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UNIVERSIDADE FEDERAL DE VIÇOSA

LAIS FERNANDA BATISTA

AMÊNDOA DE BARU (*Dipteryx alata* Vog.): PESQUISA EXPLORATÓRIA E DESENVOLVIMENTO DE NOVOS PRODUTOS

VIÇOSA - MINAS GERAIS

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Tese apresentada à Universidade Federal de Viçosa, como parte das exigências do Programa de Pós-Graduação em Ciência e Tecnologia de Alimentos, para obtenção do título de *Doctor Scientiae*.

Orientadora: Márcia Cristina Teixeira Ribeiro Vidigal

Coorientadores: Ana Clarissa dos Santos Pires

Luis Henrique Mendes da Silva

VIÇOSA - MINAS GERAIS

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Márcia Cristina Teixeira Ribeiro Vidigal

Orientadora

A minha mãe Carmem,

ao meu companheiro Leonardo,

a minha família e amigos e todos que de alguma

forma me permitiram chegar até aqui.

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"Aprender é a única coisa de que a mente nunca se cansa, nunca tem medo e nunca se arrepende" ***Leonardo Da Vinci***

RESUMO

BATISTA, Laís Fernanda, D.Sc., Universidade Federal de Viçosa, março de 2024. **Amêndoa de baru (*dipteryx alata* vog.): pesquisa exploratória e desenvolvimento de novos produtos.** Orientadora: Márcia Cristina Teixeira Ribeiro Vidigal. Coorientadores: Ana Clarissa dos Santos Pires e Luis Henrique Mendes da Silva.

O mercado de alimentos à base de plantas segue em expansão, atraindo consumidores com diferentes hábitos culturais e motivacionais, principalmente quando se leva em consideração os aspectos relacionados à saúde e aos benefícios potenciais que os novos hábitos alimentares podem proporcionar. Dentre os alimentos desse setor, destacam-se as bebidas à base de plantas com composições próprias, contribuindo para uma dieta equilibrada e nutritiva. A biodiversidade do Brasil, rica em plantas pouco exploradas, pode fornecer ingredientes para desenvolvimento de novos produtos, como a amêndoa de baru, que vem sendo reconhecida por suas propriedades nutricionais, contribuindo para a saudabilidade e estimulando a segurança alimentar. Neste sentido, este estudo visa entender as demandas dos consumidores que podem direcionar o desenvolvimento de produtos que valorizem essas matérias-primas pouco conhecidas, usando metodologias sensoriais tais como grupo de foco e entrevistas individuais. O estudo foi dividido em 4 artigos no qual primeiramente, foi abordado sobre a exploração dos hábitos alimentares de diferentes grupos de consumidores e suas percepções sobre alimentos *comfort foods* feitos à base de plantas, como gelados comestíveis e hambúrgueres de castanha, tendo como principal diferencial a utilização do *software* Iramuteq para analisar os dados qualitativos. Em seguida, as percepções dos consumidores em relação às fontes vegetais nativas pouco usadas no Brasil para o desenvolvimento de alimentos à base de plantas, que podem contribuir para um sistema alimentar sustentável, foi objeto de estudo para avaliar as demandas em âmbito nacional. No terceiro artigo, bebidas à base de amêndoa baru adoçadas com sacarose ou alulose foram avaliadas, por 100 consumidores quanto à influência das informações sobre os ingredientes, benefícios à saúde descritos no rótulo frontal. Dessa forma, por meio dos resultados deste artigo, é possível elaborar estratégias de *marketing* mais eficazes e melhorias na formulação para promover maior aceitabilidade de produtos à base de plantas. Além disso, as bebidas foram caracterizadas quanto à composição, o pH, a análise instrumental da cor, as características microbiologia, propriedades reológicas e a avaliação da cinética de desestabilização, não havendo diferença significativa ($p<0,05$) entre elas. Já no quarto trabalho, foi elaborado o processo de obtenção e caracterização da farinha feita a partir da torta do baru, agregando valor a esse coproduto e propondo novas formas de aproveitar a matéria-prima integralmente.

Palavras-chave: Grupo de foco; Análise sensorial; Novos produtos; Amêndoa de baru.

ABSTRACT

BATISTA, Laís Fernanda, D.Sc., Universidade Federal de Viçosa, March, 2024. **Baru almond (*dipteryx alata* vog.): exploratory research and development of new products.** Advisor: Márcia Cristina Teixeira Ribeiro Vidigal. Co-advisors: Ana Clarissa dos Santos Pires and Luis Henrique Mendes da Silva.

The *plant-based* food market continues to grow, attracting consumers with diverse cultural habits and motivations, especially when considering the aspects related to health and the potential benefits that new dietary habits can provide. Among the foods in this sector, highlight plant-based beverages, with own compositions, contributing to a balanced and nutritious diet. Brazil's rich biodiversity, abundant in underexplored plants, can provide ingredients for developing plant-based products, such as baru almonds, which have been recognized for their nutritional properties, contributing to health and promoting food security. This study aims to understand consumer demands that can guide the development of products that value these little-known raw materials, using sensory methodologies such as focus groups and individual interviews. The study was divided into papers, beginning with the exploration of the dietary habits of different consumer groups and their perceptions of comfort foods made from plant-based ingredients, such as edible ices and chestnut burgers, which have as one of their differentials the use of the *software* Iramuteq to analyze qualitative data. Subsequently, consumers' perceptions regarding underutilized native plant sources in Brazil in the development of plant-based foods, which can contribute to a sustainable food system, were studied to assess national demands. In the third article, plant-based beverages made from baru almond with sucrose and allulose were evaluated as a function of for the influence ingredients, baru health benefits, and front labels by 100 consumers. The results can contribute to the development of more effective marketing strategies and improvements in formulation to promote greater acceptability. Furthermore, the beverages were characterized in terms of composition, pH, color, characterirtics microbiology, properties rheology, and destabilization kinetics, with nosignificant difference. Finally, in the last part of the work, the process of obtaining and characterizing flour made from baru cake was elaborated, adding value to this co-product and proposing new ways to utilize the raw material entirely.

Keywords: Focus group; Sensory analysis; New products; Baru almond.

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INTRODUÇÃO GERAL

O mercado de alimentos à base de plantas cada vez mais se estabelece, com perspectiva de movimentar até 2035, cerca de US$ 370 bilhões de dólares (GFI, 2021). O consumo desses alimentos é feito por consumidores das mais diferentes culturas e motivações relacionadas, principalmente, à saúde e aos benefícios potenciais que tais mudanças nos hábitos alimentares podem oferecer (McClements e McClements, 2023). De acordo com Pérez-Rodríguez et al. (2023), quando se trata do mercado de bebidas à base de plantas, o produto deve ser considerado além de uma alternativa vegetal, uma vez que se trata de um alimento que apresenta uma composição própria, e pode ser incluído como parte de uma dieta equilibrada, rica em componentes funcionais e nutricionais e contribuir para melhorar a saúde populacional em geral.

A biodiversidade encontrada nos biomas brasileiros possui grande potencial para o desenvolvimento de produtos à base de plantas, especialmente a partir de fontes vegetais pouco exploradas comercialmente, como a amêndoa de baru. Tradicionalmente consumido pelas comunidades do Cerrado brasileiro, este fruto destaca-se pelo seu valor nutricional, com potenciais benefícios à saúde (Lima *et al.*, 2022a; Souza *et al.*, 2018a).

Desta forma, a amêndoa de baru tem sido considerada como uma escolha promissora para a indústria alimentícia, uma vez que promove a valorização de ingredientes tradicionais e sustentáveis, buscando alcançar a segurança alimentar por meio de quatro pilares principais, a citar disponibilidade e estabilidade de alimentos (Mwangi *et al.*, 2023). Diante do exposto, o trabalho teve como objetivo geral desenvolver produtos que valorizem as matérias primas nacionais pouco conhecidas, mas que tem potencial para ter boa aceitação, utilizando metodologias variadas para compreender as demandas dos consumidores e entregar produtos mais direcionados e com maior potencial de aceitação.

Nesse contexto, o trabalho está estruturado na forma de artigos, em que o artigo 1 buscou-se explorar o comportamento de três grupos de consumidores com diferentes hábitos alimentares e as suas percepções sobre alimentos *comfort food* [1] feitos à base de plantas, buscando compreender os fatores que motivam o consumo desses produtos e suas expectativas em relação a dois novos alimentos de conforto (gelados comestíveis e hambúrgueres à base de castanhas). A análise dos dados foi feita utilizando o software Iramuteq por meio da análise

[1] Alimentos com o potencial de promover o bem-estar, gerando efeitos psicológicos e/ou emocionais positivos, bem como uma sensação de recompensa durante seu consumo.

textual de artigos, transcrições e questionários, utilizando cálculo de frequência e análise multivariada, para avaliar as diferenças e semelhanças entre as percepções dos grupos (Veganos/vegetarianos; Especialistas da área de alimentos; Consumidores comuns) bem como suas expectativas e opiniões. A análise dos dados obtidos nos grupos de foco usando o Iramuteq foi realizada de forma mais aprimorada e menos subjetiva do que avaliação qualitativa convencional.

No artigo 2, foi possível obter as percepções de 212 consumidores em relação às fontes vegetais nativas dos biomas brasileiros pouco utilizadas no desenvolvimento de alimentos à base de plantas, com o potencial de contribuir com um sistema alimentar sustentável, com respondentes das diferentes regiões do Brasil, por meio de metodologias variadas, como questionários individuais e ferramentas de análise de textuais.

No artigo 3, bebidas à base de amêndoas de baru, o Baruccino, com adição de sacarose ou alulose, foram desenvolvidas e avaliadas quanto à influência das informações dos ingredientes, dos benefícios à saúde do baru e do rótulo frontal na percepção e aceitação sensorial por 100 consumidores. As bebidas também foram caracterizadas quanto à composição centesimal, pH, teor de sólidos solúveis, cor, microbiologia, reologia, e estudos de cinética de desestabilização.

No artigo 4, a conclusão do estudo teve como objetivo a obtenção e a caracterização física e química e além das propriedades tecnológicas da farinha obtida a partir da torta resultante do processamento das bebidas feitas a partir das amêndoas de baru, como forma de agregar valor a esse coproduto e propor novas formas de aproveitar de maneira integral a matéria-prima e direcionando sua aplicação em novos produtos.

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PAPER 1

Comfort plant-based food: What do consumers want? - A focus group study with different consumers groups

Article published in the *Journal of Gastronomy and Food Science*
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ABSTRACT

The perception about the consumption of plant-based foods was carried out using the focus group technique with three groups of consumers, namely, food science professionals/students, vegans and vegetarians, and general consumers. Information was obtained on the opinion, desires and motivators of the consumption of foods with the substitution of animal protein with a vegetable one. In addition, the word association technique was used to evoke the perception of two comfort foods made from chestnuts (analogous to ice cream and burgers) by consumers. From data analysis with the Iramuteq tool, three main themes were suggested to represent the participants' views on plant-based foods: sustainability and ethics; health and wellness; and sensoriality and pleasure. Similarities and divergences regarding the perception between the groups were discussed. Sensory and nutritional aspects, curiosity, and price were the most important factors in determining the acceptance and/or consumption of comfort plant-based foods.

Keywords: Consumer behavior; Chestnuts; *Comfort foods*; Iramuteq.

Highlights

- The Iramuteq software contributed to less subjectivity and analysis time of qualitative data.
- *Plant-based* food themes: Sensory and pleasure, Health and well-being, Sustainability and Ethics.
- The burger and ice cream made with nuts generated positive expectations in different niches of consumers.
- Price, sensory and nutritional aspects, and lack of information can be challenging to the development of new products.

1. Introduction

Over the last few years, the plant-based market has undergone substantial growth and transformed from a niche market to a consolidated segment (Tonsor et al., 2023). *Plant-based* meat, dairy products and their analogous derivatives are among the main innovations in the sector, which is mainly driven by changes in consumer lifestyles, the number of consumers with restrictions on products of animal origin, the popularization of veganism and vegetarianism, and also due to the increase in the number of flexitarians (consumers willing to reduce and rethink the consumption of animal products) (Dagevos, 2021; Malek and Umberger, 2021).

In addition to this increasing trend of *plant-based* foods, comfort food had the potential to promote well-being by generating positive psychological and/or emotional effects, as well as a sense of reward (Spencer et al., 2018a), especially during the COVID-19 pandemic (Scarmozzino and Visioli, 2020). In a survey conducted by Wansink and Sangerman (2000) with North American participants, it was reported that ice cream (14%) and hamburger (beef/steak) (11%) are among the main *comfort foods* preferred by these consumers. Pinto et al. (2020) observed that non-sensory characteristics, such as cultural predilections, health concerns, self-awareness, past experiences, familiarity, satiety, and taste influence their preferences of comfort foods. The study reports that pizza and hamburgers are the most common comfort foods as they are often consumed in Brazilian restaurants. The most mentioned comfort food category that brought emotional comfort during the COVID-19 pandemic in a study carried out with Brazilian consumers was “sweet”, which includes ice cream (Souza et al., 2023). However, the development of comfort foods, such as ice cream and burgers made with plant-based ingredients with adequate sensory and nutritional quality is a major technological challenge for the food industry (Alcorta et al., 2021; Arab et al., 2019).

Nuts are rich in minerals, fats, and some bioactive compounds, such as polyphenols and carotenoids, which can provide positive benefits to human health (Polmann et al., 2021; Samtiya et al., 2021). The consumption of nuts can promote health benefits in the human body, due to the presence of some antioxidant compounds that can reduce the risk of developing some diseases related to oxidative stress and can also play a role in reducing cholesterol levels (Bento et al., 2014; de Souza et al., 2018; Lima et al., 2021). Moreover, a significant variety of nuts commonly found in Brazilian biomes is not yet explored to its full potential. Therefore,

the development of *comfort foods* that meet the consumers' demands, especially those willing to adopt a healthier lifestyle and are also concerned with environmental issues.

In this context, the understanding of factors that influence consumers' perceptions about new products made from nuts can provide essential information for the development of foods and marketing strategies. Studies regarding the behavior of consumers in relation to *plant-based* foods have been carried out in different countries over the last few years, through check-all-that-apply (CATA) methodologies in United States of America (USA), Singapore and Australia (Cardello et al., 2022), France (Niimi et al., 2022), rate-all-that-apply (RATA) in Germany (Pointke et al., 2022), Denmark (Aaslyng and Højer, 2021), and also the combination of both methods was evaluated in a study conducted by Jaeger and Ares (2017) in China. Due to its large population and varied biodiversity, Brazil has potential to act as a key country in the development and popularization of *plant-based* foods. Importantly, the rising trend of flexitarians, vegans and vegetarians can also impact this niche market, which is also in line with the environmental sustainability caused by the reduction in the consumption of animal-based products.

Studies approaching consumers' perceptions of foods are generally based on qualitative methodologies, such as individual interviews, focus groups, or free word association technique with traditional data analysis. In these studies, focus groups are an important tool to obtain insights into consumers' feelings and thoughts and data analysis. However, the large volume of information generated, in addition to the subjectivity and possibility of bias when selecting the information for analysis, are the main limitations of this methodology (Lazar et al., 2017). Therefore, using textual data software for qualitative analysis, such as Iramuteq, can minimize such limitations. This software is widely used to analyze data from transcribed verbal material produced from interviews, documents, assays, among others, with great potential for application in the area of qualitative sensory analysis (Camargo and Justo, 2013; de Souza et al., 2018; Lahlou, 1994). The use of Iramuteq software applied to analysis of consumers' perceptions was reported by Vieira et al. (2022) who determined new insights into perceptions of technological claims in Greek-style yogurt during the COVID-19 pandemic through a structured questionnaire. Lucchese-Cheung et al. (2021) also used Iramuteq as a tool to analyze the perception of Brazilian consumers about a new product according to the sensory descriptions provided by the participants.

In this context, the objective of this study was to explore the behavior and perception of three groups of consumers with differences in their awareness and dietary habits about

comfort plant-based foods. It is expected to provide a better understanding of the factors that motivate the consumption of plant-based products and their expectations towards two new *comfort foods* (ice cream and burgers made with chestnuts). Data analysis using the Iramuteq software aims to identify differences and similarities between the perceptions of groups, as well as their expectations and opinions.

2. Methods

An exploratory study was performed with three different focus groups in order to evaluate the consumers' perception about *plant-based* foods, assessing their opinion regarding the substitution of animal protein by alternative sources, such as plant-based proteins, as well as its impact on sensory perceptions of comfort foods For this purpose, images of vegan ice cream and burgers were presented to the participants and they were asked to characterize these images with descriptive terms using the free word association technique. This technique makes it possible to identify the most important characteristics of the products in order to guide the perception of consumption and the acceptance of new products.

The study was conducted after approval of the project by the Human Research Ethics Committee of the Federal University of Viçosa (UFV), substantiated with opinion number 5.291.419.

2.1. Focus Group

Participants were invited by email to participate in this study. Then, they were assigned to one of the three proposed focus groups: Group 1 (G1) composed of researchers, students and professors of food science/engineering (n=5 female; n=3 male), Group 2 (G2) composed of vegetarians and vegans (n=4 female; n=4 male), and Group 3 of general consumers with no dietary restrictions (n=4 female; n=4 male). Consumers' perceptions and acceptance of foods is influenced by different factors, including levels of knowledge, and consumption habits (Schäufele, Hamm, 2017; Van Bussel, 2022, Wendin and Nyberg, 2021). Therefore, in order to assess the influence of knowledge about food science and nutrition, people who study and/or work in the field of Food Science were placed in G1. They were supposed to compare their perception about comfort plant-based foods with other participants who did not possess the same expertise in this field (G2 and G3). The choice of each group was designed so that the

interview in a systematic and simultaneous way promoted greater discussion among the participants. According to Acocella (2012) and Nguyen et al. (2020), it is advisable that the discussion takes place between people who share similar interests and who feel equal to create a homogeneous group and avoid any situation that can cause inhibition and discourage the conversation. Importantly, G1 participants were expected to possess more knowledge regarding food composition and their impact on nutrition, which should influence their perceptions about the comfort plant-based foods. Also, for G2 participants, it was important to understand the main motivators behind their choice for plant-based foods, as well as their expectations about these products. On the other hand, general consumers without dietary restrictions and without academic knowledge in food science (G3) could be potential consumers of plant-based foods.

Each group was asked to provide information, ideas and experiences, as well as their knowledge on the subject, which can be used as a basis for directing the development of plant-based products and marketing strategies for different groups of consumers. The focus group sessions were conducted online via Google Meet, according to the procedures established by Krueger & Casey (2008). A total of 24 individuals participated in the study, with eight participants (n=8) per group. Furthermore, it was assured that the participants did not belong to two distinct groups simultaneously. All the participants were adults older than 18, primary food purchasers, and/or who prepared their own meals. In the focus group sessions, it is recommended the participation of seven to 12 individuals per session (Harris et al., 2009).

The sessions were conducted with the assistance of a moderator and two assistants, who were responsible for taking notes and recording these sessions with the consent of the participants. After an explanation of how the session would be conducted, the moderator asked permission to start recording and asked the questions present in the questionnaire (Table 1). The same questions were asked for both groups G1 and G3, while for G2 some questions were modified since this group was already familiar with the subject of the study. Furthermore, it was made clear that the purpose of the session and the questions was to obtain their individual opinions regarding the topic mentioned above. The duration of each session was approximately 1 hour.

Table 1. Questions addressed in the focus group.

Group 1 (food experts) and 3 (general consumers)	Group 2 (vegetarians and vegans)
1. Do you have the habit of reading the labels of foods that you buy or consume? If yes, what information do you focus on? If not, why not?	1. Do you have the habit of reading the labels of foods that you buy or consume? If yes, what information do you focus on? If not, why not?
2. Would you be interested in consuming foods made by replacing an animal protein with a vegetable one? What are the reasons for your decision?	2. What characteristics do you consider important when purchasing a plant-based food that is analogous to that made with an animal protein? Why?
3. What characteristics do you consider important in foods made with vegetable protein as a substitute to an animal protein?	3. Do you think that plant-based foods analogous to those made with animal proteins are restricted to vegan and/or vegetarian consumers? Why?
4. For what kind of target public do you think these products would be appropriate? What are your reasons for your answer?	4. What makes it difficult for vegans and/or vegetarians to purchase plant-based foods analogous to those made with animal proteins?
5. Would you buy this type of product? Why?	5. What types of plant sources would be a better replacement for an animal protein?
6. What types of plant sources would be a better replacement for an animal protein?	6. What types of plant-based foods do you consume in substitution to those traditionally made with animal proteins (such as milk, meat, and their derivatives)? What are the reasons for your decision?
7. What types of foods traditionally made with animal proteins (such as milk, meat and their derivatives) would you be willing to consume if they were made with vegetable proteins? Why?	7. What would (or will) be the long-term impact for you if you were replacing animal proteins with plant proteins?
8. What would (or will) be the long-term impact for you if you were replacing animal proteins with plant proteins?	8. What do you think about the partial replacement of animal proteins for plant-based ones in foods? Why?

2.2. Word Association

After the questions, the free word association technique was used to determine the participants' perceptions about *plant-based* products made with chestnuts. These plant-based products were chosen due to their increasing demand as an alternative to conventional meat and milk products, in addition to their versatility and acceptance among consumers (Pontonio et al., 2022; Spencer et al., 2018b).

The test consisted of presenting two images, where the first one was an image of a plant-based burger, and the second one was of a plant-based ice cream (Fig. A1 and A2) (Appendix A - Supplementary material). As a visual stimulus, the participants were instructed to observe the image and then describe their thoughts or feelings that emerged from the presentation of the stimulus (Ares and Deliza, 2010; Esmerino et al., 2017). The images were presented separately with their respective description of chestnut protein burger and creamy chestnut ice cream. After the presentation of the images, the participants were asked to provide their answers without any further intervention.

3. Analysis of results

The responses obtained in the sessions were analyzed using the IRaMuTeQ (Interface for Multidimensional Text Analysis and Questionnaires) software. This software is licensed by GNU, which uses R. Studio version 5.1 to carry out the statistics of the collected data (interviews, lists of words, questionnaires), using the chi-square test (χ^2). The preparation of the textual corpus and the analysis of the answers given by the participants were performed based on the procedures proposed by Sousa (2021) and Camargo and Justo (2013).

The Descending Hierarchical Classification (CHD) is one of the analyses performed by Iramuteq. The principle of the analysis is to identify and classify the terms according to the frequency of citation, where the most cited terms present a higher size. Based on this information, a dictionary consisting of a single class is created. Through chi-square tests (χ^2), additional classes are created until the formation of homogeneous classes, where words are grouped based on their lexical form, which means that words belonging to similar categories are grouped together. This process provides the degree of association between the words in a given text and the classes with similar meaning, based on the frequencies of the reduced forms.

For example, these words with similar meanings are grouped together, enabling the identification of patterns between the lemma and the formed class.

In order to assess the social representation of the presented plant-based foods, the prototypical analysis was used to evaluate the data generated by the word free association technique. According to Lo Monaco and Bonetto (2019), social representation is a set of ideas, opinions, and beliefs that can be shared between groups regarding a specific stimulus, providing a better understanding of the consumers' perception about a new product. This methodology has been applied to obtain new suggestions that bring insights into the development of new foods and their potential acceptance based on consumers' behavior (Bäckström et al., 2004; Onwezen et al., 2013; Polli et al., 2021).

The responses of each participant were organized in the form of a matrix (database) in the same order the participants were assigned, from which a graph of four quadrants was generated using two coordinates to classify the described evoked feelings. In the evocation analysis, after choosing the theme and the stimulus to be presented, participants are prompted to express the first words, feelings, and thoughts that the given stimulus provokes. Generally, the first words are considered the most important and are associated by the participants with the stimulus, which could be an image, a phrase, or an excerpt from a book. These responses are then recorded in a spreadsheet in the order they were provided by the participants, and the obtained results can be a way to identify patterns and establish which words or terms are most frequently associated with the stimulus. The first coordinate is obtained from the order of mean of evocation (OME), where the terms promptly evoked are shown in one extreme of the quadrant, whereas the terms that were cited later are presented in the opposite extreme. The second coordinate presents the most cited and frequent terms and the less evoked ones. Thus, the evoked elements were arranged in one of the four quadrants considering these two coordinates, as shown in Fig.1.

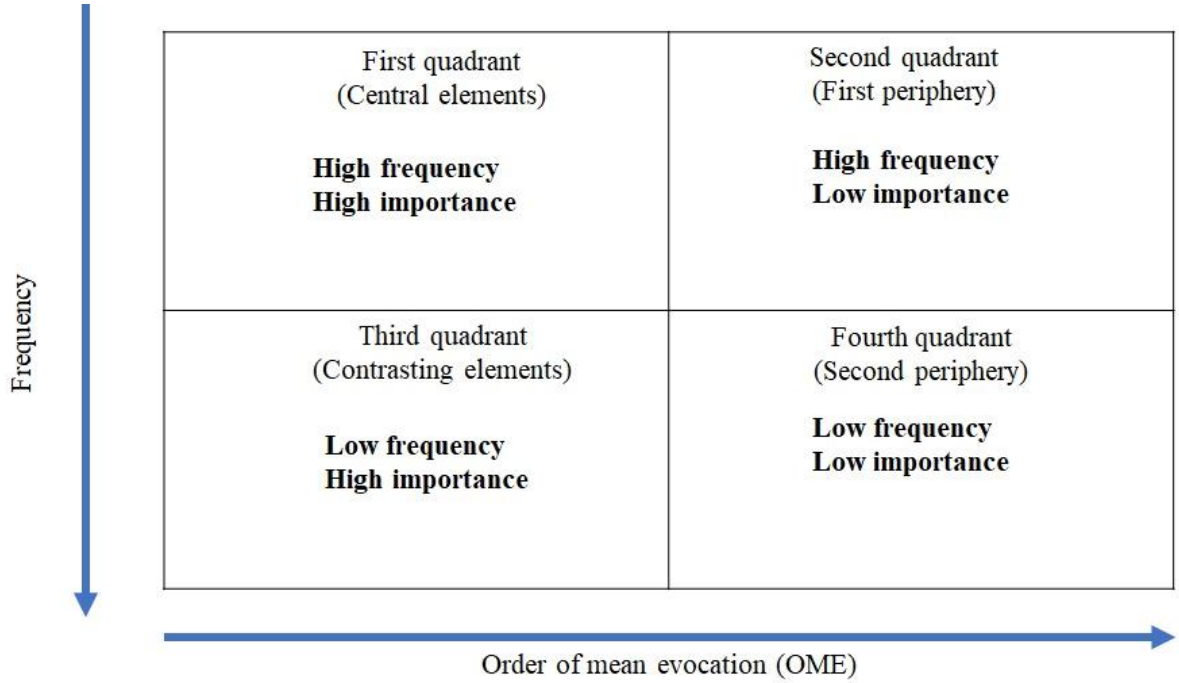

Fig. 1. Representation of the graph of the prototypical analysis and disposition of the quadrants.

The determination of the cutoff point of the coordinates as well as the minimum frequency to be used by the software was determined based on the definitions proposed by Vieira et al. (2022).

4. Results and discussion

4.1. Focus group: grouping themes and global perception

The content of the interviews allowed us to understand the perceptions about the subject from a general perspective of the three different groups of consumers. From the CHD analysis of the text segments corresponding to the participants' answers, the words were considered statistically significant with χ^2>=3.84 and p<0.0001, allowing the qualitative analysis of the data. Lower χ^2 values indicate a lower relationship between the variables. An utilization rate of 83.5% was obtained, allowing the generation of three main themes: Sensory and Pleasure; Health and well-being; and Sustainability and ethics. These ideas represent the main motivations considered important in the selection and/or consumption of plant-based foods from the perspective of groups of consumers with different levels of knowledge about food

processing and nutrition, and their consumption habits. According to Perez-Cueto et al. (2022), promoting a change in diet in order to obtain a diet rich in vegetables is still challenging for consumers, and the different experiences of barriers is mainly explained by the dietary lifestyle.

The results provide insights into the factors that mainly drive the development of new *plant-based foods*, meaning that these terms can assist in developing new products and marketing approaches to increase their sensory acceptance. Indeed, the choice of a product by consumers is based on relevant multisensory experiences. The comments and responses from consumers of the three groups (G1, G2 and G3) are presented in Table 2 (a, b e c) and discussed in the next sections.

Table 2a. Comments of participants theme Sensory and Pleasure.

Comments
1. “I would buy it out of curiosity. I am interested in trying the new products and evaluating a possible dietary substitution of some foods in the future" (G1; woman).
2. "I'm interested in trying new products to evaluate the taste, which is important." If the taste doesn't please me, I wouldn't be interested in consuming this product. I wouldn't completely replace animal protein with a vegetable one." (G1; woman).
3. “The taste and texture are important attributes in foods, but I don't expect it to be the same as conventional meat." (G2 woman).
4. "The first thing that I would do to start replacing animal protein with a vegetable one would be to recover all the affective repertoire I have when eating meat. Therefore, the meat-analog product needs to provide all the emotions, texture, flavor and smell. At first, I would have to induce my brain to accept the new product". (G3; Man)

Table 2b. Comments of participants theme Health and well-being.

Comments	
5. " I mainly check the nutritional value, the food ingredient composition, the presence of artificial colorants such as tartrazine, the functional role of the ingredients, what is more consumed and more natural, as well as the presence of sugar and the caloric value" (G1; Woman).	12. "I would be interested in plant-based products out of curiosity, or if the product brings some functional claim regarding the protein content, for example, with health benefits that can be compared to the ones made with animal protein." (G1; Woman)
6. "I have the habit of reading the labels of all the foods I buy. I often check the presence of preservatives and the amount of sodium in the formulation as well" (G2; Man).	13. "In food products, I would check the information regarding sugar and artificial sweeteners content (which I don't like much), the presence of starch, modified starch or gums, and if the ingredient composition is matching the given information. In whole grain products, I would check the presence of whole grain flour and other grains" (G1; Woman).
7. "Honestly, at most, I check the expiration date only, and I do not pay attention to any other information present in the food label. I don't have any dietary restrictions, maybe that's why." (G3; Man).	14. "I wouldn't buy analogous *plant-based* products" (G3; Man)
8. "I check the expiration date at most, not much more than that." (G3; Man)	15. "The consumption of plant-based food products is very positive, considering that the origin of the coronavirus (COVID-19) seems to be related to products of animal origin. Thus, I believe that plant proteins can provide better food safety compared to animal products." (G3; Woman)
9. "I don't read any food labels, probably because of cultural aspects." (G3; Man)	16. "Healthy, because currently I am concerned about the use of pesticides in vegetable products. Even though I consider that the consumption of vegetables is healthy, it is important to further assess the presence of pesticides and/or agrochemicals, and other compounds in these prod
10. "I see people who become vegetarians seeking to better understand what they are consuming. Generally, you are going to be more careful about choosing micronutrients." (G2; Woman)	
11. "In terms of health, there are several studies that report that meat and sausages can be carcinogenic, so health can certainly be improved with a diet based on vegetable proteins." (G2; Man)	

Table 2c. Comments of participants theme Sustainability and ethics.

Comments
17. “I believe there will be an impact on the industry and the production chain in general”. “This process should be gradual, which means that some industrial plants are being reformulated and innovative products are coming to the market". (G1; Man)
18. "I think the next generations will look down on those who eat meat. I'm in the Faculty of Law and nowadays there are already discussions about animal cruelty within the area". (G2; Woman)
19. "I don't eat meat because of the animal exploitation industry, and also because I don't like the taste of meat." “Therefore, I think it is very wrong to consume foods that comply with animal sacrifice." (G2; Woman)
20. "I believe that for vegetable protein, we can have better food safety in relation to the origin and alteration of products since I think it is easier to control the production of *plant-based* products. The indiscriminate use of antibiotics in cattle brings to us this idea of antibiotic residue in the meat consumed and a greater antimicrobial resistance that is reaching alarming limits." (G3; Woman)
21. "The plant-based market is an opportunity to increase food security for the entire world's population." (G3; Man).

4.1.1. Sensory and Pleasure

The search for new aromas, textures and flavors is a strategy to improve the sensory attributes of new products in order to meet the sensory expectations from the consumers' point of view, providing them pleasure through food with positive sensory attributes. In this context, the development of *plant-based* foods faces some challenges, where sensory perceptions are very important, regardless of other benefits that the consumption of these foods may provide. The terms frequently associated with the *plant-based* foods by the participants of the three consumer groups are presented in Table 3, indicating the most relevant attributes.

Table 3. Most frequent terms associated with the theme of sensorility and pleasure.

Sensoriality and pleasure (36.4%)			
Terms	**Chi-square value (χ^2)**	**Terms**	**Cchi-square value (χ^2)**
Quality	60.80	Curiosity	39.00
Flavor	49.97	Try	29.77
Texture	30.72	Analogue products	26.43
Food	30.40	Interest	15.77
Experience	15.68	Taste	12.79
Taste	12.04	Soy meat	11.04
Eat	11.29	New products	8.90
Pleasing	9.06	Beef milk	8.01
Sensory	7.42	Vegetable milk	7.38
Acceptance	5.85	Price	5.53

The terms quality, flavor, curiosity, and texture were the most frequently mentioned by the participants, with a strong association between the terms and the class sensoriality and pleasure, which are key factors in product development (Starowicz et al., 2022). In a study

carried out by Patinho et al. (2021), the terms “different flavor”, “softness”, “aromatic”, and “seasoned” were the most used to describe the sensory characteristics of a burger made with mushroom. Furthermore, according to Lima-Filho et al. (2016), sensoriality and pleasure are strongly related, among other factors, to the increase in the level of education, information and the income of the population.

Some answers obtained from the participants reinforce the idea that the substitution of animal proteins with vegetable ones is likely to bring a pleasant experience to the consumer (Table 1).

The relationship between sensory perception and pleasure seems to be more important for participants in G1 group regarding the substitution of animal products with plant sources. This group has theoretical and practical knowledge on the subject, and most of them indicated an interest in trying plant-based foods analogous to their traditional ones, mainly out of curiosity, as long as they meet their sensory expectations about this new product (Table 1, see comments 1 and 2). In fact, among the factors that influence food choices, the nutritional knowledge of the consumers is one of the most important (Topolska et al., 2021). Ares et al. (2008), when evaluating the influence of nutritional knowledge on perceived healthiness and willingness to try functional foods, concluded that consumers with the highest level of knowledge were more willing to try the evaluated functional foods with added fiber or antioxidants.

The participants in G2 group are more familiar with the sensory modifications compared to their analogous animal-based products, since they already have a diet restricted to plant-based foods. This group seems to be less demanding about the flavor and texture similarities between plant-based products and those formulated with animal protein (Table 1, see comment 3). Some participants reported that they did not appreciate some sensory attributes of meat, for example, such as odor, taste and texture. This result corroborates Kerslake et al. (2022) who reported that vegetarians and vegans were not seeking meat sensory properties in plant-based products.

The G3 group, on the other hand, would generally accept a plant-based protein product as long as it tastes good, and for this group, the sensory memory needs to be often stimulated. Although there is a growing demand for plant-based foods, consumers may experience food neofobia (Pasqualone, 2022), which means some aversion to new or unfamiliar foods. In this way, it is important that plant-based foods refer to a gustatory/affective memory and are fundamentally tasty, otherwise it is unlikely that consumers without dietary restrictions will be

willing to try it (Table 1, see comment 4). In addition to sensory characteristics, for the participants, other factors also impact the desires and demands for a *plant-based* product, such as brand appeal, reliability, values, packaging, and price, as was also observed by Beacom et al. (2022).

Therefore, the sensory characteristics and pleasure in consuming a food are important at different levels according to familiarity, expectations, knowledge, and lifestyle. The vegan/vegetarian public tends to accept a lower sensory quality for ethical/moral reasons related to the reduced use of environmental resources, lower pollutant emissions and less waste.

4.1.2. Health and well-being

Health and well-being are related to the increasing demand of some individuals for a healthier diet, stimulating different consumers' niches, such as functional products and foods directed to the public with restrictive diets and weight control (Noguerol et al., 2021).

The substitution of animal products by *plant-based* proteins in their diet was associated by the participants mainly with soy, label reading, grains, vegetable mix, and sodium content (Table 4). Soy was mentioned as the most popular grain used by participants in plant-based food processing. For vegan, vegetarian and flexitarian consumers, the consumption of various plant sources, including legumes and grains, is considered crucial for maintaining a healthier diet able to promote well-being and improve the quality of life and health.

Table 4. Most frequent terms associated with the theme of heathiness and wellness.

Helthiness and wellness (28.2%)			
Terms	**Chi-square value (χ^2)**	**Terms**	**Chi-square value (χ^2)**
Soybeans	114.82	Read the labels	155.71
Chickpeas	81.77	Sodium content	50.91
Vegetable mix	55.70	Caloric value	31.44
Lentil	42.98	Expiration date	31.44
Bean	42.19	Sugar content	25.06
Legumes	24.27	Conservative	25.06
Protein	20.03	Concern	18.72
Quinoa	19.09	Protein content	12.81
Ora-pro-nobis	18.13	Egg	12.61

Food labels are an important source of information for consumers and can influence their purchasing decisions, such as the type of the ingredients, preparation, and nutritional properties (Ni Mhurchu et al., 2018; Talati et al., 2016). The search for information about food composition by consumers has already been reported by some authors, who indicate that health-related issues are one of the main reasons for reading food labels (Banovic et al., 2018; Springmann et al., 2016; Sucapane et al., 2021). Label reading was a term strongly associated

with class “Health and wellness” by the three groups of consumers with different motivations. For G1 and G2 groups, the habit of reading of the food labels mainly refers to the assess of information regarding sugar and sodium levels, presence of preservatives, caloric value, and expiration date (Table 1, see comments 5 and 6). The results indicate that knowledge about foods and their impact on nutrition strongly influences consumers' choice for health foods, as observed in a study conducted by Lucas et al. (2022). They reported that nutritional knowledge about superfoods, which are defined by the Oxford English Dictionary as nutritious and beneficial for health and well-being, influences consumers' interest in healthier food options.

However, for G3 group, in general, the label reading was superficially done, whether due to convenience, or lack of knowledge or time (Table 1, see comments 7, 8 and 9). The purchase of already known and consumed products and brands was reported as the main reason for this behavior, which corroborates recent studies (Canavari and Coderoni, 2020; Vemula et al., 2014).

In this context, the habit of reading labels often depends on the consumers food restriction, or the consumers interest in reducing the consumption of a specific ingredient that is not considered healthy. Therefore, the habit of not reading labels can lead to less healthy food choices, which can influence health and the feeling of well-being. The information contained in the labels is a way of allowing consumers to make informed choices, being the main means of communication between consumers and the food industry, as long as they can understand such information. According to Mulders et al. (2018), the ability of consumers to use the information found on product labels to make more conscious and healthier food choices is not clear. Despite this, physical and nutritional well-being remains one of the main demands to be met, as indicated by some participants.

Sodium content was also a concern of the participants. Therefore, for these consumers, the amount of ingredients considered unhealthy, such as salt, should not be in excess in the formulation of a product made with an animal protein substitute.

The vegan and vegetarian consumers (G2) appear to be up to date on recent studies suggesting that substituting plant-based products for animal-based products reduces the risk of cardiovascular disease and type 2 diabetes (Richter et al., 2015; Tonstad et al., 2009). According to Lamberg-Allardt et al. (2023), substituting animal proteins by vegetable ones play a significant role in reducing the risks of mortality by cardiovascular diseases, which can be considered a good strategy in terms of health.

For G2 group, there is a concern about consuming foods that can provide proteins from various sources such as quinoa, soy, and chickpeas, to ensure adequate nutrition (Table 1, see comments 10 and 11). G1 participants are very demanding about the real benefit provided by the substitution of animal protein by a vegetable one. In addition, they check other constituents that may impact their health (Table 1, see comments 12 and 13).

G3 participants point out that the *plant-based foods* analogues must be able to provide an adequate and bioavailable amino acid profile, which is a common requirement regarding the introduction of new healthy foods. According to Aschemann-Witzel et al. (2020), there is no consensus regarding the possibility to produce sufficient amounts of plant proteins with the same nutritional profile as animal-based proteins. However, this is not the consensus of the group (Table 1, see comment 14).

Most of the participants in G3 group considered the consumption of plant-based products as part of a healthy diet, but do not believe that substituting animal protein by a plant-based one is related to a good quality of diet. There's no denying that meat has many benefits to health, including a profile of amino acids, vitamins and minerals, some of which are not found in any product other than meat. So this fact should be taken into consideration.

Another important factor is that some participants highlighted the increase in food security, which, for them, could be strongly associated with the increased consumption of *plant-based* products (Table 1, see comments 15 and 16).

The G3 group, composed of general consumers, showed greater divergence regarding their perceptions about health and well-being, as they had different beliefs and experiences. There were consumers who believe that a plant-based diet was unhealthy. Therefore, providing accurate and reliable information on the positive effects of plant foods on health can raise awareness and, consequently, facilitate the substitution, even partial, of products formulated with animal proteins by vegetable proteins.

4.1.3. Sustainability and ethics

The class “sustainability and ethics” include ideas associated with animal welfare, food safety, use of natural resources, in order to find alternatives for food production and consumption that generate less impact on the environment (Brunin et al., 2022; Verain et al., 2021). The most frequent terms associated with this theme, as mentioned by the three groups

of participants (Table 5), were related to animal cruelty, industry, sustainability, development, and environmental impact.

Table 5. Most frequent terms associated with the theme of sustainability and ethics.

Sustainability and ethics (35.3%)			
Terms	**Chi-square value (χ^2)**	**Terms**	**Chi-square value (χ^2)**
Animal cruelty	29.14	Industry	31.67
Sustainability	19.76	Development	22.89
Perception	19.76	Environmental impact	22.0
Environmental devastation	19.76	Environment	18.24
Meet	10.07	Production	14.69
Vegetarian	8.70	Life	13.67
Diet	8.19	Sustainable	13.67
Vegan	6.33	Population	13.06
Food	5.93	Health	12.8
Society	5.28	Future	8.79

The perception of sustainability and ethics reflects what the consumers expect from the product, aligned with concerns about the environment, future generations, and animal welfare. According to Peano et al. (2018), the definition of sustainability includes the preservation and maintenance of natural resources, decent working conditions, and global access to health and food safety. Furthermore, the study affirms that consumers' awareness is fundamental for promoting sustainability.

This theme indicates how the development of new products needs to be conducted in balance with the environment, making the transformation of food systems focused on the rational and sustainable use of natural resources, promoting sustainable production and consumption. Noguerol et al. (2021), when evaluating the perception of *plant-based* products labels, observed that omnivorous, vegan, vegetarian and flexitarian consumers were increasingly interested in the sustainability associated with their own diets. Giacalone et al. (2022) highlighted that with an expectation of about 9.8 billion people to feed in 2050, the transition to a more *plant-based* diet is critical to limiting environmental impact and ensuring the sustainability of global food systems. Thus, food production needs to be remodeled and more sustainable production options should be encouraged. Çakmakçı et al. (2023) emphasized the need for sustainable food systems to enhance the production of current food demands without compromising the environment and also ensuring this awareness to future generations.

For the food specialists (G1), sustainability and ethics involve the issues related to the way how the food industry will adapt to this new long-term reality and the organization and technical preparation of the production chain in the development of new analogous products. In addition, for this group, the demand for these foods, in Brazil, needs to be strong enough for this new niche of market to sustain itself (Table 1, see comment 17).

Vegans and vegetarians (G2) reported that the main motivations for consuming plant-based products are the reduction of animal cruelty and the protection/preservation of the environment. For them, the development and consumption of plant-based products help improve production practices in order to minimize damage to the environment and animals (Table 1, see comments 18 and 19).

For some participants of G3, the sustainable appeal and the promotion of ecologically correct practices involving the development of plant-based products promote increased food security (Table 1, see comments 20 and 21). However, a question has also been raised about the use of pesticides, water use, and genetic modifications in crop production. According to

Reipurth et al. (2019), environmental effects were identified as one of the barriers to adopting a more plant-based diet for segments with high consumption of meat or all animal products.

4.2. Free word association technique - prototypical analysis.

From the images presented as stimuli in the word association technique, the perceptions, ideas and opinions of the participants were obtained in relation to two plant-based products: a burger and an ice cream made with chestnut. From the analysis of the results, for the stimulus of the burger made with chestnuts, the graph of the prototypical analysis was generated (Diagram 1), where the evocations of the participants were presented.

	Central elements ≤ 2.35 Rangs > 2.35	**First periphery**
< 3.60 frequencies ≥ 3.60	Crunchy (f= 6; AOE= 2.0) Flavor (f=4; AOE= 2.0)	Curiosity (f= 7; AOE= 2.6) Tasty (f= 5; AOE= 3.0) Would try (f= 5; AOE= 3.0) Nutritive (f= 4; AOE= 3.8)
	Contrasting elements	**Second periphery**
	Dry (f= 3; AOE= 1.0)	Health (f= 3; AOE= 2.7) Expensive (f= 2; AOE= 3.0) Pleasure texture (f=2; AOE= 3.0)

Diagram 1. Prototypical analysis of the responses obtained through the free association of words technique using the image of a burguer made with chesnuts.

The words located in the central nucleus represent the most accessible evocations readily pointed out by the participants. As represented in the central core, the participants pointed out that sensory aspects and curiosity are the elements that best represent the perceptions about the chestnut burger. This result indicates the interest in the product, represented by the thoughts such as "curiosity" and "I would try". The sensory properties of *plant-based* foods specifically comfort foods, such as hamburger and ice cream, play an important role regarding the acceptance by (G1, G2 and G3) participants. In the case of meat products based on plant sources, sensory characteristics such as texture, taste, and odor are very important and consumers tend to be more demanding of quality (Collier et al., 2021; Hoek et al., 2011). The contrast zone indicates evocations of low frequency, which suggest a contrast

of ideas/opinions. In fact, a product with healthy appeal is also desired in conjunction with the factors of greater importance such as sensory attributes. The third quadrant (contrast zone-bottom left) is composed of the word “dry”, which means, for a small group of consumers, that the analogue hamburger may be associated with a negative perception of texture.

The second and fourth quadrants reinforce the perception that the sensory aspects are more important for the acceptance of this product, responsible for stimulating their curiosity and their interest in this stimulus. In addition, the words “health” and “nutritious" indicate that they also consider that aspects associated with healthiness are present in this product, which means that the composition of these foods must be able to generate a sense of physical well-being (Gimenes-Minasse, 2016).

The results obtained for the ice cream made with chestnuts is presented in Diagram 2. The central core of the social representation of chestnut ice cream is based on the importance that the texture and flavor represent for this type of product, being a determining idea shared by the participants in this study. Furthermore, the interest in a new product is expressed by the words “curiosity” and “I would try”, present in the first and second quadrants, respectively. The first periphery comprises "I would try" (higher than average frequency) and can be linked to the curiosity about this new product, in addition to the term "nutritious". The second periphery and the contrast zone, despite showing the less frequent evocations, bring the health theme represented by "healthy" and "less caloric", highlighting the importance of this characteristic in the context of a plant-based food. The perceived healthiness may be associated with the presence of nuts in the product. Nuts are described as health promoting and are known for reducing the incidence of some diet-associated diseases (Massantini et al., 2021; Silva et al., 2019).

	Central elements ≤ 2.36 Rangs > 2.36	**First periphery**
< 3.69 frequencies ≥ 3.69	Tasty (f= 6; AOE= 2.2) Curiosity (f= 6; AOE= 2.2) Pleasant texture (f=5; AOE= 1.6)	Would try (f= 8; AOE= 2.8) Nutritive (f= 4; AOE= 3.5)
	Contrasting elements	**Second periphery**
	Health (f= 3; AOE= 1.7) Refreshing (f= 3; AOE= 2.0) Not creamy (f=2; AOE= 2.0)	Pleasant color (f= 3; AOE= 3.0) Expensive (f= 3; AOE= 3.0) Less caloric (f=2; AOE= 3.0)

Diagram 2. Prototypical analysis of the responses obtained through the free association of words technique using the image of ice cream made with chesnuts.

The term non-creamy (contrast zone) was also reported less frequently (f) and OME; however, it reinforces the decisive role of sensoriality in the development of new products. As previously reported for the chestnut burger, the price attributed to these products described by the word "expensive" indicates that such evocation, despite the low frequency, is a relevant factor capable of directing the choice and/or acceptance of the two comfort *plant based* foods. The price can be a limiting factor to an increase in the consumption of these products. For some products, having a higher price, in general, is a negative aspect, especially when associated with lower family incomes, and may be a limiting factor for this niche of market. In general, plant-based products are more expensive than conventional ones, made with animal proteins (Lang, 2020; Schiano et al., 2020).

The change in the diet and the acceptance of a product based on plant sources has an appeal that such products can be nutritious and healthy, which corroborates the results obtained in this study. In general, nuts have a beneficial nutritional composition, as there are many studies relating the association of this product consumption with health benefits and reduction of the incidence of some diet-associated diseases (Massantini et al., 2021; Silva et al., 2019). Thus, the exploration of these plant sources with varied compositions and distinct properties has the potential to be added to various products, strongly impacting the development of products with new alternatives and also with sensory characteristics that meet the expectations of consumers. Moreover, Brazil has a great diversity of alternative food sources rich in bioactive compounds that can be explored, like many nuts, contributing to the social and economic issues of the local residents and producers located in these areas.

Considering the two comfort products presented, there was an idea shared by the majority of the participants that new developed products should be optimized in order to provide the feeling of well-being. Both the chestnut burger and the ice cream used as stimuli were positively perceived by the participants, demonstrating their potential to be well accepted as a *comfort food*. According to Gimenes-Minasse (2016), the upward trend regarding a greater appreciation for healthy and natural eating habits, the concept of *comfort foods* emerges to go beyond the consumption of sustainable and nutritionally balanced food, also incorporating the cultural and emotional aspects at the time of eating. In this context, the development of new *plant-based* foods with comforting characteristics can be a way to boost the expansion of this

market niche, especially for people who do not have any food restrictions and have adopted a more flexible and balanced diet.

Study limitations

This study significantly contributes to identify perceptions of consumers with different levels of knowledge and eating habits about plant-based foods made with chestnut in order the assess the acceptance of these products in different groups of consumers. Even though the focus groups had a significant diversity in terms of age, gender, income, and cultural aspects, future studies focusing on groups with different cultural aspects may corroborate our findings. Importantly, the choice for comfort plant-based foods is influenced by the price of these products; specifically, in Brazil, nut-based products are not very affordable. However, despite the high cost of nuts, some individuals seek their health benefits, in addition to sustainability, ethical and emotional issues, among other motivators for the consumption of comfort and plant-based foods. Grunert et al. (2014) state that high price is often considered a trade-off of sustainable products, but taste, product quality, and nutritional information have also been suggested as a strong influence for consumers to purchase sustainable foods. Moreover, promoting the diversification of regional options can increase the supply and availability of more affordable choices.

Indeed, the choice of these groups is an essential aspect of the study, as it directly affects the validity of the results. It is important to recognize that individuals' levels of education and knowledge play a significant role in their decision-making processes and food choices. Higher levels of education and knowledge about food processing and nutrition often lead to more informed choices about eating habits, food selection and awareness of health-related factors. Studies involving focus groups have been conducted in which consumers' choice is based on their knowledge and/or habits (Andreani et al., 2023; Almeida et al., 2022; Adamczyk et al., 2022; Crovato et al., 2022; Perez-Cueto et al., 2022). Future studies with groups of consumers focusing on non-sensory characteristics such as culture, availability and access to different types of plant foods, price, etc., can be interesting to pursue.

In online surveys, there are limitations such as the requirement of internet access for participation, difficulty directly monitoring the participants. However, it allows the participation of individuals from different regions of Brazil and in conditions of social isolation, as happened during the COVID-19 pandemic. Richard et al. (2021) highlights the

potential of online focus groups to generate diversity of ideas at a level comparable to face-to-face focus groups.

5. Conclusion

New insights regarding the development of new products and marketing strategies were obtained from the perceptions of different groups of consumers about plant-based foods. The main themes that emerged from the interviews were sensory and pleasure; health and well-being; and sustainability and ethics.

The Iramuteq software is an interesting tool to analyze the qualitative results of focus group, reducing the time of analysis by applying a more direct approach, which reduces the subjectivity normally present in studies related to this area. In addition, the adoption of marketing strategies that are committed to reduce the carbon footprint, such as reformulating the product labels and reinforcing the presence of native ingredients that have the potential to meet new demands are interesting. In general, most of the participants were open and willing to try innovative plant-based products as long as they meet the desired demands. On the other hand, each group presented different motivations and clear definitions of how these new products need to be developed. However, the price is still a limiting factor, which impacts the acquisition and consumption of these products. We can suggest that some attributes, such as “healthy”, “nutritious”, “sustainably produced”, when aligned with consumers' expectations play an important role in marketing strategies to arouse interest regarding the consumption of comfort plant-based foods made with chestnut.

Implications for gastronomy

Implications for gastronomy the gastronomic implications of this research are based on the fact that the results regarding the perception of comfort plant-based foods, obtained from three focus groups composed of different consumer profiles, can be used to encourage and popularize the development and consumption of new plant-based products, especially those produced with alternative vegetable sources, such as Brazil nuts. Assessing consumer perceptions of plant-based foods, such as hamburgers and ice cream analogs, can provide valuable information about the demands and expectations of vegan, vegetarian, flexitarian, and unrestricted consumers. In addition, new insights were obtained from statistical analysis using

the Iramuteq software on marketing strategies oriented to plant-based products, as well as providing a better understanding of the factors that influence the replacement of an animal protein with a vegetable in food matrices. Therefore, this manuscript brings to the industry and marketing sectors the possibility of improving the quality of information that reaches the consumer.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Appendix A. Supplementary data

Figure A1. Image stimulus: burger made with nuts.

Fonte: https://www.youtube.com/watch?v=uD--PqaC0oM

Figure A2. Image stimulus: ice cream made with nuts.

Fonte: https://www.cini.com.br/blog/receitas/prepare-estas-deliciosas-sobremesas-com-sua-cini/

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ARTIGO 2

Uso de fontes nativas dos biomas brasileiros no desenvolvimento de alimentos plant-based: quais as percepções dos consumidores?

Artigo submetido à revista *Cadernos de Ciência & Tecnologia (EMBRAPA)* (em revisão)

RESUMO

O comportamento e a percepção dos consumidores sobre o uso potencial de fontes vegetais não convencionais podem orientar o desenvolvimento de novos produtos alimentícios. Por essa razão, este tece como objetivo explorar as percepções dos consumidores de diferentes regiões do Brasil (n=212) a respeito do uso de matérias-primas vegetais dos biomas nativos no desenvolvimento de alimentos à base de plantas utilizando metodologias de análise exploratória de dados e técnicas como CATA que permitem traçar o perfil sensorial de um produto utilizando como ferramenta para coleta dos dados um questionário online e avaliação dos resultados utilizando o software Iramuteq. Como resultado, 82,1% dos participantes demonstraram interesse em consumir esses produtos, sendo eles a sustentabilidade ambiental, a geração de renda para as populações locais e as preocupações com a saúde os principais fatores motivadores para o uso de fontes nativas vegetais. Cerca de 42,9% dos participantes teriam interesse em consumir alimentos com substituição de proteínas de origem animal por proteínas de origem vegetal, sendo considerados mais saudáveis, naturais e sustentáveis, desde que a experiência sensorial seja agradável. As frutas/frutos (43,4%) e as amêndoas/castanhas (37,7%) despertaram maior interesse para serem utilizadas no desenvolvimento de sorvetes e bebidas feitas de plantas. Assim, valorizar as matérias-primas vegetais dos biomas brasileiros pode fomentar o desenvolvimento socioeconômico regional e impulsionar a produção e consumo de vegetais nativos para atender a demanda por alimentos *plant-based*.

Termos para indexação: Questionário: Objetivos ODS: Fontes vegetais.

ABSTRACT

The behavior and perception of consumers regarding the potential use of unconventional plant sources can guide the development of new food products. Therefore, the study aimed to explore the consumers' perceptions from different regions of Brazil (n=212) regarding the native

biomes in the development of plant material to develop plant-based foods through data exploration analysis methodologies and techniques such as CATA that allow tracing the sensory profile of a product using an online questionnaire as a data collection tool and evaluating the results using the Iramuteq software. The resultas showed that 82.1% of the participants showed interest in consuming these products, with environmental sustainability, income generation for local populations, and health concerns being the main motivating factors for the use of native plant sources. Furthermore, 42.9% of the participants indicated an interest in consuming foods with plant-based protein as a substitution for animal-based proteins, considering them healthier, more natural, and sustainable, as long as the sensory experience is enjoyable. Fruits (43.4%) and nuts (37.7%) were the plant sources that aroused the most interest as raw material in developing plant-based ice creams and beverages. Thus, valuing plant raw materials from Brazilian biomes can foster regional socioeconomic development and contribute to the production and consumption of native plants to meet the demand for plant-based foods.

Index terms: Questionnaire: SDG objectives: Vegetable sources.

INTRODUÇÃO

O mercado de produtos feitos de plantas vem crescendo nos últimos anos, sendo uma alternativa para atender a demanda da população mundial, que atualmente ultrapassa a marca de 8 bilhões de pessoas. Este crescimento é decorrente dos apelos por padrões sustentáveis de consumo e produção de alimentos com danos mínimos ao ambiente e aos animais (SCHIANO et al., 2020).

Uma diversidade de produtos feitos de plantas está disponível aos consumidores, que cada vez mais buscam fazer escolhas alimentares que possam impactar positivamente sua saúde e o meio ambiente e a experiência de sabor. Segundo PINTO et al. (2020), os consumidores não procuram mais restringir certos alimentos em sua dieta, mas sim substituí-los por opções mais saudáveis. Esta transformação impulsionou uma tendência global centrada nas expectativas dos consumidores e baseadas em estudos científicos que demonstram os benefícios em potencial que uma dieta mais saudável pode gerar para a saúde.

A relação entre alimentação e bem-estar foi discutida por CARVALHO & CONTE-JUNIOR (2021), apontando os benefícios de alimentos e plantas nativas brasileiras para a saúde. Neste contexto, há uma oportunidade de estimular o desenvolvimento de novos

produtos a partir de espécies vegetais nativas, distribuídas entre os biomas brasileiros. Essas plantas geralmente apresentam potencial funcional, nutricional e tecnológico, porém são pouco conhecidas e explorados industrialmente, muitas vezes devido à sua regionalidade (SAMPAIO NETO, et al, 2020).

O desenvolvimento de produtos a partir da prospecção de novas matérias-primas promove a inovação e a cadeia produtiva dos alimentos. A utilização de fontes vegetais alternativas para a produção de alimentos podem ser uma estratégia de atender os objetivos da agenda 2030, assinada pela Organização das Nações Unidas (ONU) em 2015. Essa iniciativa visa, superar o desafio de alimentar a população com alimentos seguros e saudáveis, erradicando a fome e melhorando a segurança alimentar (CASARIN et al., 2023, MORAIS-DA-SILVA, 2022).

Muitos dos ODS têm potencial para serem alcançados por meio do aproveitamento estratégico dos recursos encontrados nos biomas brasileiros, que além de popularizar a pesquisa de novas fontes alimentícias de alto valor nutricional, promovem a expansão da oferta de produtos e o estímulo à produção e consumo responsáveis. Neste sentido, o uso de fontes vegetais nativas na produção de alimentos com substituição total ou parcial da proteína animal pode ser um diferencial para o setor. Porém, a compreensão das percepções e expectativas dos consumidores sobre os alimentos análogos de base vegetal é essencial para o sucesso no mercado.

Pesquisas têm sido desenvolvidas com o intuito de identificar os atributos de qualidade considerados mais importantes pelos consumidores durante o processo de escolha e aceitação de produtos de origem vegetal, tais como: análogos de carne (WANG et al., 2022, CHEZAN et al., 2022), bebidas feitas à base de plantas (SILVA et al., 2020), e sorvetes de origem vegetal (SIPPLE et al., 2022). No entanto, o estudo sobre as percepções do consumidor brasileiro sobre o uso de fontes vegetais alternativas nativas do bioma brasileiro no desenvolvimento de alimentos à base de plantas não foi encontrado na literatura.

Existem várias ferramentas úteis para capturar as percepções dos consumidores de forma rápida e prática, entre elas os questionários. Estudos explorando as preferências, percepções e comportamentos de vários grupos em relação a novos produtos à base de plantas foram conduzidos utilizando questionários físicos e/ou *online* (PÉREZ-CUETO et al., 2022; NOGUEROL et al., 2021). A interpretação das respostas obtidas por meio de questionários pode auxiliar no desenvolvimento de alimentos mais alinhados aos desejos dos consumidores, sendo um instrumento que permite projetar estratégias de marketing para atingir diferentes

segmentos de consumidores e para se destacar em um mercado competitivo como o mercado de alimentos (SIPPLE et al., 2022). Assim, este trabalho teve como objetivo, por meio da aplicação de questionários obter as percepções dos consumidores em relação às fontes vegetais nativas pouco utilizadas no desenvolvimento de alimentos à base de plantas, com o potencial de contribuir com um sistema alimentar sustentável.

METODOLOGIA

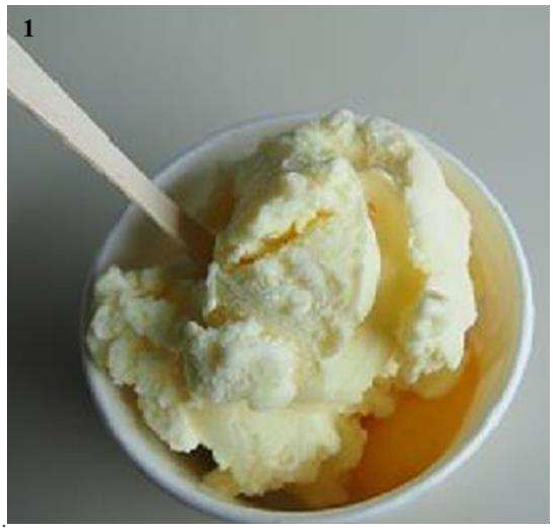
A aplicação do questionário online foi realizada após aprovação do projeto pelo Comitê de Ética em Pesquisa com Seres Humanos da Universidade Federal de Viçosa (UFV), parecer consubstanciado pelo número 5.291.419. O foco do instrumento foi entender como a substituição de proteínas vegetal em produtos tradicionalmente feitos com proteínas de fonte animal é percebida, tendo a participação de indivíduos de diferentes regiões do Brasil, que foram convidados, via mídias sociais, a participar da pesquisa.

Foram recrutados 212 consumidores dos mais variados perfis para participar da pesquisa, sendo a coleta de dados totalmente *online*, utilizando a ferramenta *Google Forms*. Um termo de consentimento livre e esclarecido foi apresentado aos participantes e estes após concordarem em participar da pesquisa iniciaram o preenchimento do formulário.

O questionário foi elaborado por questões relacionadas ao estilo de vida quanto à alimentação e compra de alimentos e ao consumo de produtos feitos a partir de fontes vegetais, ao interesse pelos alimentos *plant-based*, à determinação das características importantes no desenvolvimento de novos produtos alimentícios e à indicação das fontes vegetais mais interessantes para desenvolver esses produtos. Dados demográficos como sexo, faixa etária, renda e estado onde residem também foi objeto da coleta de informações. Em seguida, por meio da aplicação da metodologia *Check-all-that-apply (CATA*), os participantes foram solicitados a selecionar a partir de uma lista de termos descritivos e afetivos, todos os termos que se aplicam aos dois produtos à base de plantas apresentados: bebida e sorvete feitos à base de castanhas (Figura 1).

Figura 1. Imagens apresentadas aos particpantes para obtenção dos termos descritivos e afetivos por ordem de apresentação no questionário (1. Sorvete de castanhas e 2. bebida feita

de castanhas e cacau).



Fonte: 1. https://www.cini.com.br/blog/receitas/prepare-estas-deliciosas-sobremesas-com-sua-cini/ Acesso em: 2021; 2. https://criarcomercrescer.com/2020/08/bebidas-vegetais-em-5-min-sem-desperdicio.html Acesso em 2021.

Os termos descritivos e afetivos foram apresentados aleatoriamente aos participantes. As respostas de cada participante foram avaliadas qualitativamente e os termos obtidos no CATA foram organizadas em forma de matriz (banco de dados), e na ordem indicada pelos participantes e analisadas utilizando o software Iramuteq. Por meio da análise de frequência múltipla, os dados foram organizados na ordem em que foram ditas e aquelas palavras evocadas como primeiras opções, consideradas as mais importantes para descrever o produto (CAMARGO & JUSTO, 2013).

RESULTADOS E DISCUSSÃO

A pesquisa contou com a participação de 212 indivíduos (18 anos ou mais), sendo 74,1% do sexo feminino e 25,9% do sexo masculino de diferentes regiões do país (Tabela 1).

Tabela 1. Perfil sociodemográfico dos participantes da pesquisa.

Participantes (n=212)	**(%)**
Gênero	
Feminino	74,1
Masculino	25,9
Idade	
18-27	46,7
27-35	32,5
36-45	11,3
>45	9,4
Renda	
até 2 salários-mínimos	17,5
2-4 salários-mínimos	30,7
4-10 salários-mínimos	35,4
> 10 salários	16,5
Região do país	
Sudeste	75,9
Nordeste	11,3
Sul	4,7
Norte	4,7
Centro-oeste	3,3

Fonte: Autor (es), (2022).

Por meio das respostas obtidas no questionário, quando foi perguntado aos participantes sobre seu estilo de vida e dieta alimentar, 76,8% dos consumidores consideram-se como onívoros, ou seja, consomem produtos de origem animal e de origem vegetal. Em seguida, tem-se que 12,7% se declaram flexitarianos, em que cotidianamente aumentam o consumo de produtos de origem vegetal e reduzem o consumo de produtos de origem animal. Ademais, 4,7% dos participantes consideram-se vegetarianos estritos, assim, não utilizam nenhum derivado de origem animal na sua alimentação, e 1,9% consideram-se veganos, ou seja, não consomem produtos de origem animal e produtos testados em animais. Dos participantes do sexo masculino, 22,3% (n=47) se consideram onívoros, 1,9% (n=4) veganos, e 1,4% (n=3) vegetarianos estritos. Enquanto 54% (n=115) das mulheres se declararam onívoras, 10,4% veganas (n=22) e 5,7% (n=12) vegetarianas estritas. O número de mulheres veganas/vegetarianas estritas foi superior ao dos homens. Este resultado corrobora com o de autores como RUDY (2012) e TROCCHIA & JANDA (2008), que relataram que homens e mulheres diferem em suas preferências por produtos vegetais, sendo as mulheres mais receptivas para dietas veganas/vegetarianas. Nas sociedades ocidentais, as mulheres têm duas vezes mais chances de serem veganas ou vegetarianas (MODLINSKA et al. (2020).

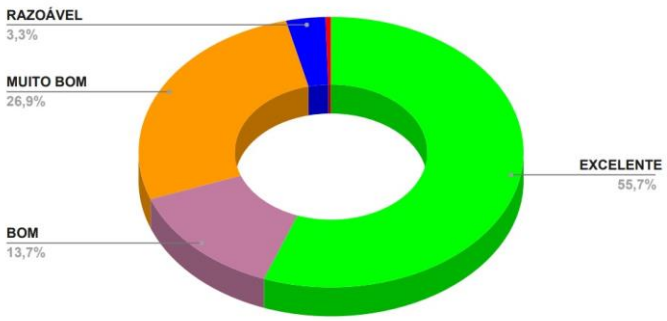
Em relação ao consumo de alimentos com substituição de proteínas de origem animal por proteínas de origem vegetal, 42,9% dos consumidores teriam interesse nesse tipo de consumo e 39,2% talvez teriam interesse. Esse resultado reflete na tendencia de um mercado mais diversificado, em que os consumidores migram entre as proteínas vegetais e animais conforme as suas necessidades e desejos. Segundo ALCORTA et al. (2021) e HE et al. (2021), muitos consumidores têm buscado por alimentos que possam substituir parcial ou totalmente a proteína animal, mas que entreguem qualidade sensorial e fatores nutricionais, iguais ou superiores às das fontes convencionais.

Nesse contexto, a respeito do grau de substituição de ingredientes de fonte animal por fonte vegetal em um produto lácteo ou cárneo, 50,7% dos participantes estão dispostos a aceitar uma substituição parcial dos ingredientes, ou seja, um produto lácteo ou cárneo utilizando fontes animais e vegetais, 31,3% estão de acordo com a substituição total, isto é, um produto análogo ao lácteo ou cárneo feito somente com ingredientes de fonte vegetal, e apenas 18% não aceitam a substituição da fonte animal por fonte vegetal.

A utilização de fontes vegetais nativas e pouco conhecidas do bioma brasileiro foi bem recebida pelos participantes, sendo indicada como excelente por mais de 55% dos respondentes (Figura 2). Cerca de 90% dos participantes aprovam o uso de fontes vegetais nativas no

desenvolvimento de produtos à base de plantas. Isso mostra que o consumidor está disposto a conhecer novos alimentos a partir dessas matérias-primas.

Figura 2. Percepção dos respondentes sobre o uso de fontes nativas aplicadas ao desenvolvimento de produtos.

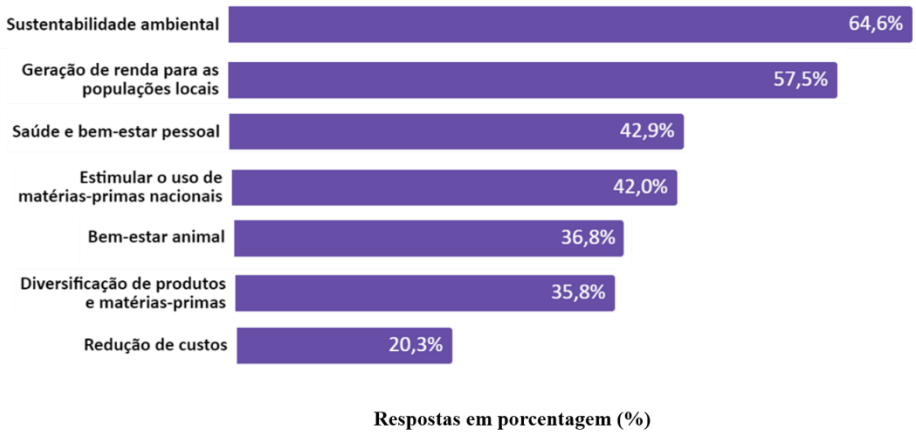


Fonte: Autor (es), (2022).

Diferentes fatores podem ter influência na percepção que os consumidores têm sobre a substituição de proteínas de fontes animais por fontes vegetais, podendo gerar diferentes atitudes em relação ao uso das fontes vegetais encontradas nos diferentes biomas brasileiros. Vale ressaltar que não existe uma unanimidade sobre quais são os fatores mais importantes, podendo existir algumas divergências em um mesmo grupo de consumidores. Assim, esses resultados são bastante variados e mostram como essa percepção é alterada dependendo da região de estudo, do perfil do consumidor e dos produtos avaliados. Dentre os motivos mais importantes que justificam o uso de fontes vegetais nativas do bioma brasileiro no desenvolvimento de produtos, destacam-se a sustentabilidade ambiental (64,5%), a geração de renda para as populações locais (57,3%), a saúde e bem-estar pessoal (42,9%) e estímulo ao uso de matérias-primas nacionais (42,0%) (Figura 3).

Figura 3. Principais motivações indicadas para justificar o uso de fontes vegetais nativas do

bioma brasileiro indicadas pelos participantes.



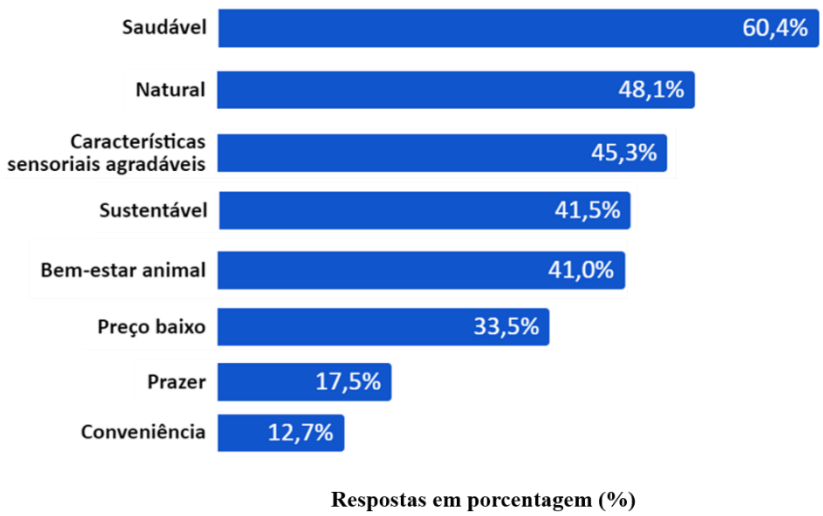
Fonte: Autor (es), (2022).

Essa análise exploratória reforça a ideia de que, para os consumidores o desenvolvimento de novos produtos deve estar alinhado às questões ambientais, além de promover a melhoria da qualidade de vida e trabalho das populações que dependem dessas culturas vegetais como fonte de renda. Alguns estudos já relataram a percepção do consumidor em relação à origem, segurança e qualidade dos alimentos e frisaram o impacto causado pela produção e processamento dos alimentos, bem como a relevância de práticas em consonância com o meio ambiente (MESÍAS et al. ,2021; PETRESCU et al., 2019; TRUONG, et al., 2022; VAN BUSSEL et al., 2022). Preocupações com a saúde (42,9%) também foram apresentadas como motivo para o uso de fontes de plantas nativas em produtos *plant-based*. De acordo com PINTO et al. (2021), o aumento da percepção da saudabilidade dos alimentos está impulsionando as escolhas alimentares atuais e futuras.

Em relação ao potencial das fontes vegetais nativas para o desenvolvimento de novos produtos, as frutas/frutos (43,6%) e castanhas/amêndoas (37,4%) foram consideradas as principais alternativas para serem utilizadas como matérias-primas. Existe uma diversidade de castanhas/nozes (“pracaxi”, baru, sapucaia) e frutas (uvaia, araçá, cupuaçu, guaraná) pouco exploradas e muitas vezes desconhecidas pela maioria da população brasileira. Assim, desenvolver produtos a partir dessas e de outras fontes promoverá o aumento da diversidade de produtos de origem vegetal e permitirá a expansão comercial desses produtos para regiões diferentes daquelas onde as fontes vegetais são tradicionalmente produzidas, promovendo a popularização e ampliação do seu consumo. Leguminosas como grãos-de-bico, lentilha, soja, feijão e amendoim, tiveram 15,6% de interesse pelos consumidores, e os cereais, como arroz, aveia e sorgo, foram escolhidos por apenas 3,3% dos participantes como matérias-primas potenciais para alimentos à base de plantas.

Em relação ao consumo de produtos feitos a partir de fontes vegetais 61,3% dos participantes indicaram consumir ou já ter consumido, com destaque para o hambúrguer vegetal (57,5%), seguido das bebidas à base de plantas (51,4%). Os três fatores mais importantes considerados no momento da compra e/ou no consumo desses produtos para os consumidores foram a saudabilidade (60,4%), o emprego de ingredientes naturais (48,1%) e ter as características sensoriais agradáveis (45,3%), ou seja, o produto deve ser nutritivo, com baixos teores de açúcares e sódio, e sem a adição de aditivos artificiais. Em síntese, o consumidor demanda produtos mais naturais e com processamento mínimo (Figura 4). Desta forma, o consumo de alimentos feitos de à base de plantas é impulsionado por apelos caráter e nutritivo, pela estética *clean label* (rótulo limpo) e agradável e que seja sensorialmente. Para 57,1% e 36,8% dos respondentes, essas motivações de consumo/compra de alimentos são consideradas como muito importantes e importantes, respectivamente, sendo determinantes para a escolha dos produtos que serão consumidos.

Figura 4. Motivações importantes consideradas na compra/consumo de produtos feitos de plantas.



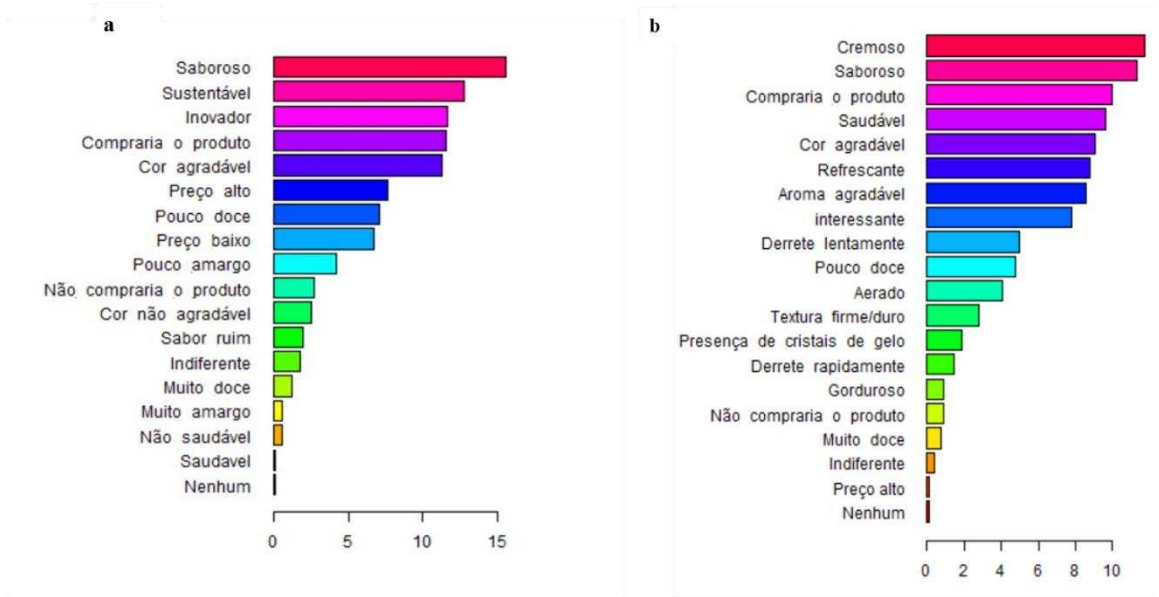
Fonte: Autor (es), (2022).

A substituição de ingredientes de origem animal por fontes vegetais com potencial tecnológico e nutricional pode trazer benefícios à saúde dos consumidores (SILVA et al., 2020). Nesse sentido, fontes nativas dos biomas brasileiros, como castanhas e frutas exóticas, podem ser uma alternativa não só para ampliar a diversidade de produtos, mas também para estimular a segurança alimentar que pode ser uma forma de garantir a conservação dos ecossistemas, a preservação da biodiversidade e a melhoria da qualidade de vida das

comunidades locais. É importante adotar práticas de manejo sustentável, promover a valorização dos produtos da biodiversidade, valorizando o comércio e os produtos locais. Nesse sentido, os consumidores entendem que os produtos que eles querem consumir precisam ser desenvolvidos minimizando o uso de recursos e os prejuízos ao meio ambiente e aumentando a conscientização sobre o bem-estar animal.

Foram apresentadas duas imagens de dois produtos feitos de amêndoas aos participantes para que a partir da observação dessas indicassem a partir de uma lista de termos apresentados, quais deles melhor descrevem as características do produto de acordo com suas percepções. A frequência de menção dos termos descritores e afetivos evocados pelos participantes na metodologia CATA estão indicados na Figura 5 para a bebida e para o sorvete feitos de amêndoas.

Figura 5. Frequência de menção dos termos descritores obtidos por CATA para a) bebida de castanhas e b) sorvete feito de castanhas.



Fonte: Autor (es), (2023).

Para os participantes, a bebida foi caracterizada pelos termos saboroso, sustentável, inovador, compraria o produto e cor agradável. Para o sorvete à base de castanhas, termos como, cremoso, saboroso, compraria o produto, refrescante, cor agradável, saudável, aroma agradável e interesse foram mais importantes para caracterizar o produto. O preço alto foi associado aos dois produtos, sendo um fator que pode limitar a compra e ou consumo, principalmente para a bebida que apresentou uma maior frequência de menção. No geral, esses

resultados indicam que esses produtos à base de castanhas são descritos pelos consumidores por atributos sensoriais agradáveis (aparência, aroma, sabor e textura) e como inovadores, o que desperta o interesse e a disposição de comprar esses produtos.

Assim, o desenvolvimento de novos produtos à base de plantas tem como principal objetivo proporcionar experiências sensoriais que atendam às exigências dos consumidores. Além disso, o desenvolvimento de produtos a partir de fontes nativas e pouco conhecidas pode ser uma maneira de desenvolver produtos mais sustentáveis e inovadores, agregando valor a produtos e matérias primas, além de promover o desenvolvimento regional, que fornece renda para as populações locais.

CONCLUSÃO

Os consumidores tiveram uma percepção positiva quanto aos alimentos feitos à base de fontes nativas, indicando interesse em consumir esse tipo de produto. Sustentabilidade ambiental, geração de renda para a população local, saúde e bem-estar pessoal, e estímulo ao uso de matérias-primas nacionais foram consideradas as principais razões para o uso de fontes vegetais alternativas no desenvolvimento de produtos à base de plantas. Assim, é possível ainda concluir que nozes, frutas exóticas e sementes do bioma brasileiro, pouco exploradas do ponto de vista científico e tecnológico, são potenciais fontes de matérias-primas para a indústria de alimentos ao agregar valor aos produtos, fomentar o desenvolvimento sustentável, gerar renda e ampliar o consumo dessas fontes alternativas.

Apelos como saudável, natural, bem-estar animal, sustentável e características sensoriais agradáveis podem impulsionar o mercado de alimentos feitos de plantas indulgentes, com qualidade sensorial e nutricional alinhados com os desejos dos consumidores. A partir dos resultados, eles identificaram três segmentos em função da frequência de consumo tanto de alimentos de origem vegetal quanto animal, sendo eles: favorável ao animal, minimamente processado e amigo do ambiente. Os resultados ainda indicam que existe uma parcela dos consumidores dispostos a consumir produtos à base de plantas dentro de suas expectativas, permitindo que esse mercado continue crescendo, porém, um fator limitante é o alto valor desses produtos, quando comparado ao de produtos de matérias-primas de origem animal.

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PAPER 3

Baru almond beverage (Baruccino) with different sweeteners: nutritional and physical properties and exploration of sensory and non-sensory perceptions

Highlights

- Beverages with sucrose and allulose showed similar chemical and structural properties.
- “High added sugar” did not discourage consumers from purchasing the beverage with sucrose.
- "No sugar added" had a positive impact on purchase intention for the beverage with allulose.
- 50% of participants are interested in consuming foods made from baru almonds.
- Allulose has the potential to substitute sucrose in foods.

Abstract

Winter plant-based beverages made from baru almonds with the addition of sucrose (FS) or allulose (FA) were evaluated in two acceptation sensory sessions (blind test and test with information about the ingredients, their benefits, and the product label) by 100 potential consumers. Additionally, the beverages were characterized for their centesimal composition, pH, soluble solids content, and instrumental color and microbiological analyses, steady state rheology, and kinetic stability test (Turbiscan). The sensory acceptability of both formulations increased when information was provided, reaching an acceptability index exceeding 70%. Furthermore, the sweet taste was the primary driver of the acceptance, with consumers generally indicating a preference for sucrose as the sweetener. The perception of the sweet taste of FA compared to FS was 67% and 63% in the blind and informed tests, respectively. The formulations showed similar results in terms of physical, chemical, and rheological properties, as well as kinetic and microbiological stability. Thus, this study underscores the potential of allulose to replace sucrose without significantly altering product characteristics, showcasing its importance from both technological and sensory perspectives. Additionally, the novel product

developed with baru contributes to the diversification and valorization of this Brazilian Cerrado fruit, as well as being a tasty alternative for vegan, vegetarian, and flexitarian consumers.

Keywords: Sucrose, Allulose; Rheology; Stability; Sweet Taste; Sensory Analysis.

1. Introduction

Products made from plants have enormous growth potential, especially when developed from native and underexplored sources with potential health benefits, such as the baru almond. The baru almond comes from the baruzeiro tree (*Dipteryx alata* Vog.), native to the Brazilian Cerrado, and has the potential to drive the development of new products and popularize knowledge about this and other lesser-known sources, creating new combinations and flavors (Reis & Schmiele, 2019; Santos et al., 2022; Viana et al., 2023). Additionally, baru almonds are rich in vitamins, proteins, lipids, and other components capable of providing nutritional and functional benefits, enabling the development of products with a greater appeal to health-conscious consumers (Monteiro et al., 2022; Polmann et al., 2021; Viana et al., 2023).

Despite these advantages, the success of plant-based products in the market hinges significantly on their sensory quality. This critical factor is influenced by various elements, including sensory profile, information provided to consumers, and individual perceptions (Li et al., 2019; Pointke et al., 2022).

In addition to the growing demand for plant-based foods, a rising number of consumers are actively seeking healthier dietary options. This trend aligns with the guidelines set forth by the World Health Organization (WHO), which advocates for reducing sodium, saturated fat, and added sugar intake. Among the various substitutes for sucrose, allulose emerges as a promising alternative, boasting sweetness akin to sucrose. Among various sucrose substitutes, allulose is a promising alternative due to its sweetness like sucrose. Allulose is considered a rare sugar, derived from figs and some dried fruits, and is mostly produced by enzymatic catalysis (Jia et al., 2023; Xia et al., 2021; Jiang et al., 2020). It is not metabolized by the body, aiming to meet the demand for products with reduced sugar content and low calories (0.4 cal/g), and recognized as safe (GRAS) by the Food and Drug Administration (FDA) (Chen et al., 2022; Xia et al., 2021). Studies have evaluated the use of allulose to replace sucrose in products, such as cookies (Bolger et al., 2021; Jeong et al., 2024), and cakes (Lee et al., 2022a; Özgür & Uçar, 2023).

Furthermore, foods with reduced in added sugar align with the new labeling and mandatory nutritional information rules proposed by various governments, including Brazil, Mexico, and Chile. Front-of-package nutrition labeling, such as traffic light/advisory labels, magnifying glass, Nutri-score, and numerical Nutrition-information labels, aims to provide consumers with clearer information and facilitate the identification and selection of products based on their ingredients (Mazzù et al., 2023; Shrestha et al., 2023; Talati et al., 2016).

Studies exploring how product information affects consumer perception have become increasingly relevant for understanding purchasing decisions, particularly how consumer knowledge of ingredients and nutrients influences acceptance. In this context, the objective is to comprehend how information about plant-based winter beverages made from baru almonds, with either sucrose or allulose, influences sensory perception and contributes to the development of more effective marketing strategies and formulation enhancements. The beverages were characterized for centesimal composition pH, color soluble solids content, microbiology, rheology, studies on kinetic destabilization, and evaluated sensorially (blind and informed tests) by consumers. In this regard, the research has the potential to provide valuable insights for the food and beverage industry as it strives to meet the growing demands for healthier, sustainable, and ethical alternatives.

2. Material and methods

Roasted baru almonds, sucrose, cocoa powder, instant coffee, and cinnamon powder were obtained from local markets in Viçosa-MG (20° 45' 14" S / 42° 52' 55" W). Allulose was imported for commercial Elmar LTDA (lot: 1083756), and guar gum and xanthan gum were sourced from Sigma-Aldrich.

2.1. Development of Baruccino beverages

The winter beverages formulations were developed at the Innovation Laboratory of the Department of Food Technology at the Federal University of Viçosa. Following preliminary tests, two beverage formulations were produced with the addition of sucrose and the other one with allulose, keeping the remaining ingredients constant. The ingredients used in the development of the formulations and their respective percentages (w/w) were as follows: 58.5% water, 19.5% baru almonds, 14.8% sweetener (sugar or allulose), 5.1% cocoa powder (100%), 1.6% instant coffee, 0.2% cinnamon powder, 0.2% guar gum, and 0.1% xanthan gum.

The development of the formulations was divided into three main stages, as indicated in Fig. 1. In the first stage, the baru almonds were soaked and refrigerated (8 ºC) for 15 hours. This stage aims to improve the palatability of the beverage by removing residual water-soluble tannins. The soaking water was discarded, and the nuts were then rinsed. In the second stage, the nuts were processed with hot water, filtered, and reprocessed with the remaining ingredients. In the third stage, the ingredients were homogenized, followed by slow pasteurization, cooling, and storage under refrigeration.

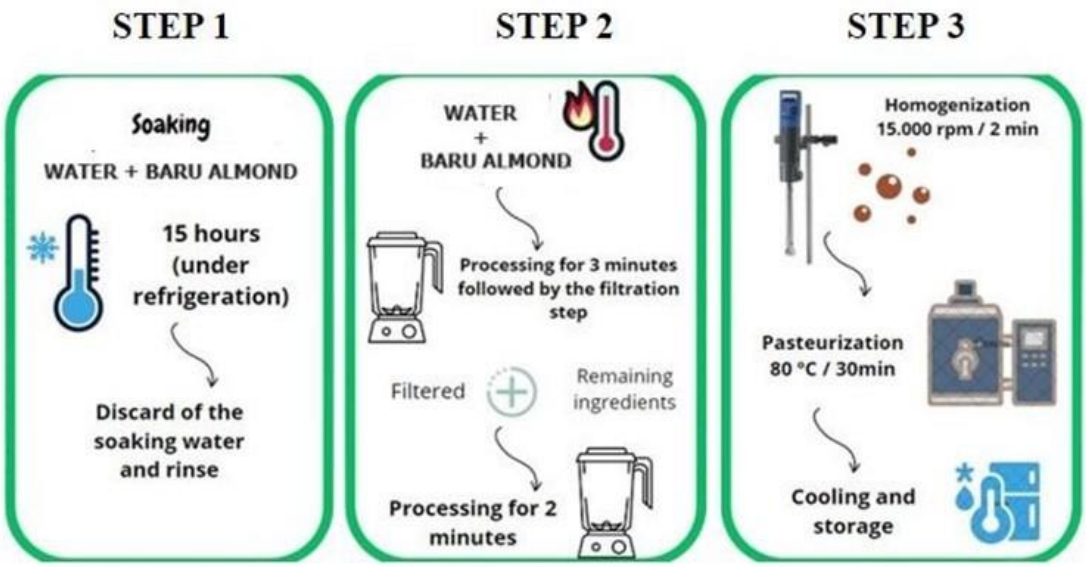

Fig 1. Stages of general processing used in the development of plant-based winter beverages. Source: The authors.

The samples were identified as FS: formulation with sucrose addition and FA: formulation with allulose addition. To assess the impact of the sweetener type and added gums on the kinetic stability of the formulations, two controls were developed: C1 with no sweetener addition and C2 with no sweetener and gum additions.

2.2. Centesimal Composition and Nutritional Information

To construct the nutritional information table, the protein content was determined based on total nitrogen using the Kjeldahl method (AOAC, 2020), with a conversion factor of 5.75. The lipid content was obtained by the Mojonnier ether extraction method (Champagne et al.,

2009; Zakidou et al., 2022). Moisture and ash content were determined gravimetrically using the AOAC (2016) methodologies, and total carbohydrate content was obtained by difference.

The nutritional table for the formulations was developed based on the technical criteria established by Resolution RDC 429 (ANVISA, 2020a) and Normative Instruction IN 75 (ANVISA, 2020b), and the results of the centesimal composition. Total sugar and added sugar values were calculated from the added amounts of each ingredient. The determination of sodium content was carried out by flame photometry. All analyses were conducted in triplicate.

2.3. Chemical and physical analyses

The pH values of each formulation were measured in triplicate by inserting the electrode (pHmetro Gehaka PG2000) directly into the sample. The soluble solids content (SST) was determined using a digital refractometer (Atago brand, pocket refractometer Pal^{-1}) with a scale graduated in degrees Brix (ºBrix). Color properties of the samples were evaluated by measuring the L* (lightness, ranging from black to white), a* (chromaticity from green to red), and b* (chromaticity from blue to yellow) parameters using a calibrated Colorquest® XE colorimeter (HunterLab, USA) with a 10º observation angle and D65 illuminant (average daily sunlight). From these parameters, the cylindrical coordinate h* (hue angle) was calculated using the equation $h = arct\ (b^*/\ a^*)$, and C* (chroma) using the equation $C^* = \sqrt{(a^*)^2 + (b^*)^2}$. The total color variation (ΔE*) was also calculated using the equation $\Delta E* = \sqrt{(\Delta L^*)^2 + (\Delta a^*)^2 + \Delta b^*)^2}$.

2.4. Rheological Behavior – Rotational Tests (Flow Curves)

Rheological analyses of the plant-based winter beverages were conducted using a Thermo Haake MARS rotational rheometer (Thermo Electron Corp., Germany), equipped with a thermostatic bath (Phoenix 2C30P, Thermo Electron Corp., Germany). Measurements were taken using a Z20Din stainless steel sensor, in triplicate, at a temperature of 60 ºC. Flow curves of the beverages were determined by applying a shear rate from 0.01 to 250 s^{-1} in three curves (ascending, descending, and ascending) of 150 s each, measuring the corresponding shear stress (σ). The Herschel-Bulkley rheological model was fitted to the experimental data, represented by the equation $\sigma = \sigma_0 \quad K.\ \dot{\gamma}^n$.

In which σ is the shear stress (Pa), σ_0 is the yield stress (Pa), K is the consistency index ($Pa \cdot s^n$), n is the flow behavior index (dimensionless), and γ is the shear rate (s^{-1}). Apparent viscosity was assessed at a shear rate of 100 s^{-1} to compare treatments, as established for the evaluation of thickened beverages (Germain et al., 2006; Kim et al., 2014; Patra et al., 2021).

2.5. Microbiological Analyses

To ensure the safety and health of the untrained assessors, Baruccino formulations were evaluated based on microbiological criteria established by the Normative Instruction IN 161 (ANVISA, 2022c) and Resolution RDC 724 (ANVISA, 2022d). The evaluation focused on the presence/absence of *Salmonella* spp., using a rapid test on Petrifilm (3M), standard plate count using the surface plating method for coagulase-positive *Staphylococci*, filamentous fungi, and Enterobacteriaceae following methodologies proposed by the Association of Official Analytical Chemists (AOAC, 2016). The results were compared with the limits established by current legislation in Brazil.

2.6. Kinetic Stability

The kinetic stability of the formulations was assessed using a Turbiscan Lab (Formulation Smart Scientific Analysis, France), where an infrared light source (wavelength 880 nm) irradiates the sample, capturing backscattering (BS) and/or transmission (T) signals. After processing, 20 mL of each formulation was placed in glass cells and evaluated at 60 ºC for 3h, with data collected at 5-min intervals (37 scans). This procedure provided the Turbiscan Stability Index (TSI) values and the kinetic stability profile of the samples over time. The signals acquired over time concerning the sample's height are calculated according to Equation 4.

$$TSI\ (t) = \frac{1}{N_h} \sum_{ti=1}^{tmax} \sum_{zi=zmin}^{zmax} |BST(t_i, z_i) - BST\ (t_{i-1}, z_i)|$$

which *T*max is the measurement point corresponding to time *t* when TSI is calculated, *Z*min is the lower limit, *Z*max is the upper limit of the selected height, and *h (Zmin−Zmax) / ΔhNh* = (Zmin −Zmax) / Δ*h* is the number of positions concerning the height in the selected scanning zone.

Furthermore, the TSI value can be used for classifying samples regarding their kinetic stability and its correlation with visual perception, employing the scale illustrated in Fig. 2.

Fig 2. TSI rating scale according to stability. Source: The authors.

2.7. Sensory analysis

The sensory evaluation of formulations FS and FA was conducted in two sessions: a blind test and a second session with product information presented (informed test), both by the same group of consumers. A total of 100 regular consumers of winter beverages based on coffee and milk were invited to participate.

In both sessions, samples were evaluated using the Rate-All-That-Apply (RATA) and sensory acceptance tests. In the RATA test, attributes were assessed using a 3-point intensity scale ranging from not applicable (0), low (1), medium (2), to high (3). The 14 sensory attributes were defined based on descriptive studies of winter beverages found in the literature (Esperança et al., 2022; Seninde & Chambers, 2020), and tasting of winter beverages with baru. The terms raised were brown color, brightness, cocoa aroma, nutty aroma, sweet taste, unpleasant flavor, nutty flavor, cocoa flavor, cinnamon flavor, pleasant flavor, fatty flavor, creamy, homogeneous texture, and presence of particles. These attributes were presented to assessors in a random order.

Sensory acceptance of FS and FA was evaluated using a 9-point hedonic scale, ranging from 1=disliked extremely to 9=liked extremely, regarding the attributes of appearance, texture, flavor, and overall impression. The Acceptability Index (AI %) for each formulation was calculated using the equation IA (%) = (A/B) *100, in which A=average score obtained for the formulation and B=maximum score given for the formulation (Feitosa et al., 2023).

To comprehend the commercial potential of the beverages, the assessment of the intention to purchase was obtained, indicating to what extent the assessors would be willing to

buy the beverage after tasting it. The options generally range from 5="Definitely Would Buy" to 1="Definitely Would Not Buy," with intermediate scales representing different degrees of willingness to make a purchase. The sensory analysis sessions were conducted after the project's approval by the Ethics in Human Research Committee at the Federal University of Viçosa (UFV), substantiated by the opinion number 5.291.419.

2.7.1. First Session (Blind Test)

In the initial session, the assessors were informed solely that they were evaluating a winter beverage. Formulations FS and FA were served at 60 ºC, presented in a monadic sequence and random order, identified with random three-digit numbers. Consumers were provided with a sensory evaluation form (Supplementary Material Fig. S1) and water for mouth cleansing between samples.

2.7.2. Second Session (Informed Test)

Similar to the first session, after instructions regarding the sensory test procedure, assessors received the samples randomly. They were provided with the same sensory evaluation form as in Session 1, along with a representation of a label for each formulation (Supplementary Material Fig. S2) and a brief description of the samples, and the benefits associated with consuming baru almonds, as described below.

♦ ***Baruccino:*** A beverage based on baru almonds with cocoa flavor, added soluble coffee, and cinnamon.

♦ ***Baru almond (Dipteryx alata Vog):*** Native species of the Brazilian Cerrado.

♦ ***Benefits:*** A good source of energy with high levels of proteins, lipids, fibers, and minerals. Additionally, it is rich in antioxidant compounds such as carotenoids and tocopherols, which have the potential to promote health benefits.

At the end of each session, participants answered some questions to collect demographic data, information about their consumption habits, and their prior knowledge about baru almonds. The interval between the two sessions was a minimum of three days.

2.8. Statistical Analysis

The experiment was conducted using a completely randomized design with two formulations one with allulose (FA) and other with sucrose (FS), in two replications. The results of the centesimal, physical, and structural characterization were evaluated using one-way ANOVA, followed by Tukey's mean test, when necessary.

Sensory data were evaluated through analysis of variance (ANOVA) with two sources of variation (treatments and assessor) for each attribute. Paired-sample t-tests were performed to evaluate the influence of information on consumers' perception of attributes in the RATA and on sensory acceptability. The adopted significance level was α=0.05.

3. Results and Discussion

3.1. Centesimal Composition and Nutritional Information

The determination of centesimal composition da FS e FA they are presents in the Table 1 being crucial for obtaining the proportion of nutrients present in 100 mL for g of the food, which is used in developing nutritional tables for labeling purposes.

Table 1. Composition centesimal and nutritional.

Composition	FS	FA
Total water content (g)	61.0±0.0	66.0±0.4
Carbohydrates (g)	29.0	24.0
Sugar adicionados (g)	14.8 ±0.01	14.8±0.01
Proteins (g)	4.4 ± 0.2	4.6 ± 0.1
Lipids (g)	5.0±0.5	5.0±0.3
Ash (g)	0.01±0.00	0.01±0.00
Sodium (g)	40.0 ±2.0	40.0 ± 3.0

The moisture content representing the measure of the total water contained in a food product. The average total, an important indicator for the nutritional value of the formulations. The values found classify the winter beverage with baru as a potential source of protein since legislation IN 75 (ANVISA, 2020b), considered a protein source the product that contains approximately 5 g/100 mL of food. In a study conducted by Zakidou et al. (2022), cappuccinos made from soy and a combination of soy and coconut presented average protein contents of 3.12 ± 0.06 g/ 100 mL and 1.33 ± 0.04 g/ 100 mL, respectively. Poojary et al. (2023), when comparing the protein content of four types of commercial cappuccinos with and without milk, found an average content of 2.8 g/100mL. Therefore, winter beverage formulations with baru almonds showed higher protein levels than those found in studies with other plant-based beverages and commercial cappuccinos.

Total lipid contents were the same for FS and FA, 5 g/100mL. Among the ingredients, baru almonds contributed the most to the lipid content of winter beverages. In this sense, the amount of saturated fat in formulations can be considered low, since baru almonds contain approximately 38.20 g/100g lipids to 43.60 g/100g to (da Cruz et al., 2019; Takemoto et al., 2001), consisting predominantly of unsaturated fatty acids. The average total carbohydrate content, representing the sum of metabolizable total carbohydrates and dietary fibers.

The new labeling regulations aim to establish clearer and more objective rules for better communication between consumers and the information on food labels, enabling more informed and conscious choices about the products that are part of their dietary habits. Among the required information, the added sugar content stands out, which was this value exceeds the limit established by Brazilian legislation for liquid products (7.5 g of added sugar in 100 mL; below this limit it is not necessary to insert the magnifying glass on the front label (ANVISA,

2020b). Thus, FS should include on the front label a seal informing consumers that the product is "high in added sugar. On the other hand, the FA formulation can be considered sugar-free (<1 g/100 mL), according to FDA standards. The “sugar-free” claim would be relevant information for consumers who tend to limit their sugar consumption. According to Pérez-Rodríguez et al. (2023), marketed plant-based beverages have a highly variable sugar content, ranging from 0 to 14.5 g of sugars/100 mL, depending on the amount and type of vegetable material and the addition of sugars for sensory reasons.

Regarding sodium level, both beverage formulations averaged, these sodium levels fall below the critical limit established for the use of nutritional claims such as "very low in sodium" (maximum 40 mg of sodium in 50 mL of the product). This aspect can enhance the attractiveness of the baru almond winter beverage to consumers.

Similarly, for FS and FA, the use of a magnifying glass on the front panel with information about saturated fat content is not obligatory, as they are below the critical limit for mandatory use (≥ 3g/ 100 mL). Therefore, the product has the potential to be considered healthy, given that excessive intake of sodium and saturated fat through the diet is generally associated with negative health effects such as high blood pressure, obesity, and diabetes (Astrup et al., 2020; Casey et al., 2021; Kloss et al., 2015).

Craig et al. (2022) analyzed 51 single-serve plant-based beverages based on the nutritional label listed on the commercial packaging and found that two thirds of them had high sugar levels (more than 5 g of total sugars/serving: 10% of Daily Value - DV), 63% were low in fat (not more than 1 g of saturated fat/serving: 5% of the DV), and only 39% were low in sodium (not more than 115 mg sodium/serving: 5% of DV). Therefore, the winter beverage containing baru almonds, that one with allulose (FA), is interesting from a nutritional aspect for consumers, especially for populations with restrictions on sugar, saturated fat, and sodium consumption.

Regarding the caloric value of the beverages, FA presented 160.2 kcal/100g and FS 181.4 kcal/100g. Replacing sucrose with allulose reduced caloric intake by 11.7%. According to Hossain et al. (2015), information, allulose is considered a low-calorie sweetener (<0.2 kcal/g) with 90% less calories than sucrose. Therefore, the replacement of sugars in foods and beverages with allulose would reduce their caloric and sugar content and reduce their glycemic and insulinemic impact, effects that can help with weight control and the reduction of cardiometabolic risk factors (Au-Yeung et al., 2023). Furthermore, traditional winter beverages made with milk generally have a higher caloric value than the plant-based formulations

developed. Costa Fernandes et al. (2021) obtained caloric values ranging from 283.01 to 302.88 kcal/100g for cappuccino-flavored dulce de leche, with different levels of instant coffee and cocoa powder.

Thus, the plant-based winter beverages with baru almonds developed aim to align with the guidelines proposed by the WHO to reduce the consumption of sugar, salt, and saturated fats, as a means of preventing and controlling diseases and complex risk factors through the consumption of healthier products. Furthermore, the nutritional profile provided by oleaginous seeds such as baru almonds, which contain substances like oleic and linoleic acids, minerals, and various antioxidants, may contribute to delaying the development of many diseases, including cardiovascular diseases and diabetes (Campidelli et al., 2022; Lima et al., 2022).

3.2. Chemical and physical characterization

FS and FA exhibited pH values of 6.04 ± 0.00 and 5.94 ± 0.05, and total soluble solids (TSS) of 33.08 ± 0.23. and 32.7 ± 0.44, respectively. The FS and FA formulations did not differ from each other ($p>0.05$) concerning the color parameters L*, a*, b*, h, and C* (Table 2). Figure 3 illustrates the visual aspect of the *plant-based* formulations produced, which resemble traditional winter beverages made with milk, such as cappuccino.

Table 2. Color parameters values, Rheological parameters by Herschel-Bulkley model and Microbiological analyses of the winter beverages with baru almond.

Color parameters		
	FS	FA
L*	24.6[a]	24.1[a]
a*	11.74[a]	11.84[a]
b*	18.57[a]	18.77[a]
h°	57.6[a]	57.9[a]
C*	22.0[a]	22.2[a]
Rheological parameters		
	FS	FA
τ_0 (Pa)	2.28[a] ± 0.15	1.82[a] ± 0.29
K (Pa.s^n)	1.45[a] ± 0.20	1.27[a] ± 0.15
N	0.62[a] ± 0.02	0.63[a]± 0.01
R^2	0.9998 ± 0.00	0.9999± 0.00
Microbiological analyses		
	FS	FA
Filamentous Fungi (CFU/mL)	$1.6x10^2$	$4.1x10^1$
Coagulase-positive Staphylococci (CFU/mL)	negative	negative
Enterobacteriaceae (CFU/mL)	<1/mL (est.)*	<1/mL (est.)*
Salmonella (Presence/Absence 25mL)	Absence	Absence

Means followed by the same letter in the lines do not differ from each other by Tukey's test ($p > 0.05$). **FA** = formulation with allulose; **FS =** formulation with sucrose.

***estimated. FA=** formulation with allulose; **FS=** formulation with sucrose

Fig 3. Winter beverages with baru almonds: a. formulation with allulose (FA) b. formulation with sucrose (FS). Source: The authors.

Brightness (L* coordinate) closer to zero on a scale, indicated the where the darker sample, while closer to one hundred, the lighter. Thus, the winter beverages with baru almonds exhibited a dark hue, which can be explained by the cocoa characteristic. Regarding hue, FS and FA had a mean value of 57.75, indicating that their color was browner (hue angle = 40–75) than yellow (hue angle = 90) or orange (hue angle = 45) (Simas et al., 2009). As for Chroma (C*), which gives the intensity or quantity of a shade, plant-based winter beverages showed a low C* (22.1 on average) since a more intense or saturated color. Furthermore, the ΔE value between FS and FA (0.55) indicates that the substitution of sucrose for allulose does not promote a difference in color perceptible to the naked eye ($0 < \Delta E < 1$: observer does not notice the difference) (Mokrzycki & Tatol, 2011).

3.3. Rheological Behavior

All formulations exhibited non-Newtonian fluid behavior with yield stress. The Herschel-Bulkley rheological model fits well with the experimental data, with $R^2 \geq 0.9998$. The rheological parameters obtained for the fitted models are presented in Table 2. The apparent viscosity of the winter beverages with baru almonds as a function of shear rate at 60 ºC is illustrated in Fig. 4. A reduction in apparent viscosity with increasing applied shear rate, indicating a pseudoplastic behavior, can be observed. This is confirmed by the value of $n<1$ (Table 3). Yao et al. (2023) obtained a similar shear-thinning behavior when evaluating the

rheological properties of plant-based made beverages from six different sources (soy, peanut, adlay, azuki bean, oats, and buckwheat).

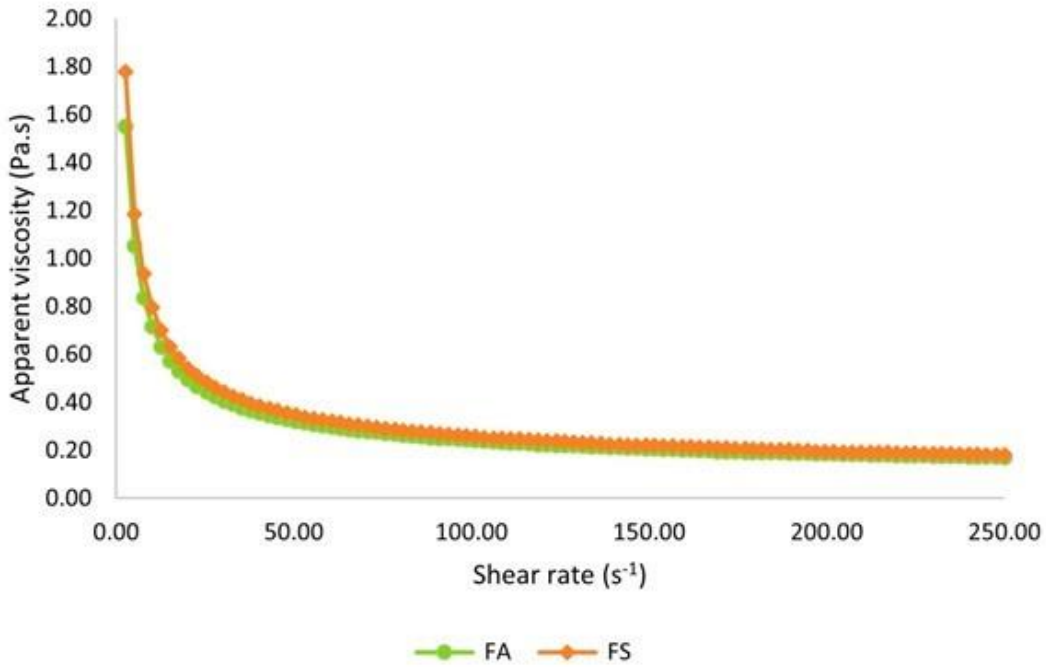

Fig 4. Apparent viscosity as a function of shear rate at 60 ºC. FA = formulation with allulose; FS = formulation with sucrose. Source: The authors.

The apparent viscosity at 100 s^{-1} (η_{100}) did not differ significantly between formulations ($p>0.05$), which presented an average value of 0.29 Pa.s. This values is close to that found in the literature under similar temperature conditions for nut-based beverages (η_{100} = 0.252 Pa.s) (Silva et al., 2020). Sweeteners play an important role in the viscosity of foods, along with proteins and lipids. According to Peasura & Sinchaipanit (2022), the type of sweetener not only affects the physical and chemical properties, besides the rheological behavior of samples, making the substitution of sucrose even more challenging. However, it was observed that the replacement of sucrose did not affect the flow behavior of winter beverages with baru almonds, which can be confirmed by the similar values of η_{100}, τ_0, k, and n, for FS and FA.

3.4. Microbiological Analyses

As sugar is recognized for its role in food preservation, its substitution can impact the microbiological quality of the food. Therefore, microbiological analyses were conducted to

ensure the beverage's fitness for consumption, and the results are presented in Table 2. The FS and FA meet the microbiological criteria described by legislation, considered of acceptable quality concerning the counts of filamentous fungi and *Enterobacteriaceae,* with the absence of *Salmonella*. Additionally, after confirmatory tests, negative results were obtained for coagulase-positive *Staphylococci.* According to Prado et al. (2021), *Salmonella spp., Escherichia coli, and Staphylococcus spp.* are the principal causes of outbreaks associated with the consumption of contaminated foods, with handling and lack of hygiene being the main agents responsible for contamination. Moreover, most of these outbreaks are linked to animal products, but they can also affect plant-based products that are mishandled. However, no outbreaks associated with them have been reported in the current literature (Bharathan et al., 2023; Bintsis, 2017; Heredia & García, 2018).

In this context, *plant-based* products generally exhibit higher food safety from a microbiological standpoint, associated with the adoption of good manufacturing practices throughout processing, which is important to ensure the quality of the final product. Thus, the formulations can be considered safe for consumption during sensory evaluation, without causing harm to the consumer's health, deemed of acceptable quality according to the established criteria by Brazilian legislation.

3.5. Kinetic Stability

The kinetic stability of the formulated beverages FS and FA and the controls C1 and C2 was observed over a period of 180 min, at 60°C, from which the Turbiscan Stability Index (TSI) scale was obtained. TSI is a dimensionless number in which the result of all occurrences of destabilization phenomena in the sample that can be measured by the noticeable change in backscatter or transmission signal intensity over the height of the sample, during the analysis period. Fig. 5 shows the initial stability state of the formulations in the first 5, 20 and 180 min.

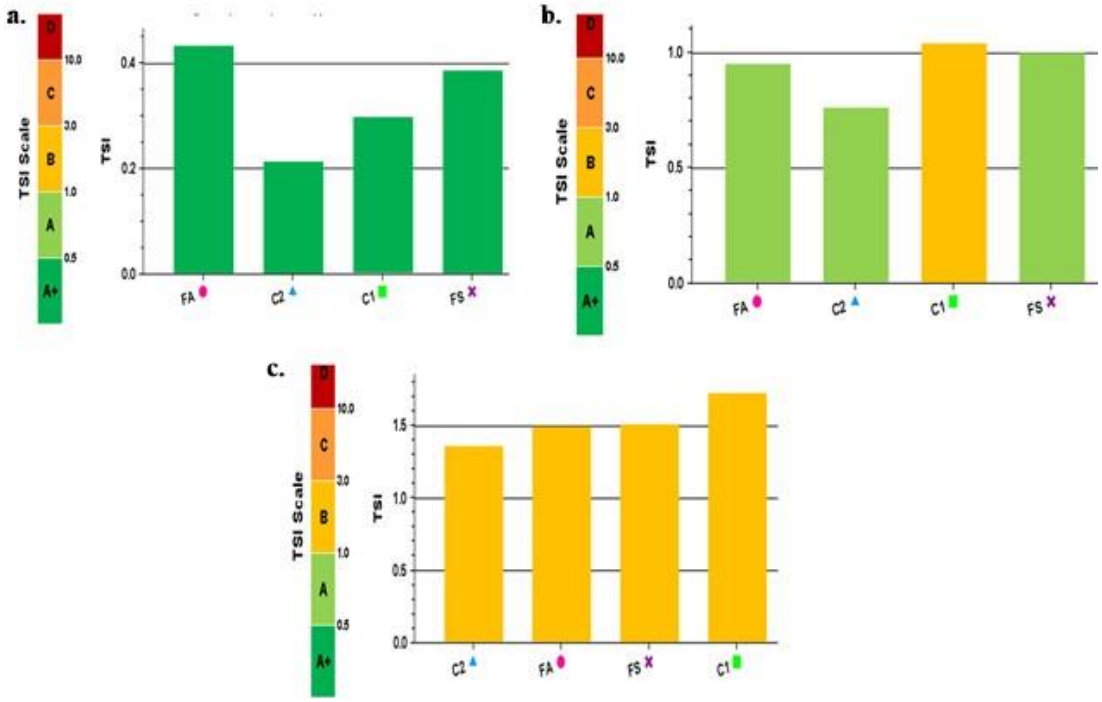

Fig 5. TSI Scale a. 5 minutes scanning, b. 20 minutes scanning of samples c. 180 min scanning evaluated at 60 ºC. FA = formulation with allulose; FS = formulation with sucrose; C1 = formulation without addition of sweeteners; C2 = formulation without addition of sweeteners. Source: The authors.

Initially (Fig. 5a), all four formulations exhibit excellent visual stability classified as A+ (dark green), with no significant destabilization observed and low TSI values (<0.42). From Figure 5b, a reduction in the kinetic stability of plant-based winter beverages can be observed at 20 min of scanning, especially for C1 (formulation without added sweeteners). The FA, C2, and FS became classified as A (light green), although visually the sample is considered good, where the equipment begins to detect the existence and occurrence of some destabilization mechanism at a very early stage. However, in 90% of cases, such destabilization phenomena are not visible or are perceived with the naked eye. C1 is classified as B (yellow) and presents a TSI value above 1.0, indicating the onset of some destabilization phenomenon, i.e., changes occurring in the sample height relative to the reference point. When the samples have TSI scale values in the range of 1.0 to 3.0, destabilization becomes detectable.

Fig. 5c indicates that after 180 min of analysis, winter beverages with baru almonds suffered the action of destabilizing mechanisms. The observed reduction in kinetic stability is mainly due to the sedimentation of cocoa and soluble coffee particles that settle at the bottom

of the glass cell, leading to a macroscopic phase separation and consequent clarification of the sample. This undesirable characteristic may affect product acceptance.

The destabilization mechanisms associated with increased lipid diffusion may be related to both coalescence (particles within the system colliding and forming a new particle) and Ostwald ripening (smaller particles transferring through diffusion of their molecules to others, increasing in size and becoming part of them) (Patra et al., 2021). Over time, at a temperature of 60 °C, lipid diffusion contributes to the occurrence of Ostwald ripening and coalescence, which over time may lead to macroscopic phase separation, as evidenced by changes detected in the analysis and cream formation at the top, where under the studied conditions, it occurred due to the increased speed at which particles rise, influenced by the average diameter and density, expressed by the Stokes equation (1).

$$\boldsymbol{vs} = \frac{\boldsymbol{d^2\,(\rho_{p-}\,\rho_L)*g}}{\boldsymbol{18_\eta}} \qquad (1)$$

Thus, over time, even though they have been homogenized, the new membrane formed is mainly due to the adsorption of proteins on the surface of lipids, and this may not have been completely effective in forming more uniform globules, despite the likely reduction in their size, which increases over time and causes the samples to lose their kinetic stability. Such detected variations indicate that the destabilization mechanisms described were detected by the equipment after 180 minutes, and the results obtained TSI values <3.0 indicate that the formulations remained visually stable, without perceptible visual alterations, thus demonstrating the Turbiscan's ability to accurately detect small changes in the evaluated samples. In descending order of kinetic instability, C1 (TSI=1.7) was the most unstable, followed by formulations FS (TSI=1.5) and FA (TSI= 1.5), and C2 (TSI=1.0), which was the most stable sample among them.

Fig. 6 illustrates the overall destabilization kinetics of the plant-based winter beverage, showing the variation of TSI values over the analysis time. The most significant increase in TSI occurs in the first 20 min of analysis and remains constant, except for C1, which had a more pronounced and variable increase than the other formulations (FS, FA, and C2), showing more uniform and homogeneous changes. Although the instability phenomena of the four formulations were noticeable in the first 20 minutes, under the test conditions, with destabilization mechanisms detected by the equipment over time, visually, no changes were observed. Therefore, this does not compromise the appearance of the product.

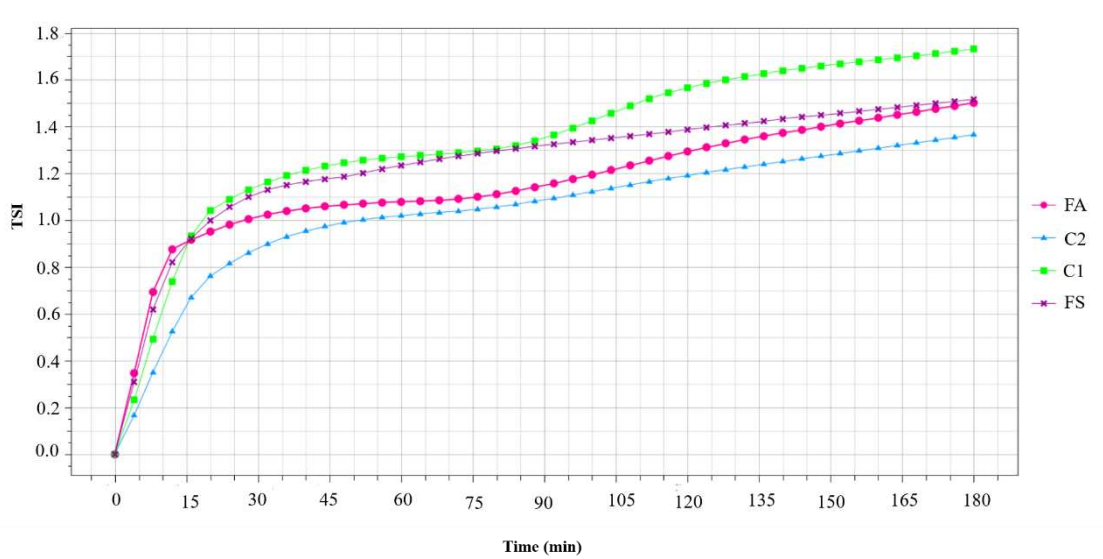

Fig 6. Global Destabilization Kinetics. FA = formulation with allulose; FS = formulation with sucrose; C1 = formulation without the addition of sweeteners; C2 = formulation without the addition of sweeteners and gums. **Source**: The authors.

The greater kinetic instability of C1 indicates that solids in general play an important role in the overall stability of *plant-based* beverages. The higher TSI values of C1 show that the sample clarifies over time due to phase separation, mainly in the upper and lower regions of the sample, where the most significant changes occurred. FS and FA exhibited very similar behavior, with FS being slightly less stable than FA. This once again demonstrates that allulose can replace sucrose without altering its characteristics, especially technological functions, in the final product. Therefore, this study indicates that winter beverages with baru almonds with sucrose (FS) or allulose (FA) have good kinetic stability at the product consumption temperature (60°C) for up to 180 minutes. Furthermore, consuming a portion of this type of product takes less time than the analysis time.

3.6. Sensory Analysis

The panel of assessors participating in the study comprised 100 volunteers, with 68% being female and 32% men, with ages ranging between 18 and 65 years. Regarding the sensory characterization of the FS and FA beverages through RATA in both sessions (blind test and informed test), significant differences ($p<0.05$) were found between the formulations for the attributes sweet taste, pleasant flavor, and unpleasant flavor.

The replacement of sucrose with allulose did not significantly affect the sensory perception of the attributes: brown color, brightness, cocoa aroma, nutty aroma, cocoa flavor, sweet taste, nutty flavor, cinnamon flavor, fatty, unpleasant flavor, creamy, pleasant flavor, homogeneous texture, and presence of particles (Table 3). Based on the scores obtained, the attributes of unpleasant flavor, cinnamon flavor, fatty (blind test) do not characterize the winter beverages with baru almonds, as the averages are below 1, ranging between "not applicable" and "low" perceived intensity. The intensity of the pleasant flavor for FS was 2.24 and 2.27 and for FA it was 1.61 and 1.77, in the blind and informed tests, respectively.

Table 3. Mean values of attributes obtained in the RATA test conducted in blind and informed conditions, for winter beverages with baru almond.

Descriptor terms	**FS (Blind test)**	**FS (Informed test)**	**FA (Blind test)**	**FA (Informed test)**
Brown color	2.74^{aA}	2.75^{aA}	2.73^{aA}	2.75^{aA}
Brightness	2.41^{aA}	2.50^{aB}	2.48^{aA}	2.57^{aB}
Cocoa aroma	1.94^{aA}	1.83^{aA}	1.99^{aA}	1.80^{aB}
Nutty aroma	2.02^{aA}	2.02^{aA}	1.97^{aA}	2.09^{aA}
Sweet taste	1.61^{aA}	1.54^{aA}	1.08^{bA}	0.97^{bA}
Cocoa flavor	2.18^{aA}	1.89^{aB}	2.19^{aA}	1.87^{aB}
Pleasant flavor	2.14^{aA}	2.27^{aA}	1.61^{bA}	1.77^{bB}
Unpleasant flavor	0.70^{aA}	0.60^{aA}	0.98^{bA}	0.93^{bA}
Nutty flavor	2.25^{aA}	2.20^{aA}	2.16^{aA}	2.21^{aA}
Cinnamon flavor	0.83^{aA}	0.86^{aB}	0.81^{aA}	0.93^{aA}
Fatty	0.97^{aA}	0.95^{aA}	0.98^{aA}	1.11^{aA}
Creamy	1.74^{aA}	2.16^{aA}	1.64^{aA}	2.02^{aA}
Homogeneous texture	2.13^{aA}	2.32^{aB}	2.11^{aA}	2.24^{aA}
Presence of particles	1.36^{aA}	1.10^{aA}	1.27^{aA}	1.17^{aA}

Equal lowercase letters on the same line mean that there are no significant differences between the samples FS and FA in the blind test and informed test for each descriptor term ($p < 0.05$). Equal uppercase letters on the same line mean that there are no significant differences between the sessions of blind test and informed test for each descriptor term for available the effect of information ($p < 0.05$).

After receiving the label and information (session 2 - Informed test), the values of the FS' attributes increased from session 1 to session 2 and they were considered significantly differences ($p<0.05$) were found between sessions 1 and 2, for the attributes cocoa flavor, cinnamon flavor, presence of particles, homogeneous texture, and brightness. No significant differences ($p>0.05$) were found for the other evaluated attributes. On the other hand, for FA, there was a significant difference between the blind and informed tests ($p<0.05$) for the attribute's cocoa aroma and cocoa flavor, with a reduction in the intensity of perception of these attributes, and an increase in the perceived intensity for brightness and pleasant flavor. Therefore, the information provided about allulose had a significant positive effect on the perception of pleasant flavor and brightness.

For the sweet taste, the greater intensity was attributed to FS (m=1.61), compared to FA (m=1.08), corresponding to a percentage of perceived sweetness equivalent to 67% of allulose in relation to sucrose, in the blind test. In the informed test, the means for FS and FA were m=1.54 and m=0.97, respectively, indicating that allulose presented sweetness equivalent to 63% of sucrose. The sweetness equivalence results found for the FA beverage in the blind test may be comparable to those found in the literature, describing the equivalent sweetness of allulose (70%) compared to the sweetness provided by sucrose (Bolger et al., 2021; Xin & Ran, 2024). In this case, the information about the type sweetener (sucrose or allulose) affected the perception of sweet taste equivalence, considered an important attribute in the acceptance of beverages (Au-Yeung et al., 2023; Bolger et al., 2021). Furthermore, the intensity of the sweet taste was considered by consumers to be "low" for FA (means close to 1) and ranged from "low" to "medium" for FS (means between 1 and 2), based on the results of both sessions (Table 5).

The hedonic means for the attributes evaluated in the acceptance test and the acceptability index are presented in Table 4. In the blind test, FS and FA were statistically equal concerning the acceptance of appearance, aroma, and texture ($p > 0.05$). For flavor and overall impression, the formulation containing sucrose (FS) was more accepted than the one containing allulose (FA) ($p < 0.05$). FS presented hedonic means between 6.62 (texture) and 7.94 (appearance) in the blind test, and between 6.98 (texture) and 8.18 (appearance and aroma) in the informed test. The hedonic means for FA varied between 5.59 (flavor) and 7.93 (appearance) in the blind test and between 5.86 (flavor) and 8.03 (appearance) in the informed test; the means overall impression was between the hedonic terms "I liked slightly" and "I liked moderately".

Table 4. Hedonic means and Acceptability Index (AI%) and purchase intention for the winter beverages with baru almond.

Sensor	FS (Blind test)	FS (Informed test)	FA (Blind test)	FA (Informed test)
Appearance	7.94^{aA}	8.18^{aB}	7.93^{aA}	8.03^{bA}
AI	**88.22**	**90.88**	**88.11**	**89.22**
Aroma	7.12^{aA}	8.18^{aB}	6.91^{aA}	7.10^{bA}
AI	**79.11**	**90.88**	**76.77**	**78.88**
Texture	6.62^{aA}	6.98^{aB}	6.36^{aA}	6.58^{bA}
AI	**73.55**	**77.55**	**70.66**	**73.11**
Flavor	6.65^{aA}	6.99^{aA}	5.59^{bA}	5.86^{bA}
AI	**73.88**	**76.66**	**62.11**	**65.11**
Overall impression	6.93^{aA}	7.33^{aB}	6.37^{bA}	6.54^{bA}
AI	**76.99**	**81.44**	**70.70**	**72.66**
Purchase intention	3.38^{aA}	3.61^{aA}	2.87^{bB}	3.22^{bA}

Equal lowercase letters, on the same line, mean that there are no significant differences between the samples, for each descriptor term ($p>0.05$). Equal uppercase letters, on the same line, mean that there are no significant differences between the sessions, for each descriptor term ($p>0.05$). **FA=** formulation with allulose; **FS=** formulation with sucrose.

There was no influence of information on FA acceptability, since hedonic means did not vary significantly between sessions ($p > 0.05$). However, FS was significantly influenced by information ($p < 0.05$) for appearance, aroma, texture, and overall impression, with an increase in the average acceptability for all these attributes. The AI% values for FS formulation also increased in the test with information, being greater than 72.66%, except for the flavor attribute. For a product to be considered accepted, AI should be at least 70%, considering its sensory properties. Thus, both formulations were well accepted by general consumers with no dietary restrictions, who accounted for more than 90% of the participants. This result suggests that the plant-based winter drinks developed could be attractive not only to vegans, vegetarians, and flexitarians, but also to consumers who do not follow restrictive diets. Rincon et al. (2020) developed a new beverage based on chickpea and coconut, obtaining low sensory acceptability (<70%) among general consumers, achieving higher acceptability averages when the same

samples were evaluated in a second session, conducted with consumers more specific to this type of beverage.

Therefore, FA has the potential to be better accepted by consumers, mainly with adjustments in the formulation to increase its sweetness, which may have compromised the acceptance of the flavor of the plant-based winter beverage. Furthermore, few differences were found between FS and FA in relation to the other attributes evaluated, suggesting that allulose can act as a good substitute for sucrose without compromising the sensorial characteristics of appearance, texture, and aroma of the product. The results of the means obtained by the attitude scale, which aims to measure the potential purchase intention of the FS and FA beverages, are presented in Table 4.

The information did not significantly affect ($p > 0.05$) the purchase intention for FS. However, higher mean scores for purchase intention were observed for this formulation, both in the blind test and in the informed test, with mean scores above 3, indicating a tendency to consider purchasing the FS. The information contained on the front label "high in added sugar" did not discourage consumers from purchasing the product.

For FA, significant differences were found between sessions 1 and 2 ($p < 0.05$), showing the positive effect of information on purchase intention. There was an increase in the mean of the attitude scale, going from "probably wouldn't buy" to "might or might not buy" with a mean score of 2.88 in the blind test, to "might or might not buy" to "probably would buy" with a mean score of 3.22 in the informed test. Information about the nutritional table, free added sugar on the front label, and the health benefits of baru promoted an increase in the purchase intention of the plant-based winter beverage with allulose. This result corroborates the studies by Khan et al. (2023), when evaluating the impact of marketing interventions on sugar-free and sugar-sweetened soft drink sales, reported that the interventions had a statistically significant impact for sugar-free drinks but not for sugar-sweetened drinks. On average, sales of the sugar-free product were 56.75% higher than those of the control site with added sucrose.

When asked about the habit of consuming sweetened winter beverages, 61% of consumers indicated consuming such products with added sugar, while 22% use sweeteners (natural or artificial), and only 17% do not add any sweetener, as illustrated in Fig. 7. As a result, the majority of the untrained assessors indicated a habit of consuming and familiarity with products sweetened with sucrose. This statement, while advocating for the exploration of alternative sweeteners to replace sucrose, highlights the necessity of finding viable substitutes

that meet consumers' desires without compromising product quality or consumer preference (Cheetra, 2022; Lee et al., 2022b; Milner et al., 2020; Singh et al., 2023).

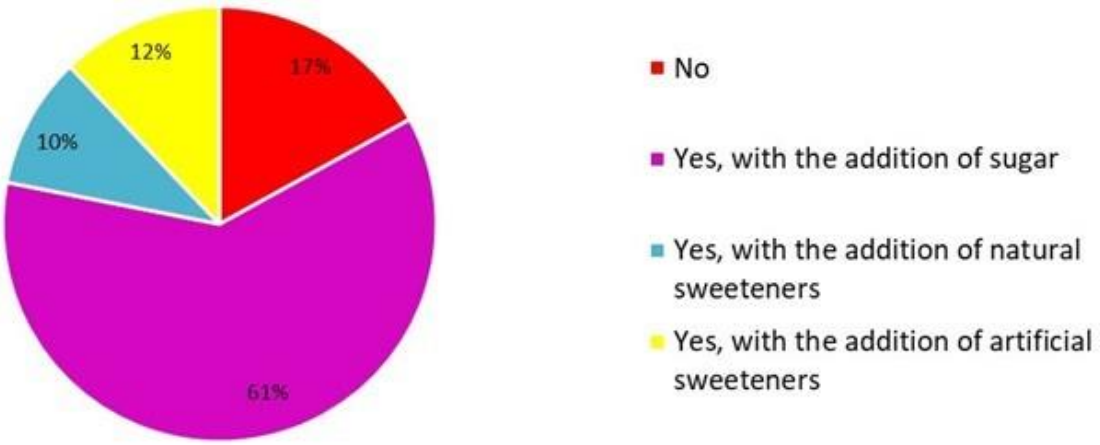

Fig 7. Percentage of response in relation to the consumption of sweetened winter beverages. Source: The authors.

According to Beauchamp (2016), the sweet taste has the power to stimulate the consumption of a particular product, motivating and shaping consumer behavior. These authors also suggest a direct relationship between the sweet taste and the perception of the non-toxicity of a food, meaning that the sweeter the taste, the less toxic it is perceived, serving as a survival mechanism throughout history. Christiansen et al. (2023) evaluated the preferences and perceptions of various groups of consumers regarding the consumption of different low-calorie sweeteners using a validated questionnaire and reported that older age was associated with avoidance of sweeteners and further suggested that their consumption was perceived as beneficial to health compared to sucrose consumption.

Due to the similarities regarding the perception of some sensory attributes and sensory acceptability, we can suggest that allulose can act as a good substitute for sucrose without compromising the sensory quality of the product, indicating differences in the perception of sweetness in formulations where FS was indicated as sweeter than FA.

Furthermore, it is suggested that information about the nutritional benefits of baru almonds may enhance the product's acceptance, especially considering that only 25% of the participants were familiar with this type of nut.

It is believed that knowledge about such benefits can boost the development and consumption of plant-based beverages with baru almonds, as 50% of volunteers expressed interest in consuming products made from baru. The nutritional value, especially in terms of

protein content, attributed to the addition of baru almonds has the potential to enhance acceptance of *plant-based* winter beverages. Currently, consumers have been seeking more information about the ingredients and components present in food, contributing to health improvement through the provided benefits (Jürkenbeck, 2023; Tønnesen et al., 2022). According to Batista et al. (2023), the adoption of marketing strategies, such as reformulating labels and reinforcing the presence of native ingredients, has the potential to meet the demands of consumers for plant-based foods. These authors suggest three main themes to represent consumers' views on plant-based foods: sustainability and ethics; health and wellness; and sensoriality and pleasure.

In a systematic evaluation of the effects of nutritional claims on consumer behavior, Ballco & Gracia (2022) found that factors such as familiarity and knowledge about the nutritional benefits associated with consumption could positively impact choices. Therefore, the new product presents a nutritious alternative, with sensorial quality to serve different consumer groups, including vegans, vegetarians, flexitarians, and general consumers without dietary restrictions

4. Conclusion

The replacement of sucrose with allulose can be carried out without modifying the centesimal composition and the physical and chemical composition, rheological, and kinetic characteristics of the developed plant-based beverages. Additionally, the winter beverages with baru almond containing sucrose (FS) or allulose (FA) were well accepted by the untrained assessors. However, consumers had higher acceptance of FS, which was characterized by greater sweetness intensity. The similarity in terms of the perception of sensory attributes (except sweetness) indicate that allulose is a promising substitute for sucrose.

The search for sweeteners that replace sucrose is a challenge in terms of technology, stability, and sensorial quality. Therefore, allulose can be an alternative to replace sucrose in plant-based beverages, serving consumers who seek well-being and health. The winter beverage with baru almond, especially the one with allulose, has a good nutritional profile for the consumer due to its protein content (around 4.5%) and low saturated fat, and free of added sugar. Furthermore, the knowledge about the excellent source of essential nutrients and the health benefits, makes the beverage attractive to different consumer groups concerned with wellbeing and seeking and flavorful. In addition to the nutritional benefits, the winter beverage

with baru almond can contribute to sustainability through the responsible production of ingredients, promoting local and environmentally friendly production methods, and adding value to products.

Implications for gastronomy

The sensorial acceptance of Baruccino (baru nut-based drink with cocoa flavor, added soluble coffee and cinnamon) shows the potential of baru, a fruit native to the Brazilian Cerrado, for use by the food industry, contributing to its diversification and valorization. Replacing sucrose with allulose in the plant-based drink did not promote changes in important sensory properties, such as flavor and texture, nor in technological properties, which could expand its use in sugar-free foods. These results can be used to develop innovative foods with desirable properties. Additionally, this study emphasizes the importance of providing information to consumers, especially regarding the innovative ingredient (in this case, baru), their benefits, and the presence or absence of sugar, so that they can make more assertive decisions.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Material Suplementar

Name:_____ Gender: F ( ) M ( ) Year of birth: _____
Date:_____Telephone_____Email:_____

Please evaluate the appearance and aroma of the sample, and then taste it. Identify (mark with an X) your opinion regarding the intensity of the attributes according to the scale below:

Sample code:_____

	ATTRIBUTES	Not Applicable	Low	Medium	High
Appearance	Brown color	( )	( )	( )	( )
	Brightness	( )	( )	( )	( )
Aroma	Cocoa aroma	( )	( )	( )	( )
	Chesnut aroma	( )	( )	( )	( )
Flavor	Sweet taste	( )	( )	( )	( )
	Cocoa flavor	( )	( )	( )	( )
	Pleasant flavor	( )	( )	( )	( )
	Chesnut flavor	( )	( )	( )	( )
	Cinnamon flavor	( )	( )	( )	( )
	Unpleasant flavor	( )	( )	( )	( )
	Fatty	( )	( )	( )	( )
Texture	Creamy	( )	( )	( )	( )
	Homogeneous texture	( )	( )	( )	( )
	Presence of particles	( )	( )	( )	( )

ACCEPTANCE

Please, rate using the scale below how much you liked or disliked the product in relation to the attributes:

9 - Like extremely
8 - Like very much
7 - Like moderately
6 - Like slightly
5 - Neither like nor dislike
4 - Disliked slightly

Appearance: _____
Aroma: _____
Texture: _____
Flavor: _____
Overall impression: _____

3 - Dislike moderately

2 - Dislike very much

1 - Dislike extremely

Comments: _____

PURCHASE INTENTION

( ) Definitely would buy

( ) Probably would buy

( ) Might or might not buy

( ) Probably would not buy

( ) Definitely would not buy

Comments: _____

Fig. S1. English version of the evaluation form model presented to consumers during the two sensory analysis sessions.

ARTIGO 4

Farinha de amêndoa de baru (*Dipteryx alata* Vog.): obtenção, caracterização físico-química, propriedades tecnológicas e capacidade antioxidante de um coproduto do processamento de bebida vegetal

RESUMO

O processamento de bebidas à base de plantas utilizando a amêndoa de baru pode gerar coprodutos com grande potencial de utilização, que se alinha a busca por soluções sustentáveis na produção de alimentos. Nesse contexto, o objetivo foi avaliar as propriedades físico-químicas, tecno-funcionais e capacidade antioxidante da farinha de amêndoa de baru, produzida a partir da massa resultante do processamento da bebida de baru e retida na etapa de filtração. A farinha obtida apresentou um alto contéudo de proteínas (26,0 % ± 0,2) e lipídios (47,3 % ±0,1), indicando que este pode ser um ingrediente alternativo para enriquecimento de alimentos. Em relação as propriedades tecnofuncionais, a farinha apresentou maior capacidade de retenção de água do que a capacidade de retenção de óleo, respectivamente 2,92 e 1,14 g g^{-1} de farinha. apresentou. O conteúdo de compostos fenólicos totais foi em média 222 mg/100 g, A atividade antioxidante pelos métodos ABTS e DPPH foi respectivamente de 133,96 μmol de Trolox por grama de farinha e de 350 mg de antioxidante por mL de extrato (IC_{50}). Nesse sentido, o consumo da farinha tem o potencial de fornecer compostos antioxidantes que são benéficos para a saúde. Assim, a farinha obtida como coproduto do processamento de uma bebida de baru apresenta propriedades tecno-funcionais interessantes que podem orientar sua aplicação no desenvolvimento de novos produtos, contribuindo para a redução de resíduos.

Palavras-chave: Ingrediente; Alimentos; Novos produtos; Aproveitamento.

1. INTRODUÇÃO

O processamento de alimentos pode gerar resíduos, coprodutos e subprodutos que, quando não são devidamente gerenciados, contribuem para o aumento do desperdício de alimentos (Dal' Magro e Talamini, 2019; Silva *et al.*, 2023; Sinkko *et al.*, 2019; Viana *et al.*, 2023). A Organização das Nações Unidas para Agricultura e Alimentação, do termo em inglês *Food and Agriculture Organization* (FAO), estimam que um terço dos alimentos produzidos no mundo são desperdiçados gerando custos econômicos, ambientais e sociais em que o desperdício de alimentos está relacionado a qualquer situação na qual alimentos considerados

“seguros e nutritivos” sejam descartados ou sejam utilizados com objetivos não alimentares, considerando todos os elos da cadeia de abastecimento (Abbade, 2020; FAO, 2021).

A amêndoa de baru representa um quarto do fruto e contém 20-30% de proteínas, 40% de lipídeos, além de importantes micronutrientes como cálcio, zinco, carotenoides, e compostos fenólicos, sendo seu consumo associado a benefícios à saúde como redução de doenças cardiovasculares, infecções, controle de colesterol e diabetes, e redução de gordura abdominal (Fernandes et al., 2010; Lima et al., 2022; Mérillon e Ramawat, 2020; Souza, de et al., 2018) A casca (epicarpo) e a polpa (mesocarpo) são ricas em compostos fenólicos e carboidratos, enquanto o endocarpo é uma fonte lenhosa para a produção de biocarvão e biocombustível (Monteiro, Carvalho e Boas, 2022; Oliveira, De et al., 2020; Viana et al., 2023). Assim, durante o desenvolvimento de novos produtos à base de baru, é necessário um planejamento meticuloso que considere o processamento completo desse alimento, propondo formas de aproveitar todo o fruto e soluções para a utilização dos resíduos como coprodutos.

Assim, a busca por soluções sustentáveis é essencial para enfrentar desafios globais de segurança alimentar e consumo responsável de matérias-primas. Coprodutos gerados no processamento de alimentos à base de amêndoas, como é o caso do baru têm grande potencial de aproveitamento de forma utilizar integralmente a parte comestível, gerando impactos positivos que estão alinhados aos Objetivos de Desenvolvimento Sustentável (ODS) propostos pela Organização das Nações Unidas (ONU) para serem alcançados até 2030 (Silva, da *et al.*, 2021; Strokal, Biemans e Oel, van, 2019; Viana *et al.*, 2023).

O processamento de bebidas feitas à base de plantas a partir da amêndoa de baru gera dois coprodutos/resíduos principais: a película marrom que recobre a amêndoa e a torta de amêndoa retida durante a operação de filtração (Ferreira *et al.*, 2015). Subprodutos obtidos a partir de fontes vegetais podem ser transformados em farinhas com potencial para serem utilizadas no desenvolvimento de produtos ricos em fibras, proteínas, entre outros compostos (Santos, Lopes da Silva e Pintado, 2022; Singh *et al.*, 2022)

Nesse sentido, o objetivo deste estudo foi elaborar e caracterizar a farinha da torta de baru (FTB) resultante do processamento de bebidas feitas a partir da amêndoa de baru por meio de análises fisico-químicas, tecnofuncionais e atividade antioxidante. Este trabalho busca, portanto, agregar valor a esse coproduto e aproveitar de maneira integral a matéria-prima a fim de atender a ODS 2, que busca acabar com a fome, alcançar a segurança alimentar, melhorar a nutrição e promover a agricultura sustentável, e a ODS 12, que estimula o consumo e a produção responsáveis (ONU, 2024).

2. MATERIAL E MÉTODOS

2.1. Material

A amêndoa de baru (*Dipteryx alata* Vog.) foi adquirida em um comércio local da cidade de Viçosa. Os reagentes químicos utilizadas foram de grau analítico P.A, ácido nítrico, ácido nitroperclórico, água destilada, Lauril sulfato de sódio, óleo de soja, acetona, metanol, Folin-Ciocalteu, ácido gálico, DPPH (2,2-difenil-1-picrilhidrazil, ABTS (2,2'-azinobis3-etil-benzotiazolina-6-sulfonato), Trolox (Ácido -6-hidroxi-2,5,7,8-tetrametilcromano-2-carboxílico).

2.1 Processamento da farinha de baru

A farinha de baru foi elaborada a partir da secagem e da moagem da torta obtida após o processamento da bebida feita a partir da amêndoa de baru. A torta foi resultante da trituração da amêndoa de baru com água quente, em liquidificador (3min), e filtração com auxílio de um voal previamente esterilizado. Posteriormente, a torta foi submetida à secagem em estufa de circulação forçada (Ethik Technology), à temperatura de 60 $\pm$ 2 ºC por 8 horas. A escolha da temperatura de secagem foi feita com base no trabalho de (Guimarães *et al.*, 2020), uma vez que nessa condição ocorrem menores modificações nutricionais e sensoriais que podem afetar a qualidade do produto. Em seguida, a matéria seca foi macerada, com auxílio de um almofariz, obtendo a farinha conforme ilustrado na Figura 1. Após a secagem e maceração da farinha de baru, o produto foi armazenado a vácuo e mantida sob refrigeração (8 $\pm$ 2 ºC), até a realização das análises.

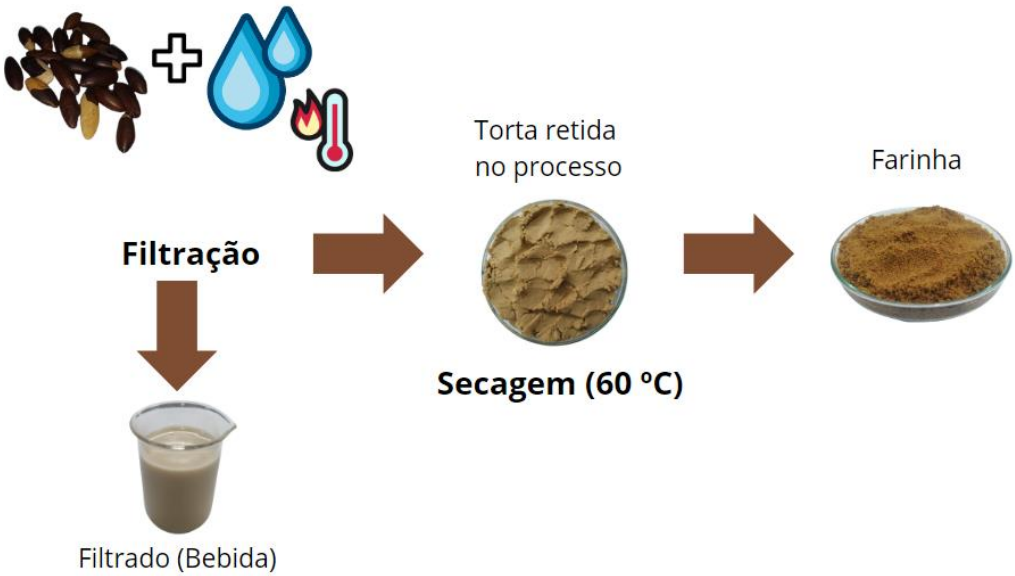

Figura 1. Esquema de processamento da bebida e obtenção da farinha a partir da torta. Fonte: Os autores.

2.2. Composição centesimal

A determinação da composição centesimal da farinha da torta de amêndoa de baru é uma etapa importante para a definição do valor nutricional, fornecendo informações para o desenvolvimento de novos produtos e elaboração da informação nutricional. A determinação da umidade foi feita secando a amostra até peso constante em estufa 105 ± 2 ºC, enquanto o resíduo mineral fixo (RMF) e as cinzas foram obtidas incinerando a amostra em mufla a 550 ± 2 ºC (Silva *et al.*, 2022) . A quantificação do teor de proteínas foi baseada na determinação de nitrogênio total, e foi realizada utilizando o método de Kjeldahl (Fator de correção = 5,75) (Magro *et al.*, 2024). A quantificação de lipídeos totais foi realizada de acordo com o método de Soxhlet por meio da extração lipídica utilizando solvente à quente (Ojeda, Genevois e Busch, 2023). O conteúdo de carboidratos totais foi obtido por diferença.

2.3. Análises químicas e físicas

O valor de pH foi medido em triplicata, inserindo o eletrodo (pHmetro Gehaka PG2000) diretamente no sobrenadante da amostra (1g), que foi dispersa em 10 mL de água destilada, conforme metodologia descrita por Adolfo Lutz (2008). A determinação da atividade de água (Aw) foi realizada a 25 ± 1 °C, no qual 7,5 g de amostra foi adicionada à uma cápsula circular

de plástico, em quantidade suficiente para cobrir o fundo da cápsula, e o valor de Aw foi estabelecido utilizando medidor digital (Dew Point Water Activity Meter 4TE, AquaLab).

As propriedades de cor da farinha foram avaliadas pela mensuração das coordenadas L* (luminosidade, que varia do preto ao branco), a* (cromaticidade que vai do verde ao vermelho) e b* (cromaticidade do azul ao amarelo) em espectrofotômetro de cor Colorquest® XE (HunterLab, USA), devidamente calibrado, com ângulo de observação de 10º e iluminante D65 (luz solar média diária). A partir das coordenadas, os atributos de cor h* (ângulo hue), C* (croma) e ΔE* (variação total da cor) foram calculados, utilizando as equações 1, 2 e 3, propostas pelo sistema de coordenada of the Comission Internationale de l'Eclairage (CIE) (CIE, 2024 Ferreira e Spricigo, 2017).

$$h = \left(\frac{b^*}{a^*}\right) \qquad (1)$$

$$C^* = \sqrt{(a^*)^2 + \left(b^*\right)^2} \qquad (2)$$

$$\Delta E^* = \sqrt{\Delta L^* + \Delta a^* + \Delta b^*} \qquad (3)$$

2.4. Propriedades tecno-funcionais

2.4.1 Capacidade de absorção de água e Capacidade de retenção de óleo

A capacidade de retenção de água (CRA) e a capacidade de retenção de óleo (CRO) da farinha de baru foram determinadas pela adição de 0,1 g de amostra em micro-tubos de centrífuga (1,5 mL), contendo 1,0 mL de água para a CRA ou 1,0 mL de óleo de soja para a CRO. Em seguida, os micro-tubos foram homogeneizados, deixados em repouso à temperatura ambiente (25 $\pm$ 2 ºC) por 30 min, e posteriormente, centrifugadas a 6000 × rpm por 30 min, utilizando micro-centrífuga (Model SBC 140). O sobrenadante foi descartado, os micros-tubos pesados e suas respectivas massas determinadas e a CRA e o CRO foram calculadas com base na equação 4 (Silva et al., 2022). A análise foi realizada em triplicata, com três repetições.

$$CRAouCRO(g/gdeamostra) = \frac{M_1 - M_t - M_0}{M_0} \quad \text{(Eq. 4)}$$

Sendo que:

M_1 é a massa (g) do tubo com a amostra úmida, após o descarte do sobrenadante residual de água ou óleo.

M_0 é a massa (g) inicial da amostra pesada.

M_t é a massa (g) do micro tubo tipo Eppendorf vazio.

2.4.2 Capacidade emulsificante e estabilidade da emulsão

A capacidade emulsificante da farinha de baru e a estabilidade da emulsão formada foram avaliada sob diferentes condições, de acordo com a metodologia proposta por Silva et. al. 2022, com modificações. Dessa forma, 0,3 g de amostra foram adicionadas em 60 mL de água destilada (A1); em 60 mL de água mais 5 mL de óleo de soja comercial (A2); e em 60 mL de água mais 20 mL de óleo de soja comercial (A3), e homogeneizados em Ultra-Turrax (9500 rpm) à temperatura ambiente (25 $\pm$ 2 ºC), por 1 min. Em seguida, a absorbância das misturas foram determinadas em espectrofotômetro (λ= 500 nm), previamente zerado com lauril sulfato de sódio (LSS) (solução LSS 0,1% (m/v)), sendo a leitura correspondente ao tempo zero (A0). Após 10 min, uma nova alíquota da amostra foi preparada, conforme descrito anteriormente, e a absorbância (A10) foi novamente medida em espectrofotômetro (UV/VIS (918-GBD). O Índice de Atividade Emulsificante (EAI - Emulsifying Activity Index) foi calculado em m²/g, utilizando a equação abaixo.

$$EAI(m^2/g) = \frac{2*2{,}303*100*A_0}{C*fv*10000} \quad \text{(Eq. 5)}$$

Sendo que:

A0 = absorbância da emulsão no tempo zero (após a homogeneização);

c = a concentração da amostra proteica (g/mL) (massa da amostra dividida por 60 mL).

NOTA: Os números 2 e 2,303 são valores fixos, como proposto por Pearce e Kinsella (1978). O número 100 corresponde ao fator de diluição, fv é a fração de volume do óleo adicionado/presente na emulsão e 10000 é usado para a correção da unidade de expressão do resultado.

O Índice de Estabilidade da Emulsão (ESI em minutos) foi calculado utilizando a equação abaixo:

$$ESI(min) = \frac{A_0}{A_0 - A_{10}} * 10 \qquad \text{(Eq. 6)}$$

Sendo que:

A10 = absorbância da emulsão no tempo após 10 min;

2.5. Determinação de compostos fenólicos totais (CFT)

A determinação dos compostos fenólicos totais (CFT) da farinha de baru foi realizada de acordo com metodologia proposta por Singleton e Rossi (1965). Primeiramente, foi preparado um extrato por meio da mistura de solventes (metanol 50% v/v, acetona 70% v/v e água), utilizado como branco, e acrescido com 2,5 g de farinha de baru para determinação do teor de compostos fenólicos totais da amostra. Após 60 min de reação do extrato com o reagente de Folin-Ciocalteu, a densidade óptica foi determinada a 765 nm, em espectrofotômetro (UV/VIS-918-GBD). Uma curva de calibração (Y= 0,007 x + 0,024; R^2 = 0,9925) foi previamente preparada, utilizando ácido gálico como padrão, e os resultados obtidos foram expressos em mg de ácido gálico equivalente por 100 g de amostra (mg de EAG/100 g de amostra).

2.6. Determinação da capacidade antioxidante (ABTS e DPPH)

A determinação da capacidade antioxidante da farinha de baru foi realizada conforme metodologia descrita por (Re *et al.*, 1999), utilizando uma curva padrão de Trolox (0 a 150 μmol.L^{-1}) com diferentes concentrações da amostra, juntamente com o radical ABTS • + (2,2'-azinobis3-etil-benzotiazolina-6-sulfonato). As leituras da amostra foram realizadas em espectrofotômetro UV-visível, λ= 734 nm, após 6 minutos do início da reação foi preparado uma mistura de solventes (acetona 70 % v/v: metanol 50 v/v %: água e 2,5 g de farinha) e utilizado como branco, para calibrar o espectrofotômetro. Todas as etapas desta análise foram realizadas ao abrigo da luz. Os resultados foram expressos em Trolox Equivalente (TE), (μmol de Trolox /g de matéria seca), utilizando uma curva de calibração (Y= -0,0888x + 0,5054; R^2= 0,9902). (Nenadis et al., 2004).

A análise de DPPH (2,2-difenil-1-picrilhidrazil) foi realizada de acordo com a metodologia proposta por Brand-Williams, Cuvelier e Berset, 1995, e descrita por Boroski et

al 2015. O meio reacional foi preparado a partir de uma solução de DPPH (0,1 mmol.L^{-1}), recentemente preparada, e adicionada a diferentes concentrações do extrato da farinha e incubada por 45 min, ao abrigo da luz. Em seguida, a redução da absorbância foi avaliada em espectrofotômetro (UV/VIS-918 GBD), em λ= 517 nm, sendo construída a curva de calibração para calcular o valor do IC_{50} e do índice de atividade antioxidante (IAA), conforme equação abaixo proposta por (Scherer e Godoy, 2009).

$$IAA = \frac{[DPPH]_{final}}{IC_{50}} \qquad \text{(Eq. 7)}$$

Sendo que:
[DPPH] final = concentração final da solução DPPH
IC_{50} = concentração de extrato antioxidante necessária para inibir 50% do radical DPPH.
Ambos expressos em mg/mL.

3. Análise dos resultados

Os resultados foram analisados por meio de análise descritiva, sendo calculadas as médias e os respectivos desvios padrão e por meio da realização de ANOVA seguido de teste de Tukey, quando necessário.

4. RESULTADOS E DISCUSSÃO

4.1. Composição centesimal

O rendimento da farinha de baru após secagem e moagem foi de 22 % em relação a massa inicial da torta prensada, proveniente do processamento de bebida à base de amêndoa de baru. O teor médio de umidade da farinha da torta da amêndoa de baru foi de 3,6% (m/m) (Tabela 1), valor próximo aos encontrados na literatura para farinhas da polpa e da casca da amêndoa de baru (4,67 %) seca em estufa de circulação forçada a 60ºC °C (tempo de secagem não informado pelos autores) Santos et al., 2022 e abaixo do valor máximo (15%) estabelecido pela legislação brasileita para farinha (BRASIL, 2022). Esse baixo teor de umidade das farinhas é importante para conservação deste produto, visto que a água pode favorever o crescimento microbiano, a ativação de enzimas, e desencadear reaçãoes (Lancelot *et al.*, 2021).

Tabela 1. Valores médios (± desvio padrão) da composição centesimal da farinha da torta do processamento de bebida de baru.

Características	**Valores Médios (% m/m)**
Carboidratos totais	21,8
Água total	3,6±0,1
Proteínas	26,0±0,2
Lipídeos	47,3 ± 0,1
Cinzas	1,8±0,1

A farinha da torta de amêndoa apresentou teor de proteínas elevado (26%), sendo esse macronutriente considerado importante e indispensável à saúde e nutrição humana (Kumar *et al.*, 2022). A farinha da torta da amêndoa de baru apresentou maior teor proteico do que a farinha obtida a partir do resíduo gerado da produção de bebidas isotônicas (9,52%) (Ferreira *et al.*, 2015). Fontes vegetais com alto teor de proteínas têm sido alvo de diversos estudos com o objetivo de substituir as proteínas de fonte animal, impulsionando as pesquisas por fontes alternativas e não convencionais. Maciel et al. (2020) obtiveram a partir da torta de noz pecã, uma farinha contendo 21,87 g de proteína/100 g de farinha. Canaan et al., 2022, ao avaliarem o potencial de geração de produtos de alto valor agregado da okara (torta obtida a partir do processamento de leite de soja), destacaram que tais resíduos apresentaram alto valor nutricional, com 39,0% de proteína, 24,09% de lipídios e 16,75% de fibras totais, sendo considerada uma fonte proteica de baixo custo e pouco valorizada.

No que se refere ao teor de lipídeos totais, farinha da torta de amêndoa de baru apresentou um alto conteúdo (47,3%). No entanto, os lipídios provenientes de oleaginosas apresentam um bom perfil de ácidos graxos (Ômega 6, Ômega 3 e ácido oleico), atribuído principalmente aos ácidos graxos poli-insaturados (PUFA) e/ou ácidos graxos monoinsaturados (MUFA), compostos amplamente aclamados por seu comprovado impacto positivo na saúde humana (Gandhi, Tiwari e Sellamuthu, 2022; Gonçalves et al., 2023; Jardim, Domingues e Alves, 2023; Polmann et al., 2021). Em geral, o óleo da amêndoa de baru apresenta uma composição de cerca de 50% de PUFAS e 30% de MUFAS, que associado a presença de outros compostos, pode ser benéfico à saúde com efeitos na redução de massa

corporal e nos níveis de colesterol, além de reduzir estresse oxidativo (antioxidantes)(Alves-Santos, Fernandes e Naves, 2021; Paulo *et al.*, 2023).

O teor de carboidratos totais para a FTB é semelhante aos teores encontrados para farinhas de amendoas que em geral varia entre 20-25%, sendo considerado do ponto de vista nutricional como baixo em carboidratos quando comparado as farinhas de cereais, além disso, tais carboidratos podem constribuir para a saúde digestiva além de aumentar a saciedade. Morais et al., 2020 ao avaliar o conteúdo de carboidratos de farinhas da torta obtida do processamento de bebidas de castanha de caju, obteve respectivamente para as formulações A e B 27,53% e 26,27% de carboidratos que o obtido neste trabalho. Os carboidratos são fonte importante de energia, sendo um dos três principais macronutrientes presentes na dieta humana, além disso auxiliam no controle da glicose no sangue e o metabolismo da insulina (Holesh, Aslam e Martins 2023; Sievenpiper, 2021).

Já o teor de cinzas tem relação com o conteúdo mineral da farinha, para aquelas produzidas tendo como fontes amendoas e castanhas esse conteúdo pode variar de 2-3% estando o valor obtido para a FTB dentro dessa faixa, onde o conteúdo obtido pode refletir que esta apresenta alta qualidade em relação ao conteúdo mineral. O teor médio de cinzas determinado por Morais et al., 2020 foi em média de 2% para as farinhas obtidas a partir da torta de castasnha de caju.

A farinha obtida a partir do resíduo gerado da produção de bebida plant-based por ser fonte de proteínas, e pode ser utilizada para enriquecer o valor nutricional de diferentes produtos alimentícios. Além disso, essas farinhas obtidas de subprodutos ou co-produtos têm potencial para atuar com diferentes funções tecnológicas, melhorando a qualidade e aspectos associados a textura dos alimentos (Padayachee *et al.*, 2017; Santos, Lopes da Silva e Pintado, 2022).

4.2. Análises Físicas e químicas

Os valores de pH e de atividade de água (Aw) da farinha produzida a partir da torta de amêndoa de baru foram 6,24 ±0,05 e 0,2234 ± 0,002, respectivamente. A Aw é uma medida relacionado ao desenvolvimento microbiano, e em valores de Aw na faixa de 0,3-0,2, em geral, não ocorre proliferação microbiana (Garces-Vega, Ryser e Marks, 2019; Olaimat *et al.*, 2020). Em contrapartida, em função do elevado teor de lipídios, como os ácidos graxos insaturados, e do baixo valor de Aw, problemas com oxidação podem ocasionar rancidez na farinha nesse

caso, o armazenamento adequado tem forte influência sobre a qualidade final do produto (Barden e Decker, 2013).

Na Tabela 2 estão representados os valores determinados para as coordenadas L*, hº e C*. A cor perceptível para a torta e a farinha de amêndoa baseia-se na combinação tridimensional entre essas coordenadas cilíndricas, permitindo determinar em qual espaço de cor a torta e a farinha obtida estão posicionadas. Além da determinação das coordenadas, a diferença de cor total (ΔE*) entre as amostras também foi calculada.

Tabela 2. Coordenadas de cor obtidas para a torta da amêndoa e para a farinha obtida a partir dela.

	Amostras	
Coordenadas	**Torta da amêndoa**	**Farinha**
L*	56,42 ± 1,1	46,53± 1,1
a*	6,03± 0,08	12,53± 0,27
b*	21,39± 0,18	28,16± 1,1
hº	74,26	65,98
C*	22,22	31,26
ΔE*	13,63	

A partir das coordenadas colorimétricas a* e b*, pode-se observar que as amostras se encontram localizadas no primeiro quadrante, que varia de 0º (vermelho) a 90º (amarelo), do espaço de cor L*, a* e b*, representadas graficamente conforme Figura 2.

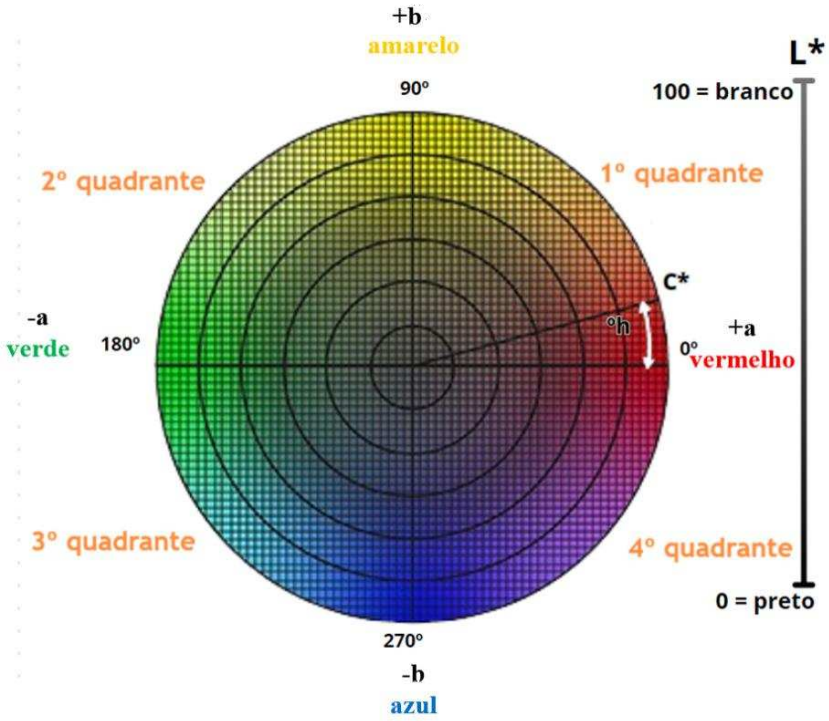

Figura 2. Espaço de cor para as coordenadas L*, a* e b*. **Fonte:** Os autores.

A luminosidade (L*) está localizada no eixo principal da Figura 2, na qual quanto mais próximo de zero o valor atribuído a L* mais escura é a amostra e quanto mais próxima de cem for esse valor mais clara é a amostra. Nesse contexto, foi observado que a torta se apresentou mais clara do que a farinha. Quanto à tonalidade, o valor do ângulo h (em graus) indicou que a amostra está situada no primeiro quadrante, sendo os valores de a* e b* positivos e se encontram na região do laranja. Já a saturação (C*) fornece a intensidade ou a quantidade de uma tonalidade, ou seja, quanto maior o valor dessa coordenada, mais intensa e perceptível será a cor, assim a farinha obtida apresenta uma cor mais intensa comparada a da torta (Ferreira e Spricigo, 2017; Pathare, Opara e Al-Said, 2013).

A partir da diferença total de cor (ΔE*), foi possível inferir sobre as alterações de coloração que ocorreram na torta de baru durante o processo de secagem e moagem, demonstrando que a farinha produzida apresentou mudanças perceptíveis visualmente. O valor da diferença total de cor observada foi de 13,63, com redução da coordenada L*, indicando escurecimento da amostra. De acordo com(Ferreira *et al.*, 2021), diferenças observadas com ΔE*>3 poderiam ser percebidas com facilidade pelo consumidor, podendo ser descritas como bastante pronunciada. Essa variação pode ser explicada pela temperatura empregada durante a secagem (60 ºC), que pode ter contribuído para a ocorrência de processos espontâneos como a

oxidação lipídica de ácidos graxos insaturados, que são suscetíveis às mudanças de cor, além da formação de compostos de baixo peso molecular, sendo o calor, a luz e a presença de oxigênio fatores promotores da reação além de reações de escurecimento enzimático (Chemat *et al.*, 2023). No entanto, após a obtenção da farinha de baru, é importante entender e controlar o processo de armazenamento para retardar mudanças indesejadas na cor e na qualidade do produto.

Similarmente, Maciel et al., 2020 produziram farinhas a partir da torta de noz pecã e encontraram a tonalidade marrom com valores localizados também no primeiro quadrante (0 - 90º) do espaço de cor, no entanto o ao valor de L* foi maior do que os encontrado para as farinhas de baru, indicando produtos de coloração mais clara. Pasqualone et al., 2020, ao desenvolverem biscoitos formulados com 10% e 20% de farinha de casca de amêndoa, como forma de aproveitar esse subproduto, observaram uma $\Delta E^*>12$ quando comparado com a formulação contendo somente farinha de trigo, sendo essa diferença maior à medida que uma maior concentração de farinha de amêndoa foi adicionada. Por haver alteração facilmente perceptível na tonalidade do produto, durante a substituição da farinha convencional por aquela obtida de coprodutos ou subprodutos, uma avaliação da percepção e da aceitação dos consumidores deve ser feita, já que cor é um atributo importante para a qualidade dos alimentos.

4.3. Propriedades tecno-funcionais

4.3.1. Capacidade de retenção de água capacidade de retenção de óleo

O valor médio da capacidade de retenção de água (WHC) da farinha de baru foi de 2,92 ± 0,05 (g de água/g de amostra), enquanto o valor médio da capacidade de retenção de óleo foi de 1,14± 0,07 (g de óleo / g de amostra), conforme representado pela Figura 3.

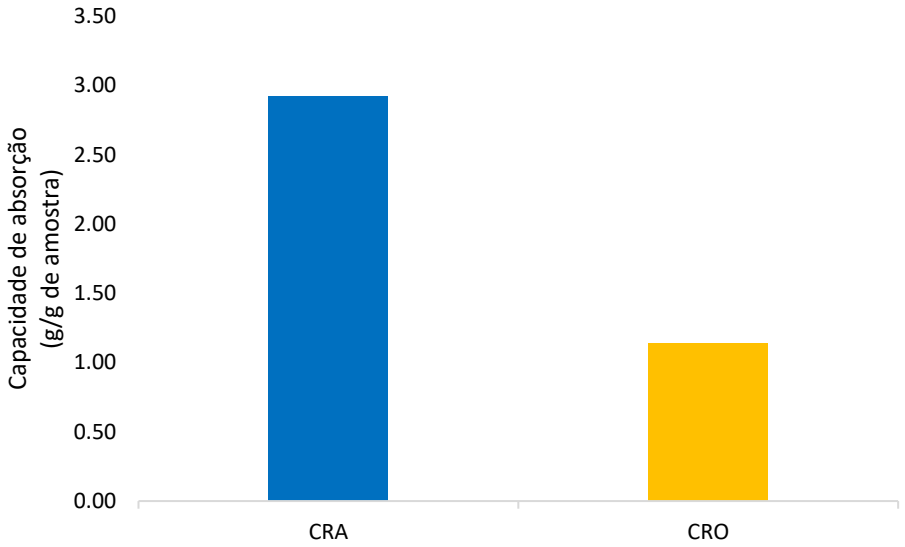

Figura 3. Capacidade de absorção de água (CRA) e capacidade de absorção de óleo (CRO) da farinha obtida da torta retida na etapa de filtração da bebida.

A avaliação das propriedades CRA e CRO é importante para o emprego da farinha de baru como ingrediente e sua aplicação para o desenvolvimento de diversos produtos, sendo utilizados como uma maneira de predizer a sua influência nas propriedades tecnológicas do alimento (Guimarães *et al.*, 2020). De acordo com Vieira 2017, uma CRO mais elevada é interessante quando se deseja produtos com maior estabilidade, sendo estes formulados com maior teor de lipídeos ou na forma de emulsões. No caso de uma CRA mais elevada, o emprego do ingrediente seria benéfico para modificação da viscosidade e da textura de alguns produtos.

Jain, Prakash e Radha, 2015 obtitiveram uma CRA de 2,38 g/g de amostra para a farinha de amendoim desengorduradas, sendo este valor inferior ao obtido neste estudo. A capacidade de absorver água das farinhas está relacionado a quantidade de aminoácidos polares disponíveis para interagir com água (Chandra, Singh e Kumari, 2015; Kuntz, (1971). Em geral, ingredientes com maior WHC são adequados para aplicações em alimentos mais viscosos, como molhos, e em produtos de panificação.

No caso da capacidade de absorção de óleo, como a farinha de baru apresenta um alto teor de lipídeos, a absorção do óleo de soja pode ter sido dificultada. De acordo com Chandra, Singh e Kumari, 2015, um teor elevado de lipídeos pode afetar de maneira negativa a capacidade de absorção de óleo de farinhas compostas (combinação de diferentes tipos de farinhas), uma vez que as cadeias de aminoácidos apolares das proteínas são responsáveis pela OHC, pois interagem com os lipídeos, permitindo a retenção do óleo que foi absorvido (Du *et*

al., 2014). No entanto, farinha da torta da amêndoa de baru, embora possua baixa capacidade de retenção de óleo, apresenta potencial para atuar como substituto parcial e/ou total da farinha de trigo.

4.3.2. Capacidade emulsificante e estabilidade da emulsão.

A capacidade emulsificante da farinha de baru foi avaliada em três condições distintas sendo estas sem adição de óleo de soja, com adição de 5 mL de óleo e com 20 mL de óleo, e está ilustrada na Figura 4. Observou-se diferenças significativas ($p<0.05$) entre os tratamentos, sendo que a farinha sem a adição de óleo de soja apresentou um maior Índice de Atividade Emulsificante (2769,94 EAI m^2/g) em comparação com as duas condições estudadas.

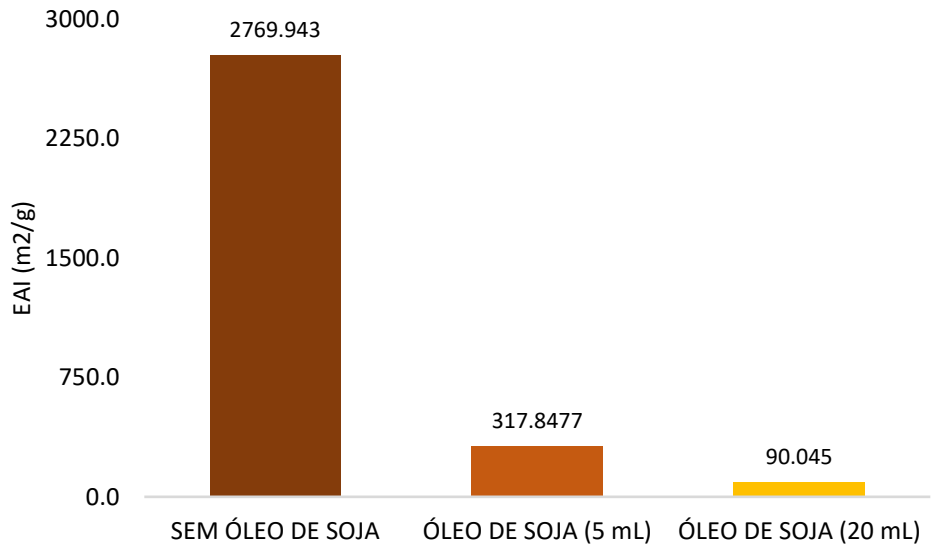

Figura 4. Capacidade emulsificante da farinha sem adição de óleo de soja, com adição de 5 mL de óleo de soja e com 20 mL de óleo de soja. **Fonte**: os autores.

A capacidade emulsificante é uma propriedade importante quando se trata de produtos alimentícios ricos em proteína, podendo ser afetada por fatores variados como o pH, o tipo de proteína, entre outros fatores (Teixeira *et al.*, 2018). No entanto, de acordo com Khattab, Arntfield e Nyachoti, 2009, emulsões que tem como base a ligação entre proteína-gordura-água, devem levar em consideração a influência de diferentes fatores químicos e físicos que podem estar envolvidos na formação da emulsão e que podem afetar tanto a textura quando a estabilidade delas. A presença de lipídeos é outro fator que pode afetar a capacidade emulsificante como descrito por (Teixeira *et al.*, 2018), que obteve uma EAI 20 m^2/g em

farinhas de castanha de sapucaia parcialmente desengordurada. Além disso, os autores ainda afirmaram que a gordura remanescente teve influência nas propriedades da emulsão. Neste trabalho, maiores médias de EAI foram obtidas para a amostra sem adição de óleo de soja, indicando que os lipídeos da amêndoa foram os principais responsáveis pelo processo de emulsificação.

O Índice de Estabilidade da Emulsão (ESI) variou entre 169 min para a condição sem óleo de seja e 323 min para a condição com 5 mL de óleo de soja (Figura 5), indicando que a adição de óleo de soja favorece a estabilidade física do sistema, ao longo do tempo.

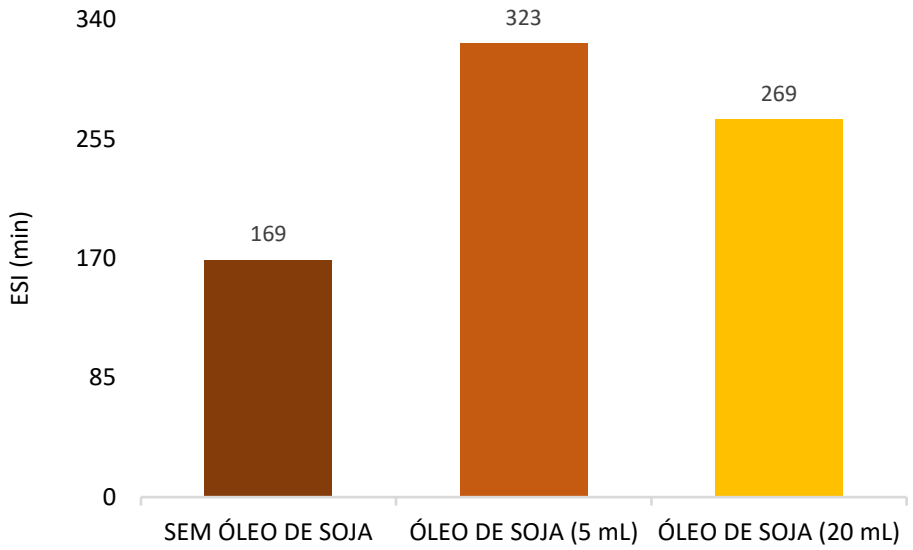

Figura 5. Índice de estabilidade e estabilidade cinética das amostras em diferentes condições.

Essa maior estabilidade pode ser explicada pelo aumento da concentração das gotículas de óleo presente na emulsão, fazendo com que esta fique mais resistente a coalescência e fazendo com que as gotículas de óleo levem mais tempo para coalescer, dessa forma, a estabilidade física melhora à medida que a concentração dessas gotas é incrementada, uma vez que essa concentração frequentemente pode ser expressa em termos da fração volumétrica da fase dispersa, ou seja, a quantidade de óleo em relação ao volume total da emulsão (McClements, Weiss e Corradini, 2020). Entretanto, o excesso de óleo, pode reduzir essa estabilidade, uma vez que nas condições aqui avaliadas essa relação não é direta, acarretando na desestabilização.

4.4. Determinação de compostos fenólicos totais (CFT)

O teor médio dos compostos fenólicos totais (CFT) da farinha de baru foi de 206,85±0,05 (mg de GAE/100 g de amostra), cujos resultados foram superiores aos obtidos por (Borges *et al.*, 2022; Lemos *et al.*, 2012) para a farinha de amêndoa de baru parcialmente desengordurada, cujos valores foram 28,06 ±5.61 e 113,3±1,8 (mg GAE·100 g^{-1}), respectivamente. Siqueira, Pacheco e Naves, 2015, entretanto, obteveram valores superiores para farinha de baru parcialmente desengordurada com teor médio de 588,11 mg GAE·100 g^{-1} de amostra.

Essa variação entre os valores de CFT pode ser atribuído ao tipo de solvente utilizado na preparação do extrato (metanol 50% v/v - acetona 70% v/v - água) (Castro, de, Mota e Cazedey, 2022; Mauro *et al.*, 2021). De acordo com (Santos *et al.*, 2020), os compostos fenólicos totais apresentam diversas propriedades capazes de conferir benefício à saúde em função de sua atividade de redução de elétrons, promovendo efeitos antimicrobianos e anti-inflamatórios, além de proteger o coração reduzindo o risco de desenvolvimento de doenças cardiovasculares.

Campidelli *et al.*, 2022 sugerem que a amêndoa de baru pode ser, dentre outras nozes, uma das mais consumidas no mundo, principalmente em função de sua composição rica em nutrientes e polifenóis como por exemplo a castanha de caju, macadâmias e avelãs. Assim, A farinha obtida da torta após o processamento da bebida mantém um elevado teor de compostos fenólicos, o que sugere seu potencial uso em alimentos, em vez de ser descartada como resíduo apresentando boa composição compostos fenólicos, distribuidos em 12 tipos diferentes de ácidos fenólicos possiveis de serem identificados (Lima *et al.*, 2022; Oliveira-Alves *et al.*, 2020).

4.5. Determinação da capacidade antioxidante (ABTS e DPPH)

A capacidade antioxidante da farinha de baru, determinada pela metodologia do radical ABTS, foi de 133,96 µmol de Trolox por 1 g de farinha, indicando a capacidade de sequestrar os radicais livres equivalente ao composto Trolox. Mauro *et al.*, 2021obtiveram aproximadamente 200 µmol de Trolox/g de farinha produzida a partir da amêndoa de baru, utilizando diferentes solventes (1: água; 2: acetona 80%; 3: etanol 80%; 4:metanol 80%; 5: Mistura de solventes (metanol 50% : acetona 70% : água)) no processo de extração. O tipo de solvente pode influenciar na determinação da capacidade antioxidante (Insanu *et al.*, 2022; Silva *et al.*, 2020). Boroski et al. 2015, ressaltam a importância da polaridade dos solventes que

pode afetar tanto a transferência de elétrons quanto a de hidrogênio. Em geral, recomenda-se o uso de solventes orgânicos em meio aquoso ao invés de solventes orgânicos puros, priorizando o uso de solventes não tóxicos.

Em relação a capacidade de sequestrar o radical DPPH foram foram necessários cerca de 350 mg de antioxidante por mL de extrato preparados a partir da farinha da torta de amêndoa de baru baru, sendo esta quantidade capaz de reduzi-lo em 50%. Assim ela apresenta uma baixa atividade antioxidante com uma IAA igua a 0,034, uma vez que o valores calculados são inferiores a 0,5 (Boroski et al., 2015; Scherer e Godoy, 2009). A literatura considera a amêndoa de baru como uma boa fonte de compostos com potencial antioxidante e seu consumo é indicado para aumentar a proteção contra doenças como diabetes e para a melhoria da resposta imunológica (Lemos *et al.*, 2012; Polmann *et al.*, 2021; Shahidi *et al.*, 2019).

Assim, a farinha demosntrou a capacidade de reduzir a atividades antioxidante utilizando o método ABTS e DPPH onde neste últimos os resultados foram de baixa capacidade de reduzir o radical que pode ter sido influenciado devido ao emprego de diferentes métodos de extração, a escolha do solvente, a proporção massa e solvente e principalmente a variação inerente à matéria-prima podem afetar os valores observados.

5. Conclusão

A farinha obtida como coproduto do processamento das bebidas à base de amêndoa de baru apresentou um elevado teor de proteínas, lipídios e compostos fenólicos, demonstrando potencial para ser utilizada como um ingrediente versátil e nutritivo no desenvolvimento e enriquecimento de alimentos, como bolos, brownies, doces tipo paçoca e barras de cereais. Adicionalmente, a farinha mostrou boas propriedades tecnológicas, incluindo capacidade de retenção de água e óleo, o que é favorável para sua aplicação em produtos alimentícios. Sua capacidade de emulsificação e estabilidade da semulsão reforça seu valor como ingrediente tecnofuncional. O reaproveitamento desta farinha não apenas contribui para a redução do desperdício alimentar, aproveitando integralmente a amêndoa de baru, mas também promove práticas mais sustentáveis e saudáveis na indústria alimentícia. As amêndoas de baru rica em, uma fonte pouco conhecida e explorada do bioma Cerrado, oferecem benefícios nutricionais e podem contribuir para uma dieta equilibrada, alinhando-se a hábitos alimentares mais saudáveis.

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CONCLUSÃO GERAL

O trabalho desenvolvido buscou utilizar diferentes metodologias sensoriais (qualitativas e quantitativas) para obtenção de informações sobre as percepções dos consumidores brasileiros sobre alimentos feitos de plantas. Além disso, propôs uma inovação no tratamento de dados qualitativos utilizando como ferramenta para análise dos dados coletados nas sessões de grupos de foco o software Iramuteq para reduzir a subjetividade e o tempo de análise desses dados.

A amêndoa de baru se mostrou uma fonte promissora para o desenvolvimento de alimentos *plant-based*. As bebidas de inverno feitas com amêndoas de baru, com sacarose e alulose, obtiveram boa aceitação pelos consumidores, que em sua maioria desconheciam a castanha de baru, mas demonstraram interesse em consumir produtos obtidos a partir dessa matéria prima. Esse interesse foi motivado principalmente pelas informações fornecidas sobre o baru e pela percepção de benefícios à saúde, principalmente no que diz respeito a substituição de açucares por edulcorantes que é uma demanda crescente e pode influenciar a tomada de decisão do consumidor.

Por fim, durante o processamento da bebida de inverno feitas com amêndoas de baru foi gerado um coproduto, a torta retida após a etapa de filtração, que foi utilizada para produção da farinha que foi caracterizada química e fisicamente. Portanto, foi proposto uma forma de aproveitar integralmente toda a matéria prima do processamento das bebidas, a fim de reduzir o desperdício e valorizar esse coproduto que se apresenta como um ingrediente de boa qualidade para o desenvolvimento outros produtos, com alto teor de proteínas e lipídeos. Essa farinha pode ser uma alternativa para ser adicionada integralmente ou forma parcial para melhorar a qualidade nutricional de alimentos e reduzir custos.

Nesse contexto, a popularidade e a difusão do conhecimento sobre a amêndoa de baru, fonte nativa brasileira, podem ser uma oportunidade para impulsionar o desenvolvimento de produtos *plant-based* indulgentes, sustentáveis e saudáveis, com características sensoriais agradáveis para atender os as demandas dos consumidores, principalmente os veganos, vegetarianos e flexitarianos.