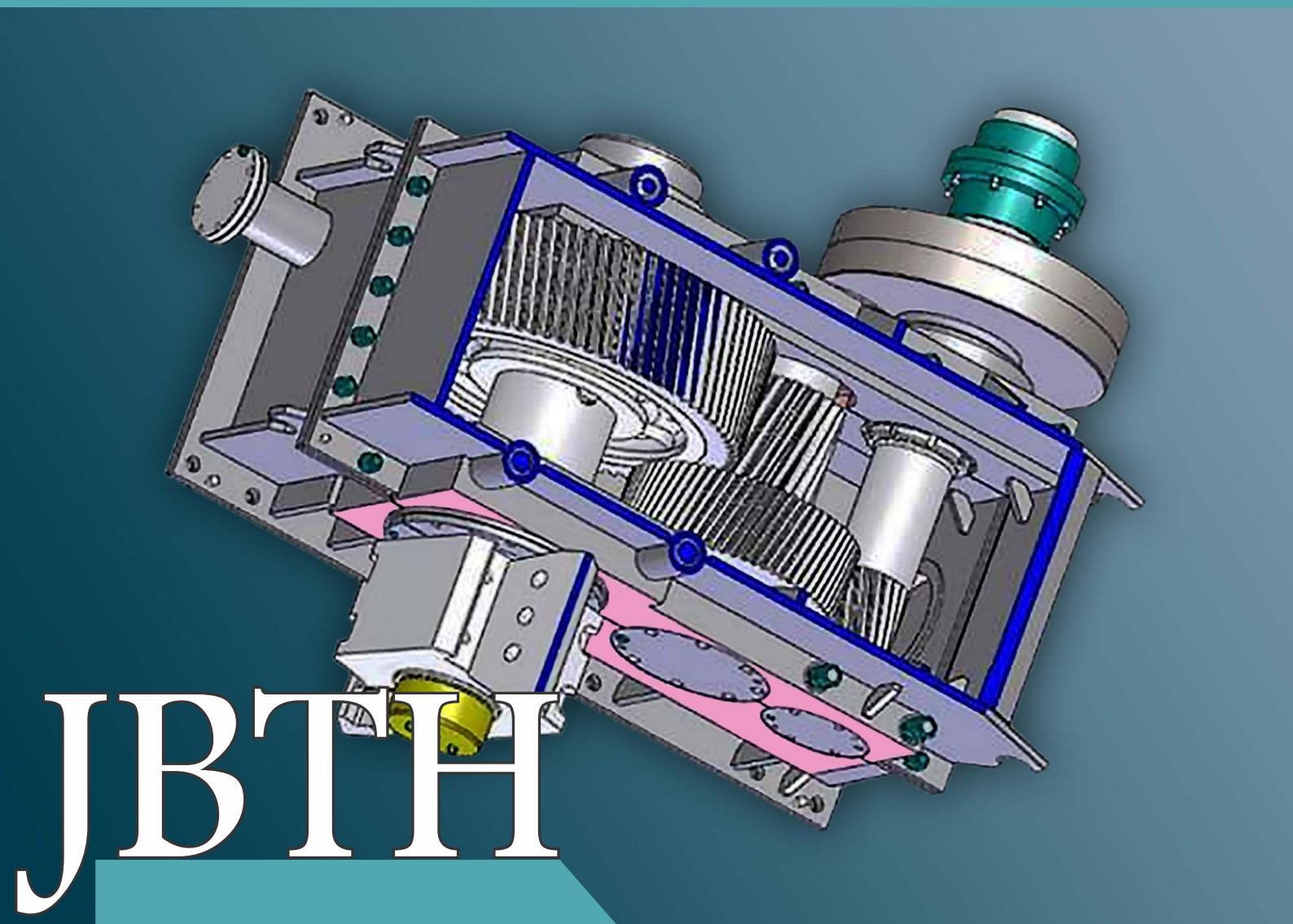
ISSN: 2764-5886
e-ISSN: 2764-622X

Volume 8· Nº 5 · October 2025

Journal of Bioengineering, Technologies and Health

An Official Publication of
SENAI CIMATEC



JBTH

ISSN: 2764-5886 / e-ISSN 2764-622X

Volume 8 • Number 5 • October 2025

JOURNAL OF BIOENGINEERING TECHNOLOGIES AND HEALTH

An Official Publication of SENAI CIMATEC

PUBLISHED BY SENAI CIMATEC

Sistema FIEB | SENAI CIMATEC
PELO FUTURO DA INOVAÇÃO

October 2025
Printed in Brazil

JOURNAL OF BIOENGINEERING TECHNOLOGIES AND HEALTH

An Official Publication of SENAI CIMATEC

JOURNAL OF BIOENGINEERING TECHNOLOGIES AND HEALTH

Volume 8 • Number 5 **SUMMARY** *October 2025*

Original Articles

Case Report

Instructions for Authors

Statement of Editorial Policy

Checklist for Submitted Manuscripts

The Journal of Bioengineering, Technologies and Health (JBTH) is an official publication of the SENAI CIMATEC University (Serviço Nacional de Aprendizagem Industrial - Universidade Centro Integrado de Manufatura e Tecnologia). It is published bimonthly (February - April - June - August - October - December) in English by SENAI CIMATEC University – Avenida Orlando Gomes, 1845, Piatã, Zip Code: 41650-010, Salvador-Bahia-Brazil; phone: (55 71) 3879-5501. The editorial offices are at SENAI CIMATEC University.

Editorial Office

Correspondence concerning subscriptions, advertisements, claims for missing issues, changes of address, and communications to the editors should be addressed to the Deputy Editor, Dr. Roberto Badaró, SENAI CIMATEC University (Journal of Bioengineering, Technologies and Health – JBTH) – Avenida Orlando Gomes, 1845, Piatã, Zip code: 41650-010, Salvador-Bahia-Brazil; phone: (55 71) 3879-5501; or sent by e-mail: jbth@fieb.org.br / jbth.cimatec@gmail.com.

Permissions

Postmaster

Send address changes to JBTH, Avenida Orlando Gomes, 1845, Piatã, Zip Code: 41650-010, Salvador-Bahia-Brazil.

Information by JBTH-SENAI CIMATEC University
Address: Avenida Orlando Gomes, 1845, Piatã, Zip Code: 41650-010, Salvador-Bahia-Brazil
Home-page: www.jbth.com.br
E-mail: jbth@fieb.org.br / jbth.cimatec@gmail.com
Phone: (55 71) 3879-5501 / 3879-5500 / 3879-9500

DOI:10.34178

ISSN: 2764-5886 / e-ISSN 2764-622X

COVER: Figure 1. Rolling mill gearbox – CAD model. Analysis of Maximum Stress due to Bending in Helical Gears: Comparison Between the Agma Method and Finite Element Analysis by Hebert Tairone dos Santos Silva et al. Figure Souce (Common Law): GMB Heavy Industries, 2025 from https://gmbindustries.com/rolling-mill-gear-boxes/

Freeze-Dried Cambuí Fruit (*Myrciaria tenella* O. Berg): Physicochemical Characterization, Bioactive Potential, and Technological Prospecting

Rosália Sobral Costa Neta[1], Regina Santiago Campos Nascimento[1], Suyare Araújo Ramalho[2], Meire Ane Pitta da Costa[2*]

[1]Federal University of Sergipe; [2]Federal Institute of Sergipe; Aracaju, Sergipe Brazil

This study investigated the physicochemical properties, bioactive potential, and technological prospects of freeze-dried cambuí fruit (*Myrciaria tenella* O. Berg), a little-explored native Brazilian species. Analyses of pH, titratable acidity, moisture, lipids, total phenolic compounds, flavonoids, and antioxidant activity were performed on different methanolic and ethanolic extracts. The results revealed high levels of phenolic compounds and flavonoids, particularly in 60% solvent extracts, along with significant antioxidant activity, highlighting the fruit's functional potential. Low pH and intermediate moisture contributed to the stability of bioactive compounds, while the high lipid content favored efficient extraction. Technological prospection indicated that cambuí remains underexplored in patents and scientific research, revealing opportunities for innovation in food, pharmaceutical, and nutraceutical products. These findings underscore the importance of sustainably utilizing Brazilian biodiversity and provide a foundation for the development of new technologies based on cambuí.

Keywords: Freeze-Dried Cambuí. Flavonoids. Antioxidants. Phenolic Compounds. Technological Prospection.

The cambuí is the fruit of the cambuí tree, whose scientific name is *Myrciaria tenella* O. Berg, a frutiferous plant belonging to the Myrtaceae family [1]. The cambuí fruit is a glossy berry found in colors from red to purple [2]. This fruit is little known despite being a native plant of Brazil [3] and belonging to the same genus as *Myrciaria cauliflora* (Mart.) Berg, known as jabuticaba, which is a widely consumed fruit for juices, jams, and liquors in Brazil [4].

The Myrtaceae family species are consumed by the Brazilian population for their adstringent, anti-inflammatory, and anti-hypertensive properties [5]. Those plants are naturally distributed throughout the southern hemisphere countries [6]. In Brazil, plants of the *Myrciaria* genus can be found in several Brazilian biomes, e.g, the Amazon Rainforest, Caatinga, Cerrado, and Pampa. Antonelo and colleagues (2023) [5] found that essential oils extracted from plants of the Myrtaceae family, including the *M. tenella*, present antioxidant, antimicrobial, and *in vitro* cytotoxic activity against adrenocortical carcinoma.

As for the berries of *Myrciaria* genus plants, they stand out for their high yield of an antioxidant-rich pulp [4]. Those fruits also present high quantities of the functional pigment anthocyanin, which provides them with their red, blue, or violet coloration [4]. Ferreira and colleagues (2024) [7] studied the essential oils of *Myrciaria tenella* (DC.) O. Berg and identified their main components as being (*E*)-caryophilen, δ-cadinen, caryophilen, and viridifloren. They also found that those essential oils have antioxidant activity and are potential agents that can be used against oral diseases. In addition, Almeida and Silva (2011) [8] noted the outstanding vitamin C source potential of the cambuí fruit, particularly its purple berries.

Despite its bioactive and biotechnological potential, the cambuí remains underexplored and underinvestigated when compared to other fruits of the Myrtaceae family. The studies regarding the cambuí are scarce. There are only 12 papers, published between 2006 and 2021, related to "*Myrciaria tenella* O. Berg" in the research platform managed by the Brazilian federal agency CAPES (Coordenação de Aperfeiçoamento de Pessoal de Nível Superior), which gathers research papers from several databases and provides

Received on 10 July 2025; revised 21 September 2025.
Address for correspondence: Meire Ane Pitta da Costa. Av. Eng. Gentil Tavares, 1166 - Getúlio Vargas, Aracaju - SE, Zipcode: 49055-260. E-mail: meire.costa@ifs.edu.br.
Original extended abstract presented at SAPCT 2025.

J Bioeng. Tech. Health 2025;8(5):408-418

free access to them for students, teachers, and researchers.

Thus, this work provides a characterization of the cambuí berries (*Myrciaria tenella* O. Berg) and the technological prospects of related studies. The purpose of this work is to produce scientific knowledge on the properties of cambuí to guide the development of cambuí-based technologies and products, such as drinks and pharmaceutical drugs.

Materials and Methods

Experimental Technological Prospection

The search for technological prior art related to the 'cambuí' fruit was conducted in national and international patent databases, including the National Institute of Industrial Property (INPI), Espacenet, World Intellectual Property Organization (WIPO), The Lens, and Japan Patent Office. At the same time, research was carried out in scientific journal databases through the journal portal of the "Coordenação de Aperfeiçoamento de Pessoal de Nível Superior (CAPES)", accessed via the Federal University of Sergipe (UFS).

The search strategies employed Boolean logical operators applied to specific fields (keywords, title, abstract, and author) using the following descriptors: "*Myrciaria cuspidata*" OR "cambuí" OR "*Myrciaria tenella* O. Berg" OR "*Myrciaria floribunda* (West ex Willd.) O. Berg".

Additionally, the analysis of the scientific impact was conducted on the Web of Science® indexing database (https://www.webofknowledge.com), using the same descriptors and search criteria.The results were organized to generate graphical representations related to the publication period, document types, prominent authors, and thematic categories of the platform, to understand the scientific production associated with the fruit 'cambuí'.

Sampling

The cambuí berries sampled for this study were collected directly from the cambuí tree in Morro do Chapéu, BA, Brazil. The samples were sieved to remove solid impurities (e.g, sticks and leaves), washed, dried, and frozen. The frozen samples were transported to the lab in cool boxes and kept in the Ultra-low temperature freezer (Liotop UFR30) for 2 h at -80 ºC.

Lyophilization of the Fruit Sample

The fruits were kept in the lyophilizer (Liotop L101) for 48 h, at -62 ºC and under <100 mmHg. As the fruits had not yet fully dehydrated, they were frozen in the Ultra-low temperature freezer for 2 hours and then kept in the lyophilizer for 48 hours.

Extracts Preparation

The extracts were obtained using a method adapted from Lima and colleagues (2012) [9]. Ethanol-water and methanol-water solutions containing 20%, 40%, and 60% organic solvent were used for the extraction. The ground lyophilized fruits were mixed with the extraction solvents in a 5:100 (g/mL) ratio in triplicate. The mixture was stirred for 1 h on an orbital shaker (Quimis). The liquid was collected on Falcon tubes and centrifuged at 400 rpm for 45 min, and the supernatant was transferred to amber flasks.

Antioxidant Activity Analyses

The antioxidant activity was analyzed by the DPPH radical scavenging method described by Lima and colleagues (2012) [9]. For the analyses, 3.750 mL of DPPH 0.62 $g.L^{-1}$ and 0.750 mL of extract were mixed; the extracts were replaced with the extraction solvents for the blank preparation. The samples were homogenized by vortex agitation for 1 min twice, with a 5-minute break in between. The triplicates were analyzed at 517 nm using a Shimadzu UV-1800 UV Spectrophotometer.

Total Flavonoids Determination

The determination of flavonoid compounds was

carried out using the method described by Woisky and Salatino (1998) and modified by Lima and colleagues (2012) [9]. For the analyses, 10 mL of $AlCl_3$ 20 $g.L^{-1}$ and 1 mL of extract were mixed; the extracts were replaced with the extraction solvents for the blank preparation. The samples were homogenized by vortex agitation for 1 min. The triplicates were analyzed at 425 nm on a Shimadzu UV-1800 UV Spectrophotometer.

Total Phenolics Determination

The determination of flavonoid compounds was carried out using the Swain and Hills (1959) method, as described by Lima and colleagues (2012) [9]. For the analyses, 1 mL of ethanol, 5 mL of distilled water, 0.5 mL of Folin Ciocalteau, 1 mL of Na_2CO_3 20 $g.L^{-1}$, and 0.250 mL of extract were mixed; the extracts were replaced with the extraction solvents for the blank preparation. The samples were homogenized by vortex agitation for 1 min. The triplicates were analyzed at 725 nm on a Shimadzu UV-1800 UV Spectrophotometer.

Moisture

The moisture analyses were carried out by the Instituto Adolfo Lutz (2008) [10]method. In triplicate, 5 g of the lyophilized samples in pre-calibrated aluminum capsules were placed in the oven at 105 °C for 2 h and then in the desiccator for 30 min. The mass of the samples was measured before and after the heating process, and the % of moisture was determined by the relative variation of the sample mass due to the evaporation process.

Lipids determination

The determination of lipids was performed using the method described by Bligh and Dyer (1959) [11]. In triplicate, 2.5 g of the lyophilized samples, 10 mL of chloroform, 20 mL of methanol, and 8 mL of distilled water were mixed. After 30 minutes of stirring on an orbital shaker (Quimis), 10 mL of chloroform and 10 mL of 1.5% Na_2SO_4 were added, and the mixture was stirred for 2 minutes. The mixture was transferred to a separatory funnel.

Once the phases were visually separated, the lipidic phase was collected and filtered. The lipidic phase was maintained at 90 °C in the oven for 30 minutes to remove moisture. After cooling down, the mass of the lipidic phase was measured. The % of lipids was calculated by Equation 1, where m_1 is the mass of the empty beaker, m_2 is the mass of the beaker containing the lipidic phase, and m is the initial mass of the lyophilized cambuí.

$$Lipids\ (\%) = \frac{(m_2 - m_1) \times 4 \times 100}{m} \quad \textbf{Equation 1}$$

Analyses of pH

The pH analyses were carried out by the Instituto Adolfo Lutz (2008)10 method. For the determination of the pH, 5 g of lyophilized cambuí and 50 mL of distilled water were mixed. The pH was measured using the DIGIMED DM-22 pH Meter.

Titratable Acidity Analyses

The titratable acidity analyses were carried out by the Instituto Adolfo Lutz (2008) [10] method. In triplicate, 5 g of lyophilized cambuí and 50 mL of distilled water were mixed. The samples were titrated with 0.1 M NaOH, using phenolphthalein as an indicator. The titratable acidity was calculated by Equation 2, where V corresponds to the volume (mL) of NaOH 0,1 M used for the titration, f to the solution factor of 0,1 M, m to the mass of lyophilized cambuí, and C to the correction factor for the NaOH 1 M (which equals 10).

$$Acidity\ (\%) = \frac{(V \times f \times 100)}{C \times m} \quad \textbf{Equation 2}$$

Results and Discussion

Technological Prospection

The prior art search was conducted in the INPI, Espacenet, WIPO, The Lens, and Japan Patent databases, as well as in CAPES journals through

access provided by the Federal University of Sergipe. The search strategy employed Boolean logical operators applied to keywords, titles, abstracts, and authors, using the following descriptors: "*Myrciaria cuspidata*" OR "CAMBUÍ" OR "*Myrciaria tenella* O. Berg" OR "*Myrciaria floribunda* (West ex Willd.) O. Berg".

On the INPI (National Institute of Intellectual Property) website, only 1 patent was found with the application number (BR 10 2021 021304 3 A2) and title: Fumigating formulation in microemulsion for controlling *Sitophilus zeamais* using *Myrciaria floribunda* and *Pothomorphe umbellata*. This invention describes an insecticidal fumigating formulation composed of essential oils from *Myrciaria floribunda*, with major constituents (*E*)-caryophyllene (26.81%) and viridiflorol (6.64%), and *Pothomorphe umbellata*, with β-pinene (27.33%) and α-pinene (14.55%), effective in controlling *Sitophilus zeamais* in corn grains. The formulation, prepared in emulsion with Tween 80 at 120 ppm, and applied to filter paper discs in containers with 20 insects, demonstrated fumigant activity, resulting in a significant reduction in population after 7 days. The technology demonstrates agro-industrial potential for application during harvest and/or storage, distinguishing itself for its practicality, safety, and effectiveness in pest management.

In the WIPO database, only patent no. BR102021019690 was identified, specifically regarding the preparation process of a tea that affects the growth of multidrug-resistant bacteria. The inventors described the process of obtaining an antibacterial tea from the fruit of *Myrciaria floribunda* (cambuí), which is rich in flavonoids and phenolic compounds and is effective against Gram-positive bacteria, particularly multidrug-resistant *Enterococcus faecium*. The process involves drying, grinding, and extraction using pressurized hot water, resulting in a bioactive plant extract. The preparation can be applied in food, pharmaceutical, and veterinary formulations, acting as an active agent against bacterial infections.This is an industrial process designed to produce plant substances with pharmacological activity.

In the Japan office patent sites, Espacenet, and The Lens, no studies involving applications of the "cambuí" fruit were found. As for the Web of Science search results, Figure 1 shows the scientific production related to the fruit that was examined. The available related papers on cambuí were published between 1997 and 2025, reaching their peak in 2021. However, this research topic remains relatively underexplored, considering the results and the number of publications up to 2025. A total of 27 publications were identified.

For the analysis of the fruit "cambuí", the scientific impact was assessed using the Web of Science® indexing database (https://www.webofknowledge.com), based on keywords, titles, abstracts, and authors (Topic), applying the same Boolean logical operators. This search yielded graphical outputs, including publication periods, document types, manuscript authors, and Web of Science categories associated with the fruit "cambuí".

Other than that, it was observed that 26 out of 27 scientific publications found are of the common article type; only one article is classified as a review, and one as early access. This division is expected because, to produce review articles, the topic should theoretically be well-explored in the literature, allowing researchers to gather a sufficient number of articles to discuss the desired subject.

The principal authors who have written about the fruit 'cambuí', as reported by Web of Science, are: Alvares-Carvalho, Antonelo; Amaral; Alves-Aquila; Andrade-Silva; Apel; Andrino; Aragão; Augusti; and Baldo. Knowing that each of the authors contributed only one manuscript each, this contribution is considered small compared to scientific publications on other native fruits of Brazil.

As shown in Figure 2, the platform categorizes articles into various fields, including molecular biochemistry, biotechnology applications, cell biology, applied chemistry, medicinal chemistry, multidisciplinary chemistry, food science and technology, medical research, pharmacological and pharmaceutical sciences, and plant sciences. It is

Figure 1. Number of publications over time for the search of "*Myrciaria cuspidata*" OR "CAMBUÍ" OR "*Myrciaria tenella* O. Berg" OR "*Myrciaria floribunda* (West ex Willd.) O. Berg" in keywords, titles, abstracts, and authors on the Web of Science® platform.

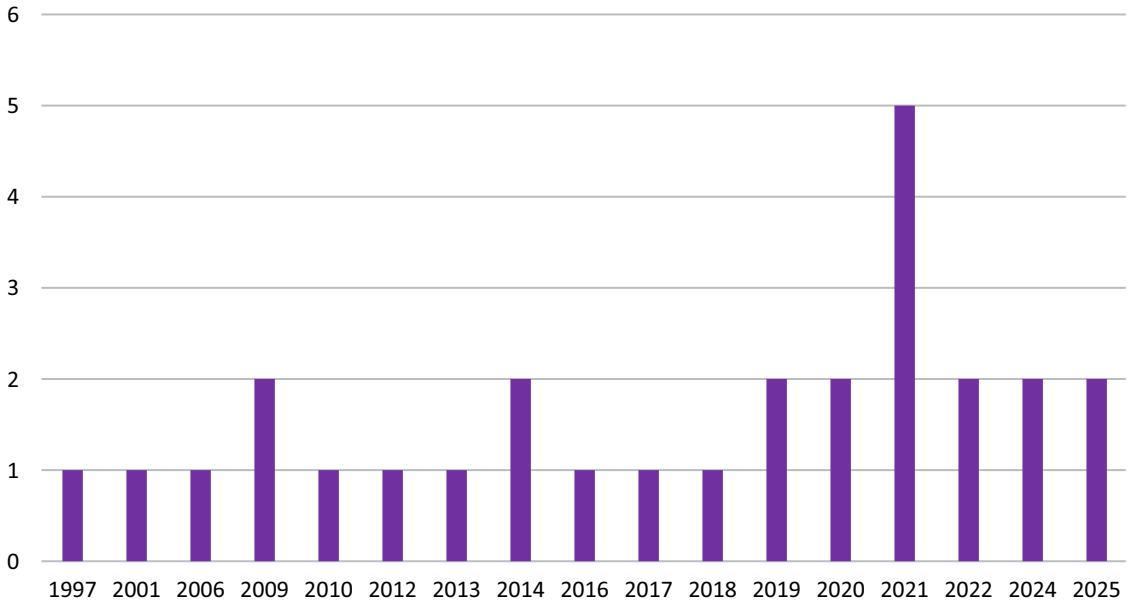
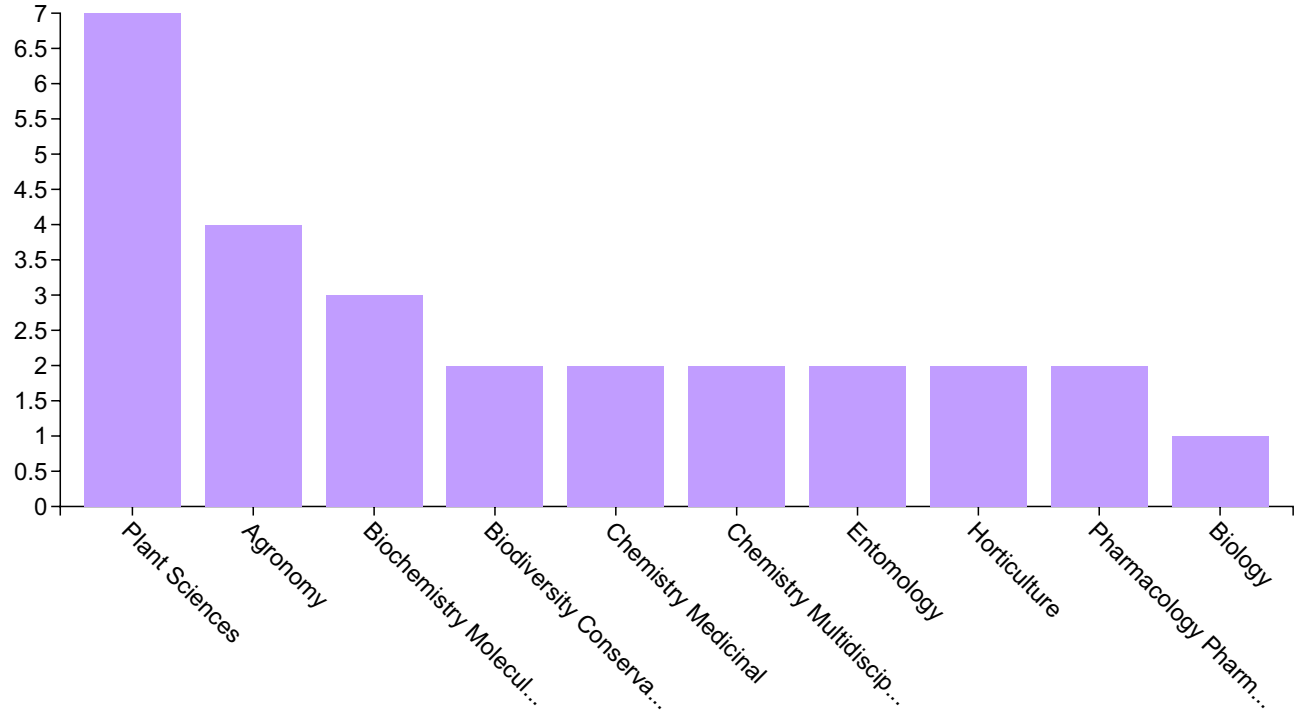


Figure 2. Categories of the Web of Science® platform for the search of "*Myrciaria cuspidata*" OR "CAMBUÍ" OR "*Myrciaria tenella* O. Berg" OR "*Myrciaria floribunda* (West ex Willd.) O. Berg" in keywords, titles, abstracts, and authors (Topic) on the Web of Science® platform.



noted that the most relevant categories in Cambuí-related papers were molecular biochemistry, medicinal chemistry, food science and technology, and plant science.

The increasing appreciation of species of the Myrtaceae family in the scientific literature is intrinsically related to their phytochemical diversity, therapeutic potential, and broad applicability in the pharmaceutical, food, cosmetic, and agricultural industries. The integrative analysis of the selected studies highlights complementary approaches that reinforce the relevance of this botanical family, especially in the context of Brazilian biodiversity. One of the points of convergence among the studies is the rich composition of flavonoids and phenolic compounds identified in several species, such as *Myrciaria floribunda*, *Myrciaria tenella*, and Cambuí. Correia and colleagues (2022) [12] synthesized this information by highlighting the main flavonoids — anthocyanins (cyanidin, petunidin, malvidin, and delphinidin), catechin, quercetin, and rutin — in native fruits, associating them with antioxidant, anti-inflammatory, antidiabetic, and cardioprotective properties. This perspective is corroborated by Ribeiro and colleagues (2019) [13], who demonstrated the bioactive potential of *Myrciaria tenella* leaves, particularly rutin, in both *in vitro* and *in vivo* assays, thereby broadening the nutraceutical applicability of these species.

In a more in-depth manner, Santos and colleagues (2020) [14] reveal that extracts from the bark of *Myrciaria floribunda* not only concentrate phenols and anthocyanins but also express vigorous antinociceptive activity, mediated by the opioid system, with low toxicity. The association between chemical composition and pharmacological effects reinforces the importance of integrative studies that correlate phytochemical data with pharmacological tests.

Complementarily, through physicochemical analyses and mass spectrometry, García and colleagues (2021) [15] detail the composition of *Myrciaria floribunda* fruits, demonstrating a correlation between the orange coloring of the fruits, high concentration of phenolic compounds, and antioxidant activity. The comparison between the findings of Santos and colleagues (2020) [14] and García and colleagues (2021) [15] is particularly enlightening. Both studies examine the same species but focus on different plant structures (peel and fruit), suggesting that distinct organs accumulate specialized metabolites with potential functional and therapeutic applications.

Regarding essential oils, Amaral and colleagues (2013) [16] and Apel and colleagues (2002) [17] provide complementary views on the volatile composition of species in the genus *Eugenia* and *Neomitranthes*. Amaral and colleagues (2013) [16] explore the chemical variability between the leaves and fruits of *Neomitranthes obscura* (also known as "cambuí-preto"), revealing a predominance of sesquiterpenes in the leaves and a shift in the ratio between monoterpenes and sesquiterpenes in the fruits, which is associated with their coloration. This variation may reflect metabolic adaptations related to maturation and the attraction of dispersers, which is also a relevant aspect for the chemical ecology of the plant. On the other hand, Apel and colleagues (2002) [17] identified oxygenated sesquiterpenes, such as β-caryophyllene, viridiflorene, and globulol, in southern Brazilian species of *Eugenia*, highlighting their potential applications in aromatherapy and folk medicine.Both studies emphasize the diversity of volatile metabolites in Myrtaceae and their potential as aromatic and medicinal resources.

The pharmacological dimension is also explored by Ferreira and colleagues (2020) [18], who demonstrate the antileishmanial action of extracts from the fruits of *Eugenia moraviana* (Myrtaceae) against promastigote and amastigote forms, associating the effects with the presence of phenolics and flavonoids. The low cytotoxicity and the impact on the morphology of the parasites position this extract as a promising candidate for alternative therapies in the treatment of leishmaniasis. We highlight that this antiparasitic activity aligns with the antioxidant properties described by other authors, suggesting that the multifunctionality of phenolic compounds can be explored in various therapeutic contexts.

From an ecological and anatomical perspective, the study by Sosa and Gonzalez (2024) [19] examines the morphology of colleters in species of the tribe Myrteae, which are secretory structures that protect meristematic tissues. This study offers insights into the functional taxonomy of the subfamily Myrtoideae, suggesting that anatomical features have implications not only for systematic classification but also for understanding species adaptation and resilience in their natural habitats. This structural analysis can be integrated with phytochemical data, thereby expanding our understanding of the mechanisms underlying the production and secretion of secondary metabolites. Finally, Magedans and colleagues (2024) [20] address the phytotoxic activity of leaf extracts from *Myrciaria cuspidata*, highlighting allelopathic effects attributed to compounds such as tannic acid, quercetin, and gallic acid. This study broadens the perspectives for the application of Myrtaceae in sustainable agriculture by proposing their use as natural bioherbicides in the management of invasive plants.

Thus, when analyzing the nine studies together, a thematic convergence is observed, centered on the phytochemical diversity and functional potential of species from the Myrtaceae family. The integration of physicochemical, morphological, and pharmacological analyses reveals a broad spectrum of applications, ranging from functional and pharmaceutical products to agricultural bioinputs. It reinforces the importance of conserving and sustainably utilizing Brazilian flora. The alignment between chemical data and biological effects significantly contributes to the advancement of bioprospecting and the development of technologies based on national biodiversity [7,12–17,19,20].

Table 1. Lipids, pH, titratable acidity, and moisture analyses' results for the lyophilized cambuí sample.

Physicochemical Analyses	
Lipids (%)	81.31 ± 3.22
pH	3.94 ± 0.22
Titratable acidity (%)	2.76 ± 0.46
Moisture (%)	17.09 ± 0.37

Physico-Chemical Analyses

Table 1 presents the results of the analyses of the physicochemical properties of freeze-dried cambuí

The results obtained demonstrate marked differences in lipid content among regional fruit species. While Baldini (2016) [21] reported average values of 1.21% ± 0.052 lipids in freeze-dried araçá-boi, the determination carried out for cambuí revealed a substantially higher content of 81.31% ± 3.22. This discrepancy suggests not only inherent variations in the metabolic and physiological profiles of the species but also implications for the nutritional and technological potential of these fruits. Araçá-boi, due to its low lipid levels, tends to be more closely associated with low-energy-value products.

In contrast, cambuí, with its high concentration, may represent an alternative source of bioactive lipid compounds. Furthermore, factors such as fruit ripening, environmental growing conditions, and extraction methodologies may contribute to the magnitude of these differences and should be considered in future comparative studies [22].

The cambuí sample exhibited a pH of 3.94. For cambuíva, a fruit of the same genus as cambuí, Garcia and colleagues (2022) [15] reported pH values ranging from 3.26 to 3.70. Goldoni and colleagues (2019) [23] analyzed capoteira, reporting a value of 3.38. According to these studies, pH is influenced by various factors, including species, environmental conditions, and the ripening stage, among others. Fruits with higher acidity decompose more readily and are therefore widely utilized in the food industry [24].

The presence of total organic acids in the fruits was determined by titratable acidity, an important parameter in flavor assessment. The evaluated fruits showed a titratable acidity of 2.76%. The value observed for cambuí samples was higher than that of another fruit from the Myrtaceae

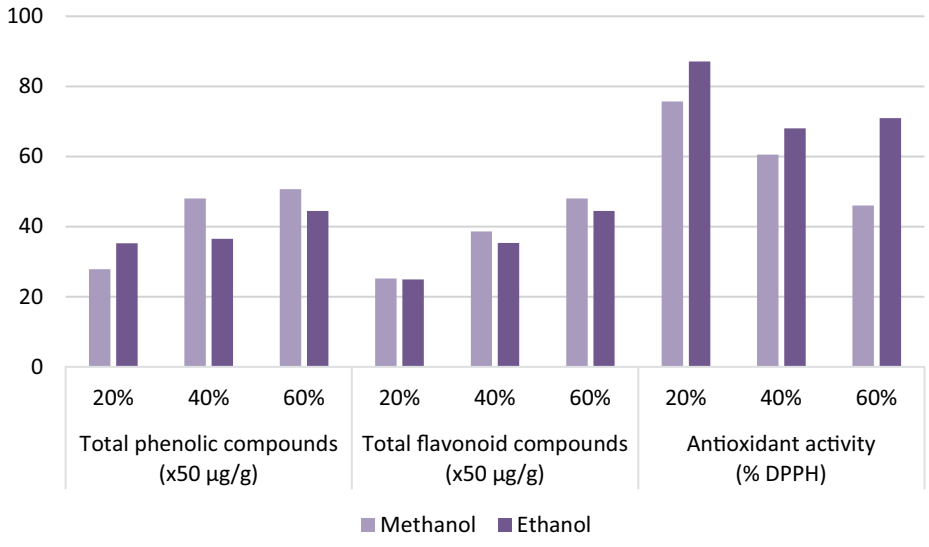
family, guava, which presented titratable acidity values ranging from 0.17 to 0.62%, as reported by Singh and colleagues (2023) [25], who evaluated different ripening stages. The cambuí sample also exhibited higher acidity than that reported by Souza and colleagues (2021) in the analysis of 'Sabará' jabuticaba, with values ranging from 0.51 to 0.70% (m/V of pulp).Since the analyzed cambuí was freeze-dried, the removal of water by this process promoted pulp concentration, thereby increasing the proportion of available substances per gram of sample.

In the literature, no moisture analyses were found for freeze-dried cambuí, which was determined in this study to be 17.09%. However, values are available for fresh purple cambuí and dried pulp, corresponding to 82.0% and 3.1%, respectively, as determined by Freitas (2021) [27]. It is expected that freeze-dried fruits present intermediate moisture values between fresh and heat-dried samples. In the former, the naturally occurring liquids are preserved, whereas in the latter, water removal by heating affects not only moisture but also acidity [28].Freeze-drying is a well-established drying process that removes water through sublimation, preserving the nutritional characteristics, as well

Table 2. Total phenolic compounds, total flavonoid compounds, and antioxidant activity analyses' results for each extract of lyophilized cambuí.

Extraction solution	Total phenolic compounds (µg/g)	Total flavonoid compounds (µg/g)	Antioxidant activity (% DPPH)
Methanol 20%	1392.74 ± 0.08	1261.40 ± 0.05	75.69 ± 0.02
Methanol 40%	2400.38 ± 0.04	1930.07 ± 0.01	60.58 ± 0.02
Methanol 60%	2535.03 ± 0.02	2400.07 ± 0.14	45.98 ± 0.03
Ethanol 20%	1761.84 ± 0.04	1247.07 ± 0.26	87.10 ± 0.09
Ethanol 40%	1826.42 ± 0.03	1767.40 ± 0.07	68.03 ± 0.08
Ethanol 60%	2221.60 ± 0.05	2221.40 ± 0.09	70.99 ± 0.05

Figure 3. Comparison of total phenolic compounds, total flavonoid compounds, and antioxidant activity of lyophilized cambuí extracts obtained with extraction solutions of 20, 40, and 60% methanol or ethanol.



as the fruit's color and aroma [29].

Table 2 presents the results of the analyses of total phenolic compounds, total flavonoids, and antioxidant activity of methanolic and ethanolic extracts from freeze-dried cambuí fruit; and Figure 3 the comparison os phenolic and flavonoids compounds.

The total phenolic content was higher in the 60% extracts, both ethanolic and methanolic, with values exceeding 2.2 mg/g. No reports on lyophilized cambuí were found in the literature; therefore, results were compared with those of other lyophilized fruits. The values obtained for lyophilized cambuí were similar to those determined for guava (1.85 and 4.06 mg/g), as reported by Singh and colleagues (2023) [25].

The quantification of flavonoids showed higher amounts in both 60% solutions compared to the other extract concentrations, yielding values between 2.2 and 2.4 mg/g. Antioxidant activity, in turn, showed the best results in both 20% extract solutions, reaching values above 85%.

The relatively low pH (3.94 ± 0.22) and the titratable acidity (2.76 ± 0.46%) contribute to the stability of phenolic compounds, particularly anthocyanins, which may explain part of the values observed in the Figure 3 [30].In addition, the low moisture content (17.09 ± 0.37%) reduces enzymatic degradation of antioxidants, favoring the preservation of antioxidant activity in the extracts [31]. In this context, characteristics such as high lipid content, low acidity, and reduced moisture emerge as key factors both for extraction efficiency and the stability of bioactive compounds [32,33].

Conclusion

The technological and scientific prospecting conducted indicates that the cambuí fruit (*Myrciaria* spp.) remains underexplored in terms of innovation and applied research, with only two patents registered and a limited number of indexed scientific publications compared to other native Brazilian fruits. Nevertheless, the studies analyzed demonstrate the significant functional and bioactive potential of cambuí, primarily associated with its richness in phenolic compounds and flavonoids, which are directly linked to antioxidant, anti-inflammatory, cardioprotective, and even antiparasitic activities.

The results obtained in this study confirm this potential, revealing high levels of total phenolics and flavonoids, as well as significant antioxidant activity, particularly in 60% extraction solutions. The chemical composition of freeze-dried cambuí, combined with its physicochemical characteristics, such as titratable acidity and intermediate moisture content, further supports its applicability across various sectors, with particular relevance to the food, pharmaceutical, and bioproduct industries.

Overall, the integration of phytochemical, pharmacological, and technological findings demonstrates that cambuí represents a valuable source of bioactive compounds, whose sustainable exploitation can promote bioprospecting and the development of new technologies based on Brazilian biodiversity. Thus, this study not only contributes to advancing knowledge about the species but also highlights the need for further research to explore its properties and applications, thereby strengthening the link between science, innovation, and the conservation of the national flora.

Acknowledgments

This study was financially supported by the Conselho Nacional de Pesquisa (CNPq). Thanks to the CLQM (Multi-User Chemistry Laboratory Center) at the Federal University of Sergipe for their support with the analyses.

References

1. Gonçalves GM, Martins V de C, da Costa ARH, et al. Essential oil of *Myrciaria tenella* (DC.) O. Berg: effects of distillation time on its chemical composition and evaluation of its anti-inflammatory and antinociceptive effects. Journal of Essential Oil Research. 2021;33(4):394-409. doi:10.1080/10412905.2021.1899993

2. Lédo A da S, Barin LB, Silva AVC da, Sá FP de, Machado C de A. *In vitro* germination and acclimatization of cambui tree type seedlings. Ciência Rural. 2014;44(8):1355-1359. doi:10.1590/0103-8478cr20131063
3. Santana JGS, Nascimento ALS, Costa TS, Almeida TMB de, Rabbani ARC, Muniz AVC da S. Estimation of genetic diversity in a natural population of cambui tree (*Myrciaria tenella* O. Berg) using ISSR markers. Genetics and Molecular Research. 2016;15(4).
4. Borges LL, Conceição EC, Silveira D. Active compounds and medicinal properties of *Myrciaria* genus. Food Chem. 2014;153:224-233. doi:10.1016/j.foodchem.2013.12.064
5. Antonelo FA, Rodrigues MS, Cruz LC, et al. Bioactive compounds derived from Brazilian Myrtaceae species: Chemical composition and antioxidant, antimicrobial and cytotoxic activities. Biocatal Agric Biotechnol. 2023;48:102629. doi:10.1016/j.bcab.2023.102629
6. Gomes JP, Dacoregio HM, Silva KM da, Rosa LH da, Bortoluzzi RL da C. Myrtaceae na Bacia do Rio Caveiras: Características Ecológicas e Usos Não Madeireiros. Floresta e Ambiente. 2017;24(0). doi:10.1590/2179-8087.011115
7. Ferreira OO, Costa VG, Cruz JN, et al. Chemical composition and *in vitro* and *in silico* Biological activities of *Myrciaria tenella* (DC.) O.Berg (Myrtaceae) essential oil from Brazil. J Food Biochem. 2024;2024:1-8. doi:10.1155/2024/2848736
8. Pinheiro LR, Almeida CS, da Silva AVC. Diversidade genética de uma população natural de cambuizeiro e avaliação pós-colheita de seus frutos. Scientia Plena. 2011;7(6).
9. Lima MA de, Teixeira LN, Sousa PB de, Silva M de JM da, Carvalho LFM. Determinação de fenólicos, flavonoides e atividade antioxidante da pimenta dedo-de-moça (*Capsicum baccatum* var. pedulum) comercializada na cidade de Imperatriz - MA. In: VII CONNEPI. 2012:1-7. Accessed September 19, 2025. https://propi.ifto.edu.br/ocs/index.php/connepi/vii/paper/viewFile/1084/2836
10. Instituto Adolfo Lutz (São Paulo). Métodos Físico-Químicos Para Análise de Alimentos. 4th ed. (Zenebon O, Pascuet NS, Tiglea P, eds.). Instituto Adolfo Lutz; 2008. Accessed April 27, 2025. https://www.ial.sp.gov.br/ial/publicacoes/livros/metodos-fisico-quimicos-para-analise-de-alimentos
11. Bligh EG, Dyer WJ. A rapid method of total lipid extraction and purification. Can J Biochem Physiol. 1959;37(8):911-917. doi:10.1139/o59-099
12. Correia VT da V, Silva PR da, Ribeiro CMS, et al. An integrative review on the main flavonoids found in some species of the Myrtaceae family: phytochemical characterization, health benefits and development of products. Plants. 2022;11(20):2796. doi:10.3390/plants11202796
13. Ribeiro ARC, Cordeiro ML da S, Silva LMP, et al. *Myrciaria tenella* (DC.) O. Berg (Myrtaceae) leaves as a source of antioxidant compounds. Antioxidants. 2019;8(8):310. doi:10.3390/antiox8080310
14. Santos IB da S, Santos B dos S, Oliveira JRS de, et al. Antioxidant action and *in vivo* anti-inflammatory and antinociceptive activities of *Myrciaria floribunda* fruit peels: possible involvement of opioidergic system. Adv Pharmacol Pharm Sci. 2020;2020:1-11. doi:10.1155/2020/1258707
15. García YM, Ramos ALCC, Oliveira Júnior AH de, et al. Physicochemical Characterization and Paper Spray Mass Spectrometry Analysis of *Myrciaria floribunda* (H. West ex Willd.) O. Berg Accessions. Molecules. 2021;26(23):7206. doi:10.3390/molecules26237206
16. Amaral RR, Fernandes CP, Caramel OP, et al. Essential Oils from Fruits with Different Colors and Leaves of *Neomitranthes obscura* (DC.) N. Silveira: An Endemic Species from Brazilian Atlantic Forest. Biomed Res Int. 2013;2013:1-7. doi:10.1155/2013/723181
17. Apel MA, Sobral M, Henriques AT, Menut C, Bessière JM. Chemical Composition of the Essential Oils from Southern Brazilian *Eugenia* Species. Part IV: Section Racemulosae. Journal of Essential Oil Research. 2002;14(4):290-292. doi:10.1080/10412905.2002.9699858
18. Ferreira FBP, Ramos-Milaré ÁCFH, Cabral MRP, et al. Chemical composition, antileishmanial and antioxidant activity of *Eugenia moraviana* (Myrtaceae) fruit extract. Medicinal Chemistry Research. 2020;29(9):1621-1631. doi:10.1007/s00044-020-02588-3
19. Sosa CM, Gonzalez AM. Homogeneous colleters in Myrteae (Myrtaceae). Protoplasma. 2024;261(1):15-29. doi:10.1007/s00709-023-01876-0
20. Magedans YVS, Antonelo FA, Rodrigues-Honda KCS, Ribeiro POS, Alves-Áquila ME, Fett-Neto AG. Phytotoxic Activity of *Myrciaria cuspidata* O. Berg, a Dominant Myrtaceae Woodland Tree Native of Brazil. Plants. 2024;13(23):3293. doi:10.3390/plants13233293
21. Baldini TF. Avaliação do Potencial Antioxidante do Araçá-Boi (*Eugenia stipitata*) Liofilizado e do Néctar de Maçã Suplementado com o Mesmo. Universidade Estadual de Campinas; 2016. doi:10.47749/T/UNICAMP.2016.978886
22. Uarrota VG. Differences in lipid metabolism, polar metabolites, and phenolics in *Persea americana* under two storage conditions. Horticulturae. 2023;9(2):234. doi:10.3390/horticulturae9020234
23. Goldoni J, Giacobbo CL, Galon L, Zarzzeka C, Uberti A, Lugaresi A. Physicochemical characterization of fruits of *Campomanesia guazumifolia* (Cambess.) O. Berg (Myrtaceae). Acta Sci Biol Sci. 2019;41:e45923. doi:10.4025/actascibiolsci.v41i1.45923

24. Pott DM, Vallarino JG, Osorio S. Metabolite changes during postharvest storage: Effects on fruit quality traits. Metabolites. 2020;10(5):187. doi:10.3390/metabo10050187
25. Singh A, Singh BK, Barman K, Singh AK. Influence of Maturity Stage on Post-harvest Quality of Guava Cultivars. Int J Plant Soil Sci. 2023;35(20):824-834. doi:10.9734/ijpss/2023/v35i203875
26. Souza PHM de, Gomes FR, Oliveira JAA, et al. Caracterização de frutos de jabuticaba 'Sabará provenientes da região de Jataí-GO. Revista Brasileira de Agropecuária Sustentável. 2021;11(1):78-85.
27. Freitas V de CM. Obtenção de Compostos Bioativos de Cambuí Roxo (*Eugenia candolleana*) por Diferentes Métodos de Extração. Graduação em Engenharia de Alimentos. Universidade Federal de São Carlos; 2021. Accessed August 27, 2025. https://repositorio.ufscar.br/handle/ufscar/14331?show=full
28. Antunes P, Dias S, Gonçalves D, et al. Impact of different dehydration methods on drying efficiency, nutritional and physico-chemical quality of strawberries slices (Fragaria ananassa). Processes. 2025;13(7):2065. doi:10.3390/pr13072065
29. Nwankwo CS, Okpomor EO, Dibagar N, Wodecki M, Zwierz W, Figiel A. Recent Developments in the Hybridization of the Freeze-Drying Technique in Food Dehydration: A Review on Chemical and Sensory Qualities. Foods. 2023;12(18):3437. doi:10.3390/foods12183437
30. Seth R, Fiecke C, Ma G, et al. Characterization of anthocyanins, phenolics, and flavonoids in a global carrot collection through application of chemometrics and FT-NIR spectroscopy. Food Chem X. 2025;29:102807. doi:10.1016/j.fochx.2025.102807
31. Yang S, Sun F, Wu X, et al. Establishment of DAS-ELISA and lateral flow immunochromatography for the detection of peanut allergen Ara h 3 after heat-moisture treatment. Food Chem. 2025;472:142910. doi:10.1016/j.foodchem.2025.142910
32. Abedelmaksoud TG, Younis MI, Altemimi AB, Tlay RH, Ali Hassan N. Bioactive Compounds of Plant-Based Food: Extraction, Isolation, Identification, Characteristics, and Emerging Applications. Food Sci Nutr. 2025;13(6). doi:10.1002/fsn3.70351
33. Ingale OS, Pravin BP, Pawase PA, et al. Enhancing bioactive stability and applications: microencapsulation in fruit and vegetable waste valorization. Discover Food. 2025;5(1):148. doi:10.1007/s44187-025-00412-8

Influence of Carnauba Wax on the Physical and Mechanical Properties of PBS/PLA/Vegetable Fibers Blend Composites

Talyta Silva Prado[1]*, Paulo Romano Cruz Correia[2], Marcus Vinicius Badaró de Oliveira Ribeiro[1], Erick Pinto Marques[1], Luciano Pisanu[1]

[1]SENAI CIMATEC University; [2]TRL9 Tech – Research and Development; Salvador, Bahia Brazil

Polymeric composites with vegetable fibers have attracted academic and industrial attention due to their ease of obtaining, combination of intrinsic properties, and environmental concerns. PBS/PLA blends reinforced with vegetable fibers from the coffee industry enhance sustainability and circular-economy characteristics. To increase the hydrophobicity and surface quality of polymer composites, carnauba wax proved an excellent alternative, given its organic nature, versatility, and compatibility with biopolymers. Therefore, this study had the objective to evaluate the influence of wax addition on the physical and mechanical wettability properties of PBS/PLA/vegetable fiber blend composites. The presence of wax in the 40% vegetable fiber formulation improved fiber cohesion and distribution, resulting in greater flexibility. Furthermore, in both formulations containing wax, an improvement in the contact angle was observed, with only the one containing 40% fiber reaching an angle greater than 90°, characteristic of hydrophobic materials, corroborating the theory of the wax's plasticizing action in this formulation.

Keywords: Polymer Blends. Carnauba Wax. PBS. Barrier Agent.

Polymeric blends have attracted significant attention, both from an academic and an industrial point of view, due to the relative ease of obtaining and developing new synthetic routes at relatively low cost through combinations of polymers with the properties of interest [1,2].

So, biopolymers have highlighted blend technology, as their properties can be improved and their processability enhanced. The PBS/PLA/Vegetable Fiber blend is an example of this, as PLA has several advantages such as a large processing scale, good rigidity, and resistance, however, it has a high cost, low capacity to absorb energy, low deformation to the point of rupture and, therefore, at levels of high mechanical demand, its use is limited [3].

To minimize these limitations, PBS is added, a biodegradable aliphatic polyester with good thermal stability and resistance to solvents and other chemicals, excellent processability, and low production cost [4,5]. Vegetable fiber, originating from coffee processing residues, aims to add distinct mechanical and organoleptic characteristics to the material, in addition to serving as a sustainable and economically viable alternative for disposing of these residues, since, when in environments conducive to degradation, it degrades through the action of microorganisms.

Aiming at the application of this polymeric blend in the packaging industry, the great challenge focuses on improving the permeability property to water vapor, since the transfer of moisture, whether through loss or gain of water with the external environment, favors the formation of lumps and microbial growth, in addition to reducing the crispiness of food, when it is destined for the food sector [6]. Conversely, for the plastics industry, the application challenge focuses on improving product surface quality, dispersing fillers and pigments, enhancing resistance to degradation, and improving material flexibility.

Carnauba wax is an excellent proposed solution, offering versatility, high compatibility, low molecular polarity, cost reduction, increased competitiveness in the current market, and being a natural product derived from organic, renewable sources that causes progressively smaller environmental impact [7].

Received on 16 July 2025; revised 24 September 2025.

Address for correspondence: Talyta Silva Prado. Av. Eng. Gentil Tavares, 1166 - Getúlio Vargas, Aracaju - SE, Zipcode: 49055-260. E-mail: talytaprado765@gmail.com.

J Bioeng. Tech. Health 2025;8(5):419-423

This study evaluated the effect of wax addition on the physical and mechanical properties and wettability of PBS/PLA/vegetable fiber blend composites, verifying its potential as a barrier agent for applications in the packaging and surface sectors.

Materials and Methods

The methodological process adopted for this study included drying and dehumidifying the raw materials, processing and molding the compounds, and, finally, characterizing and testing the specimens. PBS and vegetable fiber from coffee processing were dried at 90 °C for 48 hours, while PLA was dried at 70 °C for 4 hours. The extrusion process occurred using the formulations presented in Table 1, using an IMACOM twin-screw co-rotational extruder, Figure 1A - model DRC 30:40 IF, screw diameter of 30 mm, and L/D ratio of 40 - screw speed 116 rpm, and temperature zones equal to Z1 and Z2: 80 °C, Z3: 90 °C, Z4: 115 °C, Z5 and Z6: 150 °C, Z7: 160 °C, Z8: 155 °C, Z9: 160 °C, Z10: 145 °C and Z11: 33 °C.

Results and Discussion

Vegetable fibers can act as structural reinforcements within the polymer matrix, improving the tensile strength of the compound by providing high specific resistance, which contributes to the material's ability to withstand loads. However, Table 2 shows that the formulation containing 40% fiber (FR40) had a decrease in maximum stress and specific deformation, while the modulus of elasticity increased compared to the formulation containing 30% fiber (FR30).

A possible explanation is that, when passing certain "acceptable" filler levels, not all particles were allowed to be wetted by the polymeric matrix in the molten state, indicating that the chemical interaction at the fiber-matrix interface was less efficient than expected [8]. As a result of a possible

Table 1. Composition of formulations.

Formulations	(%)			
	PBS	PLA	Vegetable Fibers	Carnauba Wax
FC40	50	10	39.5	0.5
FC30	60		29.5	
FC40	50		40	0
FC30	60		30	

Figure 1. Equipment for processing and testing composites. A) IMACOM extruder; B) ROMI injection molding machine; C) Universal mechanical testing machine; D) Impact testing equipment.

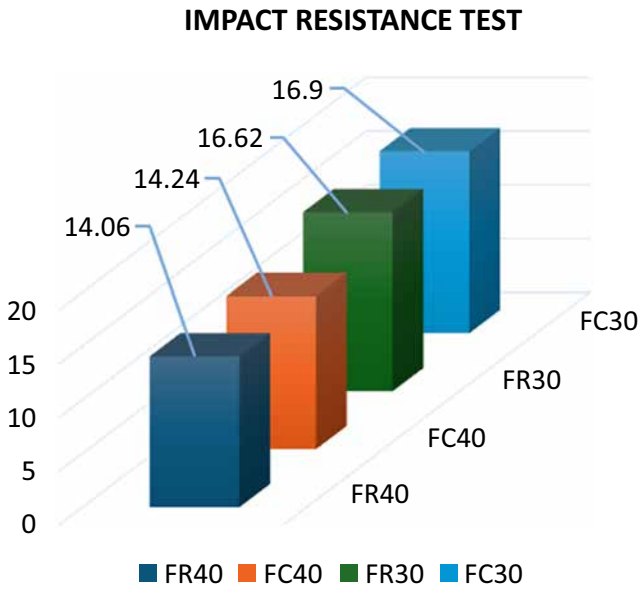
Table 2. Data from mechanical tests: Maximum strength, modulus of elasticity, and specific rupture strain.

Composition	Tension Force Max. (MPa)	Modulus of elasticity (MPa)	Def. Spec. breaking (%)
FC40	15.73 ± 0.61	1675 ± 63.61	3,162 ± 0.30
FR40	16.25 ± 0.37	1638 ± 40.14	2,940 ± 0.18
FC30	17.47± 0.35	1460 ± 39.45	3,648 ± 0.16
FR30	17.35± 0.34	1439 ± 50.92	3,741 ± 0.36

non-uniform distribution of the fiber in the matrix, some agglomerates of poorly cohesive fibers may have been formed, generating small voids and/or defined stress points. Another hypothesis is that fillers stiffer than the matrix may increase the composite's elastic modulus.

Taken together, the analysis in Figure 2 shows a greater impact resistance for the compound with 30% (FR30) than for the one with 40% (FR40), corroborating the idea that in FR40 there was no good promotion of the interaction between the fiber and the matrix, in addition to the development of several tension points that reduce the capacity to absorb energy before failure, thus compromising the mechanical performance of the assembly.

Figure 2. Impact resistance test.



Considering these circumstances, carnauba wax may be an option for improving the interaction between the materials in the composite blend, given its chemical properties, good compatibility, and low molecular polarity. Therefore, when the wax was applied, the FC40 formulation showed a 3.2% reduction in maximum tension.

This behavior can be explained by a possible plasticizing effect of the wax, which enhances cohesion between the polymer blend and the vegetable fiber, thereby increasing the material's flexibility, as evidenced by the slight variation in deformation capacity of this formulation.

However, the modulus of elasticity of FC40 did not show any significant variation, remaining within the margin of error (Table 2). This can be inferred from the fact that the wax improved the cohesion between the fibers and the polymeric matrix, and from the uniform distribution of loads, reducing stress concentrations and delamination.

However, because the material has a high fiber content and a PLA matrix with a high modulus of elasticity, this performance was not demonstrated. For FC30, since it already has a more acceptable level of vegetable fillers in the blend, we observe that the addition of wax did not influence the mechanical properties of the material in such a way that in FC40, this followed a trend already expected for composites with vegetable fillers and the values of stress, modulus of elasticity and specific deformation remained within the margin of error of the data. Thus, in this material, the wax in question facilitated particle mobility during the extrusion process, reduced the tendency of the

material to adhere to surfaces, and improved the surface quality of the products.

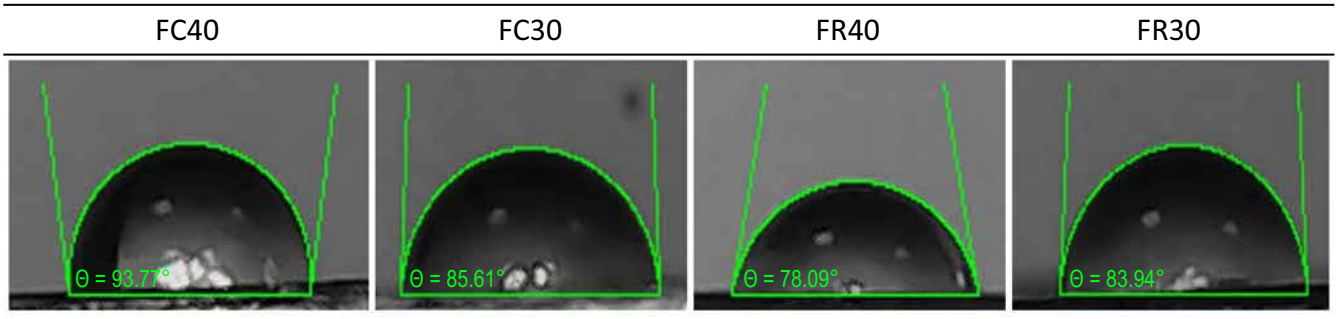
In terms of impact resistance, Figure 2 shows that, when comparing the FC40 and FC30 formulations with their FR40 and FR30 counterparts, respectively, the presence of PLA and carnauba wax increased impact resistance slightly. This is due to the wax, which improves the cohesion between the polymer blend and the vegetable fiber through its potential for plasticizing and compatibilizing. At the same time, the PLA contributes to the material's rigidity.

However, impact resistance is still limited by the high fiber content. Thus, it is noted that FC30 exhibits the highest impact resistance among the samples, due to the optimized amount of vegetable fiber, which allows good distribution and interaction with the PBS matrix, resulting in a material that effectively balances stiffness and impact resistance.

The contact angle analysis, in turn, aims to evaluate the wettability and surface adhesion properties of materials, providing crucial information on surface energy, interfacial interactions, and potential applications across coatings, adhesives, and biomaterials.

Figure 3 shows that the FC40 and FC30 formulations improved the contact angle, indicating that the use of wax may have enhanced the composite surfaces, increasing their hydrophobicity. However, only the increase in FC40 was sufficient to reach an angle greater than 90°, characteristic of hydrophobic specimens, in which there is no wettability, which reaffirms the theory of the plasticizing action of wax when 40% of vegetable fiber is present.

Figure 3. Contact angle test.



Conclusion

Therefore, it is concluded that the formulations developed with wax, FC40, and FC30 demonstrated improvements in hydrophobicity properties and impact resistance, with variable performance depending on the fiber content. These formulations are promising for applications that require moisture-barrier properties, due to their low wettability, and can enable greater process speed in automatic packaging machines. The information obtained is relevant for the optimization of polymeric materials to meet specific demands in various industrial applications and to strengthen the circular economy.

Acknowledgments

The authors would like to acknowledge the Polymer Laboratory, SENAI-CIMATEC.

References

1. Utracki LA. Polymer alloys and blends: thermodynamics and rheology. Munich: Hanser; 1989. p. 356.
2. Utracki LA. Polymer blends handbook. Vol. 1. Dordrecht: Kluwer Academic Publishers; 2002.
3. Sarantópoulos CIGL, Oliveira LM. Embalagens plásticas flexíveis: principais polímeros e avaliação

de propriedades. Campinas: CETEA/ITAL; 2002.
4. Caetano RMJ, et al. Oil biodegradation systems based on γ-irradiated poly(butylene succinate). Macromol Symp. 2018;380(1).
5. Ferreira LP, et al. Preparo de nanocompósitos de poli(succinato de butileno) (PBS) e argila montmorilonita organofílica via polimerização in situ. Polímeros. 2014;24(5):604–11.
6. Södergård A, Stolt M. Properties of lactic acid-based polymers and their correlation with composition. Prog Polym Sci. 2002;27:1123–63.
7. Karaski TU, Ribeiro FM. Embalagem e sustentabilidade: desafios e orientações no contexto da economia circular. São Paulo: CETESB; 2016.
8. Marcovich NE, Aranguren MI, Reboredo MM. Modified wood flour as thermoset fillers. Part I: effect of the chemical modification and percentage of filler on mechanical properties. Polymer. 2001;42(2):825.

3D Vision Accessibility: the Product Development Process

Antônia Larissa Reis Barbosa[1*], Carlos Alberto de Arruda[1], Hérica de Souza Araújo[1], Lucas de Figueiredo Soares[1], Marina Ferrari de Sena[1], Yuri Uriel Cerqueira Gil Braz Moreira[1], Valter Estevão Beal[1], Cristiano Vasconcellos Ferreira[1,2]

[1]SENAI CIMATEC University; Salvador, Bahia; [2]Federal University of Santa Catarina; Joinville, Santa Catarina, Brazil

Research indicates a significant increase in the use of prescription glasses worldwide. Along with this trend, there is an increasing interest in 3D movies (stereoscopic cinema) in the film industry. This requires an image overlay system associated with the use of specific glasses (3D glasses). However, the challenge faced by consumers who already wear prescription glasses is their use in conjunction with 3D glasses. Therefore, the purpose of this work is to describe the Product Development Process (PDP) and its application in developing a solution that enhances the immersive experience, providing greater comfort to users of prescription glasses while watching 3D movies.
Keywords: Product Development Process. Accessibility. 3D Vision. 3D Movies. Prescription Glasses.

The global prevalence of eyeglass usage among adults exceeds 4 billion, with projections indicating that by 2050, half of the world's population will rely on prescription eyewear, as reported by the American Academy of Ophthalmology (n.d.) [1].Concurrently, in 2023, over 113 million individuals frequented movie theaters in a single year. Within the cinematic landscape, the popularity of 3D films has surged over the past decade, although recent years have witnessed a decline, particularly in the wake of the COVID-19 pandemic. Despite this, significant advancements have been made in transitioning from traditional two-dimensional (2D) imagery to immersive three-dimensional (3D) experiences [2,3].

Addressing a fundamental social demand for spaces conducive to relaxation and escapism from daily routines, film viewing remains one of the foremost leisure activities worldwide. To meet evolving consumer expectations, the film industry has prioritized enhancing entertainment quality through technological innovations, notably through the production of 3D movies [3].

3D cinema, leveraging stereoscopic techniques, creates an illusion of depth perception by projecting identical images from distinct viewpoints, necessitating the use of specialized glasses for optimal viewing. This technology relies on the human brain's ability to fuse these disparate images, facilitating the perception of three-dimensional space [4,5]. However, individuals who already wear prescription glasses encounter unique challenges when attempting to enjoy 3D films, resulting from the cumbersome overlay of two sets of eyewear.

This overlap could present discomfort, visual distortion, and impede the intended immersive experience. Although 3D glasses incorporate technologies to simulate depth, their compatibility with prescription eyewear remains limited, compromising visual acuity. Consequently, the inability to provide a seamless viewing experience for individuals with visual impairments poses a significant challenge to the 3D film market, potentially constraining its audience base and market growth. The first approach to capturing and displaying 3D images was based on the concept of stereoscopy. Stereoscopic systems are based on the imitation of the human binocular visual system (HVS). Following this idea, a pair of photos (or movies) of the same 3D scene is taken with a pair of cameras configured with some horizontal separation between them. Later, the images are shown independently to the observer's eyes so that the left eye (or right) can only see the image captured with the left (or right) camera.

This way, some binocular disparity is induced, which stimulates the convergence of visual axes.

Received on 22 July 2025; revised 21 September 2025.
Address for correspondence: Antônia Larissa Reis Barbosa. Av. Orlando Gomes, 1845, Piatã, Salvador, Bahia, Brazil. Zipcode: 41650-010. E-mail: larissabarbosadesign@gmail.com.

J Bioeng. Tech. Health 2025;8(5):424-430

This process provides the brain with information that allows it to perceive and estimate the deep content of the scene [4].

Acknowledging these challenges underscores the imperative of enhancing accessibility in entertainment. Accordingly, this study aims to address the intersection of 3D glasses usage by prescription glass wearers and the associated difficulties. Through the application of Product Development Process (PDP) methodologies, this research endeavors to propose innovative solutions that optimize comfort and immersion for prescription glass wearers during 3D movie viewing.

Rozenfeld and colleagues (2006) emphasize the importance of robust product development efforts that align with international standards, underscoring the need for enhanced expertise in PDP management [6]. This study adheres to standardized procedures while adapting to the unique requirements of each project, leveraging multidisciplinary collaboration to devise conceptual solutions.

This paper presents a comprehensive approach to addressing the challenges posed by 3D movie viewing for prescription glass wearers, applying a PDP methodology, methods, and tools. Through collaborative efforts, this study aims to enhance accessibility in entertainment, providing an inclusive and immersive cinematic experience for all viewers.

Materials and Methods

The method employed in this research is based on a traditional product development approach that incorporates both quantitative and qualitative methods. The sequence presents the method applied in this research, which is organized into four phases: design specification, conceptual design, preliminary design, and detailed design.

Design Specification Phase

Identifying the clients' needs: To map potential market opportunities, potential consumer problems were identified through joint brainstorming sessions. After identifying the problems, the process of mapping key criteria began, including the target audience, market demand, problem interfaces, the existence of applied and/or similar solutions, and the motivation for development. With the preliminary information mapped, the target problem for this study was chosen.

Study of the State-of the-Art and Technological

Mapping: This stage involved surveying, analyzing, and synthesizing the current knowledge available on the subject. Through research in different databases and consultation with the Google Patents platform, an extensive investigation was conducted on 3D glasses technology and its limitations. To address this, the development team conducted various activities, including defining the problem system, analyzing the primary interfaces involved, examining the product life cycle, mapping competitors and similar products, surveying relevant standards and regulations, and analyzing the business model.

Market Research and Analysis: Following an understanding of the problem, the process of identifying customer needs commenced. This stage was carried out through the elaboration and application of a questionnaire aimed at the target audience of the product under development (young adult users of prescription glasses), using the MS Forms tool. The application of the survey resulted in the collection of 35 responses, which were statistically analyzed, generating a list of expressed needs.

Quality Function Deployment (QFD) Application: The QFD application stage involved translating the needs identified in the previous stage into requirements, analyzing the relationship between these needs and the translated requirements, and conducting a marketing analysis to evaluate conflicts between the requirements.

Conceptual Design Phase

Definition of the Functional Structure: After consolidating the QFD matrix, the process of defining the functional structure began, starting from identifying the primary function of the device under development (global function). After validating the global function, the decomposition of this function into the other involved functionalities (functional synthesis) was performed.

Elaboration of the Morphological Matrix: The detailing of the functional structure of the device was preceded by elaborating the morphological matrix, a tool capable of mapping the possible solutions/variations for each function proposed in the functional synthesis, enabling the generation of different concepts through the combination of the different solution options raised.

TRIZ Method Application: The application stage of the TRIZ (Theory of Inventive Problem Solving) method involved analyzing the conflicting requirements identified by the QFD matrix. The process was carried out by identifying engineering parameters equivalent to the project requirements and applying TRIZ to identify inventive principles recommended as a solution for each conflict. Based on the identified principles, the team identified applications for each one in solving the problem.

Concept Generation and Prioritization: After completing the morphological matrix and analyzing the contributions obtained through the TRIZ method, the process of generating ideas for the product began, considering the information gathered in the previous stages and combining the different variations predicted for each function in the morphological matrix. After the ideation phase, the concepts were evaluated and prioritized through the Pugh decision matrix. This tool enables comparative analysis between the generated concepts and customer needs, based on a reference product [7].

Preliminary and Detailed Design Phase

Concept Detailing: At the end of the process and with the concepts already prioritized, the best solution was selected and refined into a more detailed concept, including product specifications, key features, and customer benefits.

Results and Discussion

Problem System

The selection of a problem for investigation resulted in the identification of three key issues. Problem A focuses on improving the separation of household waste to facilitate recycling, while Problem C aims to optimize the process of cleaning, drying, and storing clothes in domestic environments. Problem B, which was chosen for detailed development, addresses the challenges that eyeglass wearers encounter when watching 3D movies. The incompatibility of conventional 3D glasses, which cause discomfort when worn over prescription glasses, highlights the need for a more integrated and comfortable solution. The key interfaces of the problem include prescription and 3D glasses, the user, the projected film, and the cinema halls. Figure 1 illustrates the target problem system of the research.

Life Cycle

Following the team's analysis, information was gathered about the product's lifecycle and its primary customers, as presented in Table 1.

Similar Competitors and Patents

For a detailed analysis, the Google Patents platform was used to examine patent data from 1993 to March 2024, initially identifying 450 documents, which were filtered down to 358 granted patents. These patents showcase significant advancements in 3D glasses, emphasizing customization and comfort with adjustments for interpupillary distance, temple length, and visual focus. Innovations such as heating

Figure 1. Problem system interfaces.

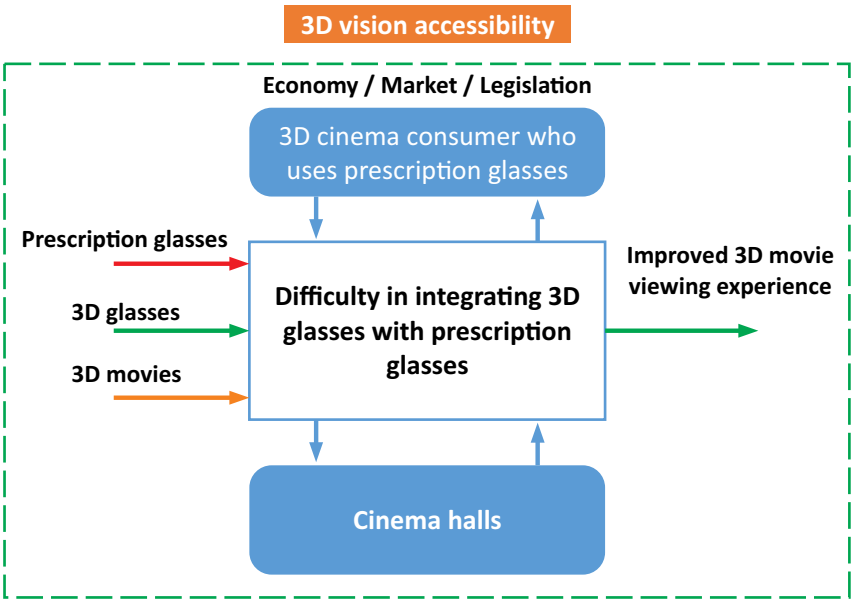


Table 1. Product lifecycle and identification of main customers.

Type	Phase	Customers
Manufacturer	Demand/Opportunity	Project team
	Development	Project team
	Manufacturing and assembly	Third-party product manufacturer
Intermediary	Transportation and Storage	Logistics company
	Purchase and Sale	e-commerce
External	Installation	Cinema
	Use	End user
	Maintenance	Cinema
	Reuse, Recycling, and Disp'osal	Recycling companies

pads and cold compresses enhance prolonged use by reducing fogging and visual fatigue. Additions such as augmented reality, integrated audio, modular designs, and the use of materials like silicone and fluorescent paint enhance immersion and comfort, particularly in low-light environments.

Identification of Customer Needs

For a detailed analysis, the Google Patents platform was used to examine patent data from 1993 to March 2024, initially identifying 450 documents, which were filtered down to 358 granted patents. These patents showcase significant advancements in 3D glasses, emphasizing customization and comfort with adjustments for interpupillary distance, temple length, and visual focus. Innovations such as heating pads and cold compresses enhance prolonged use by reducing fogging and visual fatigue. Additions such as augmented reality, integrated audio, modular designs, and the use of materials like silicone and

fluorescent paint enhance immersion and comfort, particularly in low-light environments.

The method used to gather customer needs was through an online survey form. Initially, the survey targeted 35 individuals who had experience with 3D movies in cinemas and used prescription glasses. Based on the survey results, customer needs were analyzed and transformed into specific requirements for product development.

Quality Function Deployment (QFD)

Utilizing the Quality Function Deployment (QFD) methodology, a prioritization ranking of the specified requirements was determined. This ranking incorporated the significance assigned to each requirement by both the client during the research phase and the development team. Additionally, the results of the requirements conflict tool were included in the ranking. The results showed that the requirements associated with comfort and practicality were more pronounced, such as the number of adaptable models, percentage of transparency, number of operations, and mass. Otherwise, the lowest was the commercialization cost, which is associated with the cinema owner's needs. The expectation was that the number of corners and edges associated with the consumer's comfort would be considered a relevant requirement; however, it was not.

The primary emphasis among the requirements lies in the adaptability of 3D glasses to accommodate prescription glasses, a pivotal aspect in fulfilling a fundamental necessity. A diverse range of adjustments enhances compatibility with various models of prescription glasses available in the market. Additionally, the transparency percentage garnered significant attention, guaranteeing the provision of sharp images. Mass emerged as another critical requirement, directly impacting user comfort. Moreover, the number of operations, quantity of parts, and manufacturing/ operational expenses play vital roles in assessing the economic feasibility of the product. Decreasing these metrics is advantageous in meeting the requirements of both cinemas and manufacturers, thereby diminishing operational and logistical expenses.

Another ranking was generated using the QFD tool through benchmarking. During this phase, the primary competing products underwent evaluation against the exact pre-established requirements. This facilitated the identification of the product that most effectively fulfilled the requirements, thereby serving as a benchmark for concept development. The outcomes of the main competitors' ranking are illustrated in Table 2.

Morphological Matrix

Based on the morphological matrix, three concepts were generated, each with possible solutions for the functions proposed in the functional synthesis. This matrix enables the generation of different concepts to fulfill the assigned functions, combining various solution options that have been identified. This systematic and organized approach facilitates the analysis and selection of the best combinations of solutions to meet the requirements of solution development. To achieve better results in concept generation, the TRIZ tool was used to identify innovative solutions based on the conflicts presented in the QFD roof. The application of TRIZ aims to identify the equivalence among the 39 technical parameters.

Table 2. Benchmarking ranking of primary competitors.

Model	Ranking
Clip on polarized 3d glasses	121
Anaglyph Hinged Glasses	111
Benq Link Active 3D Glasses	97

Concept Selection and Detailing

Proposed by Altshuller and the project requirements. For this purpose, the five priority requirements from the ranking generated by the QFD presented in Table 3 were used to analyze the conflicts between them. Based on the TRIZ matrix, inventive principles resulting from the conflicts are identified to search for analogous solutions adapted to the problem. For concept selection, the Pugh decision matrix is applied. This method is used to compare the generated concepts with customer needs. It is used in engineering and design to make informed decisions about which concept or solution is most suitable for meeting project requirements. For the application of the Pugh method, the clip-on polarized 3D glasses were defined as the reference product, corresponding to the benchmarking product that obtained the highest score in the QFD, for evaluating the performance of each generated concept in relation to meeting the needs, as presented in Figure 2.

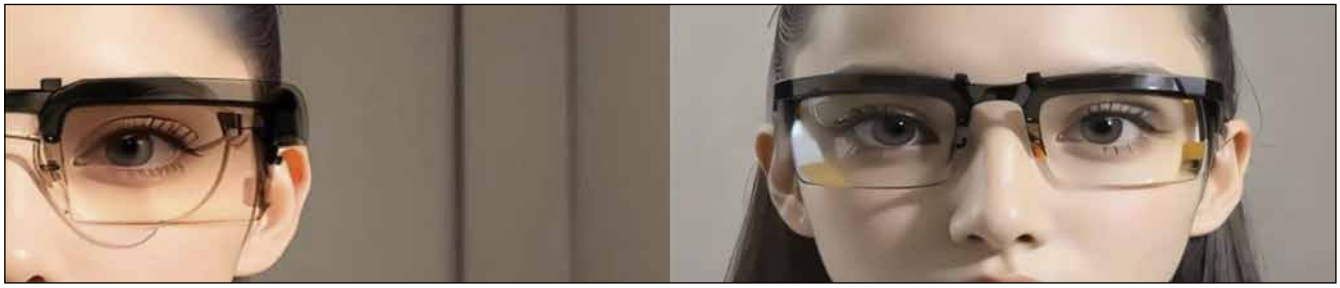
The first concept showed the highest potential for meeting the proposed requirements, presenting better performance possibilities than the evaluated commercial competitors. This concept is based on a solution that caters to both glasses-wearers and non-wearers, with a stronger emphasis on users of prescription glasses to provide greater comfort and convenience while maintaining style and simplicity. This concept is presented in Figure 3. The system was designed using flexible, moldable material to adapt easily to the user's face and fit various models of prescription glasses, enhancing usability, operation, and maintenance. Its central and lateral locking pins provide increased stability.

A key feature is its modularity, which allows for the simple addition of extra lenses and straps. This enables the replacement of lenses with different types as needed by the cinema and offers strap

Figure 2. Pugh matrix for concept selection.

Need	*Customer grade*	*Customer weight*	*Generated Concepts*			
			I	II	III	IV
Adaptable to prescription glasses	6	0.6	1	1	1	Reference
Clear image	9	0.6	1	-1	0	
Be comfortable	9	0.6	0	1	1	
Do not damage prescription glasses	1	0.6	1	-1	1	
Good fixation on the face	6	0.6	1	1	0	
Easy to operate	3	0.6	1	-1	1	
Allow a wide field of view	6	0.6	1	1	0	
Be light	3	0.6	-1	1	0	
Low operation/maintenance cost	6	0.3	1	-1	1	
No contamination between users	9	0.3	0	0	0	
Low acquisition cost	3	0.3	0	1	1	
Be resistant/robust	9	0.3	0	0	0	
Be compact	6	0.3	1	1	0	
Low manufacturing cost	9	0.1	0	0	0	
Few pieces	6	0.1	1	1	1	
		Total:	**21**	**11,7**	**14.7**	

Figure 3. 3D glasses concept with the highest potential for meeting the proposed requirements.



options for users without prescription glasses, with a structure that is moldable to various face shapes. The project chose polarized lenses due to their popularity and cost-effectiveness in cinemas compared to active glasses, which require higher lighting performance and image quality for overlay. Although aimed at incremental improvements in commercial solutions, the development involved medium complexity in terms of 3D cinema technology and user experience. Ensuring comfort and adaptability is crucial, requiring an understanding of subjective scenarios.

Conclusion

The product development process plays a crucial role in creating innovative and competitive solutions. According to Rozenfeld10, it is fundamental for companies to succeed in developing innovative, competitive, and high-quality products, allowing them to meet market demands efficiently and effectively. Despite the research outcome presenting a simplified solution aimed at incremental improvement in commercial solutions, the development demonstrated moderate complexity in the domain of 3D cinema technology and a limited understanding of the user experience in this context. Meeting the needs for comfort and adaptability is a commitment to quality criteria, which requires perception and understanding of subjective scenarios.

Acknowledgments

The authors express their gratitude to SENAI CIMATEC and its Postgraduate Program in Industrial Management and Technology.

References

1. Academia Americana de Oftalmologia. Facing the Myopia Epidemic. EyeNet Magazine. Available at: https://www.aao.org/eyenet/article/facing-the-myopia-epidemic.
2. Sean Y. Os óculos de filme 3D são o futuro do entretenimento? Available at: https://www.researchdive.com/8616/3d-cinema-screen-market
3. Princy AJ. Quais avanços recentes nas telas de cinema 3D trazem uma nova estética para a tela grande? Research Dive. Available at: https://www.researchdive.com/blog/what-recent-advancements-in-3d-cinema-screens-bring-new-aesthetics-to-the-big-screen. 4. Martínez-Corral M, Javidi B. Fundamentos de imagens e exibições 3D: um tutorial sobre imagens integrais, campo de luz e sistemas plenópticos. Adv Opt Photon. 2018;3:512-566.
5. Rojas G, et al. Stereoscopic three-dimensional visualization applied to multimodal brain images: clinical applications and a functional connectivity atlas. Neuroscience. 2014;8. doi:10.3389/fnins.2014.00328.
6. Rozenfeld H, Forcellini FA, Amaral DC, Toledo JCS. Gestão de Desenvolvimento de Produtos: Uma referência para a melhoria do processo. São Paulo: Saraiva; 2006.
7. Karnjanasomwong J, Thawesaengskulthai N. TRIZ-Pugh Model: new approach for creative problem solving and decision making. In: IEEE International Conference on Industrial Engineering and Engineering Management (IEEM). Singapore; 2015. p. 1757-1761. doi:10.1109/IEEM.2015.7385949.

Development of a Method for Conducting Short-Circuit Test Under UN38.3 Standard for Batteries Composed of Primery Lithium Metal Cells

Ruan Sávio Ferreira Zeferino[1]*, Breno Prazeres Barbosa[1], Alan Gramacho dos Santos[1]
[1]SENAI CIMATEC University; Salvador, Bahia, Brazil

Lithium batteries have been utilized in a wide range of applications, from land vehicles and aircraft to isolated systems such as underwater equipment and space satellites, where autonomy is a crucial factor. However, these batteries pose significant risks in cases of external damage, malfunction, or exposure to environments that interfere with their internal chemical reactions. This has led to the creation of specific standards to regulate their transport and storage. Therefore, this work proposes a methodology for conducting a short-circuit test, a component of the certification process for the UN38.3 standard on the safe transportation of lithium batteries.
Keywords: UN38.3. Transport and Safety. Battery. Metallic Lithium.

Embedded electronics is a field of great prominence in the development of autonomous systems, allowing the integration of sensors, actuators, and control algorithms into compact and efficient devices [1]. Systems designed to operate in isolated and extreme environments, such as orbiting satellites and underwater devices, depend on energy sources that ensure their operation for long periods [2]. In this sense, autonomy becomes a relevant aspect, as the system must operate continuously and independently, without external intervention.

For these systems to remain operational without external interaction, one option is the use of batteries. Among the battery technologies currently available on the market, lithium batteries are widely mentioned in the literature due to their high voltage per cell, high energy density (around 500 Wh/kg), and low self-discharge rate—characteristics that favor long service life and optimization of space occupied by the cells, making them a relevant choice for applications demanding extended autonomy [3-6].

Received on 28 June 2025; revised 27 September 2025.
Address for correspondence: Ruan Sávio Ferreira Zeferino. Av. Orlando Gomes, 1845, Piatã, Salvador, Bahia, Brazil. Zipcode: 41650-010. E-mail: zeferinoruan@gmail.com.
Original extended abstract presented at SAPCT 2025. Award-winning undergraduate fellow at SAPCT 2025.

J Bioeng. Tech. Health 2025;8(5):431-434

However, lithium batteries are susceptible to temperature variations and overcharging. Due to lithium's reactivity, under certain conditions—such as exposure to high temperatures, physical damage, or short circuits—these batteries may undergo uncontrolled chemical reactions, resulting in the leakage of toxic substances, fire, and explosion [7]. To mitigate these risks, international safety standards were established, among them UN38.3, a regulation developed by the United Nations that defines a series of rigorous tests to ensure the safety of lithium batteries during transport and storage [8]. In this context, this work aims to present a methodology for conducting one of the qualification tests for safe transport under the UN UN38.3 standard, for batteries assembled with tested lithium cells, totaling a mass equal to or less than 500 g of Li.

Theoretical Foundation

The air transport of lithium batteries has become increasingly common, mainly due to the high speed of this mode, which allows cargo to reach its destination faster than other transport options. However, when the lithium content exceeds 1 g or the capacity surpasses 20 Wh, it is necessary to meet the regulatory requirements for the air transport of hazardous goods [7]. UN38.3 establishes eight distinct tests that evaluate the behavior of batteries under various

adverse conditions, including exposure to high and low temperatures, vibration, impact, external short circuits, and overcharge.

Certification under this standard significantly reduces the risk of accidents, thereby protecting both logistics operators and end-users.

For batteries assembled with tested cells totaling less than 500 g of lithium, three tests are required: vibration (T3), mechanical shock (T4), and external short circuit (T5). Although UN38.3 requires that this type of battery undergo all tests (T3, T4, and T5) to ensure transport and handling safety, this work focuses exclusively on the short-circuit test. This choice is due to the importance of this test in evaluating the thermal stability of the battery under extreme operating conditions.

The short circuit represents one of the most critical scenarios for lithium batteries, as the sudden rise in current can trigger internal processes that compromise their integrity and safety. This abrupt increase in current intensifies power dissipation in the internal elements of the battery, leading to the rapid heating of its components.

If the temperature exceeds a certain threshold, the stability of the electrolytes and electrochemical materials may be compromised, leading to the phenomenon of thermal runaway. In this state, the battery enters a self-sustaining cycle of heating and decomposition of its materials, culminating in the release of flammable gases, possible fires, and, in extreme cases, explosions. To prevent such conditions, a BMS (Battery Management System) is used, which is responsible for controlling, managing, and protecting the batteries [9]. The BMS is part of the battery and must be accredited together with the cells.

Proposed Method

The short-circuit test aims to evaluate the battery's behavior under a condition of continuous external short circuit. In this case study, the test will be performed with a battery pack capable of providing two voltage levels.

Prerequisites

- Minimum of two operators.
- Assembled battery pack.
- Class D fire extinguisher – suitable for metallic lithium batteries.
- Metal barrel at least 35% filled with sand or vermiculite.
- Long metal bar with a straight end. Gloves with thermal protection greater than 58°C.
- PPE:
  - Protective boots with plastic toe caps.
  - Face shield or safety goggles.

Equipment

- Multimeters with a thermocouple.
- Thermal paste.
- Climatic chamber.
- Infrared thermometer.
- Thermal camera.
- Multimeters in ammeter mode with recording capability.
- Recording camera.
- Computers.
- Flexible copper cable with PVC insulation and resistance $\leq 0.1\ \Omega$ – sized according to the maximum short-circuit current for each voltage level.
- Circuit breaker, curve C, with DC interruption capacity – sized according to the conductor's capacity.

Procedure

To carry out the short-circuit test, the cell or battery must be placed in the climatic chamber, where it will be heated until reaching a homogeneous stabilized temperature of (57 ± 4) °C. To monitor this temperature, thermocouples fixed with thermal paste must be used on the external casing. The climatic chamber must be configured and started for heating. Temperature confirmation must be made using

an infrared thermometer and a thermal camera. Next, the short-circuit circuit assembly proceeds. The circuit breaker must be installed in series with the positive terminal of the battery, sectioning both voltage levels. Ammeters must be connected in series with each circuit to monitor current. Additionally, a recording camera must be positioned to record the entire test visually. Figure 1 shows the experimental bench for the short-circuit test, with a battery capable of providing two independent voltage levels.

After reaching the stabilized temperature, the battery must be removed from the chamber, and the ammeter recording initiated. Current data must be recorded continuously, while temperature data must be noted every 5 minutes. With the circuit assembled, the battery is subjected to a short circuit.If any apparent damage occurs, a metal bar must be used to knock the battery into the containment barrel, and then the circuit breaker must be activated to stop the test. Throughout the entire process, the temperature must be constantly monitored using thermocouples and a thermal camera.

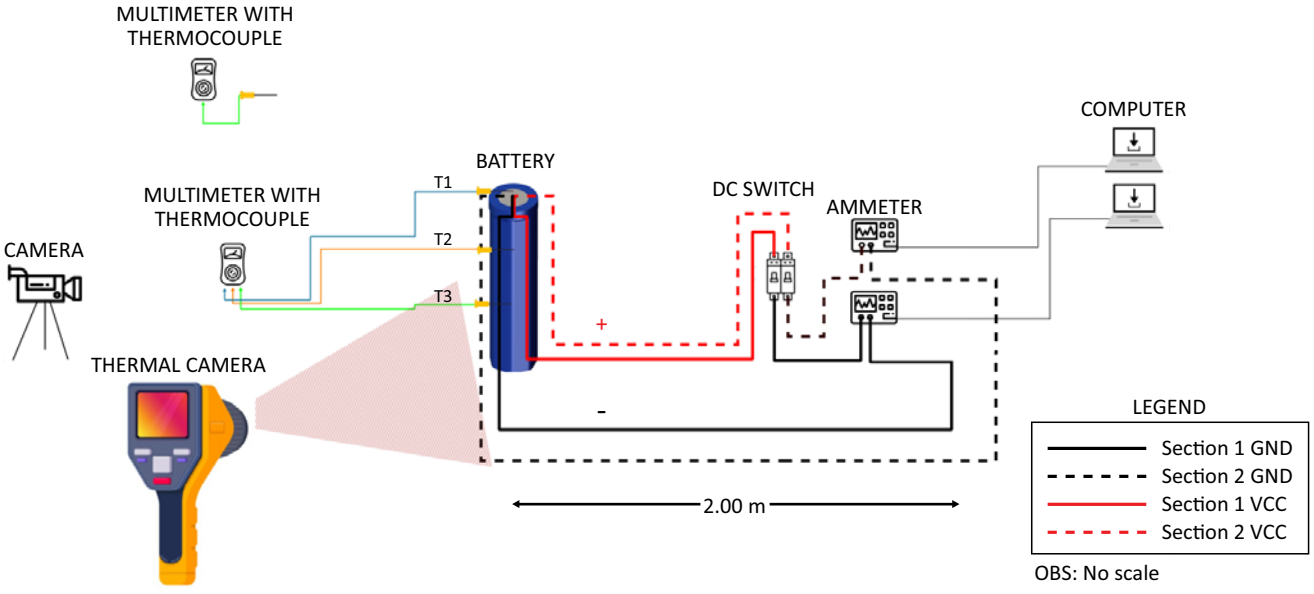
The short-circuit condition is interrupted at least one hour after the battery returns to a temperature of (57 ± 4) °C. For the battery to be approved, the external temperature must not exceed 170°C, and there must be no disassembly, rupture, or fire during the test and within 6 hours after the test.

Conclusion

The safety of metallic lithium batteries has been a growing concern in research and regulations. The UN38.3 standard establishes requirements for the transportation and commercialization of these batteries, especially during air transport, as a requirement of international hazardous goods regulations.

Thus, this work aimed to provide a methodology that enables researchers to apply the external short-circuit test safely, allowing for the collection of preliminary data on battery behavior before performing the test in accredited laboratories. This enables the identification of potential inadequacies and adjustments to batteries and BMS devices before the official test, thereby reducing the risk of failure and optimizing the certification time. However, this methodology does not replace formal tests conducted by certified entities; instead, it contributes to a preliminary analysis, helping to adapt products to regulatory requirements.

Figure 1. Test setup.



Acknowledgments

The authors would like to thank SENAI CIMATEC, Shell Brasil Petróleo LTDA, Petrobras, the Brazilian Company of Research and Industrial Innovation (EMBRAPII), and the National Agency of Petroleum, Natural Gas, and Biofuels (ANP) for their support and investment in R&D&I.

References

1. Filho RP, Fontgalland IL. Tecnologia embarcada e a Indústria 4.0. E-Acadêmica. 2022;3(1):e103195.
2. Lopez JL, et al. On-demand ocean-bottom nodes (OD OBN) for low-cost reservoir monitoring. In: Third International Meeting for Applied Geoscience & Energy. Houston: Society of Exploration Geophysicists and American Association of Petroleum Geologists; 2023. p. 197-201.
3. Alves LM. As vantagens das baterias de lítio: um estudo de caso. Itapetininga; 2022.
4. Franchi LDC. Análise e implementação de métodos de estimação de parâmetros de célula de lítio. Porto Alegre; 2022.
5. Barreto AA, et al. Análise do efeito do tempo de descarga na vida útil de baterias de íon-lítio em aplicações de sistemas fotovoltaicos com fluxo reverso. Rio de Janeiro; 2024.
6. Michelini A. Baterias de lítio. 2020. Access: Mar 11, 2025.
7. Gomes RR, Augusto SAS. Possíveis riscos de acidentes no transporte de baterias de lítio no modal aéreo. 2023.
8. United Nations. Recommendations on the Transport of Dangerous Goods: Manual of Tests and Criteria. 7th rev. ed. New York: United Nations; 2019.
9. Alves CLGS, et al. Análise térmica e avaliação das incertezas dos parâmetros do modelo elétrico da bateria de lítio-íon. 2019.

Analysis of Maximum Stress due to Bending in Helical Gears: Comparison Between the Agma Method and Finite Element Analysis

Hebert Tairone dos Santos Silva[1,2*], Gabriel Aelo Ribeiro[1], Icaro Figueiredo Vilasboas[1], João Pedro Cheloni[1], Rodrigo Silveira de Santiago[1], Lucas Lincoln Fonseca Soares[1], Juan Carlos Romero Albino[1]

[1]SENAI CIMATEC University; [2]Federal Institute of Science and Technology of Bahia; Salvador, Bahia, Brazil

This study presents a methodology for designing helical gears based on Shigley's calculation approach and AGMA standards, including the calculation of maximum bending stresses and the application of safety factors. The analytical results were compared with numerical results obtained from a structural analysis using the Finite Element Method (FEM), applying the von Mises yield initiation failure criterion. The methodology involved defining geometric and operational parameters, calculating the tangential load, and considering overload factors to achieve more realistic simulations. The maximum stress obtained from the finite element analysis showed a 3.85% difference relative to the analytical calculation from the AGMA standard, demonstrating good agreement between the methodologies.
Keywords: Helical Gears. AGMA Standard. Maximum Bending Stress. Finite Element Method.

Helical gears used to transmit small powers and short center-to-center distances [1] have greater face width in contact than spur gears of the same size, which gives them a higher load-carrying capacity [2]. In addition, the load is distributed among several teeth, allowing smoother transmission and more consistent elastic flexibility [2], as occurs in rolling mill gearboxes, as illustrated in Figure 1. Due to these characteristics, the design of helical gears requires detailed study and conservative methods to ensure greater reliability and component life.

This study aims to explore three main aspects: (1) the design of helical gears based on Shigley's book [3] and AGMA standards, using a virtual example with fundamental parameters, including the calculation of maximum bending stresses and their respective factors; (2) the modeling of the gear designed following the AGMA methodology for defining tooth dimensions; and (3) the simplified static structural analysis of the pinion (using finite elements) to compare with the maximum bending stress through the von Mises criterion.

Received on 14 May 2025; revised 21 September 2025.
Address for correspondence: Hebert Tairone dos Santos Silva. Av. Orlando Gomes, 1845, Piatã, Salvador, Bahia, Brazil. Zipcode: 41650-010. E-mail: heberttairone25@gmail.com.
Original extended abstract presented at SAPCT 2025. Award-winning undergraduate fellow at SAPCT 2025.

J Bioeng. Tech. Health 2025;8(5):435-439

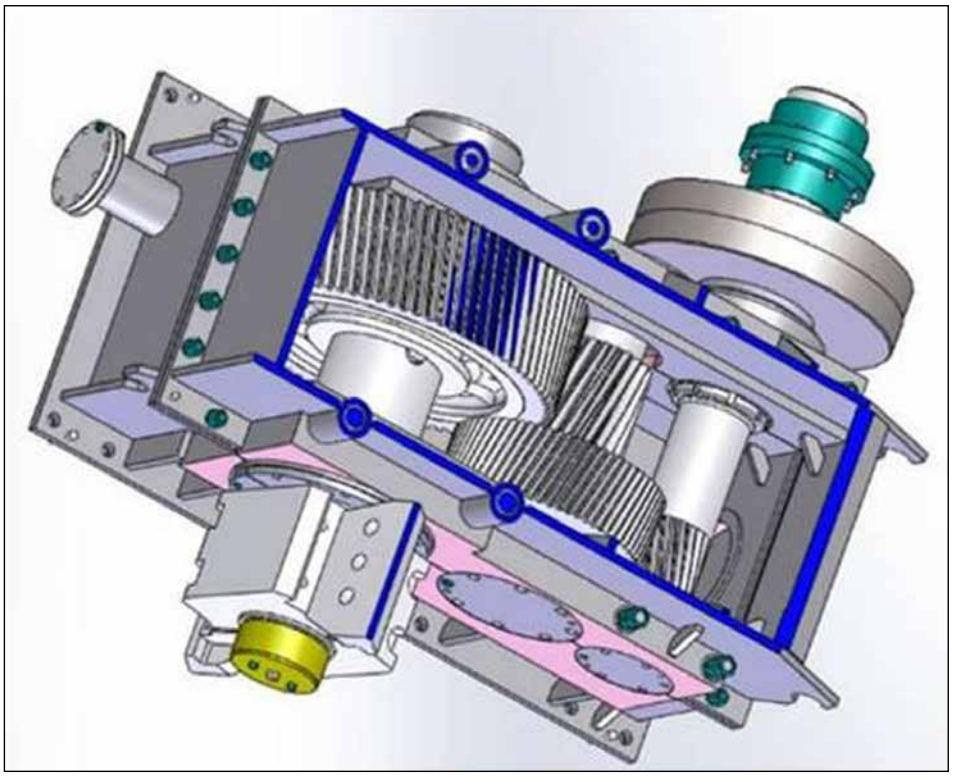
Rolling, one of the primary steel forming processes, involves reducing the material's cross-section to predetermined dimensions and shapes [4]. During the process, rotating work rolls, driven by motors and gearboxes (Figure 1), generate enough energy to deform the rolled material [5]. According to Santi and Trazzi (2015), due to the large forces present in the rolling process, the drive system must be robust enough to withstand the imposed loads [6].

Materials and Methods

The helical gears designed in this study had their initial parameters defined in Kutz's book [7] and are presented in Table 1, which outlines the geometric characteristics of the gears and their operating conditions. Based on these specifications, the necessary dimensions were calculated for modeling the gear and pinion in SolidWorks, as illustrated in Figure 2, along with the boundary and loading conditions used in Ansys.

During the gear modeling, a fillet with a 1.5 mm radius was added at the tooth root. This region received a more detailed mesh refinement to ensure accuracy in the load application area. For analysis, the gear wheel was suppressed, and a tangential load equivalent to 4500 [N] was applied directly to the pinion tooth face. Table 2 presents the factors used for the analytical calculation of maximum bending stresses, the safety factors for the pinion and gear,

Figure 1. Rolling mill gearbox – CAD model.

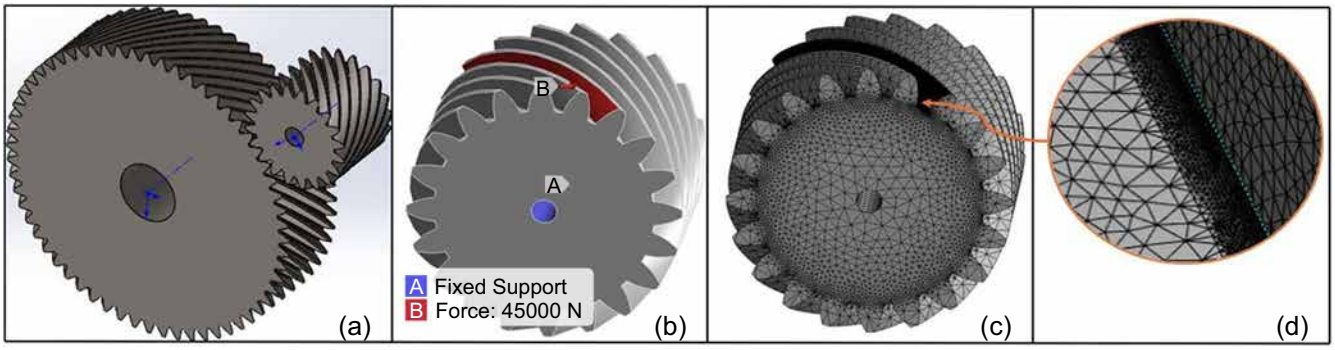


Source: GMB Heavy Industries, 2025 [8].

Table 1. Gear parameters and operating conditions.

ParametersValues					
Number of pinion teeth (*Np*)	20	Gear hardness	300 HB	Reliability	99%
Number of gear teeth (*Nc*)	60	Modulus of elasticity (pinion and gear)	205 GPa	Operating temperature	120 °C
Metric module (m)	10 mm	Poisson's coefficient (pinion and gear)	0.29	Quality standard	Qv = 7
Transmission ratio	3:1	Maximum torque on input shaft	2,000 Nm	Pinion pitch diameter (dp)	200 mm
Pressure angle (ϕ)	20°	Pinion rotation	1000 rpm	Gear pitch diameter (dg)	600 mm
Helix angle (ψ)	30°	Machine load	Heavy shock	Transverse angle (ϕt)	22.08°
Pinion hardness	370 HB	Power source overload	Medium shock	Face width (b)	157.08 mm

Figure 2. (a) CAD gear model, (b) boundary and loading conditions, (c) finite element model, and (d) detail of the fillet region at the pinion root.



and the results obtained, calculated using equations (1), (2), and (3).

The comparative methodology between the AGMA and Finite Element Methods adopted is similar to that of Queiroz de Jesus and colleagues (2024) [9], differing in the type of gear used (spur gears) and in its specific application (high-performance automotive), resulting in efforts of different magnitudes.

$$\sigma = W_t K_o K_v K_s \frac{1}{b_m} \frac{K_h K_b}{Y_j} \quad \text{Eq. 1}$$

$$\sigma_R = \frac{S_t Y_N}{K_T K_R} \quad \text{Eq. 2}$$

$$S_F = \frac{\sigma_R}{\sigma} \quad \text{Eq. 3}$$

An important aspect of the analysis is the overload factor (*Ko*), applied conservatively in the AGMA calculation. This factor incorporates external loads that exceed the nominal tangential load Wt in specific applications, accounting for variations [10] in torque and operational shocks that can amplify the forces acting on the pinion.

Thus, the maximum bending stress was calculated considering the worst-case scenario, ensuring a more realistic approach. For the simulation, the tangential load applied to the tooth was defined as $KoWt$ = 45,000 N. To reduce computational cost, the simulation was performed only on the gear subjected to the highest maximum stresses generated by contact with the mating gear, maintaining the conservative approach without compromising result accuracy.

Results and Discussion

The results presented consist of the analytical calculation of the pinion tooth root stress and the stress field calculated using the finite element method. Table 2 presents the results of maximum bending stresses and analytically calculated safety factors, obtained using SMath and Excel software, along with the dimensioning factors employed to achieve these results.

Figure 3 shows the von Mises stress plot in the region where maximum bending stress occurs on the pinion tooth. It is observed that the maximum equivalent von Mises stress at the tooth root of the gear was approximately 3.85% lower than the value calculated analytically according to the AGMA standard. The error obtained is consistent with the values found in the works of Gidado, Muhammad and Umar (2014) [10] and Queiroz de Jesus and colleagues (2024) [9].

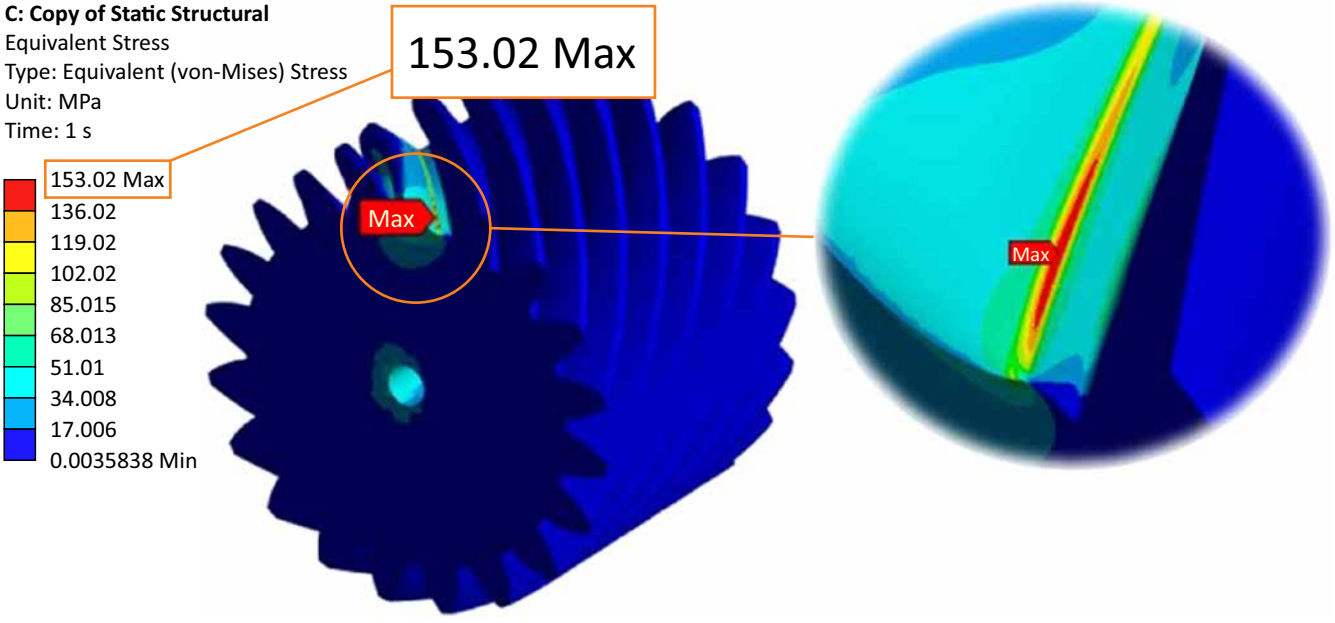
Conclusion

The study corroborated the effectiveness of the finite element method in validating the analytical design of helical gears, in accordance with AGMA standards, highlighting its applicability in high-demand projects. The simulation performed in Ansys® showed good agreement with the analytical calculations, while the inclusion of the overload factor provided a more conservative forecast under adverse scenarios.

Table 2. Maximum bending stress and safety factors.

Bending Strength of Helical Gears		**Safety Factors of Helical Gears**	
Tangential force (W_t)	20,000 N	Pinion bending strength (σ_R)P	275.60 MPa
Dynamic factor (K_v)	1.476	Gear bending strength (σ_R)G	320.00 MPa
Overload factor (K_o)	2.25	Stress-cycle factors (Y_N)P	0.94
Size factor pinion (K_s)P	1.21	Stress-cycle factors (Y_N)G	0.96
Size factor gear (K_s)G	1.22	Reliability factor (K_R)	1.00
Load distribution factor (K_m)	1.35	Temperature factor (K_T)	1.00
Rim thickness factor (K_b)	1		
Geometric bending strength factor (Y_j)P	0.4371		
Geometric bending strength factor (Y_j)G	0.5307		
Results			
Maximum pinion bending stress	158.90 MPa	Pinion safety factor (SF)P	1.73
Maximum gear bending stress (σ) G	131.81 MPa	Gear safety factor (SF)G	2.43

Figure 3. Result of the analysis in ANSYS.



For future studies, it is recommended to investigate gear tooth fatigue by estimating the number of cycles until crack initiation and propagation through numerical and analytical analyses.

References

1. Stipkovic Filho M. Engrenagens: geometria, dimensionamento, controle, geração, ensaios. 2. ed. Rio de Janeiro: Editora Guanabara; 1983.
2. Lynwander P. Gear Drive Systems: Design and Application. Boca Raton: CRC Press; 2019.
3. Budynas RG, Nisbett JK. Elementos de Máquinas de Shigley. 10. ed. São Paulo: McGraw Hill Brasil; 2016.
4. Gouvêa MR. Aplicação de inteligência computacional na determinação da força de laminação. Available at: http://mtcm18.sid.inpe.br/col/lac.inpe.br/lucio/2002/11.13.11.48/doc/workcap2_Revisaofinal_douglas.PDF.
5. Maxwell. Processos de laminação. PUC-Rio; [s.d.]. Available at: https://www.maxwell.vrac.puc-rio.br/10090/1p090_3.PDF.
6. Santi GB, Trazzi RF. Análise de falha e redimensionamento de caixa de engrenagens de um laminador. Projeto de Graduação. [s.l.]: [s.n.]; [s.d.].
7. Kutz M, editor. Mechanical Engineers' Handbook. Volume 1: Materials and Engineering Mechanics. Hoboken: John Wiley & Sons; 2015.
8. GMB Heavy Industries, 2025. Available at: https://gmbindustries.com/rolling-mill-gear-boxes/
9. Jesus DQ, et al. Feasibility study on the use of a commercial steering box in an SAE formula prototype using the finite element method. Blucher; 2024. p. 652-8.
10. Gidado AY, Muhammad I, Umar A. Design, modeling and analysis of helical gear according to bending strength using AGMA and ANSYS. Int J Eng Trends Technol. 2014;8(9).

Sulfur Enrichment in Biodiesel Precipitates: Possible Causes and Impacts

Laura Maria Mota do Rio Bamar[1]*, Madson Moreira Nascimento[1], Lilian Lefol Nani Guarieiro[1]
[1]SENAI CIMATEC University; Salvador, Bahia, Brazil

Biodiesel is widely used as an additive to fossil diesel because it is a renewable and biodegradable biofuel that reduces pollutant emissions. Although considered a clean fuel, concerns persist regarding its use due to its tendency to form precipitates that can damage automotive components. Therefore, like any other fuel, biodiesel must meet a series of specifications to ensure its quality for commercialization. One such specification is the maximum sulfur content, as this element is a significant contributor to the greenhouse effect, as well as to corrosion in equipment and damage to automotive engines. Thus, this study aimed to analyze the sulfur concentration in biodiesel samples using the ICP-OES technique. The results showed that the precipitate samples had a higher sulfur content than their respective supernatant samples.
Keywords: Biodiesel. Sulfur Content. Biodiesel Precipitate.

Since 2008, the addition of biodiesel to fossil diesel has been mandatory in Brazil, as it is a renewable and non-toxic biofuel that also provides greater lubricity to diesel. Biodiesel (B100) can be obtained through the transesterification reaction between a triglyceride (which may be of animal or vegetable origin) and a primary alcohol (such as methanol or ethanol), producing glycerol as a byproduct [1].

However, despite its advantages, biodiesel still presents some challenges due to its composition, such as its ability to absorb moisture and its higher tendency to form precipitates. The formation of precipitates in biodiesel not only compromises its quality and that of diesel-biodiesel blends (BX) but can also cause clogging of automotive filters and injector valves [2].

Despite these challenges, B100 remains one of the most produced biofuels in Brazil [3] due to its low aromatic content, high cetane number, and low sulfur content, among other characteristics that make it an eco-friendly fuel [4]. Nevertheless, to maintain these advantages, it is important to monitor its properties to ensure its quality continuously. Maintaining fuel quality prevents deposit formation, increases equipment durability, and reduces pollutant emissions.

In Brazil, fuel quality is regulated by the National Agency of Petroleum, Natural Gas, and Biofuels (ANP), which ensures adherence to performance and safety standards. One of the ANP's specifications for biodiesel is the maximum sulfur content, which must not exceed 10 mg kg^{-1} [5]. If not monitored, high sulfur levels can cause corrosion in pipelines and storage units, damage vehicle engines, and have environmental impacts associated with the emission of sulfur oxides (SO_x) [6].

This work aimed to analyze the sulfur concentration in the supernatant and precipitate samples of biodiesel and investigate its possible causes using an inductively coupled plasma optical emission spectrometer ICP-OES.

Materials and Methods

After collecting 500 mL of biodiesel sample, the aliquot was transferred to a distillation funnel and left to stand for seven days to allow the precipitate to separate. Both the precipitate and the supernatant were then collected and stored in separate Falcon tubes. This procedure was carried out for eight biodiesel samples, designated as BD-X, where BD represents "biodiesel" and X represents the sample number. The sulfur content

Received on 18 May 2025; revised 23 September 2025.
Address for correspondence: Laura Maria Mota do Rio Bamar. Av. Orlando Gomes, 1845, Piatã, Salvador, Bahia, Brazil. Zipcode: 41650-010. E-mail: laura.mariamrb@gmail.com.
Original extended abstract presented at SAPCT 2025. Award-winning undergraduate student at SAPCT 2025.

J Bioeng. Tech. Health 2025;8(5):440-442

was measured using an inductively ICP-OES iCAP PRO XP Duo, Thermo Scientific.

Results and Discussion

The concentrations of sulfur content in the biodiesel samples are shown in Figure 1. We observe an increase in sulfur content from the supernatant to the precipitate of the same biodiesel sample. One possible explanation is that sulfur originates from contaminants in the raw material in the form of a compound with low solubility in biodiesel, which may precipitate over time, thereby enriching the biodiesel precipitate with sulfur [7].

Another possible explanation is the presence of microbial activity. Although sulfur can act as an inhibitor of microbial action in diesel and diesel/biodiesel blends, sulfate-reducing bacteria (SRB) may metabolize sulfur and form insoluble compounds such as iron sulfide (FeS). These bacteria can use sulfate (SO_4^{2-}) to generate sulfide ions (S^{2-}) in solution, which precipitate instantly [8].

Additionally, sulfur may react with other metals such as iron, copper, and zinc to form metallic sulfides, which are known for their very low solubility [9].

Although studies have shown that high sulfur concentrations can inhibit microbial growth in fossil diesel and biodiesel mixtures due to their inhibitory properties [6], there are still few studies in the literature addressing the significance of sulfur concentration in pure biodiesel. Even though biodiesel is virtually sulfur-free, the element can be extracted along with vegetable oils in the form of phospholipids and glucosinolates [7].

Conclusion

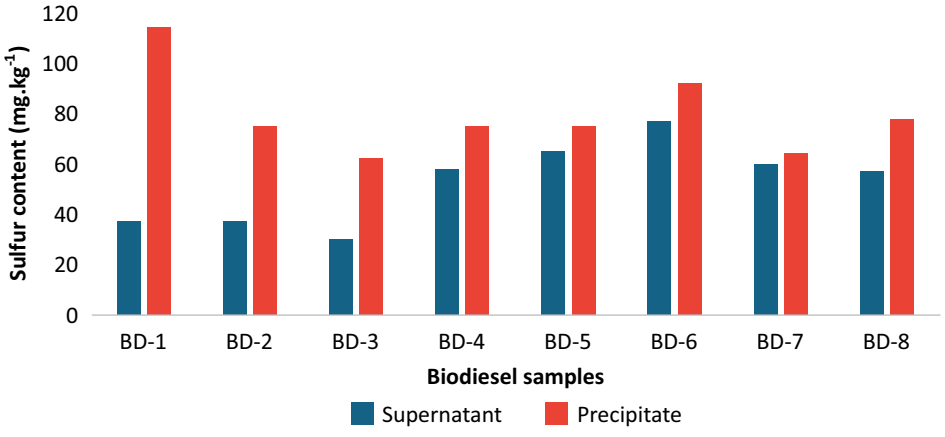
In all samples, the sulfur content exceeded the maximum limit established by ANP and was even higher in the precipitate samples compared to their corresponding supernatant samples. This increase may be related to the concentration of sulfur in impurities originating from the raw material and/or the biodiesel production process, the presence of microbial colonies, or possible reactions of sulfur with other metals resulting in the formation of metallic sulfides.

Further research is needed to confirm the origin of sulfur and identify the cause of the increased sulfur content in the precipitate compared to the remaining biodiesel liquid.

Acknowledgments

The authors thank the Human Resources Program of the National Agency of Petroleum, Natural Gas and Biofuels (PRH/ANP–PRH27.1/SENAI CIMATEC), supported with resources from investments by qualified petroleum companies under the R&D clause of ANP Resolution No.

Figure 1. Sulfur content by biodiesel sample (mg kg^{-1}).



50/2015, and the São Paulo Research Foundation (FAPESP), grant No. 2024/10433-6, for their financial support.

References

1. Lôbo IP, Ferreira SLC, Cruz RS. Biodiesel: parâmetros de qualidade e métodos analíticos. Quím Nova. 2009;32:1596-608.
2. Bamar LM, et al. Impacts and causes of precipitate formation in biodiesel: a review. Blucher Engineering Proceedings. Salvador; 2024.
3. Rego E. Brasil é o segundo maior produtor de biocombustíveis do mundo. Exame. 3 jul 2024. Available at: https://exame.com/esg/brasil-e-o-segundo-maior-produtor-de-biocombustiveis-do-mundo/.
4. Elgharabawy AS, et al. A review on biodiesel feedstocks and production technologies. J Chil Chem Soc. 2021;66(1):5098-109.
5. Agência Nacional do Petróleo, Gás Natural e Biocombustíveis (ANP). Resolução ANP nº 920, de 4 de abril de 2023. Diário Oficial da União. 06 abr 2023;65:62.
6. Polinarski MA, et al. Avaliação da influência da água e enxofre no controle microbiológico em combustíveis diesel Bx utilizando radiação ultravioleta. 2020.
7. De Quadros DPC, et al. Contaminantes em biodiesel e controle de qualidade. Rev Virtual Quím. 2011;3(5):376-84.
8. Oliveira FR, et al. Uso de bactérias redutoras de sulfato no tratamento de efluentes contendo sulfato e metais. 2004.
9. Martins CR, et al. Sulfetos: por que nem todos são insolúveis? Quím Nova. Salvador; 2010.

Calibration of a Distributed Temperature Sensor in Optical Fiber Based on OFDR

Leonardo Santos Magalhães[1]*, Rafael Andrade Vieira[1], Milena Ventura[1], Valéria Loureiro da Silva[1]
[1]SENAI CIMATEC University; Salvador, Bahia, Brazil

Optical Frequency Domain Reflectometry (OFDR) is a distributed sensing technique that uses a laser to sweep the frequency of light and record the backscattered signal along an optical fiber. Equipment such as the ODISI 6101 by LUNA employs this method for strain and temperature measurement. The present work aims to present a calibration method for an optical fiber distributed temperature sensor based on OFDR, through experimental bench tests, resulting in an equation describing the relationship between temperature and spectral shift for temperature measurement.
Keywords: Optical Fiber. OFDR. Calibration. Temperature Sensing.

OFDR is a distributed sensing technique that employs a laser to sweep the frequency of light and record the backscattered signal along an optical fiber. Using Fourier transforms, the signal is converted into a spatial profile, allowing distributed mapping of variations along the fiber. According to the studies of Wegmuller and colleagues [1] and Eickhoff and colleagues [2], OFDR can be used to analyze wavelength shifts and changes in the refractive index resulting from Rayleigh scattering, as well as the spatial distribution of scattering and attenuation characteristics.

From these signals, information about the internal expansion of the fiber and temperature can be extracted. This is achieved through analysis of the wavelength shift relative to the initial wavelength profile. In the case of temperature, the wavelength deviation occurs due to fiber expansion and changes in the refractive index of its core.

The potential of OFDR to provide accurate, distributed measurements with high spatial resolution has been widely demonstrated in the literature, including works by Kreger and colleagues [3] and Wegmuller and colleagues [1], which highlight its applicability in thermal sensing and structural strain measurement [3-4].

In this work, we propose a fiber calibration method that involves determining the relationship between wavelength shift and temperature, enabling distributed temperature measurement along the optical fiber by utilizing the fiber itself as the sensing element. The proposed approach not only validates the calibration methodology but also expands the applicability of OFDR in advanced distributed sensing systems.

Materials and Methods

The measurement and calibration of the optical fiber were performed by acquiring the spectral shift of a trace generated by the OFDR interrogator. The fiber was placed on a heating plate, and the experimental tests were repeated three times to ensure reproducibility of the results.

The equipment used included an Allerbest heating plate, Corning ClearCurve optical fiber (which has lower optical power loss due to micro- and macro-bending), a Fluke True-RMS 289 multimeter with a thermocouple for monitoring plate temperature, and a LUNA ODISI 6101 system, which operates using reflectometry techniques based on Rayleigh backscattering to determine a reference trace of the fiber. The ODISI saves this trace, and subsequent traces are measured and compared to it. The difference

Received on 22 May 2025; revised 17 September 2025.
Address for correspondence: Leonardo Santos Magalhães. Av. Orlando Gomes, 1845, Piatã, Salvador, Bahia, Brazil. Zipcode: 41650-010. E-mail: leonardo.magalhaes@fbter.org.br.
Original extended abstract presented at SAPCT 2025. Award-winning undergraduate student at SAPCT 2025.

J Bioeng. Tech. Health 2025;8(5):443-445

between the traces can be correlated with strain and temperature in the fiber core.

The experimental setup consisted of arranging the ClearCurve optical fiber into a coil with six turns placed on the heating plate, as shown in Figures 1 and 2. The fiber was connected to the ODISI, and using the LUNA OD6 software, fiber sensing data were collected. The temperature was recorded at 2.6 mm intervals, corresponding to the spatial resolution configured on the equipment.

A Python code was developed to identify the initial and final indices of the vector shared by ODISI where the fiber position was located.The code scans the vector and locates the highest deformation peak, corresponding to the intentional strain applied to the fiber, allowing for the precise identification of the segment under analysis. The data collection width was set to 96 points, corresponding to a fiber length of 252.2 mm in contact with the heating plate.

Spectral data acquisition was performed at temperatures ranging from 20°C to 100°C in 10°C increments. A second Python code was developed to collect and store the spectral shift data in text files.

Ninety-six spectral shift data points were collected for each of the nine temperature levels. The first plot displays the average of the 96 shift values for each temperature, yielding nine averages for each of the three tests. The second plot displays the average of the means of each test, resulting in nine final average values. Finally, a linear regression was applied to the mean data, producing the sensor's calibration curve.

Results and Discussion

Figures 3 and 4 present the relationship between temperature and spectral shift, along with their respective linear regressions. These results quantify the dependence between wavelength displacement and thermal variation, allowing calibration of the optical sensor. Figure 3 shows the experimental data obtained in each of the three tests, represented by different colors (blue for the first test, red for the second, and yellow for the third). The linear regressions associated with each dataset enable comparative analysis, demonstrating measurement reproducibility and spectral shift variation as a function of temperature. The average values obtained in the three tests, along with the corresponding linear regression, are illustrated in Figure 4. The equation resulting from the linear regression defines the sensor's calibration curve, serving as a reference for future measurements. The good correlation observed between the experimental data and the linear model reinforces the reliability of the proposed

Figure 1. Optical fiber attached to the heating plate.

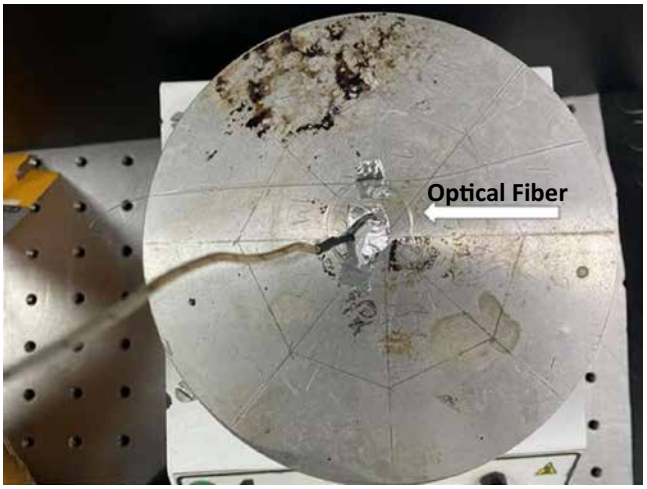


Figure 2. Composition of the experiment.

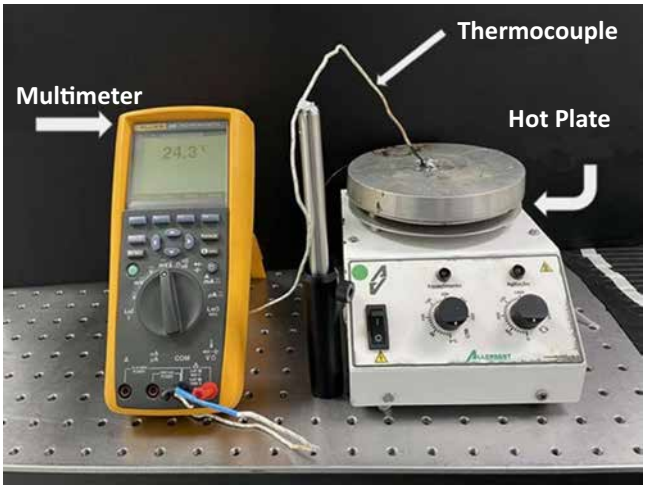


Figure 3. Three-test comparison graph.

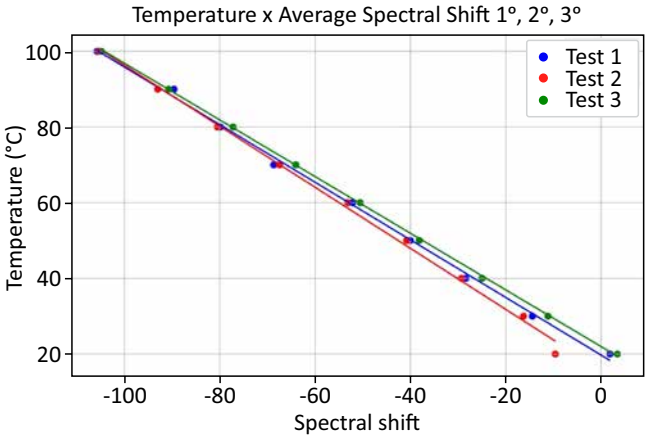
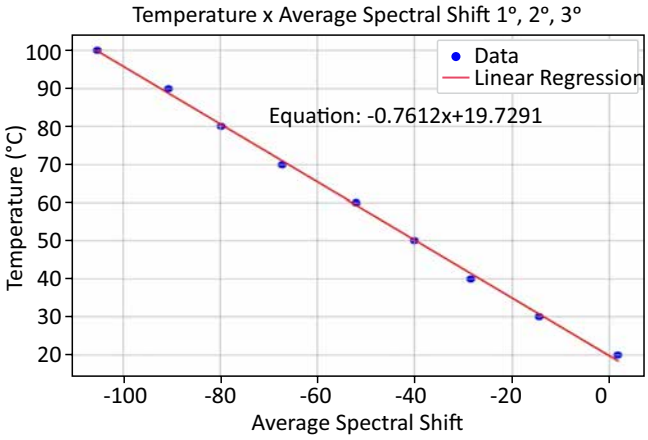


Figure 4. Temperature *vs*. spectral shift graph.



method, confirming the feasibility of using optical fiber as a sensing element for precise distributed temperature monitoring.

Conclusion

For temperature measurement using OFDR and fiber calibration, the relationship between wavelength shift and temperature was utilized.

According to the Figure 4, after performing linear regression, the calibration curve equation for the OFDR sensor was obtained as:
–0.761x + 19.7, which is used for temperature calibration based on the relationship between spectral shift and temperature along the optical fiber.These results demonstrate the precision and effectiveness of the applied method, making a significant contribution to the development and advancement of distributed temperature monitoring research. The proposed approach not only validates the calibration technique but also lays the groundwork for future applications and enhancements.

Acknowledgments

This research was conducted in partnership between SENAI CIMATEC and CNPq. The authors would like to thank CNPq, the Brazilian Company of Research and Industrial Innovation (EMBRAPII), the Optics and Photonics Laboratory, and the National Agency of Petroleum, Natural Gas, and Biofuels (ANP) for their support and investments in R&D&I.

References

1. Wegmuller M. High resolution fibre distributed measurements with coherent OFDR. Rio de Janeiro; 2000.
2. Eickhoff W. Optical frequency-domain reflectometry in single-mode fibers. Optical Fiber Communication Conference; 1981.
3. Kreger ST, Gifford DK, Froggatt ME, Soller BJ, Wolfe MS. High resolution distributed strain or temperature measurements in single- and multi-mode fiber using swept-wavelength interferometry. Luna Technologies; 2006.
4. Kreger ST, Rahim A, Garg N, Klute S. Optical frequency domain reflectometry: principles and applications in fiber optic sensing. Conference Proceedings; 2016.

Evaluation of Corrosion in a Glycerin-Based Fluid System

Ruza Gabriela Medeiros de Araújo Macedo[1]*, Renata Gomes Carvalho[1], Ygor Tadeu Bispo dos Santos[1], Lilian Lefol Nani Guarieiro[1]

[1]SENAI CIMATEC University Center; Salvador, Bahia, Brazil

The challenges in oil exploration and production in increasingly deep reservoirs require the development of technologies capable of overcoming harsh environmental conditions, such as high temperatures and pressures. A necessary stage before financial investments in new technologies is the execution of laboratory-scale tests to simulate the operational conditions to which systems will be subjected. In this context, this work aims to evaluate the inhibitory power of a glycerin-based fluid system. The results obtained so far show a corrosion rate of 0.038 mm/year for the fluid without glycerin and 0.0019 mm/year with glycerin. Therefore, glycerin contributes to a lower corrosion rate, making it favorable for use in such systems.

Keywords: Corrosion. Inhibitor. Glycerin.

Currently, many onshore and offshore oil and gas resources around the world are found in high-temperature and high-pressure reservoirs, which pose a significant challenge for oil exploration. Fluids are among the primary resources used in drilling and completion operations, although their characteristics may vary depending on the stage of the process.

The challenges of oil exploration and production in deep reservoirs demand the development of technologies that can withstand these extreme environments. Before any financial investment in a new technology, laboratory-scale tests are required to approximate the experimental conditions to those expected during actual operations.

In this context, the composition of the fluid used is of utmost importance, requiring careful control of several parameters, such as cost-effectiveness, component availability, environmental and reservoir compatibility, stability, low crystallization point, high density, suitable pH, low damage potential, and low corrosion rate. Generally, fluids used in well intervention operations are saline solutions, which give them a corrosive character.

Received on 16 June 2025; revised 23 September 2025.

Address for correspondence: Ruza Gabriela Medeiros de Araújo Macedo. Av. Orlando Gomes, 1845, Piatã, Salvador, Bahia, Brazil. Zipcode: 41650-010. E-mail: ruzagma@gmail.com.edu.br.Original extended abstract presented at SAPCT 2025.

J Bioeng. Tech. Health 2025;8(5):446-449

Globally, the cost of corrosion amounts to approximately 2.5 trillion dollars annually, corresponding to about 3.4% of the world's GDP [1]. In the oil and gas industry alone, approximately US$1372 billion is spent annually due to corrosion-related problems [1]. An effective way to mitigate corrosion is through the use of inhibitors. Organic and inorganic molecules with active functional groups, such as N, O, and S, are widely employed to prevent corrosion issues [1].

The effectiveness of a corrosion inhibitor depends on various parameters, including temperature, pressure, stress severity, and the concentration of dissolved solids [2]. Chemical inhibitors play an essential role in controlling corrosion in tubular steels. In oil and gas production, different types of steel are used to manufacture materials such as pipelines, casings, and tubing. Among them, X80 steel is one of the most widely applied. Therefore, selecting an appropriate inhibitor requires a comprehensive understanding of the treatment conditions, including temperature, pressure, fluid properties, pH, and flow characteristics [3].

The Production Development Laboratory (LDP) is an ongoing project at SENAI CIMATEC Park, in partnership with Petrobras, Shell, and ANP. It will support research in the oil and gas sector, aiming to simulate the operational conditions of Brazil's pre-salt reservoirs. The LDP will include the construction of a 300-meter well drilled in a single phase, equipped with different casing strings and components subjected to specific test

conditions. Within this healthy environment, the fluid will be exposed to defined pressure and temperature conditions to evaluate its performance. The objective of this work, therefore, is to assess the inhibitory effect of a glycerin-based fluid system to ensure the long-term integrity of these tubular materials.

Materials and Methods

Sample Preparation

Corrosion studies were carried out on carbon steel API 5L X80. Each specimen had an exposed area of 1.95 cm² and was embedded in acrylic resin with electrical contact through a copper wire. The specimens were polished with sandpapers (600, 800, and 1200 grit) to achieve a uniform texture, then washed with isopropyl alcohol and distilled water to remove organic residues (oils and debris) before being immediately immersed in the test fluid for electrochemical testing.

Electrochemical Testing

The electrochemical test followed the methodology described by Macedo (2011), using a conventional three-electrode electrochemical cell composed of a working electrode (API 5L X80 steel), a reference electrode (Ag/AgCl), and a counter electrode (Pt). The tests were conducted using a Metrohm PGSTAT128N potentiostat/galvanostat at room temperature (~25 °C).

The test commenced with a 60-minute open-circuit potential (OCP) stabilization period, followed by the acquisition of a polarization curve at a scan rate of 0.01 mV/s over a potential range of –1.5 V to +1.5 V relative to the OCP.

Test Fluids

Fluid A (Raw Water): Water from an artesian well (intended as the water source for the LDP facilities), collected on 25/02/2025, with pH 5, conductivity 92 µS/cm, and temperature 23.7 °C.

Fluid B (70:30 fluid): 400 mL prepared in a 70:30 ratio, composed of 300 mL raw water and 100 mL glycerin (Biobrotas, 99% purity). The solution exhibited an electrical conductivity of 44 µS and a pH of 6.

Results and Discussion

Figure 1 shows the polarization curves obtained with the API 5L X80 steel electrode in artesian well water and in the 70:30 water–glycerin mixture, at a scan rate of 1 mV/s.The addition of glycerin caused a shift in the corrosion potential, indicating its inhibitory potential against chloride-induced corrosion.

The corrosion potential of raw water was –889 mV, and with the addition of 30% glycerin, it shifted to –817 mV. Using Tafel extrapolation, the electrochemical parameters (current density and corrosion rate) were determined, as shown in Table 1.

The data indicate a reduction in corrosion rate with the addition of glycerin to the system. The corrosion current also decreased, suggesting the formation of a protective layer that limits ion permeation through the electrical double layer to the metallic surface.Thus, glycerin acts as an effective corrosion inhibitor.

The inhibition efficiency (IE) of glycerin was estimated using the Equation 1 [4]:

$$\mathcal{E}\,(\%) = \theta * 100 = \frac{T_S - T_C}{T_S} * 100 \qquad \text{Eq. 1}$$

where Ts is the corrosion rate without glycerin, and Tc is the corrosion rate with glycerin. This calculation indicates an inhibition efficiency of approximately 50%. However, a higher inhibition level is desirable. Therefore, additional polarization and mass-loss tests are being conducted with the addition of an imidazoline-based corrosion inhibitor.

Conclusion

We concluded that glycerin significantly reduces the corrosion rate of the system, making it a viable

Figure 1. Polarization curves obtained with the API 5L X80 steel electrode in artesian well water and in a 70:30 water–glycerin fluid at 25 °C. ν = 1 mV/s.

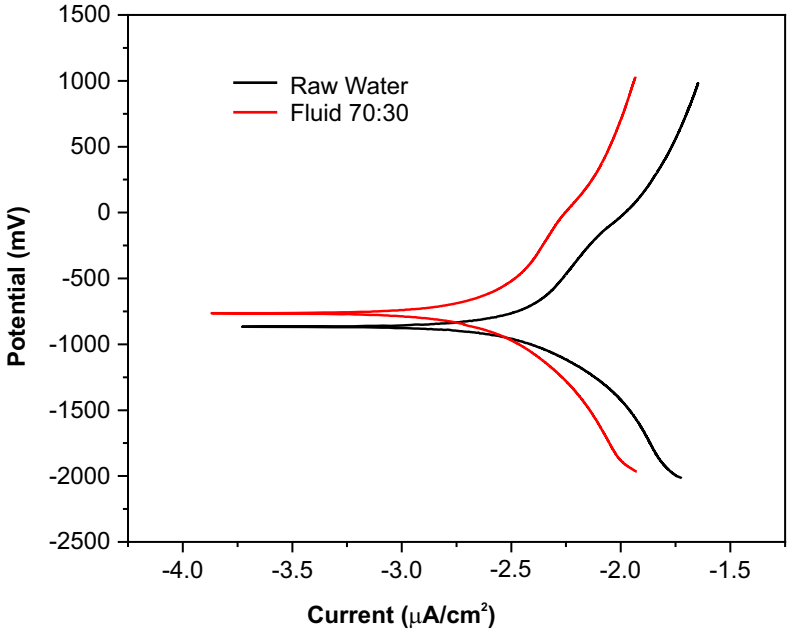


Table 1. Electrochemical parameters obtained from Tafel extrapolation for API 5L X80 steel processes in the presence of glycerin at 25 °C.

Fluid	E_{corr} (mV)	I_{corr} (μA/cm²)	CR (mm/year)
Raw Water	–865	3.32	0.038
Fluid 70:30	–817	1.83	0.019

component in healthy intervention fluids. Although the system achieved an inhibition efficiency of 50%, higher efficiency is desirable to ensure metallic stability over an estimated 20-year operational lifetime. Therefore, immersion and mass-loss tests are currently in progress using imidazoline-based inhibitors to achieve an inhibition efficiency greater than 70%.

Acknowledgments

The authors acknowledge the financial support of the Human Resources Program of the National Agency of Petroleum, Natural Gas and Biofuels (PRH/ANP–PRH27.1/SENAI CIMATEC), funded by resources from petroleum companies under the R&D clause of ANP Resolution No. 50/2015, and the São Paulo Research Foundation (FAPESP), Grant No. 2024/10433-6.

References

1. Obot IB, et al. A review study on the challenges and progress of corrosion inhibitor testing under extreme conditions in the oil and gas industries. Geoenergy Sci Eng. 2023;226:211762. Available from: https://doi.org/10.1016/j.geoen.2023.211762
2. Golchinvafa A, et al. The effect of natural inhibitor concentration of Fumaria officinalis and temperature

on corrosion protection mechanism in API X80 pipeline steel in 1 M H_2SO_4 solution. Int J Press Vessel Pip. 2020;188:104241. Available from: https://doi.org/10.1016/j.ijpvp.2020.104241

3. Chauhan DS, Madhan Kumar A, Quraishi MA. Hexamethylenediamine functionalized glucose as a new and environmentally benign corrosion inhibitor for copper. Chem Eng Res Des. 2019;150:99–115. Available from: https://doi.org/10.1016/j.cherd.2019.07.020
4. Wang HL, Liu RB, Xin J. Inhibiting effects of some mercapto-triazole derivatives on the corrosion of mild steel in 1.0 M HCl medium. Corros Sci. 2004 Oct;46(10):2455-66. Available from: https://WOS:000224049300007

The Use of Computational Tools in Criminal Proceedings in Brazil: A Proposal for a Technological Model to Contribute to the Speed-Up of Cases Involving Persons Imprisoned Without Final Conviction

Abdon Campos dos Santos[1]*, Filipe Cardoso Brito[1], Hugo Saba Pereira Cardoso[1], Aloísio Santos Nascimento Filho[1]
[1]SENAI CIMATEC University; Salvador, Bahia, Brazil

Brazil's National Council of Justice (CNJ) records qualitative data regarding procedural slowness. Meanwhile, the National Penitentiary Department System (SISDEPEN) provides quantitative data on the incarcerated population in Brazil. An analysis of the use of computational tools that could contribute to expediting proceedings for imprisoned persons may open new approaches and contributions applicable to judicial processes. The analysis of government and judicial data, combined with a review of the scientific literature, appears promising in the search for tools to assist the judiciary in decision-making, with a particular emphasis on those detained on a provisional basis. In this context, the development of a technological model could analyze millions of cases against specific legal variables and present judges with potential situations eligible for the granting of liberty—whether provisional or otherwise—thus contributing to procedural efficiency.
Keywords: Artificial Intelligence. Procedural Celerity. Criminal Proceeding.

In Brazil, in the second half of 2023, there were 644,316 incarcerated individuals, of whom 175,279 were provisionally detained—that is, persons without a final judgment. Thus, provisional detainees represented 27.20% of the total prison population, approximately one-third of the total inmate population [1]. Conversely, those incarcerated with a final judgment—therefore serving sentences in a closed regime without authorization to leave the prison unit temporarily—totaled 344,649 [1]. Comparing the number of those serving final sentences in a closed regime with those provisionally detained, the percentage rises to 53.49% [1].

However, the challenge lies in analyzing a universe of 175,279 cases (as of the second half of 2023), which yields an average of 6,491 cases per state of the federation [1]. The Brazilian judiciary, however, faces a scenario of slowness, as indicated by studies from the National Council of Justice (CNJ). As of October 27, 2023, the council's ombudsman had recorded 31,714 submissions [2].

Received on 10 June 2025; revised 28 September 2025.
Address for correspondence: Abdon Campos dos Santos. Av. Orlando Gomes, 1845, Piatã, Salvador, Bahia, Brazil. Zipcode: 41650-010. E-mail: abdoncampos@gmail.com.

J Bioeng. Tech. Health 2025;8(5):450-453

Of these, 22,123 were complaints about delays in case processing, corresponding to 69.67% of submissions [2]. This is highly relevant, since the CNJ, in setting its goals for 2024, established celerity as its top priority through the Justice 4.0 program [2].

In this context—with many people incarcerated while awaiting trial and a considerable volume of complaints about the system's sluggishness—the following question arises: Which initiatives and experiences in the use of technology have been applied within the Brazilian justice system to optimize processes? In seeking to answer this question, the challenge is to present a conceptual model capable of integrating data from different information systems on millions of criminal cases, in order to analyze and identify cases with potential for closure or those in which the law authorizes awaiting the outcome at liberty.

Materials and Methods

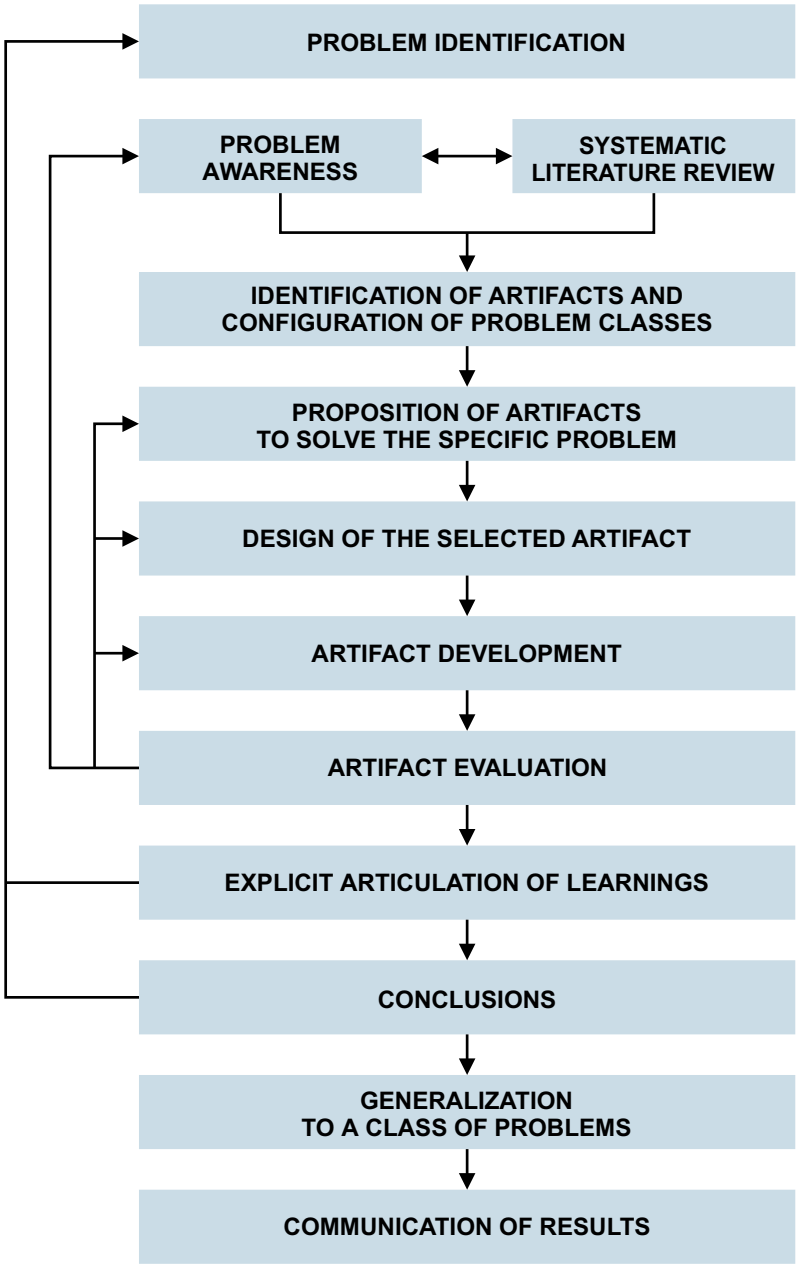
The method involves analyzing data from SISDEPEN, which records information on sentence execution, preventive detention, and security measures applied to individuals under custody in Brazil's penal system. These data are consolidated by the CNJ and published in annual reports. Thus, the research will investigate the

problem using official Brazilian data, which is fundamental for developing the research method.

Another key element for developing the research method will be the analysis of relevant scientific works on the topic. In a preliminary search, using the Scopus portal with the terms "artificial intelligence," "justice," and "criminal" applied to the "abstract" field, 352 results were found. Using the same criteria in the Web of Science portal yielded 125 results. The choice to use English terms stems from the need to encompass the most significant possible number of publications, which are generally disseminated in that language.

The results are subjected to a literature review analysis method, possibly employing the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) method. After reviewing the scientific output, the research

Figure 1. DSR method [3].



will develop a technological model to identify the thousands of criminal proceedings involving persons imprisoned without a final conviction and to cross-reference them with the numerous legal criteria and requirements that may allow a judicial grant of provisional or definitive liberty, thereby presenting elements to assist judges in decision-making.

The development of this technological model will follow the Design Science (DS) methodology, using the Design Science Research (DSR) method. This method aims to consolidate knowledge about designing solutions for existing systems, solving real problems by developing new solutions. To this end, Design Science employs the concept of artifacts, which refer to the products to be developed [3]. Figure 1 details of the DSR method [3].

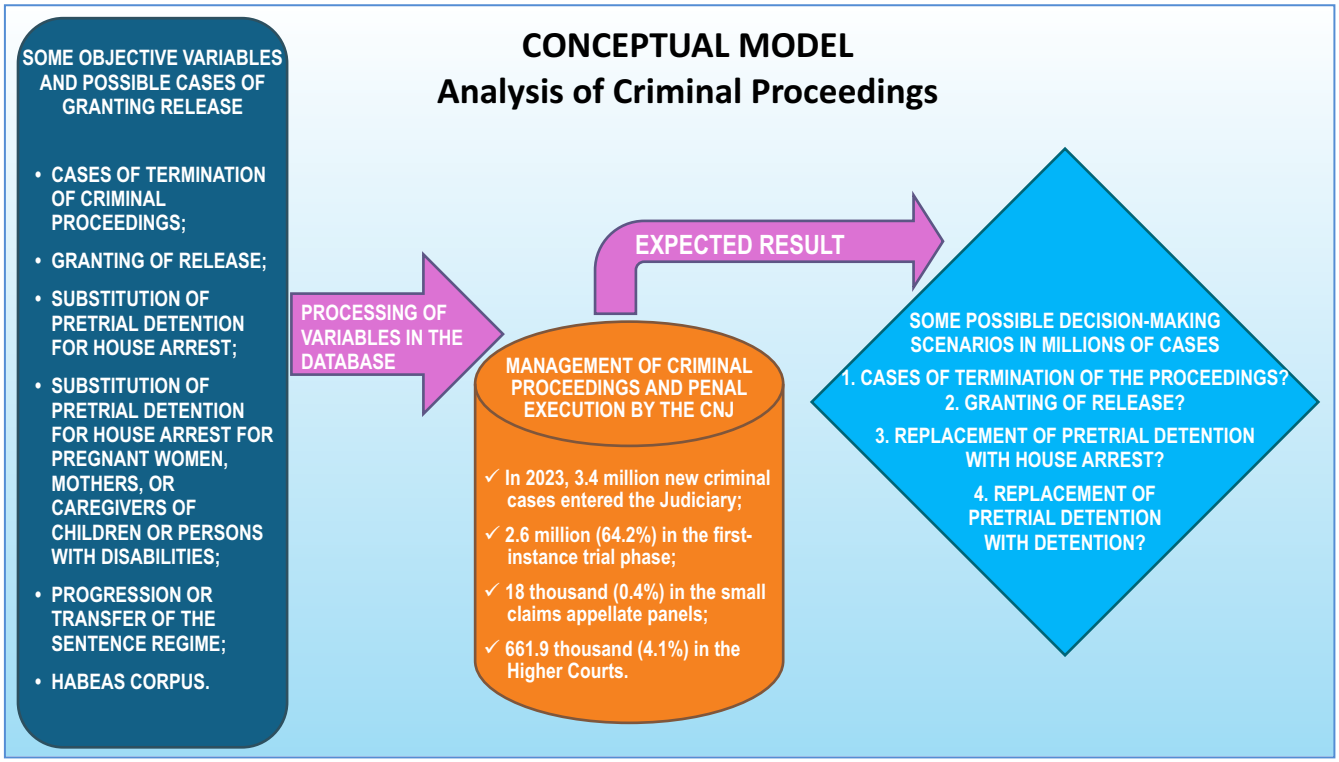
Theoretical Foundation

The conceptual model mentioned in the meth is illustrated in Figure 2 and is designed to integrate certain variables under which Brazilian legislation authorizes procedural actions, in accordance with the legal criteria outlined in the Federal Constitution [4], the Penal Code [5], the Code of Criminal Procedure [6], and the Law of Criminal Executions [7]. Examples include: extinction of criminal proceedings; the granting of provisional liberty to await the outcome; replacement of preventive detention with house arrest; replacement of preventive detention with house arrest for pregnant women, mothers, or persons responsible for children or people with disabilities; progression or transfer of the sentence-compliance regime; and habeas corpus for granting provisional liberty in the face of an arrest that has become illegal.

Conclsuion

The technological model, as shown in Figure 2, emerges as a way to analyze numerous variables

Figure 2. Conceptual model for the analysis of criminal proceedings [8].



of objective criteria (legal determinations of a general and abstract nature, applicable to society at large without distinction) and subjective criteria (applicable to concrete cases, individualizing persons according to the principle of individualized sentencing) using data from thousands of cases involving individuals imprisoned without a final conviction.

The expected result is that the model will help save staff time in the criminal justice system by reducing the manual analysis of cases involving provisional detainees. This would produce procedural celerity and, consequently, contribute to reducing the number of incarcerated persons awaiting trial—thus serving as another instrument to improve the delivery of judicial services in Brazil.

References

1. Brasil. Ministério da Justiça. Secretaria Nacional de Políticas Penais. Sistema de Informações do Departamento Penitenciário Nacional – SISDEPEN; 2023. Available at: https://www.gov.br/senappen/pt-br/servicos/sisdepen
2. Conselho Nacional de Justiça. Relatório Anual 2023. Brasília: CNJ; 2024. Available at: https://www.cnj.jus.br/wp-content/uploads/2024/02/relatorio-anual-v-10-2024-01-25.pdf
3. Dresch A, Lacerda DP, Junior JAV A. Design science research: método de pesquisa para avanço da ciência e tecnologia. Porto Alegre: Bookman; 2020.
4. Brasil. Constituição da República Federativa do Brasil de 1988. Brasília, DF: Diário Oficial da União; 5 out 1988. Available at: http://www.planalto.gov.br/ccivil_03/constituicao/ConstituicaoCompilado.htm
5. Brasil. Decreto-Lei nº 2.848, de 7 de dezembro de 1940. Código Penal. Brasília, DF: Diário Oficial da União; 31 dez 1940. p. 23911. Available at: https://www.planalto.gov.br/ccivil_03/decreto-lei/del2848compilado.htm
6. Brasil. Decreto-Lei nº 3.689, de 3 de outubro de 1941. Código de Processo Penal. Brasília, DF: Diário Oficial da União; 13 out 1941. Available at: https://www.planalto.gov.br/ccivil_03/decreto-lei/del2848compilado.htm
7. Brasil. Lei nº 7.210, de 11 de julho de 1984. Institui a Lei de Execução Penal. Available at: https://www.planalto.gov.br/ccivil_03/leis/l7210.htm
8. Conselho Nacional de Justiça. Justiça em Números 2024. Brasília: CNJ; 2024. Available at: https://www.cnj.jus.br/wp-content/uploads/2024/05/justica-em-numeros-2024-v-28-05-2024.pdf

Proposal for a Prospective Strategic Planning Model for Research Institutes: A Case Study on Innovation Management Within the Health Economic-Industrial Complex

Marcelo Santos Ramos[1]*, Camila de Sousa Pereira Guizzo[1], Bruna Aparecida Souza Machado[1]
[1]SENAI CIMATEC University; Salvador, Bahia, Brazil

The healthcare industry plays a significant role in national GDP and is heavily invested in frontier technologies. Health innovations are closely tied to the scientific sector, which generates evidence for the development of new drugs, medical equipment, and clinical procedures. However, transforming research outcomes into products has been a persistent bottleneck in Brazil. Given this challenge, the study aims to propose a prospective strategic planning model for managing research, development, and innovation (RDI). This is a case study based on the Design Science Research (DSR) methodology, focusing on the production of an artifact. The study will follow five stages to construct the theoretical framework, assess the state of the art in prospective strategic planning for R&D, conduct content analysis of interviews, and validate the model through a focus group. The expected contribution is to enhance RDI management within the Health Economic-Industrial Complex (HEIC).
Keywords: Health Economic-Industrial Complex. Health Innovation. Prospective Strategic Planning Methods. Business Intelligence.

The health industry is recognized for its dynamism, knowledge absorption, and balance between economic development and social well-being, with Brazil's Unified Health System (SUS) among the largest consumers of innovation [1,2]. Health-related activities and services, both public and private, account for around 9 million jobs, 10% of the GDP, and one-third of national investment in research and innovation [3].

In Brazil, the productive health system, comprising both industrial and service sectors, exhibits high innovation intensity and is one of the most dynamic areas of the knowledge economy. It is referred to as the Health Economic-Industrial Complex (HEIC) [2,3]. The incorporation of innovation and technological development has been key to achieving competitive advantage in various industries [4]. However, despite the growing generation of scientific knowledge, this has not translated effectively into innovation [5]. Thus, universities and research institutes must move forward with the transfer of technologies under development to generate tangible products for society. Technological foresight emerges as a valuable tool for identifying opportunities by leveraging scenarios and trends to guide strategic decision-making in innovation management for the healthcare sector [6].

Therefore, an in-depth analysis of prospective planning methods and the identification of those most suited to the empirical reality of health research institutes (HRI) can enhance the scientific and technological capacity of these organizations and promote the integration of new products, services, and processes within the HEIC [7].

The objective of this study is to propose a methodological model for prospective strategic planning applied to HRI in Brazil, focusing on the introduction of innovations in the chemical-biotechnological and information-connectivity subsystems of the HEIC.

Materials and Methods

This exploratory research is grounded in the Design Science Research (DSR) methodology, which seeks to produce a viable artifact—whether a construct, model, method, or instantiation—

Received on 26 June 2025; revised 28 September 2025.
Address for correspondence: Ricardo Lima Travassos. Av. Orlando Gomes, 1845 - Piatã, Salvador – BA – Brazil, Zip Code: 41650-010. E-mail: marcelosramos77@gmail.com.
Original extended abstract presented at SAPCT 2025.

J Bioeng. Tech. Health 2025;8(5):454-456

utilizing rigorous methods for both construction and evaluation [8].

The study will proceed through five main stages: Narrative literature review on health innovation, prospective strategic planning methods, and the HEIC, including aspects related to the State's role in regulation and innovation policy.

Documentary research, based on secondary administrative data from an HRI project portfolio, to identify competencies in RDI. This stage aims to detect PDI projects capable of generating innovation in: The chemical and biotechnological subsystem (e.g., medicines, active pharmaceutical ingredients, vaccines, reagents, and diagnostics), and the information and connectivity subsystem (e.g., Health 4.0 enabling technologies such as Big Data, IoT, cloud computing, AI, and additive manufacturing).

Qualitative research, using content analysis [9] of semi-structured interviews with researchers and managers at the selected HRI, to assess perceptions about foresight methods that enhance strategic planning for RDI.

Development of the methodological model, structured according to results from the previous stages, integrating theoretical, empirical, and technological insights.

Validation of the model through a focus group composed of actors from the health innovation ecosystem identified in earlier phases, to evaluate and refine the artifact's effectiveness in strengthening HRI innovation role within the HEIC.

Theorethical Foundation

The transformations in global production and innovation since the 2000s have been largely driven by the strategies of transnational corporations (TNCs) and national governments. In the health sector, major TNCs dominate the global pharmaceutical market, and their home countries actively promote the maximization of intellectual property rights through TRIPS, thereby consolidating monopolies in frontier knowledge sectors [10,11].

The innovation ecosystem in health comprises a complex institutional arrangement involving industrial firms, health service providers, academic and research institutions, funding agencies, civil society, and regulatory and policy bodies for science, technology, industry, health, and intellectual property [3].

In this context, technological foresight is understood as any activity that enhances the understanding of the future consequences of current developments and decisions. It adopts a systemic approach, considering all interrelated factors and actors to identify possible, desirable, and achievable futures [12].

Technological foresight enables evaluation of the current landscape in the health sector, identifying how technologies have been developed and incorporated into the market, their competitiveness, and potential areas for improvement [13]. Its ultimate goal is to uncover strategic research areas and emerging technologies capable of generating scalable economic and social benefits [14].

Understanding innovation processes and their ecosystem is therefore crucial for designing public policies and organizational strategies that can identify and address bottlenecks limiting health innovation [15].

Conclusion

This study aims to enhance innovation management processes within health research institutions by proposing a prospective strategic planning model for innovation, grounded in business intelligence tools. The model is expected to generate reliable, actionable information to support decision-making in HRI enabling a more refined vision of the future and strengthening their role in the HEIC innovation ecosystem. Once validated, the model will be made available for application in other HRI institutions interested in adopting prospective methodologies for managing technological and industrial innovation. The proposed methodological model aims to

foster research, development, and innovation in technologies and services that promote health, prevention, diagnosis, treatment, and rehabilitation, thereby contributing to reducing vulnerabilities in the SUS and expanding universal health access in Brazil.

Acknowledgments

The authors acknowledge the SENAI CIMATEC and the Research Support Foundation of the State of Bahia (FAPESB) for the PhD scholarship under Grant Agreement No. BOL0295/2024, part of the institutional quota of the CIMATEC University.

References

1. Rocha KCR, Gadelha CAG. Estudo comparativo entre empresa farmacêutica global e instituição pública de produção e inovação em saúde. Saúde Debate. 2023;47(138):393-403. https://doi.org/10.1590/0103-1104202313802
2. Guimarães R. Sobre a soberania sanitária no Complexo Industrial da Saúde. Ciênc Saúde Colet. 2023 Nov;28(11):3093-100. Available from: https://doi.org/10.1590/1413-812320232811.02192023
3. Gadelha CAG. Complexo Econômico-Industrial da Saúde: a base econômica e material do Sistema Único de Saúde. Cad Saúde Pública. 2022;38:e00263321.
2. Pires MCFS, Santa Rita LP, Pires ACS. Perfil do núcleo de inovação tecnológica na gestão da inovação: um estudo na Universidade Federal de Alagoas. Navus Rev Gest Tecnol. 2020;10:21.
5. Toledo PTM. A gestão da inovação em universidades: evolução, modelos e propostas para instituições brasileiras [tese]. Campinas: UNICAMP; 2015. https://doi.org/10.47749/T/UNICAMP.2015.957040
6. Longa LCD, et al. Estudos prospectivos como estratégia para subsidiar tomada de decisão em projetos de pesquisa e desenvolvimento na Fiocruz [tese]. Rio de Janeiro: Fiocruz; 2022. Available from: https://www.arca.fiocruz.br/handle/icict/56858
7. Rodrigues PHA, Silva RDFC, Kiss C. Mudanças recentes e continuidade da dependência tecnológica e econômica na indústria farmacêutica no Brasil. Cad Saúde Pública. 2022;38:e00104020. https://doi.org/10.1590/0102-311X00104020
8. Lacerda DP, Dresch A, Proença A, Antunes Júnior JAV. Design Science Research: método de pesquisa para a engenharia de produção. Gest Prod. 2013;20(4):741–61. https://doi.org/10.1590/S0104-530X2013005000014
9. Bardin L. Análise de conteúdo. São Paulo: Edições 70; 2011.
10. Padula R. BRICS: potencialidades de cooperação e papel na governança global de saúde no contexto da pandemia. Saúde Debate. 2020;44:40–61. https://doi.org/10.1590/0103-11042020E402
11. Hiratuka C, Sarti F, Fonseca CVC, Sugimoto TN. Financeirização, concorrência global e desafios para o CEIS no Brasil. In: Gadelha CAG, Gimenez DM, Cassiolato JE, organizadores. Saúde é desenvolvimento: o complexo econômico-industrial da saúde como opção estratégica nacional. Rio de Janeiro: Fiocruz-CEE; 2022.
12. Nascimento TC, Cajavilca ESR, Santos AT. Sistematização de um modelo de prospecção tecnológica com as ferramentas Espacenet e Iramuteq: aplicação para banco de dados de patentes verdes do elemento fósforo. Cad Prospecção. 2019;12(3):563–75.
13. Fermo VC, Caetano J. A prospecção tecnológica no desenvolvimento de tecnologias em saúde: conhecendo o estado da arte. In: Desenvolvimento de Tecnologias em Pesquisa e Saúde: da teoria à prática. São Paulo: Editora Científica Digital; 2022. ISBN: 978-65-5360-108-6.
14. Barros MC, Porto Junior FGR. Prospecção Tecnológica: o que é e para que serve? A prospecção tecnológica como ferramenta de planejamento estratégico na gestão pública [livro eletrônico]. Palmas (TO): EdUFT; 2021.
15. Ramos MS, Scavuzzi AMA, Moraes DC, Reis VG, Pereira-Guizzo CS. Challenges of innovation in the Health Economic-Industrial Complex: a case study on implementation of research results in a Brazilian science and technology institution. J Bioeng Technol Health. 2024;7:99–104. https://doi.org/10.34178/JBTH.V7I1.375

Instructions for Authors

The Authors must indicate in a cover letter the address, telephone number and e-mail of the corresponding author. The corresponding author will be asked to make a statement confirming that the content of the manuscript represents the views of the co-authors, that neither the corresponding author nor the co-authors have submitted duplicate or overlapping manuscripts elsewhere, and that the items indicated as personal communications in the text are supported by the referenced person. Also, the protocol letter with the number should be included in the submission article, as well as the name of sponsors (if applicable).

Manuscripts may be submitted within designated categories of communication, including:

- Original basic or clinical investigation (original articles on topics of broad interest in the field of bioengineering and biotechnology applied to health). We particularly welcome papers that discuss epidemiological aspects of international health, clinical reports, clinical trials and reports of laboratory investigations.
- Case presentation and discussion (case reports must be carefully documented and must be of importance because they illustrate or describe unusual features or have important practice implications).
- Brief reports of new methods or observations (short communications brief reports of unusual or preliminary findings).
- State-of-the-art presentations (reviews on protocols of importance to readers in diverse geographic areas. These should be comprehensive and fully referenced).
- Review articles (reviews on topics of importance with a new approach in the discussion). However, review articles only will be accepted after an invitation of the Editors.
- Letters to the editor or editorials concerning previous publications (correspondence relating to papers recently published in the Journal, or containing brief reports of unusual or preliminary findings).
- Editor's corner, containing ideas, hypotheses and comments (papers that advance a hypothesis or represent an opinion relating to a topic of current interest).
- Innovative medical products (description of new biotechnology and innovative products applied to health).
- Health innovation initiatives articles (innovative articles of technological production in Brazil and worldwide, national policies and directives related to technology applied to health in our country and abroad).

The authors should checklist comparing the text with the template of the Journal.

Supplements to the JBTH include articles under a unifying theme, such as those summarizing presentations of symposia or focusing on a specific subject. These will be added to the regular publication of the Journal as appropriate, and will be peer reviewed in the same manner as submitted manuscripts.

Statement of Editorial Policy

The editors of the Journal reserve the right to edit manuscripts for clarity, grammar and style. Authors will have an opportunity to review these changes prior to creation of galley proofs. Changes in content after galley proofs will be sent for reviewing and could be required charges to the author. The JBTH does not accept articles which duplicate or overlap publications elsewhere.

Peer-Review Process

All manuscripts are assigned to an Associate Editor by the Editor-in-Chief and Deputy Editor, and sent to outside experts for peer review. The Associate Editor, aided by the reviewers' comments, makes a recommendation to the Editor-in-Chief regarding the merits of the manuscript. The Editor-in-Chief makes a final decision to accept, reject, or request revision of the manuscript. A request for revision does not guarantee ultimate acceptance of the revised manuscript.

Manuscripts may also be sent out for statistical review ou *ad hoc* reviewers. The average time from submission to first decision is three weeks.

Revisions

Manuscripts that are sent back to authors for revision must be returned to the editorial office by 15 days after the date of the revision request. Unless the decision letter specifically indicates otherwise, it is important not to increase the text length of the manuscript in responding to the comments. The cover letter must include a point-by-point response to the reviewers and Editors comments, and should indicate any additional changes made. Any alteration in authorship, including a change in order of authors, must be agreed upon by all authors, and a statement signed by all authors must be submitted to the editorial office.

Style

Manuscripts may be submitted only in electronic form by www.jbth.com.br. Each manuscript will be assigned a registration number, and the author notified that the manuscript is complete and appropriate to begin the review process. The submission file is in OpenOffice, Microsoft Word, or RTF document file format for texts and JPG (300dpi) for figures.

Authors must indicate in a cover letter the address, telephone number, fax number, and e-mail of the corresponding author. The corresponding author will be asked to make a statement confirming that the content of the manuscript represents the views of the co-authors, that neither the corresponding author nor the co-authors have submitted duplicate or overlapping manuscripts elsewhere, and that the items indicated as personal communications in the text are supported by the referenced person.

Manuscripts are to be typed as indicated in Guide for Authors, as well as text, tables, references, legends. All pages are to be numbered with the order of presentation as follows: title page, abstract, text, acknowledgements, references, tables, figure legends and figures. A running title of not more than 40 characters should be at the top of each page. References should be listed consecutively in the text and recorded as follows in the reference list, and must follow the format of the National Library of Medicine as in Index Medicus and "Uniform Requirements for Manuscripts Submitted to Biomedical Journals" or in "Vancouver Citation Style". Titles of journals not listed in Index Medicus should be spelled out in full.

Manuscript style will follow accepted standards. Please refer to the JBTH for guidance. The final style will be determined by the Editor-in-Chief as reviewed and accepted by the manuscript's corresponding author.

Approval of the Ethics Committee

The JBTH will only accept articles that are approved by the ethics committees of the respective institutions (protocol number and/or approval certification should be sent after the references). The protocol number should be included in the end of the Introduction section of the article.

Publication Ethics

Authors should observe high standards with respect to publication ethics as set out by the International Committee of Medical Journal Editors (ICMJE). Falsification or fabrication of data, plagiarism, including duplicate publication of the authors' own work without proper citation, and misappropriation of the work are all unacceptable practices. Any cases of ethical misconduct are treated very seriously and will be dealt with in accordance with the JBTH guidelines.

Conflicts of Interest

At the point of submission, each author should reveal any financial interests or connections, direct or indirect, or other situations that might raise the question of bias in the work reported or the conclusions, implications, or opinions stated - including pertinent commercial or other sources of funding for the individual author(s) or for the associated department(s) or organizations(s), and personal relationships. There is a potential conflict of interest when anyone involved in the publication process has a financial or other beneficial interest in

the products or concepts mentioned in a submitted manuscript or in competing products that might bias his or her judgment.

Material Disclaimer

The opinions expressed in JBTH are those of the authors and contributors, and do not necessarily reflect those of the SENAI CIMATEC, the editors, the editorial board, or the organization with which the authors are affiliated.

Privacy Statement

The names and email addresses entered in this Journal site will be used exclusively for the stated purposes of this journal and will not be made available for any other purpose or to any other party.

Brief Policies of Style

Manuscript	Original	Review	Birief Comunication	Case Report	Editorial ; Letter to the Editor; Editor' s Corner	Innovative Medical Products	State-of-the-Art	Health Innovation Initiatives
Font Type	Times or Arial	Times or Arial	Times or Arial	Times or Arial	Times or Arial	Times or Arial	Times or Arial	Times or Arial
Number of Words – Title	120	90	95	85	70	60	120	90
Font Size/Space-Title	12; double space	12; double space	12; double space	12; double space	12; double space	12; double space	12; double space	12; double space
Font Size/Space-Abstracts/Key Words and Abbreviations	10; single space	10; single space	10; single space	10; single space	-	-	10; single space	10; single space
Number of Words – Abstracts/Key Words	300/5	300/5	200/5	250/5	-	-	300/5	300/5
Font Size/Space-Text	12; Double space	12; Double space	12; Double space	12; Double space	12; Double space	12; Double space	12; Double space	12; Double space
Number of Words – Text	5,000 including spaces	5,500 including spaces	2,500 including spaces	1,000 including spaces	1,000 including spaces	550 including spaces	5,000 including spaces	5,500 including spaces
Number of Figures	8 (title font size 12, double space)	3 (title font size 12, double space)	2 (title font size 12, double space)	2 (title font size 12, double space)	-	2 (title font size 12, double space)	8 (title font size 12, double space)	8 (title font size 12, double space)
Number of Tables/Graphic	7 title font size 12, double space	2 title font size 12, double space	2(title font size 12, double space)	1(title font size 12, double space)	-	-	7 title font size 12, double space	4 title font size 12, double space
Number of Authors and Co-authors*	15	10	5	10	3	3	15	10
References	20 (font size 10,single space	30(font size 10,single space	15 (font size 10,single space)	10 (font size 10,single space)	10 (font size 10,single space	5(font size 10,single space	20 (font size 10,single space	20

*First and last name with a sequencing overwritten number. Corresponding author(s) should be identified with an asterisk; Type 10, Times or Arial, single space. Running title of not more than 40 characters should be at the top of each page. References should be listed consecutively in the text. References must be cited on (not above) the line of text and in brackets instead of parentheses, e.g., [7,8]. References must be numbered in the order in which they appear in the text. References not cited in the text cannot appear in the reference section. References only or first cited in a table or figures are numbered according to where the table or figure is cited in the text. For instance, if a table is placed after reference 8, a new reference cited in table 1 would be reference 9.1 would be reference 9.

Checklist for Submitted Manuscripts

❑1. Please provide a cover letter with your submission specifying the corresponding author as well as an address, telephone number and e-mail.

❑2. Submit your paper using our website www.jbth.com.br. Use Word Perfect/Word for Windows, each with a complete set of original illustrations.

❑3. The entire manuscript (including tables and references) must be typed according to the guidelines instructions.

❑4. The order of appearance of material in all manuscripts should be as follows: title page, abstract, text, acknowledgements, references, tables, figures/graphics/diagrams with the respective legends.

❑5. The title page must include a title of not more than three printed lines (please check the guidelines of each specific manuscript), authors (no titles or degrees), institutional affiliations, a running headline of not more than 40 letters with spaces.

❑6. Acknowledgements of persons who assisted the authors should be included on the page preceding the references.

❑7. References must begin on a separate page.

❑8. References must be cited on (not above) the line of text and in brackets instead of parentheses, e.g., [7,8].

❑9. References must be numbered in the order in which they appear in the text. References not cited in the text cannot appear in the reference section. References only or first cited in a table or figures are numbered according to where the table or figure is cited in the text. For instance, if a table is placed after reference 8, a new reference cited in table 1 would be reference 9.

❑10. Reference citations must follow the format established by the "Uniform Requirements for Manuscripts Submitted to Biomedical Journals" or in "Vancouver Citation Style".

❑11. If you reference your own unpublished work (i.e., an "in press" article) in the manuscript that you are submitting, you must attach a file of the "in press" article and an acceptance letter from the journal.

❑12. If you cite unpublished data that are not your own, you must provide a letter of permission from the author of that publication.

❑13. Please provide each figure in high quality (minimum 300 dpi: JPG or TIF). Figure must be on a separate file.

❑14. If the study received a financial support, the name of the sponsors must be included in the cover letter and in the text, after the author's affiliations.

❑15. Provide the number of the Ethics Committees (please check the guidelines for authors).