AlCl_3$ solution (2%, w/v) was added and the samples were kept at rest for 6 min, followed by the addition of 1 M sodium hydroxide (39.997:1000, w/v). After 10 min, the absorbance of samples was read at 510 nm. Results were expressed in mg rutin equivalent (mg RE) per 100 mL.

Total monomeric anthocyanins were determined by the differential pH method (Giusti & Wrolstad, 2001) and the result expressed in mg malvidin-3-O-glycoside per 100 mL. Determination of the antioxidant activity by the reduction of Fe (FRAP) (Benzie & Strain, 1996) was performed in the acidified methanolic extract. Results were calculated using a calibration curve of ferrous sulphate ($FeSO_4$) and expressed in mmol FeSO4 per 100 mL. Determination of the antioxidant activity by reduction of the 2,2-diphenyl-1-picrylhydrazyl radical (DPPH) was carried out according to Brand-Williams, Cuvelier, & Berset (1995) and the results were expressed as mg of Trolox per 100 mL. Malondialdehyde (MDA) was determined as proposed by Heath and Packer (1968) and the absorbance reading was carried out at 560 and 600 nm. Results were expressed in ηmol TBARS per mL. Determination of the antioxidant activity by capturing the 2,2-azino-bis (3-ethylbenzothiazoline-6-sulfonic acid) (ABTS) radical was performed according to Re et al. (1999) and the results were expressed in mmol Trolox equivalent (TE) per 100 mL.

2.2.3.2. Profile of phenolic compounds

The profile of phenolic compounds was analyzed by HPLC (Borges et al., 2020). The mixed juices were diluted in the mobile phase (50% of solvent A: acidified water:trifluoroacetic acid (99.9:0.1, v/v) and 50% of solvent B: 100% acetonitrile) in the proportion of 1:9 (v/v). The gradient used was 0–7 min, 90% A + 10% B; 7–9 min, 60% A + 40% B; 9–10.5 min, 50% A + 50% B; 10.5–12 min, 45% A + 55% B; 12–15 min, 40% A + 60% B; 15–17 min, 60% A + 40% B; 17–22 min, 90% A + 10%, at a flow rate of 0.75 mL/min (25 °C). The phenolic compounds were quantified at 270, 320, 360 and 520 nm and the results expressed in µg/mL, except for kaempferol and *t*-cinnamic acid in ηg/mL.

2.2.3.3. Profile of biogenic amines and indexes

Biogenic amines profile was extracted and analyzed according to the method described by Gomez et al. (2020). The mobile phases used were 50% acetonitrile (A) and 100% acetonitrile (B), in a gradient of 0–2 min, 40% A + 60% B; 2–4 min, 60% A + 40% B; 4–8 min, 65% A + 35% B; 8–12 min, 85% A + 15% B; 12–15 min, 95% A + 5% B; 15–21 min, 85% A + 15% B; 21–22 min, 75% A + 25% B; 22–25 min, 40% A + 60% B. The identification of biogenic amines and amino acids was based on the retention times of the standards at 225 nm. We analyzed the amines serotonin, dopamine, agmatine, tryptamine, putrescine, cadaverine, spermidine, spermine, histamine and tyramine and the amino acids 5-hydroxytryptophan and tryptophan, which were expressed in µg/mL, and melatonin and the amino acid L-dopa which were expressed in ηg/mL.

For calculating the chemical quality index (CQI), it used the total concentration of histamine, putrescine, cadaverine, spermidine, and spermine (Table 3) (Mietz & Karmas, 1977), and was calculated using the following equation:

$$\boldsymbol{CQI} = \frac{\mathbf{histamine} + \mathbf{putrescine} + \mathbf{cadaverine}}{\mathbf{1} + \mathbf{spermidine} + \mathbf{spermine}}$$

The biogenic amine index (BAI), was calculated using the following formula (Veciana-Nogués, Mariné-Font, & Vidal-Carou, 1997):

$$\boldsymbol{BAI} = \mathbf{histamine} + \mathbf{putrescine} + \mathbf{cadaverine} + \mathbf{tyramine}$$

These indices (CQI and BAI) were elaborated taking into account foods of animal origin. The level of toxicity of amines in meat and fish is high when compared to what is found in plant samples. Thus, we feel the need to develop an index aimed at the analysis of plant samples, which we call the amine index (AI), that is:

$$\boldsymbol{AI} = \frac{(\mathbf{histamine} + \mathbf{putrescine} + \mathbf{cadaverine} + \mathbf{tyramine})}{(\mathbf{dopamine} + \mathbf{serotonin} + \mathbf{melatonin} + \mathbf{spermine} + \mathbf{spermidine})}$$

This mathematical modeling assesses both commonly health-promoting amines (e.g. dopamine, serotonin, melatonin, spermine and spermidine) and those commonly harmful to health (e.g. histamine, putrescine, cadaverine and tyramine). Considering the toxicity values of these amines (Papageorgiou et al., 2018), for values up to 50 mg/L, the ratio is considered desirable when < 1.0, acceptable when = 1.0, and not desirable when > 1.0.

2.2.4. Statistical analysis

The data were subjected to analysis of variance (ANOVA), followed by means comparison tests (Scott–Knott, $p \leq 0.05$) between the different juices and sweet potato genotypes used in the mixtures. Sensory analysis evaluations were submitted to the Kruskal–Wallis test ($p \leq 0.05$). Data variance analysis was performed using the SISVAR program and principal component analysis (PCA) was performed using XLSTAT software (2017 version; Addinsoft, France).

2.3 - Results and Discussion

2.3.1. Physicochemical properties and sensorial analysis

Characterization of the purple sweet potato ‘JNRX12’ used in the preparation of juices (Table 1) shows low levels of TA (0.23%) and a high SS/TA ratio (66.21) due to the SS content (15.23 °Brix). Other studies describe higher TA values, that is, between 0.39% and 0.42% and a lower ratio (35.48 to 37.51) in raw purple-fleshed sweet potatoes, and TA and ratio between 0.37% and 0.41% and 36.11 and 55.76, respectively, in thermally processed purple-fleshed sweet potatoes (Basílio et al., 2020). The incorporation of these sweet potatoes in grape juice contributed to a significant improvement in the physicochemical characteristics, such as a decrease in TA and an increase in the SS/TA ratio (Table 1), with the exception of SS, which were not significantly different

Table 1.

Physicochemical characteristics of mixed juices and purple-fleshed sweet potatoes (JNRX12): pH, soluble solids (SS) (º Brix), titratable acidity (TA) (% tartaric acid), ratio (SS / TA), color intensity (CI), browning index (BI) and sensory aspects (color, aroma, flavor, body and global aspects).

Physicochemical analysis*	JNRX12	V	VP10	VP30	C	CP10	CP30	B	BP10	BP30
pH	6.54 ± 0.03 ^{a*}	4.31 ± 0.02 ^{c}	4.53 ± 0.03 ^{b}	4.40 ± 0.00 ^{b}	3.63 ± 0.01 ^{e}	3.73 ± 0.01 ^{d}	3.90 ± 0.00 ^{d}	3.86 ± 0.02 ^{d}	4.00 ± 0.02 ^{d}	4.21 ± 0.01 ^{c}
SS	15.23 ± 1.00 ^{ns}	16.17 ± 2.71	18.47 ± 0.60	17.33 ± 0.9	16.60 ± 0.53	16.40 ± 0.73	18.07 ± 1.20	15.73 ± 0.28	15.00 ± 0.53	17.40 ± 1.33
TA	0.23 ± 0.01 ^{e}	0.93 ± 0.02 ^{a}	0.83 ± 0.01 ^{c}	0.84 ± 0.00 ^{c}	1.05 ± 0.02 ^{a}	0.82 ± 0.02 ^{c}	0.83 ± 0.00 ^{c}	0.88 ± 0.02 ^{b}	0.79 ± 0.01 ^{d}	0.83 ± 0.01 ^{c}
Ratio	66.21 ± 0.50 ^{a}	17.47 ± 2.86 ^{c}	22.22 ± 1.07 ^{b}	20.59 ± 1.06 ^{b}	15.75 ± 0.33 ^{c}	19.99 ± 1.26 ^{b}	21.65 ± 1.42 ^{b}	17.98 ± 0.69 ^{c}	19.00 ± 0.83 ^{c}	20.97 ± 1.35 ^{b}
Color aspects *										
CI	-	18.79 ± 0.18 ^{c}	30.35 ± 0.89 ^{a}	31.86 ± 4.82 ^{a}	20.38 ± 2.93 ^{b}	25.32 ± 2.30 ^{b}	22.78 ± 4.75 ^{b}	12.83 ± 0.57 ^{c}	13.96 ± 1.12 ^{c}	17.08 ± 0.29 ^{c}
BI	-	0.92 ± 0.01 ^{b}	0.96 ± 0.01 ^{b}	0.81 ± 0.08 ^{c}	0.75 ± 0.01 ^{c}	0.67 ± 0.02 ^{d}	0.80 ± 0.01 ^{c}	0.81 ± 0.02 ^{c}	0.73 ± 0.00 ^{d}	1.07 ± 0.01 ^{a}
Sensorial aspects **										

Color	-	489.51 ns	510.88	488.11	439.08	502.23	476.24	493.50	511.29	470.5
Aroma	-	410.89 cd	391.12 d	409.67 cd	530.21 abc	479.81 abcd	517.00 abcd	628.33 a	586.47 ab	535.4 abc
Flavor	-	424.73 def	278.82 f	361.48 ef	517.73 abcd	530.82 abc	543.19 abc	620.13 ab	621.82 a	471.2 bcde
Texture	-	419.43 ns	415.61	427.00	516.56	521.12	528.67	565.00	531.91	468.6
Global aspects	-	417.54 cdef	290.44 f	364.32 ef	533.10 abc	500.91 abcd	524.17 abc	609.78 a	605.53 a	533.9 abc

*Means followed by the same letter in the line do not differ statistically from each other by Scott-Knott test ($p \leq 0.05$). ** Means followed by the same letter in the line do not differ statistically from each other by Kruskal-Wallis test ($p \leq 0.05$).

V = 'BRS Violeta'; VP10 = 'BRS Violeta' + 10% 'JNRX12'; VP30 = 'BRS Violeta' + 30% 'JNRX12'; C = 'BRS Cora'; CP10 = 'BRS Cora' + 10% 'JNRX12'; CP30 = 'BRS Cora' + 30% 'JNRX12'; B = 'Bordô'; BP10 = 'Bordô'+10% 'JNRX12';

BP30 = 'Bordô' + 30% 'JNRX12'.

Sweet potatoes have a higher pH and lower acidity compared to grapes (Table 1), which contributes to an improvement in the SS / AT ratio. In Brazilian hybrid grapes (‘BRS Violeta’ and ‘BRS Cora’) (Table 1), the SS/TA ratio (ratio) was higher in juices mixed with sweet potato, regardless of the proportion used, with values greater than 20, due to the high SS content. These features are important, since they resulted in better consumer acceptance of the product. These characteristics are important, as they resulted in better acceptance of the product by the consumer, including individuals with some food selectivity to acidic foods.

Color parameters were also influenced by the addition of sweet potato (Table 1). In grapes, anthocyanins are the major pigments and are responsible for the purplish hue (Gomez-Gomez et al., 2018), as they are in purple-fleshed sweet potatoes (Table 2). The CI was higher in juices elaborated with ‘BRS Violeta’ plus purple-fleshed sweet potato (Table 1). The relationship between yellowish pigments and red pigments determines browning, which demonstrates the possible oxidation of anthocyanins causing the development of a brown color, since the action of polyphenoloxidase results in the formation of quinones, causing darkening (Muche et al., 2018). The highest browning values were detected in juices elaborated with ‘Bordô’ grapes, alone or with 30% purple sweet potato (Table 1).

The cultivars, mainly ‘BRS Violeta’ and ‘BRS Cora’, are commonly used in the preparation of blends with grapes that have less CI, in order to intensify the color (Gomez-Gomez et al., 2018). In addition to factors such as climate, region, growing season, other factors can influence the color index, such as the processing method (hot pressing) used in our study. This method favors the extraction and stability of compounds responsible for the color (e.g. tannins and anthocyanins). According to

Silva et al. (2019), there is greater color intensity and less browning in blends from ‘Isabel Precoce’ (80%) and ‘BRS Violeta’ (20%) by hot press and hot break, compared to the cold extraction method. This result may be attributed to the inactivation of enzymes that occurs by the action of high temperatures, including polyphenoloxidase, responsible for enzymatic browning (Muche et al., 2018).

The elaboration of mixed grape juice and sweet potatoes influenced the perceptions of aroma, flavor and overall appearance (Table 1). Juices from ‘BRS Violeta’, whether mixed with sweet potatoes or not, were the least appreciated in all respects. These grapes are used in smaller proportions in blends because they have a high tannin content (Silva et al., 2019), which possibly contributed to the negative evaluations. Although it showed differentiation *in vitro*, color was a neutral parameter for the evaluators, with no noticeable variations. Juices elaborated with ‘Bordô’ and ‘BRS Cora’ grapes were the most appreciated for their aroma and flavor, including those mixed with sweet potatoes. The ‘BRS Cora’ grape is known for its high levels of acidity (Lima et al., 2014), which may have been softened by the incorporation of sweet potato. Evaluation of the texture of the beverage indicates that the incorporation of sweet potato during the preparation of juices did not result in an increase in foreign lees/sediments. In general, the results were influenced by the grape used and the incorporation of purple-fleshed sweet potatoes was well accepted, especially for juices elaborated with the ‘Bordô’ and ‘BRS Cora’ grapes.

The results of the physicochemical analysis, including color and sensory analysis, were compared using PCA, which explained 79.82% of the data variance (Fig. 1). ‘BRS Violeta’ grape juices, with or without the addition of sweet potatoes, and juice elaborated with ‘Bordô’ grapes and 30% sweet potatoes were grouped in PC1−. Even though these juices showed affinity with important physicochemical characteristics for

sensory evaluation such as pH, SS, ratio and CI (Table 1), they had similar browning values (Table 1). These results justify the negative evaluations, since the flavor and aroma could be compromised, resulting in a lower purchase intention. Juice elaborated only with 'BRS Cora' was isolated in PC1+ and PC2+ due to its TA (1.05 %) (Table 1) and when mixed with sweet potato, regardless of quantity, it was grouped closer to the sensory attributes of approval (PC1+) (Figure 1). '

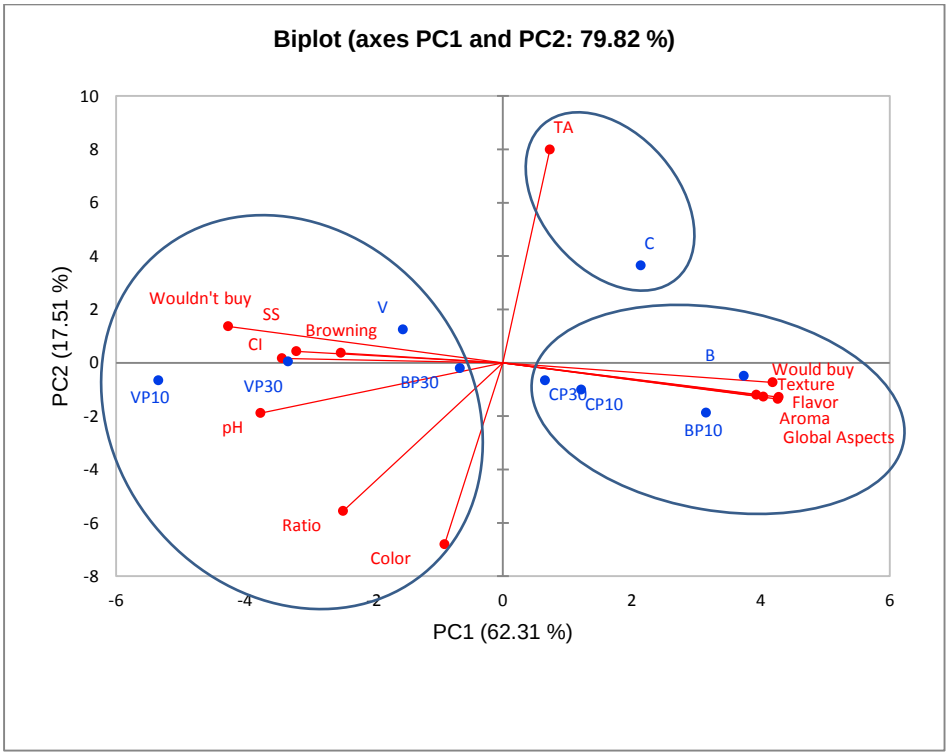


Fig. 1. Two-dimensional projection and scores from chemical characteristics pH, soluble solids, total titratable acidity, color indices and sensory aspects of mixed juices from grapes and sweet potatoes with purple pulp. Treatments are represented by dots, where V='BRS Violeta; VP10='BRS Violeta'+10% JNRX12; VP30= 'BRS Violeta'+30% JNRX12; C='BRS Cora'; CP10= 'BRS Cora'+10% JNRX12; CP30= 'BRS Cora'+30% JNRX12; B= 'Bordô'; BP10 = 'Bordô'+10% JNRX12; BP30 = 'Bordô'+30% e 'JNRX12'.

Bordô' has as its main quality a strong aroma and fruity and foxy flavor, characteristic of the species *Vitis labrusca*, derived from the compounds methyl anthranilate, furaneol

and 2-aminoacetophenone (Dutra et al., 2021). Juices made with ‘Bordô’ grapes or mixed with 10% sweet potato, and juices elaborated with ‘BRS Cora’ and sweet potatoes were grouped in PC1+ and presented the highest scores in the sensory analysis.

2.3.2. Phenolic compounds and antioxidant activity

The elaboration of a beverage composed of grapes and colored sweet potatoes significantly influenced the content and profile of phenolic compounds compared to whole grape juice, as well as the antioxidant activity (Table 2). Whole juices had lower values for bioactive compounds and antioxidant capacity compared to those to which ‘sweet potato was added (Table 2). These results reinforce that the use of non-commercial tuberous roots in the production of mixed juices provides access to quality- and health-promoting foods in an environmentally, culturally, economically and socially sustainable way (Galanakis, 2013). The combinations of grapes and sweet potatoes, especially the mixed juices VP30, CP30 and BP30, contained the highest content of total phenolic compounds and total anthocyanins, while juices elaborated with ‘BRS Violeta’ presented the highest levels of total flavonoids.

Table 2.

Phenolic compounds of mixed juices of grapes and purple pulp sweet potatoes (µg / mL) and purple pulp sweet potato 'JNRX12' (µg / g).

Compounds	JNRX12	V	VP10	VP30	C	CP10	CP30	B	BP10	BP30
Anthocyanins										
Cyanidin 3-O-glucoside	163.40 ± 6.90 ^{a}	38.94 ± 0.37 ^{e}	71.80 ± 3.24 ^{d}	108.91 ± 1.71 ^{b}	38.14 ± 3.21 ^{e}	66.72 ± 2.66 ^{d}	83.93 ± 2.08 ^{c}	9.64 ± 1.25 ^{g}	13.55 ± 1.74 ^{g}	19.32 ± 1.01 ^{f}
Cyanidin 3.5-diglucoside	122.87 ± 16.06 ^{a}	26.67 ± 1.27 ^{e}	37.95 ± 3.21 ^{d}	69.05 ± 1.77 ^{b}	23.83 ± 2.84 ^{e}	25.48 ± 1.62 ^{e}	46.40 ± 1.92 ^{c}	5.54 ± 0.61 ^{f}	5.22 ± 0.27 ^{f}	10.68 ± 0.02 ^{f}
Peonidin 3-O-glucoside	97.34 ± 7.34 ^{a}	16.49 ± 0.33 ^{c}	8.12 ± 0.09 ^{e}	22.85 ± 0.83 ^{b}	6.24 ± 0.18 ^{e}	7.97 ± 0.04 ^{e}	12.58 ± 0.01 ^{d}	21.74 ± 0.96 ^{b}	17.36 ± 1.43 ^{c}	23.39 ± 0.42 ^{b}
Delphinidin 3-O-glucoside	44.63 ± 17.36 ^{b}	207.81 ± 7.19 ^{a}	48.62 ± 4.07 ^{b}	186.57 ± 1.39 ^{a}	178.92 ± 16.46 ^{a}	154.00 ± 1.72 ^{a}	140.40 ± 3.13 ^{a}	30.79 ± 1.60 ^{b}	41.26 ± 4.25 ^{b}	58.85 ± 5.36 ^{b}
Malvidin 3-O-glucoside	Nd	121.25 ± 0.69 ^{a}	98.95 ± 3.03 ^{b}	70.96 ± 2.79 ^{d}	96.33 ± 1.33 ^{b}	76.65 ± 1.22 ^{c}	80.44 ± 0.34 ^{c}	23.20 ± 4.05 ^{e}	11.72 ± 0.89 ^{f}	8.38 ± 2.17 ^{f}
Malvidin 3.5-diglucoside	65.02 ± 2.82 ^{d}	164.73 ± 2.03 ^{a}	107.7 ± 3.06 ^{c}	153.75 ± 1.36 ^{b}	26.65 ± 0.94 ^{e}	11.10 ± 1.25 ^{f}	15.13 ± 1.70 ^{f}	81.68 ± 1.94 ^{d}	59.68 ± 2.63 ^{d}	68.91 ± 1.67 ^{d}
Σ Anthocyanins	493.26 ± 50.48	575.89 ± 11.88	373.14 ± 16.70	612.09 ± 9.85	370.11 ± 24.96	341.92 ± 8.51	378.88 ± 9.18	172.59 ± 10.41	148.79 ± 11.21	189.53 ± 10.65
Flavonols										
Rutin	7.99 ± 1.80 ^{a}	4.93 ± 0.18 ^{b}	1.55 ± 0.04 ^{e}	3.19 ± 0.10 ^{c}	1.20 ± 0.01 ^{e}	1.20 ± 0.01 ^{e}	1.50 ± 0.40 ^{e}	4.24 ± 0.10 ^{c}	2.65 ± 0.32 ^{d}	3.76 ± 0.27 ^{c}
Quercetin	1.59 ± 0.27 ^{d}	3.91 ± 0.01 ^{a}	2.94 ± 0.03 ^{c}	3.59 ± 0.18 ^{b}	0.57 ± 0.02 ^{f}	0.05 ± 0.01 ^{f}	0.61 ± 0.04 ^{f}	0.83 ± 0.00 ^{e}	1.03 ± 0.2 ^{e}	0.88 ± 0.11 ^{e}
3-O-metilquercetin	6.59 ± 0.58 ^{a}	1.03 ± 0.03 ^{b}	0.59 ± 0.01 ^{d}	0.79 ± 0.02 ^{c}	0.02 ± 0.00 ^{f}	0.05 ± 0.01 ^{f}	0.14 ± 0.01 ^{e}	0.09 ± 0.01 ^{f}	0.09 ± 0.01 ^{f}	0.44 ± 0.01 ^{d}
Kaempferol (ng / mL)	1135.91 ± 239.65 ^{a}	131.89 ± 14.39 ^{b}	136.18 ± 10.65 ^{b}	132.85 ± 0.25 ^{b}	1.44 ± 0.36 ^{c}	1.33 ± 0.25 ^{c}	3.38 ± 0.83 ^{c}	3.57 ± 0.03 ^{c}	4.64± 2.10 ^{c}	3.73 ± 0.73 ^{c}
Σ Flavonols	17.30 ± 2.88	10.00 ± 0.23	5.21 ± 0.09	7.7 ± 0.30	1.79 ± 0.03	1.31 ± 0.03	2.25 ± 0.45	5.16 ± 0.11	3.77 ± 0.53	5.08 ± 0.39
Phenolic acids										
Gallic	86.75 ± 12.00 ^{a}	29.47 ± 4.98 ^{e}	44.36 ± 8.48 ^{d}	95.14 ± 6.62 ^{a}	38.99 ± 4.20 ^{d}	56.13 ± 2.25 ^{c}	70.07 ± 6.38 ^{b}	18.68 ± 1.31 ^{e}	22.69 ± 1.56 ^{e}	33.31 ± 2.16 ^{e}
p-Coumaric	10.52 ± 0.28 ^{a}	1.10 ± 0.09 ^{e}	3.82 ± 0.11 ^{c}	8.53 ± 1.13 ^{b}	Nd	1.71 ± 0.23 ^{d}	4.55 ± 0.23 ^{c}	2.49 ± 0.02 ^{d}	3.52 ± 0.05 ^{c}	5.25 ± 0.45 ^{c}
Caffeic	7.18 ± 0.71 ^{a}	2.04 ± 0.08 ^{c}	1.06 ± 0.02 ^{d}	3.05 ± 0.12 ^{b}	1.02 ± 0.30 ^{f}	1.16 ± 0.04 ^{d}	1.57 ± 0.29 ^{c}	1.37 ± 0.01 ^{c}	1.91 ± 0.10 ^{b}	2.45 ± 0.33 ^{b}
t-ferulic	4.62 ± 0.31 ^{a}	Nd	1.42 ± 0.07 ^{c}	2.94 ± 0.11 ^{b}	0.10 ± 0.00 ^{f}	0.62 ± 0.00 ^{d}	1.08 ± 0.07 ^{c}	1.52 ± 0.04 ^{d}	2.81 ± 0.08 ^{c}	3.56 ± 0.37 ^{b}
t-cinamic (ng / mL)	97.64 ± 13.11 ^{a}	6.44 ± 0.70 ^{b}	8.25 ± 3.98 ^{b}	12.53 ± 0.20 ^{b}	0.70 ± 0.15 ^{c}	1.05 ± 0.22 ^{c}	1.39 ± 0.22 ^{c}	0.99 ± 0.23 ^{c}	2.95 ± 0.15 ^{c}	10.44 ± 0.06 ^{b}
Chlorogenic	65.79 ± 1.29 ^{a}	5.51 ± 0.10 ^{d}	12.91 ± 0.38 ^{c}	18.35 ± 0.39 ^{b}	9.33 ± 0.65 ^{d}	11.39 ± 0.23 ^{c}	16.62 ± 0.14 ^{b}	10.74 ± 0.34 ^{c}	11.7 ± 0.38 ^{c}	14.80 ± 0.27 ^{b}
Σ Phenolic acids	174.95 ± 14.60	38.16 ± 5.25	63.57 ± 9.06	128.02 ± 8.37	49.45 ± 5.3	71.02 ± 2.75	93.90 ± 7.11	34.80 ± 1.73	42.63 ± 2.18	69.76 ± 3.87
Stilbene										
t-resveratrol	Nd	1.87 ± 0.06 ^{a}	1.40 ± 0.00 ^{b}	1.10 ± 0.07 ^{b}	1.88 ± 0.02 ^{a}	1.82 ± 0.00 ^{a}	1.56 ± 0.14 ^{b}	1.91 ± 0.13 ^{a}	1.57 ± 0.09 ^{b}	1.38 ± 0.17 ^{b}

Flavonas										
Luteolin	4.31 ± 0.05 [a]	1.71 ± 0.08 [c]	0.93 ± 0.01 [d]	1.73 ± 0.01 [c]	0.42 ± 0.02 [e]	0.18 ± 0.03 [e]	0.19 ± 0.01 [e]	2.58 ± 0.01 [b]	1.53 ± 0.21 [c]	2.01 ± 0.43 [c]
Flavan-3-ol										
Catechin	3.00 ± 0.36 [c]	27.85 ± 2.06 [a]	11.59 ± 1.12 [b]	13.74 ± 0.17 [b]	0.37 ± 0.05 [c]	0.85 ± 0.01 [d]	2.45 ± 0.07 [c]	0.05 ± 0.00 [d]	0.50 ± 0.03 [d]	2.96 ± 0.06 [c]
Σ Phenolic Compounds	692.82 ± 68.05	655.48 ± 20.12	455.84 ± 21.99	764.38 ± 18.77	424.02 ± 29.22	417.10 ± 26.83	479.23 ± 17.08	217.09 ± 12.45	198.79 ± 14.49	270.72 ± 15.51
TPC	9991.02 ± 132.17 [a]	5489.26 ± 684.11 [d]	6660.54 ± 279.17 [c]	9197.66 ± 510.02 [a]	3836.17 ± 661.11 [e]	6732.10 ± 515.03 [c]	7972.35 ± 527.47 [b]	2718.14 ± 26.87 [f]	2910.78 ± 602.00 [f]	3386.49 ± 655.05 e
TF	1866.47 ± 0.33 [a]	1263.41 ± 343.03 [c]	1664.02 ± 130.69 [b]	1758.31 ± 141.25 [a]	599.61 ± 36.78 [f]	708.44 ± 94.98 [e]	909.57 ± 81.79 [d]	991.00 ± 7.81 [d]	968.24 ± 35.03 [d]	805 ± 60 e
TA	179.13 ± 98.05 [c]	312.65 ± 62.48 [c]	447.77 ± 28.08 [b]	674.74 ± 17.07 [a]	125.29 ± 17.13 [d]	164.06 ± 23.55 [d]	188.36 ± 10.01 [c]	268.43 ± 1.22 [c]	286.15 ± 3.10 [c]	330 ± 10 c
DPPH	431.23 ± 11.04 [c]	513.47 ± 9.4 [c]	653.46 ± 1.24 [a]	699.53 ± 5.06 [a]	445.66 ± 4.81 [c]	497.62 ± 19.47 [c]	577.83 ± 22.77 [b]	337.26 ± 16.42 [d]	360.60 ± 14.38 [d]	412.3 ± 9.6 c
FRAP	358.13 ± 32.63 [c]	2627.99 ± 307.21 [a]	2936 ± 151 [a]	2427.32 ± 162.78 [a]	1764.31 ± 41.44 [b]	1943.41 ± 275.63 [a]	1943.12 ± 321.06 [a]	1747.47 ± 113.84 [b]	1614.67 ± 139.71 [b]	1504 ± 32 [b]
MDA	27.30 ± 0.53 [f]	112.53 ± 1.22 [c]	123.8 ± 8.5 [b]	139.54 ± 0.23 [a]	54.53 ± 0.56 [e]	58.03 ± 0.75 [e]	57.47 ± 4.18 [e]	106.87 ± 15.13 [c]	80.26 ± 2.10 [d]	61.4 ± 2.94 [e]
ABTS	514.89 ± 12.44 [d]	1030.73 ± 29.14 [c]	1525 ± 116 [b]	1908.24 ± 57.65 [a]	490.78 ± 133.71 [d]	838.48 ± 69.05 [c]	829.17 ± 22.04 [c]	581.16 ± 36.05 [d]	500.03 ± 69.01 [d]	558 ± 16 [d]

* Means followed by the same letter in the line do not differ statistically from each other by the Scott-Knott test ($p \leq 0.05$). V = 'BRS Violeta'; VP10 = 'BRS Violeta' + 10% 'JNRX12'; VP30 = 'BRS Violeta' + 30% 'JNRX12'; C = 'BRS Cora';

CP10 = 'BRS Cora' + 10% 'JNRX12'; CP30 = 'BRS Cora' + 30% 'JNRX12'; B = 'Bordô'; BP10 = 'Bordô'+10% 'JNRX12'; BP30 = 'Bordô' + 30% 'JNRX12'. Nd = not detected.

Grapes are rich in phenolic compounds, highly unstable molecules depending on the environmental conditions (luminosity, temperature, pH), however, the association of these bioactive compounds with polysaccharides founded in sweet potatoes such as dietary fibers and starch facilitate bioaccessibility and bioavailability (Jakobek & Matić, 2019).The inclusion of purple-fleshed sweet potato in the preparation of beverages with grapes contributes to the increase in the content of some specific phenolic compounds, as cyanidin 3-*O*-glucoside, cyanidin 3.5-diglucoside, peonidin 3-*O*-glucoside, *p*-coumaric acid, *t*-ferulic acid and chlorogenic acid (Table 2). In addition, studies demonstrate that purple-fleshed sweet potato shows higher antioxidant capacity than black carrot, eggplant and red onion, mainly due to their high levels of anthocyanins (Frond et al., 2019).

The incorporation of 30% sweet potato in juices, regardless of the grape genotype, increased the total phenolic compounds and antioxidant activity measured by the DPPH (Table 2). When the antioxidant activity was determined via FRAP and ABTS, only the addition of sweet potato to ‘BRS Cora’ grape juice, regardless of the concentration, increased the antioxidant activity. Analysis via MDA shows that ‘BRS Violeta’ juices combined with 10% and 30% potatoes have a greater capacity to scavenge free radicals. These data resulting from the different methods are important for evaluations, mainly because each method is related to specific molecules, as well as the solubility.

The profile of phenolic compounds (Table 2) shows interesting results in relation to mixed grape juice and purple-fleshed sweet potato, especially in relation to the flavonoids. These molecules have a neuroprotective action and seem to influence the reduction of progressive neuronal loss that occurs in neurodegenerative diseases,

especially Parkinson's disease (Magalingam, Radhakrishnan, & Haleagrahara, 2015). In 'JNRX12', the major anthocyanin was cyanidin-3-glucoside (163.40 µg/g), while in 'Bordô' juices, a higher content of malvidin 3,5-diglucoside was detected (81.68 µg/mL) and in pure 'BRS Violeta' and 'BRS Cora' juices, delphinidin 3-O-glucoside was the anthocyanin that occurred at the highest levels (207.80 and 178.92 µg/mL, respectively). The major anthocyanin of the 'BRS Violeta' grapes juices found in our study is monoglycosylated, different from the diglycosylated anthocyanins that are commonly described in hybrid grapes (Gomez-Gomez et al., 2018; Monteiro et al., 2021). This result can be attributed to growing conditions and climate, among other factors. In addition, the anthocyanin content in mixed juice may have been affected by pH. The highest pH was detected in 'BRS Violeta' grape juice and the addition of 'JNRX12' did not induce changes in pH, when compared to whole grape juice. However, the addition of 'JNRX 12 positively influenced the CI (Table 1), which also have the highest content of total anthocyanins, mainly VP30 (Table 2). Recent studies have associated anthocyanins and derivatives as inhibitors of the major protease and spike glycoprotein (S-protein) of SARS-CoV-2 (Messaoudi et al., 2021). Thus, these mixed juices could be an excellent source of anthocyanins with beneficial effects on health.

The levels of the rutin, 3-*O*-methylquercetin and kaempferol in sweet potato were higher than those found in grape juice; however, incorporation of the tuber did not guarantee higher levels of these compounds in mixed beverages (Table 2). Rutin was the major compound in most juices, whether elaborated with grapes alone or mixed with sweet potatoes.

In whole or mixed juices, it was shown that gallic acid was the major compound in relation to other phenolic acids, in addition to occurring at a higher level in sweet

potatoes (Table 2). The therapeutic potential of this phenolic acid is known, with patents associated with its anticarcinogenic, antimicrobial, antimutagenic, antiangiogenic and anti-inflammatory properties (Dludla et al., 2019). In this experiment, it was possible to observe that treatments with higher levels of anthocyanins also presented higher levels of gallic acid. Gallic acid molecules, by donating H^+ atoms from phenolic groups to radicals, act in the co-pigmentation and protection of anthocyanins and in color stability by inhibiting the interaction of radicals with anthocyanins (Roidoung et al., 2016). Chlorogenic acid is commonly found in the leaves and edible roots of sweet potato (Carrera et al., 2021) and the consumption mitigates negative effects of obesity such as cardiovascular, liver and metabolic alterations in mice (He et al., 2020). Stilbene was not detected in sweet potatoes and their addition to grape juice reduced this phenolic compound due to dilution.

Purple sweet potato ‘JNRX12’ had a higher luteolin content (4.3 µg/g) compared to all juices (Table 2). ‘BRS Violeta’ grape juice had a higher catechin content. The inclusion of ‘JNRX12’ promoted an increase in catechin levels in juices from ‘BRS Cora’ and ‘Bordô’, especially with 30% sweet potato. The intake of foods rich in this flavonoid can be effective in reducing body fat, contributing to the prevention of various diseases related to modern lifestyles, such as obesity (Sasaki, Li, Cichon, Kopec, & Bruno, 2021) Furthermore, recent studies have demonstrated the potential of this phytochemical against SARS-CoV-2 proteins, which are directly involved in virus–host interaction, virus replication within the host, and disease progression and transmission (Mishra et al., 2021).

Aiming at a descriptive model for grouping phenolic compounds and antioxidant activity with the different juices, the results obtained were compared using PCA. Together, PC1 and PC2 explained 70.69% of the data variance (Fig. 2).

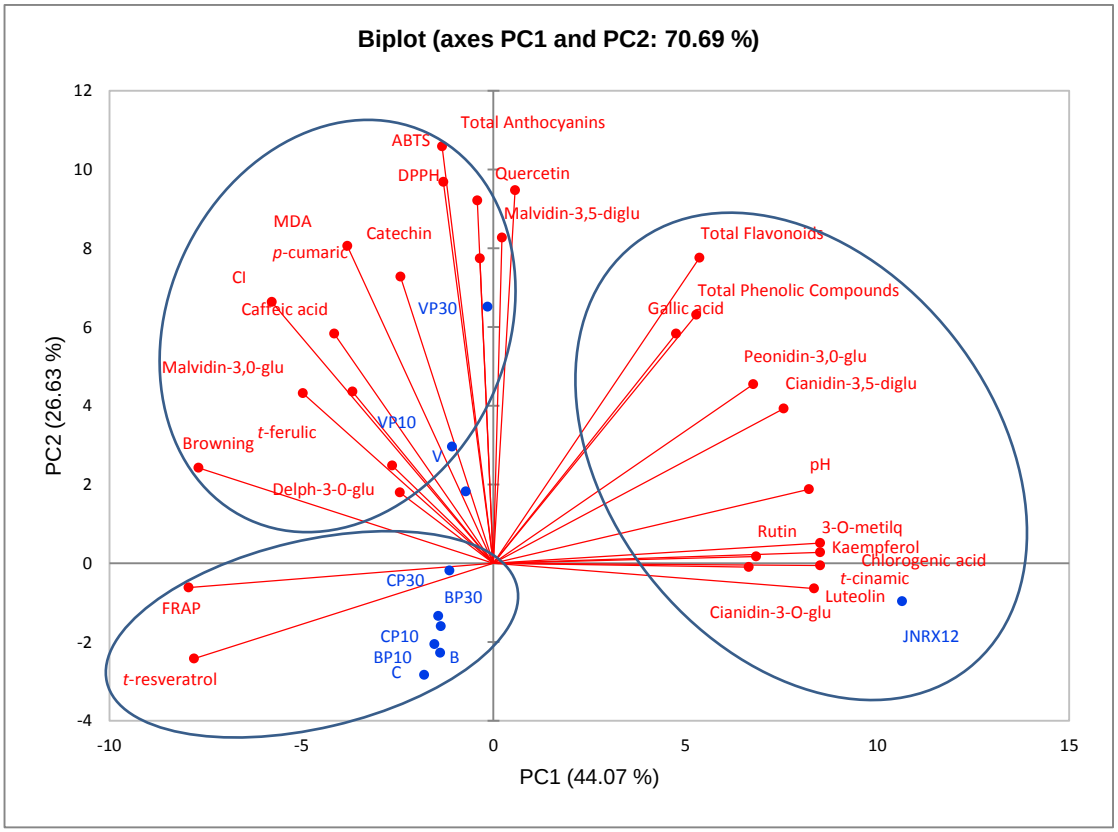


Fig. 2. Two-dimensional projection and scores from profile of phenolic compounds, total phenolic compounds, total flavonoids, total monomeric anthocyanins, antioxidant activity (DPPH, FRAP, ABTS and MDA), pH, color intensity and browning of mixed grape and potato juice purple pulp sweets. Treatments are represented by dots, where V=’BRS Violeta; VP10=’BRS Violeta’+10% JNRX12; VP30= ’BRS Violeta’+30% JNRX12; C=’BRS Cora’; CP10= ’BRS Cora’+10% JNRX12; CP30= ’BRS Cora’+30% JNRX12; B= ‘Bordô’; BP10 = ‘Bordô’+10% JNRX12; BP30 = ‘Bordô’+30% e ‘JNRX12’.

It is clearly noticed that the sweet potato was grouped in PC1+ by affinity with the phenolic compounds, which demonstrates how interesting the addition of this tuber to grape juice is (Table 2 and Fig. 2).

Mixed juices were grouped in PC1−. Juices elaborated from ‘BRS Violeta’ showed the highest levels of bioactive compounds and, consequently, the highest antioxidant capacity (Table 2). Furthermore, these juices had a higher CI compared to the other juices, including an BI greater than that of ‘BRS Cora’ (Table 1). The mixed juices with

‘BRS Cora’ and ‘Bordô’ were grouped into PC1− and PC2−, respectively, together with *trans*-resveratrol and with the antioxidant activity measured via FRAP (Table 2), indicating that these juices could be important sources of stilbenes, in addition to antioxidant capacity.

2.3.3. Biogenic amines

The amino acids L-dopa, 5-hydroxytryptophan and tryptophan and the biogenic amines were detected in all juices studied (Table 3). The addition of 10% and 30% sweet potatoes to ‘BRS Violeta’ juices favored the increase of L-dopa (35.59 and 30.91 ηg/mL, respectively). Parkinson’s disease, associated with the severe loss of dopaminergic neurons in the *substantia nigra pars compacta*, has L-dopa as its most widespread treatment (Oertel & Schulz, 2016).

Table 3.

Biogenic amines and amino acids (µg / mL) of mixed juices of red-fleshed grapes and sweet potatoes and ‘JN RX12’ red-fleshed sweet potato (µg / g).

Compound	JN RX12	V	VP10	VP30	C	CP10	CP30	B	BP10	BP30
Amino acids										
L-Dopa (ng / mL)	16.54 ± 2.30 ^{c}	14.24 ± 1.31 ^{d}	35.59 ± 0.55 ^{a}	30.91 ± 0.56 ^{b}	3.93 ± 1.07 ^{f}	2.37 ± 0.08 ^{f}	1.38 ± 0.02 ^{f}	20.18 ± 2.60 ^{c}	8.97 ± 0.29 ^{e}	7.38 ± 2.44 ^{e}
Tryptamine	14.42 ± 0.02 ^{a}	2.45 ± 0.04 ^{b}	2.19 ± 0.03 ^{c}	1.75 ± 0.02 ^{d}	1.06 ± 0.01 ^{f}	1.40 ± 0.02 ^{e}	1.33 ± 0.03 ^{e}	1.89 ± 0.03 ^{d}	1.82 ± 0.11 ^{d}	1.89 ± 0.04 ^{d}
5-hidroxitryptophan	87.78 ± 5.60 ^{a}	36.91 ± 0.92 ^{b}	16.67 ± 0.02 ^{e}	11.85 ± 0.77 ^{f}	35.33 ± 0.51 ^{b}	18.43 ± 1.00 ^{d}	29.06 ± 0.12 ^{c}	15.80 ± 0.56 ^{e}	18.92 ± 0.88 ^{d}	16.74 ± 0.21 ^{e}
Tryptophan	62.47 ± 4.21 ^{e}	45.57 ± 0.93 ^{f}	27.62 ± 1.20 ^{h}	38.72 ± 1.07 ^{g}	146.48 ± 0.32 ^{a}	133.06 ± 0.58 ^{b}	155.82 ± 1.05 ^{a}	75.79 ± 1.16 ^{d}	110.39 ± 0.23 ^{c}	109.47 ± 1.06 ^{c}
Monoamines										
Melatonin (ng / mL)	28687.16 ± 1551.57 ^{a}	Nd	0.96 ± 0.10 ^{c}	1.07 ± 0.02 ^{c}	2.21 ± 0.11 ^{c}	2.79 ± 0.17 ^{b}	3.72 ± 0.15 ^{b}	1.14 ± 0.13 ^{c}	1.56 ± 0.38 ^{c}	2.50 ± 0.79 ^{b}
Serotonin	10.95 ± 0.31 ^{a}	0.77 ± 0.03 ^{f}	3.91 ± 0.01 ^{b}	1.78 ± 0.03 ^{d}	0.83 ± 0.01 ^{e}	1.15 ± 0.00 ^{e}	0.80 ± 0.00 ^{f}	0.96 ± 0.02 ^{e}	3.65 ± 0.07 ^{b}	2.56 ± 0.00 ^{c}
Dopamine	0.28 ± 0.01 ^{d}	0.77 ± 0.05 ^{c}	2.53 ± 0.19 ^{a}	2.50 ± 0.22 ^{a}	1.50 ± 0.03 ^{b}	1.72 ± 0.07 ^{b}	0.89 ± 0.04 ^{c}	1.83 ± 0.01 ^{b}	2.44 ± 0.02 ^{a}	1.50 ± 0.06 ^{b}

Histamine	0.60 ± 0.03 [a]	0.04 ± 0.00 [f]	0.11 ± 0.010 [e]	0.18 ± 0.010 [d]	0.04 ± 0.001 [f]	0.04 ± 0.001 [f]	0.04 ± 0.002 [f]	0.17 ± 0.001 [d]	0.22 ± 0.001 [c]	0.30 ± 0.00 [b]
Tyramine	1.55 ± 0.04 [a]	0.25 ± 0.03 [b]	1.41 ± 0.47 [a]	0.77 ± 0.01 [b]	0.29 ± 0.00 [b]	0.45 ± 0.02 [b]	0.27 ± 0.00 [b]	0.35 ± 0.02 [b]	0.62 ± 0.02 [b]	1.18 ± 0.03 [a]
Diamines										
Putrescine	1.10 ± 0.00 [a]	0.09 ± 0.00 [f]	0.18 ± 0.01 [d]	0.14 ± 0.02 [e]	0.05 ± 0.01 [f]	0.07 ± 0.01 [f]	0.13 ± 0.01 [e]	0.31 ± 0.02 [c]	0.46 ± 0.01 [b]	0.41 ± 0.02 [b]
Cadaverine	0.36 ± 0.05 [b]	0.25 ± 0.01 [c]	0.38 ± 0.00 [b]	0.29 ± 0.01 [c]	0.43 ± 0.02 [b]	0.47 ± 0.02 [a]	0.59 ± 0.05 [a]	0.30 ± 0.03 [c]	0.54 ± 0.01 [a]	0.64 ± 0.06 [a]
Polyamines										
Spermidine	1.06 ± 0.01 [a]	0.12 ± 0.02 [d]	0.46 ± 0.01 [c]	0.39 ± 0.01 [c]	0.19 ± 0.06 [d]	0.33 ± 0.02 [c]	0.20 ± 0.02 [d]	0.71 ± 0.09 [b]	0.75 ± 0.01 [b]	0.75 ± 0.03 [b]
Spermine	4.11 ± 0.01 [a]	0.88 ± 0.03 [d]	3.11 ± 0.21 [b]	2.79 ± 0.10 [b]	1.72 ± 0.01 [c]	1.90 ± 0.25 [c]	0.97 ± 0.03 [d]	0.93 ± 0.14 [d]	0.52 ± 0.02 [e]	0.35 ± 0.02 [e]
Agmatine	12.23 ± 0.02 [a]	0.27 ± 0.02 [g]	0.58 ± 0.02 [f]	0.72 ± 0.01 [e]	1.24 ± 0.01 [d]	0.86 ± 0.00 [e]	1.02 ± 0.01 [d]	2.01 ± 0.05 [b]	1.64 ± 0.02 [c]	2.06 ± 0.02 [b]
Quality indexes										
CQI	0.33 ± 0.02 [c]	0.19 ± 0.00 [d]	0.15 ± 0.00 [e]	0.14 ± 0.00 [e]	0.18 ± 0.01 [d]	0.18 ± 0.00 [d]	0.35 ± 0.02 [c]	0.30 ± 0.02 [c]	0.54 ± 0.03 [b]	0.64 ± 0.01 [a]
BAI	3.61 ± 0.11 [b]	1.61 ± 0.02 [d]	5.86 ± 0.07 [a]	5.59 ± 0.09 [a]	1.59 ± 0.02 [d]	1.68 ± 0.01 [d]	2.09 ± 0.03 [c]	1.12 ± 0.00 [e]	1.69 ± 0.02 [d]	1.59 ± 0.04 [d]
AI	0.08 ± 0.02 [d]	0.64 ± 0.02 [b]	0.59 ± 0.02 [b]	0.75 ± 0.02 [a]	0.38 ± 0.02 [c]	0.33 ± 0.02 [c]	0.73 ± 0.02 [a]	0.25 ± 0.02 [c]	0.23 ± 0.02 [c]	0.31 ± 0.02 [c]

* Means followed by the same letter in the line do not differ statistically from each other by the Scott-Knott test ($p \leq 0.05$). V = 'BRS Violeta'; VP10 = 'BRS Violeta' + 10% 'JNRX12'; VP30 = 'BRS Violeta' + 30% 'JNRX12'; C = 'BRS Cora'; CP10 = 'BRS Cora' + 10% 'JNRX12'; CP30 = 'BRS Cora' + 30% 'JNRX12'; B = 'Bordô'; BP10 = 'Bordô'+10% 'JNRX12'; BP30 = 'Bordô' + 30% 'JNRX12'.

Nd = not detected. CQI = chemical quality index; BAI = biogenic amine index; AI = amine index.

The dopamine content in the juices was higher than that detected in purple sweet potato. Juices elaborated with 'Bordô' and 'BRS Violeta' plus 10% sweet potato and 'BRS Violeta' plus 30% 'JNRX12' had the highest dopamine content (Table 3). Recent studies associate the dopamine and serotonin synthesis pathways with Covid-19 pathophysiology, since the angiotensin I-converting enzyme 2 (ACE2) gene, which encodes the main SARS-CoV-2 receptor, and the Dopa Decarboxylase (DDC) gene, which encodes the enzyme that catalyzes the biosynthesis of some amines, are similar in terms of co-expression and co-regulation in non-neuronal cell types (Attademo & Bernardini, 2021).

Serotonin formation may occur via tryptamine or 5-OH-tryptophan. Tryptamine, one of the substrates for the formation of serotonin, occurs in higher levels in sweet potatoes (14.42 µg/g). The values obtained in this study were higher than those described by (Islam et al., 2016) in raw sweet potato (0.63 µg/g fw). The highest levels of 5-OH-

tryptophan were detected in sweet potatoes (87.78 µg/g) and their addition to grape juice promoted a decrease in content, except for ‘BP10’.

A higher serotonin content was detected in sweet potato (10.95 µg/g) than in whole grape juices (0.87, 0.83 and 0.96 µg/g for ‘BRS Violeta’, ‘BRS Cora’ and ‘Bordô’ juices, respectively). The addition of ‘JNRX12’ sweet potato to grape juices promoted an increase in the content of serotonin, regardless of the grape genotype (Table 3). These levels are higher than those found by Islam et al. (2016) for wine grapes and raw sweet potatoes. It is also worth stressing out that serotonin is essential for regulating metabolic and physiological processes such as appetite, anxiety, sleep, mood and blood pressure (Strasser et al., 2016).

Tryptophan is the precursor of serotonin and melatonin and its ingestion is important for several metabolic processes, mainly related to mood (Islam et al., 2016). Mixed juices of ‘BRS Cora’ and ‘Bordô’ with 30% sweet potato had higher levels of tryptophan (155.82 and 109.47 µg/mL, respectively) than whole juices. Islam et al. (2016) detected 5.04 µg/g of tryptophan in red grapes (*Vitis vinifera*) and 12.81 µg/g in sweet potatoes, values lower than those found in ‘JNRX12’ and mixed juices. This difference may be attributed to the different genotypes, as to crop management, to climate and to the processing method. According to (Strasser et al., 2016), the recommended daily intake of L-tryptophan is 5 mg/kg body weight, which confirms that the juices elaborated can be considered important sources of L-tryptophan.

Melatonin was detected at higher levels in sweet potato, highlighting that the addition of sweet potato to grape juice is interesting to enrich the product (Table 3). It is worth pointing out that this result is quite interesting, since it shows the importance of using purple sweet potato as a source of melatonin (28687.16 ηg/mL) for the preparation of mixed beverages, mainly with grape juice. In grape juices elaborated from 'BRS

Violeta' no melatonin was detected, while in 'BRS Cora' and 'Bordô', the levels were lower (2.21 and 1.14 ηg/mL) compared to those juices that contained sweet potato (Table 3), inducing a dilution of melatonin level. Mercolini, Mandrioli, & Raggi (2012) reported values of 0.5 ηg/mL in grape juices. Intake of melatonin has recently been associated with the reduction of oxidative stress caused by infection with the coronavirus, due to its immuno-responsive effects, by increasing the activity of antioxidant enzymes and binding up to 10 free radicals per molecule, in addition to showing high bioavailability in the human body (Gurunathan et al., 2021). Furthermore, extrapineal melatonin has been described as a possible therapy or prophylaxis for insulin resistance, in addition to presenting characteristics such as anti-oxidant, anti-inflammatory chronobiotic and possibly as an epigenetic regulator (Korkmaz et al., 2009). A brief review of the literature demonstrates that doses are different depending on the purpose, i.e., as an antioxidant, melatonin can be used in doses between 10 - 100 mg per day (Leonardo-Mendonça et al., 2017; Kennaway, 2020). In postmenopausal women with osteopenia, daily doses between 1 to 3 mg can be used to improve sleep quality (Amstrup et al., 2015).

The ‘JNRX12’ showed the highest levels of histamine (0.60 µg/mL) and tyramine (1.55 µg/mL) when compared to whole and mixed grape juices. Both monoamines are described to induce allergic processes, nausea, heart palpitations and migraines, and these effects can be caused by low activity of drug-induced aminooxidases or genetic predisposition (Veciana-Nogués, Mariné-Font, & Vidal-Carou, 1997). In our study, the levels detected do not exceed those described as toxic. Histamine levels greater than 500 mg/L can cause disturbances, manifested as urticarial, vomiting, fevers and hypertension, among others (Papageorgiou et al., 2018). In European countries,

harmful histamine consumption values are those in the range of 2 to 10 µg/mL in wines (Landete et al., 2005), higher than those found for the studied juices.

Both putrescine and cadaverine can potentiate the effects of histamine and tyramine by inhibiting the action of oxidative enzymes (Papageorgiou et al., 2018). Putrescine levels were higher in sweet potato (1.10 µg/g) than in whole or mixed grape juices. The highest levels of cadaverine were verified in juices elaborated with 'BRS Cora' or 'Bordô' grapes and sweet potato. Although the presence of this diamine in foods and beverages indicates contamination by microorganisms (Gomez et al., 2020), cadaverine has the ability to eliminate free radicals (Papageorgiou et al., 2018), highlighting the importance of ingesting this diamine at levels considered to be safe. Despite few studies in humans, the literature shows a non-observed adverse effect level (NOAEL) of 2000 ppm (180 mg/kg body weight/day) (established in Wistar rats) for both putrescine and cadaverine (Til et al., 1997; EFSA, 2011). The intake of foods such as cheese, fermented sausages, fish and fish products can be harmful to health, as they may contain levels higher than the lowest adverse effect level (LOAEL) of putrescine or cadaverine (LOAEL / putrescine = 10 mM, equivalent to 881.50 mg/kg and LOAEL / cadaverine = 5 mM, equivalent to 510.89 mg/kg) as described by del Rio et al. (2019) in the intestinal cell line HT29 (ECACC 91072201). In our mixed beverages, we found no putrescine or cadaverine levels that induce hazard to health.

The polyamines spermidine and spermine were detected at a higher level in sweet potato compared to whole or mixed juices (Table 3). Spermine and spermidine are described as antioxidants and are involved in cell division, growth and differentiation processes (Diamante et al., 2019). Even though juices are a good source of spermidine and spermine, due to their relationship with cell division, people with cancer problems should avoid high levels of both polyamines (Papageorgiou et al., 2018). On the other

hand, spermidine is an important amine and moderate consumption (0.05% of total daily nitrogen intake) of it can improve trauma treatment by improving the rate of protein absorption and decreasing glutamine depletion (Larqué et al., 2007).

Agmatine has therapeutic potential for depression and comorbidities associated with depression, Alzheimer's disease and alcoholism (Moretti et al., 2015). Studies demonstrated that the ingestion (orally) of doses of 0.0001 – 1 mg/kg promoted an antidepressant effect in an animal model, suggesting that the ingestion of agmatine may contribute to the reduction of symptoms related to Parkinson's disease (Moretti et al., 2015). Thus, ingesting 100 mL of mixed juice of 'Bordô' with sweet potato can provide up to 0.02 mg of agmatine, or 0.0003 mg/kg for a person with an average weight of 60 kg.

For better visualization of the data distribution of amino compounds in sweet potato and in juices, PCA was performed (Fig. 3), which explained 80.55% of the data variance. PC1 explained 55.16% of the data variance and grouped the 'JNRX12' (PC1+) away from the whole and mixed juices (PC1−). The amines spermine, serotonin, melatonin, tryptamine, histamine, agmatine, putrescine and spermidine and the amino acid 5-hydroxytryptophan were grouped with purple sweet potato (PC1+), indicating the highest content of these compounds in the tubers. Whole and mixed grape juices were grouped with the amines tyramine, dopamine, and cadaverine and with the amino acid tryptophan (PC1−), indicating a higher content in juices than in sweet potato (Table 3). PC2 was responsible for grouping the amines of the grape juices. Juices elaborated with 'BRS Violeta', regardless of the sweet potato concentration, were grouped in PC2+, due to the dopamine content. The mixed juices of 'BRS Cora' and 'Bordô' with 10% and 30% of 'JNRX12' and the juices of 'BRS Cora'

grapes were grouped in PC2− as they presented a higher content of tryptophan and cadaverine (Table 3).

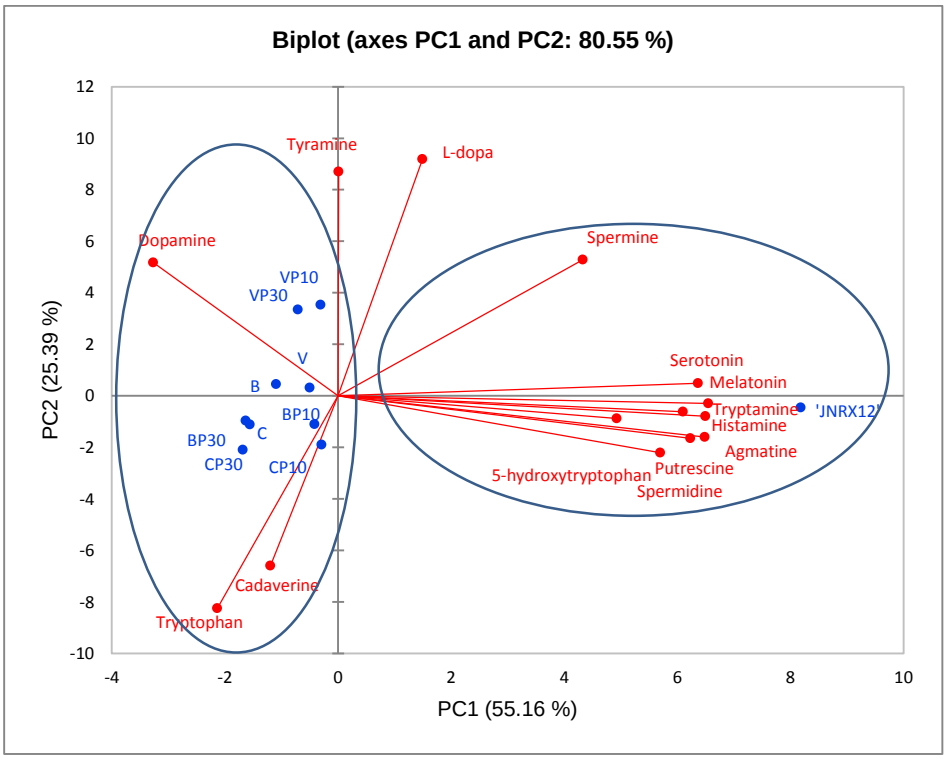


Fig. 3. Two-dimensional projection and scores from biogenic amines of purple pulp and sweet potato mixed grape and sweet potato juices ‘JNRX12’. Treatments are represented by dots, where V=’BRS Violeta; VP10=’BRS Violeta’+10% JNRX12; VP30= ’BRS Violeta’+30% JNRX12; C=’BRS Cora’; CP10= ’BRS Cora’+10% JNRX12; CP30= ’BRS Cora’+30% JNRX12; B= ‘Bordô’; BP10 = ‘Bordô’+10% JNRX12; BP30 = ‘Bordô’+30% e ‘JNRX12’.

The quality index (CQI) was calculated in order to verify the food safety of whole and mixed juices (Table 3). The CQI found for all combinations were within the limits considered acceptable (between 0 and 1). Assessed by BAI, the combinations of ‘BRS Violeta’ juice and purple-fleshed sweet potato (10% and 30%) fell into the ‘intermediate’ category, while the other treatments were classified as acceptable. The mean AI values found for all juices and sweet potato were considered desirable (values

< 1.0) and the mixed juices composed of ‘BRS Violeta’ and ‘BRS Cora’ grapes plus 30% purple-fleshed sweet potato were those that had values closer to 1.0. In general, the ‘JNRX12’ sweet potato and the mixed and whole juices presented quality index values below the levels considered toxic for human consumption. The AI, proposed exclusively for evaluating foods from plant matrices, can be considered a good tool to verify the quality and safety of consumption of these products, with or without processing.

2.4 - Conclusion

The addition of purple-fleshed sweet potato to ‘BRS Violeta’, ‘BRS Cora’ or ‘Bordô’ grape juice improved the sensory attributes (less acidic beverage), increased levels of phenolic compounds (e. g. anthocyanins, phenolic acids and flavonols) and decreased levels of undesirable biogenic amines (e.g. histamine, tyramine, putrescine and cadaverine). Therefore, the inclusion of ‘JNRX12’ providing considerable amounts of essential amino acids and beneficial amines (e.g. tryptophan, melatonin and serotonin), when compared to whole grape juices, regardless of genotype. All juices elaborated with ‘BRS Violeta’ had a high phenolic potential and can be used as sources of antioxidant compounds in food and nonfood industries (e. g. pharmaceutical, cosmetic and chemical industries), since they were the least appreciated sensory. ‘Bordô’ grape juices, in the whole and mixed versions with 10% of ‘JN RX 12’ were the most appreciated sensory and have bioactive potential and high levels of spermidine. Mixed ‘BRS Cora’ and sweet potato juices are less acidic and become more appreciated by the consumer. ‘BRS Cora’ with 30% of sweet potato was the most interesting beverage because it pleased consumers in all sensory aspects, maintained

higher levels of phenolic compounds than the 'Bordo' grape juices and showed higher levels of tryptophan and melatonin. Purple-fleshed sweet potatoes and grapes are distinct plant matrices that share high levels of bioactive compounds. Together in an innovative and easy-to-prepare product, these mixed juices could be an interesting option for the industry and, consequently, for consumers. Furthermore, these mixed beverages are sustainable and profitable options, as they become a destination for waste from the sweet potato production chain.

Conflict of interest statement

Authors declare no conflict of interest.

Author contributions

Letícia Silva Pereira Basílio: Conceptualization, Data curation, Formal analysis, Investigation, Methodology, Writing - original draft. **Cristine Vanz Borges**: Data curation, Methodology, Writing - original draft and Writing - review & editing. **Igor Otavio Minatel**: Methodology, Investigation and Validation. **Pablo Forlan Vargas:** Methodology, Investigation and Validation**. Marco Antonio Tecchio:** Methodology, Investigation and Validation. **Fabio Vianello**: Conceptualization, Writing - review & editing. **Giuseppina Pace Pereira Lima**: Conceptualization, Supervision, Resources, Investigation, Methodology, Writing - original draft and Writing - review & editing.

Acknowledgment

The authors gratefully acknowledge the support by São Paulo Research Foundation (FAPESP - Brazil) (grants 2016/22665-2 and 2019/27227-1) and National Council for Scientific and Technological Development, Brazil (CNPq) (grants 307571/2019-0 and 201218/2020-8).

References

Attademo, L., & Bernardini, F. (2021). Are dopamine and serotonin involved in COVID-19 pathophysiology? *European Journal of Psychiatry*, *35*(1), 62–63. https://doi.org/10.1016/j.ejpsy.2020.10.004

Basílio, L. S. P.; Borges, C. V.; Vargas, P. F.; Fernades, A. M.; Camargo, J. P. C.; Belin, M. A. F.; Ferrarini, M. E. H.; Lima, G. P. P. (2020). Potential of colored sweet potato genotypes as source of bioactive compounds. *Revista Iberoamericana de Tecnología Postcosecha*, *21*(2).

Benzie, I. F. F., & Strain, J. J. (1996). The Ferric Reducing Ability of Plasma (FRAP) as a Measure of "Antioxidant Power": The FRAP Assay. *Analytical Biochemistry*, *239*(1), 70–76. https://doi.org/10.1006/abio.1996.0292

Borges, C.V., Belin, M. A. F., Amorim, E. P., Minatel, I. O., Monteiro, G. C., Gomez Gomez, H. A., Monar, G. R. S., & Lima, G. P. P. (2019). Bioactive amines changes during the ripening and thermal processes of bananas and plantains. *Food Chemistry*, *298*. https://doi.org/10.1016/j.foodchem.2019.125020

Borges, C. V., Maraschin, M., Coelho, D. S., Leonel, M., Gomez, H. A. G., Belin, M. A. F., Diamante, M. S., Amorim, E. P., Gianeti, T., Castro, G. R., & Lima, G. P.

P. (2020). Nutritional value and antioxidant compounds during the ripening and after domestic cooking of bananas and plantains. *Food Research International*, *132*(February), 109061. https://doi.org/10.1016/j.foodres.2020.109061

Brand-Williams, W., Cuvelier, M. E., & Berset, C. (1995). Use of a free radical method to evaluate antioxidant activity. *LWT - Food Science and Technology*, *28*(1), 25–30. https://doi.org/10.1016/S0023-6438(95)80008-5

Diamante, M. S., Borges, C. V., Bartira, M., Minatel, I. O., Corrêa, C. R., Alonzo, H., Gomez, G., Pace, G., & Lima, P. (2019). *Bioactive Amines Screening in Four Genotypes of Thermally Processed Cauliflower*. 1–16.

Dludla, P. V., Nkambule, B. B., Jack, B., Mkandla, Z., Mutize, T., Silvestri, S., Orlando, P., Tiano, L., Louw, J., & Mazibuko-Mbeje, S. E. (2019). Inflammation and oxidative stress in an obese state and the protective effects of gallic acid. *Nutrients*, *11*(1). https://doi.org/10.3390/nu11010023

Dutra, M. da C. P., Viana, A. C., Pereira, G. E., Nassur, R. de C. M. R., & Lima, M. dos S. (2021). Whole, concentrated and reconstituted grape juice: Impact of processes on phenolic composition, “foxy” aromas, organic acids, sugars and antioxidant capacity. *Food Chemistry*, *343*(October), 128399. https://doi.org/10.1016/j.foodchem.2020.128399

Galanakis, C. M. (2013). Emerging technologies for the production of nutraceuticals from agricultural by-products: A viewpoint of opportunities and challenges. In *Food and Bioproducts Processing* (Vol. 91, Issue 4, pp. 575–579). https://doi.org/10.1016/j.fbp.2013.01.004

Giusti, M. M., & Wrolstad, R. E. (2001). Characterization and Measurement of Anthocyanins by UV - Visible Spectroscopy Characterization and Measurement

of Anthocyanins by UV-Visible Spectroscopy. *Current Protocols in Food Analytical Chemistry*, *August 2001*, 0–13. https://doi.org/10.1002/0471142913.faf0102s00

Glories, Y. (1984). La couleur des vins rouges. Mesure, origine et interprétation. *Connaissance de La Vigne et Du Vin*, *18*(4), 253–271.

Gomez-Gomez, H. A., Minatel, I. O., Borges, C. V., Marques, M. O. M., Silva, E. T. da, Monteiro, G. C., Silva, M. J. R. da, Tecchio, M. A., & Lima, G. P. P. (2018). Phenolic Compounds and Polyamines in Grape-Derived Beverages. *Journal of Agricultural Science*, *10*(12), 65. https://doi.org/10.5539/jas.v10n12p65

Gomez, H. A. G.; Marques, M. O. M.; Borges, C. V.; Minatel, I. O.; Monteiro, G. C.; Ritschel, P. S.; Zanus, M. C.; Diamante, M. S.; Kluge, R. A.; Lima, G. P. P. (2020). Biogenic Amines and the Antioxidant Capacity of Juice and Wine from Brazilian Hybrid Grapevines. *Plant Foods for Human Nutrition*, *75*(2), 258–264. https://doi.org/10.1007/s11130-020-00811-5

Gurunathan, S., Kang, M.-H., Choi, Y., Reiter, R. J., & Kim, J.-H. (2021). Melatonin: A potential therapeutic agent against COVID-19. *Melatonin Research*, *4*(1), 30–69. https://doi.org/10.32794/mr11250081

IAL. (2008). *Métodos físicos-quimicos para análise de Alimentos* (P. Zenebon, O.; Pascuet, N. S.; Tiglea (ed.); 4th ed.). Instituto Adolfo Lutz. https://doi.org/10.1017/CBO9781107415324.004

Islam, J., Shirakawa, H., Nguyen, T. K., Aso, H., & Komai, M. (2016). Simultaneous analysis of serotonin, tryptophan and tryptamine levels in common fresh fruits and vegetables in Japan using fluorescence HPLC. *Food Bioscience*, *13*, 56–59. https://doi.org/10.1016/j.fbio.2015.12.006

Jakobek, L., & Matić, P. (2019). Non-covalent dietary fiber-polyphenol interactions and their influence on polyphenol bioaccessibility. *Trends in Food Science & Technology*, *83*, 235–247.

Landete, J. M., Ferrer, S., Polo, L., & Pardo, I. (2005). Biogenic amines in wines from three Spanish regions. *Journal of Agricultural and Food Chemistry*, *53*(4), 1119–1124. https://doi.org/10.1021/jf049340k

Larqué, E., Sabater-Molina, M., & Zamora, S. (2007). Biological significance of dietary polyamines. *Nutrition (Burbank, Los Angeles County, Calif.)*, *23*(1), 87–95. https://doi.org/10.1016/j.nut.2006.09.006

Lima, M. D. S., Silani, I. D. S. V., Toaldo, I. M., Corrêa, L. C., Biasoto, A. C. T., Pereira, G. E., Bordignon-Luiz, M. T., & Ninow, J. L. (2014). Phenolic compounds, organic acids and antioxidant activity of grape juices produced from new Brazilian varieties planted in the Northeast Region of Brazil. *Food Chemistry*, *161*, 94–103. https://doi.org/10.1016/j.foodchem.2014.03.109

Magalingam, K. B., Radhakrishnan, A. K., & Haleagrahara, N. (2015). Protective Mechanisms of Flavonoids in Parkinson's Disease. *Oxidative Medicine and Cellular Longevity*, *2015*. https://doi.org/10.1155/2015/314560

Meilgaarde, Morten, Civille, Gail Vance, Carr, B. T. V. C. (1999). *Sensory Evalution Techniques* (Vol. 49, Issue 24). CRC press.

Mercolini, L., Mandrioli, R., & Raggi, M. A. (2012). Content of melatonin and other antioxidants in grape-related foodstuffs: Measurement using a MEPS-HPLC-F method. *Journal of Pineal Research*, *53*(1), 21–28. https://doi.org/10.1111/j.1600-079X.2011.00967.x

Messaoudi, O., Gouzi, H., El-Hoshoudy, A. N., Benaceur, F., Patel, C., Goswami, D., Boukerouis, D., & Bendahou, M. (2021). Berries anthocyanins as potential SARS-CoV–2 inhibitors targeting the viral attachment and replication; molecular docking simulation. *Egyptian Journal of Petroleum*, *30*(1), 33–43. https://doi.org/10.1016/j.ejpe.2021.01.001

Mishra, C. B., Pandey, P., Sharma, R. D., Malik, M. Z., Mongre, R. K., Lynn, A. M., Prasad, R., Jeon, R., & Prakash, A. (2021). Identifying the natural polyphenol catechin as a multi-targeted agent against SARS-CoV-2 for the plausible therapy of COVID-19: An integrated computational approach. *Briefings in Bioinformatics*, *22*(2), 1346–1360. https://doi.org/10.1093/bib/bbaa378

Monteiro, G. C., Minatel, I. O., Junior, A. P., Gomez-Gomez, H. A., de Camargo, J. P. C., Diamante, M. S., Pereira Basílio, L. S., Tecchio, M. A., & Lima, G. P. P. (2021). Bioactive compounds and antioxidant capacity of grape pomace flours. In *Lwt* (Vol. 135). https://doi.org/10.1016/j.lwt.2020.110053

Moretti, M., Neis, V. B., Matheus, F. C., Cunha, M. P., Rosa, P. B., Ribeiro, C. M., Rodrigues, A. L. S., & Prediger, R. D. (2015). Effects of Agmatine on Depressive-Like Behavior Induced by Intracerebroventricular Administration of 1-Methyl-4-phenylpyridinium (MPP+). *Neurotoxicity Research*, *28*(3), 222–231. https://doi.org/10.1007/s12640-015-9540-1

Muche, B. M., Speers, R. A., & Rupasinghe, H. P. V. (2018). Storage Temperature Impacts on Anthocyanins Degradation, Color Changes and Haze Development in Juice of “Merlot” and “Ruby” Grapes (Vitis vinifera). *Frontiers in Nutrition*, *5*(October), 1–9. https://doi.org/10.3389/fnut.2018.00100

Oertel, W., & Schulz, J. B. (2016). Current and experimental treatments of Parkinson

disease: A guide for neuroscientists. *Journal of Neurochemistry*, *139*, 325–337. https://doi.org/10.1111/jnc.13750

Papageorgiou, M., Lambropoulou, D., Morrison, C., Kłodzińska, E., Namieśnik, J., & Płotka-Wasylka, J. (2018). Literature update of analytical methods for biogenic amines determination in food and beverages. In *TrAC - Trends in Analytical Chemistry* (Vol. 98, pp. 128–142). https://doi.org/10.1016/j.trac.2017.11.001

Pękal, A., & Pyrzynska, K. (2014). Evaluation of Aluminium Complexation Reaction for Flavonoid Content Assay. *Food Analytical Methods*, *7*(9), 1776–1782. https://doi.org/10.1007/s12161-014-9814-x

Raupp, D. da S., Gardingo, J. R., Schebeski, L. dos S., Amadeu, C. A., & Borsato, A. V. (2009). Processamento de tomate seco de diferentes cultivares. *Acta Amazonica*, *39*(2), 415–421. https://doi.org/10.1590/s0044-59672009000200021

Roidoung, S., Dolan, K. D., & Siddiq, M. (2016). Gallic acid as a protective antioxidant against anthocyanin degradation and color loss in vitamin-C fortified cranberry juice. *Food Chemistry*, *210*, 422–427. https://doi.org/10.1016/j.foodchem.2016.04.133

Sasaki, G. Y. ., Li, J.; Cichon, M. J. ., Kopec, R. E. ., & Bruno, R. S. (2021). Catechin-Rich Green Tea Extract and the Loss-of-TLR4 Signaling Differentially Alter the Hepatic Metabolome in Mice with Nonalcoholic Steatohepatitis. *Molecular Nutrition and Food Research*, *65*(2), 1–28. https://doi.org/10.1002/mnfr.202000998

Silva, G. G., Dutra, M. da C. P., de Oliveira, J. B., Rybka, A. C. P., Pereira, G. E., & dos Santos Lima, M. (2019). Processing methods with heat increases bioactive phenolic compounds and antioxidant activity in grape juices. *Journal of Food*

Biochemistry, *43*(3), 1–10. https://doi.org/10.1111/jfbc.12732

Singleton, V. L., & Rossi, J. A. . J. (1965). Colorimetry of Total Phenolics with Phosphomolybdic-Phosphotungstic Acid Reagents. *Am. J. Enol. Vitic.*, *16*(3), 144–158.

Strasser, B., Gostner, J. M., & Fuchs, D. (2016). Mood, food, and cognition: Role of tryptophan and serotonin. *Current Opinion in Clinical Nutrition and Metabolic Care*, *19*(1), 55–61. https://doi.org/10.1097/MCO.0000000000000237

Veciana-Nogués, M, T.; Mariné-Font, A.; Vidal-Carou, M. C. (1997). Biogenic amines as hygienic quality indicators of tuna. Relationship with microbial counts, ATP-related compounds volatile amines and organoleptic changes. Journal of Agricultural and Food Chemistry, v.45, p.2036-2041. *Journal of Agricultural and Food Chemistry*, *45*, 2036–2041.

CAPÍTULO 3

PERFIL FITOQUÍMICO E ATIVIDADE ANTIOXIDANTE DE BATATAS-DOCES COLORIDAS PROCESSADAS TERMICAMENTE

RESUMO

Os efeitos de métodos caseiros de cocção (e. g. fervura, vapor, forno e micro-ondas) nos teores de compostos bioativos e atividade antioxidante em batatas-doces de polpa colorida (e. g. creme/branca, amarela, laranja e roxa) foram investigados. Em um primeiro momento, dezesseis genótipos foram avaliados por espectrofotometria em relação ao teor de compostos fenólicos totais, flavonoides totais, atividade antioxidantes (DPPH e MDA), carotenoides totais (polpa creme/branca, amarela e laranja) e antocianinas totais (polpa roxa). Destes, cinco genótipos de polpa laranja (‘5623’, ‘LLR15’, ‘3515’, ‘2603’ e ‘Beauregard’) e cinco de polpa roxa (JNRX1’, ‘JNRX2’, ‘JNRX7’ e ‘JNRX12’ e ‘Trabuca’) foram avaliados por HPLC quanto ao perfil de polifenóis, aminas biogênicas e aminoácidos, além de calculado o índice de aminas. A atividade antioxidante de todos os genótipos foi maior após o cozimento. Batatas-doces de polpa laranja possuem maiores teores de compostos fenólicos e carotenoides comparadas a batatas-doces de polpa amarela e branca/creme. Batatas-doces roxas mostraram menor teor de compostos fenólicos quando fervidas em água e assadas diretamente em forno. Batatas-doces laranja cozidas em micro-ondas e forno com proteção de papel alumínio apresentarem maiores teores de ácidos fenólicos, flavonóis, catequina, aminoácidos e aminas benéficas. Maiores teores de bioativos foram encontrados em batatas-doces roxas após cozimento por vapor, micro-ondas e forno com proteção de papel alumínio. Genótipos coloridos mostraram um perfil fitoquímico melhor do que o de genótipos tradicionalmente comercializados e são opções interessantes para produtores, consumidores e indústria.

Palavras-chaves: *Ipomoea batatas* Lam; Compostos Bioativos; Aminas Biogênicas; Cozimento

3.1 - INTRODUÇÃO

A batata-doce (*Ipomoea batatas* Lam.) é uma dicotiledônea da família Convolvulaceae. Devido a sua capacidade de adaptação climática, pode ser cultivada em regiões tropicais, subtropicais e em algumas regiões temperadas (Alam et al. 2016). Em países em desenvolvimento, genótipos de polpa e casca coloridas são utilizados em programas de biofortificação, com destaque às batatas-doces alaranjadas (OLONIYO *et al.*, 2021)

No Brasil, os genótipos de batata-doce polpa creme/branca são tradicionalmente cultivados e comercializados em todas as regiões produtoras (BASÍLIO, Letícia *et al.*, 2022). Contudo, com o crescente interesse da população por uma alimentação diversificada e saudável e com o interesse da indústria de alimentos pela batata-doce como matéria-prima, genótipos coloridos têm despertado o interesse. Batatas-doces de polpa laranja, além de mostrarem elevado valor nutricional, são fontes de β-caroteno, percursor da vitamina A no organismo (OLONIYO *et al.*, 2021). Batatas-doces de polpa roxa também possuem em sua composição bioativos interessantes, com destaque para ácidos fenólicos e antocianinas (Basílio et al. 2022).

Batatas-doces, quando cruas, possuem altos teores de compostos antinutricionais (e. g. oxalatos, taninos, fitatos, saponinas, alcalóides e cianeto de hidrogênio) a depender de condições genéticas e ambientais, que podem dificultar a biodisponibilidade e bioacessibilidade de nutrientes e compostos quando consumidos (Siener; Seidler; Hönow, 2020). O cozimento das raízes é indispensável por eliminar a ação indesejada destes compostos e pode ser realizado por métodos tradicionais de cocção como fervura, vapor, assado e frito ou ainda por aparelhagens modernas como micro-ondas e fritadeira a ar (Hong & Koh 2016). Além disso, a depender do método escolhido, pode ocorrer uma melhor extração dos compostos de interesse (e. g. nutrientes, minerais e fitoquímicos) da matriz celular vegetal ou perdas por lixiviação (Nicoletto, Vianello, Sambo 2018).

Este estudo mostrou o conteúdo de compostos bioativos e atividade antioxidante de genótipos de batata-doce colorida crus e após o cozimento em métodos tradicionais (e. g. fervura, vapor, micro-ondas e forno com e sem embalagem de papel alumínio) além de avaliar o efeito dos processamentos térmicos no perfil de

polifenóis (e. g. ácidos fenólicos, flavonoides, antocianinas), de aminoácidos e de aminas biogênicas e índice de aminas.

3.2 - MATERIAL E MÉTODOS

Os genótipos de batata-doce de polpa roxa ‘JNRX1’, ‘JNRX2’, ‘JNRX7’ e ‘JNRX12’ e ‘Trabuca’ (Figura 1) e de polpa laranja ‘LLR15’ foram adquiridas através de produtores da região de Presidente Prudente – SP (Latitude: 22° 7′ 39″ S, Longitude: 51° 23′ 8″ W, Altitude: 475m). Os genótipos de batata-doce de polpa laranja ‘2913’, ‘3418’, ’3513’, ‘5202’, ‘2603’, ‘5623’, ‘Beaudegard’ e o genótipo de polpa amarela ‘1603’ (Figura 2), foram cultivados em Ilha Solteira (Latitude: 20° 25′ 52″ S, Longitude: 51° 20′ 17″ W, Altitude: 366m). As batatas-doces de polpa branca ‘Canadense’ e ‘Coquinho’ (Figura 3) foram adquiridas em mercado local, oriundas do CEASGEP-Bauru. Após a colheita e transporte, as amostras foram armazenadas em câmara fria (5±1ºC) no Laboratório de Bioquímica Vegetal do Departamento de Ciências Químicas e Biológicas (UNESP – Botucatu) até o início das análises.

Figura 1 - Genótipos de batata-doce de polpa e casca roxa

Figura 2 - Genótipos de batata-doce de polpa laranja e amarela

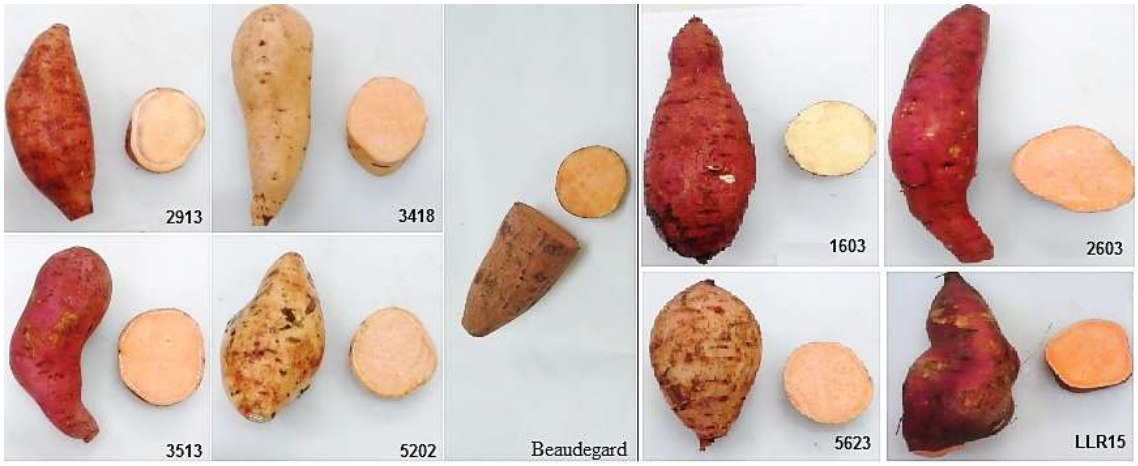
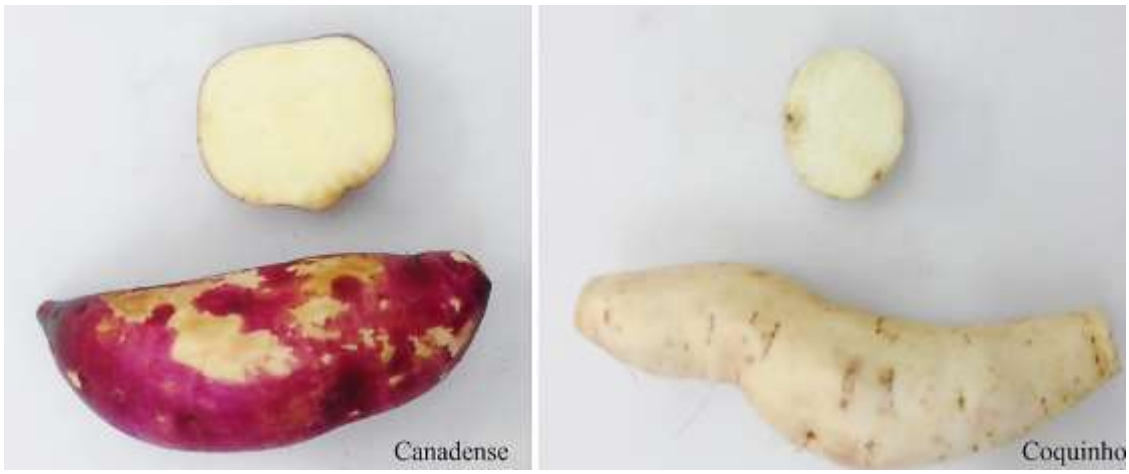


Figura 3 - Genótipos de batata-doce de polpa branca



Após a higienização em água corrente, foram feitos cortes transversais nas raízes, com aproximadamente 1,5 cm de espessura e as partes mais extremas foram descartadas. As batatas-doces não foram descascadas.

Cinco métodos de cocção foram utilizados: cozimento em micro-ondas em embalagem plástica (Mi), vapor (V), fervura em água (Fe), assadas em forno convencional e embaladas em papel alumínio (Fp) e assadas em forno convencional (Fsp). As batatas-doces cruas, de todos os genótipos, foram consideradas o tratamento controle.

O tempo de cocção foi definido como o ponto em que o material não apresente resistência à perfuração por garfo, sendo utilizados 3 minutos para cocção em micro-ondas, 12 minutos para cocção por fervura e vapor e 24 minutos para cocção em forno à 230 º C (embaladas ou não em papel alumínio). Para o tratamento fervura, foram

utilizados 750 ml de água deionizada e para o tratamento vapor, 630 ml. Após o cozimento ou não (controle), as raízes foram maceradas em nitrogênio líquido e armazenadas a – 20ºC para análises de compostos bioativos, que foram realizadas em triplicata.

Em todos os genótipos foram analisados compostos fenólicos totais, flavonoides totais e capacidade antioxidante pelo método de DPPH e MDA. Nas raízes de polpa laranja, foram analisados os carotenoides totais e nos de polpa roxa, as antocianinas monoméricas totais.

O conteúdo de fenóis totais foi analisado por método espectrofotométrico, utilizando como reagente o reativo de Folin Ciocalteu (Singleton & Rossi, 1965). Após o período de incubação, as amostras foram lidas à 725 nm. Os resultados foram baseados em uma curva-padrão e expressos em mg de equivalente de ácido gálico por 100 g^{-1}.

O conteúdo de flavonoides totais foi analisado de acordo com o método adaptado por Pekal et al. (2014)(POPOVA et al., 2004)(POPOVA et al., 2004)(POPOVA et al., 2004)(POPOVA et al., 2004) onde os resultados foram expressos em mg equivalente de rutina por 100 $g^{-1,}$ após a leitura em 510 nm.

A análise de DPPH foi realizada como descrito por Brand-Williams et al. (1995) em espectrofotômetro (517 nm), onde o decaimento da absorbância das amostras correlacionado ao decaimento da absorbância do controle (branco) resultou na porcentagem de sequestro de radicais livres, sendo em seguida convertida em mg de Trolox por 100 g de amostra fresca. O malondialdeído (MDA) foi determinado por metodologia descrita por Heath & Packer (1968) e os resultados foram expressos em nmol TBARS g^{-1}.

As antocianinas monoméricas totais foram determinadas pelo método do pH diferencial (Giusti & Wrolstad 2001) com resultado expresso em mg cianidina-3-o-glicosídeo 100 g^{-1} e os carotenoides totais analisados segundo Lichtenthaler (1987), determinando em espectrofotômetro os teores de clorofila *a*, clorofila *b* e carotenoides totais, expressos em mg por 100 g^{-1}.

As amostras referentes aos cinco genótipos de polpa roxa (‘JNRX1’, ‘JNRX2’, ‘JNRX7’ e ‘JNRX12’ e ‘Trabuca’) e polpa laranja (‘LLR15’, ‘5603’, ‘2603’, ‘Beaudegard’ e ‘3515’) mais representativos quanto ao teor total de compostos fenólicos e atividade antioxidante foram analisados a nível de HPLC em relação ao perfil de polifenóis, aminoácidos e aminas biogênicas, seguindo a metodologia de Borges et al. (2020) e

Diamante et al. (2019), respectivamente. Foi avaliado o índice de aminas biogênicas proposto por Basílio et al. (2022), expresso pela equação:

$$AI = \frac{(\mathbf{histamina} + \mathbf{putrescina} + \mathbf{cadaverina} + \mathbf{tiramina})}{(\mathbf{dopamina} + \mathbf{serotonina} + \mathbf{melatonina} + \mathbf{espermina} + \mathbf{espermidina})}$$

As raízes foram processadas de forma aleatória e as análises foram realizadas em triplicada. Os dados foram submetidos à análise de variância (ANOVA), seguida pelo teste Scott-Knott (agrupamento das médias) ($p < 0,05$), com auxílio do programa SISVAR, comparando os genótipos por cor da polpa. As análises de componentes principais (PCA) foram realizadas através do software XLSTAT (versão 2017; Addinsoft, France).

3.3 - RESULTADOS E DISCUSSÃO

Para estabelecer um modelo descritivo do agrupamento de genótipos de acordo com seus compostos bioativos e processamento térmico, foi aplicada a análise de componentes principais. Em genótipos de polpa creme, amarela e laranja, a PC1 e PC2 corresponderam a 77,89% (Figura 4). O eixo PC1 cobriu 60,52% da variância total dos dados e foi responsável por separar os genótipos pela atividade antioxidante, teor de carotenoides totais e teor de compostos fenólicos.

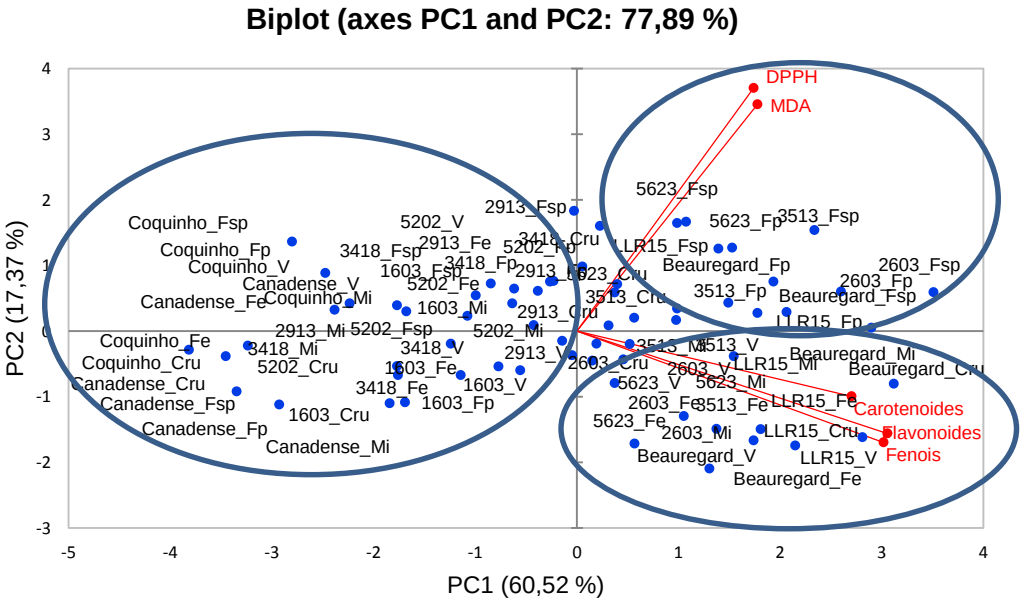
A PC1- agrupou os genótipos de polpa creme ‘Coquinho’ e ‘Canadense’, os de polpa amarela ‘1603’ e ’5202’ e de polpa laranja ‘2913’ e ‘3418’, independente do tratamento térmico. Embora os genótipos de polpa creme sejam os mais comercializados e consumidos no país (Basilio et al, 2022), a presença de pigmentos está ligada a compostos com forte potencial antioxidante, favorecendo a promoção da saúde quando consumidos (DIAMANTE *et al.*, 2021).

Na PC1+ agruparam-se os genótipos de polpa laranja ‘5623’, ‘LLR15’, ‘3515’, ‘2603’ e ‘Beauregard’. ‘Beauregard’ é uma cultivar americana reconhecida pelos altos teores de β-caroteno e potencial na fabricação de alimentos funcionais (HUMIA *et al.*, 2020) confirmado pelo agrupamento na PC1+ e PC2. Normalmente, a coloração alaranjada é associada ao teor de carotenoides na batata-doce. A biodisponibilidade

deste composto pode variar de acordo com fatores genéticos e ambientais, como a época de colheita (SIMOES *et al.*, 2020).

Foi possível observar divisão entre os tratamentos térmicos nos eixos PC2- (Fe, Mi e V) e PC2+ (Fp e Fsp). Os tratamentos que envolveram torrefação se agruparam devido à maior atividade antioxidante. O tempo total de cozimento em forno utilizado neste trabalho, com ou sem proteção, foi maior do que o utilizado nos tratamentos em micro-ondas, vapor e fervura. O ato de cozinhar amolece a parede celular, auxiliando na extração de componentes e favorecendo a atividade antioxidante (Diamante et al, 2021), explicando este resultado.

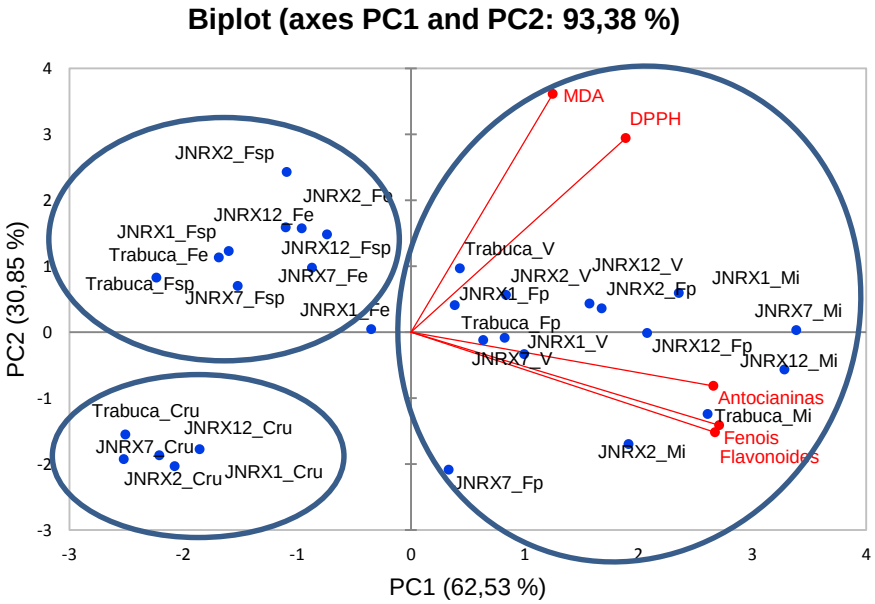
Figura 4 - Projeção bidimensional e pontuações de compostos fenólicos totais (mg EAG 100 mg^{-1}), flavonoides totais (mg ER 100mg^{-1}), carotenoides totais (mg 100 mg^{-1}), capacidade antioxidante pelo método MDA (nmol TBARS g^{-1}) e DPPH (mg trolox 100 mg^{-1}) de genótipos de batatas-doces de polpa branca, amarela e laranja crus e submetidos a tratamentos térmicos. Mi = micro-ondas; V= vapor; Fe= Fervura; Fp = Forno com proteção de papel alumínio e Fsp = forno sem proteção



Na análise de componentes principais dos genótipos de polpa roxa foi ainda mais visível a relação entre o cozimento e o potencial antioxidante (Figura 5). PC1 correspondeu a 62,53% e PC2 a 30,85%, somando 93,38% de precisão. A divisão ocorreu de acordo com a disponibilidade de compostos fenólicos (e. g. fenólicos totais, flavonoides totais e antocianinas totais) e atividade antioxidante.

Os tratamentos controle se agruparam em PC1- , bem como os tratamentos térmicos de fervura e forno sem proteção de papel alumínio, independente do genótipo. Da mesma forma, agrupou-se na PC1+ todos os genótipos tratados termicamente por micro-ondas, vapor e forno com proteção de papel alumínio. Diminuição dos teores de antocianinas (51-81% em relação à amostra crua) nas batatas-doces coreanas de polpa roxa ‘Sinjami’ e ‘Yeonjami’ também foi observado após o cozimento em forno e fervura, exibindo mudanças na coloração após os tratamentos térmicos (Hong & Koh, 2015). Em batatas-doces roxas as antocianinas são os pigmentos majoritários em polpas e cascas (Basilio et al 2020). Antocianinas são sensíveis a mudanças de temperatura (Monteiro et al. 2021) além de altamente hidrossolúveis (GOMEZ-GOMEZ *et al.*, 2018) o que pode explicar menor teor destes compostos quando cozidas em água fervente e forno sem proteção.

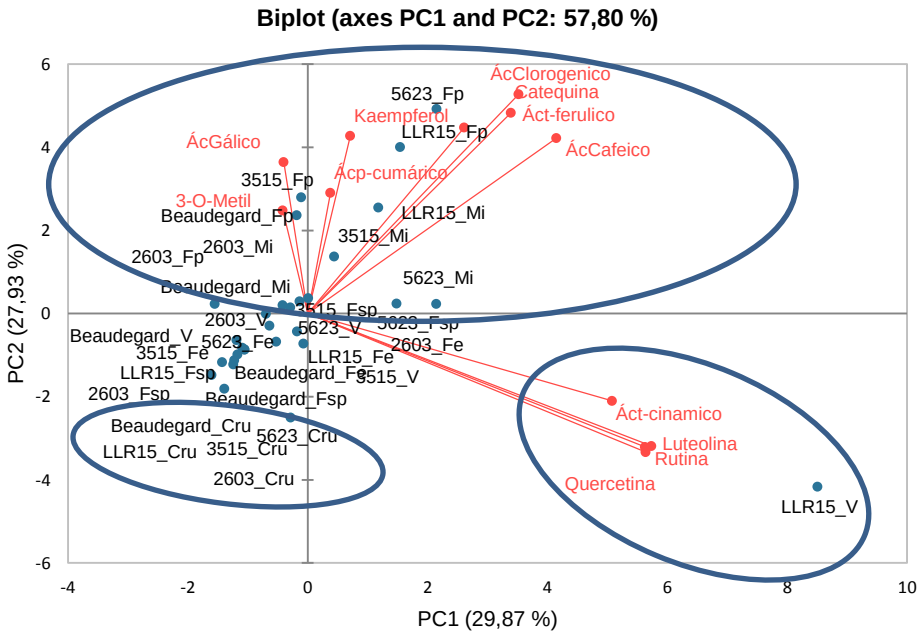
Figura 5 - Projeção bidimensional e pontuações de compostos fenólicos totais (mg EAG 100 mg^{-1}), flavonoides totais (mg ER 100mg^{-1}), antocianinas monoméricas totais (mg 100 mg^{-1}), capacidade antioxidante pelo método MDA (nmol TBARS g^{-1}) e DPPH (mg trolox 100 mg^{-1}) de genótipos de batatas-doces de polpa roxa crus e submetidos a tratamentos térmicos. Mi = micro-ondas; V= vapor; Fe= Fervura; Fp = Forno com proteção de papel alumínio e Fsp = forno sem proteção



Estabelecendo um modelo de agrupamento do perfil de compostos fenólicos de batatas-doces alaranjadas, aplicou-se a PCA, que explicou 57,80% da variância dos dados (Figura 6). Os tratamentos controle, isentos de cozimento, uniram-se na PC2-. O cozimento em vapor do genótipo 'LLR15' favoreceu os teores de ácido *t*-cinâmico, luteolina, rutina e quercetina. O ácido *t*-cinâmico é um poderoso anti-inflamatório e antioxidante (NGUYEN *et al.*, 2021) e a luteolina está associada a propriedades anticancerígenas por induz apoptose (morte celular programada) e inibir a proliferação celular (LIN *et al.*, 2008). Rutina e quercetina, por sua vez, possuem efeitos antioxidantes comprovado contra os danos causados pelo excesso de espécies reativas de oxigênio em pacientes com anemia falciforme (HENNEBERG *et al.*, 2013).

Os genótipos de polpa laranja submetidos ao tratamento térmico por micro-ondas e forno com proteção de papel alumínio agruparam-se na PC2+ por apresentarem maiores teores de ácidos fenólicos (e. g. ácido gálico, ácido clorogênico, ácido *p*-cumárico e ácido *t*-ferúlico), flavonóis (e. g. kaempferol e 3-O-metilquercetina) e catequina. Semelhante ocorreu após torrefação no forno (240° C por 30, 35 e 40 min) das batatas-doces de polpa laranja 'California', 'Beauregard' e 'Covington', que mostraram níveis mais elevados de derivados cafeoilquínicos (e. g. ácido clorogênico) à medida em que aumentava o tempo de cozimento (CARRERA *et al.*, 2021). O consumo de polifenóis oriundos de matrizes vegetais está associado a melhor qualidade de vida. Na população jovem, geralmente influenciada por maus hábitos alimentares, esses compostos atuam na melhoria da plasticidade neuronal através da proteína CREB (Camp Response Element Binding) no hipocampo, responsável pela manutenção das funções cognitivas (CARRILLO; ZAFRILLA; MARHUENDA, 2019).

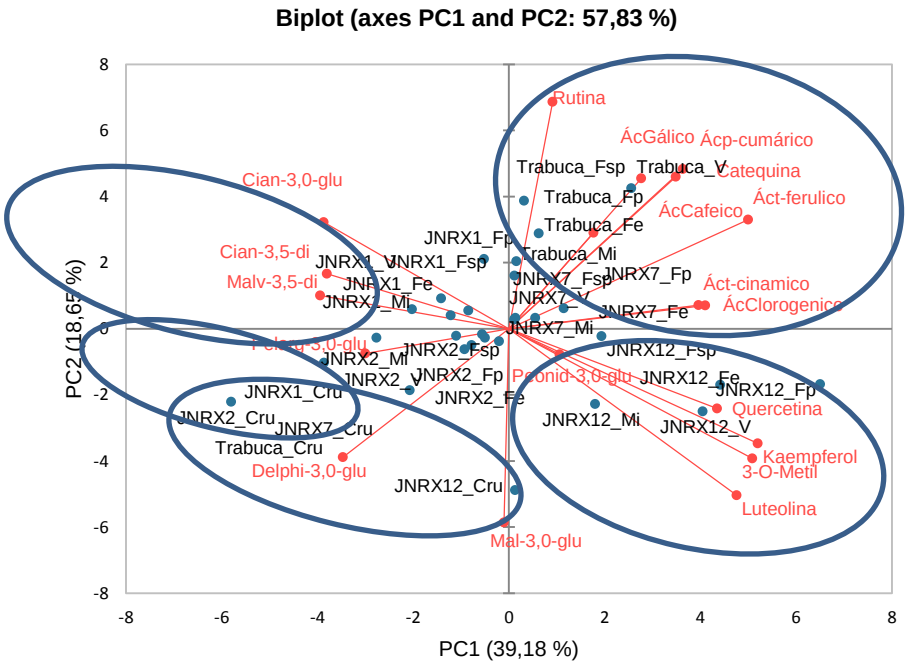
Figura 6 - Projeção bidimensional e pontuações do perfil de compostos de genótipos de batatas-doces de polpa laranja crus e submetidos a tratamentos térmicos. Mi = micro-ondas; V= vapor; Fe= Fervura; Fp = Forno com proteção de papel alumínio e Fsp = forno sem proteção.



A análise de componentes principais aplicada ao perfil de compostos fenólicos em batatas-doces de polpa roxa explicou 57,83% da variância dos dados (Figura 7). Os compostos polifenólicos da batata-doce podem ser separados em duas grandes categorias: flavonoides (e. g. antocianinas) e ácidos fenólicos (KURNIANINGSIH *et al.*, 2020). Avaliando as batatas-doces roxas, observou-se maior afinidade entre os genótipos do que entre os tratamentos térmicos empregados, embora tenha ocorrido um agrupamento dos genótipos crus na PC1+ e PC2-, aparentemente relacionado aos teores de delfinidina-3-O-glucosídeo.

A variabilidade genética pode influenciar em diferentes respostas em relação a disponibilidade de compostos fenólicos após o cozimento, incluindo ácidos fenólicos que são dissolvidos em vacúolos e apoplastos (Nicoletto; Vianello; Sambo, 2017). Os tratamentos térmicos do genótipo ‘JNRX1’ agruparam-se devido aos teores das antocianinas cianidina-3-O-glucosídeo, cianidina-3,5-diglucosídeo e malvidina-3,5-diglucosídeo. O cozimento batatas-doces ‘JNRX2’ fez com que se agregassem pelos teores de pelargonidina-3-O-glucosídeo. Em amostras de ‘JNRX7’e ‘Trabuca’, a presença de maiores teores de ácidos fenólicos (e. g. ácido gálico, ácido *p*-cumárico, ácido *t*-ferúlico, ácido caféico, ácido clorogênico e ácido *t*-cinâmico), rutina e catequina agrupou-os na PC1-/ PC2+. Por fim, os tratamentos em ‘JNRX12’ se agruparam em proximidade aos parâmetros de flavonóis (e. g. quercetina, kaempferol e 3-O-metilquercetina) e luteolina.

Figura 7 - Projeção bidimensional e pontuações do perfil de compostos de genótipos de batatas-doces de polpa roxa crus e submetidos a tratamentos térmicos. Mi = micro-ondas; V= vapor; Fe= Fervura; Fp = Forno com proteção de papel alumínio e Fsp = forno sem proteção.



O método e tempo de cozimento afeta os níveis de aminas biogênicas aumentando ou diminuindo sua disponibilidade, mesmo não sendo consideradas termoestáveis (Borges et al. 2019). Alterações no perfil de aminas foram observadas após o tratamento térmico em batatas-doces de polpa colorida (Tabela 1). Em relação a avaliação geral, o nível de compostos está relacionado ao genótipo avaliado, independentemente da cor da polpa. Não detectamos níveis de cadaverina e melatonina nas amostras de batata-doce laranja.

O processamento térmico por micro-ondas aumentou o nível de histamina, com exceção do genótipo ‘Beauregard’, que foi maior sem tratamento térmico. Este genótipo também foi o único que apresentou maior nível de putrescina quando o genótipo estava cru, já que o teor deste composto foi maior após o cozimento para os outros genótipos avaliados. Todos os genótipos de polpa laranja mostraram teores maiores de tiramina quando cozidos por torrefação em forno sem proteção. Os níveis de histamina e cadaverina nas batatas-doces roxas foram maiores quando fervidas em água (‘JNRX1’

e ‘JNRX7’), micro-ondas (‘JNRX12’) e vapor (‘Trabuca’). Não detectamos cadaverina nos tratamentos do genótipo ‘JNRX2’. Maiores níveis de putrescina foram encontrados após fervura, em todos os genótipos avaliados. Histamina e tiramina, são aminas relacionadas a alergia alimentares enquanto putrescina e cadaverina estão relacionadas à qualidade dos produtos (Gomez-Gomez et al. 2020). São consideradas aminas prejudiciais, pois podem ocorrer reações adversas e até intoxicação se consumidas em teores elevados (PAPAGEORGIOU *et al.*, 2018).

A fervura, processamento térmico comumente utilizado no âmbito doméstico, não interferiu nos níveis gerais de aminas biogênicas em amostras de polpa de laranja. Nestes genótipos, o cozimento por micro-ondas e vapor aumentou os níveis de serotonina e/ou dopamina nos genótipos ‘LLR15’, ‘5623’ e ‘2306’ enquanto em ‘Beauregard’ (Fsp) e ‘3515’ (Fp) a torrefação em forno aumentou a disponibilidade destes compostos. Em genótipos de polpa roxa, o cozimento em forno com proteção (Fp) aumentou o nível de dopamina em todos os genótipos, enquanto a serotonina foi favorecida pelos tratamentos vapor (‘JNRX2’, ‘JNRX12’ e Trabuca) e forno com proteção (‘JNRX1’ e ‘JNRX7’). Serotonina e dopamina são neurotransmissores importantes que atuam na regulação de vias específicas e são responsáveis pelas sensações de prazer e satisfação e alterações neurobiológicas indesejadas (e. g. depressão, ansiedade, bipolaridade) podem ocorrer na ausência destas moléculas (CONIO *et al.*, 2020). A melatonina é uma molécula que regula o ciclo sono e outros ritmos circadianos e sazonais, além de atuar como imunoestimulador e agente citoprotetor (Hardeland, Pandi-Perumal, Cardinali 2006). Neste ensaio encontramos indícios de melatonina apenas no genótipo de polpa roxa ‘JNRX12’ e o cozimento em vapor proporcionou maior teor deste composto.

Os níveis de espermina e espermidina nos genótipos alaranjados apresentaram variação de acordo com o genótipo, sem relações entre o método de preparo. O cozimento no micro-ondas aumenta os níveis de espermidina na maioria das amostras roxas. Em alimentos de origem vegetal é comum que o nível de espermidina seja maior que o de espermina. Ambas são aminas relacionadas ao crescimento e proliferação de células humanas e o consumo dessas aminas é considerado tóxico em teores acima de 60mg/ 100g (Kalač & Krausová 2005) o que não ocorreu neste estudo.

O índice de aminas (IA) sugere que valores próximos a 1,0 são aceitáveis, enquanto valores abaixo de 1,0 são considerados desejáveis (Basílio et al., 2022). Neste estudo, com exceção de 'JNRX1' cozida em micro-ondas (1,24) e fervura (1,01), todos os índices foram considerados desejáveis, mostrando que o balanço entre aminas comumente prejudiciais e aminas promotoras da saúde foi favorável.

Tabela 1 - Aminas biogênicas e índice de qualidade (IA) em batatas-doces de polpa laranja e roxa cruas e submetidas a tratamentos térmicos (mg/100g)

Genótipo	Cozimen	Histamina	Putrescina	Cadaverin	Tiramina	Dopamin	Serotonin	Melatonin	Espermir	Espermidin	IA
LLR15*	Cru	39,3±1,2 fE	66,3±1,6 cI	Nd	1,4±0,1 d	3,3±0,4 eC	11,4±1,1 e	Nd	4,8±0,8 b	4,5±0,2 eC	0,44 c
	Mi	81,3±2,6 bA	101,0±1,4 a	Nd	1,0±0,1 d	4,1±0,6 eI	21,6±1,2 dA	Nd	5,7±1,5 a	5,9±0,1 dB	0,49 c
	V	41,2±1,4 fE	57,1±0,6 dC	Nd	0,3±0,0 d	6,0±0,5 dA	14,6±0,6 e	Nd	3,5±0,5 c	6,0±0,1 dB	0,33 d
	Fe	43,0±1,3 fE	57,3±1,1 dC	Nd	2,9±0,6 d	4,2±0,4 eI	14,0±0,6 e	Nd	3,2±0,4 c	7,7±0,5 cA	0,36 d
	Fp	41,2±1,1 fE	57,4±0,9 dC	Nd	2,9±0,6 d	2,5±0,5 eC	9,5±0,4 eC	Nd	3,7±0,5 c	5,7±0,1 cB	0,48 c
	Fsp	37,8±1,8 fE	56,7±0,2 dC	Nd	3,7±0,5 d	1,8±0,6 eI	6,1±0,2 eI	Nd	3,6±0,1 c	4,8±0,5 dC	0,60 b
5623	Cru	7,3±2,4 hD	36,2±0,2 eC	Nd	0,1±0,0 d	4,7±0,4 eC	19,6±0,3 d	Nd	2,7±0,2 c	6,6±0,1 dC	0,13 fG
	Mi	102,6±2,1 b	84,0±0,3 bI	Nd	0,1±0,0 d	11,2±0,0 c	57,1±0,1 c	Nd	2,3±0,2 d	5,9±0,2 dD	0,24 e
	V	96,3±1,4 bI	98,3±0,1 aA	Nd	1,3±0,4 d	8,2±0,5 dI	31,3±0,1 d	Nd	3,9±0,2 b	8,9±0,2 cA	0,37 d
	Fe	36,2±1,1 fG	30,8±0,3 fG	Nd	0,5±0,0 d	6,4±0,5 dI	9,3±0,4 eI	Nd	5,0±0,1 b	7,1±0,1 cC	0,24 e
	Fp	86,4±1,8 bI	23,9±0,5 fI	Nd	1,1±0,3 d	13,1±0,6 c	6,7±0,6 eI	Nd	3,2±0,1 c	6,8±0,6 dC	0,37 d
	Fsp	114,1±1,6 a	28,8±1,2 fI	Nd	1,5±0,1 d	15,3±0,4 c	17,8±0,4 e	Nd	5,0±0,5 b	7,9±0,5 cB	0,31 d
2306	Cru	37,1±0,2 fI	34,3±0,4 eI	Nd	1,1±0,2 d	2,7±0,3 eC	36,7±0,4 d	Nd	4,4±0,6 b	5,0±0,1 eB	0,15 fG
	Mi	95,2±4,2 aA	67,9±0,6 cI	Nd	0,6±0,0 d	8,9±0,1 dI	73,80±0,6 c	Nd	3,0±0,1 c	4,2±0,2 eC	0,18 e
	V	82,8±1,6 bI	60,5±0,5 dG	Nd	0,7±0,0 d	8,3±1,2 dI	19,7±0,3 d	Nd	3,2±0,6 c	3,9±0,1 eD	0,41 c
	Fe	88,3±2,3 bI	73,7±0,3 cA	Nd	0,4±0,0 d	10,8±1,5 c	29,1±0,4 d	Nd	3,7±0,4 c	5,4±0,2 eB	0,33 d
	Fp	57,6±2,5 dG	68,1±0,2 cI	Nd	1,1±0,5 d	12,4±1,8 c	25,8±0,4 d	Nd	2,1±0,5 d	5,6±0,1 dB	0,28 e
	Fsp	52,2±5,1 eG	34,7±,1 eD	Nd	0,9±0,0 d	2,1±1,1 eC	22,8±0,8 d	Nd	0,6±0,0 e	6,2±0,5 dA	0,28 e
Beaudega	Cru	56,7±4,3 dA	36,9±0,8 eA	Nd	0,4±0,0 dE	14,5±1,6 c	1,9±0,4 eE	Nd	1,3±0,1 e	5,0±0,4 eC	0,42 c
	Mi	14,1±1,2 hI	5,1±0,9 hD	Nd	12,7±1,0 bI	15,3±2,4 c	58,7±1,3 cI	Nd	2,1±0,2 d	23,6±0,2 aA	0,03 g
	V	21,7±1,8 gG	4,0±0,20 hI	Nd	6,5±0,6 cD	15,6±1,4 c	28,6±1,2 dI	Nd	5,1±0,6 b	19,0±0,1 bE	0,05 g
	Fe	19,3±2,1 gG	24,8±0,4 fE	Nd	9,9±0,2 bC	13,4±1,5 c	37,5±1,2 dG	Nd	3,9±0,4 b	3,2±0,5 eD	0,09 g
	Fp	26,0±2,3 gI	29,5±1,2 fE	Nd	12,3±0,2 bI	26,2±2,1 a	87,0±2,6 bA	Nd	4,2±0,2 b	6,9±0,6 dC	0,05 g
	Fsp	23,0±2,2 gI	16,7±0,6 gG	Nd	31,3±1,5 aA	20,3±2,5 b	23,6±2,4 dI	Nd	4,2±0,2 b	15,4±0,5 bE	0,11 fA
3515	Cru	48,9±1,0 eI	82,0±1,6 bG	Nd	1,3±0,6 d	4,8±1,1 eC	1,9±0,1 eI	Nd	5,1±0,1 b	6,3±0,5 dA	0,73 a
	Mi	97,8±0,3 aA	92,0±1,5 aI	Nd	2,1±0,1 d	3,5±0,5 eC	44,0±1,2 d	Nd	6,6±0,2 a	4,9±0,4B	0,33 d
	V	84,6±,3,0 b	85,5±1,1 bG	Nd	1,4±0,1 d	1,3±0,4 eI	68,8±2,3 c	Nd	4,7±0,1 b	3,7±0,1 eC	0,22 e
	Fe	87,3±1,8 bI	102,7±2,0 a	Nd	1,0±0,1 d	10,9±1,3 c	95,7±2,1 b	Nd	6,2±0,1 a	4,7±0,2 eB	0,16 fI
	Fp	11,5±0,5 hI	23,9±2,3 fI	Nd	Nd	3,5±0,4 eC	3,4±0,9 eI	Nd	2,7±0,0 cI	1,8±0,1 eD	0,31 d
	Fsp	67,0±5,1 cG	95,0±5,1 aI	Nd	2,3±0,1 d	19,5±0,5 b	162,2±8,5 a	Nd	2,9±0,1 cI	4,7±0,1 eB	0,09 g
Genótipo	**Cozimen**	**Histamina**	**Putrescina**	**Cadaverin**	**Tiramina**	**Dopamin**	**Serotonin**	**Melatonin**	**Espermir**	**Espermidin**	**IA**
JNRX1	Cru	20,6±0,4 dI	7,8±1,4 hD	5,3±0,4 fD	0,5±0,0 b	3,8±0,5 cI	3,7±0,1 eC	Nd	1,4±0,3 c	2,3±0,5 fD	0,30 e
	Mi	87,3±2,8 cI	83,5±1,8 bA	55,3±1,4 eI	0,4±0,0 b	11,1±0,4 a	2,6±0,1 eC	Nd	0,9±0,0 cI	5,3±0,3 eC	1,24 a
	V	75,4±3,0 cG	22,8±2,0 fE	47,8±0,0 eI	1,8±0,1 b	11,0±0,7 a	10,5±1,5 e	Nd	2,4±0,8 c	7,1±0,0 dB	0,48 c
	Fe	116,6±2,4 b	49,5±2,1 dA	101,3±1,9 bA	0,9±0,0 b	7,7±0,3 bC	10,4±0,3 e	Nd	0,9±0,1 cI	7,4±0,0 dB	1,01 a
	Fp	86,8±1,0 cI	49,1±3,9 dA	98,0±7,1 bA	1,2±0,2 b	12,8±1,2 a	12,6±1,8 e	Nd	2,3±0,9 c	8,4±0,4 dA	0,65 c

	Fsp	45,2±1,6 dE	10,2±2,0 hG	26,3±0,3 eG	3,1±0,5 b	9,1±0,5 bE	1,0±0,0 eE	Nd	1,6±0,3 c	4,4±0,0 eC0,52 c
JNRX2	Cru	70,7±2,1 cC	44,8±1,5 dE	Nd	4,0±1,1 a	12,6±0,8 a	57,9±1,1 c	Nd	4,7±0,6 b	9,6±1,1 dC0,14 e
	Mi	107,2±0,6 b	68,8±0,6 cC	Nd	3,2±0,6 b	12,9±0,2 a	56,0±0,5 c	Nd	7,5±1,3 a	13,8±0,2 bE0,20 e
	V	111,9±1,3 b	73,7±0,4 bC	Nd	4,5±0,5 a	12,4±0,1 a	88,2±0,5 a	Nd	4,4±0,9 b	13,7±0,9 bE0,16 e
	Fe	184,6±4,3 a	114,3±3,9 a	Nd	6,7±0,3 a	12,6±0,3 a	72,6±1,6 b	Nd	1,5±0,2C	16,7±0,6 aA0,29 e
	Fp	133,3±1,1 b	82,7±0,8 bD	Nd	6,5±0,2 a	14,2±0,3 a	51,0±0,5 d	Nd	0,5±0,0 cF	15,3±1,8 aA0,28 e
	Fsp	89,7±0,7 cC	57,3±0,7 cE	Nd	5,4±0,2 a	10,4±0,3 a	47,8±0,4 d	Nd	0,4±0,0 cF	16,2±0,0 aA0,20 e
JNRX7	Cru	22,7±0,3 dE	12,0±1,4 gG	21,2±0,2 eE	4,6±0,4 a	8,1±0,4 bE	7,7±0,2 eC	Nd	0,8±0,1 cF	6,6±1,4 dC0,26 e
	Mi	84,5±1,6 cB	54,0±0,1 dD	63,3±0,4 dA	5,5±0,3 a	14,2±1,2 a	9,2±0,1 eE	Nd	1, 3±0,1 c	12,3±1,7 eA0,56 c
	V	70,8±0,4 cC	8,6±0,6 hD	43,1±0,6 eB	0,5±0,0 b	10,7±0,4 a	7,3±0,3 eC	Nd	2,1±0,1 c	7,9±1,1 dB0,35 e
	Fe	92,6±1,0 cA	61,4±0,6 cA	74,3±0,5 dA	1,8±0,2 b	12,4±0,5 a	6,0±0,1 eE	Nd	0,9±0,3 cF	8,4±0,2 dB0,70 c
	Fp	24,1±2,2 dE	16,7±2,7 gG	19,5±1,7 eE	2,5±0,3 b	17,3±0,2 a	11,3±0,2 e	Nd	1,6±0,0 c	4,9±0,9 eC0,28 e
	Fsp	17,8±3,1 dE	7,9±1,8 hD	29,6±0,2 eG	0,8±0,0 b	7,4±0,3 bE	7,0±0,2 eC	Nd	0,7±0,1 cF	5,6±0,0 eC0,27 e
JNRX12	Cru	118,1±2,1 b	30,3±2,5 eE	100,5±1,0 b	4,9±0,8 a	7,9±0,9 bC	6,0±0,5 eE	8,5±2,3bE	0,4±0,1 c	6,3±0,0 eC0,87 b
	Mi	145,9±1,3 b	25,1±0,1 fG	135,1±1,7 a	2,0±0,4 b	11,1±1,0 a	6,2±0,2 eE	8,3±0,9 bE	1,7±0,1 c	7,4±0,5 dB0,84 b
	V	109,2±1,2 b	20,7±1,2 fG	103,1±0,7 b	2,4±0,0 b	13,4±0,3 a	8,4±,0 eA	10,9±0,7 a	1,2±0,2 c	11,0±0,9 cA0,59 c
	Fe	104,9±4,5 b	36,5±2,1 eA	111,2±1,3 b	0,9±0,1 b	10,6±0,4 a	5,6±0,8 eC	Nd	1,6±0,1 c	5,9±0,2 eC0,80 b
	Fp	78,5±4,3 cC	29,9±3,4 eE	84,8±1,4 cC	1,6±0,1 b	15,2±0,2 a	6,5±0,5 eE	Nd	1,4±0,0 c	6,1±0,4 eC0,67 c
	Fsp	114,9±6,7 b	30,3±1,4 eE	101,3±3,1 b	5,0±0,2 a	11,5±0,1 a	7,3±0,7 eE	6,0±2,9 cC	1,6±0,2 c	8,3±0,3 dB0,70 c
Trabuca	Cru	10,2±0,3 dG	11,0±3,0 hE	Nd	0,5±0,0 b	1,1±0,0 cE	1,4±0,0 eE	Nd	0,5±0,0 c	1,3±0,4 fD 0,51 c
	Mi	29,4±0,9 dE	24,8±1,0 fA	29,0±0,4 eC	6,4±0,6 a	11,5±0,8 a	10,6±0,2 e	Nd	0,6±0,0 c	7,5±1,2 dB0,30 e
	V	109,1±4,2 b	6,3±1,2 hC	87,7±2,2 cA	0,9±0,4 b	9,2±0,3 bE	13,3±0,7 e	Nd	0,6±0,0 c	5,5±0,6 eC0,71 c
	Fe	38,1±1,3 dE	24,0±0,7 fA	32,6±1,7 eC	0,9±0,2 b	6,5±0,6 bC	9,9±0,3 eE	Nd	1,1±0,1 c	5,9±1,3 eC0,41 c
	Fp	30,0±0,6 dE	24,3±2,6 fA	40,2±3,7 eE	2,6±0,1 b	13,1±0,3 a	13,2±0,3 e	Nd	1,3±0,2 c	9,0±0,8 dA0,27 e
	Fsp	22,5±0,5 dE	14,5±2,6 gE	14,5±1,2 fE	1,2±0,4 b	4,2±0,1 cE	7,6±0,2 eC	Nd	0,9±0,0 c	5,6±1,4 eC0,29 e

*Médias seguidas da mesma letra minúscula (todos os tratamentos) e letra maiúscula (genótipos) não diferem estatisticamente entre si. O teste de Scott-Knott foi aplicado ao nível de 5% de probabilidade. Mi = micro-ondas; V= vapor; Fe = fervura, Fp = forno com proteção de papel alumínio; Fsp = forno sem proteção. Nd = não detectado; AI = índice de aminas.

Aminas biogênicas e aminoácidos de matrizes vegetais também exercem um papel interessante como antioxidantes no organismo (Diamante et al., 2019). Houve redução do 5-hidroxitriptofano após o cozimento em todos os genótipos de polpa laranja avaliados. Em batatas-doces roxas, este composto foi maior em amostras cruas apenas para o genótipo ‘JNRX2’ e o cozimento em micro-ondas e forno com proteção favoreceu a disponibilidade nos demais genótipos.

Os níveis de triptofano em batatas-doces de polpa alaranjada foram maiores nos genótipos crus e cozidos por micro-ondas e/ou forno sem proteção de papel alumínio. Em genótipo de polpa roxa, os níveis deste composto foram elevados nos tratamentos crus e cozidos em micro-ondas para os genótipos ‘JNRX1’, ‘JNRX2’ e ‘JNX7’ e apenas nos tratamentos sem cozimento para os genótipos ‘JNX12’ e ‘Trabuca’. Triptofano e 5-hidroxitriptofano não são produzidos em células animais e são precursores de serotonina no organismo (Conio et al., 2020). As batatas-doces avaliadas neste estudo mostraram ser fontes potenciais destes aminoácidos. O consumo destes compostos está associado

a melhorias na função cognitiva, memória, atenção, processamento emocional e desempenho psicomotor (Silber & Schmitt 2010).

Níveis de triptamina foram elevados após o processamento térmico em genótipos de polpa laranja e roxa (Tabela 2). Não houve diferenciação entre os tratamentos para triptamina nos genótipos 'LLR15', '2306', 'Beauregard', 'JNRX12' e 'Trabuca'. O processamento térmico por micro-ondas, vapor e forno sem proteção proporcionou maior teor de triptamina em '5623' e '3515', enquanto o cozimento por vapor e/ou forno com proteção de papel alumínio favoreceu o teor destes compostos nos genótipos roxos 'JNRX1', 'JNRX2' e 'JNRX7'. Estes resultados ressaltam a diversidade das matrizes vegetais estudadas de acordo com o pigmento majoritário, mostrando maior ou menor propensão a extração dos compostos bioativos devido a temperatura. A função biológica da triptamina em plantas não é clara e sugere-se que além de estar presente na rota metabólica da serotonina e melatonina, esta molécula desempenhe papel semelhante ao da auxina e se acumule mais nos frutos do que em outras partes vegetativas (NEGRI *et al.*, 2021).

Os teores de L-dopa também foram maiores nos genótipos de polpa laranja e roxa após o cozimento, com destaque para o processamento térmico em micro-ondas, vapor e torrefação em forno sem proteção de papel alumínio em genótipos alaranjados e com proteção em genótipos roxos. Ao cozinhar um alimento embalado em papel alumínio, a parte opaca emite a radiação que flui da chama para o alimento, em comparação com a face brilhante. Assim, o uso da proteção de papel alumínio na torrefação contribuiu para que compostos de interesse se mantivessem em batatas-doces roxas, mesmo em temperaturas mais elevadas.

Tabela 2 - Aminoácidos em genótipos de batatas-doces de polpa laranja e roxa crus e submetidos a tratamentos térmicos (mg/100g)

Genótipos	Cozimento	5-Hidroxitriptofano	Triptofano	Triptamina	L-dopa (µg/100g)
LLR15*	Cru	694,0±4,0 aA	1192,6±27 aA	37,6±2,4 b^{NS}	88,8±2,7 dB
	Mi	36,3±6,1 dD	1212,8±57 aA	30,9±2,6 c	91,2±3,4 dA
	V	39,6±1,0 dD	979,9±6,3 bC	31,0±2,5 c	72,4±2,5 dC
	Fe	18,4±3,9 eE	929,0±1,6 bC	31,2±2,2 c	73,8±2,1 dC
	Fp	68,3±0,2 dC	1010,4±24 aB	30,8±2,2 c	72,7±2,2 dC

	Fsp	148,9±3,5 cB	1097,1±12 aB	31,2±0,1 c	75,5±2,1 dC
5623	Cru	596,1±2,0 bA	540,8±0,4 dA	37,7±0,5 bB	36,9±1,5 eD
	Mi	44,6±0,4 dB	651,6±6,4 cA	42,1±2,6 aA	29,6±0,4 eD
	V	45,7±0,9 dB	394,1±7,8 eC	41,8±1,1 aA	171,9±0,5 cA
	Fe	36,5±0,7 dC	508,0±2,5 dB	38,1±0,4 bB	92,1±0,6 dC
	Fp	57,6±2,8 dB	399,7±1,5 dC	29,5±2,1 cC	81,7±0,1 dC
	Fsp	66,9±1,7 dB	605,3±11 cA	43,3±1,8 aA	133,5±0,2 cB
2306	Cru	644,2±5,6 bA	838,8±11 bA	25,4±1,6 d^{NS}	24,7±0,6 eC
	Mi	35,6±1,3 dC	517,7±16 dC	27,5±1,4 c	16,4±0,4 eD
	V	57,4±1,8 dB	672,9±14 cB	23,4±1,5 d	23,0±1,1 eC
	Fe	41,7±0,6 dB	765,4±25 cB	20,1±2,4 e	25,5±1,1 eC
	Fp	6,8±0,4 eD	541,7±26 dC	23,8±1,6 d	36,6±0,5 eB
	Fsp	56,3±0,3 dB	806,4±1,1 bA	26,3±0,5 d	45,8±0,4 eA
Beaudegard	Cru	605,1±0,1 bA	633,0±1,1 cA	28,9±0,4 c^{NS}	23,7±0,5 eE
	Mi	33,3±1,2 dD	691,1±24 cA	30,0±0,5 c	313,6±6,4 bB
	V	30,6±1,6 eD	558,4±14 dB	33,1±0,1 c	328,5±5,4 bB
	Fe	24,3±0,9 eD	508,4±25 eB	30,9±0,5 c	67,7±0,5 dD
	Fp	116,8±1,9 cB	529,7±26 dB	33,1±1,3 c	182,0±0,6 cC
	Fsp	50,4±4,3 dC	670,4±25 cA	30,8±1,4 c	412,3±4,7 aA
3515	Cru	637,5±8,1 bA	1154,8±35 aA	29,3±2,4cB	119,2±5,4 cB
	Mi	54,3±5,1 dB	1023,4±36 aA	37,8±3,1 bA	146,2±1,1 cA
	V	53,6±4,5 dB	752,9±28 cB	38,2±2,6 bA	45,1±0,5 eC
	Fe	46,6±1,2 dB	846,6±24 bB	32,5±7,8 cB	53,7±0,1 eC
	Fp	41,8±7,1 dB	284,6±11 eC	16,1±0,5 eC	15,4±0,3 eD
	Fsp	87,2±3,5 dB	690,7±23 cB	38,1±2,4 bA	38,8±5,1 eC

Genótipos	**Cozimento**	**5-Hidroxitriptofano**	**Triptofano**	**Triptamina**	**L-dopa (µg/100g)**
JNRX1	Cru	225,9±3,2 dD	692,8±7,6 bA	22,8±0,3 eB	33,8±0,8 cE
	Mi	425,1±5,1 cC	715,4±4,1 bA	22,8±0,5 eB	26,9±0,9 cE
	V	554,3±1,9 bB	627,4±1,7 cB	21,7±0,1 eC	87,0±2,3 bB
	Fe	503,5±4,6 bC	409,5±7,6 dC	17,1±0,6 fD	52,4±0,1 cC
	Fp	679,5±4,2 aA	541,9±4,7 dB	62,2±3,8 aA	100,5±0,5 bA
	Fsp	559,2±6,2 bB	398,3±1,4 dD	20,2±0,2 fC	41,0±0,8 cD
JNRX2	Cru	375,6±0,7 cA	361,8±1,2 eA	29,0±0,9 cC	77,5±1,8 bD
	Mi	11,2±0,3 eD	359,4±2,1 eA	29,0±0,3 cC	87,8±3,7 bC
	V	67,7±0,4 eC	248,5±0,8 eB	35,3±0,3 bA	87,5±1,1 bC
	Fe	89,6±0,6 eB	255,6±3,8 eB	31,9±0,1 bB	94,8±1,1 bB
	Fp	10,1±0,1 eD	253,2±0,5 eB	35,3±1,5 bA	107,2±2,5 bA
	Fsp	15,2±0,5 eD	259,1±3,1 eB	29,6±0,1 c eC	109,6±3,1 bA
JNRX7	Cru	456,3±5,0 c*B*	848,9±1,2 aA	21,6±2,8 eC	114,6±3,5 bB
	Mi	341,5±4,6 dC	855,7±6,1 aA	19,4±0,1 fC	200,2±2,9 aA
	V	258,0±3,7 dD	673,1±4,4 cD	23,1±0,0 eB	68,8±1,6 bC
	Fe	563,3±4,2 bB	819,5±1,3 aB	23,1±1,1 eB	55,9±0,9 cD
	Fp	701,2±2,3 aA	822,4±6,7 aB	25,6±0,4 eA	45,6±0,8 cE
	Fsp	263,6±4,4 dD	716,5±4,2 bC	21,3±1,9 eC	56,5±0,2 cD
JNRX12	Cru	557,2±3,7 bA	979,9±2,9 aA	18,2±0,8 f^{NS}	55,3±0,4 cD
	Mi	562,5±1,2 bA	865,5±1,9 aC	21,7±0,3 e	35,2±1,0 cD
	V	429,6±1,0 cB	762,6±2,3 bD	19,4±1,6 f	147,2±2,6 aB
	Fe	487,7±1,8 cB	835,3±5,7 aC	18,6±0,1 f	155,8±2,4 aB
	Fp	561,6±1,3 bA	893,9±3,2 aB	22,8±0,6 e	93,7±4,8 bC

	Fsp	370,1±1,4 cC	898,7±1,8 aB	21,5±0,5 e	192,6±4,1 aA
Trabuca	Cru	294,2±4,8 dB	474,4±8,3 dA	24,4±0,1 d^{NS}	20,5±0,3 cC
	Mi	252,4±1,9 dC	326,5±8,3 eB	24,3±1,0 d	98,4±0,7 bA
	V	272,4±5,3 dC	331,9±4,2 eB	23,5±0,5 e	12,5±0,5 cD
	Fe	304,3±5,3 dB	363,9±7,5 eB	22,5±0,5 e	33,7±1,2 cC
	Fp	380,1±3,4 cA	331,0±7,9 eB	24,8±0,0 d	178,0±8,1 aA
	Fsp	233,7±1,1 dC	350,5±8,8 eB	23,4±0,2 e	92,3±1,7 bB

*Médias seguidas da mesma letra minúscula (todos os tratamentos) e letra maiúscula (genótipos) não diferem estatisticamente entre si. O teste de Scott-Knott foi aplicado ao nível de 5% de probabilidade. Mi = micro-ondas; V= vapor; Fe = fervura, Fp = forno com proteção de papel alumínio; Fsp = forno sem proteção. Nd = não detectado

3.4 - CONCLUSÃO

O consumo de batata-doce de polpa colorida após diferentes processamentos térmicos é benéfico à saúde e, além de garantir digestibilidade e palatabilidade, promoveu alterações benéficas nos níveis de polifenóis, aminas biogênicas e aminoácidos promotores da saúde. O uso de água fervente, prática comum de cozimento nos lares, não mostrou aumento de nenhum dos compostos bioativos estudados. Em batatas-doces de polpa laranja, o cozimento em micro-ondas e forno com ou sem proteção de papel alumínio proporcionou maior atividade antioxidante e melhor extração de fitoquímicos (e. g. ácidos fenólicos, flavonóis, aminas biogênicas e aminoácidos). Em genótipos de polpa roxa, maiores teores de bioativos e atividade antioxidante foram encontrados após o processamento térmico por vapor, micro-ondas e forno com proteção de papel alumínio.

REFERÊNCIAS

BASILIO, L. S. P. *et al*. Potential of colored sweet potato genotypes as source of bioactive compounds. **Revista Iberoamericana de Tecnología Postcosecha**, no. 21 (2), p. 1487-1502. 2020.

BASÍLIO, L. S. P. *et al.* New beverage based on grapes and purple-fleshed sweet potatoes: Use of non-standard tubers. **Food Bioscience**, vol. 47, p. 101626, 2022. DOI https://doi.org/10.1016/j.fbio.2022.101626. Available at: https://www.sciencedirect.com/science/article/pii/S2212429222000852.

BASÍLIO, L.; SILVA. *et al.* Pluralidade da batata-doce do campo à mesa: uma revisão narrativa. **Open science research i**. [*S. l.*: *s. n.*], p. 174–190. 2022.

BORGES, C. V. *et al*. Bioactive amines changes during the ripening and thermal processes of bananas and plantains. **Food Chemistry**, vol. 298, p. 125020, 2019. DOI https://doi.org/10.1016/j.foodchem.2019.125020. Available at: http://www.sciencedirect.com/science/article/pii/S0308814619311227.

BORGES, C. V. *et al.* Nutritional value and antioxidant compounds during the ripening and after domestic cooking of bananas and plantains. **Food Research International**, vol. 132, p. 109061, 2020. .

BRAND-WILLIAMS. *et al*. Use of a free radical method to evaluate antioxidant activity. **LWT - Food Science and Technology**, vol. 28, no. 1, p. 25–30, Jan. 1995. https://doi.org/10.1016/S0023-6438(95)80008-5.

CARRERA, C. *et al*. How Different Cooking Methods Affect the Phenolic Composition of Sweet Potato for Human Consumption (Ipomea batata (L.) Lam). **Agronomy**, vol. 11, no. 8, p. 1636, 2021. .

CARRILLO, J. Á.; ZAFRILLA, M. P.; MARHUENDA, J. Cognitive Function and Consumption of Fruit and Vegetable Polyphenols in a Young Population: Is There a Relationship? **Foods**, vol. 8, no. 10, 2019. DOI 10.3390/foods8100507. Available at: https://www.mdpi.com/2304-8158/8/10/507.

CONIO, B. *et al.* Opposite effects of dopamine and serotonin on resting-state networks: review and implications for psychiatric disorders. **Molecular Psychiatry**, vol. 25, no. 1, p. 82–93, 2020. DOI 10.1038/s41380-019-0406-4. Available at: https://doi.org/10.1038/s41380-019-0406-4.

DIAMANTE, M. S. *et al.* Bioactive Amines Screening in Four Genotypes of Thermally Processed Cauliflower. **Antioxidants**, vol. 8, no. 8, p. 311, 2019. .

DIAMANTE, M. S. *et al.* Domestic cooking practices influence the carotenoid and tocopherol content in colored cauliflower. **Food Chemistry**, vol. 340, p. 127901, 2021. .

GIUSTI, M. M.; WROLSTAD, R. E. Characterization and measurement of anthocyanins by UV-visible spectroscopy. **Current protocols in food analytical chemistry**, no. 1, p. F1-2, 2001. .

GOMEZ-GOMEZ, H. A. *et al.* P. Phenolic Compounds and Polyamines in Grape-Derived Beverages. **Journal of Agricultural Science**, vol. 10, no. 12, 2018. .

GOMEZ-GOMEZ, H. A. G. *et al.* Biogenic Amines and the Antioxidant Capacity of Juice and Wine from Brazilian Hybrid Grapevines. **Plant Foods for Human**

Nutrition, vol. 75, no. 2, 2020. https://doi.org/10.1007/s11130-020-00811-5.

HARDELAND, R.; PANDI-PERUMAL, S. R.; CARDINALI, D. P. Melatonin. **The international journal of biochemistry & cell biology**, Netherlands, vol. 38, no. 3, p. 313–316, Mar. 2006. https://doi.org/10.1016/j.biocel.2005.08.020.

HEATH, R. L.; PACKER, L. Photoperoxidation in isolated chloroplasts. **Archives of Biochemistry and Biophysics**, vol. 125, no. 1, p. 189–198, 1968. https://doi.org/10.1016/0003-9861(68)90654-1.

HENNEBERG, R. *et al*. Protective effect of flavonoids against reactive oxygen species production in sickle cell anemia patients treated with hydroxyurea. **Revista brasileira de hematologia e hemoterapia**, vol. 35, no. 1, p. 52–55, 2013. https://doi.org/10.5581/1516-8484.20130015.

HONG, K. H.; KOH, E. Effects of cooking methods on anthocyanins and total phenolics in purple-fleshed sweet potato. **Journal of Food Processing and Preservation**, vol. 40, no. 5, p. 1054–1063, 2016. .

HUMIA, B. V. *et al*. Physicochemical and sensory profile of Beauregard sweet potato beer. **Food Chemistry**, vol. 312, p. 126087, 2020. DOI https://doi.org/10.1016/j.foodchem.2019.126087. Available at: https://www.sciencedirect.com/science/article/pii/S0308814619322368.

KALAČ, P.; KRAUSOVÁ, P. A review of dietary polyamines: Formation, implications for growth and health and occurrence in foods. **Food Chemistry**, vol. 90, no. 1, p. 219–230, 2005. DOI https://doi.org/10.1016/j.foodchem.2004.03.044. Available at: https://www.sciencedirect.com/science/article/pii/S0308814604002961.

KURNIANINGSIH, N. *et al*. The Behavioral Effect of Anthocyanin from Purple Sweet Potatoes on Prenatally Stressed Offspring Mice. **Systematic Reviews in Pharmacy**, vol. 11, no. 10, p. 482–490, 2020. .

LICHTENTHALER, H. K. Chlorophylls and carotenoids: pigments of photosynthetic biomembranes. **Methods in enzymology**. [*S. l.*]: Elsevier, 1987. vol. 148, p. 350–382.

LIN, Y. *et al*. Luteolin, a flavonoid with potential for cancer prevention and therapy. **Current cancer drug targets**, vol. 8, no. 7, p. 634–646, 2008. .

MONTEIRO, G. C. *et al*. Bioactive compounds and antioxidant capacity of grape pomace flours. **LWT**, vol. 135, p. 110053, 2020. .

NEGRI, S. *et al.* The case of tryptamine and serotonin in plants: a mysterious precursor for an illustrious metabolite. **Journal of Experimental Botany**, vol. 72, no. 15, p. 5336–5355, 28 Jul. 2021. DOI 10.1093/jxb/erab220. Available at: https://doi.org/10.1093/jxb/erab220.

NGUYEN, H. C. *et al.* Bioactive compounds, antioxidants, and health benefits of sweet potato leaves. **Molecules**, vol. 26, no. 7, p. 1820, 2021. .

NICOLETTO, C.; VIANELLO, F.; SAMBO, P. Effect of different home-cooking methods on textural and nutritional properties of sweet potato genotypes grown in temperate climate conditions. **Journal of the Science of Food and Agriculture**, vol. 98, no. 2, p. 574–581, 2018. .

OLONIYO, R. O. *et al.* Orange-fleshed sweet potatoes composite bread: A good carrier of beta (β)-carotene and antioxidant properties. **Journal of Food**

Biochemistry, vol. 45, no. 3, p. e13423, 2021. .

PAPAGEORGIOU, M. *et al.* Literature update of analytical methods for biogenic amines determination in food and beverages. **TrAC Trends in Analytical Chemistry**, vol. 98, p. 128–142, 2018. .

PĘKAL, A.; PYRZYNSKA, K. Evaluation of aluminium complexation reaction for flavonoid content assay. **Food Analytical Methods**, vol. 7, no. 9, p. 1776–1782, 2014. .

POPOVA, M. *et al*. Validated methods for the quantification of biologically active constituents of poplar-type propolis. **Phytochemical Analysis: An International Journal of Plant Chemical and Biochemical Techniques**, vol. 15, no. 4, p. 235–240, 2004. .

SIENER, R.; SEIDLER, A.; HÖNOW, R. Oxalate-rich foods. **Food Science and Technology**, vol. 41, p. 169–173, 2020. .

SILBER, B. Y.; SCHMITT, J. A. J. Effects of tryptophan loading on human cognition, mood, and sleep. **Neuroscience & biobehavioral reviews**, vol. 34, no. 3, p. 387–407, 2010. .

SIMOES, A. do N. *et al.* Delaying the harvest induces bioactive compounds and maintains the quality of sweet potatoes. **Journal of food biochemistry**, vol. 44, no. 8, p. e13322, 2020. .

SINGLETON, V.; ROSSI, J. R. Determination of tannins in wines. **J. Enology and viticulture**, vol. 6, no. 3, p. 114, 1965.

CAPÍTULO 4

SWEET POTATO POLYPHENOLS@SAMN COMPLEX – PARCIAL RESULTS

4.1 - INTRODUCTION

Phenolic compounds are formed by plants through reactions of their secondary metabolism and are used to protect the cells and tissues against damages. For plants used as food, phenolic compounds, in addition to protection against various biotic and abiotic conditions, contribute to the food characteristic texture, flavor, aroma, astringency, and color (Huang et al, 2005).

Sweet potato tubers belong to a very diverse group of vegetables that include different colors of peel (white, cream, yellow, orange, pink and red) and flesh (white, cream, orange, yellow and purple). This coloration is generally influenced by the level of metabolites found in the tubers, including phenolic compounds (Basilio et al., 2020) .

Among the natural phenolic compounds, polyphenols are relevant compounds in various industries (e.g., pharmaceutical, chemical, cosmetic, or food industry) and the isolation of these biomolecules from their natural sources is usually performed by methods such as chromatography, electrophoresis, ultrafiltration, or precipitation and solvent extraction (Magro et al., 2014). The use of nanoparticles (SAMNs), which exhibit specific binding properties for polyphenols, may be an interesting and inexpensive alternative for the isolation and subsequent use of phenolic compounds (Magro et al., 2016).

4.2 - MATERIALS AND METHODS

The orange-fleshed sweet potatoes ‘LLR15’, ‘5623’, ‘3515’ and ‘Beaudegard’ (Figure 1) and purple-fleshed sweet potato ‘JNRX1’, ‘JNRX2’,‘JNRX7’, ‘JNRX12’ e ‘Trabuca’ (Figure 2) were harvested in Presidente Prudente, São Paulo, Brazil (22° 7′

39″ S, 51° 23′ 8″ W at an altitude of 475 m). In this study were used SAMN (i.e., surface active maghemite nanoparticles) synthesized in biochemistry laboratory of Department of Comparative Biomedicine and Food Science of Università degli Studi di Padova (UNIPD) in the size range of 10nm.

Sweet potatoes, mostly non-commercial standard, were sliced (3 mm thick) with the skin, lyophilized, and stored at low temperature (4° C).

Figure 1 - Orange fleshed swwet potatoes '3515', 'Beaudegard', '5623' and 'LLR15'.

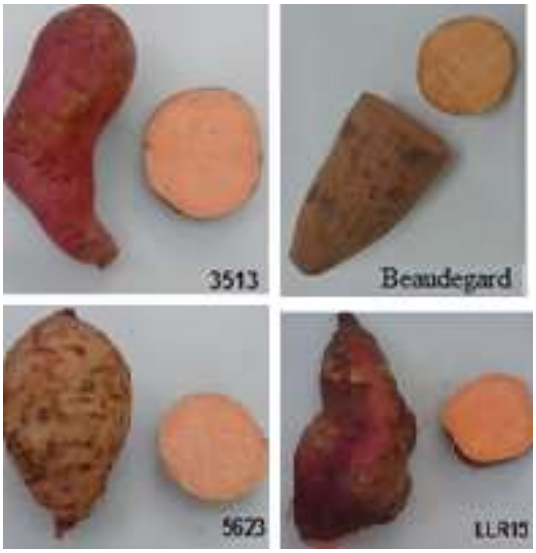


Figure 2 - Purple fleshed sweet potatoes 'JNRX1', 'JNRX2', 'JNRX7', JNRX12' and 'Trabuca'.

The profile of phenolic compounds was analyzed by HPLC. The samples (0,2 mg) were extract in 5 ml of the mobile phase (50% of solvent A: acidified water:trifluoroacetic acid (99.9:0.1, v/v) and 50% of solvent B: 100% acetonitrile) in the proportion of 1:9 (v/v). The phenolic compounds were quantified at 270, 320, 360 and 520 nm and the results expressed in 100 mg/ g.

To prepare the aqueous extracts, the purple-flesh sweet potato and the orange-flesh sweet potato lyophilized powder were dissolved in ultrapure water at 1 mg/mL and 2 mg/mL, respectively. The solutions were mixed for 30 seconds using a vortex and incubated in an ultrasonic bath for 30 minutes. After this, the samples were centrifuged for 5 minutes at 6000 rpm (7000 g) and the supernatant was collected.

A 0.5 g/L suspension of naked SAMNs was prepared and incubated with the recovered supernatant of the colored sweet potato extracts (1 mg/mL for the purple one and 2 mg/mL for the orange one) with continuous stirring at 4°C for 6 hours.

After the incubation period, the nanoparticles were separated by applying an external magnetic field. Two washes were performed with ultrapure water. The amount of phenolic compounds bound to SAMNs was calculated from the disappearance of the absorbance peak in the supernatants at 265 nm, for the orange samples, or 290 nm, for the purple samples. After washing the SAMNs, removal of the adsorbed phenolic compounds was carried out in a solution of ammonia (2 M). Also the fourier-transform infrared spectroscopy (FTIR) assay was performed.

The entire process was carried out in duplicate and the results were expressed as a percentage.

4.3 - PARCIAL RESULTS

Fractions of orange and purple sweet potato phenolic compounds adsorbed on the nanoparticles are reported in Table 1. The content of phenolic compounds in purple samples is higher than the content found in the orange samples (Table 2). This was confirmed once a larger fraction of the purple sweet potato polyphenols interacted with the SAMN surface, compared to the orange sweet potato polyphenols (Table 1).

Table 1 - Percentage of sweet potato phenolic compounds bound on SAMNs.

SP polyphenols@SAMN (%)	
Orange Sweet Potatoes	
LLR15	7,47
O5623	7,11
O3515	3,01
Beaudegard	10,35
Purple Sweet Potatoes	
JNRX1	32,16
JNRX2	20,41
JNRX7	16,47
JNRX12	38,13
Trabuca	4,18

Table 2 - Average contents of phenolic compounds in purple and orange pulp raw sweet potatoes (mg / 100g).

Compounds	JNRX1	JNRX2	JNRX7	JNRX12	Trabuca	Beaudegard	3515	LLR15	5623
Anthocyanins									
Cyanidin 3-O-glucoside	28,71	279,87	27,00	203,34	119,17	-	-	-	-
Cyanidin 3.5-diglucoside	23,10	179,92	25,43	nd	107,75	-	-	-	-
Peonidin 3-O-glucoside	120,92	205,15	151,61	367,50	52,96	-	-	-	-
Delphinidin 3-O-glucoside	231,14	831,36	236,14	352,02	135,24	-	-	-	-
Malvidin 3-O-glucoside	321,53	416,58	493,43	nd	37,63	-	-	-	-
Malvidin 3.5-diglucoside	644,95	252,02	65,82	1490,45	51,46	-	-	-	-
Flavonols									
Rutin	16,19	15,09	14,18	11,20	29,97	nd	nd	nd	1,98
Quercetin	nd	13,04	1,88	36,06	3,60	nd	nd	nd	1,46
3-O-metilquercetin	nd	0,20	0,08	14,79	0,09	nd	1,87	nd	nd
Kaempferol	nd	2,34	0,79	10,09	1,07	nd	5,73	nd	nd
Phenolic acids									
Gallic	53,36	30,58	75,87	69,19	151,96	170,84	270,35	186,40	132,18
p-Coumaric	71,78	39,64	82,24	124,98	12,99	443,27	7,82	10,05	5,54

Caffeic	17,43	15,74	14,77	16,93	5,74	0,00	14,97	9,97	22,29
t-ferulic	33,07	62,13	34,43	247,59	8,24	711,88	103,85	25,17	55,87
t-cinamic	0,10	0,01	0,03	0,77	0,45	0,02	0,04	0,51	0,20
Chlorogenic	213,63	387,20	227,59	1427,55	49,91	769,76	114,43	63,67	148,95
Flavonas									
Luteolin	nd	4,5430	0,9915	37,3573	1,3505	nd	nd	nd	3,8849
Flavan-3-ol									
Catechin	nd	nd	26,02	13,65	31,91	nd	10,75	3,74	1,33

Nd = not detected.

Among oranges sweet potatoes, ‘Beauregard’ (10,35%) is the one with the highest fraction of sweet potato phenolic compounds bound on SAMNs (Figure 3 and Figure 4). Among the purple pulp samples, ‘JNRX12’ (38,13%) phenolic compounds showed the higher percentage of interaction.

Figure 3 - Percentage of removed polyphenols by SAMNs from total sample A) oranges and B) purples sweet potatoes.

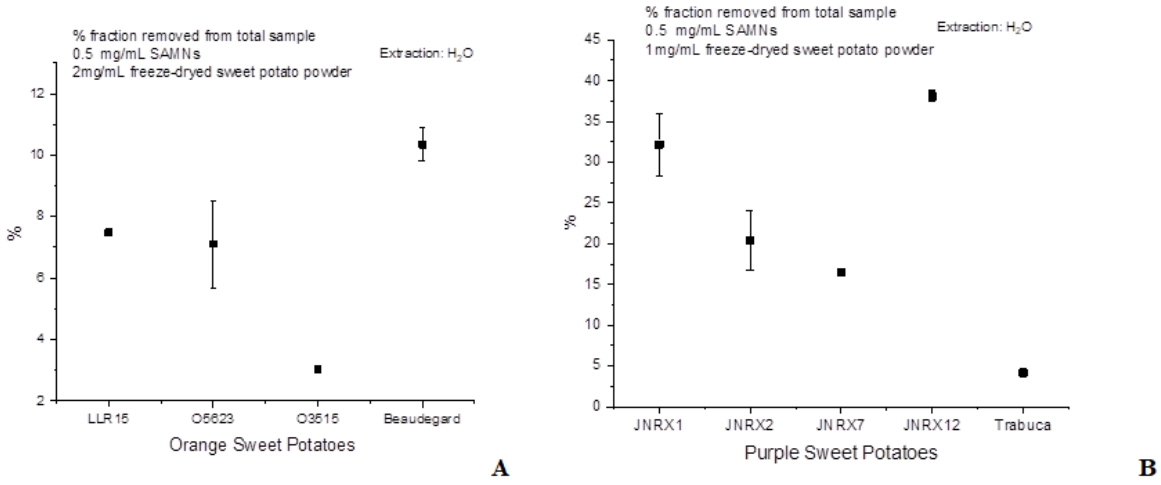
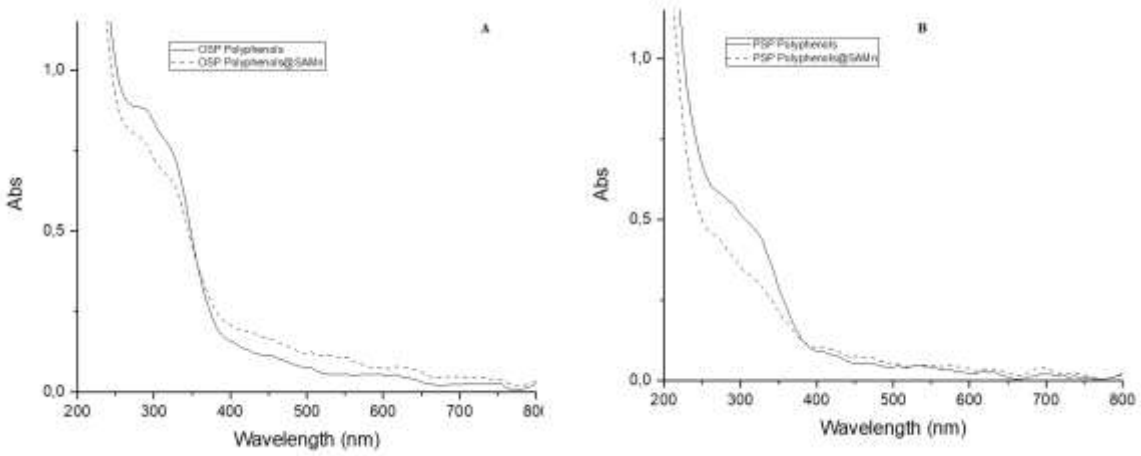


Figure 4 - Scan of orange sweet potato 'Beauregard' polyphenol extract (2mg/ml) and polyphenols@SAMn complex (A) and scan of purple sweet potato 'JNRX12' polyphenol extract (1mg/ml) and polyphenols@SAMn complex (B).



Meanwhile, fourier-transform infrared spectroscopy (FTIR) showed interesting results (Figure 5 and 6).

Figure 5 - FTIR graph of orange sweet potato ('LLR15') phenolic compounds@SAMNs complex

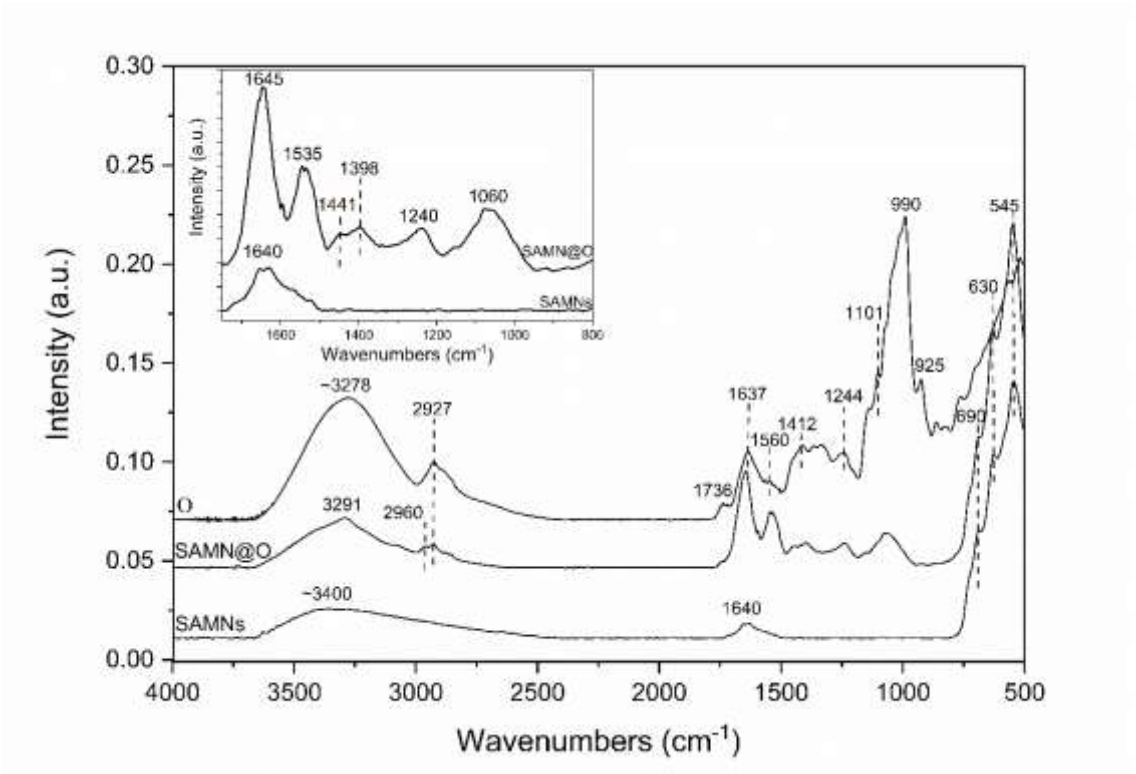
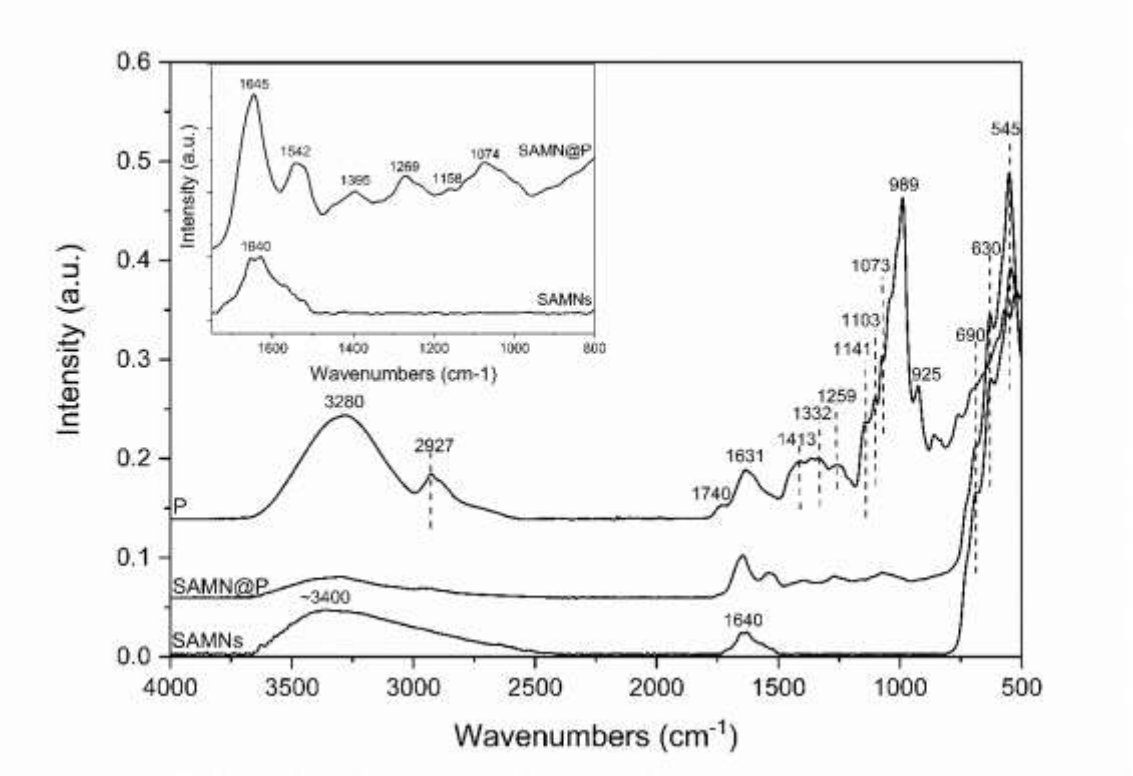


Figure 6 - FTIR graph of purple sweet potato ('JNRX7') phenolic compounds@SAMNs complex



4.4 - CONCLUSION

The sweet potato polyphenols@SAMN complex is effective, regardless of the color of the plant matrix, but sweet potatoes of purplish coloration provided greater interaction with SAMNs.

REFERENCES

BASILIO, L. S. P. *et al*. Potential of colored sweet potato genotypes as source of bioactive compounds. **Revista Iberoamericana de Tecnología Postcosecha**, no. 21 (2), p. 1487-1502. 2020.

HUANG, D.; OU, B.; PRIOR, R. L. The chemistry behind antioxidant capacity assays. **Journal of agricultural and food chemistry**, v. 53, n. 6, p. 1841-1856, 2005.

MAGRO, M. *et al*. A magnetically drivable nanovehicle for curcumin with antioxidant capacity and MRI relaxation properties. **Chemistry–A European Journal**, v. 20, n. 37, p. 11913-11920, 2014.

MAGRO, M. *et al*. Electrocatalytic nanostructured ferric tannates: characterization and application of a polyphenol nanosensor. **ChemPhysChem**, v. 17, n. 20, p. 3196-3203, 2016.

CONSIDERAÇÕES FINAIS

A batata-doce se destaca pela versatilidade no uso, pelo cultivo relativamente fácil, de baixo investimento e pela sua adaptabilidade, o que agrada produtores e comerciantes. A cultura desperta também o interesse de pesquisas voltadas ao melhoramento genético, obtendo sucesso em programas de biofortificação. Na indústria, o amido de batata-doce tem se mostrando uma matéria-prima latente.

Considerando a crescente demanda pelo consumidor por alimentos saudáveis, com propriedades bioativas, a batata-doce torna-se uma hortaliça modelo. Inicialmente, o consumo da raiz era voltado apenas para o suprimento de calorias e hoje é associado a aspectos nutracêuticos embora ainda seja necessária maior divulgação e incorporação de genótipos coloridos na alimentação dos brasileiros.

Além do amido, os compostos fenólicos de batata-doce mostraram-se interessantes para indústria. Nunca houve um estudo a este nível em relação aos compostos fenólicos presentes em batatas-doces, especialmente se tratando de batatas-doces de polpa colorida. Nossa proposta foi explorar através da nanotecnologia todo o potencial destes compostos e sua capacidade de interação com nanopartículas, contribuindo com informações importantes não só para a comunidade científica como para a população em geral.

A cultura possibilita a utilização de toda a planta na fabricação de novos produtos, o que agrega valor e se torna uma prática economicamente viável e sustentável, principalmente considerando o uso de tubérculos fora do padrão.

REFERÊNCIAS

BASILIO, L. S. P. *et al*. Potential of colored sweet potato genotypes as source of bioactive compounds. **Revista Iberoamericana de Tecnología Postcosecha**, no. 21 (2), p. 1487-1502. 2020.

BASÍLIO, L. S. P. *et al*. New beverage based on grapes and purple-fleshed sweet potatoes: Use of non-standard tubers. **Food Bioscience**, vol. 47, p. 101626, 2022. DOI https://doi.org/10.1016/j.fbio.2022.101626. Available at: https://www.sciencedirect.com/science/article/pii/S2212429222000852.

BASÍLIO, L. S. P. *et al.* Pluralidade da batata-doce do campo à mesa: uma revisão narrativa. **Open science research i**. [*S. l.*: *s. n.*], p. 174–190, 2022.

BORGES, C. V. *et al*. Bioactive amines changes during the ripening and thermal processes of bananas and plantains. **Food Chemistry**, vol. 298, p. 125020, 2019. DOI https://doi.org/10.1016/j.foodchem.2019.125020. Available at: http://www.sciencedirect.com/science/article/pii/S0308814619311227.

BORGES, C. V. *et al.* Nutritional value and antioxidant compounds during the ripening and after domestic cooking of bananas and plantains. **Food Research International**, vol. 132, p. 109061, 2020. .

BRAND-WILLIAMS, W. *et al.* Use of a free radical method to evaluate antioxidant activity. **LWT - Food Science and Technology**, vol. 28, no. 1, p. 25–30, Jan. 1995. https://doi.org/10.1016/S0023-6438(95)80008-5.

CARRERA, C. *et al.* How Different Cooking Methods Affect the Phenolic Composition of Sweet Potato for Human Consumption (Ipomea batata (L.) Lam). **Agronomy**, vol. 11, no. 8, p. 1636, 2021. .

CARRILLO, J. Á.; ZAFRILLA, M. P.; MARHUENDA, J. Cognitive Function and Consumption of Fruit and Vegetable Polyphenols in a Young Population: Is There a Relationship? **Foods**, vol. 8, no. 10, 2019. DOI 10.3390/foods8100507. Available at: https://www.mdpi.com/2304-8158/8/10/507.

CONIO, B. *et al.* Opposite effects of dopamine and serotonin on resting-state networks: review and implications for psychiatric disorders. **Molecular Psychiatry**, vol. 25, no. 1, p. 82–93, 2020. DOI 10.1038/s41380-019-0406-4. Available at: https://doi.org/10.1038/s41380-019-0406-4.

DIAMANTE, M. S. *et al*. Bioactive Amines Screening in Four Genotypes of Thermally Processed Cauliflower. **Antioxidants**, vol. 8, no. 8, p. 311, 2019. .

DIAMANTE, M. S. *et al*. Domestic cooking practices influence the carotenoid and tocopherol content in colored cauliflower. **Food Chemistry**, vol. 340, p. 127901, 2021. .

GIUSTI, M. M.; WROLSTAD, R. E. Characterization and measurement of anthocyanins by UV-visible spectroscopy. **Current protocols in food analytical chemistry**, no. 1, p. F1-2, 2001. .

GOMEZ-GOMEZ, H. A. *et al*. Phenolic Compounds and Polyamines in Grape-Derived Beverages. **Journal of Agricultural Science**, vol. 10, no. 12, 2018. .

GOMEZ, H. A. G. *et al.* Biogenic Amines and the Antioxidant Capacity of Juice and Wine from Brazilian Hybrid Grapevines. **Plant Foods for Human Nutrition**, vol. 75, no. 2, 2020. https://doi.org/10.1007/s11130-020-00811-5.

HARDELAND, R.; PANDI-PERUMAL, S. R.; CARDINALI, D. P. Melatonin. **The international journal of biochemistry & cell biology**, Netherlands, vol. 38, no. 3, p. 313–316, Mar. 2006. https://doi.org/10.1016/j.biocel.2005.08.020.

HEATH, R. L.; PACKER, L. Photoperoxidation in isolated chloroplasts. **Archives of Biochemistry and Biophysics**, vol. 125, no. 1, p. 189–198, 1968. https://doi.org/10.1016/0003-9861(68)90654-1.

HENNEBERG, R. *et al*. Protective effect of flavonoids against reactive oxygen species production in sickle cell anemia patients treated with hydroxyurea. **Revista brasileira de hematologia e hemoterapia**, vol. 35, no. 1, p. 52–55, 2013. https://doi.org/10.5581/1516-8484.20130015.

HONG, K. H.; KOH, E. Effects of cooking methods on anthocyanins and total phenolics in purple-fleshed sweet potato. **Journal of Food Processing and Preservation**, vol. 40, no. 5, p. 1054–1063, 2016. .

HUMIA, B. V. *et al*. Physicochemical and sensory profile of Beauregard sweet potato beer. **Food Chemistry**, vol. 312, p. 126087, 2020. DOI https://doi.org/10.1016/j.foodchem.2019.126087. Available at: https://www.sciencedirect.com/science/article/pii/S0308814619322368.

KALAČ, P.; KRAUSOVÁ, P. A review of dietary polyamines: Formation, implications for growth and health and occurrence in foods. **Food Chemistry**, vol. 90, no. 1, p. 219–230, 2005. DOI https://doi.org/10.1016/j.foodchem.2004.03.044. Available at: https://www.sciencedirect.com/science/article/pii/S0308814604002961.

KURNIANINGSIH, N. *et al*. The Behavioral Effect of Anthocyanin from Purple Sweet Potatoes on Prenatally Stressed Offspring Mice. **Systematic Reviews in Pharmacy**, vol. 11, no. 10, p. 482–490, 2020. .

LICHTENTHALER, H. K. Chlorophylls and carotenoids: pigments of photosynthetic biomembranes. **Methods in enzymology**. [*S. l.*]: Elsevier, 1987. vol. 148, p. 350–382.

LIN, Y.; SHI, R.; WANG, X.; SHEN, H.-M. Luteolin, a flavonoid with potential for cancer prevention and therapy. **Current cancer drug targets**, vol. 8, no. 7, p. 634–646, 2008. .

MONTEIRO, G. C. *et al.* Bioactive compounds and antioxidant capacity of grape pomace flours. **LWT**, vol. 135, p. 110053, 2020. .

NEGRI, S. *et al*. The case of tryptamine and serotonin in plants: a mysterious precursor for an illustrious metabolite. **Journal of Experimental Botany**, vol. 72, no. 15, p. 5336–5355, 28 Jul. 2021. DOI 10.1093/jxb/erab220. Available at: https://doi.org/10.1093/jxb/erab220.

NGUYEN, H. C. *et al.* Bioactive compounds, antioxidants, and health benefits of sweet potato leaves. **Molecules**, vol. 26, no. 7, p. 1820, 2021. .

NICOLETTO, C.; VIANELLO, F.; SAMBO, P. Effect of different home-cooking methods on textural and nutritional properties of sweet potato genotypes grown in temperate climate conditions. **Journal of the Science of Food and Agriculture**, vol. 98, no. 2, p. 574–581, 2018. .

OLONIYO, R. O. *et al.* Orange-fleshed sweet potatoes composite bread: A good carrier of beta (β)-carotene and antioxidant properties. **Journal of Food Biochemistry**, vol. 45, no. 3, p. e13423, 2021. .

PAPAGEORGIOU, M. *et al.* Literature update of analytical methods for biogenic amines determination in food and beverages. **TrAC Trends in Analytical Chemistry**, vol. 98, p. 128–142, 2018. .

PĘKAL, A.; PYRZYNSKA, K. Evaluation of aluminium complexation reaction for flavonoid content assay. **Food Analytical Methods**, vol. 7, no. 9, p. 1776–1782, 2014. .

POPOVA, M. *et al*. Validated methods for the quantification of biologically active constituents of poplar-type propolis. **Phytochemical Analysis: An International Journal of Plant Chemical and Biochemical Techniques**, vol. 15, no. 4, p. 235–240, 2004. .

SIENER, R.; SEIDLER, A.; HÖNOW, R. Oxalate-rich foods. **Food Science and Technology**, vol. 41, p. 169–173, 2020. .

SILBER, B. Y.; SCHMITT, J. A. J. Effects of tryptophan loading on human cognition, mood, and sleep. **Neuroscience & biobehavioral reviews**, vol. 34, no. 3, p. 387–407, 2010. .

SIMOES, A. do N. *et al.* Delaying the harvest induces bioactive compounds and maintains the quality of sweet potatoes. **Journal of food biochemistry**, vol. 44, no. 8, p. e13322, 2020. .

SINGLETON, V.; ROSSI, J. R. Determination of tannins in wines. **J. Enology and viticulture**, vol. 6, no. 3, p. 114, 1965. .