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Faculdade de Ciências Biológicas e Ambientais – FCBA

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BIOCONVERSÃO DA POLPA DE BOCAIUVA VERDE POR *Pleurotus ostreatus* PARA OBTENÇÃO DE BOLO *LOW CARB*

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Dourados – MS

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Tese apresentada à Universidade Federal da Grande Dourados (UFGD), como parte dos requisitos exigidos para obtenção do título de DOUTOR em Biotecnologia e Biodiversidade.

Área de Concentração: Biotecnologia e Biodiversidade

Orientador: Dr. Gustavo Graciano Fonseca

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Por

ALINE JANAINA GIUNCO

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RESUMO

GIUNCO, Aline Janaina. Universidade Federal da Grande Dourados, novembro de 2020. **Bioconversão da polpa de bocaiuva verde por *Pleurotus ostreatus* para obtenção de bolo *low carb.*** Orientador: Prof. Dr. Gustavo Graciano Fonseca. Coorientadores: Dr. Marcelo Fossa da Paz e Dr. Fernando Araripe Gonçalves Torres.

A bocaiuva é uma palmeira do cerrado, amplamente distribuída em quase todo o Brasil, sendo abundante no Mato Grosso do Sul e Mato Grosso. A polpa do fruto maduro apresenta características nutricionais, sensoriais e funcionais importantes para a saúde. Contudo é um fruto pouco utilizado na alimentação humana, principalmente no estádio de maturação verde e existe pouca informação sobre as propriedades nutricionais e funcionais desse fruto nas suas diferentes espécies, principalmente da *Acrocomia totai*. Diante disso, o objetivo do estudo foi a bioconversão da polpa de bocaiuva verde por *Pleurotus ostreatus* para obtenção de bolo *low carb*, visando a obtenção de um produto alimentício com propriedades nutricionais, funcionais e sensorialmente aceito pelos consumidores. Na avaliação do crescimento e a composição proximal do cogumelo comestível *Pleurotus ostreatus* em substratos de polpa de bocaiuva verde com diferentes fontes de nitrogênio (8 tratamentos) mostrou que a adição de nitrato de amônio como fonte de nitrogênio no tratamento T3 potencializou a bioconversão de carboidratos da polpa de bocaiúva verde de *Pleurotus ostreatus* em proteínas, fibras e lipídios de valioso potencial nutricional, o que se revela promissor para o desenvolvimento de novos produtos alimentícios com valor nutracêutico agregado. No desenvolvimento e avaliação de bolos com baixo teor de carboidratos produzidos a partir da polpa de bocaiúva verde enriquecida com *pleurotus ostreatus,* mostrou que a farinha de bocaiúva verde enriquecida com *P. ostreatus* pode ser utilizada para o desenvolvimento de bolo *low carb* com componentes nutricionais aprimorados e características sensoriais aceitáveis. Essas informações podem subsidiar estudos sobre as propriedades nutricionais partir da polpa de bocaiúva verde enriquecida com *pleurotus ostreatus,* bem como viabilizar a aplicação biotecnológica e a produção em larga escala das espécies de *Acrocomia*.

Palavras-chave: *Acrocomia*, cogumelo comestível, fonte de nitrogênio, composição proximal e cultivo em estado sólido.

ABSTRACT

GIUNCO, Aline Janaina. Federal University of Grande Dourados, November 2020. **Bioconversion of the green bocaiuva pulp by *Pleurotus ostreatus* to obtain low carb cake.** Advisor: Prof. Dr. Gustavo Graciano Fonseca. Co-supervisors: Dr. Marcelo Fossa da Paz and Dr. Fernando Araripe Gonçalves Torres.

The bocaiuva is a cerrado palm, widely distributed in almost all of Brazil, being abundant in Mato Grosso do Sul and Mato Grosso. The pulp of the ripe fruit has important nutritional, sensory and functional characteristics for health. However, it is a fruit little used in human food, mainly in the stage of green maturation and there is little information about the nutritional and functional properties of this fruit in its different species, mainly of *Acrocomia totai*. Therefore, the objective of the study was the bioconversion of the green bocaiuva pulp by *Pleurotus ostreatus* to obtain a low carb cake, aiming to obtain a food product with nutritional, functional and sensorially accepted by consumers. In the evaluation of the growth and the proximal composition of the edible mushroom *Pleurotus ostreatus* in green pulp substrates with different nitrogen sources (8 treatments) showed that the addition of ammonium nitrate as a nitrogen source in the T3 treatment potentiated the bioconversion of carbohydrates from green bocaiúva pulp of *Pleurotus ostreatus* in proteins, fibers and lipids of valuable nutritional potential, which is promising for the development of new food products with added nutraceutical value. In the development and evaluation of low-carbohydrate cakes produced from the pulp of green bocaiúva enriched with *pleurotus ostreatus*, it showed that the green bocaiúva flour enriched with *P. ostreatus* can be used for the development of low carb cake with enhanced nutritional components and acceptable sensory characteristics. This information can support studies on the nutritional properties of the green pulp of bocaiúva enriched with *pleurotus ostreatus*, as well as enabling the biotechnological application and large-scale production of *Acrocomia* species.

Keywords: *Acrocomy*, edible mushroom, nitrogen source, proximal composition and solid state cultivation.

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5-LOX	arachidonate 5-lipoxygenase
AI	adiposity index
AKI	acute kidney injury
AN	ammonium nitrate
ANOVA	Analysis of variance
AS	ammonia sulphate
BP	green bocaiuva pulp
BPWB	dehydrated green bocaiuva pulp plus wheat bran
COX-2	cyclooxygenase-2
CP	cyclophosphamide
DTF	transverse diameter of the fruit
ED	endocarp mass
EP	epicarp mass
ET	endocarp thickness
F1	Low-carb cake with coconut flour
F2	Low-carb cake with green bocaiuva flour without the increment
F3	Low-carb cake with mushroom enriched green bocaiuva flour and ammonia nitrate
F4	Low-carb cake with green enriched mushroom flour without supplementation
FAO	United Nations Food and Agriculture Organization
FV	fruit volume
GBIF	Global Biodiversity Information Facility
HPD	High protein diets
HPV	papilomavírus humano
LD	oral lethal dose
LDA	longitudinal diameter of the almond
LDF	longitudinal diameter of the fruit
LDL	Low Density Lipoproteins
MA	almond mass

MF	fruit mas
MM	mesocarp mass
N	ammonium nitrate
ND	not determined
Org	Organização
PCV	proximate composition variation
PDA	potato dextrose agar
ST	strength training
T1	dehydrated green bocaiuva pulp and water
T2	dehydrated green bocaiuva pulp and Urea
T3	dehydrated green bocaiuva pulp and ammonium nitrate
T4	dehydrated green bocaiuva pulp and ammonium
T5	green bocaiuva pulp / wheat bran and water
T6	green bocaiuva pulp / wheat bran and urea
T7	green bocaiuva pulp / wheat bran and ammonium nitrate
T8	green bocaiuva pulp / wheat bran and ammonia sulphate
U	urea
WB	wheat bran
WHO	World Health Organization

CAPÍTULO 1

1.1 APRESENTAÇÃO

A estrutura da tese está disposta em capítulos e no formato de manuscrito científico. Assim, este Capítulo 1 traz a introdução geral, justificativa e objetivo do trabalho. No Capítulo 2 é apresentada uma revisão de literatura referente as características, propriedades e potencial de aplicação das espécies de *Acrocomia*. Essa pesquisa mostra que as espécies não têm sido valorizadas quanto ao seu potencial nutricional para formulação de produtos alimentícios, potencial de compostos bioativos para elaboração de produtos funcionais ou nutracêuticos e produtos fitoterápicos. Além disso, há escassez de informações sobre o potencial de uso dos frutos no estágio de maturação verde. Com isso, sugere-se estudos do potencial nutricional, terapêutico de aplicação biotecnológica com as outras espécies e também no estágio de maturação verde.

Diante disso, foram elaborados os capítulos 3 e 4. No Capítulo 3 é apresentada a avaliação do crescimento e a composição proximal do cogumelo comestível *Pleurotus ostreatus* em substratos de polpa de bocaiuva verde com diferentes fontes de nitrogênio. A finalidade desse capítulo foi verificar as fontes de nitrogênio que contribuem para o crescimento do cogumelo comestível *Pleurotus ostreatus*, visando a obtenção de um produto com baixo teor de carboidratos e enriquecidos em proteínas e fibras.

O Capítulo 4 apresenta o desenvolvimento e avaliação de bolos com baixo teor de carboidratos produzidos a partir da polpa de bocaiúva verde enriquecida com *Pleurotus ostreatus*, a fim de desenvolver um produto alimentício fontes de nutrientes e substâncias benéficas à saúde, que possa ser consumido com regularidade pela população e que atenda as restrições alimentares.

Finalmente, no Capítulo 5 são apresentadas as conclusões gerais.

1.2 INTRODUÇAO GERAL

A relação positiva entre o consumo de frutas e cereais ricos em fibras na prevenção e tratamento das doenças crônicas, estimula a prospecção de espécies vegetais que apresentam quantidades significativas de fibra alimentar para o desenvolvimento de novos produtos alimentícios (Bernaud & Rodrigues, 2013; Fayet-Moore et al., 2017).

A bocaiuva é uma palmeira do cerrado, amplamente distribuída em quase todo o Brasil, sendo abundante no Mato Grosso do Sul e Mato Grosso (Hiane et al., 2006, Lorenzi et al., 2010). A polpa do fruto maduro apresenta características nutricionais (Bora & Rocha, 2004; Ramos et al., 2008; Orsi et al., 2015), sensoriais (Silva et al., 2008; Ramos et al., 2008; Kinupp & Lorenzi, 2014) e funcionais importantes para a saúde (Ramos, Ramos Filho, Hiane, Braga Neto, & Siqueira, 2008; Ramiro, 2010; Silva, 2012; Orsi et al., 2015; Coimbra & Jorge, 2011; Lescano, et al., 2015; Costa et al., 2020). Contudo é um fruto pouco utilizado na alimentação humana, principalmente no estádio de maturação verde e existe pouca informação sobre as propriedades nutricionais e funcionais desse fruto nas suas diferentes espécies.

A farinha da polpa de bocaiuva verde pode apresentar ação terapêutica no controle de peso, glicose e dislipidemia, devido os seus componentes nutricionais (Ramiro, 2010; Silva, 2012; Giunco, 2018). Dessa forma, produtos alimentícios formulados com adição da farinha poderão ser uma opção alimentar contribuindo para a prevenção de doenças crônicas. Além disso, os frutos de bocaiuva, atualmente obtidos pelo extrativismo, podem ganhar mercado e serem mais valorizados e contribuindo para preservação das palmeiras, pois muitas vezes são desmatadas para fins de exploração agrícola da área.

O consumo de bocaiuva verde pode ser favorecido a partir da bioconversão da polpa de bocaiuva verde por *Pleurotus ostreatus* para obtenção de produtos alimentícios com baixo teor de carboidratos e enriquecidos em proteínas e fibras, e aceitos pela maioria dos consumidores (Ritota & Manzi, 2019).

O *P. ostreatus* é um cogumelo comestível conhecido como cogumelo ostra, que possui coloração clara (branco, cinza ou castanho) e seu basidiocarpo possui formato de folha carnuda (Jonathan & Esho, 2010). Os *Pleurotus* são fonte de nutrientes, principalmente proteínas, minerais e vitaminas B, C e D (Panjikkaran & Mathew, 2013). Esses cogumelos contêm 20-35 % de proteína (peso seco), possuem baixos teores de lipídeos e aminoácidos essenciais (Li et al., 2017; Lavelli et al., 2018). Os cogumelos podem contribuir para prevenção de algumas doenças, como hipertensão (Vaz et al., 2011), colesterol (Wei et al., 2018; Liu et al., 2019), diabetes (Asrafuzzaman et al., 2018; Liu et al., 2019; Khatun et al., 2020; Balaji et al., 2020), estresse (Akata et al., 2012), obesidade (Khatun et al., 2020) e atuar como um inibidor de apetite (Sheng et al., 2019). O *Pleurotus* por apresentar baixo valor calórico pode ser incluído em dietas com ingestão controladas de calorias (Jaworska & Bernás, 2009).

Os substratos pectocelulósicos, como cascas, polpas e bagaços de frutas, apresentam condições favorável para o cultivo de cogumelos comestíveis, pois possui menor relação carbono: nitrogênio e altas concentrações de açúcares simples, o que facilita a sua disponibilização ao fungo (Rivas et al., 2010; Cardoso et al., 2013; Silva et al., 2014; Silva et al., 2020). A adaptação das espécies de *Pleurotus* a novos substratos representa, um dos principais processo de bioconversão em produtos alimentícios com valor agregado e de qualidade nutricional (Mbassi et al., 2018; Ritota & Manzi, 2019). Dessa forma, a utilização de substratos de frutas para o cultivo de cogumelos comestível torna uma alternativa viável para o enriquecimento nutricional desses produtos e valorização das espécies dentro de uma cadeia produtiva, com produção permanente e sustentável (Carrasco-González et al., 2017; Ritota & Manzi, 2019).

Diante disso, o objetivo do estudo foi a bioconversão da polpa de bocaiuva verde por *Pleurotus ostreatus* para obtenção de bolo *low carb*, visando a obtenção de um produto alimentício com propriedades nutricionais, funcionais e sensorialmente aceito pelos consumidores.

1.3 REFERÊNCIAS[1]

Akata, I., Ergonul, B., & Kalyoncu, F. (2012). Chemical compositions and antioxidant activities of 16 wild edible mushroom species grown in Anatolia. *International Journal of Pharmacology*, *8*, 134-138. https://doi.org/10.3923/ijp.2012.134.138

Asrafuzzaman, M., Rahman, M. M., Mandal, M., Marjuque, M., Bhowmik, A., Rokeya, B., Hassan, Z., & Faruque, M. O. (2018). Oyster mushroom functions as an antihyperglycaemic through phosphorylation of AMPK and increased expression of *GLUT4* in type 2 diabetic model rats. *Journal of Taibah University for Science*, *13*, 465-471. https://doi.org/10.1016/j.jtumed.2018.02.009

Balaji, P., Madhanraj, R., Rameshkumar, K., Veeramanikandan, V., Eyini, M., Arun, A., Thulasinathan, B., Farraj, D. A. A., Elshikh, M. S., Al-Oqda, A. M., Mahmoud, A. H., Tack, J. -C., & Kim, H. -J. (2020). Evaluation of antidiabetic activity of *Pleurotus pulmonarius* against streptozotocin-nicotinamide induced diabetic wistar albino rats. *Saudi Journal of Biolical Sciences*, *27*, 913-924. https://doi.org/10.1016/j.sjbs.2020.01.027

Bernaud, F. S. R., & Rodrigues, T. C. (2013). Fibra alimentar – Ingestão adequada e efeitos sobre a saúde do metabolismo. *Arquivos Brasileiros de Endocrinologia e Metabologia*, 57(6), 1-9.

Bora, P. S., & Rocha, R. V. M. (2004). Macaiba palm: fatty and amino acids composition of fruits. *Ciência e Tecnologia de Aliment*os, 4(3), 158-162. https://doi.org/10.1080/11358120409487755

Cardoso, J. C. P., Demenjour, P. L. M. M., & Paz, M. F. (2013). Cultivation of edible mushroom *Pleurotus ostreatus* in bocaiuva bagasse by Jun-Cao technique. *Evidência*, *13*(1), 31-40.

Carrasco-González, J. A., Serna-Saldívar, S. O., & Gutiérrez-Uribe, J. A. (2017). Nutritional composition and nutraceutical properties of the *Pleurotus* fruiting bodies: Potential use as food ingrediente. *Journal of Food Composition* and *Analysis*, *58*, 69-81. https://doi.org/10.1016/j.jfca.2017.01.016

Coimbra, M. C., & Jorge, N. (2011). Proximate composition of guariroba (*Syagrus oleracea*), jerivá (*Syagrus romanzoffiana*) and macaúba (*Acrocomia aculeata*) palm fruits. *Food Research International*, 44, 2139–2142. https://doi.org/10.1016/j.foodres.2011.03.032

[1] Estas e as demais referências bibliográficas encontram-se de acordo com a Norma Taylor & Francis Journals Standard Reference Style Guide. Disponível em: https://www.tandf.co.uk//journals/authors/style/reference/tf_APA.pdf. Acessado em Outubro de 2020.

Costa, G. L. A., Buccini, D. F., Arruda, A. L. A., Favaro, S. P., & Moreno, S. E. (2020). Phytochemical profile, anti-inflammatory, antimutagenic and antioxidant properties of *Acrocomia aculeata* (Jacq.) Lodd. pulp oil. *Food Science and Technology*, *29,* 1-9. https://doi.org/10.1590/fst.25319

Fayet-Moore, F., Petocz, P., Mcconnell, A., Tuck, K., & Mansour, M. (2017). The cross-sectional association between consumption of the recommended five food group "grain (cereal)", dietary fibre and anthropometric measures among australian adults. *Nutrients*, 9, 157. https://doi.org/10.3390 / nu9020157

Giunco, A. J. (2018). Processo de obtenção de farinha. Brasil. BR 10 2018 073587 0 A2. Depositante: Universidade Federal da Grande Dourados. Depósito: 14/11/2018.

Hiane, P. A., Baldasso, P. A., Marangoni, S., & Macedo, M. L. R. (2006). Chemical and nutritional evaluation of kernels of bocaiuva, *Acrocomia aculeata* (Jacq.) Lodd. *Ciência e Tecnologia de Alimentos*, 26(3), 683-689.

Jaworska, G., & Bernás, E. (2009). Qualitative changes in *Pleurotus ostreatus* (Jacq: Fr.) Kumm. mushrooms resulting from diferente methods of preliminary processing and periods of frozen storage. *Journal of the Science of Food and Agriculture*, *89*, 1066-1075. https://doi.org/10.1002/jsfa.3557

Jonathan, S. G., & Esho, E. O. (2010). Fungi and aflatoxin detection in two oyster mushrooms *Pleurotus ostreatus* and *Pleurotus pulmonarius* from Nigeria. *Electronic Journal of Environmental, Agricultural and Food Chemistry*, *9*(11), 1722-1730

Khatun, M. A., Sato, S., & Konishi, T. (2020). Obesity preventive function of novel edible mushroom, Basidiomycetes-X (Echigoshirayukidake): Manipulations of insulin resistance and lipid metabolism. *eJTCM*, *10*, 245-251. https://doi.org/10.1016/j.jtcme.2020.03.004

Khatun, M. A., Sato, S., & Konishi, T. (2020). Obesity preventive function of novel edible mushroom, Basidiomycetes-X (Echigoshirayukidake): Manipulations of insulin resistance and lipid metabolism. *eJTCM*, *10*, 245-251. https://doi.org/10.1016/j.jtcme.2020.03.004

Kinupp, V. F., & Lorenzi, H. (2014). *Plantas Alimentícias não convencionais (PANC) no Brasil:* guia de identificação, aspectos nutricionais e receitas ilustradas. São Paulo, Instituto Plantarum de Estudos da Flora.

Lavelli, V., Proserpio, C., Gallotti, F., Laureati, M., Pagliarini, E. (2018). Circular reuse of bio-resources: the role of *Pleurotus* spp. in the development of functional foods. *Food & Function*, *9*(3), 1353-1372. https://doi.org/10.1039/c7fo01747b

Lescano, C. H., Iwamoto, R. D., Sanjinez-Argandoña, E. J., & Kassuya, C. A. L. (2015). Diuretic and Anti-Inflammatory Activities of the Microencapsulated *Acrocomia aculeata* (Arecaceae) Oil on Wistar Rats. *Journal of Medicinal Food*, 18(6), 656–662. https://doi.org/ 10.1089 / jmf.2014.0077

Li, H., Zhang, Z., Li, M., Li, X., & Sun, Z. (2017). Yield, size, nutritional value, and antioxidant activity of oyster mushrooms grown on perilla stalks. *Saudi Journal of Biological Sciences*, *24*, 347-354. https://doi.org/10.1016/j.sjbs.2015.10.001

Liu, Y., Wang, C., Mei, J., Li, Y., & Liang, Y. (2019). Hypoglycemic and hypolipidemic effects of *Phellinus linteus* mycelial extract from solid-state culture in a rat model of type 2 diabetes. *Nutrients, 11(2),* 296. https://doi.org/10.3390/nu11020296

Lorenzi, H., Noblick, L., Kahn, F., & Ferreira, E. (2010). *Flora brasileira Lorenzi:* Arecaceae (palmeiras). Nova Odessa-SP. Instituto Plantarum.

Mbassi, J. E. G., Mobou, E. Y., Ngome, F. A., & Sado, K. S. L. (2018). Effect of substrates on nutritional composition and functional properties of *Pleurotus ostreatus*. *Current Research in Agricultural Sciences*, *5*(1), 15-22. https://doi.org/10.18488/journal.68.2018.51.15.22

Orsi, D. C., Nishi, A. C. F., Carvalho, V. S., Brandão, C. C., Carvalho, A. A., & Asquieri, E. R. (2015). Chemical characterization of macauba pulp (*Acrocomia aculeata*). *Journal of Fruits and Vegetables*, 1, 45-48. https://doi.org/10.1590/S0100-29452011000300040

Panjikkaran, S. T., & Mathew, D. (2013). An environmentally friendly and cost effective technique for the commercial cultivation of oyster mushroom [*Pleurotus florida* (Mont.) Singer]. *Journal of the Science of Food and Agriculture*, *93*(4), 973-976. https://doi.org/10.1002/jsfa.5827

Ramiro, M. M. (2010). *Efeito antilipidêmico do óleo extraído da polpa de Acrocomia aculeata (macaúba) em modelo experimental de hipercolesterolemia e hipertrigliceremia induzida pela dieta rica em frutose e gordura animal em ratos machos Wistar.* Dissertação de Mestrado, UCDB, Campo Grande/ MS.

Ramos, M. I. L., Ramos Filho, M. M., Hiane, P. A., Braga Neto, J. A., & Siqueira, E. M. A. (2008). Nutritional quality of the pulp of bocaiuva *Acrocomia aculeata* (Jacq.) Lodd. *Food Science and Technology*, 28, 90-94. https://doi.org/10.1590/S0101-20612008000500015

Ritota, M., & Manzi, P. (2019). *Pleurotus* spp. cultivation on different agri-food by-products: Example of biotechnological application. *Sustainability*, *11*, 5049. https://doi.org/10.3390/su11185049

Rivas, P. M. S., Pereira Filho, A. A., Santos, F. A. S., & Rosa, I. G. (2010). Avaliação de substratos pectocelulósicos para o cultivo de cogumelos comestíveis do gênero *Pleurotus* sp. (agaricales). *Cadernos de Pesquisa*, *17*(3), 78-83.

Sheng, Y., Zhao, C., Zheng, S., Mei, X., Huang, K., Wang, G., & He, X. (2019). Anti-obesity and hypolipidemic effect of water extract from *Pleurotus citrinopileatus* in C57BL/6J mice. *Food Science & Nutrition*, *7*(4), 1295-1301. https://doi.org/10.1002/fsn3.962

Silva, C. A. A., da Silva, P. G. P., da Silva, G. F. A., Dantas, D. P., Leite, R. S. R., & Fonseca, G. G. (2020). Biotransformation of fruit residues via solid state bioprocess using *Lichtheimia ramosa*. *SN Applied Sciences*, *2*, 861. https://doi.org/10.1007/s42452-020-2689-0

Silva, C. A. A., Lacerda, M. P. F., Leite, R. S. R., & Fonseca, G. G. (2014). Physiology of *Lichtheimia ramosa* obtained by solid-state bioprocess using fruit wastes as substrate. *Bioprocess and Biosystems Engineering*, *37*(4), 727-734. https://doi.org/10.1007/s00449-013-1043-y

Silva, M. R., Lacerda, D. B. C. L., Santos, G. G., & Martins, D. M. O. (2008). Caracterização química de frutos nativos do cerrado. *Ciência Rural*, 38(6), 1790-1793.

Silva, P. V. B. S. (2012). *Caracterização química e avaliação do potencial antidiabético e citotóxico de óleo extraído de Acrocomia aculeata (macaúba).* Dissertação (Mestrado): Dourados/MS.

Vaz, J. A., Barros, L., Martins, A., Santos-Buelga, C., Vasconcelos, M. H., & Ferreira, I. C. F. R. (2011). Chemical composition of wild edible mushrooms and antioxidant properties of their water soluble polysaccharidic and ethanolic fractions. *Food Chemistry*, *126*, 610-616. https://doi.org/10.1016/j.foodchem.2010.11.063

Wei, H., Yue, S., Zhang, S., & Lu, L. (2018). Lipid-lowering effect of the *Pleurotus eryngii* (king oyster mushroom) polysaccharide from solid-state fermentation on both macrophage-derived foam cells and zebrafish models. *Polymers*, *10*(5), 492. https://doi.org/10.3390/polym10050492

CAPÍTULO 2

CHARACTERISTICS, PROPERTIES AND POTENTIAL APPLICATIONS OF *Acrocomia* SPECIES.

ABSTRACT: The Acrocomia genus is found in several countries and is explored natively and commercially in different ways. There is no consensus on the exact number of species of this genus, in addition to the lack of information on properties: nutritional, therapeutic, biometric, antioxidant and application potential of existing species. Therefore, this study aimed to analyze species of *Acrocomia* genus to confirm their properties and potential nutraceutical and nutritional. Seven species were found that represent this group, *A. aculeata*, *A. intumescens Drude*, *A. totai Mart*., *A. hassleri, A. glaucescens Lorenzi* e *A. emensis* (*Toledo*) *Lorenzi* e *A. crispa (Kunth) C.F. Baker ex Becc.* Of those that stands out the most, for being widely distributed worldwide, is *A. aculeata*. Biometric, morphological and nutritional characteristics vary according to the species and region where it is found, which can influence the exploration potential. Despite the economic diversity of *Acrocomia* exploitation and its therapeutic and application potential, they are genereally used for subsistence of native peoples throughout tropical America. In addition to commercial exploitation the species is destined for oil and oil production. The species of greatest commercial interest in Brazil and with high potential for exploration in the countries where they occur are *A. aculeata, A. totai and A. intumescens.* This shows that the species have not been valued in terms of their nutritional potential for the formulation of food products, the potential of bioactive compounds for the elaboration of functional or nutraceutical products and herbal products. In addition, there is a scarcity of information on the potential use of fruits in the green ripening stage. Thus, it is suggested studies of the nutritional, therapeutic potential of biotechnological application with the other species and also in the green maturation stage.

Keywords: Acrocomy, fatty acids, antioxidants, co-products, nutritional properties.

2.1 *Acrocomia*

2.1.1 General aspects

Acrocomia is a genus of palm trees of arboreal size belonging to the Palmae family (Arecaceae). It is native from South America and is widely distributed in Argentina, Bolivia, Brazil, and Venezuela, and Central American countries, including Mexico. It is commercially exploited in the countries where it occurs. Due to its wide geographical distribution, the phenology varies according to the region (Vianna et al., 2015, 2017).

There is no consensus regarding the number of species of this genus (Vianna et al., 2015, 2017), but the *Acrocomia aculeata* species is the one that has the most extensive occurrence and, therefore, is named with different colloquial terms in the different regions where it occurs (Almeida et al., 1998; Lorenzi et al., 2010; Galeano & Bernal, 2010; Smith, 2015; Vianna et al., 2015; Lieb et al., 2019).

All *Acrocomia* species have bunches with several round shaped fruits, consisting of epicarp (peel), mucilaginous and fibrous mesocarp (pulp), hard and dense endocarp (integument), and seed (almond) covered by the endocarp (Lorenzi et al., 2006; Vianna et al., 2017). These fruit species are considered native to the Savannah region and have nutritional, therapeutic potential (Reis & Schmiele, 2019), potential for the production of biofuels and vegetable oil (César et al., 2015; Del Río et al., 2016, Nunes et al., 2018), in addition to being commonly used for subsistence of native peoples across tropical America (Vianna et al., 2017).

The mature *Acrocomia* pulp is rich in lipids, carbohydrates, fibers (Bora and Rocha, 2004; Ramos et al., 2008; Orsi et al., 2015), copper, potassium and zinc (Ramos et al., 2008) and can supply the nutritional needs of human beings through its consumption *in natura* or processed (Ramos et al., 2008). In addition, the pulp is rich in β-carotene (Ramos et al., 2008; Orsi et al., 2015; Coimbra & Jorge, 2011) and α-tocopherol (Coimbra & Jorge, 2011), which are important carotenoids with antioxidant action and anti-inflammatory effect (Lescano et al., 2015a; Costa et al., 2020).

Several studies have analyzed the morphology (Sanjinez-Argandoña and Chuba, 2011; Brandão et al., 2014; Lescano et al., 2015b), the nutritional constituents (Hiane et al., 1990; Coimbra & Jorge, 2011; Machado et al., 2015; Lescano et al., 2015b), fatty acids (Hiane et al., 1990; Lescano et al., 2015a; Lescano et al., 2015b), carotenoids (Ramos et al., 2008; Coimbra & Jorge, 2011; Orsi et al., 2015), and minerals (Ramos et al., 2008; Lescano et al., 2015b) from the fruits.

Despite the exploration potential of the *Acrocomia* genus, most of the information reported in the literature is related mostly to the biometric characteristics, nutritional properties, and therapeutics of the *A. aculeata* species. There is still a lack of studies that present information about other species of this genus. In this sense, there is a need for studies with different species to underline their properties to justify their permanent and sustainable production within a productive chain.

2.1.2 Species and occurrence

The *Acrocomia* genus is represented by seven species, six occurring in regions of Brazil (Pará, Bahia, Ceará, Maranhão, Paraíba, Pernambuco, Piauí, Federal District, Goiás, Mato Grosso do Sul, Mato Grosso, Minas Gerais, Rio de Janeiro, São Paulo, and Paraná states. They are *A. aculeata*, *A. intumescens* Drude, *A. totai* Mart., *A. hassleri*, *A. glaucescens* Lorenzi, and *A. emensis* (Toledo) Lorenzi. The species *A. crispa* (Kunth) C.F. Baker ex Becc. is more common in Cuba (Lorenzi et al. 2010; Vianna et al., 2016; Vianna & Campos-Rocha, 2020). The species known as bocaiuva, macauba or macaiba are all *Acrocomia* sp. (Lorenzi et al., 2006; Vianna et al., 2017).

The species *A. aculeata* is named with different common terms (Table 2.1), depending on the occurrence region (Almeida et al., 1998; Galeano & Bernal 2010; Lorenzi et al., 2010; Sanjinez-Argandoña & Chuba, 2011; Smith, 2015; Vianna et al., 2015; Hernández-Zardón, 2016; Lieb et al., 2019). In Belize and Panama were found reports of the use of *Acrocomia* species receiving the common name of corozo or cohune, but with the scientific name of *Attalea cohune* in Belize (Hernández-Zardón, 2016).

Among the species found in Brazil, *A. aculeata*, *A. intumescens*, and *A. totai* are exploited by extraction for fruits' consumption. *A. intumescens* is named locally by macaiba. This species is endemic to the Brazilian Northeast region, occurring in areas of the called Wood Zone and in highland forests. *A. totai* is known as bocaiuva, distributed in most of the state of Mato Grosso do Sul, associated with the regions of the Brazilian Savannah and Pantanal (Lorenzi et al., 2010; Vianna et al., 2017).

A. hassleri occurs on the border between Brazil (at Mato Grosso do Sul state) and Paraguay, and it frequently mistaken with *A. emensis* (Toledo) Lorenzi. *A. glaucescens* Lorenzi occurs in the Brazilian state of Goiás but is also mentioned in the literature as of occurrence in the Mato Grosso do Sul state (Lorenzi et al., 2010). *A. emensis* (Toledo) Lorenzi, in its turn, is popularly known as crawling tucum. It occurs in the Brazilian states of Goiás, Mato Grosso do Sul, Minas Gerais, São Paulo and Paraná (Neiva et al., 2016). This palm is considered a species at risk of extinction due to the destruction of its natural habitat and the fact that it is not being reforested (Lorenzi et al., 2010).

Table 2.1 Occurrence of *Acrocomia* sp.

Species	Common names	Occurrences*	Occurrences by country*	References
A. aculeata	Butter tree, bacaiuveira, bocaiuva, chonta, corozo, Bahian gum, catarrh coconut, viscous coconut, thorned coconut, slobber coconut, cherished coconut, coyol, palm oil, grou grou, imbocaia , jabara, korondia, macauba, macauva, macaiba, macacauba, macajuba, macaibeira, macaja, marcova, mucaja, mucaia, macaia, Paraguayan nut, mascara oil, macaw palm, cormorant palm, Paraguayan palm, uba	666	Mexico (208); Brazil (124); Colombia (113); Costa Rica (57); Bolivia (24); Argentina (20); Paraguay (20); Nicaragua (15); Puerto Rico (11); United States (11); Honduras (10); Belize (7); Panama (7); Dominican Republic (6); El Salvador (4); Jamaica (4); Guatemala (3); Suriname (3); Trinidad and Tobago (3); and other countries***	Almeida et al,1998; Galeano & Bernal, 2010; Sanjinez-Argandoña & Chuba, 2011; Lorenzi et al. 2010; Smith 2015; Vianna et al., 2015; Hernandez-Zardón, 2016; Lieb et al., 2019
A. intumescens	Macauba, macaiba, bocaiuva, slobber coconut, bellid palm, bellid macauba, thorned coconut	27	Brazil	Lorenzi et al., 2010
A. totai	Bocaiuva, totai, bocaiuveira, macabira, mocajuba, como mbokaja (Guarani language)	44	Bolivia (14); Brazil (12); Paraguay (11); Argentina (4); United States (3)	Lorenzi et al. 2010; Moraes, 2015
A. hassleri	Field's small coconut, dwarf tucum	40	Brazil (9); Paraguay (31)	Lorenzi et al., 2010
A. glaucescens	Small macauba	19	Brazil	Lorenzi et al., 2010
A. emensis	Crawling tucum, field's small coconut, tucum	7	Brazil	Lorenzi et al., 2010; Neiva et al., 2016
A. crispa	Corojo palm	13	Cuba	Pérez et al., 2015
A. corumbaensis		2	Brazil	

*Data obtained from GBIF.org (2020). *Data that contained the geographic coordinates. **Occurrence of species in different countries ranging from 1 to 2 (adding up to a total of 16 occurrences).

2.1.3 Morphological characteristics

The morphological characteristics refers to the size of the trees, which can be distinguished mainly by their stem characteristics, in addition to other characteristics (Table 2.2).

A. aculeata presents rounded fruit, the epicarp has a green to matte green color, quite hard when the fruits are green, but brittle when ripe, the mesocarp 3 to 7 mm thick, green, cream, yellow or orange. It usually blooms at the end of the dry season. Variations in the fruiting period can occur and may be related to the geographic region (Hernández-Zardón, 2016).

A. hassleri is a species characterized by the underground stem (acaulescent) and short tomentuous peduncular bract, with sparse thorns in the median and / or apical region. It can be confused with *A. emensis*, which has a larger size, peduncular bract greater than 15 cm in length, and is all covered with thorns (Lorenzi et al., 2010). *A. emensis* is an underbrush terrestrial palm tree with many thorns on the leaves and petioles. The leaves are pinnate and arched. The fruits are globose, and their ripening occurs at the beginning of southern hemisphere summer, with fruiting occurring once a year (Lorenzi et al., 2010; Neiva et al., 2016).

2.1.4 Biometric characteristics

The fruits of *Acrocomia* sp. are arranged in clusters, being considered a drupa globosa constituted by cardiac epicarp (peel), thin, mucilaginous, fibrous and oily mesocarp (pulp) and hard and dense endocarp (integument), containing seed (almond) adhered to the lipid-rich endocarp (Almeida et al., 1998; Lorenzi et al., 2006; Vianna et al., 2017; Lieb et al., 2019). Depending on the species ecotype, the mature pulp has a yellow or orange color (da Silva et al., 2018), suggesting the presence of bioactive compounds, such as carotenoids.

The palm fruits ripen unevenly inside the bunch and are considered ripe when they start to come off the bunches and fall to the ground, which occurs from September to January in the South hemisphere (Lorenzi, 2010; Lieb et al., 2019). On the ground, the fruits are exposed to attack by insects, rodents or microbial contamination, which causes rapid degradation with quantitative and qualitative losses of their constituents, especially in the pulp.

Table 2.3 show the biometric characteristics of some *Acrocomia* sp. The values of the mass of the whole fruit and of the parts that compose show a great variation between the same species and among others, depending of their origin, especially the *A. aculeata* collected in Costa Rica. The main information found in the literature is related to the species *A. aculeata* found in Brazil.

Table 2.2 Morphological characteristics of *Acrocomia sp.*

Species	Stipe	Plant height (m)	Leave length (m)	Fruit diameter (cm)	Thorns	Fruit color	Habitat	Reference
A. aculeata	Cylindrical, straight, with base remains of fallen leaves	14-20	1.9-3	3.0-6.0, rarely up to 9	Stipe and leaves	Varied (opaque green and brown)	In general, dry and open area	Viana et al., 2017; Hernandez-Zardón, 2016
A. intumescens	Cylindrical, swollen near the middle	-	2.4-3	3.1-4.5	Stipe of young plants	Greenish, light yellow	Atlantic Forest	Vianna et al., 2017
A. totai	Cylindrical, straight, with base remains of fallen leaves	-	2.0-2.6	2.3-4.3	It may occur in the stipe and leaves	Varied	Dry and open area	Vianna et al., 2017
A. hassleri	Espinescent with underground stem	0.4-0.8	0.31-0.38	Unseen fruits	Along the rachis, more abundant at the base	Not seen	Savanna, well-drained soils	Caxambú et al., 2015
A. glaucescens	Visible scars on the leaf base	0.8-6.5	1.5-2.0	1.5-2.6	Without	Yellowish green	Savanna, sandy soils	Lorenzi et al., 2010
A. emensis	Creeper	0.40-0.60	-	1.8-2.2	Sparse in the median and / or apical region	-	-	Lorenzi et al., 2010
A. crispa	Slightly swollen stems	-	-	1.0-3.0	Spiny stems	Soft orange	-	Pérez et al., 2015; Lorenzi et a., 2010

Table 2.3 Biometric characteristics of *Acrocomia sp.*

Species	MF (g)	EP (g)	MM (g)	ED (g)	MA (g)	LDF (cm)	DTF (cm)	LDA (cm)	ET (cm)	FV (mL)	Reference
*A. aculeata**	19.64±3.57	4.13±0.52	9.20±1.18	6.89±1.21	1.14±0.23	3.85±0.80	3.35±0.40	ND	ND	ND	Ramos et al., 2008; Sanjinez-Argandoña & Chuba, 2011; Lescano et al., 2015b; Vianna et al., 2017; Oliveira et al., 2020
A. aculeata	39.2	10.13	18.23	8.03	2.93	4.2	4.27	ND	ND	ND	Alfaro-Solís et al., 2020
A. aculeata	11.55	2.16	5.07	3.15	1.17	ND	ND	ND	ND	ND	Bonet et al., 2020
A.intumescens	29.08	ND	ND	ND	ND	3.88	3.69	ND	ND	ND	Vianna et al., 2017
*A. totai**	18.03±1.16	3.76	10.49	4.05	1.37	3.13±0.21	2.72	1.53	0.38	19.00	Machado et al., 2015; Vianna et al., 2017

MF: fruit mass; EP: epicarp mass; MM: mesocarp mass; ED: endocarp mass; MA: almond mass; LDF: longitudinal diameter of the fruit; DTF: transverse diameter of the fruit; LDA: longitudinal diameter of the almond; ET: endocarp thickness; FV: fruit volume. *Data calculated by means of the results obtained by the authors. ND: not determined.

Considering the average of the values obtained in the biometric characteristics of *A. aculeata* fruits collected in two municipalities in Brazil, the pulp represented approximately 42% of the whole fruit, the peel 20%, the mass of the endocarp (seed with almond) 38%, the endocarp 31% and the almond 7% in relation to the whole fruit. In addition, each raceme produced 6.32 kg of pulp and 1.36 kg of endosperm (almond) (Sanjinez-Argandoña & Chuba, 2011). In another two localities (Brazilian Savannah and Pantanal), the fruits of this same species presented, on average, 19.6% and 17% of epicarp, 46.9% and 51% mesocarp and 5.28% and 6.75% almonds, respectively. In the Savannah, the trees presented, on average, 3.8 racemes, with an average length of 72.5 cm and an average number of 168.8 fruits per raceme, with a mass of 5.8 kg per raceme, and 645 fruits per palm, totaling 19.6 kg. In the Pantanal region, they presented, on average, 3.7 racemes, with an average length of 66.6 cm, and an average number of 258 fruits per raceme, with a mass of 4.4 kg per raceme, and 923 fruits per palm, totaling 16.1 kg (Ciconini et al., 2013). These data show the high productivity of this plant, while the high percentage of the edible part indicates the technological potential of the fruit as a raw material for the food, cosmetic, biofuel, among other products (Conceição et al., 2015).

2.1.5 Regional and economic importance

Acrocomia sp. are important oil palm trees, due to their role in local ecosystems and economies and their potential to produce vegetable oil and biofuels (Nunes et al., 2018). They are utilized for subsistence by native peoples throughout tropical America. The commercial exploitation occurs mainly for oil production in Brazil and Paraguay. They are also used for various other purposes: the palms in ornamentation, the roots as medicine, the sap in the preparation of alcoholic drinks, and the leaves to obtain fibers for the production of threads, ropes, nets, and forage, while the ripe fruits are consumed fresh or processed (Ramos et al., 2008; Vieira et al., 2017).

However, despite the economic diversity of exploitation of the species, the greatest interest in exploration is in the fruits, as they have a high potential to produce oil. It is estimated that more than 4,000-5,000 Kg / ha / year of oil can be obtained for the food, cosmetic and pharmaceutical industries, and alternatively to produce biodiesel (Del Río et al., 2016; Vianna et al., 2017). The average oil extraction yield is 19.62% from the pulp and 3.43% from the almond (Del Río et al., 2016).

A. aculeata, *A. totai* and *A. intumescens* are the three tree species of *Acrocomia* with greatest commercial interest in Brazil, with also high potential for use in other countries where they also occur. Due to the diversification of their use, they are considered an alternative to generate income for several communities. In Brazil, there are reports of the use and commercialization of these three species for several applications, *e.g.*: civil construction (rods), bovine and equine nutrition (leaves), manufacture of fishing lines (fibers), gravel substitute (endocarp), oil extraction for food, cosmetic, or biofuel (endosperm), and fresh or processed consumption (pulp) (Vianna et al., 2017).

A. aculeata is currently the most utilized *Acromonia* species in the production of biofuels, with the oil present in the mesocarp ranging from 37 to 78%. However, the other species also have potential for oil production. *A. intumescens* has between 34 and 41% while *A. totai* between 14 and 31% of oil in the mesocarp (Vianna et al., 2017). *A. aculeata* is considered as the second species of palm in the world in oil production (estimated 4,200 L / ha). The high quality of the oil is comparable to that of olive, which can be used in food, as a raw material in the production of soap and cosmetics, or for the strategic production of biofuels (Hernández-Zardón, 2016).

Edible oils can be extracted from the mesocarp and the nucleus of *Acrocomia* sp., differing mainly in their chemical composition and technological properties. The oil extracted from the almonds is transparent and colorless, being an alternative in cooking to replace the olive oil (Lieb et al., 2019).

The pulp of *A. intumescens* fruits in the Brazilian Northeast region and *A. totai* in the Mato Grosso do Sul state are exploited by local communities for fresh consumption or processed foods, such as meals, ice cream, cakes and others. Some of the elaborated products are sold by these communities to supplement the family income. On the other hand, the *A. aculeata* species is the most explored in the Brazilian Midwest region and in Pará, São Paulo, and Minas Gerais states, for the extraction of pulp oil for the production of biofuel, cosmetics and soap (Ramos et al., 2008; Coimbra et al., 2011; Sanjinez-Argandoña & Chuba, 2011; Vianna et al., 2017; Nunes et al., 2018).

The pulp of the *A. aculeata* fruit is traditionally consumed fresh but is also utilized as a source of oil by natives and people living in rural areas. Although the fruit of this species is an important component in the diet of some tribes, it is not attractive for those who are not accustomed to consuming it, due to its mucilaginous texture and oleaginous pulp (Hernández-Zardón, 2016). The pulp is also consumed in the cooked form, in the form of refreshment, as flour, pancakes, jellies, mousses, sweets and ice cream (Ramos et al., 2008; Coimbra et al, 2011; Hernández-Zardón, 2016; Nunes et al., 2018). The almonds of the *A. aculeata* fruit are consumed raw by the local population or in food products, such as sweets, or it can also be used as a source of raw material for oil extraction (Ramos et al., 2008; Coimbra et al., 2011).

Some communities take advantage of the pulp of the ripe fruit of *A. aculeata* in the production of flour for *e.g.* breads and biscuits. The pulp, in the form of flour, favors the concentration of most nutrients and increases its shelf-life, in addition to facilitating transport and storage due to the reduction in mass and volume. The flour can be incorporated into bakery products, diet products and baby foods, improving the sensory and nutritional quality of food products (Mota, 2005; Guimarães & Silva, 2008).

The use of *A. aculeata* fruits in the Mato Grosso do Sul state has a strong socioeconomic and environmental appeal. The pulp is rich in nutrients and has antioxidant action, and its use in the formulation of jams minimizes post-harvest losses, providing to consumers a product with high nutritional value all year round (da Silva et al., 2018).

A. aculeata leaves have been explored for feeding high-performance horses due to their high nutritional and energetic values. The press cake, by-product of the endosperm after extraction of oil by pressing, is used in the preparation of animal feed, due to its high nutritional content and is commonly found in the Brazilian semiarid region (Azevedo et al., 2014; Hernández-Zardón, 2016). The exocarp is used in the production of energy, such as charcoal, and leaf fibers in the manufacture of handicrafts and work utensils, such as ropes, fishing equipment; production of starch like sago (Hernández-Zardón, 2016).

It was reported that the use of *A. aculeata* has increased due to its potential for disease prevention. According to the popular knowledge, this medicinal plant has been used in the treatment of respiratory diseases and has laxative, analgesic and restorative properties (Lorenzi, 2006). In popular medicine, the roots of *A. aculeata* have been used for a long time by indigenous peoples in the states of Yucatán and Tamaulipas, in Mexico, for the treatment of diabetes (Sosnowska & Balslev, 2008). The decoction of *A. aculeata* leaves is used to treat hypertension (Agra et al., 2007).

In Brazil, the production of *A. totai* almond is carried out through family farming. The plant has gaining attention due the high oil productivity (about six tons per hectare), which represents an alternative to the growth in energy demand. In addition, the activity enables the creation of direct and indirect jobs through its production chain (Souza et al., 2017).

In the Brazilian Northeastern region, the *Acromonia* palm is represented mainly by the species *A. intumescens*. However, there is still little information in the literature related to this species. The leaves are normally used for animal nutrition and the pulps for human consumption. The oil extracted from the pulp and almond is generally used as a tonic in popular medicine due to its anti-inflammatory and antioxidant activities (Nascimento et al., 2016).

2.2 PROPERTIES OF THE FRUITS

2.2.1 Proximate composition and physical characteristics

The information on the nutritional composition of foods allows to assess the availability of nutrients and the development of research for the agricultural planning and the food industry (Coimbra et al., 2011). The proximate composition and energetic value of fruits from the species *A. aculeata*, *A. intumescens* and *A. totai* has been reported elsewhere (Table 2.4). However, information on the processing, and on the physical and chemical characteristics of the trees and the composition of the fruits from the other species of *Acrocomia* were not found (Pérez et al., 2015).

A. aculeata collected in Paraguay showed higher levels of protein (6.1 g / 100 g), ash (5 g / 100 g), carbohydrates (35.2 g / 100 g) and energetic value (382.1 Kcal / 100 g) compared with fruits obtained in other countries and with fruits from the other *Acromonia* species. However, *A. aculeata* harvested in Costa Rica had a higher lipid content (33.23 g / 100 g) compared to others. Regarding the almond, data were obtained only from *A. aculeata* found in Brazil and Paraguay. These almonds presented little variation for proteins, ash, fibers and energetic value. On the other hand, almonds from *A. aculeata* found in Paraguay showed higher lipid (56.75 g / 100 g) and lower carbohydrate (4.75 g / 100 g) contents compared to the almonds from fruits collected in Brazil.

Some food products prepared from *A. aculeata* fruits, including pulp flour, pulp flour cupcake, pulp flour alfajor, degreased flour and almond cereal bars were reported elsewhere (Table 2.5).

The bocaiuva almonds of *A. aculeata* fruits can be considered a valuable source of high digestible protein, as they do not contain protease inhibitors. The protein fractions of the bocaiuva almond are also potentially good sources of some essential amino acids, as they are rich in methionine + cysteine, valine and leucine. Nevertheless, they are limiting in some essential amino acids, such as threonine and lysine (Hiane, 2006).

Mineral content of pulp and seed from *A. aculeata* and *A. totai* fruits collected in Brazil were reported in the literature (Table 2.6). Both species had a high content of iron and zinc in the pulp, and high iron content in seed. Zinc was found higher for *A. aculeata* pulp and seed. Minerals are important nutrients for the body, as they participate in numerous functions, *e.g.* iron and zinc are essential to combat infections, increase immunity, and decreased the risk of depression (Li et al., 2017; Biasebetti et al., 2018; Nairz & Weiss, 2020).

The knowledge on the physical characteristics of the fruits is also relevant for the preparation of food products, as well as for the conservation of the processed food (Silva et al., 2019). The pulp and almonds of *A. aculeata* fruits have low acidity and high-water activity (Table 2.7), indicating high perishability of the fresh fruits and the importance of the technological process for the obtaining and preservation of processed food products.

2.2.2 Fatty acid content

Literature reports the fatty acids profile of the pulp and macauba seed oils for *Acromonia* sp. (Table 2.8). The oil obtained from the pulp is mostly composed of unsaturated fatty acids (74-81%), consisting mainly of oleic acid (63-65%), and the oil obtained from the seed has a high content of lauric acid (38-45%) (Bora & Rocha, 2004; Coimbra & Jorge, 2011; Ferrari & Azevedo Filho, 2012). The composition of the extracted oils is important in order the identify the most appropriate potential use for each raw material.

A. aculeata seed oil has high oxidative stability and contains bioactive compounds. This oil is solid at low temperatures and has a low solid fat content at room temperature (Magalhães et al., 2020).

The *A. aculeata* pulp oil consists mainly of triglycerides (about 78.5%), followed by small amounts of diglycerides (about 13.2%), free fatty acids (about 5.6%) and sterols (1.5%). The seed oil has a higher amount of triglycerides (about 98.6%), with only traces of free fatty acids (0.9%), sterols (0.2%) and monoglycerides (0.3%), allowing several possibilities of industrial (Del Río et al., 2016).

2.2.3 Enzymatic activity and Nutritional enrichment of foods

Enzymes are important products used in several applications in the textile, chemical, pharmaceutical, and food industries. Among the most important industrial enzyme are the amylases (25% of the enzyme market) (Silva et al., 2016; Lopes et al., 2020).

In Brazil, about 14.5 tons of fruit residue are produced per year due to the extraction of oil from *A. aculeata*. This generated by-product is rich in cellulose, hemicellulose, lignin and lipids. Thus, it can be used to produce fungal enzymes and edible mushrooms that degrade these components of plant biomass (Lopes et al., 2020).

Studies using residues of *A. aculeata* in fermentation by microorganisms show the production of the enzymes amylase, β-glucosidase, endoglucanase (CMCase), lipase, protease, and xylanase, with greater production of amylases and proteases (Table 2.9).

It was reported elsewhere the utilization of *Acrocomia aculeata* cake and residual oil from the biodiesel industry as substrate to produce lipase by *Moniliella spathulata* R25L270, reducing lipase production costs and, simultaneously, adding value to the waste from the biodiesel industry (Souza et al., 2015).

A. aculeata residues were reported to have potential for bioconversion by using the filamentous fungi *Lichtheimia ramosa*. The nutritional value of the fungus increased after cultivation (Table 2.10). A greatest decrease in carbohydrates and increase in fibers and proteins contents was pointed out. The protein enrichment reached 67.88% (Silva et al., 2014).

2.2.4 Bioactive compounds

Bioactive compounds, including carotenoids, tocopherols, ascorbic acid, and phenolic compounds, may be related to antioxidant capacity and other important health benefits (Verruck et al., 2018). Bioactive compounds were found in the pulp, seed, and bark of *A. aculeata* (Table 2.11). The pulp oil presents high levels of carotenoids (490 μg / g), tocopherols (212.95 mg / kg), and antioxidant capacity (63 g / g DPPH). The seeds have high content of ascorbic acid (59.34 mg / 100 g) and phenolic compounds (112.8 mg EAG / 100g).

The pulp and the peel of *A. aculeata* fruits were reported to have in their composition the carotenoids violaxanthin, luteoxanthin, lutein, zeoxanthin and β-carotene (Schex et al., 2018). Pro-vitamin A and non-pro-vitamin A carotenoids can act as antioxidants against cardiovascular disease, certain types of cancer, neurological disorders, strengthen the immune system, age-related macular degeneration and cataracts, in the activation of genes and inflammatory processes, modulating lipoxygenase. Some carotenoids, such as β-carotene, play an important nutritional role as they are capable of being converted into vitamin A (Coimbra et al., 2011). In another study, it was revealed that the β-carotene from *A. aculeata* pulp is more bioavailable than the pure β-carotene (Ramos et al., 2007), which shows the potential of the pulp as a natural source of β-carotene and vitamin A (Ramos et al., 2008).

Table 2.4 Proximate composition and energetic values of fruits from *Acrocomia* sp.

Species	Analyzed part	Compound (g/100 g)						Energetic value (kcal/100 g)	Reference
		Moisture	Protein	Lipids	Ash	Carbohydrates	Fibers		
*A. aculeata**	Pulp	47.86±7.73	3.19±1.94	15.88±10.95	1.72±0.30	21.38±14.09	12.93±1.55	226.66±83.42	Ramos et al, 2008; Silva et al., 2008; Sanjinez-Argandoña & Chuba, 2011; Lescano et al., 2015b;
*A. aculeata**	Almond	7.66±3.80	15.97±7.28	45.81±8.81	1.94±0.23	22.10±22.28	25.62±22.34	515±50.58	Hiane e al., 2006; Dessimoni-Pinto et al., 2010; Coimbra et al., 2011; Lescano et al., 2015b; Machado et al., 2015; Alves et al., 2016
*A. aculeata**	Pulp	57.03±9.61	ND	33.23±6.50	ND	ND	ND	ND	Alfaro-Solis et al., 2020
A. aculeata	Pulp	56.6	6.1	24.1	5	35.2	29.6	382.1	Bonet et al., 2020
*A. aculeata**	Almond	9.20±4.24	15.95±0.64	56.75±0.49	2.10±0.14	4.75±0.07	20.45±1.06	588.85±13.93	Bonet et al., 2020
A. intumescens	Pulp	62.2	2.5	29.6	2	3.5	ND	286,80	Silva et al., 2015
A. totai	Pulp	45.42	1.15	32.05	0.66	18.1	51.7	ND	Machado et al., 2015

*Data calculated by means of the results obtained by the authors. ND: not determined.

Table 2.5 Proximate composition and energetic value of products elaborated with fruits of *Acrocomia aculeata*.

Product	Compound (g/100 g)						Energetic value (kcal/100 g)	Reference
	Moisture	Protein	Lipids	Ash	Carbohydrates	Fibers		
Pulp flour*	9.42±1.20	5.01±2.02	20.88±0.81	4.21±1.57	66.77±6.80	13.40±0.00	434.32±24.50	Vieira et al., 2017; Rodrigues et al., 2017; Silva et al., 2020
Cupcake of pulp flour	18.35	3.63	11.93	1.56	64.53	3.91	379.12	Vieira et al., 2017
Alfajor of pulp flour	14.66	8.21	11.83	1.42	63.89	2.54	393.34	Rodrigues et al., 2017
Degreased flour	7.69	5.23	8.44	5.83	ND	ND	ND	Silva et al., 2020
Cereal bars of almond	5.79	6	7.84	1.53	75.43	3.54	396.28	Dessimoni-Pinto et al., 2010

*Data calculated by means of the results obtained by the authors.

Table 2.6 Mineral content of fruits of *Acrocomia* sp.

Species	Analyzed part	Mineral (mg/Kg)										Reference
		N	Ca	P	K	Mg	Na	Fe	Mn	Zn	Cu	
*A. aculeata**	Pulp	ND	1,270±570	370	7,700	1,080±220	37.4	56.56±39.56	8.51±7.49	32.90±23.75	10.22±12.33	Ramos et al., 2008; Silva et al., 2008; Marin et al., 2009; Lescano et al., 2015b
*A. aculeata**	Seed	ND	930±10	5,730	3,770	1,900±250	21.41	29.50±4.83	21.56±3.92	38.04±10.05	13.87±2.74	Hiane et al., 2006; Lescano et al., 2015b
A. totai	Pulp	730	450	3,580	3,950	2,210	ND	40.7	38.16	27.33	5.05	Machado et al., 2015
A. totai	Seed	3,610±1,060	810±100	640±10	9,250±20	1,420±60	ND	54.97±9.77	5.76±0.86	8.06±0.40	2.50±0.10	Machado et al., 2015

*Data calculated by means of the results obtained by the authors. ND: not determined.

Table 2.7 Physical characteristics of the fruits of *Acrocomia aculeata.*

Species	Analyzed part	Titratable acidity (%)	pH	Water activity	Reference
A. aculeata	Pulp	0.51±0.24	5.92±0.22	0.95±0.04	Sanjinez-Argandoña & Chuba, 2011; Lescano et al., 2015b; Silva et al., 2018; Souza et al., 2019
A. aculeata	Almond (kernel)	0.07±0.00	6.00±0.00	0.677±0.00	Lescano et al., 2015b

*Data calculated by means of the results obtained by the authors.

Table 2.8 Composition of fatty acids of pulp of *Acrocomia* sp.

Species	Oil	C4	C6	C8	C10	C12	C14	C15	C16	C16:1 (n7)	C17	C17:1	C18	C18:1 (n7)	C18:1 (n9)	C18:2 (n6)	C18:3	C20	C20:1	C22	C23	C24	Reference
A. aculeata	Pulp	ND	0.24±0.20	0.184±0.14	0.14±0.10	0.66±0.36	0.47±0.16	0.03	20.14±7.08	2.37±1.79	0.08	0.11	2.71±0.37	ND	66.6±9.23	5.72±2.96	1.06±0.06	0.43±0.32	0.14±0.03	0.06	ND	0.08	Hiane et al., 1990; Lescano et al., 2014; Del Río et al., 2016; Oliveira et al., 2017; Dario et al., 2018
A. aculeata	Pulp	ND	ND	ND	ND	0.1	0.1	ND	19.1	4.8	ND	ND	1.7	4.4	64.9	2.9	1.4	ND	ND	ND	ND	ND	Lieb et al., 2019
A. aculeata	Pulp	0.0	ND	0.21	0.16±0.06	1.055±0.21	0.565±0.09	ND	18.48±2.86	2.90	ND	ND	3.56±0.06	63.48±3.37	ND	4.57±0.80	0.70	0.20	ND	ND	ND	ND	Nunes et al., 2015; Bonet et al., 2020
A. intumescens	Pulp	ND	ND	ND	Tr	Tr	Tr	ND	14.08	ND	ND	ND	Tr	ND	74.14	11.78	ND	ND	ND	ND	ND	ND	Silva et al., 2015
A. aculeata	Almond	ND	0.40±0.28	3.87±2.18	3.93±0.93	42.78±4.20	9.09±1.70	ND	7.64±2.13	0.78±1.30	ND	3	3.55±1.34	0.21	26.61±5.30	10.10±20.0	0.12±0.09	0.20±0.09	0.18±0.07	0.07±0.04	ND	0.09±0.08	Lescan et al., 2015b; Del Río et al., 2016; Nunes et al., 2018; Magalhães et al., 2020
A. aculeata	Almond	ND	ND	4.9	3.1	41.6	13.4	ND	9.2	0.1	ND	ND	3.2	0.3	20.2	3.1	ND	ND	ND	ND	ND	ND	Lieb et al., 2019
A. aculeata	Almond	ND	ND	5.8	4.46±0.86	38.50±0.69	7.84±1.41	ND	6.66±0.79	0.06	ND	ND	2.62±0.55	27.56	ND	3.97	ND	ND	ND	ND	ND	ND	Lescano et al., 2015b; Bonet et al., 2020
A. intumescens	Almond	ND	ND	ND	5.03	45.44	12.61	ND	9.53	ND	ND	ND	4.31	ND	23.07	Tr	ND	ND	ND	ND	ND	ND	Silva et al., 2015

ND: not determined.Tr: traces (<1,0 g/Kg).

Table 2.9 Activity of enzymes produced by *Acrocomia* sp.

Species	Microorganism	Enzyme (U/mL)						Reference
		Protease	**Amylase**	**β-glicosidase**	**CMCase**	**Lipase**	**Xylanase**	
A. aculeata	*L. ramosa*	ND	1.80	0.01	0.58	0.02**	0.92	Silva et al., 2013, 2014
A. aculeata	*B. amyloliquefaciens**	30.38±0.2	151.16±1.17	ND	ND	ND	ND	Silva et al., 2016
A. aculeata	*Moniliella spathulata*	ND	ND	ND	ND	2.47***	ND	Souza et al., 2015

*Calculated data from the authors' experimental design (average cultivation of 36h). **Data converted from U/g to U/mL. ***Maximum activity value. ND: not determined.

Table 2.10 Variation of the composition of *Acrocomia aculeata* residue by bioprocess using the filamentous fungi *Lichtheimia ramosa*.

Substrate	Compound (g/100g)						Reference
	Moisture	**Protein**	**Lipids**	**Ash**	**Carbohydrates**	**Fibers**	
A. aculeata residue*	-	3.55±0.33	8.14±0.16	5.23 ± 0.41	20.90*	62.18±0.60	Silva et al., 2014
A. aculeata enriched residue*	-	5.07±2.28	7.56 ±3.78	8.70±2.29	10.13	69.56±6.39	

*Data calculated by the author (in dry basis). *Residue composed of pericarp, mesocarp fiber (without pulp) and endocarp. **Calculated from the average of 5 to 40 days of cultivation.

2.3 POTENTIAL APPLICATIONS

2.3.1 Activity against chronic diseases

The oil extracted from the pulp of *A. aculeata* has antidiabetic and antioxidant activities, without causing cytotoxicity in vitro in LLC-PK1 cells. The doses of oil (3, 30 or 300 mg / kg) administered orally were able to significantly decrease the high glucose levels in fructose-induced diabetic rats, and significantly reduce the glucose levels in normoglycemic rats. It was also observed that treatment with doses of oil for 24 days reduced the high plasmatic glucose induced by the administered drug streptozotocin. These findings suggested the functional potential of *A. aculeata* oil for the consumption by diabetic patients (da Silva et al., 2018).

Table 2.11 Bioactive compound of *Acrocomia* sp.

Species	Analyzed part	Total carotenoids (µg/g)	Total tocopherols (mg/kg)	Ascorbic acid (mg/100g)	Phenolic compounds (mg EAG/100g)	Antioxidant capacity (g/g DPPH)	Reference
A. aculeata	Pulp oil	490	212.95	ND	3.9	63	Oliveira et al., 2017; Coimbra et al., 2011
A. aculeata	Seed oil	1.82	23,10	ND	4.38	ND	Coimbra et al., 2011, 2012
A. aculeata	Pulp	49.0	ND	59.34	112.8	5.05	Ramos et al., 2008; da Silva et al., 2018
A. aculeata	Seed	1.9	ND	11,8	ND	ND	Lescano et al., 2015b; Silva et al., 2015
A. aculeata	Jelly	ND	ND	12.34	93	22.53	da Silva et al., 2018
A. aculeata	Exocarp	30.75	ND	ND	ND	ND	Schex et al., 2018

ND: not determined.

A study showed that the addition of *A. aculeata* seed oil to the diet of type 2 diabetic rats had a hypoglycemic effect, reduced weight gain, and a low deposition of medium chain fatty acids in the epididymal adipose tissue. These findings suggested that the oil should be considered as a promising source of energy to partially replace carbohydrates in diets to control the side effects of type 2 diabetes on blood glucose levels (Nunes et al., 2018).

High protein diets (HPD) are widely used for health and strength training performance. A study evaluated the activity of supplementary HPD with 6% lyophilized *Acrocomia* sp. fruit pulp (205.6 g / kg of protein) in metabolic parameters and body composition of rats submitted to strength training (ST). The pulp combined with an HPD reduced visceral fat and adiposity index (AI), in addition to improving glucose tolerance in rats submitted to ST. It was observed that after 12 weeks of ST, the maximum strength increased significantly in trained groups. However, the one who received the pulp presented significantly lower AI values (3.8-0.7% vs. 6.8-1.3%) and visceral fat (0.038-0.004 g / g vs. 0.067-0.012 g / g) compared to the sedentary receiving pulp (Almeida et al., 2020).

Pharmacological studies reported that the oil of *Acrocomia* sp. fruit pulp reduced cholesterol and glucose in rats (Ramiro, 2010; Silva, 2012). In another study, it was shown that the flour of the green *A. aculeata* fruit pulp is rich in soluble fiber and has functional and nutraceutical properties in the reduction of body weight, hypolipidemic activity in the total cholesterol fractions, LDL-cholesterol, triglycerides and fasting glucose in male mice (Giunco, 2018).

2.3.2 Anti-hypovitaminosis activity

Vitamin A deficient rats that received 13,475 mcg of β-carotene and 275 g of *A. aculeata* ripe fruit pulp per 1 kg of diet had a higher retinol accumulation compared to the animals that received a diet with pure β-carotene, improving the stocks of hepatic retinol, which allowed to conclude that the β-carotene present in the pulp had an anti-hypovitaminosis effect (Ramos et al., 2007).

2.3.3 Antioxidant and anti-inflammatory activities

Oxidative stress is a metabolic disorder associated with several chronic diseases that can be minimized by the action of antioxidants. The *A. aculeata* fruit pulp is widely used in the treatment of various diseases (Silva et al., 2018; Verruck et al., 2018). These properties are also present in other structures of the plant. A study recently conducted with *A. aculeata* leaf extracts obtained with water, ethanol, and methanol solvents showed highest amounts of phenolic compounds and free radical scavenging activity on the alcohol solvents. However, the extract obtained with the water solvent was more effective in protecting human erythrocytes against hemolysis and lipid peroxidation in all experimental models, which supports its use in the prevention or treatment of diseases related to oxidative stress (Monteiro-Alfredo et al., 2020).

The oil extracted from the pulp of *A. aculeata* fruits has effects in the prevention or in the mitigation of the reproductive toxicity induced by cyclophosphamide (CP) in male rats. The oil administered improved the changes induced by CP on the weight of reproductive organs, hormonal levels, sperm count and testicular histology, increased the expression of the Ckit gene, and normalized the levels of antioxidant enzymes that were altered by CP. Thus, the oil extracted from the pulp of *A. aculeata* can protect the male reproductive system against the adverse effects of CP. The high content of β-carotene in the oil was related with the antioxidant activity observed in the rats, which reinforces the need of the evaluation of the oil as a chemoprotective agent in humans (Arena et al., 2018).

The oil extracted from *A. aculeata* and microencapsulated showed anti-inflammatory, antiedematogenic, and diuretic effects in rats with paw edema and pleurisy. This was related to the fatty acids (bioactive compounds) that interfere in the inflammatory parameters. The microencapsulation by complex coacervation favored the bioavailability and the preservation of the bioactive components of the oil. A significant marked inhibition in the carrageenan-induced paw edema (67%) was observed. The oral administration of the oil at doses of 300 and 700 mg / kg significantly inhibited (91% and 81%, respectively) the leukocyte migration induced by carrageenan to the cavity pleural. These properties strengthen the development of new products based on this natural product. However, studies are needed to identify the active components responsible for the therapeutic effects (Lescano et al., 2015a).

It was reported a lipid extract (D-005) obtained from the oil of ripe fruits of *A. crispa*, with 92-96% of total fatty acids and 1-3% of free acids, ranging from of 8 to 18 carbon atoms (Pérez et al., 2015). Its anti-inflammatory activity was demonstrated later in *in vitro* and *in vivo* studies (Pérez et al., 2015; Pérez et al., 2017; Oyarzábal-Yera et al., 2019). Firstly, it was observed that increasing doses from 0.9 to 1000 µg / ml significantly inhibited the activities of the COX-2 (cyclooxygenase-2) enzyme in the microsomal fraction of the rat seminal vesicles and 5-LOX (arachidonate 5-lipoxygenase) enzyme in the cytosolic fraction of polymorphonuclear leukocytes, without modifying the activity of COX-1 in the mice microsomal platelets. The reduction of both enzymes suggested the anti-inflammatory potential of D-005 (Pérez et al., 2017).

In another study, for *in vivo* experimental models, all doses of D-005 (25 - 400 mg / kg) administered had a protective effect against acute kidney injury (AKI) induced by ischemia or renal reperfusion, significantly decreasing serum concentrations of creatinine, urea and uric acid), histopathological changes of AKI, and tubular damage. D-005 was also able to reverse oxidation disorder markers, decreasing the concentrations of the malondialdehyde and sulfhydryl groups in plasma and renal homogenates, and increasing renal catalase activity (Oyarzábal-Yera et al., 2019). This group also found that D-005 administered in doses of 5 – 200 mg / kg, in an *in vivo* experimental model of acute lung injury, moderately reduced (≈ 28% inhibition) pulmonary edema, with the dose of 200 mg / kg, causing a significant reduction in the edemas and improvement of the lung injuries, except for the lowest dose (5 mg / kg), which achieved a slight improvement in the injuries (Mena et al., 2019).

2.3.4 Antimutagenic, antigenotoxic, antiproliferative, and other activities

The oil extracted from the pulp of the *A. aculeata* fruit has no cytotoxic, genotoxic or mutagenic effects in rats, nor does it present acute and subacute toxicity after oral treatment with oil from this plant, suggesting that the LD50 (oral lethal dose) is greater than 2000 mg / kg. These results indicate that the exploration of the species great medical importance. However, other studies, such as chronic toxicity, reproductive toxicity and others, must be carried out to assess the total safety for use in humans (Traesel et al., 2014).

It was reported elsewhere several biological assays using methanolic extract of thorns from *A. totai* that have been performed against bacteria, fungi, viruses, neglected neotropical parasites, and human cancer cell strains. The extract obtained showed activities against breast, colon and cervical cancer tumor cell strains, in addition to bacteriostatic activity against *Staphylococcus aureus* and moderate activity against *Trypanosoma cruzi* forms in trypomastigote. Piceatannol (stylbenoid chemically analogous to resveratrol) was isolated from the extract and showed bacteriostatic and bactericidal effect against *S. aureus*, bacteriostatic effect against *Bacilus subtilis* and the inhibitory-evolutionary forms of *Leishmania amazonensis*. In addition, the stylbenoid was tested against the Zika virus, but showed no activity (Souza et al., 2017). *A. totai* leaves were described as a valuable source of active terpenoids that act against a human cancer cell modified by HPV (Souza et al., 2019).

The oils extracted from the pulp and the almond oil from *A. aculeata* fruit, at doses of 3, 15 and 30 mg / kg, showed chemoprotective effects and immunomodulatory activity, reducing the ability of cyclophosphamide to trigger apoptosis in the liver, spleen, and kidney cells. These results suggested that these oils can be classified as a functional food and can also be used to enrich other foods or be used as nutraceuticals with chemopreventive characteristics. However, they are not suitable as sources of adjuvants to chemotherapeutic agents, particularly the cyclophosphamide, because they inhibit the genotoxic and mutagenic actions of this agent (Magosso et al., 2016). In another study, it was observed from an *in vivo* model that the oil extracted from the pulp of *A. aculeta* fruit has, in addition to anti-inflammatory properties, antimutagenic properties, which were related to the the fatty acids content, *e.g.* acid oleic, and antioxidant compounds, *e.g.* carotenoids (Costa et al., 2020).

2.3.5 Other applications

By-products of *A. aculeata* (rachis, leaves and fruit pulp) can be used to obtain fibers and from these, cellulose nanocrystals (Corrêa et al., 2019). It is also reported the obtaining of films from *A. aculeata* pulp flour, with relevant characteristics for application as an edible coating (Silva et al., 2020).

2.4 CONCLUSION

Despite the economic importance and the diversification of use of the *Acrocomia* sp., they are marginally explored so far. The species that has the most outstanding applications both in subsistence and commercial exploitation is the *A. aculeata*. However, its greatest emphasis is on oil production, which has neglected its potential for formulating enriched food products, obtaining bioactive compounds, and the elaboration of functional, nutraceutical or phytotherapeutical products. In addition, there is a scarcity of information on the potential use of fruits at the green ripening stage.

2.5 REFERENCES

Agra, M. D. F., Freitas, P. F. D., & Barbosa-Filho, J. M. (2007). Synopsis of the plants known as medicinal and poisonous in Northeast of Brazil. *Revista Brasileira de Farmacognosia*, 17, 114-140. https://doi.org/10.1590/S0102-695X2007000100021

Alfaro-Solís, J. D., Montoya-Arroyo, A., Jiménez, V. M., Arnáez-Serrano, E., Pérez, J., Vetter, W., Frank, J., & Lewandowski, I. (2020). *Acrocomia aculeata* fruits from three regions in Costa Rica: an assessment of biometric parameters, oil content and oil fatty acid composition to evaluate industrial potential. *Agroforestry Systems,* 94, 1913 – 1927. https://doi.org/10.1007/s10457-020-00511-8

Almeida J. A., Santana, H. A. P., Motta-Santos, D., Nogueira, M. E., Silva, K. K. S., Miotto, H., Medeiros, C. S., Faria-Ravagnani C. C., Voltarelli, F. A., & Guimarães, R. C. A. (2020). High-Protein diet associated with bocaiuva supplementation decreases body fat and improves glucose tolerance in resistance-trained rats. *Journal of Medicinal Food*, 23(3), 258-265.

Almeida, S. P., Proença, C. E. B., Sano, S. M., & Ribeiro, J. F. (1998). *Cerrado: espécies vegetais úteis. Planaltina*: Embrapa Cerrados.

Alves, A. V., Sanjinez-Argandoña, E. J., Linzmeier, A. M., Cardoso, C. A. L., & Macedo, M. L. R. (2016). Chemical composition and food potential of *Pachymerus nucleorum* larvae parasitizing *Acrocomia aculeata* kernels. *PloS One,* 11(3), e0152125.

Arena, A. C., Jorge, B. C., Silva, M. C., de Barros, A. L., Fernandes, A. A. H., Nóbrega, R. H., Martinez, E. R. M., Cardoso, C. A. L., Anselmo-Franci, J. A., & Muzzi, R. M. (2018). *Acrocomia aculeata* oil: Beneficial effects on cyclophosphamide-induced reproductive toxicity in male rats. *Andrologia,* 50(6), e13028.

Azevedo, R. A., Santos, A. C. R., Ribeiro, C. S., Santos, F. P. C., Araujo, L., Bicalho, F. L., Fonseca, L. M., & Geraseev, L. C. (2014). Performance of dairy cows fed diets containing macauba meal. *Arquivo Brasileiro de Medicina Veterinaria e Zootecnia*, 66(1), 211-218.

Biasebetti, M. B. C., Rodrigues, I. D., & Mazur, C. E. (2018). Relation of vitamin and mineral consumption with the immune system: A brief review. *Visão Acadêmica,* 19(1), 130-136.

Bonet, S. R., Aguilera, L. C., Villalba, J. B., Villalba, D., Rotela, L. A., & Franco, R. B. (2020). Physicochemical characterization of the pulp and kernel of *Acrocomia aculeata*. *Investigación Agraria*, 22(1), 46-52. http://dx.doi.org/10.18004/investig.agrar.2020.junio.46-52

Bora, P. S., & Rocha, R. V. M. (2004). Macaiba palm: fatty and amino acids composition of fruits. *Ciência e Tecnologia de Alimentos*, 4(3), 58-162.

Brandão, A. A., Neves, J. M. G., Silva, H. P., Continho, P. H., Aquino, C. F., Santos, P. A., & Brandão, D.S. (2014). Caracterização biométrica de frutos de macaúba em diferentes estádios de maturação, provenientes de duas regiões do estado de minas gerais. *Global Science and Technology,* 07(02), 15-23.

Caxambú, M. G., Geraldino, H. C. L., Dettke, G. A., da Silva, A. R., & Dos Santos, E. N. (2015). Palmeiras (Arecaceae) nativas no município de Campo Mourão, Paraná, Brasil. *Rodriguésia*, 66(1), 259-270.

César, A. S., Almeida, F. A., Souza, R. P., Silva, G. C., & Atabani, A. E. (2015). The prospects of using Acrocomia aculeata (macaúba) a non-edible biodiesel feedstock in Brazil. *Renewable and Sustainable Energy Reviews*, 49, 1213-1220. http://dx.doi.org/10.1016/j.rser.2015.04.125

Ciconini, G., Favaro, S. P., Roscoe, R., Miranda, C. H. B., Tapeti, C. F., Miyahira, M. A. M., Bearari, L., Galvani, F., Borsato, A. V., Colnago, L. A., & Naka, M. H. (2013). Biometry and oil contents of *Acrocomia aculeata* fruits from the Cerrados and Pantanal biomes in Mato Grosso do Sul, Brazil. *Industrial Crops and Products.* 45, 208-214. http://dx.doi.org/10.1016/j.indcrop.2012.12.008

Coimbra, M. C., & Jorge, N. (2012). Fatty acids and bioactive compounds of the pulps and kernels of Brazilian palm species, guariroba (*Syagrus oleracea*), jerivá (*Syagrus* *romanzoffiana*) and macaúba (*Acrocomia aculeata*). *Journal of the Science of Food and Agriculture*, 92(3), 679-684.

Coimbra, M.C., & Jorge, N. (2011). Proximate composition of guariroba (*Syagrus oleracea*), jeriva (*Syagrus romanzoffiana*) and macauba (*Acrocomia aculeata*) palm fruits. *Food Research International,* 44, 2139–2142.

Conceição, L. D. H. C. S. da., Antoniassi, R., Junqueira, N. T. V., Braga, M. F., Machado, A. F. de F., Rogério, J. B., Durarte, I. D., Bizzo, H. R. (2015). Genetic diversity of Macauba from natural populations of Brasil. *BMC Res Notes*, 8, 406. http://dx.doi.org/10.1186/s13104-015-1335-1

Corrêa, A. C., Carmona, V. B., Simão, J. A., Galvani, F., Marconcini, J. M., & Mattoso, L. (2019). Cellulose nanocrystals from fibers of macauba (*Acrocomia aculeata*) and gravata (*Bromelia balansae*) from Brazilian Pantanal. *Polymers,* 11(11), 1785.

Costa, G. L. A., Buccini, D. F., Arruda, A. L. A., Favaro, S. P., & Moreno, S. E. (2020). Phytochemical profile, anti-inflammatory, antimutagenic and antioxidant properties of *Acrocomia aculeata* (Jacq.) Lodd. pulp oil. *Food Science and Technology,* 29, 1-9. http://dx.doi.org/10.1590/fst.25319

Da Silva, V. M., Campos, R. P., Borsato, A. V., Candido, C. J., & Donadon, J. R. (2018). Bocaiuva jelly: preparation, physicochemical and sensory evaluation. *Revista Brasileira de Fruticultura,* 40(5), 1-9. http://dx.doi.org/10.1590/0100-29452018846

Dario, M. F., Oliveira, F. F., Marins, D. S. S., Baby, A. R., Löbenberg, R., & Bou-Chacra, N. A. (2018). Synergistic photoprotective activity of nanocarrier containing oil of *Acrocomia aculeata* (Jacq.) Lodd. Ex. Martius—Arecaceae. *Industrial Crops and Products*, 12, 305-312, http://dx.doi.org/10.1016/j.indcrop.2017.12.021

Del Río, J. C., Evaristo, A. B., Marques, G., Martín-Ramos, P., Martín-Gil, J., & Gutiérrez, A. (2016). Chemical composition and thermal behavior of the pulp and kernel oils from macauba palm (*Acrocomia aculeata*) fruit. *Industrial Crops & Products*, 84, 294-304. https://doi.org/10.1016/j.indcrop.2016.02.018

Dessimoni-Pinto, N. A.V., Silvuma, V. M., Batista, Â. G., Vieira, G., Souza, C. R., Dumont, P. V., & Santos, G. K. M. (2010). Características físico-químicas da amêndoa de macaúba e seu aproveitaramento na elaboração de barras de cereais. Alimentos e Nutrição Araraquara, 21(1), 77-84.

Ferrari, R. A., & Azevedo Filho, J. A. (2012). Macauba as promising substrate for crude oil and biodiesel production. *Journal of Agricultural Science and Technology,* 12 (10), 1119–1126.

Galeano, G., & Bernal, R. (2010). *Palmas de Colombia*. Guía de Campo (1ed.). Bogotá, Colombia: Editorial Universidad Nacional de Colombia.

GBIF.org (08 July 2020). GBIF Occurrence Download https://doi.org/10.15468/dl.87a6e2

Giunco, A. J. (2018). Processo de obtenção de farinha. Brasil. BR 10 2018 073587 0 A2. Depositante: Universidade Federal da Grande Dourados. Depósito: 14/11/2018.

Guimarães, M. M., & Silva, M. S. (2008). Valor nutricional e características químicas e físicas de frutos de murici-passa (*Byrsonima verbascifolia*). *Ciências e Tecnologia de Alimentos,* 28(4), 817-821.

Hernandez-Zardon, A. F. (2016). Corojo palm, a natural resource for sustainable oil production. *Cultivos Tropicales,* 37(4), 13-21.

Hiane, P. A., Baldasso, P. A., Marangoni, S., & Macedo, M. L. R. (2006). Chemical and nutritional evaluation of kernels of bocaiuva, *Acrocomia aculeata (Jacq.) Lodd*. *Food Science and Technology,* 26(3), 683-689.

Hiane, P. A., Penteado, M. V. C., & Badolato, E. (1990). Teores de ácidos graxos e composição centesimal do fruto e da farinha da bocaiúva. *Revista de Alimento e Nutrição,* 2 (1), 21-26.

Lescano, C. H., Iwamoto, R. D., Sanjinez-Argandoña, E. J., Kassuya, C. A. L. (2015). Diuretic and Anti-Inflammatory Activities of the Microencapsulated *Acrocomia aculeata (Arecaceae)* Oil on Wistar Rats. *Journal of Medicinal Food,* 18(6), 656–662. https://doi.org/10.1089/jmf.2014.0077

Lescano, C. H., Iwamoto, R. D., Sanjinez-Argandoña, E. J., & Kassuya, C. A. L. (2015a). Diuretic and anti-inflammatory activities of the microencapsulated *Acrocomia aculeata* (Arecaceae) Oil on Wistar Rats. *Journal of Medicinal Food*, 18(6), 656–662.

Lescano, C. H., Oliveira, I. P., Silva, L. R., Baldivia, D. S., Sanjinez-Argandoña, E. J., Arruda, E. J., Moraes, I. C. F., & Lima, F. F. (2015b). Nutrients content, characterization and oil extraction from *Acrocomia aculeata* (Jacq.) Lodd. fruits. *African Journal of Food Science,* 9 (3), 113-119.

Li, Z., Li, B., Song, X., & Zhang, D. (2017). Ingestão dietética de zinco e ferro e risco de depressão: uma meta-análise. *Psychiatry Research*, 251, 41-47. https://doi.org/10.1016 / j.psychres.2017.02.006

Lieb, V. M., Schex, R., Esquivel, P., Jiménez, V. M., & Steingass, C. B. (2019). Fatty acids and triacylglycerols in the mesocarp and kernel oils of maturing Costa Rican *Acrocomia aculeata* fruits. *NFS Journal*, 14, 6-13. https://doi.org/10.1016 / j.nfs.2019.02.002

Lopes, L. S., Vieira, N., Da Luz, J. M. R., Silva, M. C. S., & Kasuya, M. C. M. (2020). Production of fungal enzymes in Macaúba coconut and enzymatic degradation of textile dye.

Biocatalysis and Agricultural Biotechnology, 26, Article 101651. https://doi.org/10.1016/j.bcab.2020.101651

Lorenzi, H., Noblick, L., Kahn, F., & Ferreira, E. (2010). *Flora brasileira Lorenzi:* Arecaceae (palmeiras). Nova Odessa-SP. Instituto Plantarum.

Lorenzi, H., Sartori, S., Bacher, L. B., & Lacerda, M. (2006). *Frutas brasileiras e exóticas cultivadas:* (de consumo in natura). São Paulo: Instituto Plantarum de Estudos da Flora, 2006.

Machado, W., Guimarães, M. F., Lira, F. F., Santos, J. V. F., Takahashi, L. S. A., Leal, A. C., & Coelho, G. T. C. P. (2015). Evaluation of two fruit ecotypes (*totai* and *sclerocarpa*) of macauba (*Acrocomia aculeata*). *Industrial Crops and Products,* 63, 287-293. https://doi.org/10.1016/j.indcrop.2014.11.002

Magalhães, K. T., Tavares, T. S., & Nunes, C. A. (2020). The chemical, thermal and textural characterization of fractions from Macauba kernel oil. *Food Research International,* 130, Article 108925. https://doi.org/10.1016/j.foodres.2019.108925

Magosso, M. F., Carvalho, P. C., Shneider, B. U., Pessatto, L. R., Pesarini, J. R., Silva, P. V., Correa, W. A., Kassuya, C. A., Muzzi, R. M., & Oliveira, R. J. (2016). *Acrocomia aculeata* prevents toxicogenetic damage caused by the antitumor agent cyclophosphamide. *Genetics Molecular Research.* 15(2). https://doi.org/10.4238/gmr.15027816.

Marin, A. M. F., Siqueira, E. M. A., & Arruda, S. F. (2009). Minerals, phytic acid and tannin contents of 18 fruits from the Brazilian savanna. *International Journal of Food Sciences and Nutrition:* Nutrition surveys & composition of food, 60(Suppl.7), 180-190. https://doi.org/10.1080 / 09637480902789342

Mena, L., Sierra, R., Valle, M., Molina, V., Rodriguez, S., Merino, N., Zamora, Z., González, V., & Medina, J. A. (2019). *Acrocomia crispa* fruits lipid extract prevents LPS-induced acute lung injury in mice. *Boletin Latinoamericano y del Caribe de Plantas Medicinales y Aromaticas,* 18(1), 16-26.

Monteiro-Alfredo, T., Matafome, P., Iacia, B. P., Antunes, K.Á., Dos Santos, J. M, Da Cunha, J. S. M., Oliveira, S., Oliveira, A. S., Campos, J. F., Magalhães, M., Cabral, C., Seiça, R., Cardoso, C. A. L., De Oliveira, C. F. R., Dos Santos, E. L., & Souza, K. P. (2020). *Acrocomia aculeata* (Jacq.) Lodd. ex Mart. Leaves Increase SIRT1 Levels and Improve Stress Resistance. *Oxidative Medicine Cellular Longevity*. 2020, Article ID 5238650, 1-16. https://doi.org/10.1155/2020/5238650

Moraes, R. M. (2015). Actualización de la lista de especies nativas de Arecaceae para Bolivia. *Revista de la Sociedad Boliviana de Botánica,* 8(1), 17–26.

Mota, R. V. (2005). Avaliação da qualidade de banana passa elaborada a partir de seis cultivares. *Ciências e Tecnologia de Alimentos*, 25(3), 560-563.

Nairz, M., & Weiss G. (2020). Iron in infection and immunity. *Molecular Aspects of Medicine.* 75, Article 100864. https://doi.org/10.1016/j.mam.2020.100864

Nascimento, A. D. P., Soares, L. A. L., Stragevitch, L., & Danielski, L. (2016). Extraction of *Acrocomia intumescens* crude oil with supercritical carbon dioxide: Process modeling and comparison with organic solvent extractions. *The Journal of Supercritical Fluids,* 111, 1-7. https://doi.org/10.1016/j.supflu.2016.01.013

Neiva, D. S., Melo Júnior, A. F., Oliveira, D. A., Royo, V. A., Brandão, M. M., & Menezes, E. V. (2016). *Acrocomia emensis* (Arecaceae) genetic structure and diversity using SSR molecular markers. *Genetics Molecular Research,* 15(1), Article Argmr.15017785. http://dx.doi.org/10.4238/gmr.15017785

Nunes, A. A., Favaro, S. P., Galvani, F., & Miranda, C. H. B. (2015). Good practices of harvest and processing provide high quality Macauba pulp oil. *European Journal of Lipid Science and Technology,* 117(12), 2036–2043. https://doi.org/10.1002/ejlt.201400577

Nunes, Â., Buccini, D., Jaques, J., Portugal, L., Guimarães, R., Favaro, S., Caldas, R., & Carvalho, C. (2018). Effect of *Acrocomia aculeata* kernel oil on adiposity in Type 2 diabetic rats. *Plant Foods for Human Nutrition,* 73(1), 61-67.

Oliveira, I., Correa, W., Neves, P., Silva, P., Lescano, C., Michels, F., Passos, W., Muzzi, R., Oliveira, S., & Caires, A. (2017). Optical analysis of the oils obtained from *Acrocomia aculeata* (Jacq.) Lodd: Mapping absorption-emission profiles in an induced oxidation process. *Photonics*, 4(1), 3.

Orsi, D. C., Nishi, A. C. F., Carvalho, V. S., Brandão, C. C., Carvalho, A. A., & Asquieri, E. R. (2015). Caracterização química da polpa de macaúba (*Acrocomia aculeata*). *Journal of Fruits and Vegetables,* 1(1), 45-48.

Oyarzábal-Yera, A., Rodríguez-Salgueiro, S., Merino-García, N., Ocaña-Nápoles, L., González-Núñez, L., Mena-Valdés, L., Zamora-Rodríguez, Z., Medina-Pírez, A., Jiménez-Despaigne, S., & Molina-Cuevas, V. (2019). Protective effects of D-005, a lipid extract from fruits, against ischemia/reperfusion-induced acute kidney injury in rats. *Kidney Research and Clinical Practice,* 38(4), 462-471.

Pérez, R. L. C. S., Canavaciolo, V. L. G., Murillo, R. V., Rico, C. L. M., Leyes, E. A. R., & Delange Marrero, D. (2015). Dry and milled vegetable material from *Acrocomia crispa* fruits to be used in D005 production. *Revista Cubana de Plantas Medicinales,* 20(2), 246-252.

Pérez, Y., Oyarzábal, A., Sierra, R., Mas, R., Molina, V., Jiménez, S., & González, V. (2017). Inhibition of cyclooxygenase (COX) and 5-lipoxygenase (5-LOX) by D-005 (a lipid extract of *Acrocomia crispa* fruits). Inhibición de la ciclooxigenasa (COX) y la 5-lipooxigenasa (5-LOX) por el D-005 (extracto lipidico del fruto de la *Acrocomia crispa*). *Boletin Latinoamericano y del Caribe de Plantas Medicinales y Aromaticas,* 16(3), 319-328.

Ramiro, M. M. (2010). *Efeito antilipidêmico do óleo extraído da polpa de Acrocomia aculeata (macaúba) em modelo experimental de hipercolesterolemia e hipertrigliceremia induzida pela dieta rica em frutose e gordura animal em ratos machos Wistar.* Dissertação de Mestrado, UCDB, Campo Grande/ MS.

Ramos, M. I., Siqueira, E. M., Isomura, C. C., Barbosa, A. M., & Arruda, S. F. (2007). Bocaiuva (*Acrocomia aculeata* (Jacq.) Lodd) improved Vitamin A status in rats. *Journal of Agricultural Food Chemistry,* 55(8), 3186-90.

Ramos, M. I. L., Ramos Filho, M. M., Hiane, P. A., Braga Neto, J. A., & Siqueira, E. M. A. (2008). Qualidade nutricional da polpa de bocaiúva *Acrocomia aculeata* (Jacq.) Lodd. *Ciência e Tecnologia de Alimentos,* 28(Suppl. 0), 90-94. https://doi.org/10.1590/S0101-20612008000500015

Reis, A. F., & Schmiele, M. (2019). Characteristics and potentialities of Savanna fruits in the food industry. *Brazilian Journal of Food Technology,* 22, Article e2017150. https://doi.org/10.1590/1981-6723.15017

Rodrigues, I. D., Santos, M. M. R., Candido, C. J., Santos, E. F., & Novello, D. (2017). Adição de farinha de bocaiúva em alfajores: caracterização físico-química e sensorial entre crianças. *Revista da Universidade Vale do Rio Verde,* 15(2), 721-732. https://doi.org/10.5892/ruvrd.v15i2.2993

Sanjinez-Argandoña, E. J., & Chuba, C. A. M. (2011). Caracterização biométrica, física e química de frutos da palmeira bocauiva *Acrocomia aculeata* (Jacq.) Lodd. *Revista Brasileira de Fruticultura*, 33(3), 1023-1028. http://dx.doi.org/10.1590/S0100-29452011000300040

Schex, R., Lieb, V. M., Jiménez, V. M., Esquivel, P., Schweiggerta, R. M., Carle, R., & Steingass, C.B. (2018). HPLC-DAD-APCI/ESI-MSn analysis of carotenoids and α-tocopherol in Costa Rican *Acrocomia aculeata* fruits of varying maturity stages. *Food Research International,* 105, 645-653. https://doi.org/10.1016/j.foodres.2017.11.041

Silva, A. O., Cortez-Vega, W. R., Prentice, C., & Fonseca, G. G. (2020). Development and characterization of biopolymer films based on bocaiuva (*Acromonia aculeata*) flour. *International Journal of Biological Macromolecules,* 155, 1157-1168. https://doi.org/10.1016/j.ijbiomac.2019.11.083

Silva, C. A. A., Lacerda, M. P. F., Leite, R. S. R., & Fonseca, G. G. (2014). Physiology of *Lichtheimia ramosa* obtained by solid-state bioprocess using fruit wastes as substrate. *Bioprocess and Biosystems Engineering*, 37, 727–734. https://doi.org/10.1007/s00449-013-1043-y

Silva, C. A. A., Lacerda, M. P. F., Leite, R. S. R., & Fonseca, G. G. (2013). Production of enzymes from *Lichtheimia ramosa* using Brazilian savannah fruit wastes as substrate on solid-state bioprocesses. *Electrononic Journal of Biotechnology,* 16 (5), 1–9. http://dx.doi.org/10.2225/vol16-issue5-fulltext-7

Silva, I. F., Langbehn, R. K., Silva, R. G. C., Pantoja, L. A., Vanzela, A., Paula, F. C., & Santos, A. S. (2016). α-Amylase production by *Bacillus amyloliquefaciens* utilizing macauba cake (*Acrocomia aculeata*) and peach palm flour (*Bactris gasipaes* - kunth) as substrates. *Biocatalysis and Biotransformation: Enzyme Technology in Brazil,* 34(2), 76-82. https://doi.org/10.1080/10242422.2016.1227794

Silva, M. R., Lacerda, D. B. C. L., Santos, G. G., & Martins, D. M. O. (2008). Caracterização química de frutos nativos do cerrado. *Ciência Rural,* 38(6), 1790-1793. http://dx.doi.org/10.1590/S0103-84782008000600051

Silva, P. V. B., Ramiro, M. M., Iriguchi, E. K. K., Corrêa, W. A., Lowe, J., Cardoso, C. A. L., Arena, A. C., Kassuya, C. A. L., & Muzzi, R. M. (2018). Antidiabetic, cytotoxic and antioxidant activities of oil extracted from *Acrocomia aculeata* pulp. *Nature Product Research,* 33(16), 2413-2416. http://dx.doi.org/10.1080 / 14786419.2018.1446006

Silva, P. V. B. S. (2012). *Caracterização química e avaliação do potencial antidiabético e citotóxico de óleo extraído de Acrocomia aculeata (macaúba).* Dissertação (Mestrado): Dourados/MS.

Silva, R. B., Silva-Júnior, E. V., Rodrigues, L. C., Andrade, L. H., da Silva S. I., Harand, W., & Oliveira, A. F. (2015). A comparative study of nutritional composition and potential use of some underutilized tropical fruits of Arecaceae. *Annals of the Brazilian Academy of Sciences.* 87(3), 701-1709. https://doi.org/10.1590/0001-3765201520140166

Silva, S. N., Silva, P. B., Silva, R. M., Silva, L. P. F. R., Barroso, A. J. R., Almeida, & F. A. C., Gomes, J. P. (2019). Composição físico-química e colorimétrica da polpa de frutos verdes e maduros de Cereus jamacaru. *Magistra,* 30, 11-17.

Smith, N. (2015). Palms and people in the Amazon: Springer International.

Sosnowska, J., & Balslev, H. (2008). American palms used for medicine, in the ethnobotanical and pharmacological publications. *Revista Peruana de Biología,* 15 (Supl. 1), 143–146.

Souza, G. K., Kischkel, B., Freitas, C. F., Negri, M., Back, D., Johann, G., Hioka, N., Schuquel, I. T. A., Santin, S. M. O., & Pomini, A. M. (2019). Antiproliferative activity and energy calculations of a new triterpene isolated from the palm tree *Acrocomia totai*. *Natural Product Research.* 27, 1-10.

Souza, G. K., Schuquel, I. T. A., Moura, V. M., Belloto, A. C., Chiavelli, L. U. R., Ruiz, A. L. T. G., Shiozawa, L., Carvalho, J. E., Garcia, F. P., Kaplum, V., Rodrigues, J. H. S., Scariot, D. B., Delvecchio, R., Ferreira, E. M., Santana, R., Soarese, C. A. G., Nakamura, C. V., Santin, S. M. O., & Pomini, A. M. (2017). X-ray structure of O-methyl-acrocol and anti-cancer, anti-parasitic, anti-bacterial and anti-Zika virus evaluations of the Brazilian palm tree *Acrocomia totai*. *Industrial Crops and Products,* 109, 483-492. https://doi.org/10.1016/j.indcrop.2017.08.066

Souza, L. T. A., Oliveira, J. S., Rodrigues, M. Q. R. B., Dos Santos, V. L., Pessela, B. C., & Resende, R. R. (2015). Macaúba (*Acrocomia aculeata*) cake from biodiesel processing: a low-cost substrate to produce lipases from *Moniliella spathulata* R25L270 with potential application in the oleochemical industry. *Microbial Cell Factories.* 14, 87. https://doi.org/10.1186 / s12934-015-0266-9

Traesel, G. K., Souza, J. C., Barros, A. L., Souza, M. A., Schmitz, W. O., Muzzi, R. M., Oesterreich, S. A., & Arena, A. C. (2014). Acute and subacute (28 days) oral toxicity assessment of the oil extracted from *Acrocomia aculeata* pulp in rats. *Food and Chemical Toxicology,* 74, 320-325. https://doi.org/10.1016/j.fct.2014.10.026

Verruck, S., Prudencio, E. S., & Silveira, S. M. (2018). Compostos bioativos com capacidade antioxidante e antimicrobiana em frutas. *Revista CSBEA*, 4(1), 111-124. https://doi.org/10.5965 / 24473650412018111

Vianna, S. A., Hiane, P. A., Jordão, M. N., Costa, E. C., & Pott, A. (2015). Physical and nutritional assessment of fruits of *Acrocomia aculeata* (Jacq.) Lodd ex Mart. (Arecaceae) based on pulp color. *Revista Biodiversidad Neotropical,* 5(2), 89-95. https://doi.org/10.18636/bioneotropical.v5i2.104

Vianna, S. A., Berton, L. H. C., Pott, A., Guerreiro, S. M. C., & Colombo, C. A. (2017). Biometric characterization of fruits and morphoanatomy of the mesocarp of *Acrocomia* species (Arecaceae). *International Journal of Biology,* 9(3), 78-92. https://doi.org/10.5539/ijb.v9n3p78

Vianna, S. A., & Campos-Rocha, A. (2020). *Acrocomia* in Flora do Brasil 2020 em construção. Jardim Botânico do Rio de Janeiro. Disponível em: <http://floradobrasil.jbrj.gov.br/reflora/ floradobrasil/FB15662>. Acesso em: 08 jul. 2020.

Vianna, S. A., Carmelo-Guerreiro, S., Noblick, L., & Colombo, C. (2016). Leaf anatomy of Acrocomia (Arecaceae): an additional contribution to the taxonomic resolution of a genus with great economic potential. *Plant Systematics and Evolution*, 303(2), 233-248. https://doi.org/10.1007/s00606-016-1369-4

Vieira, P. A. Z., Scheidt, R. F., Santos, M. M. R., Candido, C. J., Santos, E. F., & Novello, D. (2017). Cupcakes adicionados de farinha de bocaiúva: caracterização físico-química e avaliação sensorial entre crianças. *Revista da Universidade Vale do Rio Verde*, 15(2), 501-513. http://dx.doi.org/10.5892/ruvrd.v15i2.2943

CAPÍTULO 3

GROWTH AND PROXIMATE COMPOSITION OF *Pleurotus ostreatus* CULTIVATED ON GREEN BOCAIUVA PULP SUBSTRATES WITH DIFFERENT NITROGEN SOURCES

ABSTRACT: The aim of this work was to evaluate the growth and the proximate composition of the mycelium-based bocaiuva pulp with the edible mushroom *P. ostreatus* on green bocaiuva flour added with different sources of nitrogen (urea, ammonium nitrate and sulfate ammonia). Growth was monitored by kinectics. At the end, the proximate composition of the best three treatments (dehydrated green bocaiuva pulp and water, T1; dehydrated green bocaiuva pulp and ammonium nitrate, T3; and green bocaiuva pulp/wheat bran and ammonium nitrate, T7) was determined. Ammonium nitrate was the nitrogen source that showed the greatest growth in both substrates (T3:8.33 cm and T7:7.67 cm), in relation to the other treatments (4.67 to 7.17 cm), with emphasis on the green bocaiuva pulp. The substrate with green bocaiuva pulp and water was the one that showed the highest growth (7.50 cm), which was close to the treatment with mixed substrate and ammonium nitrate (7.67 cm). The treatment with the green bocaiuva pulp and ammonium nitrate (T3) was highlighted due to its significant increase in proteins (9.42 g 100 g^{-1}) and fibers (5.21 g 100 g^{-1}) and decrease in carbohydrates (9.52 g 100 g^{-1}), in comparison to the other treatments T7 (8.94, 2.16, and 5.99 g 100 g^{-1}, respectively) and T1 (2.78, 4.33, and 2.28 g 100 g^{-1}, respectively). The product obtained from the growth of P. ostreatus in the pulp of bocaiúva verde has promising prospects to be used as raw material in the development of new food products with added nutraceutical value.

Key words: *Acrocomia*, Edible mushroom, Nitrogen source, Proximate composition and solid-state cultivation.

3.1 INTRODUCTION

The consumption of fruits and vegetables has been estimulated in many countries because it is associated with a lower incidence of mortality from chronic non-communicable diseases (NCDs) (Miller et al. 2017; Rosário et al., 2018; Uddin et al., 2020). Among them, cardiovascular diseases, diabetes, cancer and chronic respiratory disease are prevalent. They are accentuated by smoking, physical inactivity, inadequate diet and alcohol use (Duncan et al., 2012; Pengpid & Peltzer, 2017). On the other hand, some of these diseases can be minimized or even prevented by changing eating habits, *e.g.* incorporating the daily consumption of fruits and vegetables (Raigond et al., 2018; Yuan et al., 2018; Jezewska-Zychowicz et al., 2019) with high content of vitamins, minerals, dietary fiber (Fayet-Moore et al., 2017; Arun et al., 2017; Volpe, 2019), and low glycemic indexes (Oboh et al., 2015; Raigond et al., 2018).

In the Brazilian savannah biome are found species of native or adapted fruit plants with nutritional and therapeutic properties, depending on the primary and secondary compounds derived from the plant's metabolism, as well as, by the peculiar aroma and flavor that make them attractive for consumption (Reis & Schmiele, 2019). Among these species, stands out *Acrocomia* sp., which fruits are commonly known as bocaiuva, macauba or macaiba (Vianna et al., 2017). These fruits provide mature pulp rich in lipids, carbohydrates, fibers (Bora & Rocha 2004; Ramos et al., 2008; Orsi et al., 2015), copper, iron, manganese, potassium and zinc (Ramos et al. 2008; Gonçalves et al., 2020) being able to supply the nutritional needs of human beings through ingestion natural or processed (Ramos et al. 2008; de Oliveira et al., 2020). In addition, the pulp is rich in β-carotene (Ramos et al. 2008; Coimbra & Jorge, 2011; Orsi et al. 2015) and α-tocopherol (Coimbra & Jorge, 2011), which are important carotenoids due to their antioxidant action and anti-inflammatory effect (Costa et al., 2020; Lescano et al., 2015). Most scientific studies on the nutritional and functional properties of the genus *Acrocomia* refer to the species *A. aculeata*. Studies with other species, *e.g. A. totai* are scarce and indispensable to confirm their properties, increase their value and contribute to the preservation of palm trees, as they are often deforested for agricultural purposes in the region.

The bocaiuva pulp has important nutritional, sensory and functional characteristics for health, thus being considered a promising source for the food industry (Orsi et al., 2015; Valério et al., 2019). However, it is little used in human food, mainly in the stage of green maturation. Thus, its consumption can be favored from the bioconversion of the green bocaiuva pulp by edible mushrooms in order to obtain food products with *low* carbohydrate content and enriched in proteins and fibers, that are accepted by most of the consumers (Ritota & Manzi, 2019).

Mushrooms can contribute to the prevention of some diseases, such as hypertension (Vaz et al., 2011), cholesterol (Wei et al., 2018; Liu et al., 2019), diabetes (Asrafuzzaman et al., 2018; Liu et al., 2019; Khatun et al., 2020; Balaji et al., 2020), stress (Akata et al., 2012), obesity (Khatun et al., 2020) and acting as an appetite suppressant (Sheng et al., 2019). *Pleurotus ostreatus* is an edible oyster mushroom that has a light color (white, gray or brown) and a basidiocarp with a fleshy leaf shape (Jonathan & Esho, 2010). *Pleurotus* are a source of nutrients, mainly proteins, minerals and vitamins B, C and D (Panjikkaran & Mathew, 2013). This mushroom contains 20-35% protein (dry weight) and low levels of essential lipids and amino acids (Li et al., 2017; Lavelli et al., 2018). Due to its low caloric value can be included in diets with controlled calorie intake (Jaworska & Bernás, 2009).

Pectocellulosic substrates, such as peels, pulps and fruit pomace, present favorable conditions for the cultivation of edible mushrooms, as they have a lower carbon: nitrogen ratio and high concentrations of simple sugars, which facilitates their availability to the fungus (Rivas et al., 2010; Cardoso et al., 2013; Silva et al., 2014; Silva et al., 2020). The adaptation of *Pleurotus* species to new substrates represents one of the main bioconversion processes in food products with added value and nutritional quality (Mbassi et al., 2018; Ritota & Manzi, 2019). Therefore, the use of fruit substrates for the cultivation of edible mushrooms makes it a viable alternative for the nutritional enrichment of these products and the enhancement of species within a productive chain, with permanent and sustainable production (Carrasco-González et al., 2017; Ritota & Manzi, 2019).

Thus, the objective of this work was to evaluate the growth and the proximal composition of *P. ostreatus* grown on green bocaiuva pulp substrates with different nitrogen sources, in order to obtain a product with a low carbohydrate content and rich in proteins and fibers.

3.2 MATERIAL AND METHODS

3.2.1 Microorganism and substrate

Pleurotus ostreatus URM 4072 was obtained from the Fungal Culture Collection of the Federal University of Pernambuco. The cells were received lyophilized and, after reactivation, kept in a medium inclined potato dextrose agar (PDA) immersed in mineral oil and stored at 4 °C (Fonseca et al., 2009; Silva et al., 2013). The strain was grown in Petri dishes containing Sabouraud 4% glucose agar medium at 30 °C for 10 days to reactivate the mycelial growth.

The substrates utilized were the dehydrated green bocaiuva pulp and the mixture of dehydrated green bocaiuva pulp (50%) and wheat bran (50%). The bocaiuva fruits (*Acrocomia totai* Mart) were collected in the municipality of Bela Vista-MS (56 ° 24’12.6’’ West longitude, 21° 56’15.9’’ South latitude, and 153 m altitude), Brazil.

After harvested, they were washed and sanitized with sodium dichloroisocyanurate 0.66% (w / v) solution (Sumaveg de Diversery Lever) with 200 ppm of active chlorine for 15 min. Then, the fruits were manually peeled and mechanically pulped. The pulp obtained was dehydrated in a circulation oven, with drying air speed of 1m / s at 50 ºC for 24 h. Wheat bran was purchased from a local market in the city of Dourados-MS.

3.2.2 Inoculation, cultivation and mycelial growth

The experiments were carried out with 2 pulp combinations: dehydrated green bocaiuva pulp (BP) or dehydrated green bocaiuva pulp plus wheat bran (BPWB) in a 1: 1 w / w proportion. For each combination of pulps, experiments were carried out with the addition of 2% of external nitrogen sources: urea (U), ammonium nitrate (AN), and ammonium sulfate (AS), resulting in eight treatments (Table 3.1). Each treatment was placed into 50 mL test tubes, sterilized in an autoclave at 121 ºC for 20 min and inoculated with 5 cm discs of myceliated agar. The tubes were incubated at 30 ºC and the axemic growth of the fungus was measured every 2 days with a calibrated ruler (Ilyas & Avin, 2018).

Table 3.1 Treatments for growth experiments.

Treatment	Pulp mixture	External N source
T1	BP	-
T2	BP	U
T3	BP	AN
T4	BP	AS
T5	BP/WB	-
T6	BP/WB	U
T7	BP/WB	AN
T8	BP/WB	AS

BP: green bocaiuva pulp; BP/WB: green bocaiuva pulp / wheat bran; U: urea; AN: ammonium nitrate; AS: ammonium sulfate.

3.2.3 Proximate composition

The proximate composition was determined for the dehydrated green bocaiuva pulp (BP), the wheat bran (WB), the mixture of green bocaiuva pulp and wheat bran (BP / WB) and the three best experiments with mycelial growth. The moisture content was determined by using an oven with air circulation at 70 ºC (Method nº 44-15.02, AACC 2010), the mineral residue by weighing the residues from muffle incineration at 550 °C (Method nº 08-01.01, AACC, 2010), the proteins by the Kjeldahl method (Method nº 2001.11, AOAC, 2005), the total lipids by using the Soxhlet extractor (Method nº 30-25.01, AACC, 2010), and the crude fiber by the gravimetric method using a fiber determiner (Method nº 978.10, AOAC, 2005). The determination of the carbohydrates was performed by difference (= total - moisture – minerals – lipids – proteins – fibers).

3.2.4 Energetic value and proximate composition variation (PCV)

The energy value was calculated using the Atwater coefficients that consider 4 kcal / g of sample for proteins and carbohydrates and 9 kcal / g of sample for lipids (Merril & Watt, 1973). The proximate composition variation of the cultivated media for proteins, lipids and fibers was calculated by the percentage difference between the concentration presented in the cultivated medium (greater accumulation) and treated medium (inoculated) (Equation 1), according to Fonseca et al. (2009).

$$\text{PCV (\%)} = \left(\frac{\text{Final content (\%)}}{\text{Initial content (\%)}} \text{ x } 100\right) - 100 \quad (1)$$

3.2.5 Statistical analysis

The experiments were carried out in triplicate and the results expressed as mean and standard deviation. Analysis of variance (ANOVA) and Tukey’s multiple comparison test ($P < 0.05$) were calculated using Statistica version 8.0 software (StatSoft, Inc, Tulsa, USA).

3.3 RESULTS AND DISCUSSION

3.3.1 Mycelial growth

Fig. 3.1 shows the growth curves of *P. ostreatus* on dehydrated green bocaiuva pulp and the mixture of dehydrated green bocaiuva pulp and wheat bran based substrates with different nitrogen sources (urea, ammonium nitrate and sulfate ammonia) for 40 days. In all treatments, colonization was observed after two days of inoculation, as reported elsewhere (Patel et al., 2009). The growth was evident up to the 30th day. After that, a stationary phase was observed.

Ammonium nitrate was the best nitrogen source evaluated. It allowed the highest growth in both substrates compared to the other treatments, mainly on the green bocaiuva pulp. Regarding the control treatments, it can be observed that the substrate with green bocaiuva pulp and water was the one that showed the highest growth, which was close to the treatment with ammonium nitrate and the mixture of green bocaiuva pulp and wheat bran (T7).

The type of substrate utilized has an effect on the chemical, functional and sensory characteristics of the mushrooms (Mbassi et al., 2018; Lavelli et al., 2018; Pazza et al., 2019; Valenzuela-Cobos et al., 2019). *Pleurotus* sp. extract the nutrients from the substrate through the mycelium, obtaining substances necessary for its development, such as carbon, nitrogen, vitamins and minerals (Lavelli et al., 2018; Bellettini et al., 2019). The nutritional content of the substrates can be improved by supplementing with nitrogen (Nunes et al., 2012).

The nitrogen source is an important factor in the synthesis of proteins, nucleic acids, purines, pyrimidines and polysaccharides (Drozdowski et al., 2010; Abdullah et al., 2015). Some studies have pointed out that nitrogen supplementation can increase productivity yield, but up to a certain level, as high nitrogen values can inhibit the fructitification of *Pleurotus* sp. (Silva et al., 2007). Thus, supplementation with 2% ammonium nitrate in the green bocaiuva pulp-based substrate was efficient for the mycelial growth of *P. ostreatus.*

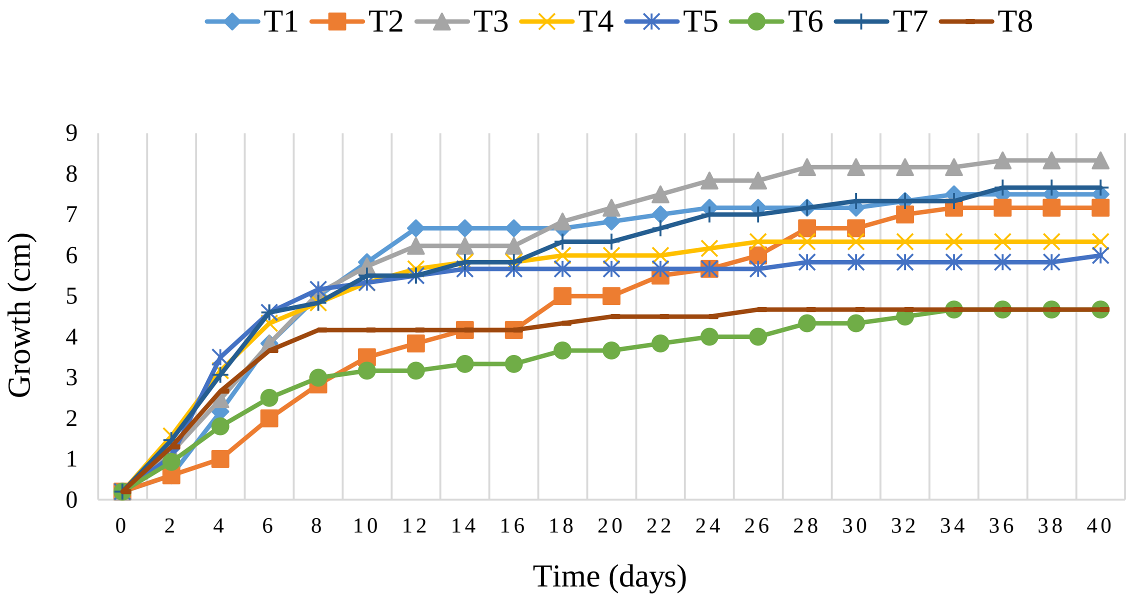

Figure 3.1 Growth curves of *Pleurotus ostreatus.*

T1: dehydrated green bocaiuva pulp (BP) and water; T2: dehydrated green bocaiuva pulp (BP) and Urea (U); T3: dehydrated green bocaiuva pulp (BP) and ammonium nitrate (AN); T4: dehydrated green bocaiuva pulp (BP) and ammonium sulfate (AS); T5: green bocaiuva pulp / wheat bran (BP/WB) and water; T6: green bocaiuva pulp / wheat bran (BP/WB) and urea (U); T7: green bocaiuva pulp / wheat bran (BP/WB) and ammonium nitrate (AN); T8: green bocaiuva pulp / wheat bran (BP/WB) and ammonia sulphate (AS).

3.3.2 Proximate composition

The results obtained for the proximate composition of wheat bran, dehydrated green bocaiuva pulp and the three best treatments with dry mycelial growth are shown in Fig. 3.2. It observes that the wheat bran, the green bocaiuva pulp and the treatments presented moistures of 1.22 ± 0.17 to 3.88 ± 0.49 g 100 g^{-1} (Fig. 3.2A). According to Brazilian legislation it should not exceed 15 g 100 g^{-1} (ANVISA, 2005a).

The type of substrate and the nitrogen source utilized for the cultivation of *Pleurotus* sp. influenced directly in the final proximate composition of the products. The main proximate components that had a significant increase ($p<0.05$) were proteins and fibers, for all treatments, in relation to the initial composition, without miceliation. It also underlines the treatment with green bocaiuva pulp and ammonium nitrate (T3) due to its significant increase in proteins (9.42 g 100 g^{-1}) (Fig. 3.2B) and fibers (5.21 g 100 g^{-1}) (Fig. 3.2C), in comparison to the other T7 treatments (8.94 and 2.16 g 100 g^{-1}, respectively) and T1 (2.78 to 4.33 g 100 g^{-1}, respectively) (Fig. 3.2B and 3.2C). The variation in protein content can be explained by the addition of a nitrogen source (ammonium nitrate) in the substrate. In accordance, it was reported elsewhere that the protein enrichment of pineapple peels by using *Trichoderma viride* was higher, when there was a better aeration and the addition of ammonium sulfate as nitrogen source (Aruna, 2019).

The increase in fiber content during the solid state bioprocess may be associated with the fungal cell wall, as it is composed of chitin fibers, which is a polysaccharide consisting of a long chain of N-acetylglycosamine, insoluble in water (Garcia-Rubio et al., 2020). The cell wall of filamentous fungi contains chitin in the proportion of 10 to 20%. These structures withstand great pressure and, thus, become responsible for the integrity of the cell wall. When chitin synthesis is interrupted, the cell wall becomes disorganized and the fungal cell undergoes deformations and osmotic instability (Bowman & Free, 2006).

It was demonstrated that the soluble dietary fiber in nejayote increased 45% after solid state cultivation with *P. ostreatus* Perla, improving the bioavailability of the fiber source as a functional ingredient (Acosta-Estrada et al., 2019).

The use of *P. ostreatus* in the bioconversion of green pulp is an alternative to produce improved foods with added value for disease prevention due to the enrichment of the nutrient content by the fungus.

According to technical regulations, T1 can be considered as a protein source and T3 and T7 as high protein content sources, all with high fiber content (ANVISA, 2012). It is recommended the daily consumption of 50 g of protein by adults and 34 g by children up to 10 years old (ANVISA, 2005b). In this sense, the intake of 100 g of T3 provides about 27 to 40% of the daily protein requirement. It also provides about 93% of the daily recommendation of fiber for adults by FAO (United Nations Food and Agriculture Organization) and WHO (World Health Organization), being that at least 25 g of fibers per day is considered enough to prevent chronic diseases (WHO/FAO, 2003).

Regarding the carbohydrate content, there was a significant reduction for all treatments (Fig. 3.2D) being greater in T3 (9.52 g 100 g^{-1}), followed by T7 (5.99 g 100 g^{-1}) and T1 (2.28 g 100 g^{-1}). The carbohydrates consumed were used as sources of carbon and energy for growth and synthesis of other compounds (Fonseca et al. 2009; Silva et al. 2013).

The minerals showed a decrease in the contents for all treatments compared to the initial characterization (2.75, 2.89, and 2.81 g 100 g^{-1} for T1, T3, and T7, respectively) (Fig. 2.2E). This decrease may be due to leaching, as a result of microbial activities that some minerals are lost or used during solid state fermentation by *Pleurotus ostreatus* (Adebayo et al., 2019). The range of values found in the present study (1.62 to 2.00 g 100 g^{-1}) is below to that reported by Silva et al. (2014), with minerals reaching up to 10.91 g 100 g^{-1}. These contents can vary depending on the fungal species and the substrate utilized.

The treatments had an increase of 0.06 to 0.53 g 100 g^{-1} of lipids in relation to the initial characterization (Fig. 3.2F). The increase in lipids may have occurred due to the production of enzymes during mycelial growth, as these lipids are intended for the construction of the cell wall of fungi (Fonseca et al., 2009; Athenaki et al., 2017) and it is also associated that some fungi species are able to accumulate lipids during the bioprocess (Dulf et al., 2016; Dulf et al., 2017; Araújo et al., 2020).

3.3.3 Energetic value and proximate composition variation

It can be observed that the treatments with green bocaiuva pulp (T1 and T3) had lower energy value in relation to the experiment with the mixture of bocaiuva pulp and wheat bran (T7) (Fig. 3.3A). This behavior may be related to the increase in the protein content, indicating that the microorganism utilized efficiently the source of exogenous nitrogen to the bioconversion of carbohydrates and some fibers into protein.

An expressive positive protein variation (enrichment) was observed for all treatments, mainly for T3 with 231.12%, followed by T7 (84.44%) and T1 (75.17%) (Fig. 3.3B). These results demonstrate that T3 was superior in terms of protein enrichment than *e.g.* the the fruit residues of *Caryocar brasiliense* (160.04%), *Annona crassiflora* (143.31%), *Campomanesia pubescens* (102.42%), and the T1 (75.17%) presented itself higher to the substrate *Acrocomia aculeata* (67.88%) with *Lichtheimia ramosa* (Silva et al. 2014). Regarding the lipid variation, it can be observed that T1 presented a higher percentage (86.76%) than that observed for T3 (75.08%) and T7 (5.57%). This enrichment was greater than that reported by Fonseca et al. (2009) who obtained 66.70% of variation using *P. ostreatus* in cultivations containing a mixture of rice bran, rice straw and sof rush. The fibers had a variation of 15.88, 24.00, and 33.51%, for T7, T1 and T3, respectively. In the study by Zusman et al. (1997) it can be observed increases up to 78 % in the fiber content in *P. ostreatus* fungi grown on corn cobs.

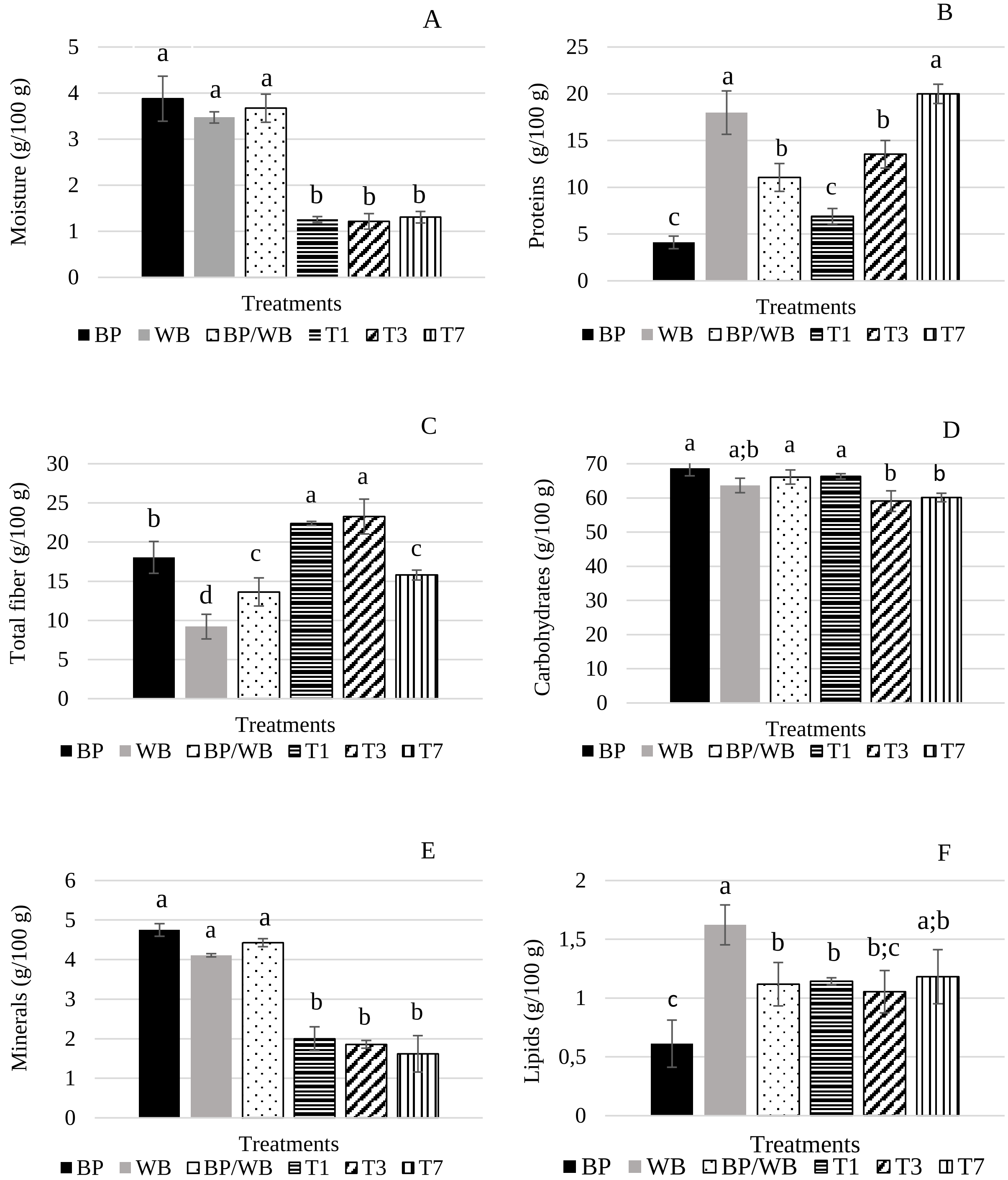

Figure 3.2 Proximate composition for different cultivation treatments with *Pleurotus ostreatus*. BP: dehydrated green bocaiuva pulp without increment; WB: wheat bran without increment; BP/WB: green bocaiuva pulp / wheat bran without increment; T1: dehydrated green bocaiuva pulp (BP) and water; T3: dehydrated green bocaiuva pulp (BP) and ammonium nitrate (AN); T7: green bocaiuva pulp / wheat bran (BP/WB) and ammonium nitrate (AN).

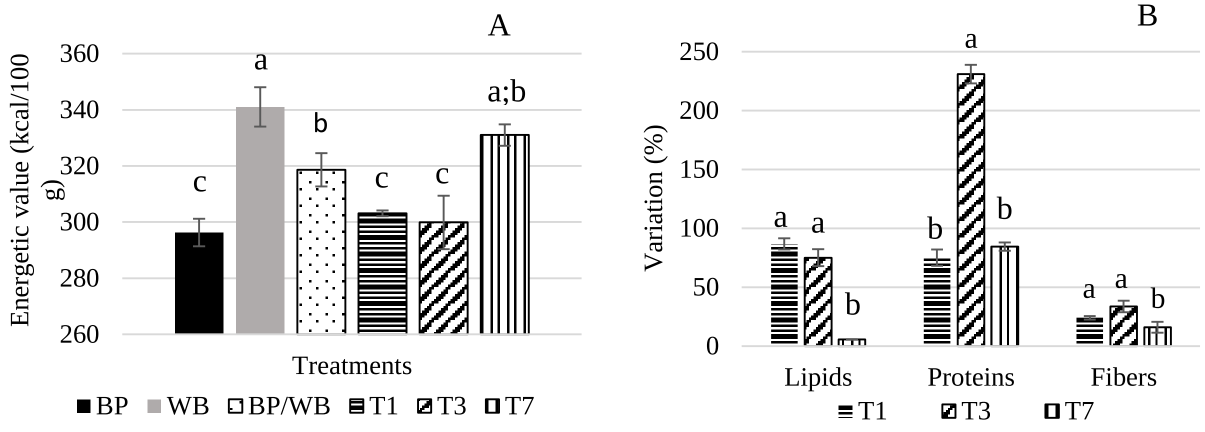

Figure 3.3 Energetic value and composition variation for lipids, proteins and fibers for different cultivation treatments with *Pleurotus ostreatus*.

BP: dehydrated green bocaiuva pulp without increment; WB: wheat bran without increment; BP/WB: green bocaiuva pulp / wheat bran without incremente; T1: dehydrated green bocaiuva pulp (BP) and water; T3: dehydrated green bocaiuva pulp (BP) and ammonium nitrate (AN); T7: green bocaiuva pulp / wheat bran (BP/WB) and ammonium nitrate (AN).

3.4 CONCLUSION

The addition of ammonium nitrate as nitrogen source in the T3 treatment contributed to better mycelial growth and potentiated the bioconversion of carbohydrates from the green pulp of *Pleurotus ostreatus* into proteins, fibers and lipids, which is promising for the development of new ones food products with nutraceutical added value.

3.5 ACKNOWLEDGMENTS

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3.6 REFERENCES

AACC. (2010). American Association of Cereal Chemists. Approved methods of the American Association of Cereal Chemists. 11° ed. Saint Paul.

Abdullah, N., Lau, C. C., & Ismail, S. M. (2015). Potential use of *Lentinus squarrosulus* mushroom as fermenting agent and source of natural antioxidant additive in livestock feed.

Journal of the Science of Food and Agriculture, 96(5), 1459-1466. https://doi.org/10.1002/jsfa.7242

Acosta-Estrada, B. A., Villela-Castrejón, J., Perez-Carrillo, E., Gómez-Sánchez, C. E., & Gutiérrez-Uribe, J. A. (2019). Effects of solid-state fungi fermentation on phenolic content, antioxidant properties and fiber composition of lime cooked maize by-product (nejayote). *Journal of Cereal Science*, *90*, 102837. https://doi.org/10.1016/j.jcs.2019.102837

Adebayo, O. C., Ogidi, C. O., & Akinyele, B. J. (2019). Nutritional value and safety of castor bean (*Ricinus communis*) seeds detoxified in solid - state fermentation by *Pleurotus ostreatus*. *Biofarmasi Journal of Natural Product Biochemistry*, *17*(2), 51-60. https://doi.org/10.13057/biofar/f170201

Akata, I., Ergonul, B., & Kalyoncu, F. (2012). Chemical compositions and antioxidant activities of 16 wild edible mushroom species grown in Anatolia. *International Journal of Pharmacology*, *8*, 134-138. https://doi.org/10.3923/ijp.2012.134.138

ANVISA. (2005a). National Health Surveillance Agency, Department of the Ministry of Health, Technical regulation for cereal products, starches, flour and bran, Resolution - RDC nº 263, Brazil.

ANVISA. (2005b). National Health Surveillance Agency, Department of the Ministry of Health, Technical Regulation on Recommended Daily Intake (IDR) of Protein, Vitamins and Minerals, Resolution - RDC nº 269, Brazil.

ANVISA. (2012). National Health Surveillance Agency, Department of the Ministry of Health, Technical Regulation on Complementary Nutrition Information, Resolution - RDC nº 54, Brazil.

AOAC. (2005). Official Methods of Analysis of AOAC International. 18 th ed. AOAC International, Arlington, Virginia, USA.

Araújo, P. S., Silva, P. G. P., Araújo, S. S., Leite, R. S. R., Silva, C. A. A., Fonseca, G. G. (2020). Changes in biochemical composition of cassava and beet residues during solid state bioprocess with *Pleurotus ostreatus. Biocatalysis and Agricultural Biotechnology*, *26*, 101641. https://doi.org/10.1016/j.bcab.2020.101641

Arun, K. B., Thomas, S., Reshmitha, T. R., Akhil, G. C., & Nisha, P. (2017). Dietary fibre and phenolic-rich extracts from *Musa paradisíaca* inflorescence ameliorates type 2 diabetes and associated cardiovascular risks. *Journal of Functional Foods*, *31*, 198-207. https://doi.org/10.1016/j.jff.2017.02.001

Aruna, T. E. (2019). Production of value-added product from pineapple peels using solid state fermentation. *Innovative Food Science & Emerging Technologies*, *57*, 102193. https://doi.org/10.1016/j.ifset.2019.102193

Asrafuzzaman, M., Rahman, M. M., Mandal, M., Marjuque, M., Bhowmik, A., Rokeya, B., Hassan, Z., & Faruque, M. O. (2018). Oyster mushroom functions as an antihyperglycaemic through phosphorylation of AMPK and increased expression of *GLUT4* in type 2 diabetic model rats. *Journal of Taibah University for Science*, *13*, 465-471. https://doi.org/10.1016/j.jtumed.2018.02.009

Athenaki, M., Gardeli, C., Diamantopoulou, P., Tchakouteu, S. S., Sarris, D., Philippoussis, A., & Papanikolaou, S. (2017). Lipids from yeasts and fungi: physiology, production and analytical considerations. *Journal of Applied Microbiology*, *124*(2), 336-367. https://doi.org/10.1111/jam.13633

Balaji, P., Madhanraj, R., Rameshkumar, K., Veeramanikandan, V., Eyini, M., Arun, A., Thulasinathan, B., Farraj, D. A. A., Elshikh, M. S., Al-Oqda, A. M., Mahmoud, A. H., Tack, J. -C., & Kim, H. -J. (2020). Evaluation of antidiabetic activity of *Pleurotus pulmonarius* against streptozotocin-nicotinamide induced diabetic wistar albino rats. *Saudi Journal of Biolical Sciences*, *27*, 913-924. https://doi.org/10.1016/j.sjbs.2020.01.027

Bellettini, M. B., Fiorda, F. A., Maieves, H. A., Teixeira, G. L., Ávila, S., Hornung, P. S., Maccari Júnior, A., & Ribani, R. H. (2016). Factors affecting mushroom *Pleurotus* spp. *Saudi Journal of Biological Sciences*, *26*, 633-646. https://doi.org/10.1016/j.sjbs.2016.12.005

Bora, P. S., & Rocha, R. V. M. (2004). Macaiba palm: fatty and amino acids composition of fruits. *Ciência e Tecnologia de Alimento*s, 4(3), 158-162. https://doi.org/10.1080/11358120409487755

Bowman S. M., & Free, S. J. (2006). The structure and synthesis of the fungal cell wall. *Bioessays.* 28(8), 799-808. https://doi.org/10.1002/bies.20441

Cardoso, J. C. P., Demenjour, P. L. M. M., & Paz, M. F. (2013). Cultivation of edible mushroom *Pleurotus ostreatus* in bocaiuva bagasse by Jun-Cao technique. *Evidência*, *13*(1), 31-40.

Carrasco-González, J. A., Serna-Saldívar, S. O., & Gutiérrez-Uribe, J. A. (2017). Nutritional composition and nutraceutical properties of the *Pleurotus* fruiting bodies: Potential use as food ingrediente. *Journal of Food Composition* and *Analysis*, *58*, 69-81. https://doi.org/10.1016/j.jfca.2017.01.016

Coimbra, M. C., & Jorge, N. (2011). Proximate composition of guariroba (*Syagrus oleracea*), jerivá (*Syagrus romanzoffiana*) and macaúba (*Acrocomia aculeata*) palm fruits. *Food Research International*, *44*, 2139-2142. https://doi.org/10.1016/j.foodres.2011.03.032

Costa, G. L. A., Buccini, D. F., Arruda, A. L. A., Favaro, S. P., & Moreno, S. E. (2020). Phytochemical profile, anti-inflammatory, antimutagenic and antioxidant properties of *Acrocomia aculeata* (Jacq.) Lodd. pulp oil. *Food Science and Technology*, *29*, 1-9. https://doi.org/10.1590/fst.25319

De Oliveira, M. C., Curi, P. N., Pio, R., Farias, D. D. H., Rigote, M. R., Schiassi, M. C. E. V., Pasqual, M., & Souza, V. R. D. (2020). Physicochemical characterization, bioactive compounds and correlations in native fruits of western Mato Grosso do Sul. *British Food Journal*, *122*, 841-851. https://doi.org/10.1108/BFJ-06-2019-0423

Drozdowski, L. A., Reimer, R. A., Temelli, F., Bell, R. C., Vasanthan, T., & Thomson, A. B. R. (2010). Glucan extracts inhibit the *in vitro* intestinal uptake of long-chain fatty acids and cholesterol and down-regulate genes involved in lipogenesis and lipid transport in rats. *Journal of Nutrition Biochemistry*, *21*, 695-701. https://doi.org/10.1016/j.jnutbio.2009.04.003

Dulf, F. V., Vodnar, D. C., & Socaciu, C. (2016). Effects of solid-state fermentation with two filamentous fungi on the total phenolic contents, flavonoids, antioxidant activities and lipid fractions of plum fruit (*Prunus domestica* L.) by-products. *Food Chemistry*, *209*, 27-36. https://doi.org/10.1016/j.foodchem.2016.04.016

Dulf, F. V., Vodnar, D. C., Dulf, E.-H., Pintea, A. (2017). Phenolic compounds, flavonoids, lipids and antioxidant potential of apricot (*Prunus armeniaca* L.) pomace fermented by two filamentous fungal strains in solid state system. *Chemistry Central Journal*, *11*(1), 92. https://doi.org/10.1186/s13065-017-0323-z

Duncan, B. B., Chor, D., Aquino, E. M. L., Bensenor, I. M., Mill, J. G., Schmidt, M. I., Lotufo, P. A., Vigo, Á., & Barreto, S. M. (2012). Chronic non-communicable diseases in Brazil: priorities for disease management and research. *Revista de Saúde Pública*, *46*, 126-34. https://doi.org/10.1590/S0034-89102012000700017

Fayet-Moore, F., Petocz, P., Mcconnell, A., Tuck, K., & Mansour, M. (2017). The cross-sectional association between consumption of the recommended five food group "grain (cereal)", dietary fibre and anthropometric measures among australian adults. *Nutrients*, *9*(2), 157. https://doi.org/10.3390/nu9020157

Fonseca, G. G., Gandra, E. A., Sclowitz, L. F., Antunes, A. P. C., & Costa, J. A. V. (2009). Protein enrichment and digestibility of soft rush (*Juncus effusus*) and rice residues using edible mushrooms *Pleurotus ostreatus* and *Pleurotus sajor-caju*. *World Journal of Microbiology and Biotechnology*, *25*, 449-456. https://doi.org/10.1007/s11274-008-9909-x

Garcia-Rubio, R., de Oliveira, H. C., Rivera, J., & Trevijano-Contador, N. (2020). The fungal cell wall: *Candida*, *Cryptococcus*, and *Aspergillus* species. *Frontiers in Microbiology*, *10*, 2993. https://doi.org/10.3389/fmicb.2019.02993

Gonçalves T. O., Filbido, G. S., Pinheiro, A. P. O, Pieretti, P. D. P., Villa, R. D., & de Oliveira, A. P. (2020). *In vitro* bioaccessibility of the Cu, Fe, Mn and Zn in the baru almond and bocaiúva pulp and, macronutrients characterization. *Journal of Food Composition and Analysis*, *86*, 103356. https://doi.org/10.1016/j.jfca.2019.103356

Ilyas, N., & Avin, F. A. (2018). Analysis of physicochemical parameters to evaluate the mycelia growth of *Pleurotus pulmonarius*. *Annual Research & Review in Biology*, *25*, 1-13. https://doi.org/10.9734/ARRB/2018/40020

Jaworska, G., & Bernás, E. (2009). Qualitative changes in *Pleurotus ostreatus* (Jacq: Fr.) Kumm. mushrooms resulting from diferente methods of preliminary processing and periods of frozen storage. *Journal of the Science of Food and Agriculture*, *89*, 1066-1075. https://doi.org/10.1002/jsfa.3557

Jezewska-Zychowicz, M., Gębski, J., Plichta, M., Guzek, D., & Kosicka-Gębska, M. (2019). Diet-related factors, physical activity, and weight status in Polish adults. *Nutrients.* 11(10), 2532. https://doi.org/10.3390/nu11102532

Jonathan, S. G., & Esho, E. O. (2010). Fungi and aflatoxin detection in two oyster mushrooms *Pleurotus ostreatus* and *Pleurotus pulmonarius* from Nigeria. *Electronic Journal of Environmental, Agricultural and Food Chemistry*, *9*(11), 1722-1730

Khatun, M. A., Sato, S., & Konishi, T. (2020). Obesity preventive function of novel edible mushroom, Basidiomycetes-X (Echigoshirayukidake): Manipulations of insulin resistance and lipid metabolism. *eJTCM*, *10*, 245-251. https://doi.org/10.1016/j.jtcme.2020.03.004

Lavelli, V., Proserpio, C., Gallotti, F., Laureati, M., Pagliarini, E. (2018). Circular reuse of bio-resources: the role of *Pleurotus* spp. in the development of functional foods. *Food & Function*, *9*(3), 1353-1372. https://doi.org/10.1039/c7fo01747b

Lescano, C. H., Iwamoto, R. D., Sanjinez-Argandoña, E. J., & Kassuya, C. A. L. (2015). Diuretic and anti-inflammatory activities of the microencapsulated *Acrocomia aculeata* (Arecaceae) oil on wistar rats. *Journal of Medicinal Food*, *18*(6), 656-662. https://doi.org/10.1089/jmf.2014.0077

Li, H., Zhang, Z., Li, M., Li, X., & Sun, Z. (2017). Yield, size, nutritional value, and antioxidant activity of oyster mushrooms grown on perilla stalks. *Saudi Journal of Biological Sciences*, *24*, 347-354. https://doi.org/10.1016/j.sjbs.2015.10.001

Liu, Y., Wang, C., Mei, J., Li, Y., & Liang, Y. (2019). Hypoglycemic and hypolipidemic effects of *Phellinus linteus* mycelial extract from solid-state culture in a rat model of type 2 diabetes. *Nutrients, 11(2)*, 296. https://doi.org/10.3390/nu11020296

Mbassi, J. E. G., Mobou, E. Y., Ngome, F. A., & Sado, K. S. L. (2018). Effect of substrates on nutritional composition and functional properties of *Pleurotus ostreatus*. *Current Research in Agricultural Sciences*, *5*(1), 15-22. https://doi.org/10.18488/journal.68.2018.51.15.22

Merril, A. L., & Watt, B. K. (1973). *Energy value of foods:* Basis and derivation. DC: United States Department of Agriculture, Washington.

Miller, V., Mente, A., Dehghan, M., Rangarajan, S., Zhang, X., Swaminathan, S., Dagenais, G., Gupta, R., Mohan, V., Lear, S., Bangdiwala, S. I., Schutte, A. E., Wentzel-Viljoen, E., Avezum, A., Altuntas, Y., Yusoff, K., Ismail, N., Peer, N., Chifamba, J., Diaz, R. … & Yusuf, S. (2017). Fruit, vegetable, and legume intake, and cardiovascular disease and deaths in 18 countries (PURE): a prospective cohort study. *The Lancet*, *390*(10107), 2037-2049. https://doi.org/10.1016/S0140-6736(17)32253-5

Nunes, M. D., da Luz, J. M. R., Paes, S. A., Ribeiro, J. J. O., da Silva, M. C. S., & Kasuya, M. C. M. (2012). Nitrogen supplementation on the productivity and the chemical composition of oyster mushroom. *Journal of Food Research* *1*(2), 113-119. https://doi.org/10.5539/jfr.v1n2p113

Oboh, G., Ademosun, A. O., Akinleye, M., Omojokun, O. S., Boligon, A. A., & Athayde, M. L. (2015). Starch composition, glycemic indices, phenolic constituents, and antioxidative and antidiabetic properties of some common tropical fruits. *Jouranl of Ethnic Foods*, *2*, 64-73. https://doi.org/10.1016/j.jef.2015.05.003

Orsi, D. C., Nishi, A. C. F., Carvalho, V. S., Brandão, C. C., Carvalho, A. A., & Asquieri, E. R. (2015). Chemical characterization of macauba pulp (*Acrocomia aculeata*). *Journal of Fruits and Vegetables*, 1, 45-48. https://doi.org/10.1590/S0100-29452011000300040

Panjikkaran, S. T., & Mathew, D. (2013). An environmentally friendly and cost effective technique for the commercial cultivation of oyster mushroom [*Pleurotus florida* (Mont.) Singer]. *Journal of the Science of Food and Agriculture*, *93*(4), 973-976. https://doi.org/10.1002/jsfa.5827

Patel, H., Gupte, A., & Gupte, S. (2009). Effect of different culture conditions and inducers on production of laccase by a basidiomycete fungal isolate *Pleurotus ostreatus* HP-1 under solid-state fermentation. *BioResources*, *4*(1), 268-284.

Pazza, A. C. V., Zardo, C., Klein, R. C. M., da Cas, T. M. S., & Bernardi, D. M. (2019). Nutritions composition and funcional physiological properties of edibles mushrooms: *Agaricus* *brasiliensis* and *Pleurotus ostreatus*. *FAG Journal of Health*, *1*(3), 240-265. https://doi.org/10.35984/fjh.v1i3.89

Pengpid, S., & Peltzer, K. (2017). Associations between behavioural risk factors and overweight and obesity among adults in population-based samples from 31 countries. *Obesity Research & Clinical Practice*, *11*, 158-166. https://doi.org/10.1016/j.orcp.2016.08.001

Raigond, P., Kaundal, B., Sood, A., Devi, S., Dutt, S., & Singh, B. (2018). Quantification of biguanide and related compounds (anti-diabetic) in vegetables and fruits. *Journal of Food Composition and Analysis*, *74*, 82-88. https://doi.org/10.1016/j.jfca.2018.09.001

Ramos, M. I. L., Ramos Filho, M. M., Hiane, P. A., Braga Neto, J. A., & Siqueira, E. M. A. (2008). Nutritional quality of the pulp of bocaiuva *Acrocomia aculeata* (Jacq.) Lodd. *Food Science and Technology*, *28*, 90-94. https://doi.org/10.1590/S0101-20612008000500015

Reis, A. F., & Schmiele, M. (2019). Characteristics and potentialities of Savanna fruits in the food industry. *Brazilian Journal of Food Technology*, *22*, 01-12. https://doi.org/10.1590/1981-6723.15017

Ritota, M., & Manzi, P. (2019). *Pleurotus* spp. cultivation on different agri-food by-products: Example of biotechnological application. *Sustainability*, *11*, 5049. https://doi.org/10.3390/su11185049

Rivas, P. M. S., Pereira Filho, A. A., Santos, F. A. S., & Rosa, I. G. (2010). Avaliação de substratos pectocelulósicos para o cultivo de cogumelos comestíveis do gênero *Pleurotus* sp. (agaricales). *Cadernos de Pesquisa*, *17*(3), 78-83.

Rosário, R., Santos, R., Lopes, L., Agostinis-Sobrinho, C., Moreira, C., Mota, J., Póvoas, S., Oliveira, A., Padrão, P., Moreira, P., & Abreu, S. (2018). Fruit, vegetable consumption and blood pressure in healthy adolescents: A longitudinal analysis from the LabMed study. *Nutrition, Metabolism and Cardiovascular Diseases*, 28(10), 1075-1080.

Sheng, Y., Zhao, C., Zheng, S., Mei, X., Huang, K., Wang, G., & He, X. (2019). Anti-obesity and hypolipidemic effect of water extract from *Pleurotus citrinopileatus* in C57BL/6J mice. *Food Science & Nutrition*, *7*(4), 1295-1301. https://doi.org/10.1002/fsn3.962

Silva, C. A. A., Lacerda, M. P. F., & Fonseca, G. G. (2013). Biotransformation of pequi and guavira fruit wastes via solid state bioprocess using *Pleurotus sajor-caju*. *International Journal of Bioscience, Biochemistry and Bioinformatics*, *3*, 88-92. https://doi.org/10.7763/IJBBB.2013.V3.171

Silva, C. A. A., da Silva, P. G. P., da Silva, G. F. A., Dantas, D. P., Leite, R. S. R., & Fonseca, G. G. (2020). Biotransformation of fruit residues via solid state bioprocess using *Lichtheimia ramosa*. *SN Applied Sciences*, *2*, 861. https://doi.org/10.1007/s42452-020-2689-0

Silva, C. A. A., Lacerda, M. P. F., Leite, R. S. R., & Fonseca, G. G. (2014). Physiology of *Lichtheimia ramosa* obtained by solid-state bioprocess using fruit wastes as substrate. *Bioprocess and Biosystems Engineering*, *37*(4), 727-734. https://doi.org/10.1007/s00449-013-1043-y

Silva, E. G., Dias, E. S., Siqueira, F. G., & Schwan, R. F. (2007). Chemical analysis of fructification bodies of *Pleurotus sajor-caju* cultivated in several nitrogen concentrations. *Ciência e Tecnologia de Alimententos*, *27*(1), 72-75. https://doi.org/10.1590/S0101-20612007000100013

Uddin, R., Lee, E. -Y., Khan, S. R., Tremblay, M. S., & Khan, A. (2020). Clustering of lifestyle risk factors for non-communicable diseases in 304,779 adolescents from 89 countries: A global perspective. *Preventive Medicine*, *131*, 105955. https://doi.org/10.1016/j.ypmed.2019.105955

Valenzuela-Cobos, J. D., Rodríguez-Grimón, R. O., Zied, D. C., Endara, A. G., Garcés-Moncayo, M. F., Garín-Aguilar, M. E., Sánchez-Hernández, A., & Del Toro, G. V. (2019). Chemical composition and biological properties of *Pleurotus* spp. cultivated on peat moss and wheat straw. *Emirates Journal of Food and Agriculture*, *31*(11), 830-836. https://doi.org/10.9755/ejfa.2019.v31.i11.2034

Valério, P. P., Celayeta, J. M. F., & Cren, E. C. (2019). Quality parameters of mechanically extracted edible macauba oils (*Acrocomia aculeata*) for potential food and alternative industrial feedstock application. *European Journal of Lipid Science and Technology*, *121*, 1800329. https://doi.org/10.1002/ejlt.201800329

Vaz, J. A., Barros, L., Martins, A., Santos-Buelga, C., Vasconcelos, M. H., & Ferreira, I. C. F. R. (2011). Chemical composition of wild edible mushrooms and antioxidant properties of their water soluble polysaccharidic and ethanolic fractions. *Food Chemistry*, *126*, 610-616. https://doi.org/10.1016/j.foodchem.2010.11.063

Vianna, S. A., Berton, L. H. C., Pott, A., Guerreiro, S. M. C., & Colombo, C. A. (2017). Biometric characterization of fruits and morphoanatomy of the mesocarp of *Acrocomia* species (Arecaceae). *International Journal of Biology*, *9*(3), 78-92. https://doi.org/10.5539/ijb.v9n3p78

Volpe, S. L. (2019). Fruit and vegetable intake and prevention of chronic disease. *ACSM's Health and Fitness Journal*, *23*, 30-31. https://doi.org/10.1249/FIT.0000000000000474

Wei, H., Yue, S., Zhang, S., & Lu, L. (2018). Lipid-lowering effect of the *Pleurotus eryngii* (king oyster mushroom) polysaccharide from solid-state fermentation on both macrophage-derived foam cells and zebrafish models. *Polymers*, *10*(5), 492. https://doi.org/10.3390/polym10050492

WHO/FAO. (2003). World Health Organization and Food and Agriculture Organization. Diet, nutrition and the prevention of chronic diseases. Report of a joint WHO/FAO Expert Consultation. *World Health Organization Technical Report Series*, 916, 1-149.

Yuan, S., Yu, H. J., Liu, M. W., Huang, Y., Yang, X. H., Tang, B. W., Song, Y., Cao, Z. K., Wu, H. J., He, Q. Q., & Gasevic, D. (2018). The association of fruit and vegetable consumption with changes in weight and body mass index in Chinese adults: a cohort study. *Public Health*, *157*, 121-126. https://doi.org/10.1016/j.puhe.2018.01.027

Zusman, I., Reifen, R., Livni, O., Smirnoff, P., Gurevich, P., Sandler, B., Nyska, A., Gal, R., Tendler, Y., & Madar, Z. (1997). Role of apoptosis, proliferating cell nuclear antigen and P53 protein in chemically induced colon cancer in rats fed corncob fiber treated with the fungus *Pleurotus ostreatus*. *Anticancer Research*, *17*(3C), 2105-2113.

CAPÍTULO 4

DEVELOPMENT AND EVALUATION OF LOW-CARB CAKES PRODUCED FROM GREEN BOCAIUVA PULP ENRICHED WITH *Pleurotus ostreatus*

ABSTRACT: *Pleurotus ostreatus* is an edible fungus with interesting nutritional properties that can be used as an ingredient to develop sustainable healthy food products. Thus, the aim of this work was to develop and evaluate low-carb cakes by replacing wheat flour with green bocaiuva pulp enriched with *P. ostreatus*. Four formulations were tested: F1: coconut flour, F2: green bocaiuva flour, F3: green bocaiuva flour enriched with mushroom and ammonium nitrate and F4: green bocaiuva flour enriched with *P. ostreatus* and water. Results indicated that all formulations can be considered as protein source foods (7.33 to 10.47 g 100 g^{-1}), with high fiber contents (7.16 to 9.43 g 100 g^{-1}), and low-carbohydrate contents (13.92 to 21.87 g 100 g^{-1}), without sugar addition. F4 presented the highest scores for all parameters of sensory analysis (color: 7.77; aroma: 7.55; texture: 7.32, flavor: 7.18 and overall rating: 7.73) and purchase intention (68% for the sum of probably and certainly would purchase). It was concluded that the green bocaiuva flour enriched with *P. ostreatus* can be used for the development of low-carb cake with improved nutritional components and acceptable sensory characteristics.

Keywords: Low-carb cake; Acrocomy; Edible fungus; Proximate composition; Sensory analysis.

4.1 INTRODUCTION

Bakery products present a high content of simple sugars of rapid absorption, high fat content and low amount of dietary fiber, which makes them highly caloric food products, contributing negatively to chronic diseases associated with the metabolic syndrome *e.g.* diabetes, obesity, dyslipidemia and some types of cancer (Duncan et al., 2012; Peris et al., 2019). In 2016, more than 1.9 billion adults aged 18 and over were overweight (39%) and 650 million were obese (13%), while 340 million children and teenagers aged 5 to 19 years were overweight or obese (WHO, 2016). Thus, there is an urgency to replace certain ingredients in order to increase the nutritional added value of processed food products (Dimou et al., 2019).

The cake is one of the most consumed food products, second only to bread (Gohara et al., 2014). This confectionery product is the result of mixing, homogenizing and baking the dough prepared by combining flours or starch, eggs, milk, butter or vegetable fat, sugars and leavening agent (Soares et al., 2018; Carvalho et al., 2019; Stavale et al., 2019). Some of the ingredients can be replaced by adding ingredients with functional or nutritional properties (Carvalho et al., 2019; Dalmolin et al., 2019; Montagner & Storck, 2019; Stavale et al., 2019) and low-carbohydrate content, which is beneficial for health, improving *e.g.* anthropometric and blood markers in healthy adults (Harvey et al., 2019). The great challenge is to improve the nutritional quality of cakes without impairing the sensory properties.

Studies have shown that sugar can be substituted for sweeteners (Dalmolin et al., 2013; Farzi et al., 2015; Pineli et al., 2016; Soares et al., 2018) and animal milk for soy milk, corn milk, chestnut milk, coconut milk, soy oil, sunflower oil or coconut oil (Drunkler et al., 2010; Correia et al., 2014; Pereira et al., 2017). Wheat is the main ingredient used in cake production and can be replaced by fruit pulp flour, contributing to the nutritional and sensory characteristics (Carvalho et al., 2019).

A promising source for the food industry in the development of new products replacing wheat flour is the pulp of the fruit of the bocaiuva (*Acrocomia sp.*), Mainly in the stage of green ripening, which its consumption is little used in human food, and can be favored to from the processing of fresh pulp into flour, with functional and nutraceutical properties, since the pulp flour from the fruit of *A. aculeata* green is rich in soluble fibers and has shown an effect in reducing body weight, a hypolipemic activity in the total cholesterol fractions, LDL-cholesterol, triglycerides and fasting glucose in male mice (Giunco, 2018).

Another promising nutrient food that can be used to replace whole or partial wheat flour is the pulp of fruits and vegetables enriched with microorganisms. According to Kolawole, Akinwande and Ade-Omowaye (2020), products developed from orange-fleshed sweet potatoes enriched with sclerotia from *Pleurotus tuberregium* showed higher levels of protein, ash, crude fiber, water-soluble vitamins and mineral composition, compared to wheat flour, and with acceptable sensory characteristics. It was also reported in the literature several nutritional properties of *Pleurotus* sp. in the prevention of insulin resistance, dyslipidemia, hypertension and obesity (Khan & Tania, 2012; Balaji et al., 2020; Dicks & Ellinger, 2020) by providing various bioactive compounds like β-glucans. Although the consumption of edible mushrooms is ancient (Ilavenil et al., 2017), its use in food applications, such as in the manufacture of cakes, has been marginally studied so far.

Thus, the aim of this work was to develop low-carb cakes by replacing wheat flour with green bocaiuva pulp enriched with the edible fungus *Pleurotus ostreatus*, and evaluate their proximate composition and sensory analysis in order to have food products rich in nutrients, with substances beneficial to health, and sensory characteristics acceptable to consumers.

4.2 MATERIAL AND METHODS

4.2.1 Microorganism and substrate

Pleurotus ostreatus URM 4072 was utilized in this study. It was obtained from the Fungi Culture Collection at the Federal University of Pernambuco. The cells were received lyophilized and, after reactivation, kept in an inclined potato dextrose agar (PDA) medium immersed in mineral oil and stored at 4 °C (Fonseca et al., 2009; Silva et al., 2013). This strain was grown in Petri dishes containing 4% glucose Sabouraud medium and incubated at 30 °C for 10 days, until obtaining adequate mycelial growth, before recovering.

The substrate utilized was dehydrated green bocaiuva pulp. The bocaiuva (*Acrocomia totai* Mart) fruits were collected in the municipality of Bela Vista, MS, Brazil (56°24’12.6’’ West longitude, 21°56’15.9’’ South latitude, and 153 m altitude). Fruits were then washed and sanitized with 0.66% (w v^{-1}) sodium dichloroisocyanurate solution (Sumaveg, Diversey Lever) with 200 ppm of active chlorine for 15 min, manually peeled and mechanically pulped. The pulp obtained was dehydrated in an air circulation oven at 50 ºC for 24 h.

4.2.2 Inoculation, cultivation and mycelial growth

The experiments were carried out by mixing 100 g of substrate (dehydrated green bocaiuva pulp) with 200 mL of N source stock solution (2% ammonium nitrate solution prepared in distilled water) in transparent polypropylene autoclavable bags measuring 20 x 30 cm. The bags were closed with cotton plugs to allow gas exchange during the process, and sterilized in an autoclave at 121 ºC for 20 min.

Inoculation of the fungus in the substrate was carried by transferring 1.3 cm diameter mycelium discs from the plates, with the aid of a 5 mL test tube and a platinum loop, previously sterilized. The bags containing the inoculated samples were stored in a bacteriological oven (30 ºC) for 30 days. After this period, the mycelium was dehydrated in an air circulation oven at 70 ºC for 24 h, crushed and sieved, obtaining a flour.

4.2.3 Preparation of low-carb cakes

After preliminary tests, a standard formulation was defined, using as raw materials: pure cocoa powder, brown coconut flour, culinary sweetener, coconut milk, butter, egg, chocolate flavoring and baking powder (F1). Three other formulations were prepared by replacing 100% of the brown coconut flour with raw green bocaiuva flour (F2), enriched green bocaiuva flour and ammonium nitrate (F3), or enriched green bocaiuva flour and water (F4) (Table 4.1). The experiments were conducted in accordance with safety, hygiene and good food handling practices established for foods (ANVISA, 2004).

The recipes were individually prepared using the standard technique according with the following steps: preheating of the domestic oven at 180 ºC; separation of the ingredients and weighing on a digital scale balance with an accuracy of 0.01 g; mixing of the ingredients in an electric mixer (Britânia, model Pérola Maxx) until obtaining a smooth and homogeneous dough; packing the dough in silicone forms (5 x 2 cm) that were placed on the top of an aluminum form (25 x 2 cm);and then baking at 180 °C for 30 min in a domestic gas oven (Brastemp, model BFS6NCBUNA).

To guarantee a homogeneous baking and the standardization of the formulations, a total of 15 units of silicone forms containing the same dough formulation were disposed in each aluminum form. After 15 min, they had their positions switched in the oven to allow each cake to be baked at the same way. After 30 min, they were taken and tested with a toothpick. If they did not pass the toothpick test, they would bake for another 3 min until the toothpick came out clean.

After baking, the cakes were cooled to room temperature (25 °C) and added in polyethylene containers with a lid for a maximum of 24 h before analysis.

4.2.4 Proximate composition and energy value

The moisture content was determined by using an oven with air circulation at 70 ºC (Method nº 44-15.02, AACC, 2010), the mineral residue by weighing the residues from muffle incineration at 550 °C (Method nº 08-01.01, AACC, 2010), the proteins by the Kjeldahl procedure (Method nº 2001.11, AOAC, 2005), the total lipids by using the Soxhlet apparatus (Method nº 30-25.01, AACC, 2010), and the crude fiber by the gravimetric method using a fiber determiner (Method nº 978.10, AOAC, 2005). The determination of the carbohydrates was performed by difference (total – moisture – minerals – lipids – proteins – fibers). The energy value was calculated using the Atwater coefficients that consider 4 kcal g^{-1} of sample for proteins and carbohydrates and 9 kcal g^{-1} of sample for lipids (Merril & Watt, 1973).

Table 4.1 Low-carb cake formulations.

Ingredient	**Formulation (g 100 g^{-1})**			
	F1	**F2**	**F3**	**F4**
Brown coconut flour	13.82	-	-	-
Green bocaiuva flour without supplementation	-	13.82	-	-
Enriched green bocaiuva flour and NH_4NO_3	-	-	13.82	-
Enriched green bocaiuva flour and water	-	-	-	13.82
Cocoa powder	0.31	0.31	0.31	0.31
Culinary sweetener	3.45	3.45	3.45	3.45
Coconut milk	41.48	41.48	41.48	41.48
Butter	6.91	6.91	6.91	6.91
Egg	33.18	33.18	33.18	33.18
Chocolate flavoring	0.16	0.16	0.16	0.16
Chemical yeast	0.69	0.69	0.69	0.69

F1: Low-carb cake with coconut flour. F2: Low-carb cake with green bocaiuva flour without the increment. F3: Low-carb cake with *Pleurotus ostreatus* enriched green bocaiuva flour and ammonia nitrate. F4: Low-carb cake with *Pleurotus ostreatus* enriched green bocaiuva flour and water.

4.2.5 Sensory analysis and purchase intention

The attributes color, smell, texture, taste, and overall impression were evaluated by 11 trained judges, aged from 21 to 44 years old, all of them students or technicians from the Federal University of Grande Dourados, through the combined acceptance-preference test, using a 9-point hedonic scale anchored at extremes 1 (I did not like it) and 9 (I liked it). The purchase intention test was also applied with a 5-point scale (1 = certainly would not purchase, and 5 = certainly would purchase). The tests were carried out in individual cabins, with white lighting, according to the recommendations of the environment and the distribution of the samples described elsewhere (Meilgaard et al., 2007).

The acceptability index (AI) was calculated according to Equation 1, where A is the average score of the attribute and B is the highest score observed for the evaluated attribute. The product was considered acceptable if the AI was at least 70% (Reis et al., 2020).

$$AI(\%) = \frac{(A \times 100)}{B} \quad (1)$$

4.2.6 Statistical analysis

The results obtained were expressed by the average of the repetitions and standard deviation. The results were submitted to the analysis of variance (ANOVA) and compared using the Tukey test at a significance level of 5% using the software Statistica (Statsoft version 8.0).

4.3 RESULTS AND DISCUSSION

4.3.1 Proximate composition and energy value

Table 2 shows the proximate composition of the *low carb* cakes made. The enrichment of bocaiuva flour with edible mushroom (F3 and F4) contributed to a product with lower moisture content and higher content of minerals, lipids, proteins and fibers in relation to the formulation with green bocaiuva flour without the increment (F2). Low carb cakes enriched with edible mushroom (F3 and F4), bocaiuva flour without the increment (F2) had a lower lipid content, and higher minerals compared to the standard formulation with coconut flour (F1). Carbohydrates showed no significant difference ($p > 0.05$) between the four formulations. Low carb cakes enriched with edible mushrooms (F3 and F4) showed an energy value similar to that of formulations without mycelia, which demonstrates that there is no direct relationship between mycelia and energy value.

All studied cake formulations can be considered low-carb according to the Technical Regulation on Complementary Nutritional Information (ANVISA, 2012), as they present protein and fibers contents above 7% for all formulations. Moreover, formulations were prepared without sugars addition when compared to traditional cakes, which represents a reduction of at least 58 to 60% in the carbohydrates content when compared to cakes with wheat or coconut flour (TACO, 2011).

The lower carbohydrate content and higher protein and fiber contents indicate that the low-carb cake formulations were nutritionally better when compared to cake added to passion fruit peel flour (42.20 g 100 g^{-1}, 6.56 g 100 g^{-1} and 9.12 g 100 g^{-1} of carbohydrates, proteins and fibers, respectively) (Reis et al., 2020) and banana and diet oat cake (26.81 g 100 g^{-1}, 4.77 g 100 g^{-1} and 2.04 g 100 g^{-1} of carbohydrates, proteins and fibers, respectively) (Souza et al., 2020). It was reported elsewhere that oyster mushroom flour can be used for the partial replacement of wheat flour in dough formulation, due to its ability to increase nutritional values and improve sensory attributes such as taste and texture the research by (Nordiana et al., 2019).

Moreover, as the obtained low-carb cakes did not present addition of sugar, whole milk, and wheat flour, they can be considered suitable for consumption by those who have restrictions on the consumption of sucrose, lactose and gluten, or who only restrict these ingredients by choice. It is worth mentioning that among all the parameters studied, the increase in the protein and in the mineral content, and the reduction in the carbohydrate content in the F3 formulation stood out with the supplementation of the N source due to the increased fungal myceliation on the flour. Thus, it is expected that the incorporation of fungal biomass should have incorporated nutritional and medical functions reported in the literature (Khan & Tania, 2012; Ilavenil et al., 2017; Vargas-Sánchez et al., 2018; Bindh & Arunava, 2019; Balaji et al., 2020; Ellinger, 2020; Nweze et al., 2020).

Based on the recommended daily consumption of 50 g of protein by adults and 34 g by children up to 10 years old (ANVISA, 2005), it can be considered that the intake of 100 g of low-carb cakes prepared with enriched flour, according to the F3 and F4 formulations, provide about 21 and 15% of the daily requirement for adults, and 31 and 22% for children, respectively. In addition, it provides about 31 and 38% of the minimum of 25 g of fiber recommended to be consumed daily to prevent chronic diseases, considering the F3 and F4 formulations, respectively (WHO/FAO, 2003).

Table 4.2 Proximate composition and energy value obtained for the low-carb cake formulations.

Component	Formulation (g 100 g^{-1})			
	F1	**F2**	**F3**	**F4**
Moisture	43.34±2.15$^{a;b}$	46.18±1.91^{a}	43.71±2.78$^{a;b}$	39.79±1.29^{b}
Minerals	2.05±0.05^{d}	2.42±0.20^{c}	3.44±0.11^{a}	3.00±0.03^{b}
Lipids	22.87±0.76^{a}	15.09±1.47^{c}	16.07±0.49$^{b;c}$	18.34±0.73^{b}
Proteins	8.86±0.73^{b}	7.33±0.75^{c}	10.47±0.38^{a}	7.57±0.06$^{b;c}$
Total fiber	8.96±0.45$^{a;b}$	7.16±0.60^{b}	7.70±0.49$^{a;b}$	9.43±1.05^{a}
Carbohydrates	13.92±3.47^{a}	21.82±4.00^{a}	18.61±2.53^{a}	21.87±2.40^{a}
Energetic value*	296.98±5.43^{a}	252.38±4.94^{b}	260.94±10.12^{b}	282.78±9.14^{a}

*In Kcal/100g^{-1}. Values are expressed as means and standard deviation (n = 3), with equal letters on the same line do not differ significantly at the level of 5% (p> 0.05) by the Tukey test. F1: Low-carb cake with coconut flour. F2: Low-carb cake with green bocaiuva flour without the increment. F3: Low-carb cake with *Pleurotus ostreatus* enriched green bocaiuva flour and ammonia nitrate. F4: Low-carb cake with *Pleurotus ostreatus* enriched green bocaiuva flour without supplementation with nitrogen.

4.3.2 Sensory analysis

The sensory characteristics of the cake are of great importance for its acceptance by consumers and, consequently, for its commercialization, being the flavor of the product decisive in this process. Figure 4.1 shows the averages of the scores attributed in the sensory analysis for the four *low-carb* cake formulations. The formulation with the green bocaiuva flour enriched with *P. ostreatus* without nitrogen supplementation (F4) was the one that presented the highest score for all parameters. The color and the aroma attributes showed no significant difference (p<0.05) in relation to the formulations. The flavor was the main parameter that negatively influenced in the consumers' choice, followed by the overall impression, for the F3. It may be related to the bitter taste caused by supplementation with ammonium nitrate (nitrogen source) during the mycelial growth of the fungus in the pulp. Despite this, F3 was better in all other attributes than the F1 (control), indicating the need for improvement in these two characteristics, as an example, the decrease in the amount of ammonium nitrate in the growth of the fungus in F3.

The formulations F2 and F4 showed acceptance indexes above 70% and 80% for all attributes (Figure 4.2). On the other hand, acceptance indexes lower than 70% were obtained for the flavor parameter in the F3, and for texture, flavor and overall evaluation in the F1, which indicate that products would not be accepted by consumers, if commercialized (Reis et al., 2020). However, these results indicate that F2 and F4 present great potential for commercialization. The low-carb cakes prepared with green bocaiuva flour, enriched or not, without nitrogen supplementation, presented acceptance rates above 70% for all attributes and nutritional value.

Another important attribute evaluated was the purchase intention to of the four low-carb cake's formulations (Figure 4.3). The results demonstrate that 68% of the judges certainly would and probably would purchase the cake F4. Most of the judges perhaps would purchase or perhaps would not purchase the cake F2 (59%). In comparison, 36% of the judges probably or certainly would not purchase the cake F1.

The average purchase intention for F4 (3.91 ± 0.97) was similar to that reported elsewhere for banana cupcakes with the addition of up to 7.0% of banana peel flour (3.42 ± 1.05 to 3.98 ± 1.03) (Carvalho et al., 2012). The purchase intention test revealed great market potential and positive purchase intention for the F4, if it were actually available on the market. Therefore, green bocaiuva flour enriched with edible mushroom *P. ostreatus* has the potential to be used in the production of cakes and possibly other bakery products with functional properties for the prevention of chronic diseases and contributing to inspire the food industry to produce food products added value.

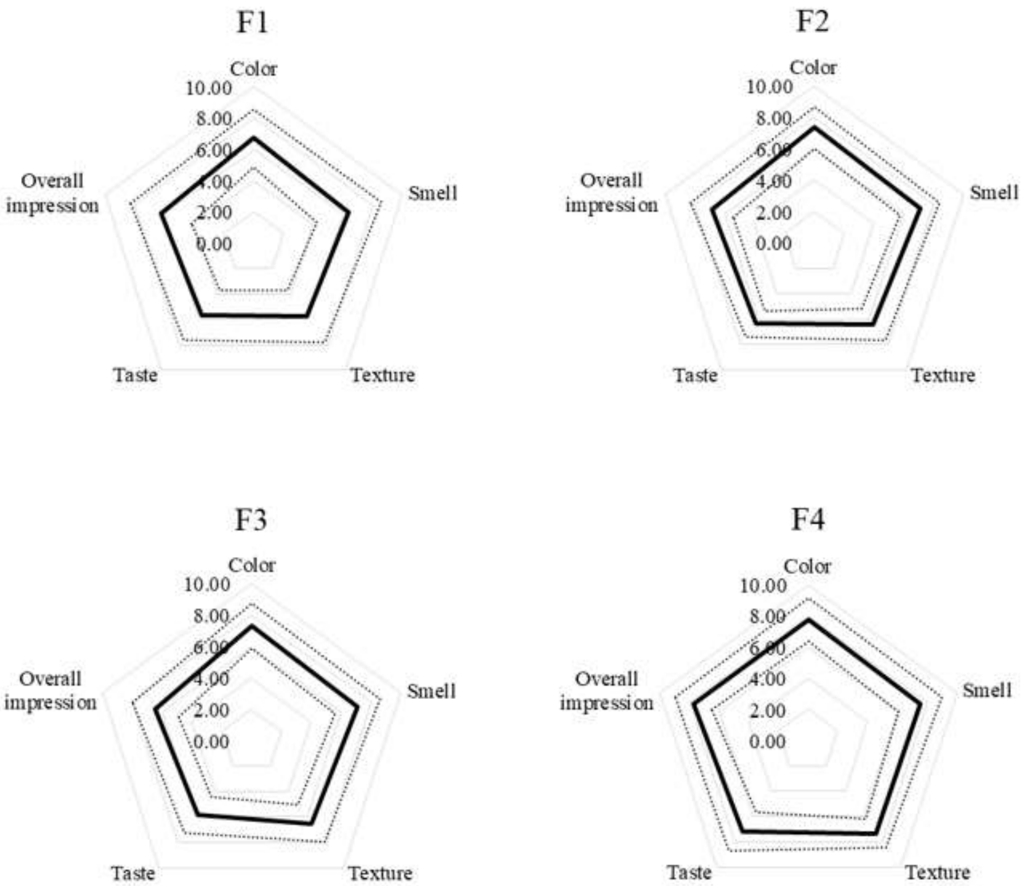

Figure 4.1 Averages of the values of the scores attributed in the sensory analysis for the four low-carb cake formulations.

F1: Low-carb cake with coconut flour. F2: Low-carb cake with green bocaiuva flour without the increment. F3: Low-carb cake with *Pleurotus ostreatus* enriched green bocaiuva flour and ammonia nitrate. F4: Low-carb cake with *Pleurotus ostreatus* enriched green bocaiuva flour without supplementation. Solid lines = Average value. Dashed lines = Standard deviation.

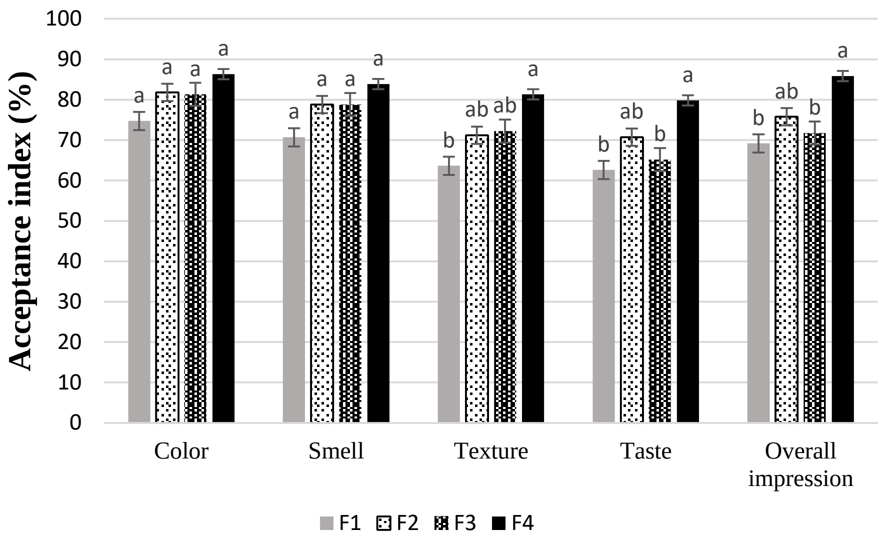

Figure 4.2 Acceptance index of the four low-carb cake formulations.

F1: Low-carb cake with coconut flour. F2: Low-carb cake with green bocaiuva flour without the increment. F3: Low-carb cake with *Pleurotus ostreatus* enriched green bocaiuva flour and ammonia nitrate. F4: Low-carb cake with *Pleurotus ostreatus* enriched green bocaiuva flour without supplementation. Values are expressed as means and standard deviation (n = 22), with equal letters on the same line do not differ significantly at the level of 5% (p> 0.05) by the Tukey test.

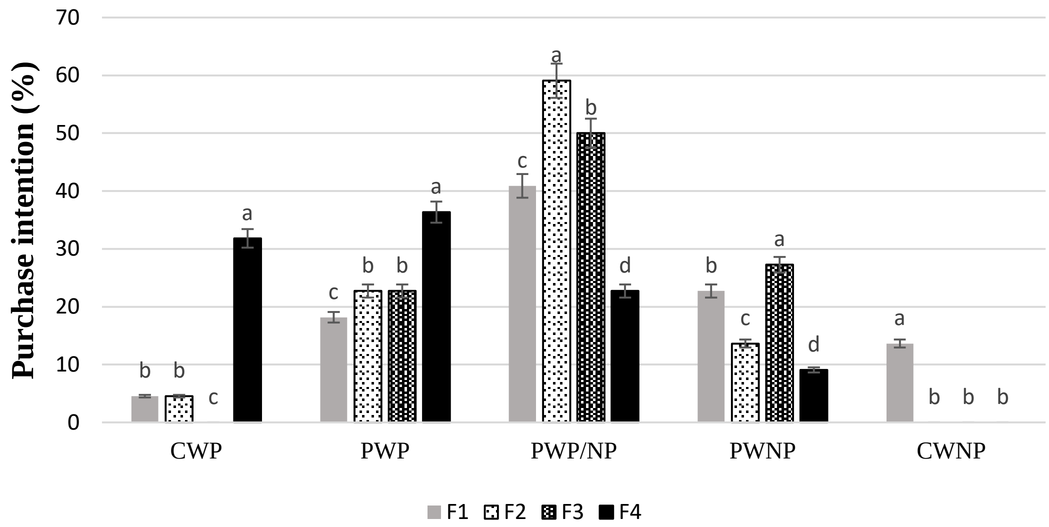

Figure 4.3 Purchase intention of the four low-carb cake formulations.

CWP: Certainly would purchase; PWP: Probably would purchase; PWP/NP: Perhaps would purchase/ not purchase; PWNP: Probably would not purchase; CWNP: Certainly would not purchase. F1: Low-carb cake with coconut flour. F2: Low-carb cake with *Pleurotus ostreatus* enriched green bocaiuva flour without the increment. F3: Low-carb cake with *Pleurotus ostreatus* enriched green bocaiuva flour and ammonia nitrate. F4: Low-carb cake with *Pleurotus ostreatus* enriched green bocaiuva flour without supplementation. Values are expressed as means and standard deviation (n = 22), with equal letters on the same line do not differ significantly at the level of 5% ($p > 0.05$) by the Tukey test.

4.4 CONCLUSION

The green bocaiuva flour enriched with *Pleurotus ostreatus* demonstrated great potential for the preparation of low-carb cakes with improved nutritional composition (F3 and F4), acceptable sensory characteristics by trained judges (F4), and great potential for commercialization (F4). However, the dosage of ammonium nitrate as the nitrogen source for the development of the fungus negatively interfered in the taste of the elaborated product (F3).

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4.6 DISCLOSURES STATEMENT

None of the authors have conflicts of interest to disclose.

4.7 REFERENCES

AACC. American Association of Cereal Chemists. (2010). Approved methods of the American Association of Cereal Chemists. 11° ed. Saint Paul.

ANVISA. National Health Surveillance Agency, Department of the Ministry of Health. (2012). Technical Regulation on Complementary Nutrition Information, Resolution - RDC nº 54, Brazil.

ANVISA. National Health Surveillance Agency, Department of the Ministry of Health. (2004). Regulation of Good Practices for Food Services, Resolution - RDC nº 216, Brazil.

ANVISA. National Health Surveillance Agency, Department of the Ministry of Health. (2005). Technical Regulation on Recommended Daily Intake (IDR) of Protein, Vitamins and Minerals, Resolution - RDC nº 269, Brazil.

AOAC. (2005). Official Methods of Analysis of AOAC International (18th ed.). AOAC International, Arlington, Virginia, USA.

Araújo, S. S., Araújo, P. S., Giunco, A. J., Silva, S. M., & Argandoña, E. J. S. (2019). Bromatology, food chemistry and antioxidant activity of *Xanthosoma sagittifolium* (L.) Schott. *Emirates Journal of Food and Agriculture*, *31*, 188-195. https://doi.org/10.9755/ejfa.2019.v31.i3.1924

Balaji, P., Madhanraj, R., Rameshkumar, K., Veeramanikandan, V., Eyini, M., Arun, A., Boobalan Thulasinathan, A. L, Farraj, D. A., Elshikh, M. S., Alokda, A. M., Mahmoud, A. H., Tack, J. -C., & Kim, H. -J. (2020). Evaluation of antidiabetic activity of *Pleurotus pulmonarius* against streptozotocin-nicotinamide induced diabetic wistar albino rats. *Saudi Journal of Biological Sciences, 27*, 913-924. https://doi.org/10.1016/j.sjbs.2020.01.027

Bindhu, J., & Arunava, D. A. S. (2019). An edible fungi *Pleurotus ostreatus* inhibits adipogenesis via suppressing expression of PPAR γ and C/EBP α in 3T3-L1 cells: In vitro validation of gene knock out of RNAs in PPAR γ using CRISPR spcas9. *Biomedicine & Pharmacotherapy, 116*, 109030. https://doi.org/10.1016/j.biopha.2019.109030

Carvalho, K. H., Bozatski, L. C., Scorsin, M., Novello, D., Perez, E., Santa, H. S. D, Scorsin, G., & Batista, M. G. (2012). Development of the cupcake added flour banana peel: sensory and chemical characteristics. *Brazilian Journal of Food and Nutrition*, *23*, 475-481.

Carvalho, L. C. C., Ferreira, I. M., Silva, A. M. O., Nunes, T. P., & Carvalho, M. G. (2019). Cake banana with fructooligosaccharide. *Revista Verde, 14,* 55-61. https://doi.org/10.18378/rvads.v14i1.5742

Correia, S. C. Z., Peres, A.P., & Degáspari, C. H. (2014). Development of drink based on sunflower seed. *Cadernos da Escola de Saúde, 2,* 27-39.

Dalmolin, C., Iensen, G., Ribeiro, J., Lopes, M., & Basso, C. (2019). Sensory analysis of a gluten-free and lactose-free brownie. *Disciplinarum Scientia, 20,* 295-303.

Dalmolin, V. T. S., Peres, P. E. C., Noguera, J. O. C., & Noguera, J. O. C. (2013). A relação educação e saúde: Uma abordagem sobre o excesso de consumo de açúcar pelo jovem. *Revista Monografias Ambientais, 10,* 2170-2178. https://doi.org/10.5902/223613086577

Dicks, L., & Ellinger, S. (2020). Effect of the intake of oyster mushrooms (*Pleurotus ostreatus*) on cardiometabolic parameters - A systematic review of clinical trials. *Nutrients*, 12, 1-18. https://doi.org/10.3390/nu12041134

Dimou, C., Karantonis, H. C., Skalkos, D., & Koutelidakis, A. E. (2019). Valorization of fruits by-products to unconventional sources of additives, oil, biomolecules and innovative functional foods. *Current Pharmaceutical Biotechnology, 20,* 776-786. https://doi.org/10.2174/1389201020666190405181537

Drunkler, D. A., Fariña, L. O., & Kaskantzis Neto, G. (2010). Cow's milk allergy and possible dietetics substitutes. *Revista do Instituto de Laticínios Cândido Tostes, 65,* 3-16.

Duncan, B. B., Chor, D., Aquino, E. M. L., Bensenor, I. M., Mill, J. G., Schmidt, M. I., Lotufo, P. A., Vigo, Á., & Barreto, S. M. (2012). Chronic non-communicable diseases in Brazil: priorities for disease management and research. *Revista Saúde Pública, 46,* 126-34. https://doi.org/10.1590/S0034-89102012000700017

Farzi, M., Saffari, M. M., & Emam-Djomeh, Z. (2015). Effects of sugar, starch and HPMC concentrations on textural properties of reduced-sugar sponge cakes. *Journal of Food Science and Technology, 52,* 444-450. https://doi.org/10.1007/s13197-013-0965-3

Fonseca, G. G., Gandra, E. A., Sclowitz, L. F., Antunes, A. P. C., & Costa, J. A. V. (2009). Protein enrichment and digestibility of soft rush (*Juncus effusus*) and rice residues using edible mushrooms *Pleurotus ostreatus* and *Pleurotus sajor-caju*. *World Journal of Microbiology and Biotechnology, 25,* 449-456. https://doi.org/10.1007/s11274-008-9909-x

Giunco, A. J. (2018). Processo de obtenção de farinha. Brasil. BR 10 2018 073587 0 A2. Depositante: Universidade Federal da Grande Dourados. Depósito: 14/11/2018.

Gohara, A. K., Souza, A. H. P., Zanqui, A. B., Souza, N. E., Visentainer, J. V., & Matsushita, M. (2014). Chemometric tools applied to the development and proximal and sensory characterization of chocolate cakes containing chia and azuki. *Acta Scientiarum Technology, 36*, 537-543. https://doi.org/10.4025/actascitechnol.v36i3.19298

Harvey, C. J. D. C., Schofield, G. M., Zinn, C., Thornley, S. J., Crofts, C., & Merien, F. L. R. (2019). Low-carbohydrate diets differing in carbohydrate restriction improve cardiometabolic and anthropometric markers in healthy adults: A randomised clinical trial. *PeerJ,* 7:e6273. https://doi.org/10.7717/peerj.6273

Ilavenil, S., Kim, D. H., Srigopalram, S., Kuppusamy, P., Valan Arasu, M., Lee, K. D., Lee, J. C., Song, Y. H., Jeong, Y-I., & Choi, K. C. (2017). Ferulic acid in *Lolium multiflorum* inhibits adipogenesis in 3T3-L1 cells and reduced high-fat-diet-induced obesity in Swiss albino mice via regulating p38MAPK and p44/42 signal pathways. *Journal of Functional Foods*, 37, 293-302. https://doi.org/10.1016/j.jff.2017.08.002

Khan, M. A., & Tania, M. (2012). Nutritional and medicinal importance of *Pleurotus* mushrooms: An overview. *Food Reviews International*, *28*, 313-329. https://doi.org/10.1080/87559129.2011.637267

Kolawole, F. L., Akinwande, B. A., & Ade-Omowaye, B. I. O. (2020). Physicochemical properties of novel cookies produced from orange fleshed sweet potato cookies enriched with sclerotium of edible mushroom (*Pleurotus tuberregium*). *Journal of the Saudi Society of Agricultural Sciences*, *19*, 174-178. https://doi.org/10.1016/j.jssas.2018.09.001

Meilgaard, M., Civille, G.V., & Carr, B.T. (2007). Sensory Evaluation Techniques. 4th ed., Boca Raton, FL: CRC Press, pp. 448.

Merril, A. L., & Watt, B. K. (1973). Energy value of foods: Basis and derivation. Washington, DC: United States Department of Agriculture.

Montagner, G. E., & Storck, C. R. (2019). Sensory analysis and the composition of gluten-free cakes with phosphate sorghum flour. *Disciplinarum Scientia*, *20*, 497-504.

Nordiana, A. B., Rosli, W. I. W., & Nizam, W. A. W. A. (2019). The effect of oyster mushroom (*Pleurotus sajor-caju*) flour incorporation on the physicochemical quality and sensorial acceptability of pasta. *International Food Research Journal*, *26*, 1249-1257.

Nweze, C. C., Rasaq, N. O., & Istifanus, B. I. (2020). Ameliorating effect of *Agaricus bisponus* and *Pleurotus ostreatus* mixed diet on Alloxan-induced hyperglycemic rats. *Scientific African*, *7,* 1-6. https://doi.org/10.1016/j.sciaf.2019.e00209

Pereira, F. P., Santos, O. A. R., Resende, R. C. M., & Henriques, B. O. (2017). Avaliação comparativa da composição nutricional do leite de soja em relação ao leite de vaca com e sem lactose. *Revista Acadêmica Conecta FASF*, *2*, 378-392.

Peris, M., Rubio-Arraez, S., Castelló, M. L., & Ortolá, M. D. (2019). From the laboratory to the kitchen: New alternatives to healthier bakery products. *Foods*, *8*, 660. https://doi.org/10.3390/comidas8120660

Pineli, L. L. O., de Aguiar, L. A., Fiusa, A., Botelho, R. B. A., Zandonadi, R. P., & Melo, L. (2016). Sensory impact of lowering sugar content in orange nectars to design healthier, low-sugar industrialized beverages. *Appetite,* 96, 239-244. https://doi.org/10.1016/j.appet.2015.09.028

Reis, L. C. R., Facco, E. M. P., Salvador, M., Flôres, S. H., & Rios, A. O. (2020). Characterization of orange passion fruit peel flour and its use as an ingredient in bakery products. *Journal of Culinary Science & Technology, 18*, 214-230. https://doi.org/10.1080/15428052.2018.1564103

Silva, C. A. A., Lacerda, M. P. F., & Fonseca, G. G. (2013). Biotransformation of pequi and guavira fruit wastes via solid state bioprocess using *Pleurotus sajor-caju*. *International Journal of Bioscience, Biochemistry and Bioinformatics, 3*, 88-92. https://doi.org/10.7763/IJBBB.2013.V3.171

Soares, J. P., Marques, G. A., Magalhães, C. S., Santos, A. B., José, J. F. B. S., Silva, D. A., Silva, E. M. M. (2018). The effect of the addition of whey protein as a substitute for wheat in the development of cakes with no added sugar. *Brazilian Journal of Food Technology*, *21,* 01-09. https://doi.org/10.1590/1981-6723.19016

Souza, R. C. O., Generoso, M. A., Amaral, D. A., Pimenta, L. B. S., Jesus, C. M. A., Oliveira, C. A., Ribeiro, E. M., Silva, J. P., Correa, G. A. C., Porto, M. B., & Mendes, J. F. (2020). Development and affective sensory analysis of banana and oat cake in traditional and diet versions. *Brazilian Applied Science Review, 4*, 1932-1946. https://doi.org/10.34115/basrv4n3-095

Stavale, M. D. O., Botelho, R. B. A., & Zandonadi, R. P. (2019). Apple as sugar substitute in cake. *Journal of Culinary Science & Technology*, *17*, 224-231. https://doi.org/10.1080/15428052.2018.1428708

TACO. Brazilian Table of Food Composition. (2011). NEPA – UNICAMP, Campinas, 4th ed. Campinas: NEPAUNICAMP, pp. 161.

Vargas-Sánchez, R. D., Torrescano-Urrutia, G. R., Ibarra-Arias, F. J., Portillo-Loera, J. J., Ríos-Rincón, F. G., & Sánchez-Escalante, A. (2018). Effect of dietary supplementation with *Pleurotus ostreatus* on growth performance and meat quality of Japanese quail. *Livestock Science*, *207*, 117-125. https://doi.org/0.1016/j.livsci.2017.11.015

WHO/FAO. World Health Organization & Food and Agriculture Organization. (2003). Diet, nutrition and the prevention of chronic diseases. Report of a joiat WHO/FAO Expert Consultation. World Health Organ Tech Rep Ser, Geneva, 916(i-vii), 1-149.

WHO. World Health Organization. (2016). Childhood overweight and obesity. World Health Organization Document Production Services: Geneva, Switzerland. Advance online publication. https://www.who.int/en/news-room/fact-sheets/detail/obesity-and-overweight.

CAPÍTULO 5

5.1 CONCLUSÃO GERAL

Apesar da importância econômica do gênero *Acrocomia* e a diversificação de seu uso, observa-se ainda subutilização das espécies. A espécie que apresenta maior destaque de exploração tanto na subsistência quanto na exploração comercial a nível nacional e mundial é a *A. aculeata*. Mas, seu maior destaque está voltado para exploração do óleo, sendo negligenciado o potencial nutritivo para formulação de produtos alimentícios enriquecidos, potencial de compostos bioativos para elaboração de produtos funcionais ou nutracêuticos, e produtos fitoterápicos. Além disso, há escassez de informações sobre o potencial de uso dos frutos no estágio de maturação verde. A adição de nitrato de amônio como fonte de nitrogênio no tratamento T3 contribuiu para o melhor crescimento micelial e potencializou a bioconversão de carboidratos da polpa de bocaiúva verde de *Pleurotus ostreatus* em proteínas, fibras e lipídios, o que se revela promissor para o desenvolvimento de novos produtos alimentícios com valor agregado nutracêutico. A farinha de bocaiúva verde enriquecida com *Pleurotus ostreatus* demonstrou grande potencial para a preparação de bolos com baixo teor de carboidratos com melhor composição nutricional (F3 e F4), características sensoriais aceitáveis por juízes treinados (F4) e grande potencial de comercialização (F4). Porém, a dosagem de nitrato de amônio como fonte de nitrogênio para o desenvolvimento do fungo interferiu negativamente no sabor do produto elaborado (F3).

APÊNDICES

Análise Descritiva Quantitativa (ADQ)

Quadro 1- Termos descritores, definições e descrição do material de referência para extremos da escala.

Atributo	Termo Descrito	Definição	Referência para os extremos da escala
Aparência	1. Cor da casca	Coloração característica de bolo que podem variar de bege claro a marrom escuro, dependendo dos ingredientes presentes.	Clara (fraco): Bolo de sabor coco, marca Italac. Escura (forte): Bolo de chocolate, marca: Pullman.
	2. Cor da massa	Coloração da massa dos bolos que podem variar de bege claro a marrom escuro, dependendo dos ingredientes presentes.	Clara: Bolo sabor baunilha, marca Vitarella. Escura: Bolo de chocolate, marca: Pullman.
	3. Brilho da casca	Capacidade reflexão a luz, com aparência brilhante ou opaco da casca do bolo.	Opaco: Biscoito de maisena, marca: Vitarella. Brilhante: Bolo de chocolate, marca: Migra.
	4. Uniformidade da casca	Homogeneidade da casca em relação à presença de bolhas de ar	Pouca: Queijo suíço, marca: Muito: Bolo de sabor chocolate, marca: Migra
	5. Tamanho das bolhas na massa	Tamanho das cavidades formadas pelas bolhas de ar	Pequena: Bolo de chocolate, marca: Pullman. Grande: Queijo suíço, marca: Raclette.
	6. Estrutura do massa	Atributo de aparência em relação à estrutura do centro do bolo	Leve: Bolo sabor baunilha, marca Vitarella. Pesado: Bolo embatumado.
Aroma	7. Chocolate	Aroma de chocolate percebido por aspiração, antes do produto ser colocado na boca.	Nenhum: Água mineral. Muito: Bolo de chocolate, marca: Baducco.
	8. Coco	Aroma volátil de coco percebido por aspiração, antes do produto ser colocado na boca.	Nenhum: Água mineral. Muito: Bolo de coco, marca: Italac.

	9.Bocaiuva enriquecida com cogumelo comestível	Aroma volátil de bocaiuva enriquecida com cogumelo comestível por aspiração, antes do produto ser colocado na boca.	Nenhum: Água mineral. Muito: Bocaiuva enriquecida com cogumelo comestível
	10. Farinha de bocaiuva sem cogumelo comestível	Aroma volátil de bocaiuva por aspiração, antes do produto ser colocado na boca.	Nenhum: Água mineral. Muito: Farinha de Bocaiuva sem cogumelo comestível.
Textura	11. Maciez	Força mínima necessária para comprimir a amostra entre os dentes	Pouca: Torrada, marca: Bauducco. Muita: Marshmallow, marca Haribo.
	12. Umidade	Sensação provocada pela quantidade de água presente no bolo	Pouca: Biscoito de maisena Muita: 1 fatia de bolo comercial sabor chocolate umedecida com 10 mL de leite/ Bolo de chocolate, marca: Pullman.
	13. Fraturabilidade	Intensidade de força pela qual o material quebra ou fratura.	Pouca: Bolo de chocolate, marca: Bauducco. Muita: Pé de moleque, marca DaColônia.
	14. Adesividade	Capacidade do produto em se aderir ao dente durante a mastigação.	Pouca: Biscoito de água e sal, marca: vitarella. Muita: Bala de caramelo de leite, marca: Butter Toffees.
	15. Gomosidade	Força necessária para desintegrar a massa do alimento, obtida durante a mastigação, até que atinja o ponto de engolir.	Pouca: Biscoito de maisena, marca Vitarella. Muita: Farinha de bocaiuva sem cogumelo.
Sabor	16. Doce	Sabor adocicado	Pouco: Miolo de pão de forma, marca: Pullman. Muito: Doce de coco, marca DaColônia.
	17. Chocolate	Intensidade do sabor de chocolate, percebido quando é colocado na boca e sentido pela língua por meio das papilas gustativas.	Nenhum: Água mineral. Muito: Bolo de chocolate, marca: Baducco.

	18. Coco	Característica do sabor de coco, percebido dentro da boca, durante a mastigação.	Nenhum: Água mineral. Muito: Bolo de coco, marca: Italac.
	19. Farinha de Bocaiuva enriquecida com cogumelo comestível	Intensidade do sabor Bocaiuva enriquecida com cogumelo comestível percebido dentro da boca durante a mastigação.	Nenhum: Água mineral. Muito: Farinha de bocaiuva com cogumelo comestível.
	20. Farinha de bocaiuva sem cogumelo comestível.	Intensidade do sabor característico associado à presença de sabor de farinha de bocaiuva sem cogumelo comestível na boca durante a mastigação.	Nenhum: Água mineral. Muito: Farinha de bocaiuva.
	21. Amargo	Intensidade do sabor característico de amargo após a deglutição.	Nenhum: solução 0,06% de glutamato monossódico. Muito: solução de 0,02% de cafeína.

Tabela 1 – Médias dos termos descritores para o atributo aparência das formulações de bolo *low carb*.

Formulações	Cor da casca	Cor da massa	Brilho da casca	Uniformidade da casca	Tamanho das bolhas na massa	Estrutura da massa
F1	4,18±1,37^{c}	3,51±1,05^{c}	5,05±1,84^{a}	5,49±1,93^{a}	2,40±1,24^{b}	3,42±1,91^{a}
F2	4,95±1,68^{c}	4,20±1,50^{c}	4,54±1,71^{a}	6,10±1,56^{a}	4,23±1,89^{a}	3,96±1,70^{a}
F3	6,21±1,61^{b}	5,93±1,17^{b}	4,26±2,05^{a}	5,85±2,00^{a}	2,80±1,65^{b}	3,55±2,02^{a}
F4	7,67±0,78^{a}	7,50±0,79^{a}	4,40±1,70^{a}	6,75±1,75^{a}	2,42±0,98^{b}	3,26±2,05^{a}

Valores são expressos com médias e desvio padrão, com letras iguais na mesma coluna não diferem significativamente entre si ao nível de 5% ($p>0,05$) pelo teste de Tukey.
Legenda: F1: Bolo *low carb* com farinha de coco. F2: Bolo *low carb* com farinha de bocaiuva verde sem o incremento. F3: Bolo *low carb* com farinha de bocaiuva verde enriquecida cogumelo e nitrato de amônia. F4: Bolo *low carb* com farinha de bocaiuva verde enriquecida cogumelo sem suplementação.

Tabela 2 – Médias dos termos descritores para o atributo aroma das formulações de bolo *low carb.*

Formulações	Chocolate	Coco	Bocaiuva enriquecida com cogumelo comestível	Farinha de bocaiuva sem o cogumelo comestível
F1	$2{,}58\pm1{,}45^{b}$	$2{,}60\pm1{,}72^{a}$	$4{,}30\pm2{,}03^{a}$	$3{,}55\pm2{,}13^{a}$
F2	$3{,}30\pm2{,}06^{b}$	$2{,}95\pm1{,}60^{a}$	$3{,}43\pm1{,}93^{a;b}$	$3{,}81\pm2{,}17^{a}$
F3	$5{,}01\pm2{,}17^{a}$	$2{,}37\pm1{,}43^{a}$	$3{,}28\pm1{,}74^{a;b}$	$3{,}69\pm2{,}18^{a}$
F4	$6{,}19\pm2{,}33^{a}$	$2{,}73\pm2{,}04^{a}$	$2{,}75\pm1{,}59^{b}$	$2{,}95\pm1{,}53^{a}$

Valores são expressos com médias e desvio padrão, com letras iguais na mesma coluna não diferem significativamente entre si ao nível de 5% ($p>0{,}05$) pelo teste de Tukey.
Legenda: F1: Bolo *low carb* com farinha de coco. F2: Bolo *low carb* com farinha de bocaiuva verde sem o incremento. F3: Bolo *low carb* com farinha de bocaiuva verde enriquecida cogumelo e nitrato de amônia. F4: Bolo *low carb* com farinha de bocaiuva verde enriquecida cogumelo sem suplementação.

Tabela 3 – Médias dos termos descritores para o atributo textura das formulações de bolo *low carb.*

Formulações	Maciez	Umidade	Fraturabilidade	Adesividade	Gomosidade
F1	$5{,}72\pm1{,}93^{a}$	$6{,}08\pm2{,}09^{a}$	$3{,}65\pm2{,}17^{a}$	$3{,}55\pm1{,}91^{a}$	$4{,}00\pm2{,}16^{b}$
F2	$5{,}49\pm1{,}70^{a}$	$4{,}32\pm1{,}30^{b}$	$3{,}98\pm1{,}92^{a}$	$4{,}69\pm1{,}56^{a}$	$5{,}75\pm1{,}56^{a}$
F3	$6{,}15\pm2{,}02^{a}$	$4{,}53\pm1{,}58^{b}$	$3{,}99\pm2{,}30^{a}$	$3{,}54\pm1{,}75^{a}$	$3{,}71\pm2{,}04^{b}$
F4	$6{,}79\pm1{,}79^{a}$	$6{,}55\pm1{,}09^{a}$	$3{,}72\pm2{,}29^{a}$	$3{,}46\pm2{,}13^{a}$	$3{,}70\pm1{,}91^{b}$

Valores são expressos com médias e desvio padrão, com letras iguais na mesma coluna não diferem significativamente entre si ao nível de 5% ($p>0{,}05$) pelo teste de Tukey.
Legenda: F1: Bolo *low carb* com farinha de coco. F2: Bolo *low carb* com farinha de bocaiuva verde sem o incremento. F3: Bolo *low carb* com farinha de bocaiuva verde enriquecida cogumelo e nitrato de amônia. F4: Bolo *low carb* com farinha de bocaiuva verde enriquecida cogumelo sem suplementação.

Tabela 4 – Médias dos termos descritores para o atributo sabor das formulações de bolo *low carb.*

Formulações	Doce	Chocolate	Coco	Bocaiuva enriquecida com cogumelo comestível	Farinha de bocaiuva	Amargo
F1	4,25±1,84 ^{a}	2,79±1,66^{b}	2,92±2,08^{a}	4,37±2,11^{a}	4,08±2,39^{a}	3,26±2,31^{b}
F2	3,70±1,47 ^{a}	2,42±1,48^{b}	2,61±1,61^{a}	3,23±1,98^{a}	4,98±2,35^{a}	2,01±0,96^{b}
F3	3,62±1,46 ^{a}	2,90±1,72^{b}	2,44±1,41^{a}	4,39±2,08^{a}	4,63±2,13^{a}	3,82±2,42^{a}
F4	4,84±2,05 ^{a}	4,37±2,24^{a}	2,66±1,68^{a}	3,46±2,15^{a}	3,73±1,66^{a}	2,51±1,55$^{a;b}$

Valores são expressos com médias e desvio padrão, com letras iguais na mesma coluna não diferem significativamente entre si ao nível de 5% (p>0,05) pelo teste de Tukey.
Legenda: F1: Bolo *low carb* com farinha de coco. F2: Bolo *low carb* com farinha de bocaiuva verde sem o incremento. F3: Bolo *low carb* com farinha de bocaiuva verde enriquecida cogumelo e nitrato de amônia. F4: Bolo *low carb* com farinha de bocaiuva verde enriquecida cogumelo sem suplementação.

Escala Hedônica

Tabela 5 – Médias dos termos descritores para o atributo aparência das formulações de bolo *low carb.*

Formulações	Cor	Aroma	Textura	Sabor	Avaliação Global	Intenção de compra
F1	6,73±1,83^{a}	6,36±2,15^{a}	5,73±2,03^{b}	5,64±1,94^{b}	6,23±2,05^{b}	2,77±1,07^{b}
F2	7,36±1,33^{a}	7,09±1,31^{a}	6,41±1,26$^{a;b}$	6,36±1,05$^{a;b}$	6,82±1,44$^{a;b}$	3,18±0,73^{b}
F3	7,32±1,43^{a}	7,09±1,48^{a}	6,50±1,44$^{a;b}$	5,86±1,42^{b}	6,45±1,53^{b}	2,95±0,72^{b}
F4	7,77±1,41^{a}	7,55±1,47^{a}	7,32±1,13^{a}	7,18±1,53^{a}	7,73±1,24^{a}	3,91±0,97^{a}

Valores são expressos com médias e desvio padrão, com letras iguais na mesma coluna não diferem significativamente entre si ao nível de 5% (p>0,05) pelo teste de Tukey.
Legenda: F1: Bolo *low carb* com farinha de coco. F2: Bolo *low carb* com farinha de bocaiuva verde sem o incremento. F3: Bolo *low carb* com farinha de bocaiuva verde enriquecida cogumelo e nitrato de amônia. F4: Bolo *low carb* com farinha de bocaiuva verde enriquecida cogumelo sem suplementação.