Pesquisa Agropecuária Brasileira

Food Technology/ Original Article

ISSN 1678-3921

Journal homepage: www.embrapa.br/pab

For manuscript submission and journal contents, access: www.scielo.br/pab

Physicochemical characterization and sensory analysis of ready-to-eat foods formulated with olive leaf flour and acerola pulp

Camila Castencio Nogueira
Universidade Federal de Pelotas, Pós-Graduação em Nutrição e Alimentos, Pelotas, RS, Brazil.
E-mail: camilacastencionogueira@gmail.com

Alice Pereira Lourenson✉
Universidade Federal de Pelotas, Pós-Graduação em Ciência e Tecnologia de Alimentos, Pelotas, RS, Brazil.
E-mail: alicelourenzon@gmail.com

Gabriela dos Santos Ferrão
Universidade Federal de Pelotas, Pós-Graduação em Ciência e Tecnologia de Alimentos, Pelotas, RS, Brazil.
E-mail: gabrielaferrao92@gmail.com

Maicon da Silva Lacerda
Universidade Federal de Pelotas, Pós-Graduação em Ciência e Tecnologia de Alimentos, Pelotas, RS, Brazil.
E-mail: maiconlcrd@gmail.com

Samson Eneji Obogo
Universidade Federal de Pelotas, Pós-Graduação em Ciência e Tecnologia de Alimentos, Pelotas, RS, Brazil.
E-mail: obogosamson@gmail.com

Márcia Arocha Gularte
Universidade Federal de Pelotas, Pós-Graduação em Ciência e Tecnologia de Alimentos, Pelotas, RS, Brazil.
E-mail: arochagularte@gmail.com

✉ Corresponding author

Received
March 23, 2026

Accepted
July 30, 2026

How to cite
NOGUEIRA, C.C.; LOURENSON, A.P.; FERRÃO, G. dos S.; LACERDA, M. da S.; OBOGO, S.E.; GULARTE, M.A. Physicochemical characterization and sensory analysis of ready-to-eat foods formulated with olive leaf flour and acerola pulp. **Pesquisa Agropecuária Brasileira**, v.61, e04431, 2026. DOI: https://doi.org/10.1590/S1678-3921.pab2026.v61.04431.

Abstract – The objective of this work was to formulate cookies and cereal bars with olive (*Olea europaea*) leaf flour and acerola (*Malpighia emarginata*) pulp and to evaluate the physicochemical composition and sensory characteristics of these products. Proximate composition, texture profile, and microbiological analyses were carried out, as well as sensory evaluation by temporal dominance of sensations using the SensoMaker software. The cereal bars showed a higher fiber (11.49 ± 0.82) and protein (12.29 ± 0.52) content due to the presence of fiber-rich ingredients and added chocolate. Crispness and sweetness were the predominant sensory attributes for both products, in line with the expected sensory profile and supported by the texture analysis, which indicated hardness values of 1,859.62 ± 52.10 g for cookies and 1,322.10 ± 49.52 g for cereal bars. The obtained results show that the inclusion of by-products such as olive leaves and acerola pulp in food formulations is a promising alternative for the sustainable use of agro-industrial resources. Olive leaf flour, rich in antioxidant compounds, and acerola pulp, with a high vitamin C content, show a high potential for the development of new products that can offer health benefits to consumers.

Index terms: diet, food safety, functional foods, health, nutritional value.

Caracterização físico-química e análise sensorial de alimentos prontos para consumo formulados com farinha de folhas de oliveira e polpa de acerola

Resumo – O objetivo deste trabalho foi formular biscoitos e barras de cereais com farinha de folhas de oliveira (*Olea europaea*) e polpa de acerola (*Malpighia emarginata*) e avaliar a composição físico-química e as características sensoriais destes produtos. Foram realizadas análises de composição centesimal, perfil de textura e microbiológicas, além de avaliação sensorial por meio da dominância temporal das sensações, com uso do programa SensoMaker. As barras de cereais apresentaram maior teor de fibras (11,49 ± 0,82) e proteínas (12,29 ± 0,52) devido à presença de ingredientes ricos em fibras e à adição de chocolate. Crocância e doçura foram os atributos sensoriais predominantes em ambos os produtos, alinhando-se ao perfil sensorial esperado e corroborando os resultados das análises de textura, que indicaram dureza de 1.859,62 ± 52,10 g para os biscoitos e de 1.322,10 ± 49,52 g para as barras de cereais. Os resultados obtidos mostram que a inclusão de subprodutos como folhas de oliveira e polpa de acerola em formulações alimentares é alternativa promissora para o uso sustentável de recursos agroindustriais. As folhas de oliveira, ricas em compostos antioxidantes, e a polpa de acerola, com alto teor de vitamina C, mostram alto potencial para

This is an open-access article distributed under the Creative Commons Attribution 4.0 International License

o desenvolvimento de novos produtos que podem trazer benefícios para a saúde dos consumidores.

Termos para indexação: dieta, segurança alimentar, alimentos funcionais, saúde, valor nutricional.

Introduction

Over several decades, Brazil has been experiencing a nutritional transition, driven by significant changes in dietary patterns associated with epidemiological and demographic shifts, marked by a decline in undernutrition accompanied by a progressive rise in overweight and obesity across different life stages (Silva et al., 2022; The State of Food Security and Nutrition…, 2024). This trend can be partly attributed to increasingly fast-paced lifestyles, which often encourage the consumption of convenience foods, compromising overall diet quality (Martins et al., 2021/2022; Kanuf et al., 2024). The result is an increase in the burden of non-communicable chronic diseases, including cardiovascular diseases, diabetes, cancer, and chronic respiratory diseases (The State of Food Security and Nutrition…, 2024).

In this scenario, the demand for nutritional care and healthier food options has intensified. Concurrently, growing concerns over the environmental impacts of food production have fueled interest in the valorization of agro-industrial by-products as sustainable ingredients for the development of functional foods, contributing to circular economy strategies and more sustainable food systems (European Commission, 2024; The State of Food Security and Nutrition…, 2024; UNEP, 2024). Examples of enriching food by-products include olive (*Olea europaea* L.) leaves and acerola (*Malpighia emarginata* DC.) pulp.

In Brazil, the leading olive oil producer is Rio Grande do Sul. In 2026, the state accounted for approximately 1.17 million liters of the nation's total 1.43 million liters – a record volume that marks a recovery from heavy losses caused by excessive rainfall during the 2024 and 2025 harvests (Silveira, 2024; Ibraoliva, 2026). The olive oil industry generates substantial amounts of by-products, including pomace, wastewater, leaves, and pruning residues, which have attracted increasing attention as valuable sources of bioactive compounds for food, pharmaceutical, cosmetic, and agricultural applications within a circular bioeconomy framework (Cecchi & Innocenti, 2023; Morciano et al., 2024). Specifically, olive leaves are generated both during tree pruning and fruit processing for olive oil or table olive production, when branches, leaves, and other debris are discarded (Romero-Márquez et al., 2024). Given the high content of phenolic compounds in olive leaves, particularly oleuropein with a strong antioxidant capacity, several studies have investigated the health benefits of incorporating these by-products into food or pharmaceutical formulations (Cavalheiro et al., 2014; Coppa et al., 2017; Martiny et al., 2020; Bortolini et al., 2021). Pereira et al. (2015), for instance, evaluated the antiproliferative effect of flavonoid morin and olive leaf extract on the H460 human lung cancer cell line, observing apoptosis-induced cell death at a concentration of 800 μg mL^{-1} olive leaf extract.

Grown in the southern region of Brazil, acerola is a fruit rich in vitamin C that can be consumed fresh or processed into juices, ice creams, and jams, in addition to being added through extracted ascorbic acid to the formulation of pharmaceutical products (Jacobs et al., 2020; Olęszki & Harasym, 2024). Although acerola is primarily used for pulp and juice production due to its high perishability, its applicability should be further explored in other food formulations considering its high concentration of bioactive compounds, including phenolics, phenylpropanoids, flavonoids, anthocyanins, carotenoids, and the aforementioned vitamin C (Magalhães, 2021).

The objective of this work was to formulate cookies and cereal bars with olive leaf flour and acerola pulp and to evaluate the physicochemical composition and sensory characteristics of these products.

Materials and Methods

The study was conducted at Centro de Ciências Químicas, Farmacêuticas e de Alimentos of Universidade Federal de Pelotas, located at the Capão do Leão campus, in the state of Rio Grande do Sul, Brazil. The research was approved by Comitê de Ética em Pesquisa com Seres Humanos, the Human Research Ethics Committee of Universidade Federal de Pelotas (under Certificate of Submission for Ethical Appraisal number 76628617.0.00005317). Participants in the sensory analysis were asked to sign an informed consent form.

The stages of the study were: production of cookie-type biscuits and cereal bars, physicochemical

analyses, and sensory evaluations at the Sensory Analysis Laboratory of Universidade Federal de Pelotas.

The ingredients used for product preparation were purchased from local markets, supermarkets, and/or natural food stores, being stored under recommended conditions. Frozen acerola pulp was bought from suppliers at the Centrais de Abastecimento (CEASA) wholesale market in the municipality of Porto Alegre, in the state of Rio Grande do Sul. Leaves from the Arbequina and Arbosana olive varieties were acquired at the Estância Guarda Velha rural property, located in the municipality of Pinheiro Machado, in the same state (31º29'59.4"S, 53º30'32.7"W). The olive leaf sample was collected during the oil extraction process. After harvesting, the leaves were washed, subjected to grinding in a blender, milled using a knife mill, and sieved using a 35 mesh screen with a 0.42 mm opening (ASTM 40/Tyler 35, Granutest, Bertel, Caieiras, SP, Brazil) to obtain a fine powder.

The cookies were prepared based on the method described by Sousa et al. (2020). The ingredients and respective quantities used in the formulation are presented in Table 1. For the preparation, the ingredients were manually mixed using a spoon until a homogeneous dough was obtained. The dough was placed on a flat surface and rolled out with a pastry roller to a thickness of 6.0 mm, then shaped using a cylindrical cutter (4.7 cm in diameter), placed on a baking tray, and baked in a preheated oven at 150°C for 10 min. After cooling, the cookies were wrapped in aluminum foil and stored in lidded plastic containers for subsequent analyses.

Table 1. Formulation of cookies enriched with olive (*Olea europaea*) leaf flour and acerola (*Malpighia emarginata*) pulp.

Ingredient	Quantity (%)
Wheat flour	29.59
Rolled oats	11.83
Chocolate chips	8.88
Soybean oil	18.64
Brown sugar	14.79
Baking powder	4.44
Olive leaf flour	5.92
Acerola pulp	5.92

The cereal bars were formulated according to Radunz et al. (2016). The ingredients used in their preparation included rolled oats, chia seeds, toasted quinoa grains, olive leaf powder, acerola pulp, and chocolate. First, the dry ingredients (rolled oats, toasted quinoa, chia seeds, and olive leaf powder) were mixed together, then acerola pulp was incorporated into the dry mixture, followed by the addition of melted chocolate that had been previously heated in a water bath. All ingredients were blended until a homogeneous mass was obtained. This mixture was poured into aluminum molds (12×5 cm) lined with aluminum foil and baked in an electric oven at 150°C for 15 min. After baking, the bars were pressed to approximately 1.0 cm in thickness, covered with plastic film, and refrigerated. Once cooled, the bars were removed from the molds and individually wrapped in aluminum foil packaging for subsequent analyses.

The chemical characterization of the formulated products was carried out in triplicate, evaluating moisture, ash, ether extract, protein, crude fiber, and carbohydrate contents, calculated by the difference in the total percentage of sample composition (Zenebon et al., 2008). The total energy value was determined using the formula:

Total energy value = (C × 4) + (P × 4) + (L × 9), where C represents carbohydrates, P is total protein, and L is ether extract.

The color profile of six cookies and six cereal bars was determined 24 hours after production (Konica Minolta, 2020). The CR-310 chroma meter (Konica Minolta, Tokyo, Japan) was used since it allows color readings in a three-dimensional system along three axes, measuring brightness from black to white (L*) and chromaticity from green to red (a*) and blue to yellow (b*).

For all samples, soluble solids content was obtained using a digital refractometer, and the results were expressed in °Brix (Latimer Jr., 2012). The pH value was measured using a benchtop pH meter, calibrated according to the manufacturer's instructions with standard buffer solutions at pH 4.0 and 7.0 (Zenebon et al., 2008).

The texture analysis was performed after product formulation. All samples were analyzed using the TA.XT Plus Texture Analyzer (Stable Micro Systems, Surrey, United Kingdom). For cookies, the texture profile analysis method, calibrated with a 5.0 kg load

cell, was applied. Each cookie was punctured using a cylindrical P/20 probe (20 mm diameter). The pre-test, test, and post-test speeds were 1.00, 0.50, and 10.00 $mm \cdot s^{-1}$, respectively, with a 50% sample penetration. Hardness and fracturability parameters were recorded (Johnson, 2023). For cereal bars, a 20 mm cylindrical probe was also used, but test speed was 5.00 $mm \cdot s^{-1}$ and sample penetration, 60%. The evaluated parameters included hardness, adhesiveness, cohesiveness, gumminess, springiness, chewiness, and resilience (Johnson, 2023).

Because they were prepared in accordance with Normative Instruction IN No. 161 of July 1, 2022 (BRASIL, 2022) that establishes microbiological standards for food products, the cookies and cereal bars were subjected to tests for *Salmonella* in 25 g, presumptive *Bacillus cereus* per gram, *Escherichia coli* per gram, and yeasts and molds per gram. Based on the characteristics of the studied material, the samples were classified under group 19(d), consisting of breads, cakes, crackers, cookies without filling, and other bakery products that are shelf-stable at room temperature (Anvisa, 2022b).

After the characterization of the formulated products, the sensory analysis was performed using the SensoMaker software (Universidade Federal de Lavras, Lavras, MG, Brazil). Data were acquired through the temporal dominance of sensations test aimed to describe the evolution of different sensations perceived during the consumption of a product.

A total of 15 trained panelists from Universidade Federal de Pelotas participated voluntarily in the study. Initially, they were familiarized with the SensoMaker software and instructed on how to record the temporal sequence of dominant sensory attributes, defined as the sensations perceived with the greatest clarity and intensity at a given moment (Pineau et al., 2009; Pinheiro et al., 2013). Prior to testing, a brief explanation of the product was provided. Samples (5.0 g) were presented on white porcelain plates, and panelists were instructed to rinse their mouths with water to clear their palate between tasting (Nunes & Pinheiro, 2014). To begin the evaluation, panelists clicked the "start" button and placed a 5.0 g sample in their mouth for 2 s. Over a 30 s period, they selected the dominant sensory attribute by clicking the corresponding button on the computer screen using the mouse.

The statistical analysis was performed with the XLSTAT software (Lumivero, Denver, CO, USA). For proximate composition, the analysis of variance and Student's t-test were applied at a 5% significance level. Results at $p \leq 0.05$ were considered statistically significant. The methodology of Pineau et al. (2009) was used in the SensoMaker software to calculate temporal dominance sensation curves for each sample. Two reference lines were plotted on the graph: the chance level, representing the dominance rate that an attribute may reach randomly; and the significance level, indicating the minimum proportion required for a sensation to be considered statistically significant. This calculation was based on the confidence interval of a binomial proportion using a normal approximation, as described by the previously cited authors. Sensations above the significance level line were considered statistically relevant in the analysis of the temporal dominance sensation curves.

Results and Discussion

Proximate composition based on the cookie and cereal bar formulations is presented in Table 2. Moisture content – an essential parameter for assessing shelf life, texture, microbiological stability, and storage characteristics (Damodaran & Parkin, 2017) – was higher in the cereal bar samples. However, both evaluated products complied with the maximum moisture content limit of 15% established by RDC No. 711 of July 1, 2022 (Anvisa, 2022b).

Table 2. Physicochemical characterization of cookie and cereal bar samples formulated with olive (*Olea europaea*) leaf flour and acerola (*Malpighia emarginata*) pulp.

Variable	Cookie	Cereal bar
Moisture (%)	2.40 ± 0.13	4.15 ± 0.32*
Ash (%)	2.13 ± 0.01	2.68 ± 0.05*
Crude fiber (%)	6.44 ± 0.24	11.49 ± 0.82*
Protein (%)	5.75 ± 0.31	12.29 ± 0.52*
Lipid (%)	17.95 ± 1.91	17.76 ± 0.58
Carbohydrate (%)	65.33 ± 1.95*	51.63 ± 1.18
Total energy value (Kcal 100 g^{-1})	445.87	415.52

*Mean and standard deviation, representing a significant difference in the column by the t-test at a 5% level.

Ash content, which indicates the presence of inorganic material (i.e., minerals) in samples (Nielsen 2017), was also higher in the cereal bars. A similar value of 2.13 ± 0.06% was obtained by Dias et al. (2020) in yam (*Dioscorea* L.) flour-based cereal bars supplemented with whey protein concentrate.

Fiber and protein contents were likewise higher in the cereal bars, driven by the inclusion of whole grains and chocolate, along with the addition of olive leaf flour and acerola pulp, both rich in dietary fiber, protein, bioactive compounds, vitamins, and minerals. Similar findings were reported in the literature. Faccioli et al. (2021) observed that olive leaf flour contained 54.08 ± 1.75 g dietary fiber and that formulations enriched with this ingredient reached protein values from 18.90 to 19.94 g. Marques et al. (2013) found a high content of 28.58 g 100 g^{-1} insoluble fiber and 11.55 g 100 g^{-1} protein in acerola bagasse flour, whereas Magalhães et al. (2021) obtained a protein content of 9.12% in acerola flour.

When incorporated into cookie and cereal bar formulations, olive leaf flour and acerola pulp not only provide nutritional benefits, but also show potential to address current consumer demands for functional, convenient, and sustainable foods (Pal et al., 2024). The resulting high fiber and protein contents, combined with natural antioxidant compounds, position these formulations as promising strategies for the prevention of non-communicable chronic diseases associated with modern lifestyles and poor dietary habits (Adefegha, 2018).

The colorimetric profile of the formulated samples is presented in Table 3. For both products, the L*, a*, and B* values indicated, respectively: a relatively low luminosity, reflecting the darker color tones of the samples; a reddish hue; and a yellowish coloration. Evaluating cookies formulated with betel (*Piper betle* L.) leaves, Karunanithi et al. (2024) also observed a more yellowish coloration in the tested samples, with values ranging from 35.5 ± 0.01 to 18.28 ± 0.02.

The average of total soluble solids was 3.6 °Brix for cookies and 2.2 °Brix for cereal bars. These low values may be associated with the fibrous nature and low sugar content of the used ingredients. Dada et al. (2024) found a similar value of 2.45 °Brix for pectin supplemented with 10% olive leaf extract, used as edible coating for cherry tomatoes [*Solanum lycopersicum* var. *cerasiforme* (Alef.) Fosberg]. Contrastingly, Aquino et al. (2010) obtained an average of 47.5 °Brix for acerola residue flour.

In the pH analysis, the detected values were 6.13 for the cookies and 5.57 for the cereal bars, reflecting the natural acidity of acerola, which has potential to aid in product preservation and inhibit microbial growth (Huang et al., 2022).

The results of the texture analysis were presented as means and standard deviations (Tables 4 and 5. Hardness and fracturability are important parameters influencing the quality of products such as cookies and cereal bars. Hardness measures the maximum force required to break a sample, whereas racturability reflects a food's tendency to crumble or disintegrate

Table 3. Colorimetric profile of cookie and cereal bar samples formulated with olive (*Olea europaea*) leaf flour and acerola (*Malpighia emarginata*) pulp[(1)].

Sample	L*	a*	b*
Cookie	30.87 ± 4.13	6.33 ± 1.45	20.13 ± 2.94
Cereal bar	37.03 ± 7.58	3.85 ± 1.82	15.57 ± 4.33

[(1)]Color readings were performed in a three-dimensional system along three axes, measuring brightness from black to white (L*) and chromaticity from green to red (a*) and blue to yellow (b*).

Table 4. Texture analysis of cookies formulated with olive (*Olea europaea*) leaf flour and acerola (*Malpighia emarginata*) pulp.

Texture characteristic	Value
Hardness (N)	18.24 ± 0.51
Fracturability (mm)	6.75 ± 0.88

Table 5. Texture analysis of cereal bars formulated with olive (*Olea europaea*) leaf flour and acerola (*Malpighia emarginata*) pulp.

Texture characteristic	Value
Hardness (g)	1,322.1 ± 49.52
Fracturability (g)	1,254.4 ± 18.90
Adhesiveness (g)	-4.056 ± 0.91
Elasticity	0.317 ± 0.03
Cohesiveness	0.096 ± 0.01
Gumminess	1,341.62 ± 27.93
Chewiness	419.587 ± 30.67
Resilience	0.049 ± 0.002

under applied force (Mancebo et al., 2015). The latter is directly associated with expected crispness and is generally related to a higher hardness (Gusmão et al., 2018). In this line, Karunanithi et al. (2024) reported higher hardness values for cookies formulated with betel (*Piper betle* L.) leaves – even the lowest concentration of 3% yielded 4,652.24 ± 122.6 g. This effect occurs because water-absorbing ingredients, such as dietary fibers, increase dough stickiness and subsequently hardness, particularly after baking (Jan et al., 2018). Regarding fracturability, the findings of the present study align with those of Sarques et al. (2024), who obtained a value of 7.95 mm for a formulation containing cocoa bran and rice flour, half of the ingredients used here.

Although the cereal bars showed a higher hardness, the values for fracturability were also higher, which is desirable to reach the expected crispness in products formulated with grains. Regarding elasticity, the results showed a low flexibility when pressure was applied. Adhesiveness was likewise relatively low despite the bar being formulated with melted milk chocolate, probably due to a reduced stickiness of the final product after baking. Favorable results were obtained for gumminess and chewiness, meaning that the cereal bars presented a low resistance when consumed.

No microorganisms – such as *Salmonella* spp., coagulase-positive *Staphylococcus*, or *Bacillus cereus* – were detected (Table 6). This absence may be associated with unfavorable conditions for microbial growth. However, thermotolerant coliforms were found at levels of < 3 most probable number per gram; notably, *Escherichia coli* was absent in the analyzed samples. The results for molds and yeasts were in accordance with current legislation (Anvisa, 2022a). Since several factors (including pH, moisture content, and handling conditions) influence microbial growth in foods, microbiological assessment is essential to ensure food safety and to deliver contamination-free products to consumers (Pereira et al., 2015).

For the sensory analysis of the cookies, the selected attributes were crunchy, sweet, leafy aroma, gritty, soft, leafy aftertaste, bitter, and dry (Figures 1 and 2). The sensation "crunchy" dominated within the first 5 s of chewing, reaching a dominance rate of approximately 0.4 between 5 and 10 s. This suggests this is the first characteristic perceived by the consumer, typical of foods with a more solid texture. Subsequently, the sensations "sweet" and "gritty" became more prominent, with lower but sustained dominance rates over time, remaining relatively stable around 15 s. From 10 s onward, a moderate dominance of the "soft" sensation was observed, indicating that the cookie presented a smoother texture after initial mastication. Macedo et al. (2020) also reported a higher dominance rate of 0.66 and 0.50 in the crunchiness and sweetness of cookie samples, respectively.

Overall, the predominance of attributes such as crunchiness and sweetness, combined with positive panelist evaluations during temporal dominance of sensations testing, indicates that incorporating the studied functional ingredients maintained product sensory quality and market potential. Consequently, the evaluated formulations offer the food industry a viable pathway for innovation aligned with environmental and social responsibility – delivering nutritionally enriched, value-added products that meet health-conscious consumer demands (Baker et al., 2022). In this context, future studies should investigate the storage stability of bioactive compounds and the long-term health benefits associated with the regular consumption of the formulated products.

Table 6. Microbiological analyses of cookies and cereal bars formulated with olive (*Olea europaea*) leaf flour and acerola (*Malpighia emarginata*) pulp[(1)].

Sample	*Salmonella* spp.	Coagulase-positive *Staphylococcus*	*Bacillus cereus*	Thermotolerant coliforms	Mold and yeast
	(in 25 g)	(UFC g^{-1})	(UFC g^{-1})		(UFC g^{-1})
Cookie	Absence	0	0	< 3 NPM g^{-1}	$2.1x10^3$
Cereal bar	Absence	0	0	< 3 NPM g^{-1}	$3.3x10^2$

[(1)]UFC, colony-forming units; and NPM, most probable number.

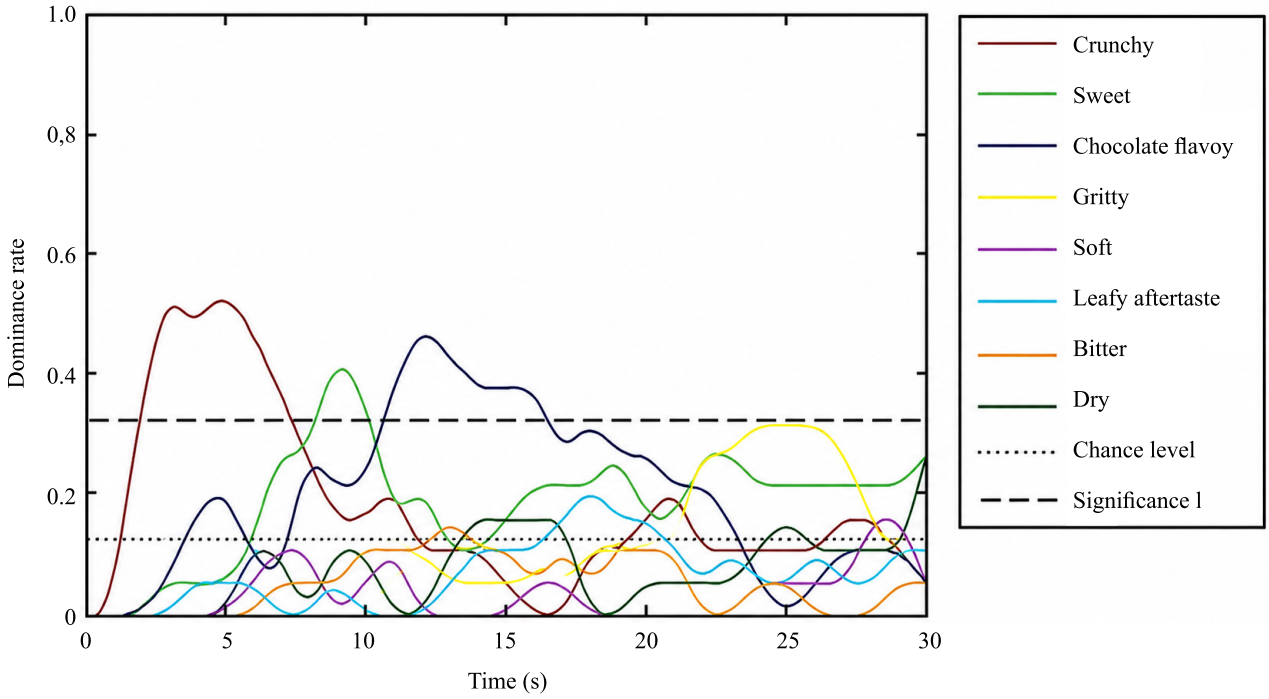

Figure 1. Temporal dominance of sensations curves for the attributes crunchy, sweet, chocolate flavor, gritty, soft, leafy aftertaste, bitter, and dry of the evaluated cookie samples formulated with olive (*Olea europaea*) leaf flour and acerola (*Malpighia emarginata*) pulp. Chance level, represents the dominance rate that an attribute may reach randomly; and significance level, indicates the minimum proportion required for a sensation to be considered statistically significant.

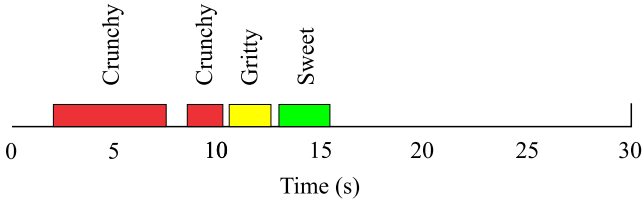

Figure 2. Example of a sequence of dominant sensory attributes recorded during the temporal dominance of sensations evaluation of cookie samples formulated with olive (*Olea europaea*) leaf flour and acerola (*Malpighia emarginata*) pulp.

Conclusions

1. The cookies and cereal bars formulated with olive (*Olea europaea*) leaves and acerola (*Malpighia emarginata*) pulp show satisfactory physicochemical and microbiological quality, desirable texture characteristics, and a good sensory acceptance, with crunchiness and sweetness standing out.

2. The incorporation of olive leaf and acerola pulp into cookies and cereal bars is a promising strategy to improve the nutritional, technological, and sensory attributes of both products, showing their feasibility as sustainable ingredients for the development of functional food products with market potential.

References

ADEFEGHA, S.A. Functional foods and nutraceuticals as dietary intervention in chronic diseases; novel perspectives for health promotion and disease prevention. **Journal of Dietary Supplements**, v.15, p.977-1009, 2018. DOI: https://doi.org/10.1080/19390211.2017.1401573.

ANVISA. Agência Nacional de Vigilância Sanitária. Instrução Normativa - IN nº 161, de 1º de julho de 2022. Estabelece os padrões microbiológicos dos alimentos. **Diário Oficial da União**, 6 jul. 2022a. Seção1, p.235-238. Available at: <https://www.in.gov.br/en/web/dou/-/instrucao-normativa-in-n-161-de-1-de-julho-de-2022-413366880>. Accessed on: Sept. 23 2026.

ANVISA. Agência Nacional de Vigilância Sanitária. Resolução - RDC nº 711, de 1º de julho de 2022. Dispõe sobre os requisitos

sanitários dos amidos, biscoitos, cereais integrais, cereais processados, farelos, farinhas, farinhas integrais, massas alimentícias e pães. **Diário Oficial da União**, 6 jul. 2022b. p.183. Available at: <https://pesquisa.in.gov.br/imprensa/jsp/visualiza/index.jsp?data=06/07/2022&jornal=515&pagina=183>. Accessed on: Feb. 10 2025.

AQUINO, A.C.M. de S.; MOÉS, R.S.; LEÃO, K.M.M.; FIGUEIREDO, A.V.D.; CASTRO, A.A. Avaliação físico-química e aceitação sensorial de biscoitos tipo cookies elaborados com farinha de resíduos de acerola. **Revista Instituto Adolfo Lutz**, v.69, p.379-386, 2010. DOI: https://doi.org/10.53393/rial.2010.v69.32640.

BAKER, M.T.; LU, P.; PARRELLA, J.A.; LEGGETTE, H.R. Consumer acceptance toward functional foods: a scoping review. **International Journal of Environmental Research and Public Health**, v.19, art.1217, 2022. DOI: https://doi.org/10.3390/ijerph19031217.

BORTOLINI, V.M. de S.; SANTOS, M.P. de los; ROCKENBACH, R.; SHIRMANN, G. da S.; BRAGANÇA, G.C.M.; MOTA, B.B.; VERBES, M.P.; PERES, W. Efeito da infusão de folhas de oliveira (*olea europaea* L) em diferentes concentrações em um modelo experimental. **Brazilian Journal of Health Review**, v.4, p.16538-16545, 2021. DOI: https://doi.org/10.34119/bjhrv4n4-169.

CAVALHEIRO, C.V.; ROSSO, V.D.; PAULUS, E.; CICHOSKI, A.J.; WAGNER, R.; MENEZES, C.R. de; BARIN, J.S. Composição química de folhas de oliveira (*Olea europea* L.) da região de Caçapava do Sul, RS. **Ciência Rural**, v.44, p.1874-1879, 2014. DOI: https://doi.org/10.1590/0103-8478cr20131139.

CECCHI, L.; KHATIB, M.; BELLUMORI, M.; CIVA, V.; DOMIZIO, P.; INNOCENTI, M.; BALLI, D.; MULINACCI, N. Industrial drying for agrifood by-products re-use: cases studies on pomegranate peel (*Punica granatum* L.) and stoned olive pomace (pâté, *Olea europaea* L.). **Food Chemistry**, v.403, art.134338, 2023. DOI: https://doi.org/10.1016/j.foodchem.2022.134338.

COPPA, C.F.S.C.; ROSIM, R.E.; OLIVEIRA, C.A.F. de; RODRIGUES, C.E. da C.; GONÇALVES, C.B. Extração de oleuropeína a partir de folhas de oliveira utilizando solvente hidroalcóolico. **Brazilian Journal of Food Technology**, v.20, e2016169, 2017. DOI: https://doi.org/10.1590/1981-6723.16916.

DADA, A.P.; CESTÁRIO, A.C. de O.; PINTRO, P.T.M.; ROSA, C.I.L.F. Extrato de folha de oliveira em revestimento comestível aplicado à tomates cereja. **Revista Observatório de la Economía Latinoamericana**, v.22, p.1-17, 2024. DOI: https://doi.org/10.55905/oelv22n6-241.

DAMODARAN, S.; PARKIN, K.L. (Ed.). **Fennema's food chemistry**. 5th ed. Boca Raton: CRC Press, 2017.

DIAS, J. de S.R.; MENDES, F.Z.C.; NOLASCO, M.V.F.M.; BOGO, D. Obtenção de farinha de inhame para elaboração de barra de cereal como suplemento alimentar e funcional. **Brazilian Journal of Development**, v.6, p.15716-15735, 2020. DOI: https://doi.org/10.34117/bjdv6n3-446.

EUROPEAN COMMISSION. Circular Economy Action Plan: for a cleaner and more competitive Europe. Brussels, 2024.

FACCIOLI, L.S.; KLEIN, M.P.; BORGES, G.R.; DALANHOL, C.S.; MACHADO, I.C.K.; GARAVAGLIA, J.; DAL BOSCO, S.M. Development of crackers with the addition of olive leaf flour (*Olea europaea* L.): chemical and sensory characterization. **LWT – Food Science and Technology**, v.141, art.110848, 2021. DOI: https://doi.org/10.1016/j.lwt.2021.110848.

GUSMÃO, R.P. de; GUSMÃO, T.A.S.; MOURA, H.V.; DUARTE, M.E.M.; CAVALCANTI-MATA, M.E.R.M. Caracterização tecnológica de cookies produzidos com diferentes concentrações de farinha de algaroba durante armazenamento por 120 dias. **Brazilian Journal of Food Technology**, v.21, e2017116, 2018. DOI: https://doi.org/10.1590/1981-6723.11617.

HUANG, J.; YANG, J.; TANG, K.; YANG, T.; TAN, H. A study on the factors influencing the preservation rate of ascorbic acid in acerola cherry pulp. **Food Science and Technology**, v.42, e16322, 2022. DOI: https://doi.org/10.1590/fst.16322.

IBRAOLIVA. Instituto Brasileiro de Olivicultura. **Safra brasileira de azeite de oliva registra produção recorde em 2026**. Porto Alegre, 2026. Available at: <https://www.ibraoliva.com.br/noticias>. Accessed on: Sept. 23 2026.

JACOBS, V.; SOUZA, F.S.; HAMM, J.B.S.; MANCILHA, F.S. Produção e caracterização de biofilmes de amido incorporados com polpa de acerola. **Revista Iberoamericana de Polímeros**, v.21, p.107-119, 2020.

JAN, K.N.; PANESAR, P.S.; SINGH, S. Optimization of antioxidant activity, textural and sensory characteristics of gluten-free cookies made from whole Indian quinoa flour. **LWT – Food Science and Technology**, v.93, p.573-582, 2018. DOI: https://doi.org/10.1016/j.lwt.2018.04.013.

JOHNSON, M. Overview of texture profile analysis. 2023. Available at: <https://texturetechnologies.com/resources/texture-profile-analysis>. Accessed on: Oct. 2 2024.

KANUF, V.S.; OLIVEIRA, E.C.A.; BORGES, G.H. de O.C.; GOMES, A.C.B.; SILVA, J.M.L. da; BASTOS, C.S.; ARRUDA, J.T. A influência do estilo de vida e hábitos alimentares no perfil nutricional de estudantes de medicina e outros acadêmicos da área da saúde. **Revista de Medicina**, v.103, e-215543, 2024. DOI: https://doi.org/10.11606/issn.1679-9836.v103i1e-215543.

KARUNANITHI, S.; GUHA, P.; SRIVASTAV, P.P. Valorization of betel leaves byproducts: a novel ingredient for sustainable cookie development. **Food Chemistry Advances**, v.5, art.100799, 2024. DOI: https://doi.org/10.1016/j.focha.2024.100799.

KHWALDIA, K.; ATTOUR, N.; MATTHES, J.; BECK, L.; SCHMID, M. Olive byproducts and their bioactive compounds as a valuable source for food packaging applications. **Comprehensive Reviews in Food Science and Food Safety**, v.21, p.1218-1253, 2022. DOI: https://doi.org/10.1111/1541-4337.12882.

KONICA MINOLTA. **Entendendo o espaço de cor L*a*b***. 2020. Available at: <https://sensing.konicaminolta.us/br/blog/entendendo-o-espaco-de-cor-lab/>. Accessed on: Oct. 29 2024.

LATIMER JR., G.W. (Ed.). **Official Methods of Analysis of AOAC International**. 19th ed. Gaithersburg: AOAC International, 2012. Official Method 932.12.

MACEDO, L.D.; ÁVILA, B.P.; SARAIVA, J.F.R.; LACERDA, M. da S.; DOMINGUES, B.P.; PEREIRA, A.M.; GURINO, E. de S.G.; GULARTE, M.A. Caracterização química e sensorial

de cookies formulados com grãos crioulos e amido de pinhão (*Araucaria angustifolia*). **Research, Society and Development**, v.9, e3491210677, 2020. DOI: https://doi.org/10.33448/rsd-v9i12.10677.

MAGALHÃES, M.P.D.; GANDRA, K.M.B.; CUNHA, L.R. da; LIMA, E.M.F. Obtenção da farinha do resíduo do processamento de acerola e avaliação de compostos bioativos e nutritivos. **Research, Society and Development**, v.10, e188101420714, 2021. DOI: https://doi.org/10.33448/rsd-v10i14.20714.

MANCEBO, C.M.; PICÓN, J.; GÓMEZ, M. Effect of flour properties on the quality characteristics of gluten free sugar-snap cookies. **LWT – Food Science and Technology**, v.64, p.264-269, 2015. DOI: https://doi.org/10.1016/j.lwt.2015.05.057.

MARQUES, T.R.; CORRÊA, A.D.; LINO, J.B. dos R.; ABREU, C.M.P. de; SIMÃO, A.A. Chemical constituents and technological functional properties of acerola (*Malpighia emarginata* DC.) waste flour. **Food Science and Technology**, v.33, p.526-531, 2013. DOI: https://doi.org/10.1590/S0101-20612013005000085.

MARTINS, K.P. dos S.; SANTOS, V.G. dos; LEANDRO, B.B. da S.; OLIVEIRA, O.M.A. de. Transição nutricional no Brasil de 2000 a 2016, com ênfase na desnutrição e obesidade. **Asklepion: Informação em Saúde**, v.1, p.113-132, 2021/2022. DOI: https://doi.org/10.21728/asklepion.2021v1n2.p113-132.

MARTINY, T.R.; PACHECO, B.S.; PEREIRA, C.M.P.; MANSILLA, A.; ASTORGA-ESPAÑA, M.S.; DOTTO, G.L.; MORAES, C.C.; ROSA, G.S. A novel biodegradable film based on κ-carrageenan activated with olive leaves extract. **Food Science & Nutrition**, v.8, p.3147-3156, 2020. DOI: https://doi.org/10.1002/fsn3.1554.

MORCIANO, M.; MALAGUTI, M.; RICCERI, F.; TIRAFERRI, A.; FASANO, M. Process optimization of osmotic membrane distillation for the extraction of valuable resources from water streams. **npj Clean Water**, 7, art.1, 2024. DOI: https://doi.org/10.1038/s41545-023-00294-2.

NIELSEN, S.S. (Ed.). **Food analysis**. 5th ed. Cham: Springer, 2017. DOI: https://doi.org/10.1007/978-3-319-45776-5.

NUNES, C.A.; PINHEIRO, A.C.M. **SensoMaker**. Version 1.0. Lavras: Universidade Federal de Lavras, 2014. [Computer software].

OLĘDZKI, R.; HARASYM, J. Acerola (*Malpighia emarginata*) anti-inflammatory activity – a review. **International Journal of Molecular Sciences**, v.25, art.2089, 2024. DOI: https://doi.org/10.3390/ijms25042089.

PAL, P.; SINGH, A.K.; SRIVASTAVA, R.K.; RATHORE, S.S.; SAHOO, U.K.; SUBUDHI, S.; SARANGI, P.K.; PRUS, P. Circular bioeconomy in action: transforming food wastes into renewable food resources. **Foods**, v.13, art.3007, 2024. DOI: https://doi.org/10.3390/foods13183007.

PEREIRA, W.L.; OLIVEIRA, T.T.; KANASHIRO, M.; COSTA, M.R. Ação antiproliferativado flavonoide morina e do extrato da folha de oliveira (*Oleaeuropaea* L.) contra a linhagem de célula H460. **Revista Brasileira de Plantas Medicinais**, v.17, p.798-806, 2015. Supl. I. DOI: https://doi.org/10.1590/1983-084X/14_020.

PINEAU, N.; SCHLICH, P.; CORDELLE, S.; MATHONNIÈRE, C.; ISSANCHOU, S.; IMBERT, A.; ROGEAUX, M.; ETIÉVANT, P.; KÖSTER, E. Temporal dominance of sensations: construction of the TDS curves and comparison with time-intensity. **Food Quality and Preference**, v.20, p.450-455, 2009. DOI: https://doi.org/10.1016/j.foodqual.2009.04.005.

PINHEIRO, A.C.M.; NUNES, C.A.; VIETORIS, V. SensoMaker: a tool for sensorial characterization of food products. **Ciência e Agrotecnologia**, v.37, p.199-201, 2013. DOI: https://doi.org/10.1590/S1413-70542013000300001.

RADÜNZ, M.; NICKEL, J.; GULARTE, M.A.; HELBIG, E. Desenvolvimento, composição centesimal e análise sensorial de barras à base de grãos de quinoa (*Chenopodium quinoa* Willd.) submetidos a diferentes tratamentos térmicos. **Demetra: Alimentação, Nutrição & Saúde**, v.11, p.977-990, 2016. DOI: https://doi.org/10.12957/demetra.2016.22384.

RIVERO-PINO, F.; MILLAN-LINARES, M.C.; VILLANUEVA-LAZO, A.; FERNANDEZ-PRIOR, Á.; MONTSERRAT-DE-LA-PAZ, S. *In vivo* evidences of the health-promoting properties of bioactive compounds obtained from olive by-products and their use as food ingredient. **Critical Reviews in Food Science and Nutrition**, v.64, p.8728-8740, 2024. DOI: https://doi.org/10.1080/10408398.2023.2203229.

ROMERO-MÁRQUEZ, J.M.; NAVARRO-HORTAL, M.D.; FORBES-HERNÁNDEZ, T.Y.; VARELA-LÓPEZ, A.; PUENTES, J.G.; SÁNCHEZ-GONZÁLEZ, C.; SUMALLA-CANO, S.; BATTINO, M.; GARCÍA-RUIZ, R.; SÁNCHEZ, S.; QUILES, J.L. Effect of olive leaf phytochemicals on the anti-acetylcholinesterase, anti-cyclooxygenase-2 and ferric reducing antioxidant capacity. **Food Chemistry**, v.444, art.138516, 2024. DOI: https://doi.org/10.1016/j.foodchem.2024.138516.

SARQUES, J.D.; SILVA, L.G.M. da; GARCIA, J.A.D.; VILAS BOAS, B.M.; NACHTIGALL, A.M. Características físico-químicas de biscoitos sem glúten, sabor chocolate, feitos com farelo de cacau, farinha de arroz e amido de milho. **Revista Observatorio de la Economía Latinoamericana**, v.22, p.1-21, 2024. DOI: https://doi.org/10.55905/oelv22n2-078.

SILVEIRA, D. **Câmara Setorial das Oliveiras apresenta números da safra 2023/2024**. Porto Alegre: Secretaria da Agricultura, Pecuária, Produção Sustentável e Irrigação, 12 jun. 2024. Available at: <https://stseapi16.hml.rs.gov.br/chuvas-em-excesso-causam-quebra-na-safra-2023-2024-de-oliveiras>. Accessed on: Nov. 11 2024.

SOARES, T.F.; ALVES, R.C.; OLIVEIRA, M.B.P.P. From olive oil production to by-products: emergent technologies to extract bioactive compounds. **Food Reviews International**, v.64, p.3342-3369, 2024. DOI: https://doi.org/10.1080/87559129.2024.2354331.

SOUSA, R.S. de; NOVAIS, T.S.; BATISTA, F.O.; ZUÑIGA, A.D.G. Análise sensorial de cookie desenvolvidos com farinha da casca de abacaxi (*Ananas comosus* (L.) Merril). **Research, Society and Development**, v.9, e45942816, 2020. DOI: https://doi.org/10.33448/rsd-v9i4.2816.

THE STATE of Food Security and Nutrition in the World 2024: financing to end hunger, food insecurity and malnutrition in all its forms. Rome: FAO, 2024. DOI: https://doi.org/10.4060/cd1254en.

UNEP. United Nations Environment Programme. **Food waste index report 2024**. Nairobi, 2024. Available at: <https://www.unep.org/resources/publication/food-waste-index-report-2024>. Accessed on: Sept. 23 2026.

ZENEBON, O.; PASCUET, N.S.; TIGLEA, P. (Coord.). **Métodos físico-químicos para análise de alimentos**. 4.ed., 1.ed. digital. São Paulo: Instituto Adolfo Lutz, 2008. 1020p.

Author contributions

Camila Castencio Nogueira: conceptualization (equal), data curation (equal), formal analysis (equal), investigation (equal), methodology (equal), writing - original draft (equal), writing - review & editing (equal); **Alice Pereira Lourenson**: corresponding author, investigation (equal), methodology (equal), writing - original draft (equal), writing - review & editing (equal); **Gabriela dos Santos Ferrão**: methodology (supporting); **Maicon da Silva Lacerda**: methodology (supporting), writing - original draft (supporting); **Samson Eneji Obogo**: writing - review & editing (equal); **Marcia Arocha Gularte**: conceptualization (equal), formal analysis (equal), investigation (equal), methodology (equal), project administration (equal), resources (equal), validation (equal), writing - original draft (lead), writing - review & editing (lead).

Chief editor: Edemar Corazza
Edited by: Madalena Rinaldi

Data availability statement

Data available upon request: research data are only available upon reasonable request to the corresponding author.

Declaration of use of AI technologies

No generative artificial intelligence (AI) was used in this study.

Conflict of interest statement

The authors declare no conflicts of interest.

Acknowledgments

To Coordenação de Aperfeiçoamento de Pessoal de Nível Superior (CAPES), for financing, in part, this study (Finance code 001); and to Conselho Nacional de Desenvolvimento Científico e Tecnológico (CNPq), for research scholarships.

Disclaimer/Publisher's note

The statements, opinions, and data contained in all texts published in Pesquisa Agropecuária Brasileira (PAB) are solely those of the individual author(s) and not of the journal's publisher, editor, and editorial team, who disclaim responsibility for any injury to people or property resulting from any referred ideas, methods, instructions, or products.

The mention of specific chemical products, machines, and commercial equipment in the texts published in this journal does not imply their recommendation by the publisher.