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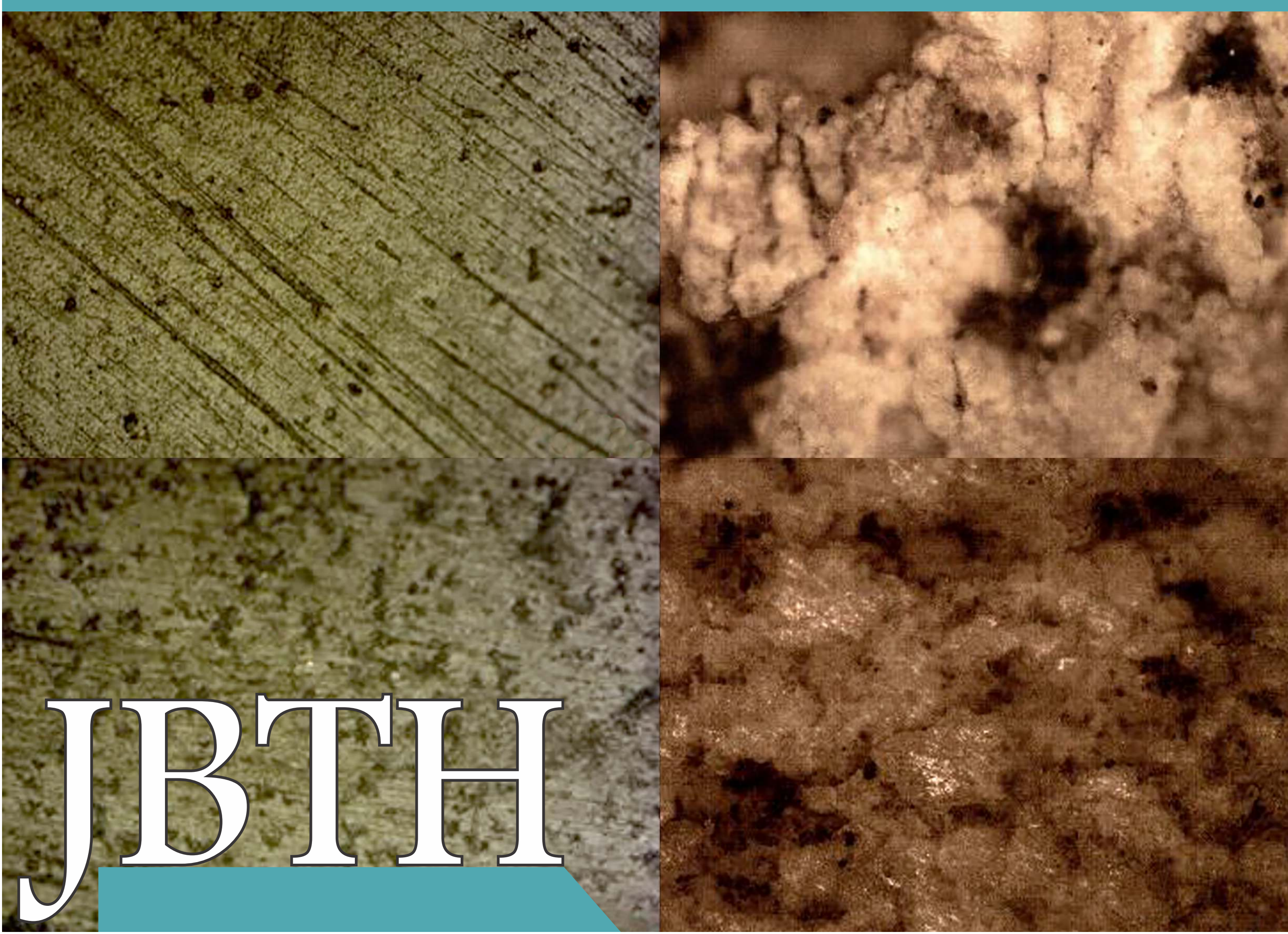

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SUMMARY

Original Articles

Systematic Review / Review Articles

Case Study

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COVER: Figure 4. Optical microscopy at 10x magnification of the test specimens. (a) F0; (b) F0-S; (c) F1; (d) F1-S. Influence of Starch on the Biodegradability of AGENACOMP® by Vitor Almeida de Novaes Galvão et al. J Bioeng Tech Health 7(1):11.

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Resistance Assessment as a Strategy to Increase the Adoption of Electronic Laboratory Notebooks

Fabíola Lopes Caetano Machado[1*], Ivanete Milagres Presot[1], Camila de Sousa Pereira Guizzo[2], Xisto Lucas Travassos Junior[3]

[1]René Rachou Institute, Oswald Cruz Foundation; Belo Horizonte, Minas Gerais; [2]SENAI CIMATEC University Center; Salvador, Bahia; [3]Federal University of Santa Catarina; Florianópolis, Santa Catarina, Brazil

Electronic Lab Notebooks (ELNs) have seen a significant rise in research laboratories. However, realizing the benefits of ELNs requires the active participation of employees within an organization. This study aims to identify the factors contributing to resistance towards adopting an ELN, specifically eLabFTW. A semi-structured questionnaire, validated by experts, was administered to record book requesters at the René Rachou Institute (FIOCRUZ MG). The findings revealed that individual decision-making factors include peer influence within the research group and familiarity with traditional physical logbooks. Assessing resistance can serve as a strategic tool to enhance system adoption.

Keywords: Electronic Lab Notebook. Resistance to Change. Strategy.

The credibility of research results relies on robust scientific principles and high-quality practices. For research to be considered scientifically valid, it must produce relevant, reliable, and reproducible results while adhering to ethical standards. Furthermore, research documentation should be auditable and accessible to the public, demonstrating that all procedures were conducted accurately within the specified timeframe. Failure to maintain comprehensive records may doubt the study's validity [1].

Traditionally, research documentation has been carried out using paper notebooks, but electronic lab notebooks (ELNs) offer several advantages. ELNs offer significant benefits over paper notebooks, including enhanced information retrieval and more accessible data sharing. They can handle and store large volumes of data, incorporating features such as data backup and security protocols. ELNs also contribute to research reproducibility and management by providing improved documentation of research processes, primarily through features like versioning and revision tracking. Moreover, implementing security measures such as passwords and access levels ensures unauthorized individuals cannot access research data. Finally, using ELNs reduces paper waste, contributing to environmental sustainability [2].

The adoption of new ELN software and its implementation by research institutions has increased since 2000, driven by the recognized benefits of digitization. However, despite the advantages offered by ELNs, several barriers have been identified. Not all ELNs have proven successful or suitable, and many commercially available and open-source software packages have become defunct over time. An analysis of 172 ELN products (96 active and 76 defunct) revealed that the average lifetime of an ELN was approximately 7 ± 4 years. Consequently, selecting the right tool can be complex for a research institution if end-users are not actively involved in implementing these digital research management processes [3].

Numerous studies [4-6] on electronic systems implementation have highlighted varying levels of user acceptance and successful change processes. Each study addresses different strategies to overcome barriers within their unique organizational contexts. Ineffective change management strategies can lead to increased resistance to change. Change agents can address this situation by providing staff with clear

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Address for correspondence: Fabíola Lopes Caetano Machado. SENAI CIMATEC University Center. Av. Orlando Gomes, 1845 - Piatã, Salvador, Bahia, Brazil. E-mail: fabiola.machado@fiocruz.br.

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information about the change and demonstrating a genuine interest in addressing the concerns of those involved. Another crucial factor that can help reduce resistance is the active participation of staff in planning and implementing change as active participants rather than passive recipients. Participation fosters a sense of control over the new process among individuals [7].

The current study targets change agents implementing ELN usage within research organizations. We aimed to identify the factors contributing to individual resistance and explore how institutions can address these challenges effectively.

Materials and Methods

This research employed a case study method [8] and followed these steps: a literature review to identify resistance factors to ELN usage, a case description, an expert evaluation of the questionnaire, and a pilot study. The semi-structured questionnaire used to assess why researchers opted for a physical book instead of eLabFTW® ELN was developed based on individual and organizational resistance factors (Table 1), derived from references [4,7].

For semantic consistency, goal achievement, inducing responses, and response time evaluation, we invited 5 experts to assess the questionnaire. These experts included one change agent of ELN implementation, one expert in human behavior to evaluate psychological values, one expert in human/software interaction, one user, and one technical support specialist. The experts' opinions were analyzed for concordance frequency, with a minimum acceptable inter-rater agreement of 90% recommended.

This case was conducted at the Oswaldo Cruz Foundation, which operates several regional units, including the René Rachou Institute (IRR/Fiocruz) in Minas Gerais, Brazil. The IRR/Fiocruz is a renowned institution in public health research, boasting 18 laboratories dedicated to studying tropical diseases such as Chagas disease, leishmaniasis, schistosomiasis, and intestinal parasites. It also houses 13 biological collections and 4 reference laboratories.

Established in 2003, the institution offers a postgraduate course in health sciences focusing on training master's and doctoral students for scientific research, teaching, and professional activities in the health field. Additionally, the IRR provides scientific and technical support to the Brazilian Public Health System (SUS).

In 2021, the eLabFTW® ELN platform was carefully implemented at IRR/FIOCRUZ after a thorough viability study. IRR researchers chose this open-source ELN to advance the use of electronic lab notebooks (Figure 1). Since its

Table 1. Resistance factors.

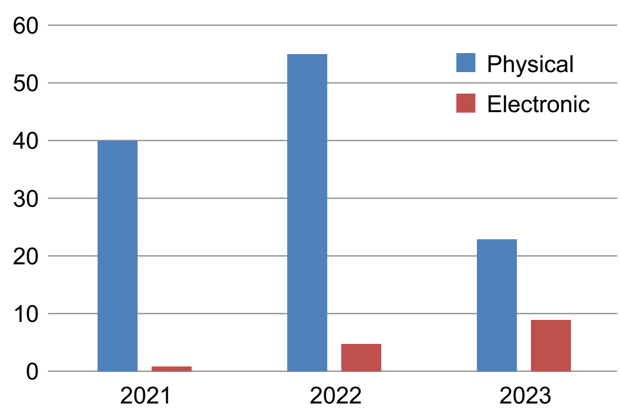
Individual	Organizational
Inertia factor: has always worked this way than will not change	Quality Management System and institutional policies: organization values and wills for changing
Example factor: others in same group did not join ELN so they do not change	Organization's formal structure, systems and processes.
Trauma factor: fear of losing data/insecurity	Computerized System quality
Lack of information: didn't know the ELN existence	Technical support quality
	Institutional communication

Source: Althunibat A and colleagues; Nedelcu and Busu [4,7].

implementation in 2021, there have been 118 lab notebook requests, of which only 15 researchers opted to use the eLabFTW® ELN to record their research data. This represents approximately 14% of all lab notebook requisitions.

Figure 1 displays the number of lab notebooks delivered over time.

Figure 1. Number of Lab notebook delivered.



To collect data for this study, we emailed a questionnaire to 102 logbook requesters, who were invited to respond using the Google Form platform. Participants' identities were kept anonymous, as the responses did not include personal details or email addresses. This research was not submitted for approval by the Research Ethics Committee as it complies with Article 1, item VII of CNS Resolution No. 510, dated April 7, 2016.

Results and Discussion

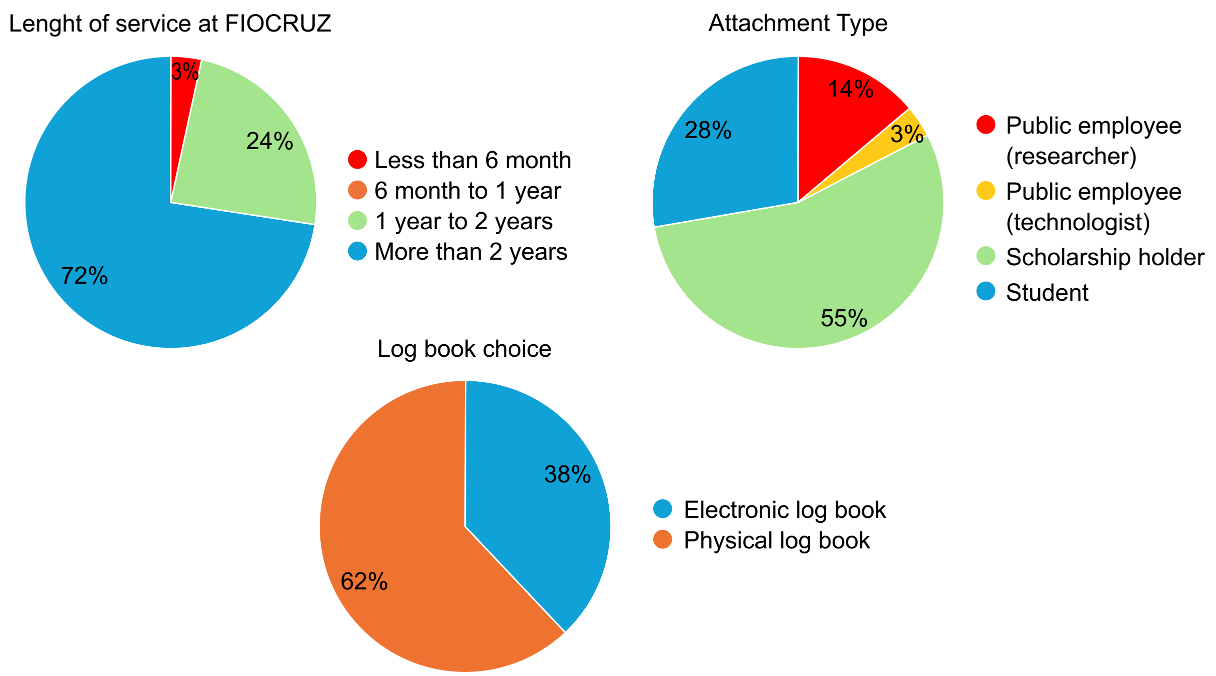
Figure 2 presents the respondents' profiles predominantly consisted of scholarship holders and students working at FIOCRUZ for over 2 years, with an average age of 35. Among the 29 respondents, nearly 40% opted for electronic logbooks to register their research data, with usage frequencies ranging from once a week to once a month. All 11 respondents who used electronic logbooks reported using the eLabFTW platform on their computers.

Regarding individual resistance factors, such as EXAMPLE, it was found that for most respondents (17), the experience within their research group influenced their choice. Only 12 respondents rated this factor below 3, indicating that the EXAMPLE factor can positively and negatively influence the decision to use an electronic record book.Among the 18 users of physical logbooks, 11 indicated that their choice was influenced by their habitual use of this type of record, highlighting the importance of considering the INERTIA factor. In contrast, only 3 users of physical logbooks rated the TRAUMA factor higher than 4, indicating that negative experiences were not a significant deterrent in choosing an electronic record book.

Communication was assessed in two aspects: awareness of the eLabFTW platform and the evaluation of information flow within FIOCRUZ. Nearly half of the respondents were aware of the platform, and 41% of respondents rated the adequacy of communication channels with a score of 4 or 5. However, 15 respondents were either unaware or did not respond, suggesting that communication remains an area for improvement within the institution. Most respondents agree with these factors regarding the training provided, the quality of training, and the recognition of the institution's efforts in providing information resources. This suggests that the organizational aspect of information is not a critical concern. However, it remains a factor that should be continuously monitored in effective change management strategies. Future training sessions could benefit from including testimonials from current eLabFTW users, given the significant impact of the EXAMPLE factor, as mentioned in the work of Bravo and colleagues [5].

As highlighted by Kanza and colleagues, people's resistance to adopting a new tool can be a significant barrier, especially if they perceive it to be complex [9]. However, the quality of the eLabFTW platform and technical support was generally well-received, with almost all electronic users agreeing that the system is easy to use, secure,

Figure 2. Respondent profile and logbook choice.



and integrates well with other record sources. Only one respondent disagreed with these aspects. This positive feedback validates the feasibility study conducted prior to implementing the system.

When respondents were asked about the resources available for using the eLabFTW platform, including internet quality and computer availability, 16 agreed that the resources were sufficient. However, suggestions for improving adherence to the eLabFTW platform highlighted the need for additional notebooks. Several strategies were proposed to address this, including improving communication in academic spaces, advertising on the intranet and requisition system, and encouraging mentors to discuss the ELN with their mentees.

The questionnaire included a range of questions and statements that assessed individual and organizational factors influencing resistance to change and evaluated the quality of the implemented computerized system. Unlike previous studies that focused on specific factors, our study comprehensively assessed various aspects. For example, Althunibat, Almaiah, and Altarawneh studied multiple factors affecting students' non-adherence to remote learning but did not delve into students' emotional responses to remote learning [4].

In contrast, Bravo and colleagues [5] designed a questionnaire to assess stakeholders' acceptance of an Educational Management System at a public university. The questionnaire had elements that allowed for evaluating both individual and organizational factors. However, the wording of the questions made them challenging to understand, and the questionnaire was lengthy, comprising 40 questions. Ben, Geyer, and Kahl [6] investigated the adherence of various stakeholders involved in IT projects within public institutions. While they did not explore individuals' emotional responses to the proposed changes, the semi-structured nature of their questionnaire might have captured such factors in respondents' answers. However, neither questionnaire specifically addressed aspects related to the quality of IT projects.

Conclusion

The study has yielded valuable insights that will be instrumental in enhancing the adoption of the eLabFTW Platform among IRR/FIOCRUZ MG employees. Individual resistance factors such as EXAMPLE and INERTIA emerged as significant influencers. Increased adherence to the new electronic data recording system will catalyze a broader migration to the new ELN platform.

The commendable efforts of FIOCRUZ's senior management in spearheading the implementation and enhancement of this innovative research data recording method have been duly acknowledged. Nevertheless, there is a recognized need to refine communication strategies and training programs further to promote the utilization of the ELN across the institution.

The questionnaire to assess individual and organizational resistance to using the eLabFTW electronic record book was distributed to all employees who requested a logbook at FIOCRUZ/MG. However, to evaluate the quality of the platform effectively, it was necessary to target electronic logbook users specifically. Separate questionnaires tailored to each profile may be beneficial to gauge resistance to comprehensively adopting the new eLabFTW platform. One questionnaire could focus on individual and organizational barriers to ELN use, applied to those who requested the physical logbook. At the same time, another could concentrate on assessing the quality of the eLabFTW system for ongoing improvement efforts.

A limitation of this study was the relatively low response rate, with less than 30% of the invitations resulting in completed questionnaires. A more significant number of respondents would provide deeper insights into the reasons for non-adherence to the electronic logbook. Despite this limitation, the questionnaire is advantageous due to its ease of application and minimal time investment required from respondents, allowing for efficient analysis. However, efforts should be made to increase the response rate in future studies for a more comprehensive understanding of resistance factors and quality assessments.

The method had limitations, particularly regarding the questionnaire response rate. To address this, the study intends to explore alternative methods, such as semi-structured interviews or focus groups. These approaches aim to provide a deeper understanding of the factors contributing to the low adherence to using the ELN. The application of these tools will extend to other FIOCRUZ units that have also implemented the eLabFTW electronic logbook.

Acknowledgments

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Influence of Starch on the Biodegradability of AGENACOMP®

Vitor Almeida de Novaes Galvão[1*], Luis Victor Rocha dos Santos[2], Marco Aurélio Silveira[2], Ana Paula Bispo Gonçalves[2], Paulo Romano Cruz Correia[2], Josiane Dantas Viana Barbosa[2], Luciano Pisanu[2]
[1]Federal University of Bahia; [2]SENAI CIMATEC University Center; Salvador, Bahia, Brazil

The compostable blend AGENACOMP®, which combines thermoplastic starch with other biopolymers, has shown potential for producing plastic bags with reduced environmental impact upon disposal, thanks to its good processability and ability to form thin films when extruded. In this study, we produced a blend of AGENACOMP® with additional incorporated starch and evaluated its properties using extrusion, injection, mechanical tests, optical microscopy, and FTIR analysis. Furthermore, we tested its biodegradability by placing samples in simulated soil for three months. Our findings revealed that the addition of starch not only accelerated degradation but also increased the tensile modulus by approximately 20%. This indicates that the modified blend exhibits improved mechanical properties while remaining environmentally friendly due to its biodegradability.
Keywords: Biopolymers. Thermoplastic Starch. AGENACOMP®. Plasticizer. Biodegradability.

In recent decades, the excessive use of polymers derived from non-renewable sources, such as polyethylene and polypropylene, has led to significant global environmental pollution, mainly due to the widespread use of plastic bags. Recognizing the necessity to continue producing these items while mitigating their environmental impact, it is imperative to explore modifications in their composition [1].

Biopolymers have emerged as promising alternatives to synthetic polymers derived from non-renewable sources. These materials, derived from biological sources, possess favorable characteristics such as biodegradability, biocompatibility, and low toxicity. The capacity to create polymeric blends using renewable resources has spurred considerable research and development in this field [2].

Among renewable sources, starch is a compelling biopolymer suitable for incorporation as a filler in polymeric blends. As an agricultural byproduct, starch is abundant, cost-effective, and contributes to biodegradability, thus reducing the environmental impact and cost of the final product. When combined with plasticizers, starch transforms into thermoplastic starch (TPS), a versatile and economical material with significant potential for film and packaging production applications. Numerous studies have highlighted the advantages of incorporating TPS into blends with polymers such as polybutylene adipate terephthalate and polylactic acid, showcasing improvements in mechanical strength. However, the intrinsic weak interfacial interaction between hydrophilic starch granules and hydrophobic polymers necessitates the addition of a compatibilizing agent like maleic anhydride. This agent has been demonstrated to enhance adhesion between the two phases, leading to more robust and functional polymeric blends [3,4].

AGENACOMP®, developed by AGRANA, is a compostable blend designed for extruding ultra-thin films. This blend combines TPS AMITROPLAST® with biopolymers and other undisclosed ingredients comprising over 50% renewable components. It is engineered to offer excellent processability in bag-manufacturing machinery, enabling the production of sub-10 μm films. Additionally, it holds certification according to the European EN 13432 standard, demonstrating its ability to degrade by 90% into CO_2, water, and minerals within 12 months under domestic composting conditions (~30°C) [5].

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Address for correspondence: Vitor Almeida de Novaes Galvão. Programa de Pós-Graduação em Engenharia Química, Rua Aristides Novis, 02 2º andar Federação. Zipcode: 40210.630. Salvador, Bahia, Brazil. E-mail: vitorngalvao@hotmail.com.

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The current study aims to evaluate the biodegradability of AGENACOMP® with added starch after three months of exposure to simulated soil.

Materials and Methods

We utilized the following materials to prepare the samples: AGENACOMP® provided by the Austrian company AGRANA, cassava starch sourced from Podium Alimentos, and a maleic anhydride additive manufactured by Elekeiroz. The methodology of this study encompassed several stages: drying the raw materials, extrusion, and dehumidification to produce test specimens via injection molding, placing the specimens in soil prepared according to the ASTM G160 standard, and ultimately characterizing the samples.

After drying the AGENACOMP® and the cassava starch in an oven at 90°C for approximately 48 hours, the material underwent processing using a co-rotating twin-screw extruder, specifically the Imacom DRC 30:40 IF model, with a screw diameter of 30 mm and an L/D ratio of 40. The material was extruded using a temperature profile for the extruder: 80, 90, 95, 100, 110, 120, 130, 140, 150, 160, and 60°C. Additionally, the screw speed was set to 45 RPM.

Table 1 presents the compositions of the produced formulations in percentage. Both F0 and F0-S have identical compositions, as do F1 and F1-S. The "-S" designation indicates that the samples from the respective formulations were placed in the simulated soil. Throughout this study, all results associated with formulations featuring this "-S" designation refer to test specimens after degradation.

We used a ROMI injection molding machine of the Primax model to obtain the test specimens, featuring a closing force capacity of 100 tons, a 50 mm diameter universal screw, and an L/D ratio of 20. Before injection, the material underwent dehumidification at 90°C using a PIOVAN dehumidifier, specifically the T501X model, for a minimum of 6 hours.

The preparation of 20 kg of simulated soil adhered to ASTM G160 standard guidelines, involving an equal mixture of animal manure, beach sand (passed through a 40-mesh sieve), and soil. The specimens were subsequently placed in a composter for three months, after which they were removed, washed, and subjected to optical microscopy using Zeiss Axio equipment. Sample characterization was conducted utilizing the Thermo Scientific Nicolet iS10 FTIR spectrometer.

We conducted tensile tests to evaluate the mechanical properties of the various blends using an EMIC testing machine, specifically the DL 2000 model, per ISO 527 standard procedures, without using an extensometer. A 9 kN load cell was employed, and the testing speed was 50 mm/min. The properties evaluated included tensile strength, elongation at break, and tensile modulus.

Table 1. Composition of the blends produced via an extrusion process, in percentage.

	AGENACOMP®	Starch	Maleic anhydride
F0	100	-	-
F1	60	37	3
F0-S	100	-	-
F1-S	60	37	3

Results and Discussion

To evaluate whether the material properties were compromised after exposure to the simulated soil conditions, we proposed that the "-S" formulations also be subjected to mechanical testing. However, only F0-S was suitable for the tests, as the F1-S samples significantly deteriorated, with a substantial mass loss. Figure 1 exhibits the appearance of the test specimens from F0-S and F1-S after the period spent in the composter and subsequent tensile testing in the case of F0-S.

After conducting the tensile tests, the tensile strength, elongation at break, and tensile modulus values were recorded for the formulations F0, F1, and F0-S. Figure 2 displays the graphs plotted with this data.

The inclusion of starch in AGENACOMP® notably decreased the material's flexibility, with the F1 formulation exhibiting an elongation at a break five times smaller than that of F0 and a tensile strength value approximately 10% lower than the control formulation (refer to Figure 2b and Figure 2a). This indicates a heightened stiffness, as reflected in the tensile modulus (refer to Figure 2c), attributed to the additional load introduced by starch. Starch's molecular structure reinforces polymeric matrices through hydrogen bonding between the polysaccharide chains and the biopolymer, increasing stiffness and mechanical strength. Additionally, three-dimensional networks form within the material's matrix, contributing to the rise in tensile modulus. The F0-S formulation displayed even lower tensile strength and elongation at break values. While the tensile modulus exhibited an overall average increase, there was significant variation in its values, indicating varying degrees and types of degradation among the test specimens. These outcomes are attributed to exposing the polymeric matrix to a humid environment. During this exposure, the hydrogen bonds between polymeric chains dissociate due to competition for interaction with water molecules, leading to material deformation and reduced stiffness [6,7].

The FTIR test plays a crucial role in the analysis and characterization of polymeric blends. Interacting with infrared light provides detailed insight into the chemical bonds in the sample under study and the presence or absence of additives, impurities, or chemical modifications [8]. Figure 3 shows the samples' FTIR spectra.

From the FTIR, it is possible to evaluate the index of terminal carboxylic groups (IGCT) because, during the degradation of polyesters by the action of microorganisms, the ester bonds break, resulting in a reduction in the molecular weight of the sample, indicated by the increase in the number of IGCT [8].

Figure 1. Test specimens after degradation and tensile testing (left: F0-S; right: F1-S).

Figure 2. Values of (a) tensile strength, (b) elongation at break, and (c) tensile modulus.

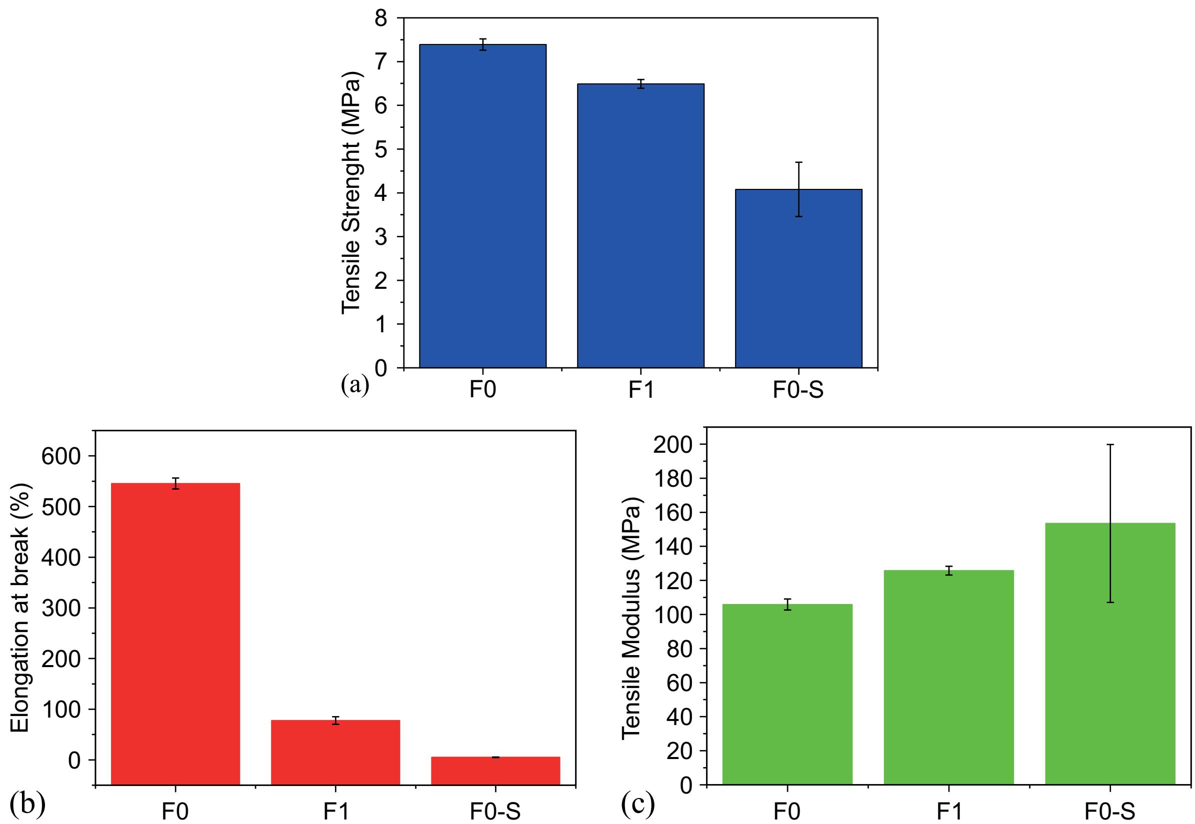


Figure 3. FTIR (a) F0 and F0-S; (b) F1 and F1-S.

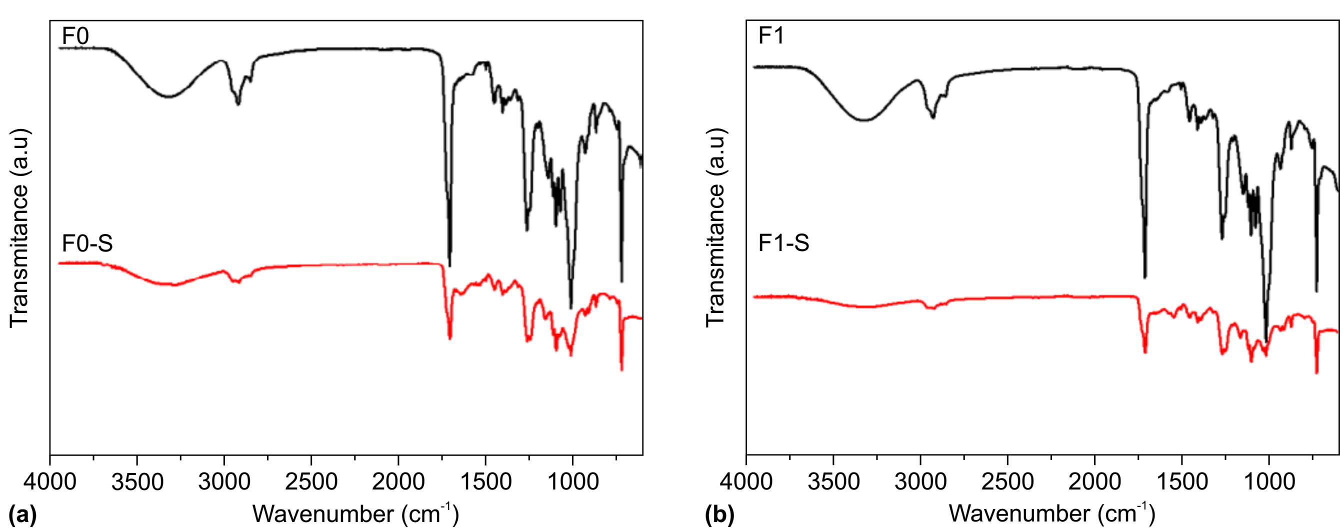
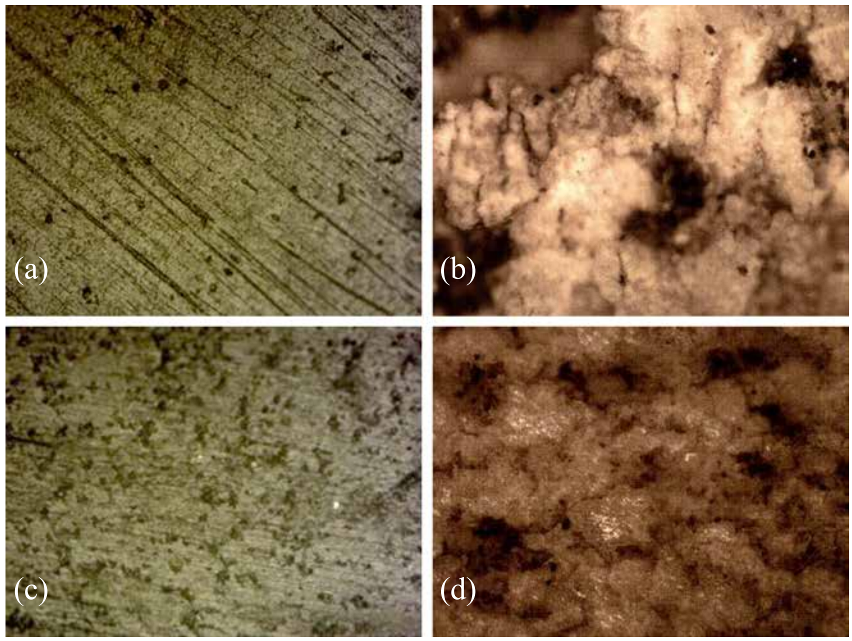


Figure 4. Optical microscopy at 10x magnification of the test specimens. (a) F0; (b) F0-S; (c) F1; (d) F1-S.



Quantification was calculated using Equation (1).

$$IGCT = \frac{absorption\ at\ 3290\ cm^{-1}}{absorption\ at\ 2970\ cm^{-1}} \quad (1)$$

From the IGCT calculations, values of 15.7 and 10.3% were found for F0 and F0-S samples, respectively. As for F1 and F1-S samples, the results were 5.8 and 9.4%, correspondingly. These findings enabled the identification that only the sample containing more starch contributed to biodegradation, attributed to the IGCT increase. This result corroborates the results of the tensile test and morphology. We used an optical microscopy to assess the extent of degradation of the materials produced (Figure 4).

Optical microscopy plays a crucial role in analyzing the morphology of degraded test specimens, offering a comprehensive visualization of the materials' characteristics and structural changes [9]. Microbial degradation follows a process wherein functional groups form within the polymeric matrix, increasing its hydrophilicity and enhancing microorganism adhesion. This initiates reactions that break the polymeric chains, reducing their molecular weight and rendering the material more accessible to these organisms. In the case of polymeric blends containing starch, biodegradation occurs in three stages. Microorganisms target the surface starch chains, leading to minor erosion, fissure development, and mass reduction. Subsequently, deeper microbial infiltration and moisture trigger more extensive material degradation. In the final stage, if starch persists in the structure, degradation can accelerate up to six times due to increased surface area [9, 10]. As depicted in Figure 4, evidence indicates that the structures underwent the action of microorganisms in the simulated soil. The presence of starch in the formulation expedited degradation, as evidenced by the fissures (dark spots). These cracks enlarge with prolonged incubation time due to ongoing microbial activity.

Conclusion

The analyses provide compelling evidence that incorporating thermoplastic starch into AGENACOMP® accelerates the material's degradation. A substantial portion of the mass of the test specimens from F1-S was lost after exposure to the simulated soil for approximately three months, as confirmed by optical microscopy and FTIR images. Additionally, the tensile test revealed reinforcement by the molecular structure of the added starch to the polymeric matrix, leading to increased stiffness and mechanical strength of the material containing the added starch. Specifically, the tensile modulus results demonstrated an approximate 20% increase.

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Application of Coffee Production Waste to Obtain Composites with Biopolimeric Matrix of PBS and ECOVIO

Talyta Silva Prado[1*], Paulo Romano Cruz Correia[1,2], Ana Paula Bispo Gonçalves[3], Josiane Dantas Viana Barbosa[1], Luciano Pisanu[1]

[1]Materials Area – SENAI CIMATEC University Center (Materials Lab); [2]SENAI CIMATEC University Center (Food and Beverage Technology Lab); [3]FIOCRUZ-Bahia; Salvador, Bahia, Brazil

Numerous environmental problems have arisen due to excessive production and consumption of non-renewable polymers. Thus, some strategies have been developed to mitigate the impacts, including degradable biopolymers, PBS, and ECOVIO, whose properties are improved by adding vegetable fibers. This work aims to obtain composites whose biopolymeric matrix will be reinforced with coffee residues and to evaluate their mechanical properties. The methodology consisted of drying, extrusion, dehumidification, injection, and tensile testing. The added residue showed good interaction with the matrix, reduced the elongation and ductility of the composites, and increased their rigidity. Thus, it was concluded that the composite (PBS WC 70/30) increased 62.5% in the elastic modulus, showing that it is the best material among those studied.

Keywords: Biopolymers. Composites. Plant Fibers. PBS. ECOVIO.

Since the beginning of the last century, polymers have become indispensable in contemporary society due to their variety of applications, properties, versatility of use, and, mainly, low production cost [1,2]. On the other hand, large-scale production, excessive consumption, and incorrect disposal are the main factors responsible for the accumulation of these synthetic polymers in different environments, causing environmental problems, which have been the world's agenda for discussions and research in various fields branches of science [3-6].

As an alternative to mitigate the environmental impacts of plastic waste, some strategies have been employed, such as incineration, recycling, landfills, biodegradation, and using biodegradable polymers. The latter, in turn, has been gaining attention for being produced from renewable sources, in addition to its degradation proceeding from the action of microorganisms, producing CO_2, CH_4, cellular components, and other products.

Among the biopolymers, PBS has properties such as high flexibility, excellent thermal stability, biological and biodegradable base, eco-efficiency, and, mainly, because it is commercially available and exhibits a gas/humidity barrier like PLA (MITSUBISHI CHEMICAL CORPORATION).

ECOVIO, in turn, is a polymeric blend between PLA and PBAT and is responsible for giving the biopolymer moderate flexibility and impact resistance while still being commercially attractive, being widely used in flexible and resistant packaging, injected, and bags [7].

However, some properties of this class of polymers need to be improved. For this, additives are incorporated by combining two or more miscible and compatible materials to add color to the material, increase the mechanical or thermal resistance of the material, increase flexibility, decrease the influence of water on material properties, and so on [8]. Some additives widely used in packaging development are plasticizers and reinforcing agents that help in the materials' processability, mechanical strength, and water resistance [9,10].

The production of these blends together with materials of natural origin, with little added value and easy to obtain, such as coconut fibers, corn, sisal, rice husks, sunflower, and coffee residues, among others, are incorporated together with the polymeric matrix (continuous phase) promoting a sustainable alternative with a reduction in the cost

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Address for correspondence: Talyta Silva Prado. Av. Centenário, 697 - Sim, Feira de Santana - BA. Zipcode: 44042-280 E-mail: talytaprado765@gmail.com.

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of production and in the mass of polymer to be used in the manufacture of the product, in addition to reusing waste that is improperly disposed of in the environment [11,12].

Brazil, as a major coffee producer and exporter, occupies the second position in the world as the largest consumer of this drink and is one of the largest food industries in the world, being divided into two main sectors: separation of the husk and mucilage of coffee fruits and, the roasting and infusion stage of the beans.

However, the high demand for coffee has produced excessive by-products in all stages of coffee processing since only 10% of the fruit are products of interest. In comparison, the other 90% become waste with different chemical compositions, among them its high biodegradability [13].

This article aims to analyze the obtainment of composites through the sustainable use of coffee by-products as a reinforcing filler in commercial biopolymers and to evaluate their mechanical properties.

Materials and Methods

The methods used for the current study were drying, extrusion, dehumidification, injection of specimens, and tensile tests.

After drying the PBS, ECOVIO, and WC (post-stripping residue) in an oven at 90°C for about 48 hours, the materials were processed according to the formulations (Table 1) in an IMACOM twin screw correlational extruder, model DRC 30: 40 IF, with a thread diameter of 30 mm and an L/D ratio of 40. The material was extruded at 37/90 /137/138/137/148/145/142/137/140/144/143°C in the respective temperature zones, with a screw speed of 200 Rpm.

A ROMI injection machine, Primax model, with a capacity of 100 tons of closing force, universal screw with a diameter of 50 mm, and an L/D ratio of 20 was used to obtain the specimens (Table 2). Before injection, the material was dehumidified at 90°C in a PIOVAN model T501X dehumidifier for a minimum of 6 hours.

In order to evaluate the mechanical properties of the different composites, the specimens were subjected to a tensile test, carried out in a testing machine from the brand EMIC – Equipamentos e Sistemas de Ensaio Ltda, Model DL 2000, according to ISO 527 type 5, without the use of an extensometer. The load cell used was 8kN.

The properties of tension, modulus of elasticity, and deformation were evaluated at maximum force at a displacement speed of 50 mm/min.

The averages and their respective standard deviations were calculated using the data to obtain the stress *versus* strain graph using the Origin Pro 8.1 program. The moisture test was performed using a halogen moisture analyzer and an infrared touch screen REF m5-thermo BEL Engineering®.

Table 1. Composite formulations.

Polymers (%)		Coffee Waste	Reference Code
ECOVIO	100	0	ECOVIO
ECOVIO	80	20	ECOVIO WC 80/20
ECOVIO	70	30	ECOVIO WC 70/70
PBS	100	0	PBS
PBS	80	20	PBS WC 80/20
PBS	70	30	PBS WC 70/30

Table 2. Processing parameters of specimens processed in an injection.

Pressure (bar) 950	**Speed (m/s)** 95	**Holding Pressure (bar)** 700	**Volume Dosage (cm^3)** 62	**Back Pressure (bar)** 10	**Dosing Speed (m/s)** 450
Temperature Real (ºC)		**Heating**			
		Front 180	**Zone 3** 150	**Zone 2** 150	**Zone 1** 148

Results and Discussion

To evaluate the mechanical properties of the composites and determine their tensile strength, the formulations were molded according to ASTM D638 (Figure 1) and subjected to a uniaxial tensile force gradually applied until failure. Table 3 shows the forces' mean values and respective standard deviations, tensile modulus, and elongation at break.

A stress-strain graph was obtained for each composite tested based on the above values. Figure 2 contains information about the mechanical behavior of the samples, including points of maximum stress and failure point.

From the tensile test, it was possible to observe that the composites obtained showed a lower tension compared to the starting materials (ECOVIO or PBS) due to the addition of residues that are responsible for reducing the elongation of the composites at the moment of rupture, taking into account considering that the formulated materials have intermediate characteristics between the matrix and the pure fiber due to the adopted principle of combined action. Cellulosic materials and those with a high fiber content have a higher modulus of elasticity than polymeric matrices, whose decrease in ductility shows an increase in the rigidity of the composites. According to Callister Jr. [14], the properties of composite materials are a function of the properties

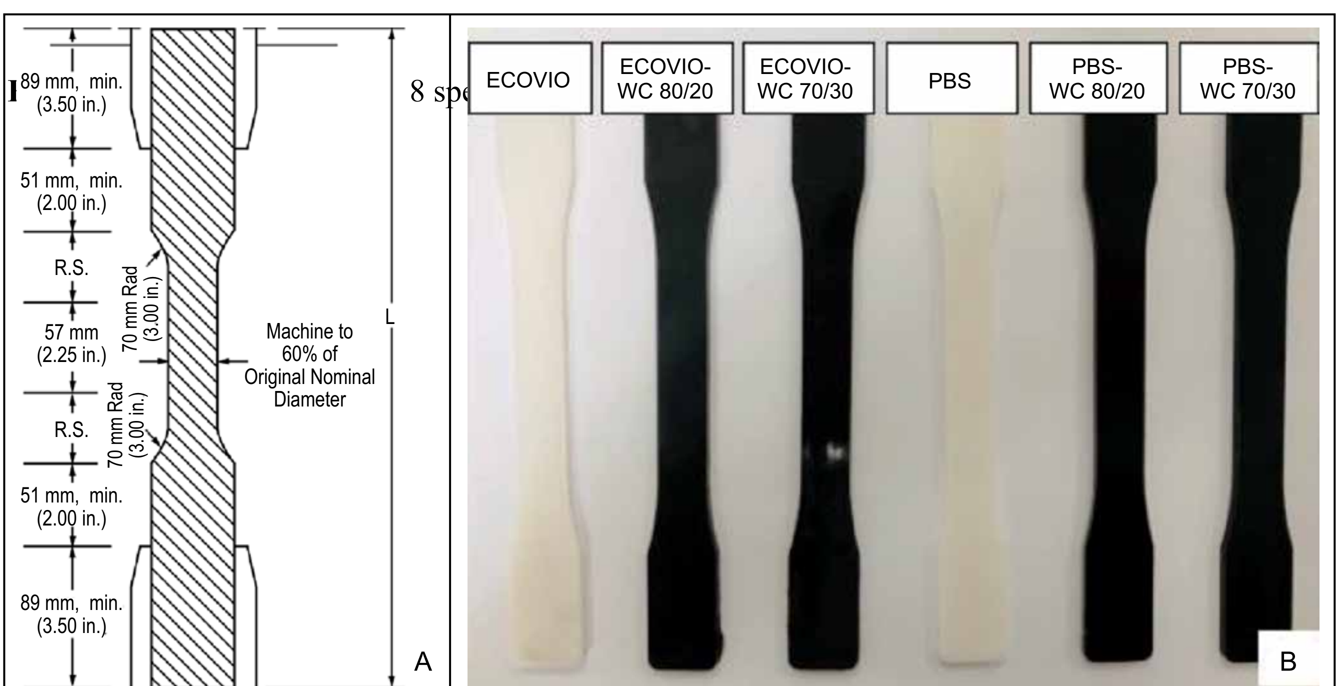
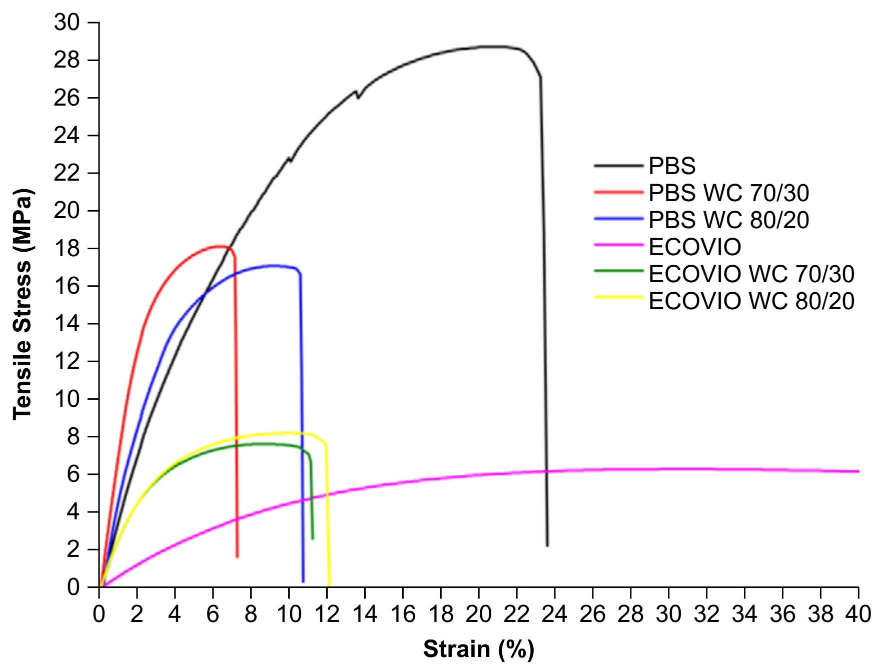


Table 3. Mechanical tests: Tensile strength, tensile modulus, and elongation break.

Composition	Tensile Strenght (MPa)	Tensile Modulus (MPa)	Elongation at Break (%)
ECOVIO - WC 80/20	9.9 ± 0.42	381.7 ± 10.11	9.7 ± 0.95
ECOVIO - WC 70/30	9.4 ± 0.52	403.6 ± 12.69	9.29 ± 1.38
ECOVIO	13.0 ± 1.08	89.95 ± 17.50	679.67 ± 18.01
PBS - WC 80/20	21.4 ± 0.52	769.8 ± 76.62	11.00 ± 1.15
PBS - WC 70/30	21.5 ± 0.58	1214.8 ± 36.7	5.51 ± 0.43
PBS	35.0 ± 0.64	455.22 ± 51.55	22.71 ± 0.95

Figure 2. Composite stress-strain graph.



of the constituent phases, their relative quantity, and the geometry of the dispersed phase, such as shape, size, distribution, and orientation of the added particles. Thus, the added fiber load entered the polymeric matrix, promoting good interaction and performance, increasing its rigidity, and evidencing a lower ductility of the composites. As for the tensile modulus, it was found that the addition of fibers to the matrices provided the composites with an increase in this value, so PBS + 30% WC was the material that acquired more excellent resistance to reversible deformation, that is, a capacity for less elastic deformation in the face of an applied force. Natural fibers present hydrophilic behavior due to hydroxyl groups in their structure, thus absorbing water from the atmosphere. According to Dackal and colleagues [15], this hydrophilic behavior of the fibers can be a problem since the absorption of water can reduce the mechanical properties. Thus, the humidity test was performed for the waste under study (WC), and an average value equal to 11,34% was found, considered, according to 16-19, above the maximum allowed, corresponding to 9%.

This difference may be associated with a prolonged exposure time of the fiber and high porosity, which facilitates water entry into its structure.

We observed that all composites presented air spaces/bubbles inside their test specimens (Figure 3) which may have contributed to its fracture, masking the accurate result regarding the material's resistance. Among the formulations, the composites with PBS presented a lower incidence of bubbles and a smaller diameter. This intervention may have come from the presence of moisture in the fiber, volatility of compounds present in the composite, or failure during the injection process to produce specimens.

Conclusion

We concluded through the tensile tests the results were promising, so that the addition of residues in the composites from the coffee industry presented a good interaction with the biopolymer matrix (ECOVIO and PBS), causing a reduction in the elongation of composites due to their high fiber content. This effect is responsible for causing a reduction in the ductility of the materials and, consequently, an increase in their rigidity. Among the formulations studied, the one containing PBS + 30% WC was the one that showed the most significant resistance deformation in the face of an applied tension force, whose calculated increase was approximately 37.5%. In this way, these composites can be used as an alternative to minimize the costs of biodegradable polymers and to be a destination for the waste in question. Other characterizations will be carried out later to elucidate the properties of these materials.

Acknowledgments

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Figure 3. Specimens of composites after tensile test.

ECOVIO- WC 80/20	ECOVIO- WC 70/30	PBS- WC 80/20	PBS - WC 70/30

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Fractional and Chemical Characterization of Green Coconut Fiber Bio-Oil Using Fast-GC×GC/TOFMS

Rafael de Oliveira Farrapeira[1,2*], Yasmine Andrade Braga[2], Jaderson Kleveston Schneider[3], Carin von Muhlen[4], Elina Bastos Caramão[1,2]

[1]Federal University of Bahia - INCT Energy and Environment; Salvador, Bahia; [2]Postgraduation Program on Industrial Biotechnology - UNIT; Aracaju, Sergipe; [3]Federal University of Pampa; São Gabriel, Rio Grande do Sul; [4]State University of Rio de Janeiro - UERJ; Rezende, Rio de Janeiro, Brazil

Brazil is renowned for its expertise in utilizing biomass for energy and biomaterials. Notably, in tandem with biomass processing, the country has a high potential for bio-products derived from agro-industrial residues, such as green coconut fibers. This study focused on using green coconut fibers in bio-oil production via pyrolysis (at 700 ºC with a heating rate of 100ºC/min). The bio-oil underwent fractionation using preparative liquid chromatography on silica (PLC) with solvents of varying polarities. The fractions of bio-oil were then analyzed using fast-GC×GC/TOFMS. This analytical technique significantly reduced the analysis time to 15 minutes per sample. The predominant compounds identified included phenols, furfural derivatives, and hydrocarbons, underscoring the bio-oil's potential for industrial applications.
Keywords: Fractionation. Fast Pyrolysis. Chromatography Analysis.

The global energy demand has spurred research into alternatives to fossil fuels, with biomass emerging as a prominent option. However, biomass has found greater prominence in producing alternatives for non-energy uses, notably inputs for the chemical, food, and pharmaceutical industries [1,2]. Industries traditionally reliant on fossil fuels benefit across the board from biomass utilization. Bioplastics, pharmaceuticals, food additives, and other products, typically derived from the petrochemical chain, can be sourced from a biorefinery utilizing various biomasses [3]. Agro-industrial residues like sugarcane straw and bagasse, coconut fibers, rice husks, and others offer the most promising balance, leveraging both environmental impact reduction through waste volume reduction and economic gains [4,5].

Expanding biomass usage necessitates the development of technologies for comprehensive characterization [6,7]. Physical and chemical data on biomass can inform toxicity, quality, and stability and aid in defining conversion and application parameters. Fundamental physicochemical properties include moisture content, volatile compounds, fixed carbon, elemental composition, and thermal degradation characteristics [8]. A practical route for residual biomass conversion is bio-oil production via pyrolysis. In this process, biomass breaks down in an inert atmosphere, yielding biochar (a porous solid), gases (used for process heat), and a diverse liquid product suitable for various applications.

Bio-oil comprises a complex mix of compounds such as ketones, phenols, aldehydes, and hydrocarbons [9-11], requiring upgrading to enhance quality, particularly for high-value chemical production or biofuel applications [11,12].

Among the upgrade processes aimed at isolating specific compounds from bio-oil, methods such as fractionation and extraction play a significant role [13]. Bio-oil upgrading through extraction/fractionation methods encompasses various techniques like organic solvent extraction, supercritical fluid extraction, ionic liquid extraction, fractional distillation, preparative

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Address for correspondence: Rafael de Oliveira Farrapeira. Avenida Marcelo Deda Chagas, s/n, Rosa Elze, São Cristóvão, Sergipe, Brazil. Zipcode: 49107-230. E-mail: rafaelfarrapeira92@gmail.com.

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liquid chromatography (PLC), membrane separation, and electrosorption [13-15].

Preparative liquid chromatography (PLC) is particularly effective in isolating chemical classes of compounds by eluting them with organic solvents of different polarities. This method enables a more precise qualitative and quantitative analysis, especially when coupled with fast-GC×GC/TOFMS.

The widespread use of green coconuts for their renowned "coconut water" on the beaches of northeastern Brazil has led to environmental concerns due to the substantial waste produced, primarily coconut fibers that are often disposed of improperly. Reducing the volume of this waste is an urgent necessity, and finding alternative uses for these residues can address both environmental and economic challenges.

Against this backdrop, this study aims to conduct rapid pyrolysis of green coconut fibers from Aracaju (northeast Brazil), analyze the resulting bio-oil, and employ a PLC fractionation approach to facilitate constituent analysis (fast-GC×GC/TOFMS). This process aims to isolate chemical classes of significant interest, paving the way for potential industrial applications.

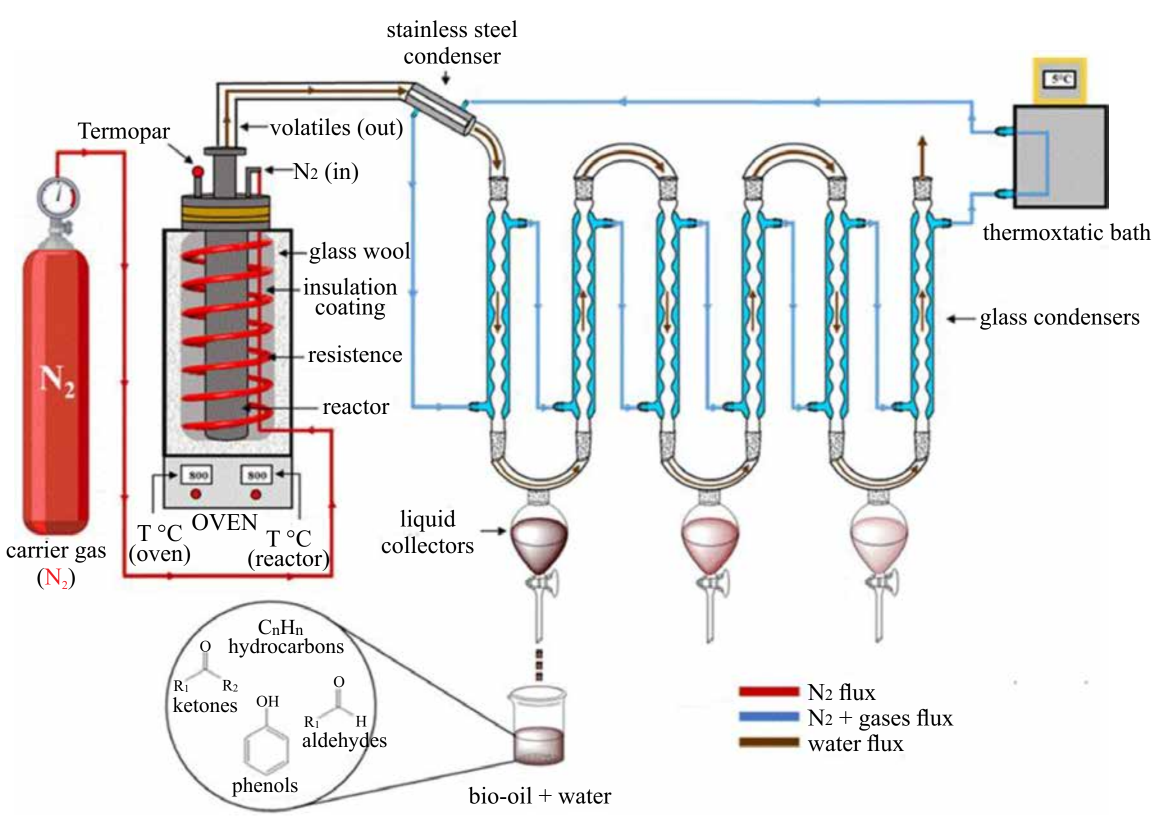
Materials and Methods

Pyrolysis Conditions

The pyrolysis process (triplicate) was carried out using a bench-scale fixed bed reactor and a vertical furnace. A resistance with a power of 3.000 W was used to heat the stainless steel reactor. Figure 1 details a description of the pyrolytic system.

In previous studies by Almeida and colleagues [16] and Bispo and colleagues [17], the biomass pyrolysis process was standardized with specific parameters. The pyrolysis duration was set at 15 minutes at a temperature of 700 °C. Each experiment utilized 20 grams of biomass, and

Figure 1. Pyrolysis system.



the heating rate was determined by the maximum power of the 3000 W resistors, resulting in a rate of 100 °C per minute. The carrier gas flow was maintained at 100 mL per minute while the condensers were kept at approximately 6°C. The mass yields of biochar and bio-oil were calculated based on their respective weights. The gas yield was determined by subtracting the sum of bio-oil and biochar yields from the initial biomass mass. Any losses incurred during the process, such as coke production, were included in the gas yield calculations. These standardized parameters ensure consistency and accuracy in pyrolysis, allowing for reliable comparisons and analysis across experiments.

Preparative Liquid Chromatography (PLC)

After determining the optimal pyrolysis conditions, the bio-oil underwent a preparative-scale liquid chromatography fractionation process. This step aimed to simplify the sample complexity to enable a more detailed identification of target compounds. Silica was employed as the stationary phase in a glass column measuring 20 cm x 1 cm, utilizing five solvents with varying polarities to produce five distinct fractions. This fractionation method was based on the methodology outlined by da Cunha and colleagues [18], albeit in an open system without column pressurization.

The procedure involved dissolving approximately 200 mg of bio-oil in 5 mL of dichloromethane (DCM) and adding it to 1 g of activated silica gel, followed by vigorous mixing. After complete solvent evaporation, the silica impregnated with bio-oil was transferred to the top of the glass column, previously packed with 10 g of activated silica using n-hexane.

Subsequently, the bio-oil was eluted using solvents of varying polarities, and the resulting fractions were collected as follows:

Fraction 1 (FR1): eluted with 25 mL of n-hexane.
Fraction 2 (FR2): eluted with 20 mL of n-hexane/toluene mixture (1:1).
Fraction 3 (FR3): eluted with 25 mL of dichloromethane / toluene mixture (4:1).
Fraction 4 (FR4): eluted with 25 mL of acetone/dichloromethane mixture (4:1).
Fraction 5 (FR5): eluted with 25 mL of methanol.

The entire procedure was performed in triplicate, and the yields of each fraction were calculated post-solvent evaporation using a gentle flow of N_2. This rigorous methodology ensures accurate fractionation and analysis of the bio-oil components, enabling a comprehensive understanding of its chemical composition.

Chromatographic Analysis - fast-GC×GC/TOFMS

The analysis of both the bio-oil and its fractions was conducted using fast GC×GC on a LECO Pegasus 4D instrument, which includes an Agilent Technologies GC 7890A system, a nitrogen-free thermal modulator, and a time-of-flight mass spectrometer (TOFMS). Bio-oil samples were prepared in vials with a 5000 ppm solution, and 1 µL from each sample was automatically injected in splitless mode. The injector temperature was maintained at 280 °C, and helium gas was the carrier gas at a 1 mL/min flow rate. The initial oven temperature was set at 45 °C for 0.20 minutes, then increased to 260 °C at a heating rate of 15 °C/min and held for 5 minutes. Two columns were utilized: RTX-5 (5% diphenyl/95% dimethyl-siloxane) with dimensions of 10 m × 0.18 mm × 0.20 µm in the first dimension, and RXI-17sil MS (50% phenyl-methyl-polysiloxane) with dimensions of 1.0 m × 0.10 mm × 0.10 µm in the second dimension. The data acquisition rate was set at 300 Hz, with the transfer line and ion source maintained at 280 °C and 250 °C, respectively. The modulator chiller temperature was -80 °C, and a modulation period of 3.5 was used, with a 15 °C difference between the primary and secondary ovens. A homolog series of linear alkanes (C7 to C30) was injected under the same conditions as the samples for tentative compound identification. The Linear Temperature Programmed Retention Indexes (LTPRI) method developed by Van Den Dool and

Kratz (1963) was employed, and the equipment software automatically calculated the retention indexes. This comprehensive analysis method accurately identifies and characterizes compounds in the bio-oil samples and their fractions.The data processing was conducted using ChromaTOF software version 451.6 from Leco, USA, which features spectral deconvolution capabilities. The tentative identification of compounds followed a two-step process. Initially, the mass spectra of analytes were compared with the NIST library. Compounds with a similarity lower than 70% and column bleed, solvent peaks, and peak tails were classified as unidentified peaks.

Subsequently, a dispersion graph was generated with the remaining compounds to assess their position in the separation space and classify peaks accordingly. Peaks that did not fit into any classification were considered unidentified. This comprehensive approach ensured a thorough analysis and identification of compounds present in the samples while minimizing the inclusion of erroneous or irrelevant data.

Results and Discussion

Table 1 summarizes the number of peaks and the percentage composition (related to the percentage area of each peak) of each class of chemical compounds found for each fraction of the samples. Figure 2 shows the distribution in terms of the percentage area of the significant constituents of each fraction, considering those compounds that presented a percentage area greater than 1% in at least one of the fractions. 287 different compounds were tentatively identified by summing the bio-oil fractions. The bio-oil fractionation enabled the identification of many hydrocarbon peaks with similar profiles in fractions 1 and 2. Almost all represent hydrocarbons (saturated, 26.69%; unsaturated, 28.53%; and aromatic, 39.96%).

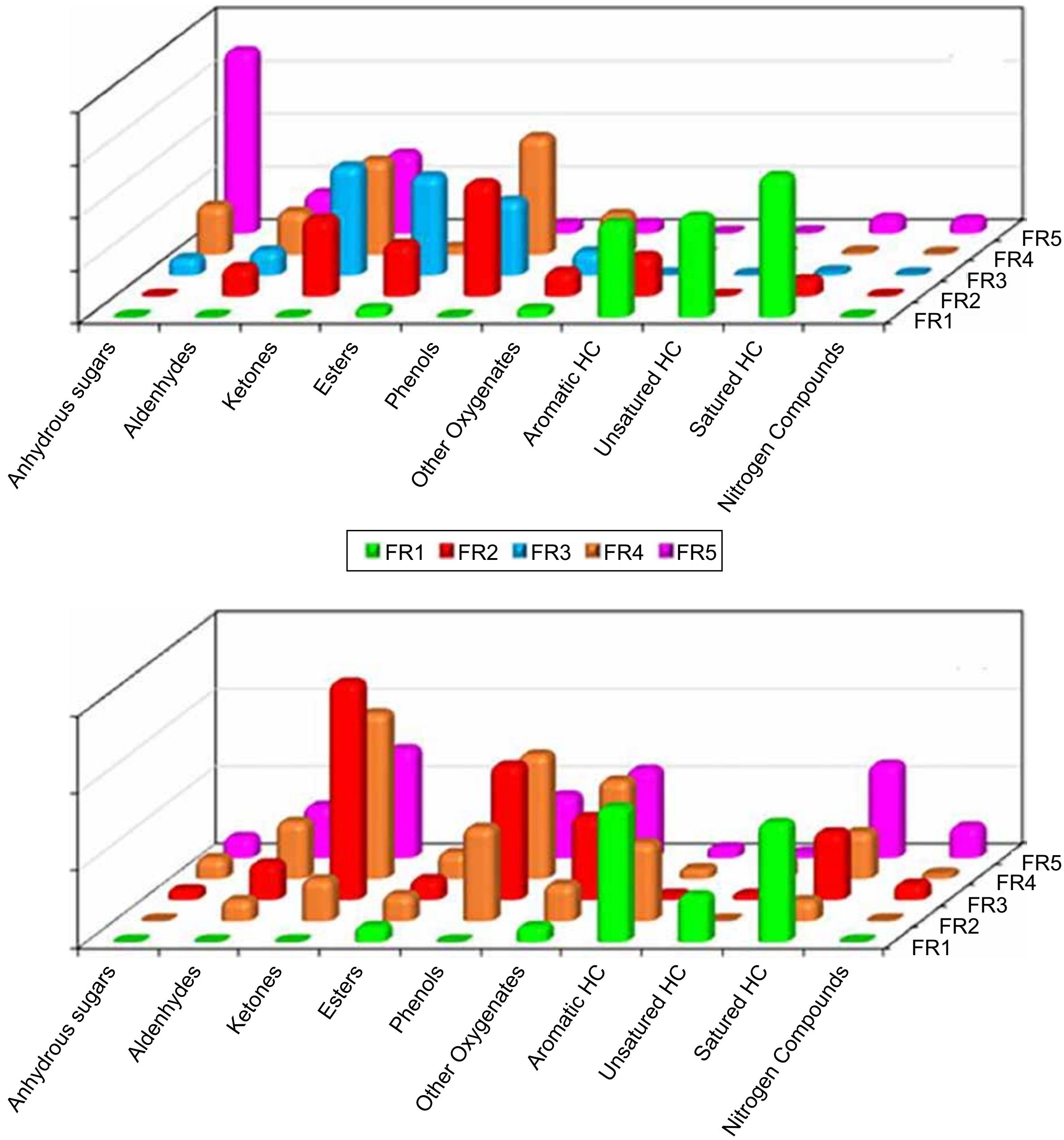
The hydrocarbons identified in Fraction 1 exhibited a high molecular mass, ranging from C17 to C32, with a notable absence of light hydrocarbons, likely due to their evaporation with the solvent post-fractionation, as described in Bordoloi et al.

Table 1. Identification of compound classes regarding the number of peaks and their percentage areas for fractionated bio-oil samples.

Chemical Classes	FR1		FR2		FR3		FR4		FR5	
	Area	Peak	Area	Peak	Area	Peak	Area	Peak	Area	Peak
Anhydrous sugars	n.d.	n.d.	n.d.	n.d.	4.85	2	13.73	4	51.68	4
Aldehydes	n.d.	n.d.	8.15	4	6.91	7	12.06	11	11.32	10
Ketones	n.d.	n.d.	21.89	8	30.87	42	26.52	32	22.56	21
Esters	2.48	3	14.85	5	27.99	4	2.02	5	0.06	1
Phenols	n.d.	n.d.	32.02	18	21.13	26	33.23	24	2.79	12
Other	2.35	3	6.94	7	6.67	16	11.48	19	2,88	17
Aromatic	26.69	26	11.41	15	0.26	1	0.05	2	0.10	2
Unsaturated	28.53	9	n.d.	n.d.	0.03	1	0.28	4	0.29	1
Saturated	39.96	23	4.74	4	1.07	13	0.60	9	4.42	18
Nitrogen	n.d.	n.d.	n.d.	n.d.	0.22	3	0.03	1	3.88	6
Total	100%	64	100%	61	100%	115	100%	111	100%	92

*n.d: not detected

Figure 2. Distribution of compound classes in terms of percentage area (a) and number of compounds (b) of PLC bio-oil fractions.



[19]. Fractions 2, 3, and 4 displayed numerous co-elutions during chromatographic runs. Fractions 3 and 4 exhibited more identified compounds, with phenolic compounds dominating fractions 2 and 4 (32.02% and 33.23%, respectively).

Concerning ketones, the majority were aromatic (acetophenones) or cyclic,falling into classes such as cyclopentanones and cyclopentenediones, primarily concentrated in fractions 4 and 5. These cyclopentanones and cyclic ketones are derivatives of cellulose and hemicellulose degradation found in biomass. More studies in the literature need to address bio-oil fractionation and chromatographic analysis. Among them, Schneider and colleagues [20] proposed a selective phenolic compound extraction method from the aqueous phase of bio-oil obtained from sawdust. This method involved alkaline and liquid-liquid extractions using hexane, dichloromethane, and toluene, similar to the extracts used in this study. Analysis was performed using GC×GC coupled with a quadrupole mass spectrometer (qMS), leading to the tentative identification of 130 compounds, predominantly phenols, ethers, ketones, aldehydes, acids, alcohols, and aromatic hydrocarbons. Major compounds included 4-methyl 1,2-benzenediol (12.1%), 1,2-benzenediol (11.1%), C2-benzenediol (7.1%), and phenol (4.8%). Bordoloi et al. [19] utilized PLC-4 fractionation on silica (hexane, toluene, ethyl acetate, and methanol solvents) for bio-oil from Scenedesmus dimorphu microalgae pyrolysis. Aromatic hydrocarbons and phenols were identified as major compounds. The first fraction (hexane) predominantly contained saturated compounds (n-alkanes, olefins, and branched hydrocarbons). The results showed notable differences from the present study, particularly in identifying phenolic compounds.

Conclusion

The PLC-5 fractionation on silica yielded five fractions based on solvent polarity. Fast-GC×GC/TOFMS analysis of these fractions demonstrated the efficiency of fractionation, revealing several compounds, particularly hydrocarbons, that were not initially identified in the original sample but were detected post-fractionation. The bio-oils exhibited elevated levels of phenols and a complex composition that was streamlined through fractionation. The separation of fractions significantly improved compound characterization, leading to an increased number of identified compounds and the discovery of new compounds that would have remained undetected without fractionation. In total, 287 compounds were identified, showcasing the substantial impact of fractionation on enhancing the analysis and understanding of bio-oil composition.

Acknowledgments

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Analysis of Plant Extracts' Influence on Coriander Plant Development (*Coriandrum sativum*): Exploring Potential for Improvement

Ary Rocha Bezerra[1*], Giovanna Cardoso da Silva Passos[1], Irma do Nascimento Gomes[1], Erica Patricia Lima Pereira[1], Gisele Gonçalves Chagas de Oliveira[1], Tatiana Oliveira do Vale[1]
[1]SENAI CIMATEC University Center; Salvador, Bahia, Brazil

This study aimed to assess the impact of a formulation containing plant extracts from castor bean (*Ricinus communis L.*), garlic (*Allium sativum*), and aloe vera (*Aloe vera*) at varying concentrations (0%, 0.5%, 1.0%, 1.5%, 5%, and 10%) on the growth and germination rate of coriander seedlings (*Coriandrum sativum*). The seedlings were cultivated in a prototype greenhouse under room temperature conditions to shield them from external weather factors. Notably, the 5% concentration exhibited significant variation, while the 10% concentration showed modest growth compared to the control group. These findings underscore the potential of natural fertilizers in enhancing the growth of herbaceous plants and advocate for exploring plant-based formulations as an ecofriendly alternative for fertilization practices.
Keywords: Plant Extracts. Coriander. Allelopathy.

The utilization of plant extracts as a sustainable source of nutrients and bioactive compounds has garnered considerable attention in the realm of agriculture. The amalgamation of extracts derived from castor bean, garlic, and aloe vera holds promise in fostering beneficial effects on the development of coriander seedlings. Each plant possesses unique properties that can synergize and facilitate the healthy growth of vegetables. While the current agricultural production model is economically feasible and extensively established, it imposes significant negative repercussions on the environment and human health. In light of this, there is a pressing need to explore and embrace comparably efficient yet more sustainable technologies. This paradigm shift is foundational in shaping future agriculture [1].

Transitioning towards sustainable agricultural practices contributes to environmental preservation and ensures the well-being of all stakeholders involved [1].

Rural farmers frequently turn to chemical fertilizers as a quick fix to address various issues concerning soil fertility and quality. However, this approach poses significant environmental risks, adversely impacting soil, water, and air quality, besides posing concerns for human health [2]. For instance, the predominant cost associated with transgenic soybean production lies in fertilizers, averaging R$570.42 per hectare [3]. The primary objective of this study was to assess the impact of a consortium of plant extracts from castor bean (*Ricinus communis L.*), garlic (*Allium sativum*), and aloe vera (*Aloe vera*) on the growth of coriander (*Coriandrum sativum*) seedlings. The study aimed to explore the potential for creating a completely natural and sustainable fertilizer while also developing a greenhouse suitable for cultivating coriander seedlings.

The analysis involved parameters such as shoot growth, root development, and other health indicators of coriander seedlings. These parameters were used to evaluate the interaction between the plant extracts to promote significant plant development without the need for synthetic chemical fertilizers. The results underscore natural fertilizers' potential to enhance herbaceous growth and highlight the exploration of vegetable formulations as a viable alternative to fertilization. This research advances sustainable agriculture by providing eco-friendly alternatives for cultivating healthy and efficient plants.

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Address for correspondence: Ary Rocha Bezerra. Avenida Orlando Gomes, 1845, Piatã. Salvador, Bahia, Brazil. Zipcode: 41650-010. E-mail: arirocha007@gmail.com.

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Materials and Methods

Preparation of Natural Fertilizer

Preparing the plant-based fertilizer involved several steps, including processing and decontamination. Equipment such as a blender, sieve, and spoon were utilized. Disinfection was done using a 1% concentration of sodium hypochlorite for 15 minutes.

To prepare the extracts, the plant parts were ground in a blender according to the proportions: 25g of castor bean, 25g of aloe vera, and 10g of garlic. The ground materials were then macerated with 100mL of distilled water. The consortium of extracts was subsequently stored in an amber bottle until ready for use [4,5].

Seedling Production for Bioassays

The soil utilized in the experiment underwent autoclaving at 120°C for 45 minutes to ensure sterility. Subsequently, this soil was filled into 200mL disposable cups previously disinfected with 2% sodium hypochlorite. Approximately 140g of topsoil was added to each cup. A greenhouse was then constructed to house the seedlings, maintaining controlled humidity, temperature, and atmospheric pressure conditions. The greenhouse dimensions were 70 cm in height and 90 cm in width.

One coriander seed was placed in each cup at approximately 1-1.5 cm depth for sowing. After sowing, irrigation was carried out using a single-channel micropipette (Olen) with a volume range of 1000-10000μL, applying 5mL of distilled water to each cup. During the pre-test phase, the seedlings received 5 mL of the fertilizer on the 11^{th} and 24^{th} days after sowing. In contrast, the control group received 5 mL of distilled water [6].

Place of the Experiment

The experiment occurred in the outdoor area of SENAI-CIMATEC, the Integrated Center for Manufacturing and Technology located in Salvador Bahia. It was conducted under room-temperature room-temperature conditions between March and May 2023.

Seedling Biometry

Seedling biometry involves measuring the height of the seedlings, which was determined by measuring the distance from the base to the apex. Additionally, the length of the primary root was measured by assessing the distance from the base to the tip after removing all substrate adhered to the root. These measurements were conducted using a caliper from Digimess [6].

Results and Discussion

The experiments showed that after applying the extract on the 11^{th} and 24^{th} days following planting, there was a decrease in the growth of coriander seedlings following the first application.However, no loss of seedling viability was observed at this stage, and a similar trend was observed after the second application of the plant extract.

These results suggest that the substances in the consortium extracts may have caused a negative allelopathic effect. This phenomenon is consistent with findings reported by Silva and colleagues [5], where the germination of cowpea seedlings (*Vigna unguiculata*) was inhibited as the concentration of dried castor bean leaf extract increased, ranging from 1% to 10%.

The root growth and stem length to the apex did not show significant differences between the 5% and 10% concentrations. However, Figures 1 and 2 indicate a more robust development in the 10% concentration compared to the 5% concentration. This difference may be attributed to the seeds' size and growth rate (Table 1). Previous research by Gatti and colleagues [7] has shown that the allelopathic effect can influence the speed of seed germination. This factor holds ecological importance, as plants with slower germination rates often exhibit smaller sizes and may be more vulnerable to stress, reducing their competitiveness for resources.

Figure 1. Biometrics of stems (base to apex) in coriander seedlings under different concentrations of plant extract (natural fertilizer).

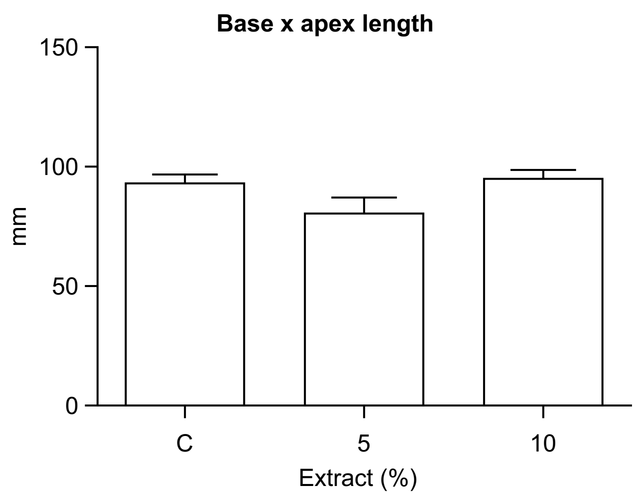


Figure 2. Biometry of roots (total length) of coriander seedlings under different concentrations of plant extract (natural fertilizer).

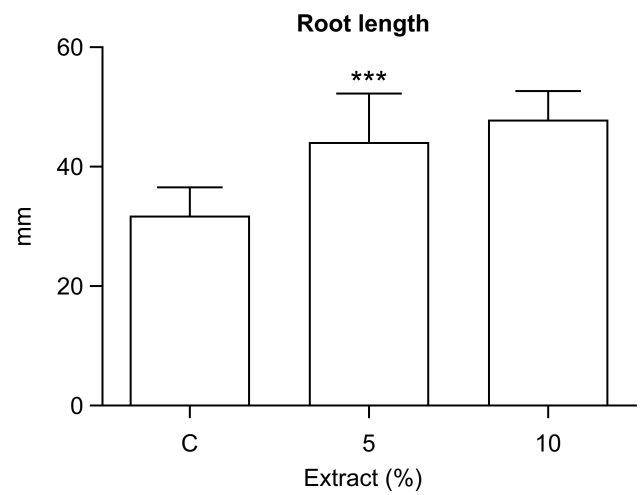


Table 1. Standard deviation of root length and length from base to apex of *Coriandrum sativum* seedlings submitted to different extract concentrations (0, 5, and 10%).

Samples (%)	Root Length (mm)	Length from Base to Apex (mm)
0	± 20.55	±14.65
5	± 33.25	± 24.23
10	± 19.22	± 16.10

According to Gatti and colleagues [7], the allelopathic effect typically impacts the speed of seed germination rather than the germination percentage. This factor carries substantial ecological significance, as plants with slower germination rates tend to be smaller in size and, thus, more susceptible to stress. Consequently, they may need more opportunities to compete effectively for resources.

In light of the potential allelopathic effects observed, a second set of experiments was conducted using lower concentrations of the plant extract (0.5%, 1%, and 1.5%). The results from this second round of testing demonstrated improved performance in developing coriander seedlings, particularly at concentrations of 0.5% and 1%.

Table 2 and Figure 3 show the root length and length standard deviations from base to apex and data from the second trial.

This indicates a positive effect on plant growth, corroborating with findings from [5], which showed that the dry extract of castor bean significantly influences the development of bean seedlings at the highest concentration (10%).

According to the results obtained by Silva and colleagues [8], a significant difference can be seen in the concentrations of biofertilizers in arugula seedlings regarding the length of the roots and height of the plants.

The data (Figure 4) showed an expressive reduction in the length from the base to the apex

Table 2. Standard deviations of root length and length from base to apex, data from the second trial.

Samples (%)	Root Length (mm)	Length from Base to Apex (mm)
0	± 28.52	±19.98
0.5	± 46.45	± 14.82
1	± 22.30	± 9.22
1.5	± 56.77	± 24.60

Figure 3. Root length data from the second test.

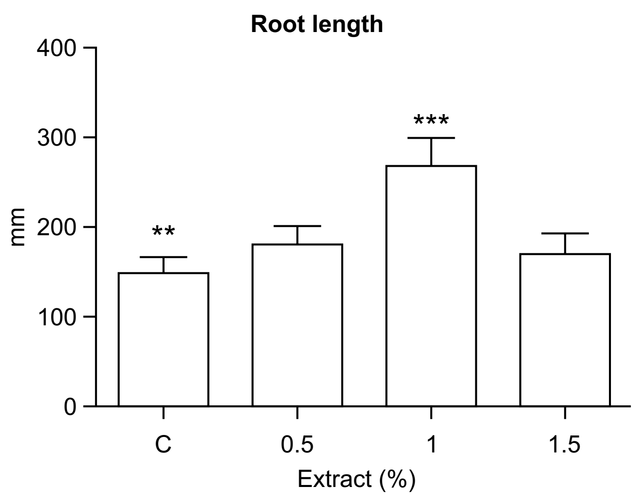
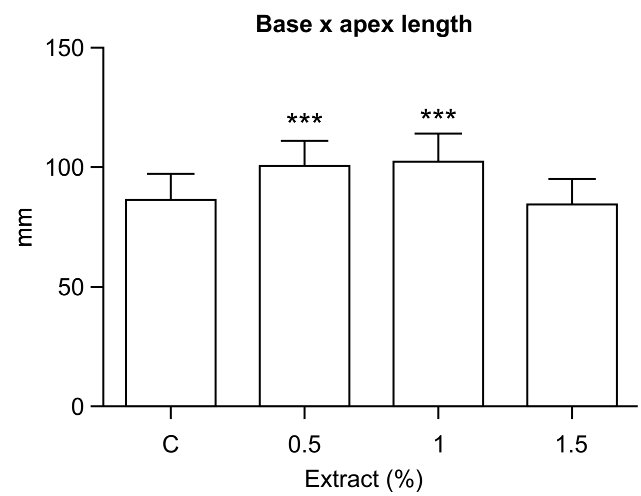


Figure 4, Displays the data referring to the length from the apex to the base.



of the seedlings at 1.5% concentrations. The corresponding means were 92 for the control concentration, 115 for 0.5%, 110 for 1.0%, and 80 for 1.5%.

Conclusion

The seedlings responded positively to the extracts, suggesting potential tolerance in mature plants. The combination of garlic, aloe vera, and castor bean extracts demonstrated promise as a natural fertilizer for coriander seedlings, with concentrations of 0.5% and 1% yielding significant results, particularly at 1%. This sustainable approach offers a means to reduce reliance on chemical fertilizers while promoting robust plant growth. Further research conducted under field conditions and across different crops is recommended to validate these findings. Utilizing these extracts as natural fertilizers could present a promising and beneficial alternative for sustainable agriculture.

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Potential Oil Production of *Chlorella vulgaris* Microalgae Cultivated in Vinasse

Alice Liberato Figueiredo da Silva[1*], Baden Peres Homem[1], Camila da Luz Nascimento[1], Ingrid Lessa Leal[1], Roseane Santos Oliveira[1], Tatiana Oliveira do Vale[1]
[1]*SENAI CIMATEC University Center, Salvador, Bahia, Brazil*

The study aimed to evaluate the potential of *Chlorella vulgaris* microalgae for oil production in treated/diluted Vinasse. The methodology involved three stages: control cultivation and vinasse 20%, 30%, and 40% concentrations (each lasting 8 days); biomass characterization; and oil extraction. The results showed that the 20% dilution had the highest production rate of chlorophyll A, chlorophyll B, and carotenoids (0.0018, 0.0002, and 0.0021125 µg.L^{-1}, respectively) and equal oil production (0.0044%) to the control culture.
Keywords: *Chlorella vulgaris*. Photosynthetic Microorganisms. Waste Treatment. Vinasse.

Microalgae have been the subject of interest for studies because they are a renewable resource and have a total capacity to provide various bioproducts, that is, substances of interest resulting from bioprocesses with economic potential and applicability in many industrial fields [1].

The controlled cultivation of microalgae has shown great promise in areas such as biodiesel production and wastewater treatment. Microalgae have several significant advantages, such as growth under simple and low-cost conditions and a highly active metabolism.

Regarding growth, many species are relatively easy to cultivate under controlled conditions and can be cultivated in photobioreactors [2], ponds, or closed systems, which allows greater flexibility and scalability in production.

We highlight that microalgae have a very high growth rate compared to other bioactive sources such as land plants. Some species of microalgae can double their biomass in a matter of hours. This rapid growth allows the large-scale production of microalgae biomass and other products derived from them in a short period, which is an essential factor for the economic viability of these processes.

Two of the main reasons that led to the choice of the species were its metabolic potential, and its ease of cultivation; that is, microalgae of this species have some significant advantages, such as growth in simple and low-cost conditions, in addition to a highly active metabolism. The present work evaluated the growth of the microalgae *Chlorella vulgaris* in treated Vinasse (diluted), oil production, and its application in the industry.

Materials and Methods

This study investigates how to reduce the oil production from *C. vulgaris*, the microalgae species chosen for the research, due to its high metabolic potential and ease of cultivation. We employed a qualitative and quantitative research approach, including experiments. In the biotechnology didactic laboratory at SENAI CIMATEC, 4 tests were performed - in duplicate, where the algal biomass of *C. vulgaris* was cultivated under stress conditions to stimulate its metabolic processes to happen with greater detectable kinetic speed [4].

A synthetic medium (BG11) was used as the standard culture medium, and alternative cultivation with Vinasse was performed for comparative analysis. Figure 1 shows the cultivation and characterization of the samples.

Acquisition of Vinasse and Microalgae

Both Vinasse and the *Chlorella vulgaris* inoculum were obtained through formal requests by

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Address for correspondence: Alice Liberato Figueiredo da Silva. Avenida Orlando Gomes, 1845, Piatã. Salvador, Bahia, Brazil. Zipcode: 41650-010. E-mail:alice.liberato17@gmail.com .

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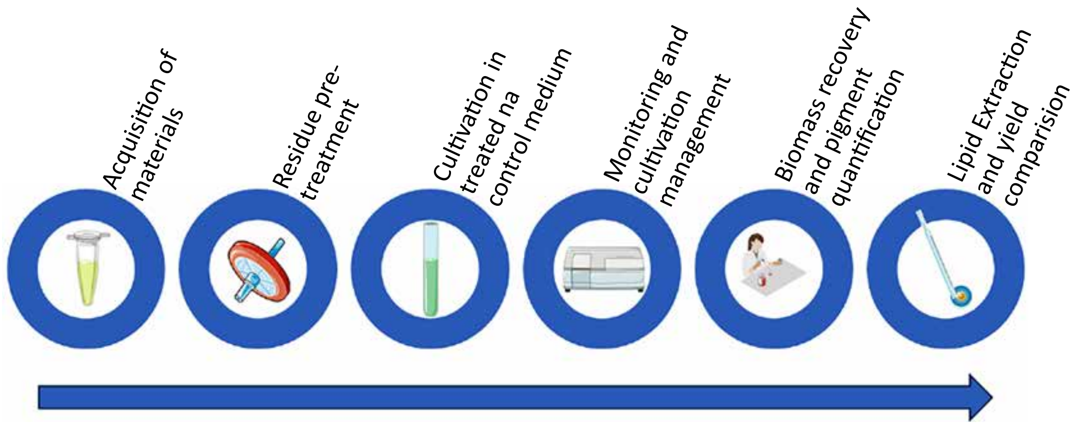
Figure 1. Cultivation and characterization of the samples.



the researchers of this study. *Chlorella vulgaris* was acquired from the Bioprospection and Biotechnology Laboratory (LabBBiotec) at the Federal University of Bahia (UFBA) in Salvador, Bahia, Brazil. Subsequently, the Vinasse was obtained from Fazenda Kiricó, a producer of artisanal cachaça (a type of Brazilian rum) located in the municipality of Mata de São João, Bahia, Brazil.

Treatment of Vinasse

The Vinasse was filtrated, starting with its mixture with smectite clay. After the settling, it underwent filtration through activated charcoal, cotton, and gauze, arranged in that order in a specially designed filter. Next, the treated Vinasse was pasteurized in a water bath at 60 °C for 30 minutes, followed by cooling (at 4 °C).

Cultination of *C. vulgaris*

For the preparation of the BG11 control culture medium, distilled water and the following proportions of reagents per 1L were used: 1.5g of $NaNO_3$; 0.04g of K_2HPO_4; 0.075g of $MgSO_4$; 0.036g of $CaCl_2$; 0.02g of Na_2CO_3; 0.006g of $C_6H_8O_7$; 0.001g of EDTA; 0.006g of $C_6H_8O_7$ xFe^{3+} γNH_3; additionally, 1mL of heavy metal solution needs to be prepared and added, with the following proportions: 0.286g/L of H_3BO_3; 0.0181g/L of MnCl; 0.022g/L of $ZnSO_4$; 0.039g/L of Na_2MoO_4; 0.0079g/L of $CuSO_2$; 0.0049g/L of $Co(NO_3)^2$ [3].

The dilution of the Vinasse in distilled water was done at different proportions (20%, 30%, and 40%) and subjected to refrigeration (4 °C) until the moment of use. The 500mL Erlenmeyer flasks were covered with cotton plugs to enable gas exchange and prevent the introduction of particles into the culture. They were then filled with 270mL of culture-covered medium (including control and alternative medium with Vinasse at 3 different dilutions) and 30mL of inoculum. Each culture was individually agitated using hoses connected to an air compressor with parameter control and monitoring for 12 hours per week (photoperiod).

Characterization of Biomass Obtained

Analysis of Cell Development by Optical Density

Optical density, also known as absorbance, is widely used in spectroscopy and biochemical analysis to quantify the concentration of a compound in a solution. This method was chosen to carry out the analyses of biomass and pigment production because it is a quantitative measure of the amount of light that a substance absorbs in a specific wavelength range of the electromagnetic spectrum, thus allowing detailed monitoring of the development of microorganisms, in this case, of the microalgae *Chlorella vulgaris* in standard medium (BG11) and different concentrations of Vinasse, in order to quantify which of these would be more advantageous in terms of growth for lipid extraction.

Chlorophyll A, Chlorophyll B, and Carotenoids Quantification

The growth of the microalgae was monitored daily by quantifying biomass and pigments (chlorophyll A, chlorophyll B, and total carotenoids) through optical density measurement using a spectrophotometer for 7 days.

The harvesting process consisted of draining the entire volume of the Erlenmeyer flasks into polyethylene buckets, previously prepared with an aluminum sulfate solution at a ratio of 2mL of flocculating solution per liter of culture. After approximately 30 minutes, the biomass separated into phases with the settling of the biomass. The excess water was then removed, leaving the biomass for the next step, where it was vacuum filtered using a system with a Kitasato flask and a porcelain funnel with filter paper, followed by drying in a kiln at 35°C for 2 days for complete drying, preparing the microalgal biomass for the lipid extraction [5].

Lipid Quantification

The lipid determination was carried out using the Bligh & Dyer method (1959). The samples were agitated until they became homogeneous. Then, the mixture was placed in a water bath on a magnetic stirring plate for 3 hours. At the end of this period, the mixture was filtered through filter paper. Next, the retained mass was discarded, and chloroform and water were added to the filtrate. Afterward, the samples were centrifuged at 1000 rpm for 3 minutes to promote the separation of the apolar (presence of lipid molecules) and polar phases [5]. After the phases were separated, the solvent was evaporated in an oven at 60 °C until completely evaporated [1].

The results were expressed as averages in graphs. A multiple linear regression was performed between the difference in measurements (dependent variable) and the mean of the measurements (independent variable) to assess similarities and differences.

Results and Discussion

Treatment of Vinasse

Unaltered Vinasse has some characteristics that are considered disadvantageous for microalgae cultivation, requiring a pre-treatment. Indeed, treating the Vinasse is necessary to reduce the organic load and turbidity and eliminate contaminants and other undesirable particles that could interfere with cellular growth and microalgal biomass production [4].

Analysis of Cell Development by Optical Density

The results showed that the cultivation of the microalga *C. vulgaris* in Vinasse diluted at 20%, 30%, and 40% was efficient and exhibited good growth compared to the control. The 20% dilution demonstrated the best growth (Figure 2). Additionally, there was unexpectedly higher growth in the control culture in the BG11 medium between days 6 and 7, surpassing the growth in the 20% diluted vinasse culture. The necessity of dilution can also be seen [7] where the dilution directly influences a specific growth, showing better results at diluted vinasse samples, also [8] displays that different concentrations of Vinasse can be used to acquire distinguished results; higher protein microalgae biomass needs equals higher Vinasse concentration; otherwise, higher carbohydrate levels mean lesser Vinasse concentration.

Analysis of Chlorophyll A, Chlorophyll B, Carotenoids' Production

We suggest that chlorophyll A (Figure 3) and chlorophyll B (Figure 4) show a significant growth of the microalgae (0.0018 and 0.0002 $\mu g.L^{-1}$, respectively). These findings support the selection of this crop for larger-scale production, aiming at extracting oil from the microalgae. It is also important to point out that, in the literature,

Figure 2. Cellular growth of the samples in different culture media over the 7 days.

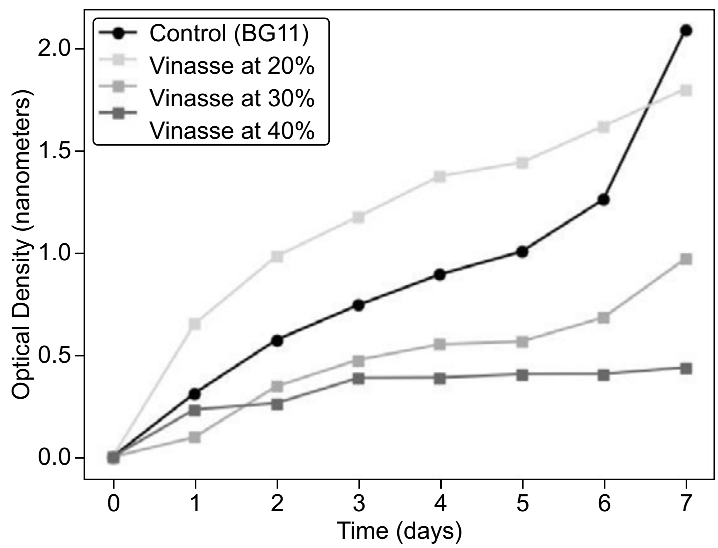


Figure 3. Production of chlorophyll A in the cultures,

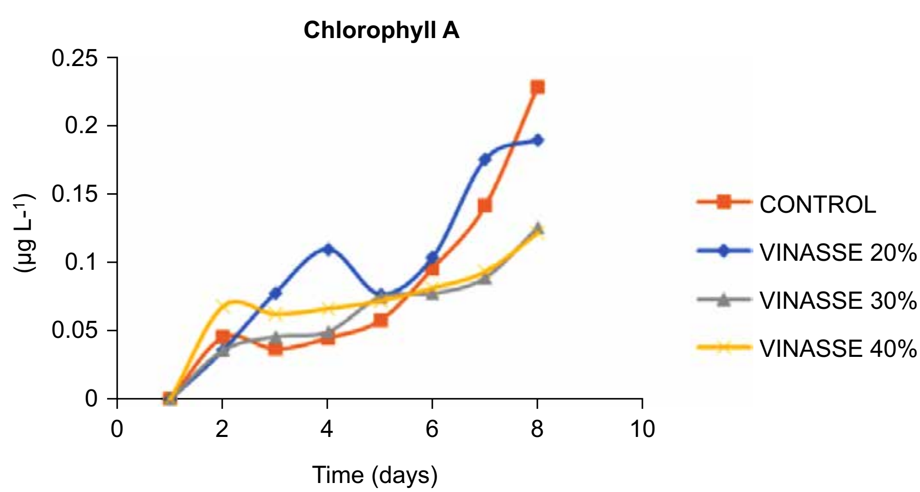
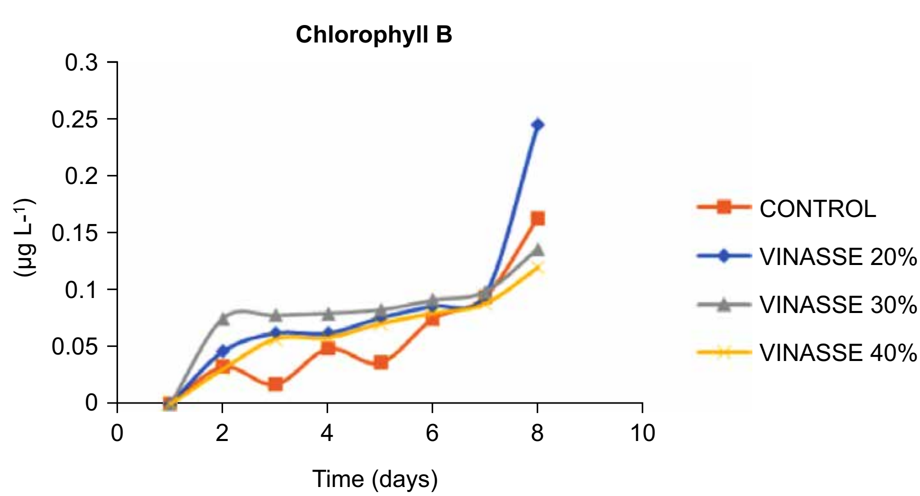


Figure 4. Production of chlorophyll B in the cultures.



the monitoring of chlorophyll A concentration is crucial in assessing microalgae growth.

Verifying the number of pigments produced is also important to evaluate the efficiency of different cultivation conditions, such as variations in light intensity, temperature, and pH, among others. This allows us to assess the best conditions for cultivating C. vulgaris and maximize its production [6]. The cultivation in Vinasse 20% also resulted in a higher production of carotenoids (0.0021125 $\mu g.L^{-1}$).

The total carotenoid production yields, observed in Figure 5, indicate that the cells cultivated in the different concentrations of Vinasse had their photosynthesis affected between days 1 and 2 of monitoring, subtly decreasing before growing again, maintaining a similar pattern during the elapsed time.

Lipid Production Rate Analysis

After the lipid extraction process of both microalgae cultures, standard (BG11 medium) and alternative (vinasse medium), it was observed that, despite the higher production from the standard culture medium, this difference, compared with Vinasse, is slight.

However, cultivation in standard medium (BG11) proved less effective in producing biomass, unlike cultivation in alternative medium (Vinasse), which was more effective.

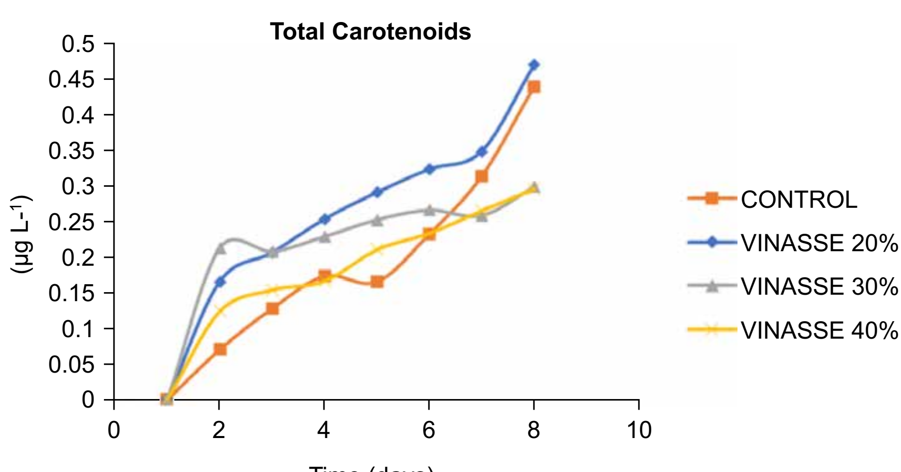
From this, it is possible to understand that cultivation in BG11 produced 34% oil while cultivation in Vinasse produced 44%.

Conclusion

This study demonstrated that the use of Vinasse treated with charcoal and smectite clay, diluted to 20%, had a positive impact on the growth of *Chlorella vulgaris* compared to synthetic medium (BG11), indicating that it provided a suitable environment for the good cellular development of the microalga. It is also possible to infer that cultivation under these conditions suggests that this medium can be a viable alternative to the traditionally chosen culture medium. This could be relevant for reducing cultivation costs by utilizing industrial byproducts, such as Vinasse, as highlighted in this study, and it can also contribute to sustainability by offering a recycling option instead of disposal.

Regarding biomass and oil production, as the dilution of Vinasse to 20% resulted in the highest production rates of chlorophyll A, chlorophyll B, and carotenoids, this indicates favorable conditions for pigment synthesis in microalgae. Furthermore, the fact that oil production was equal to the control culture suggests that using treated Vinasse did not negatively affect oil production, which is an industrially relevant compound.

Figure 5. The production of total carotenoids in each monitored culture.



This study emphasizes the potential use of *Chlorella vulgaris* cultivated in treated Vinasse as a source of biomass and oil for industrial applications. The oil produced by microalgae can be widely explored in the biofuel, cosmetics, food, supplements, and other industries.

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Design, Manufacturing and Testing of a Two-Wheeled Self-Balancing Robot

Lucas Lins Souza[1*], Matheus Henrique Nunes França[1]
[1]SENAI CIMATEC university Center; Salvador, Bahia, Brazil

This work presents a self-balancing robot's modeling, manufacturing, and testing. This study aimed to design and construct a robot capable of maintaining balance while stationary and in motion, employing an effective control strategy. The robot's design incorporates sensors, microcontrollers, actuators, and control algorithms. The control strategy involved implementing an LQR (Linear Quadratic Regulator) controller and a Kalman filter for state estimation. The results demonstrate the robot's ability to effectively maintain balance and navigate flat terrain while controlled by a joystick. This study provides valuable insights into the design and control of self-balancing robots.
Keywords: Self-Balancing Robot. LQR. Kalman Filter. Dynamic Model.

Mobile robots have garnered significant attention and importance in today's technological landscape. Among the diverse range of mobile and self-balancing robots stand out due to their myriad applications [1,2], particularly in transportation and logistics.

The choice of focusing on self-balancing robots for this project arises from their exceptional mobility on flat terrains and ability to navigate common indoor obstacles like stairs and ramps. However, achieving this mobility requires tackling the challenging task of maintaining balance, given the strongly nonlinear behavior of these robots [3].

This paper presents the balancing and teleoperation performance achieved by the implemented control system of an original two-wheeled self-balancing robot. A model-based approach was adopted for the controller, with system modeling considering the robot's dynamics and the wheel actuators, thus eliminating the need for dedicated joint controllers.

This project is an open-source research platform, providing a resource for students and researchers to delve into robotics. All software was developed using ROS (Robot Operating System) [4], a widely used open-source middleware for robotics to facilitate our study.

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Address for correspondence: Lucas Lins Souza. Rua Embira n° 149, Cond. Platno, ap 2801, T. Titânio, Salvador, Bahia, Brazil. Zipcode: 41680-113. E-mail: lucaslinssouza@gmail.com.

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Materials and Methods

Robot Prototype

The design of the robot drew inspiration from the Ascento robot [5] and the work of Kollarčík [6]. These robots feature a substantial base that houses most of the robot's mass and two articulated legs with two joints each, enabling complex maneuvers such as navigating obstacles, climbing stairs, and jumping; however, unlike these robots that use a single servomotor per leg along with an additional mechanism to ensure linear up-and-down movement, a simplified design with two servomotors was adopted for this project, similar to the robot MABEL [7].

The Figures 1 and 2 illustrate the robot's 3D model and genuine model. The upper part of the robot serves as the base, housing its sensors and electronics. An MPU6050 Inertial Measurement Unit (IMU) was utilized in this model, directly connected to a Raspberry Pi 4. The U2D2 board facilitates communication via USB between the Dynamixels and the Raspberry Pi 4. The wheels were equipped with two Dynamixels of the XM430-W210 model, while four MX-106 Dynamixels were used for the joints in the legs. Powering the entire system is a 14.8-volt lithium polymer battery (LiPO).

Figure 1. The robot's designed and manufactured model.

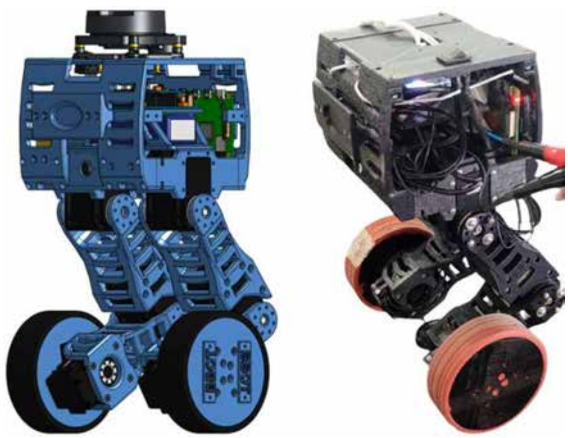
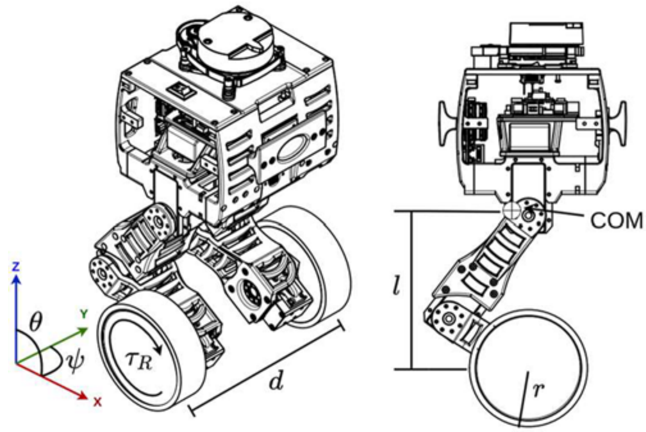


Figure 2. Robot axis and state variables.



The Dynamic Model

A two-wheeled self-balanced robot's design, modeling, and control have been extensively researched and implemented. Klemm and colleagues [5,8] constructed a self-balancing robot that combines the efficiency of wheels with the mobility of legs to navigate uneven terrain and obstacles. Kim and Kwon [9] investigated and presented the dynamic equations of the wheeled inverted pendulum, while Kollarčík [6] designed a wheeled leg system based on these equations. The model utilized in this paper (1) is the one developed in [9] using the Lagrangian method. It is important to note that this model does not account for the legs, so the robot was modeled as having a fixed rod.

$$\ddot{\boldsymbol{q}} = \boldsymbol{F}(\dot{\boldsymbol{q}}, \boldsymbol{u}) \tag{1}$$

$$\dot{\boldsymbol{q}} = [\dot{x} \quad \dot{\theta} \quad \dot{\psi}]^{\top} \tag{2}$$

$$\boldsymbol{u} = [\tau_L \quad \tau_R]^{\top} \tag{3}$$

The state vector $\boldsymbol{q}^{\cdot}$ is composed of the linear velocity $\boldsymbol{x}^{\cdot}$, the pitch velocity $\boldsymbol{\theta}^{\cdot}$, and the yaw velocity $\boldsymbol{\psi}^{\cdot}$. Figure 2 illustrates these variables. The input vector $\boldsymbol{u}$ is composed of the left and the right wheel's motor torque $\boldsymbol{\tau_L}$ and $\boldsymbol{\tau_R}$, respectively. The linearization of the system is performed by calculating $\boldsymbol{A_r}$ and $\boldsymbol{B_r}$, which are the Jacobian matrix of the system (1) concerning the state vector $\boldsymbol{q_r}$ (4) and the input vector $\boldsymbol{u}$ (3), respectively, at the system's fixed point (zero for all states). The pitch angle is added in $\boldsymbol{q_r}$ (different from $\boldsymbol{q}^{\cdot}$) because it is also desirable to control the pitch angle of the robot. This model is also in continuous time, so it must be discretized to be implemented in a microcontroller. The discretization was performed by applying the zero-order hold [10] in $\boldsymbol{A_r}$ and $\boldsymbol{B_r}$ with a sampling period of 0.0125 seconds (80 Hz).

$$\boldsymbol{q_r} = [\dot{x} \quad \dot{\theta} \quad \dot{\psi} \quad \theta]^{\top}, \quad \boldsymbol{A_r} = \left.\frac{\partial \ddot{\boldsymbol{q}}}{\partial \boldsymbol{q_r}}\right|_0, \quad \boldsymbol{B_r} = \left.\frac{\partial \ddot{\boldsymbol{q}}}{\partial \boldsymbol{u}}\right|_0 \tag{4}$$

The mathematical model of the robot relies on wheel torques as inputs, while the actuators are controlled using Pulse Width Modulation (PWM). Therefore, it is necessary to establish a relationship between these two variables to send the correct command directly to the motors rather than to a low-level joint controller. Moreover, the accurate actuators exhibit dynamics that the robot model does not consider. By integrating the robot's dynamic model with the motor's dynamic model, we can more accurately represent the system's overall dynamics.

The dynamics of the wheel motors can be represented as a first-order system, with the PWM duty cycle as input and torque as output. It is important to note that the wheels' torque serves as both the input for the robot model and the output for the motor model. The state vector of the final model comprises the states of both the robot and the motor model. However, the output vector only includes the outputs of the robot model because the motor model's outputs are not directly measurable. The final robot model is depicted in Equation (5),

$$\begin{gathered}\boldsymbol{q}_F[\boldsymbol{n}+\mathbf{1}] = \boldsymbol{A}_F\boldsymbol{q}_F[\boldsymbol{n}] + \boldsymbol{B}_F\boldsymbol{u}_F[\boldsymbol{n}],\\ \boldsymbol{y}_F[\boldsymbol{n}] = \boldsymbol{C}_F\boldsymbol{q}_F[\boldsymbol{n}],\\ \boldsymbol{q}_F[\boldsymbol{n}] = \begin{bmatrix}\boldsymbol{q}_r[\boldsymbol{n}]\\ \boldsymbol{q}_m[\boldsymbol{n}]\end{bmatrix},\quad \boldsymbol{u}_F[\boldsymbol{n}] = \boldsymbol{u}_m[\boldsymbol{n}],\\ \boldsymbol{A}_F = \begin{bmatrix}\boldsymbol{A}_r & \boldsymbol{B}_r\boldsymbol{C}_m\\ \mathbf{0}_{2\times4} & \boldsymbol{A}_m\end{bmatrix},\quad \boldsymbol{B}_F = \begin{bmatrix}\mathbf{0}_{4\times2}\\ \boldsymbol{B}_m\end{bmatrix},\\ \boldsymbol{y}_F[\boldsymbol{n}] = \boldsymbol{q}_r[\boldsymbol{n}],\quad \boldsymbol{C}_F = [\boldsymbol{I}_{4\times4}\quad \mathbf{0}_{4\times2}]\end{gathered} \tag{5}$$

where $\mathbf{0}_{ixj}$ is a zero matrix and $\boldsymbol{I}_{ixj}$ is an identity matrix of $\boldsymbol{i}$ rows and $\boldsymbol{j}$ columns and $\boldsymbol{q}_m$, $\boldsymbol{u}_m$, $\boldsymbol{A}_m$, $\boldsymbol{B}_m$, and $\boldsymbol{C}_m$ are the states, inputs, system matrix, input matrix, and output matrix of the motor model, respectively.

Control System Design

The final robot (5) describes the robot's dynamics, which means the system could be stabilized if an LQR controller was designed based on those matrices. To teleoperate the robot, however, the robot must receive and follow linear and yaw speed setpoints. Therefore, the error between the robot's current linear and yaw speed and their respective setpoints must be calculated, and the integrals of those errors must be sent to the controller as additional states. Including this integral action makes it possible to ensure that the errors approach zero; that is, the speed equals the setpoint. Therefore, an augmented model of the system (6) was built, including the integral of the linear and yaw velocity errors as two additional states and the vector $\boldsymbol{r}$ for the linear velocity $\dot{x}_{ref}$ and yaw velocity $\dot{\psi}_{ref}$ setpoints.

To design the gain matrix $\boldsymbol{K}_{LQR}$ of the controller, the matrices $\boldsymbol{Q}$ and $\boldsymbol{R}$ are required. The LQR is an optimal controller that minimizes a quadratic cost function [11], and these two matrices define the priorities in this optimization process. $\boldsymbol{Q}$, in this case, is an 8×8 diagonal matrix, where each value in its diagonal represents a weight that the controller should consider for stabilizing each system state, whereas $\boldsymbol{R}$ is a 2×2 diagonal matrix containing the weights for how much energy the controller can demand from each of the system's inputs. The control law can be defined as

$$\boldsymbol{u}_F[\boldsymbol{n}+\mathbf{1}] = -\boldsymbol{K}_{LQR}\boldsymbol{q}_{aug}[\boldsymbol{n}] \tag{7}$$

As previously mentioned, the $\boldsymbol{y}_{aug}$ does not include the outputs of the motor model because the robot prototype cannot measure the current torque of the wheel motors. Therefore, a Kalman filter was designed to address that the LQR controller needs all current state values to calculate the control effort. The Kalman Filter designed for this work was based on the final robot model, not the augmented model. The design procedure was similar to the LQR controller's [11]: by creating two matrices, namely the disturbance covariance matrix $\boldsymbol{V}_d$ and the noise covariance matrix $\boldsymbol{V}_n$, a gain matrix $\boldsymbol{K}_f$ was calculated (also by optimization), which makes the filter stable. Once stability is reached, the filter outputs converge toward the fundamental values of the final robot model's states. It is essential to highlight that the Kalman filter designed in

$$\begin{gathered}\boldsymbol{q}_{aug}[\boldsymbol{n}+\mathbf{1}] = \boldsymbol{A}_{aug}\boldsymbol{q}_{aug}[\boldsymbol{n}] + \boldsymbol{B}_{aug}\boldsymbol{u}_F[\boldsymbol{n}] + \boldsymbol{r}\\ \boldsymbol{y}_{aug}[\boldsymbol{n}] = \boldsymbol{C}_{aug}\boldsymbol{q}_{aug}[\boldsymbol{n}]\end{gathered},\qquad \boldsymbol{A}_{aug} = \begin{bmatrix}\boldsymbol{A}_F & \mathbf{0}_{6\times2}\\ \boldsymbol{G} & \boldsymbol{I}_{2\times2}\end{bmatrix},$$

$$\boldsymbol{B}_{aug} = \begin{bmatrix}\boldsymbol{B}_F\\ \mathbf{0}_{2\times2}\end{bmatrix},\qquad \boldsymbol{G} = \begin{bmatrix}-1 & 0 & 0 & 0 & 0 & 0\\ 0 & 0 & -1 & 0 & 0 & 0\end{bmatrix}, \tag{6}$$

$$\boldsymbol{q}_{aug} = [\boldsymbol{q}_F\quad \epsilon_{\dot{x}}\quad \epsilon_{\dot{\psi}}]^{\top},\qquad \boldsymbol{y}_{aug} = [\boldsymbol{q}_r\quad \epsilon_{\dot{x}}\quad \epsilon_{\dot{\psi}}]^{\top},$$

$$\boldsymbol{C}_{aug} = \begin{bmatrix}\boldsymbol{C}_F & \mathbf{0}_{4\times2}\\ \mathbf{0}_{2\times6} & \boldsymbol{I}_{2\times2}\end{bmatrix}\qquad \boldsymbol{r} = [\mathbf{0}_{1\times6}\quad \dot{x}_{ref}\quad \dot{\psi}_{ref}]^{\top}$$

this paper is a linear estimator, which means it converges while the robot operates around the fixed point. Equation (8) shows the calculation of the estimated full state vector of the final robot model $\hat{q}_F$. It can, then, be used to form q_{aug} (6), along with the error as mentioned above integrals. The whole control system is illustrated in Figure 3.

$$\hat{q}_F[n+1] = (A_F - K_f C_F)\hat{q}_F[n] + [B_F \quad K_f][u_F[n] \quad y_F[n]]^{\top} \tag{8}$$

Results

Both stability and teleoperation tests were conducted to evaluate the controller's performance. Throughout these tests, the robot was powered using a tether cable.

Stability Test

This test aimed to assess the system's response to external disturbances. Two tiny pushes were applied to the robot's base while it was balancing on flat terrain: the first from the front and the second from the back (Figures 4 and 5). The push from the back is depicted in Figure 4 (top middle frame), the Figure 5 shows the teleoperation test, and the results are presented in Figures 6 and 7.

It is evident that both pushes, occurring around seconds 6 and 11, led to an increase in the frequency of the system's oscillations, as shown in Figure 6. Eventually, the robot returned to its previous steady state. However, this steady state exhibited significant oscillations. These oscillations indicate that the controller is operating near the stability limit, suggesting that slightly larger disturbances could render the system marginally stable or even unstable.

Teleoperation Test

This test aimed to analyze whether the controller could enable the robot to follow linear and yaw velocity setpoints sent by the user via a joystick. Forward and backward motions, as well as turning right and left, were tested individually.The results are depicted in Figures 8 and 9. The robot maintained its balance throughout the test, oscillating below 0.1 radians. Figure 8 illustrates the system's response alongside the input signal, showcasing no delay, overshoot, and a settling time of approximately 3.5 seconds. Figure 9 indicates that the robot moved forward without delay but experienced a delay of around 5 seconds when moving backward.

Additionally, it was unable to reach the setpoint of 0.5 m/s. The controller executed numerous small backward and forward movements to stabilize the robot, resulting in oscillating linear velocity. This behavior also affected the settling time, exceeding 10 seconds, as shown in Figure 9 for the second setpoint.

Conclusion

In this study, we successfully designed, modeled, and implemented a self-balancing robot with an effective control strategy. We demonstrated the

Figure 3. Control block diagram.

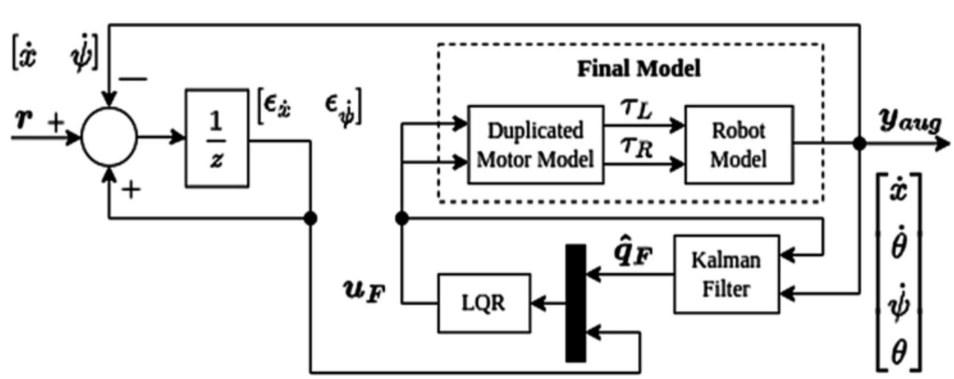


Figure 4. Robot during stability test.

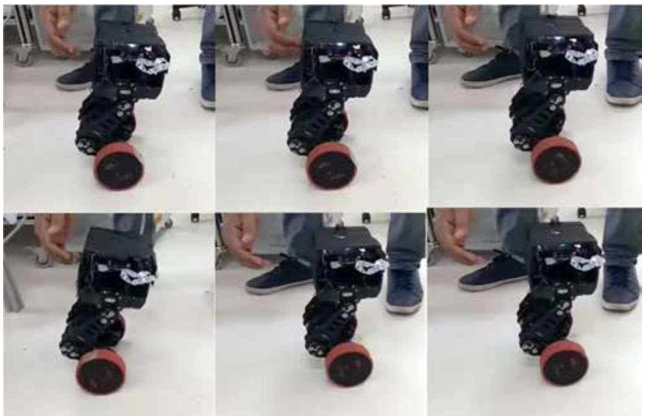


Figure 5. Robot during teleoperation test.

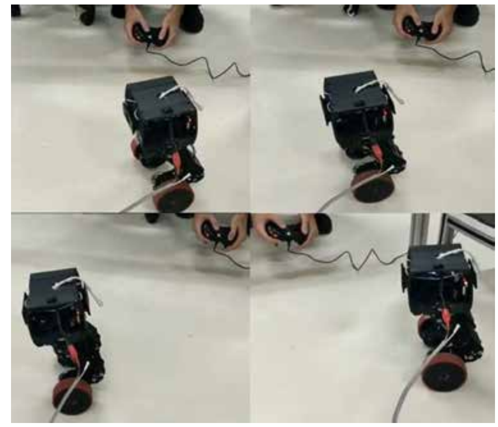


Figure 6. Linear velocity curve.

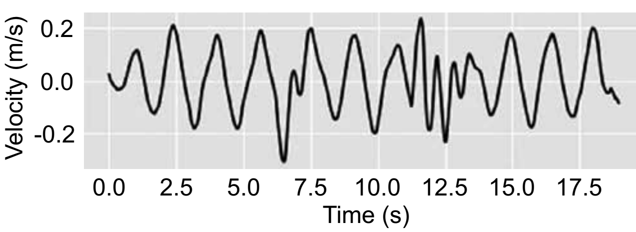
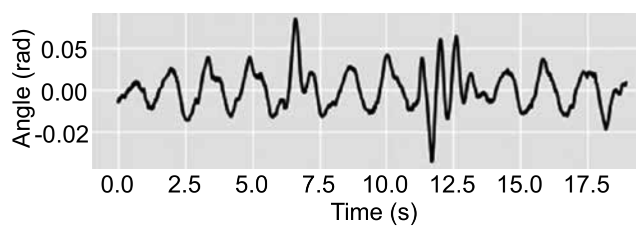


Figure 7. Pitch angle curve.



robot's ability to maintain balance through technical design, mathematical modeling, and real-world testing. The control strategy based on the Linear Quadratic Regulator (LQR) yielded promising results in a natural flat environment. The stability and teleoperation tests provided valuable insights into the controller's performance. The stability test highlighted the robot's resilience in recovering from external disturbances, albeit with noticeable linear and angular velocity curve oscillations.

Similarly, the teleoperation test showed oscillatory behavior, but the robot maintained balance with minimal pitch angle oscillations. However, these oscillations and multiple backward and forward movements led to an extended settling time. Several critical areas of improvement need attention to enhance the self-balancing robot's capabilities and robustness. Firstly, optimizing the robot's weight is crucial for reducing energy consumption and improving maneuverability.

Secondly, optimizing weight distribution to align the center of mass with the wheel-ground contact point can ensure a more stable system. Lastly, upgrading the motor system, particularly by incorporating faster motors for the wheels, can significantly enhance dynamic response and agility. Integrating alternative motor types with higher rotational speeds enables rapid and precise movements, enabling the robot to respond promptly to disturbances and achieve superior performance across various environments.

Figure 8. Yaw angle response.

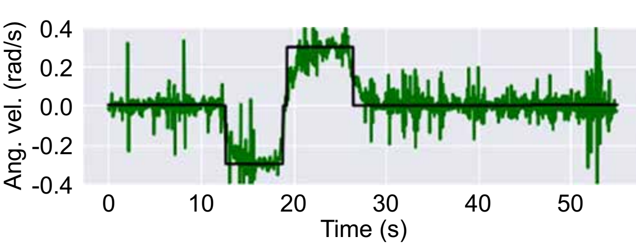
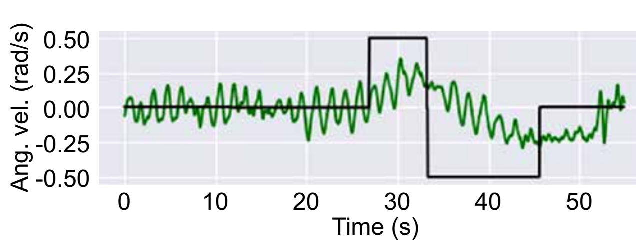


Figure 9. Linear velocity response.



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Product Development to Improve and Automate Orchard Fruit Handling

Gláucio Bessa Oliveira[1*], Bruno de Paulo Silva[1], Bruno Falcon Silveira[1], João Ricardo Lima de Oliveira[1], Priscila Coutinho Miranda[1,2], Valter Estevão Beal[1]
[1]SENAI CIMATECUniversity Center; [2]Bahia Federal Institute of Education, Science and Technology; Salvador, Bahia, Brazil

In transporting field fruits to the packing house, physical damage to the product can occur, especially if the facility is far from the orchard and needs proper traffic conditions. This study aimed to develop a solution to enhance the transportation of fruits from orchards to packing houses in the São Francisco Valley, Bahia properties. The method comprised the following steps: (1) System Definition; (2) Translation of Needs into Requirements; and (3) Generation and Detailing of Concepts. The proposed solution involves an innovative aerial transportation system utilizing high-strength cables and containers for moving fruits, eliminating the necessity for roads or other conventional means of transportation. This solution can potentially advance knowledge in the field and be implemented in similar contexts.
Keywords: Orchards. Fruit Handling. Concept Design. Automation.

In Brazil, it is estimated that up to 40% of fruits and vegetables produced are lost between harvest and reaching the consumer's table. These quantitative or qualitative losses lead to a decrease in their commercial value. Despite this, methods to reduce damages during fruit transportation remain uncommon and often ineffective [1].

Upon harvesting, fruits must be stored in shaded areas, kept off the ground, and transported swiftly to the packing house. Careful transportation is essential to prevent friction or injuries to the fruits. Typically, fruit transportation on farms is accomplished using trailers towed by tractors, animal labor, or manual handling to move fruit containers from the orchard. If the packing house is nearby, direct transport in these vehicles is feasible; otherwise, trucks are employed. However, in many orchards, there is limited access for tractors or trucks, necessitating more cautious handling to minimize physical damage to the fruits. Ideally, transportation should utilize vehicles with refrigeration systems, or measures must be taken to counter temperature increases. These measures include covering vehicles with light-colored tarps, leaving space between the tarp and containers for air circulation, optimizing container arrangement, reducing the time between harvest and transport, and stacking containers in no more than three layers to avoid fruit damage. Additionally, avoiding harvesting during peak heat hours is crucial, as heat accelerates fruit deterioration processes.

The challenges faced in Brazilian fruit farming make fruit movement a significant issue. Manual harvesting, followed by long-distance travel under harsh weather conditions, often damages fruits. A solution is needed to facilitate movement within the farm, saving time and preserving fruit quality.

This study aimed to identify and translate customer needs into well-defined requirements using quality techniques, functional analysis, and concept generation. The goal was to develop a solution to improving fruit movement from orchards to packing houses in the Vale do São Francisco region, Bahia.

Materials and Methods

This research presents an innovative system development approach aimed at addressing issues identified through primary data research with fruit

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Address for correspondence: Gláucio Bessa Oliveira. Avenida Orlando Gomes, 1845, Piatã. Salvador, Bahia, Brazil. Zipcode: 41650-010. E-mail: glaucio_bessa@hotmail.com.

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producers and the institutional ecosystem in the Vale do São Francisco region. The methodological proposal is structured into three stages: Stage 1 - System Definition; Stage 2 - Translation of Needs into Requirements; and Stage 3 - Generation and Detailing of Concepts.

The Product Development Process (PDP) is a complex activity that requires control and management for a new product to succeed in the competitive market. This complexity drives ongoing efforts to enhance and streamline the product development process, leading to various methodologies that offer theoretical support, recommend procedures, and provide valuable techniques and tools across project phases. Numerous methods, tools, and techniques support the Product Development Process (PDP), with Quality Function Deployment (QFD) being among the most commonly utilized. QFD enables measuring and translating customer needs through matrices that offer detailed insights. The advantages of applying QFD include reduced product development time, minimized design changes, cost savings, increased customer satisfaction, and more. Regarding information gathering about the target segment, various research tools were employed based on the target audience's profile.

A questionnaire was developed and administered using the Google Forms survey tool. Individual interviews were conducted with representatives of pre-selected companies, forming a "focus group" with the highest-scoring client in the evaluation. The interview and questionnaire participants identified themselves as consultants for agricultural companies or small, medium, and large fruit producers. A total of 11 participants were involved. Following team discussions and the collection of secondary data on fruit harvesting and post-harvest processes in the Vale do São Francisco region, customers (Table 1), along with their identified, translated, and valued needs, played a crucial role in developing equipment for fruit movement from orchard to packing house.

Results and Discussion

Results of Step 1 – System Definition

The results obtained from the questionnaire, market research, and patent analysis (of similar products) have allowed for identifying customer needs and a better understanding of the product that needs improvement. The main products identified include: Tobata tractors: These tractors are designed to operate in small areas and are commonly used for various agricultural tasks. They are characterized by their lightweight nature, relatively small size, and excellent maneuverability in tight spaces. Tractors with attached crates: These tractors come equipped with a body or platform capable of accommodating multiple fruit crates. The crates are designed to secure the fruits during transportation, and they are often stackable and easy to load and unload with the assistance of forklifts or winches. Further discussion will delve into the specific customer needs identified based on these products.

Results of Step 2 – Translation of Needs into Requirements

Each identified need was translated into measurable technical requirements, meaning they were converted into quantitative criteria that were collectively analyzed using Quality Function Deployment (QFD) (Table 2). This analysis considered the importance level of each requirement and their interrelationships. Requirements were categorized as functional or quality-related, depending on their connection to the expected functionality for addressing the identified problem. Upon analyzing the QFD matrix, it was noted that only one requirement does not exhibit conflict (Table 3). Consequently, the following analyses aim to elucidate some of the most critical conflicts: "Volume for fruits" with "transport volume," "weight," and "quantity of lost fruits": There are negative interactions here; a more significant volume required for fruits necessitates more volume for transportation, leading to increased weight in the

Table 1. Methodological details of the solution development for fruit movement from the orchard to the packing house.

Step 1: System Definition	Methods and Tools
The objective was to contextualize the proposed system, understanding the market and relevant interfaces.	The actors and customers involved in the fruit transportation system lifecycle, as well as competitors, similar products, and patents, were identified. Additionally, relevant standards and regulations were analyzed. The methodology included the application of the business CANVAS model to comprehensively map the key elements of the system.
Step 2: Translation of Needs into Requirements	**Methods and tools**
The customer needs identified in the previous stage were translated into clear and objective requirements.	The overall function of the system was defined, taking into consideration the requirements established through the Quality Function Deployment (QFD) technique. Conflicts between requirements were analyzed and resolved by ranking the relative importance of the requirements. Techniques such as functional synthesis and morphological matrix were used to explore various solution alternatives. The methodology included the application of the Theory of Inventive Problem Solving (TRIZ) to stimulate the generation of innovative concepts. The concepts were selected based on predefined criteria and subsequently detailed to develop a concrete proposal.
Step 3: Concept Generation and Detailing	**Methods and tools**
The overall function of the system was defined, considering the requirements established in the previous stage.	Functional synthesis and morphological matrix were used to explore various solution alternatives. The methodology included the application of the Theory of Inventive Problem Solving (TRIZ) to stimulate the generation of innovative concepts. The concepts were selected based on predefined criteria and then detailed to develop a concrete proposal. Additionally, a patent proposal was developed to highlight the originality of the proposed concepts.

solution, which in turn may result in higher fruit loss. "Product cost" and "MTBF" (Mean Time Between Failures): Lower product costs may lead to a higher likelihood of failures due to the potential use of lower-quality parts or components. "Quantity of lost fruits" and "product cost": There is an indirect relationship between the quantity of lost fruits and the product cost, as fruit losses impact production costs, potentially influencing the product's final price. "Reliability level" with "product cost": Highly reliable products less prone to failures are more expensive due to the high-quality materials and components necessary for achieving reliability. These conflict analyses help understand the trade-offs and considerations necessary for developing a practical solution that balances technical requirements with customer needs and market expectations.

Results of Step 3 – Concept Generation and Detailing

The Theory of Inventive Problem Solving (TRIZ) method was applied to develop the concept

Table 2. Correlation between needs and project requirements.

#	Client	Need	Customer's Impact	Customer's Rating	Standardized parts	Shipping Volume	Average distance from suppliers	Assembly time	Weight	Number of operations to use	Maintenance cost	MTBF	MTTR	Product cost	Amount of fruit lost	Degree of Reliability	Cost of use	Number of possible uses	Volume for fruits	Weight for fruits	Tipping angle	Speed	Number of sharp corners	Leave of absence
					#	L	km	hr	kg	#	$	dias	min	$	%	%	$/use	#	L	kg	°	m/s	#	#
					↑	↓	↓	↓	↓	↓	↓	↑	↓	↓	↓	↑	↓	↑	↑	↑	↑	↑	↓	↓
N1	Fruit growers	Not to degrade the fruit	50%	9					1					1	6		1		3	6	3	3	1	
N2		To have low product cost	50%	9	6	3	3	3	3	3	6	1	3	6	3	6	3	3	3	3	3	3		
N3		To have low maintenance cost	50%	6	6	1	3	3	1	3	6	6	6	3	1	6	3	3		3	3	3		
N4		To have high capacity	50%	3		6		1	6		1	3	3	3	3		3	3	6	6	6	6		
N5		To have stability	50%	3	1	3			3		1	1	1	3	6	1		1	3	6	6	6		3
N6		To be robust	50%	9		1		3	3		6	6	3	6	1	6	3		1	3	1	3		1
N7		To be efficient	50%	9		1			3	3	6	6	6	3	1	1	6	1	6	6		6		
N8		To operate on different terrains	50%	3	1	3			3		3	3	3	3	1		1	6			6	6		
N9		To be versatile	50%	6	1	1		1	1	3	3	3	3	6	1		1	6	3	3	6	3		
N10		To be user-friendly	50%	3				3		6	3	3	3	1	1	3	1	3						6
N11		To be fast	50%	3	1	3		1	3		3	3	3	3	3	3	3	3	3	6	6	6		3
N12	Operator	To be easy to handle	20%	9		3			3	6	3	3	3	3	3		3	3					3	3
N13		To be safe	20%	9		1			1	6	3	3	3	6	1	1	3	1		3	6	6	6	6
N14		To be ergonomic	20%	6	1				1	6	1	1	1	3	1	3	3	1		3	3	1		6
N15	Manufacturer	To use locally available raw materials	15%	6	3		6	3	1	1	3	3	3	6		6	3	3		1	1	3	3	1
N16		To be easy to manufacture and assemble	15%	9	6		1	6	3	3	6	6	6	6		6	6	6		1	1	3	3	6
N17	Logistic operator	To have low liquid volume	15%	9	1	6		6		1	3	1	1	3	1	3	3	1		3	3	3		1
N18		To have low weight	15%	9	1	6	1	6		1	3	1	1	3	1	3	3	1		3	3	1		1
		Ranking of Importance of Requirements:			67	74	31	74	87	90	155	131	126	160	88	114	116	91	86	145	119	146	27	58

Source: The authors, 2023.

Table 3. Roof of the house of quality matrix.

Roof Legend:

2	Strongly positive
1	Positive
	Neutral
-1	Negative
-2	Strongly negative

Leave of absence																				
Number of sharp corners																				1
Speed																				-1
Tipping angle																		-1		1
Weight for fruits																	-1	-1		
Volume for fruits																2	-1	-1		
Number of possible uses																				
Cost of use															1	1		-1		
Degree of Reliability																	1			1
Amount of fruit lost															-2	-2		-1		
Product cost											-2	-2	-1	-1	-1	-1	-1	-1	-1	
MTTR										-1			1							
MTBF										-2		2	1				1			
Maintenance cost								2	2	-1		-1	2	-1						
Number of operations to use								1		-1			1	-1						1
Weight							1		1	1		-1	1	-1	-2	-2	1	1		1
Assembly time					1	-1	1		1	1	1									
Average distance from suppliers							1		1	1										
Shipping Volume					2					1			1	-1	-2	-2	1			
Standardized parts			2	1			1		1	2		1	1	-1					1	

Source: The authors, 2023.

of the solution. In this process, contradictions between prioritized requirements were listed to define engineering parameters corresponding to the respective requirements. Table 4 indicates some of the principles considered and their possible applications in the final solution (selected by the Pugh method, as shown in the following sections).

Thirteen concepts were generated in the Concept Generation stage. Using the Pugh Matrix and classified based on customer needs and weights. This analysis allowed for ranking the most promising concepts to meet customer needs. Table 5 shows the result of the concept evaluation, and Table 6 shows the concepts generated. In the qualitative evaluation, '-1' values were assigned when the concept performed worse in meeting the need, '0' when the performance was equal, and '+1' when the performance was more satisfactory than the chosen reference concept.

Table 7 briefly describes the respective concepts and gives an idea of the type of product, correlating them with the functions selected by a morphological matrix.

Concept 7 presents rail and cable equipment designed for fruit transportation within orchards. This solution utilizes a system of rails and cables to move fruit containers from one location to another within the orchard. The equipment incorporates a braking system to regulate the movement speed, ensuring the safe transportation of fruits. The transportation system comprises fixed rails and cables secured to poles or trees throughout the orchard. Fruit containers are placed on hooks that move along the cables. The speed of movement is adjustable through the braking system, which can be operated manually by a person pushing the containers along the rails or automated using electric or hydraulic motors in some instances.The manual braking mechanism allows the equipment operator to stop the movement of containers, preventing fruit damage smoothly. Implementing the rail and cable equipment can streamline fruit harvesting and transportation processes, reducing time and effort. It also minimizes the risk of fruit damage compared to manual handling. However, proper care and maintenance are crucial for the equipment's optimal performance and safety, and adhering to relevant standards and regulations for orchard equipment usage is essential. The rails and cables are constructed from corrosion-resistant materials like stainless steel, ensuring durability. They can be configured in various setups to accommodate specific orchard conditions. Overall, Concept 7 provides an innovative and secure solution for transporting fruits from orchards to packing houses, enhancing efficiency and reducing the potential for fruit damage or loss.

Conclusion

This study proposes an innovative air transport system for moving fruit, utilizing cables and high-resistance containers, thus eliminating the need for traditional road transport. The system's commercial and technical feasibility is highlighted, showcasing its potential applications across various sectors. Emphasis is placed on the systematic approach and collaboration among specialists to transition this concept into a market-ready product with significant ethical impacts, particularly regarding socio-environmental benefits for small to medium-sized producers and potentially at a larger scale.

The solution is designed for scalability and adaptability, making it suitable for fruit trees and other assets. The reduction in reliance on ground infrastructure and the consequent decrease in greenhouse gas emissions are critical factors contributing to the system's acceptance and commercial success. The focus on positive environmental impacts is a strategic advantage for the product, optimizing land use and promoting sustainability.

In conclusion, the innovative air transport system, utilizing cables and high-resistance containers, holds promise for enhancing logistics in transporting various agricultural products. Its adaptability makes it applicable in similar contexts, although the study focuses explicitly on tropical fruit cultivation in the Vale do São Francisco region. The successful implementation of this system will require collaborative efforts and a deep appreciation

Table 4. Inventive principles indicated by the TRIZ method.

Contradictions			Inventive principles indicated by TRIZ	
			Inventive Principles	Possible Applications in the Solution
Maintenance Cost	X	Product Cost	Prior action	Leave pre-assembled equipment to store more fruit Perform Set-up of tools to increase versatility
Product Cost	X	Speed	Inversion	Use a more powerful motor and mount it inverted to facilitate bolting
			Counterbalance	Use balloons / big bags to transport the fruits in rough terrain. Fill in the "empty spaces" of the cargo during transport.
Product Cost	X	Cost of use	Copy	Replace hard-to-obtain, fragile and/or expensive objects with cheaper parts Using alarms with infrared sensors
			Disposable objects	Use disposable boxes in the harvest to follow it to the market
Product Cost	X	Number of possible uses	Removal / Extraction	Remove unwanted parts or use the only parts you want
			Localized Quality	Boxes or trays with compartments suitable for home type of fruit
			Dynamization	Watering or throwing insecticide during storage and transport of fruits
Maintenance Cost	X	Number of possible uses	Alignment	Build the boxes or packages with fittings to be compact, decrease vibrations and decrease "dead" freight
			Asymmetry	More resistant tires or tracks on the outside due to contact with trees
			Partial or excessive action	Wash the fruits by immersion and drying during transport to anticipate washing in the later stage
Weight of fruits	X	Tipping angle	Use of inert atmospheres	Use of inerted cotton to reduce impact and friction of fruits
Weight of fruits	X	Amount of fruit lost	Joining or mixing	Use the same water in a reservoir to cushion the fruits, perform the first wash and irrigate the orchards on the return to the packing house

Table 5. Evaluation results of the concepts.

Needs	Customer's impact	Customer's rating	Equivalent grade/score	1	2	3	4	5	6	7	8	9	10	11	12	13	Tractor + Boxes
Not to degrade the fruit	50%	9	4,5	1	1	1	1	1	1	0	1	1	1	1	1	1	REFERENCE
To have low product cost	50%	9	4,5	-1	-1	0	-1	0	-1	-1	-1	0	0	-1	-1	-1	
To have low maintenance cost	50%	6	3	-1	-1	0	0	0	-1	1	0	0	0	-1	-1	-1	
To have high capacity	50%	3	1,5	1	1	0	1	1	-1	1	1	1	0	1	1	1	
To have stability	50%	3	1,5	1	1	0	1	1	1	1	1	1	0	1	1	1	
To be robust	50%	9	4,5	1	1	1	1	1	1	0	1	1	0	1	1	1	
To be efficient	50%	9	4,5	-1	-1	1	1	1	1	1	1	1	0	-1	1	1	
To operate on different terrains	50%	3	1,5	0	0	0	0	0	1	1	0	0	0	0	0	0	
To be versatile	50%	6	3	-1	-1	0	0	0	1	1	0	0	0	-1	0	0	
To be user-friendly	50%	3	1,5	0	0	0	0	0	0	1	0	0	0	-1	0	0	
To be fast	50%	3	1,5	0	0	0	0	0	-1	1	0	0	0	-1	0	0	
To be easy to handle	20%	9	1,8	0	0	0	1	0	0	1	0	0	1	-1	0	0	
To be safe	20%	9	1,8	1	1	0	1	1	-1	0	1	1	0	1	1	1	
To be ergonomic	20%	6	1,2	1	1	0	1	1	0	1	1	1	1	1	1	1	
To use locally available raw materials	15%	6	0,9	0	0	0	0	0	1	-1	0	0	0	-1	0	0	
To be easy to manufacture and assemble	15%	9	1,35	0	0	0	0	1	0	-1	0	1	0	-1	0	0	
To have low liquid volume	15%	9	1,35	-1	-1	0	-1	0	0	-1	0	-1	0	-1	-1	-1	
To have low weight	15%	9	1,35	0	0	-1	-1	0	0	-1	0	0	0	0	0	-1	
			TOTAL	-1,4	-1,4	12	14	21	8,1	12	15	20	7,5	-8,4	11	9,3	

Table 6. Generated concepts.

(C1) - Autonomous Refrigerated Cart	**(C8)** - Water Tank Transport in a Truck Bed
(C2) - Autonomous Refrigerated Cart	**(C9)** - Tractor-Powered Compartmentalized Water Tanker
(C3) - Autonomous Refrigerated Cart	**(C10)** - Tractor-Powered Cart
(C4) - Tractor-Powered Refrigerated trailer	**(C11)** - Solar-Powered Refrigerated Trailer
(C5) - Tractor with Compartmentalized Water Tanker	**(C12)** - Refrigerated Trailer with Biodigester
(C6) - Animal-Drawn Cart	**(C13)** - Tractor-Powered Water Tanker
(C7) - Transport via Suspended Rails	

Table 7. Brief description of the selected concept.

Product Concept 7 (C7) - Transport via Suspended Rails	
Product Concepts	**Transportation via suspended rails**
Advantages	- No need for an operator (Remote operation). - Reduced fruit degradation. - Increased safety. - Solar power generation. - Transportation of fruits in nets or in bulk (such as bananas).
Disadvantages	- Longer manufacturing time and larger volume. - Need to design and create trunk lines. - Lack of versatility. - Fruits exposed to adverse weather conditions.

for its environmental benefits, paving the way for a more efficient, sustainable, and promising future in freight transport and agricultural management.

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Optical Fibers Characterization for Macrobending Sensors

Maria Eduarda Benfica Gonçalves[1*], Ciro Matheus de Lima Costa[1], Rafael Andrade Vieira[1], Jessica Guerreiro Santos Ramalho[1], Valéria Loureiro da Silva[1]

[1]SENAI CIMATEC University Center, Optics and Photonics Engineering Laboratory; Salvador, Bahia, Brazil

The article delves into characterizing macrobending losses in optical fiber coils for use in diverse sensors. It examines Single-Mode Fiber (SMF) and Multimode Fiber (MMF) with step and graded index profiles incorporated into sensor coils of varying diameters and numbers of turns. The experimental configuration involves compressing the coils to monitor optical power loss caused by attenuation. The findings reveal that SMFs experience more significant macrobending losses than MMFs, while the graded index fiber exhibits notable resistance to bending. These results offer valuable guidance for fiber selection and sensor design considerations.

Keywords: Optical Fiber. Sensor. Macrobending. Fiber Optic Coil.

In recent years, optical fiber sensors have garnered considerable attention due to their exceptional sensitivity, versatility, and durability. Optical fiber sensors emerge as a promising alternative, particularly in explosive environments where electronic sensors pose risks. Macrobending fiber sensors stand out as they are cost-effective and easily interrogated. They have found applications in various areas, such as sleep monitoring, breathing analysis, and vibration measurement. Macrobending occurs when an optical fiber is bent, causing some light to leak out of the core. The extent of this leakage depends on the bend radius, and the optical power loss serves as the sensor output. The design of such sensors relies heavily on the choice of fiber and sensor geometry, which significantly influence macrobending losses and overall sensor performance.

Hence, comprehensive macrobending data for different fiber types and bend diameters are crucial for effective fiber selection and sensor optimization. This study aims to characterize macro bend losses in fiber coils made from various fiber types, considering different coil diameters and numbers of turns. These parameters play a vital role in designing and optimizing macrobend fiber sensors. This research builds upon previous work focused on single-mode fiber and extends it to encompass multimode fibers, providing a broader understanding of macrobending behavior across different fiber types.

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Address for correspondence: Maria Eduarda Benfica Gonçalves. Av. Orlando Gomes, 1845 - Piatã. Zipcode:41650-010. Salvador, Bahia, Brazil. E-mail: maria.g@aln.senaicimatec.edu.br.

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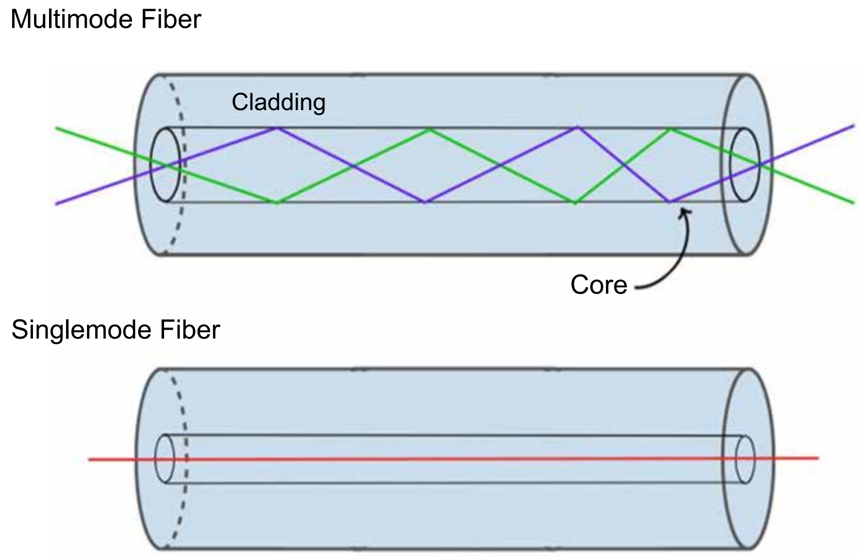
Fiber Types

There are two primary types of optical fibers: single-mode (SMF) and multimode fibers (MMF) (Figure 1). SMFs have a tiny core, usually around 9 micrometers in diameter, allowing only one light mode to travel through the fiber. This characteristic results in lower signal dispersion and attenuation. On the other hand, MMFs have a larger core, typically around 50 or 62.5 micrometers in diameter for telecommunication fibers and over 100 micrometers for sensor fibers. In MMFs, multiple light modes propagate through the glass, leading to modal dispersion and higher attenuation than SMFs. Additionally, communication fibers are optimized for specific wavelengths. MMFs operate at 850nm and 1300nm, while SMFs typically function within the wavelength range of 1310nm to 1625nm [6].

Fiber Profile Types

The profile of an optical fiber refers to the distribution of the refractive index concerning the radius of the fiber, which significantly impacts the

Figure 1. Different modes of propagation through a single-mode and a multimode fiber.



Source: Adapted from https://americanfibertek.com/2019/03/06/multimode-vs-singlemode-fiber/.

propagation of light within the fiber. An optical fiber typically consists of three main components: the core, the cladding, and, in some cases, an outer coating for additional mechanical protection [6] (Figure 2). The core is the central region for light transmission, while the cladding helps contain the light within the fiber. The first type of profile is the Step Index, characterized by an abrupt change in refractive index between the core and the cladding. The second type is the Graded Index, where the refractive index gradually changes from the core to the cladding [6]. In order to minimize macrobending losses, additional features are incorporated into the refractive index to create potential barriers that further confine the light fiel [7].

Macrobending

The phenomenon known as macrobending occurs when an optical fiber experiences a bending radius more prominent than 1 mm^2 [6]. When the fiber is bent, the light traveling through it may leak out of the core, leading to signal loss. This loss is directly related to the bending radius (Figure 3).

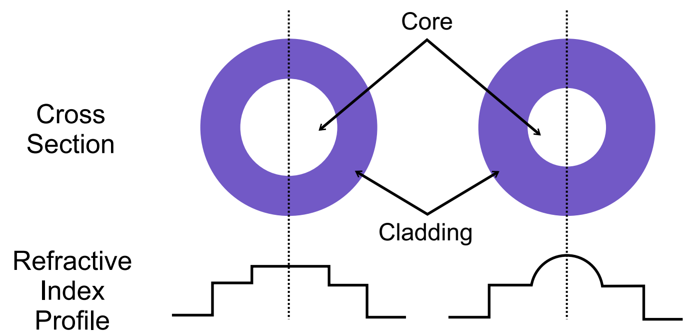
This mechanical characteristic of the fiber finds applications in various sensor types, including vibration, shape, and contact. The coil shape is particularly suitable for amplifying bending effects due to the overlap of fiber turns within the same volume. Therefore, it is crucial to characterize the profile of optical power loss in coils, considering parameters such as radius, number of turns, and curvature radius (Figure 4).

Reinsertion of Modes

Some optical fibers have a protective coating to shield the core and cladding. However, coated fibers can experience mode coupling issues caused by fiber bending. Bending or deformations introduce stress and alter the refractive index profile, leading to unintended interactions between modes. This phenomenon, known as mode coupling, causes light to transition from one mode to another, reinserting previously filtered-out modes and resulting in unexpected behavior.

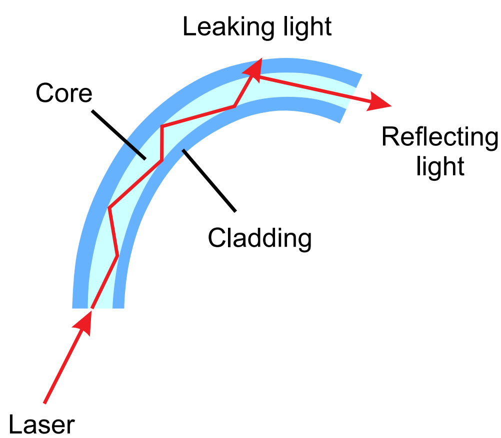
The degree of mode coupling depends on several factors, including the bending radius, fiber material, and light wavelengths. In coated single-mode fibers, oscillations observed in bend-loss curves are often attributed to the coupling between the fundamental mode and various whispering

Figure 2. Different fiber profile types.



Source: Adapted from https://www.fiberoptics4sale.com/blogs/wave-optics/step-index-optical-fibers.

Figure 3. Representation of optical power loss by bending radius [6].



Source: Adapted from Optical Fibers in the Design and Fabrication of Smart Garments–a Review [9]

Figure 4. The ideal shape for the fiber coil.

gallery modes, which are partially guided by the interface between the cladding and coating [8].

Materials and Methods

The macrobending losses of three different optical fibers were characterized. Fiber coils with a diameter of 40 mm and varying numbers of turns were constructed. The optical fibers tested included Single-Mode Fiber (SMF), Multimode Fiber (MMF) with a step-index profile, and a bend-insensitive graded index MMF.

The SMF used was CORNING-SMF-28e+, tested with four different coils having distinct numbers of turns (1, 5, 20, and 30) and utilizing a laser operating at a wavelength of 1560 nm. The MMF with a step-index used was FG105LCA from Thorlabs also tested with a coil of 30 turns but with different wavelength sources: a laser at 1560 nm and two LEDs operating at 940 nm and 650 nm. For the graded index MMF (model GIF50E from Thorlabs), a bend-insensitive type was used as a reference, with the fiber coil having 45 turns and undergoing testing. Table 1 details the specifications for each fiber coil.

The experimental setup consists of two parallel plates connected to a translational stage. One of the plates remains stationary, while the other is movable. As the movable plate shifts, the coil is continuously compressed at a constant speed of 0.01 mm/s, reducing its radius from 40 mm to 11.5, resulting in macrobending losses. The sensor readings are sampled at a rate of 0.1 s (Figure 5).

Results and Discussion

Figure 6 displays the macrobending attenuation for fiber coils a, b, c, and d. These coils were made from the same SMF28-e+ SMF but with a distinct number of turns, as described in Table 1. Figure 6 shows a more significant attenuation as the number of turns of the coil increases, as expected.

The increased macrobending attenuation for the curves from the blue curve can be seen. Figure 7 shows a macrobending attenuation comparison for three types of fiber: the SMF28-e+, the FG105LCA - ThorLabs, and the GIF50E – ThorLabs.

The grey curve presents the attenuation for the h fiber coil, which is made of the bend-insensitive graded index fiber. The results show that the unique index profile effectively eliminated bending loss for the conditions tested. The yellow, red, and blue curves represent the coils g, f, and e, respectively, with different wavelengths but the same fiber step index MMF. For the coil g, it is possible to observe that the curve for the MMF with the laser of 1560nm is noisier compared to the same fiber with the LEDS and SMF in the same wavelength. This may have occurred due to lower light coupling in the fiber coils e and f, which degraded the signal-to-noise ratio. When dealing with attenuation, there were no significant changes between the FG105LCA in different wavelengths. The figure also shows that the SMF fiber has a more significant attenuation than the MMF.

Conclusion

In conclusion, this article has successfully achieved its objective of characterizing

Table 1. Specifications of the tested optical fiber coils.

Coil	Fiber - Supplier	Type	Profile	Core diameter	Turns	nm – source
a	CORNING-SMF-28e+100Kpsi	SMF	Step Index	9 µm	1	1560nm (Laser)
b	CORNING-SMF-28e+100Kpsi	SMF	Step Index	9 µm	5	1560nm (Laser)
c	CORNING-SMF-28e+100Kpsi	SMF	Step Index	9 µm	20	1560nm (Laser)
d	CORNING-SMF-28e+100Kpsi	SMF	Step Index	9 µm	30	1560nm (Laser)
e	FG105LCA - ThorLabs	MMF	Step Index	105 µm	30	650nm (LED)
f	FG105LCA - ThorLabs	MMF	Step Index	105 µm	30	940nm (LED)
g	FG105LCA - ThorLabs	MMF	Step Index	105 µm	30	1560nm (Laser)
h	GIF50E - ThorLabs	MMF	Graded Index	50 µm	45	1560nm (Laser)

Figure 5. Experimental setup of parallel plates.

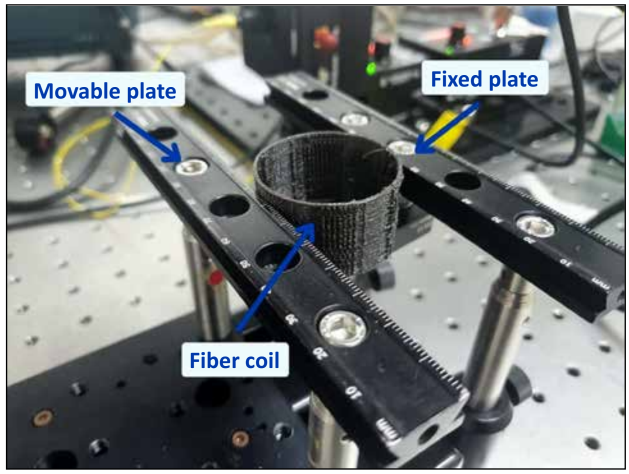
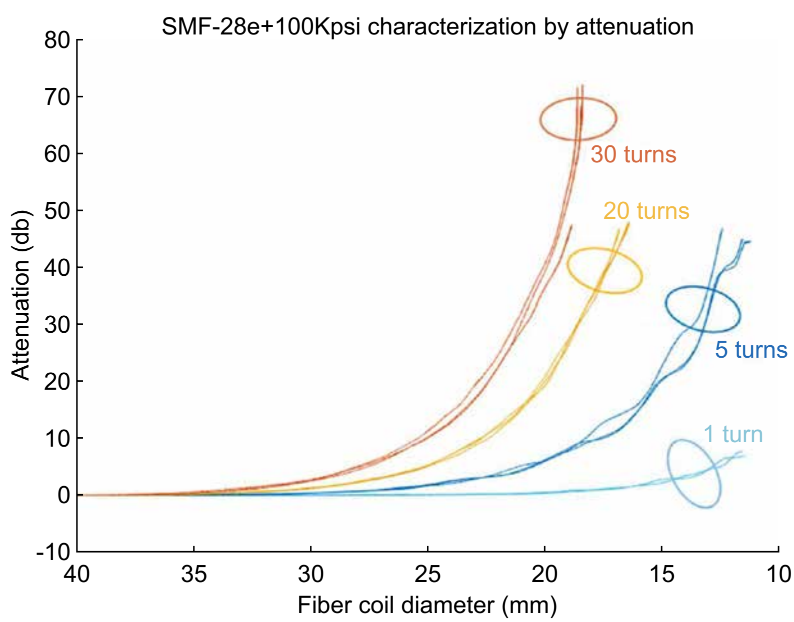


Figure 6. Attenuation is achieved by bending the radius and number of turns for the SM fiber.



Light blue – 1 turn, dark blue – 5 turns, yellow – 20 turns, and orange – 30 turns.

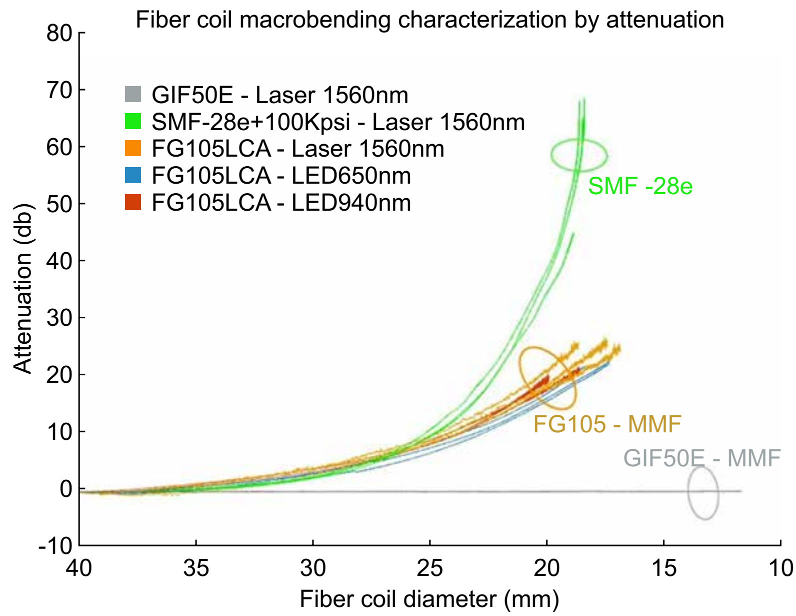
macrobending losses in fiber coils with different fiber types, providing a valuable tool for supporting the selection and design of macro bend-based sensors.

The experimental setup, which utilized two parallel plates to compress the fiber coils and observe the optical power loss due to macrobending demonstrated a direct relationship between bending radius and optical power loss.

The results indicated that Single Mode Fibers (SMFs) exhibited higher macrobending losses due to attenuation compared to Multimode Fibers (MMFs). Additionally, the attenuation increased as the number of turns in the coils increased. In contrast, the graded index fiber showed remarkable insensitivity to bending.

For future research directions, it is recommended to replicate the experiment using

Figure 7. Attenuation comparison between SMF and MMF.



different types of fiber and diverse wavelengths as light sources. Such investigations will contribute to a deeper understanding of the behavior of optical fibers under various conditions.

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Sensorial Investigation for Automated Patient Data Collection in Hospital Triage: An Exploratory Assessment of the Literature

Victor Guerra de Araújo e Souza[1,2*], Ana Luiza Cantharino Maciel[1,2], Vitor Yan Miranda Basañez[1,2], Thâmara Raíssa Monteiro Lins[2,3]

[1]SENAI CIMATEC University Center; [2]Junior Researcher at IEEE RAS CIMATEC; [3]Project advisor

This paper delves into the proposal of integrating a comprehensive system of vital signs sensors to advance the BayIEEEmax project, which aims to develop an autonomous robot to aid in the triage process within hospital settings. A thorough investigation was conducted to explore commercially available sensor types capable of measuring patients' body temperature, heart rate, and blood pressure. The research focused on assessing the identified sensor models' feasibility and compatibility with the prototype's requisite automation criteria. Ultimately, the selected set of sensors will be incorporated into a printed circuit board and integrated into the physical model of the robot for experimental validation.
Keywords: Sensors. Vital Signs. Autonomous Robot. Triage. Hospitals.

Over the years, as the population has grown, the methods of collecting and storing important data have evolved significantly. The progression has been marked from oral communication to handwritten records and from typewritten documents to printed reports. However, despite the advancements in data storage technologies, such as ample storage clouds, the methods of data collection in certain domains have not kept pace with this evolution [1].

In hospitals, one of the most critical factors for a patient's outcome is often not the treatment itself but the time spent waiting for triage. Consequently, process automation, coupled with mobile robotics, has emerged to streamline simple, repetitive tasks previously performed by professionals, thereby optimizing their time for more critical matters. Automating the triage process could significantly enhance efficiency and effectiveness within healthcare facilities [1,2].

The quest for automation and mobile robotics solutions in hospitals is increasingly prevalent [3,4]. For instance, the "Relay" robot developed by Swisslog autonomously navigates hospital premises, transporting medications, laboratory samples, and other vital materials to optimize resource allocation within healthcare facilities [5]. Similarly, the SpeciMinder robot, developed by CSS Robotics, serves a similar purpose and can map environments and interact with doors and elevators [6]. This paper aims to propose a sensor system integrated with a mobile robot to collect patient data non-invasively, thereby reducing waiting times in hospital triage efficiently.

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Address for correspondence: Sergio Santos Silva Junior. Avenida Orlando Gomes,1845, Piatã. Salvador, Bahia, Brazil. Zipcode:41650-010. E-mail: victor.souza@aln.senaicimatec.edu.br.

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Materials and Methods

The work employs an exploratory methodology to investigate bibliographic materials, including scientific articles, informational websites, and sensor datasheets. This approach facilitates a comprehensive exploration of an innovative integrated assistive robotic model. By synthesizing information from diverse sources, this methodology aims to provide a nuanced understanding of the technological landscape and inform the development of the proposed robotic system.

General System

We conducted research to identify sensors capable of safely, reliably, and non-invasively measuring vital signs crucial for initial diagnosis and prioritization of patient care to propose a model for a robot capable of automating the in-hospital triage process. These vital signs encompass heart rate, respiratory rate, oxygen saturation, body temperature, and blood pressure, collectively offering a comprehensive assessment of the patient's physiological status.

In hospital settings, continuous monitoring of vital signs is paramount to ensuring patient safety and well-being. We facilitated this with sensors to transmit pertinent data swiftly and efficiently.

Sensor Types

Among the diverse array of sensors available, those commonly utilized in hospital environments include [7]:

- **Temperature Sensors:** Designed to measure skin and body temperature in health monitoring applications, digital thermometers, health tracking devices, and portable temperature monitors are prevalent. Notably, infrared temperature sensors enable contactless measurements, while digital temperature sensors offer readings with a digital output signal in a compact printed circuit board format. PPG (Photoplethysmography) Sensors: These sensors monitor heart activity.

- **PPG Sensors:** They employ low-intensity infrared light to detect an individual's blood flow rate. Given the prevalence of various heart diseases, PPG sensors are ideal for tracking a patient's cardiac conditions [8].

- **ECG (Electrocardiogram) Sensors:** These sensors record the electrical signals of the heart, commonly used to detect heart problems and monitor heart status in various situations. ECG examinations allow for identifying different cardiac conditions, such as arrhythmias or dysrhythmias, in a non-invasive, painless manner and with rapid results [9].

- **Blood Pressure Sensors:** Vital for assessing the patient's physiological and functional status, blood pressure sensors are indispensable. Examples include the sphygmomanometer, available in analog or digital formats, which non-invasively measures blood pressure accurately, providing crucial information for evaluating the patient's clinical condition [10].

Incorporating these sensors into an in-hospital triage robot model facilitates continuous and precise collection of vital signs. This integration optimizes the patient care process by ensuring efficient and reliable triage.

Main Techniques in Health Signs Sensors

Health-related sensors are pivotal in capturing and measuring vital signs continuously and non-invasively, facilitating monitoring of the patient's condition. The data collected from these sensors find applications across a broad spectrum of healthcare scenarios. The primary techniques pertinent to the present work are:

- **Automated Auscultatory Method:** This method automates the process of auscultating Korotkoff sounds, which are the sounds produced by blood flow in an artery as the pressure of a sphygmomanometer cuff is gradually released [11]. The cycle of events involves inflating the cuff to stop blood flow, gradually reducing cuff pressure to detect the first Korotkoff sound, and identifying the periods of muffling and silence. Systolic and diastolic pressure values are presented [10].

- **Oscillatory Method:** This technique aims to measure blood pressure in an automated manner, eliminating the need for auscultating Korotkoff sounds. Pressure sensors, applied to the patient's arm, detect oscillations caused by pulsating blood flow in the arteries, which are then converted into digital values. These oscillations are interpreted by the electronic device to automatically display systolic, diastolic, and mean blood pressure [10].

- **Optical Method + Machine Learning:** This approach involves continuous and accurate monitoring and interpretation of vital signs. It utilizes sensors that use light to gather physiological information from the patient, measuring characteristics such as light absorption or reflection from biological tissue and providing vital signs data. By applying Machine Learning, these data can be used to detect anomalies, predict trends in vital sign behavior, personalize treatment, and more. This combination enables faster diagnosis and timely intervention, improving clinical outcomes [12].

- **Electric Currents Measurement Method:** This technique utilizes the electrical activity generated by the human body to monitor and obtain information about the patient's condition. It is commonly employed in EEG, ECG, and EMG, where the electrical activities of the heart and muscles are measured [13].

These methodologies collectively enhance patient monitoring, diagnosis, and treatment, fostering improved healthcare outcomes.

Results and Discussion

The data collected during the research of each type of sensor was grouped according to its functionalities: blood pressure sensors (Table 1), heart rate sensors (Table 2), and body temperature sensors (Table 3).

The data in Table 1 shows that the set of analog sphygmomanometers and stethoscopes is unfeasible for manufacturing the desired robot model. The need for a technician or nurse demonstrates a failure to comply with the central premise of the project to allow the reallocation of these employees to more requested areas and, therefore, cannot be adopted.

The digital sphygmomanometer, on the other hand, does not require the presence of a technician but needs to be placed accurately on the arm to obtain accurate measurements. The digital pulse blood pressure monitor circumvents this limitation but is inherently less accurate than the digital sphygmomanometer. Digital photoplethysmography, on the other hand, does not require direct contact with living tissue but is very sensitive to light.

Table 2 shows that the oximeter is an easy-to-use sensor, requiring only the approach of the patient's finger. In this sensor, no position adjustment is required. The smart bracelet, although also easy to use, has low reliability. It can, however, be easily connected to other systems.

The heart rate sensor can collect information by being inserted into the ear or squeezed by the patient's fingers. This makes collection as simple and easy as the oximeter. The chest sensor is not feasible as it needs to be attached around the patient, which would need a very complex mechanism for interfacing with the robot compared to the other sensors. Finally, the ECG would require the accompaniment of a technician to operate, which again would be counterproductive with the goal of automating certain functions through mobile robotics solutions.

The data presented in Table 3 shows that the digital infrared thermometer offers a non-invasive, rapid, and easily interpretable system. However, its high cost and performance reliance on battery levels limit its feasibility.

Conversely, the thermal camera provides a non-invasive data collection method unaffected by battery variations, maintaining the critical advantages of the digital infrared thermometer. While accurate and cost-effective, the digital thermometer necessitates physical contact with the patient and would require technician intervention and sanitization, rendering it impractical to integrate with the desired mobile robotics solution.

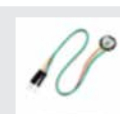
In pursuit of creating a mobile robotics platform capable of intra-hospital screening to reduce waiting times and perform non-invasive data collection, the chosen sensors are the thermal camera, oximeter, and digital sphygmomanometer.

Table 1. Blood Pressure Sensors.

Measuring Instruments	Technique	Advantages / Disadvantages	Example
Analogic sphygmomanometer + stethoscope	Automated auscultatory method (not autonomous)	Requires a technician or a nurse to operate the instrument	
Digital sphygmomanometer	Oscillatory method	No need for a technician, but require a specific position of the patient's arm	
Photoplethysmography	Optical method + machine learning	Non-invasive, do not require physical contact, sensible to light. Not commercial.	
Digital pulse blood pressure monitor	Oscillatory method	Easy manipulation and utilization with the patient, less liable than the arm sphygmomanometer	

Source: Photo references were acquired by Center Medical [14].

Table 2. Heart rate sensors.

Measuring Instruments	Technique	Advantages / Disadvantages	Example
Oximeter	Optical method	Easy patient use, no need for a specific finger position adjustment	
Smart bracelet	Optical method	Easy patient use, low reliability, easily connected to external systems	
Digital pulse blood pressure monitor	Oscillatory method	Easy manipulation and utilization with the patient	
Heart rate sensor	Optical method	Easy functionality, but needs to be attached to the ears to the patient	
Chest monitor	Electric currents measurement	Must be attached to the chest of the patient	
ECG	Electric currents measurement	Requires a technician or a nurse to operate the instrument	

Source: Photo references were acquired by Center Medical [14].

Table 3. Body temperature sensors.

Measuring Instruments	Technique	Advantages / Disadvantages	Example
Digital infrared thermometer	Infrared Method	Non-invasive, fast, easy to read, data can be saved, but has high cost, is very sensitive to product battery variation	
Thermal camera	Computational method + infrared	Non-invasive, fast, easy to read, data can be saved, but high-cost	
Digital Thermometer	Temperature sensor	Accurate and cost effective, however has physical contact with patient, would need a technician and sanitization	

Source: Photo references were acquired by Center Medical [14].

Conclusion

This study aimed to propose a mobile robotics platform capable of facilitating the in-hospital screening process by swiftly, effectively and non-invasively collecting patient data. Through a comparative analysis of various sensor types, the study determined that the oximeter, digital sphygmomanometer, and thermal camera best fulfilled the requirements for heart rate, blood pressure, and body temperature data collection, respectively.

The following steps entail investigating the integration of these circuits into a mobile robotics platform based on TurtleBot3. Additionally, the study will involve creating a Computer-Aided Design (CAD) and the simulation of this model utilizing the ROS 2 platform. These efforts will contribute to developing a robust and efficient mobile robotics solution tailored to the needs of intra-hospital screening, ultimately enhancing patient care and streamlining healthcare processes.

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Prospective Strategies to Enhance Resilience for Public Emergencies Preparedness: A Human Resources Management Perspective

Tathiana de Mello Sampaio[1,2*], Alex Santos Príncipe[1,2], Misael Sousa de Araujo[1,2]
[1]Oswaldo Cruz Foundation; Rio de Janeiro, Rio de Janeiro; [2]Department of Management and Industrial Technology, SENAI CIMATEC University Center; Salvador, Bahia, Brazil

This study aims to identify human resources management strategies that enhance organizational resilience for public health emergency preparedness. To achieve this goal, a literature search was conducted covering the period from 2016 to 2023, along with an external environmental scan to extract contributing factors for the study. The results pertain to strategies focused on enhancing skills, promoting worker health, and ensuring compliance with regulations to safeguard professionals. It is concluded that the pandemic has provided valuable experiences and positive examples that can enhance productivity capacity, with lessons learned that are essential for future public health emergency preparedness and practices that should be perpetuated.
Keywords: Resilience. Emergency Management. Preparedness. Human Resources.

In a world where uncertainties, complexity, and chaos coexist, shaping organizational decisions in the context of health emergencies, addressing these challenges is imperative. According to the International Health Regulations, health emergencies pose significant risks to public health and necessitate a coordinated international response [1], thereby presenting health within an increasingly complex and dynamically adverse scenario. These global challenges demand a thorough analysis tailored to the vulnerabilities of each context, with short-, medium-, and long-term measures in place.The emergence of health emergencies has accelerated in recent years, with diseases like Polio, Ebola, Zika, COVID-19, and Monkeypox affecting global populations [2,3]. Consequently, public health organizations must continuously implement measures to prevent, control, and mitigate harm during outbreaks, epidemics, pandemics, disasters, or when facing population assistance challenges [4], underscoring the need for robust organizational resilience [5,6].

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Address for correspondence: Tathiana de Mello Sampaio. Avenida Orlando Gomes,1845, Piatã. Salvador, Bahia, Brazil. Zipcode: 42701-310. E-mail: tathiana.sampaio@aln.senaicimatec.edu.br.

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Organizational resilience must exhibit flexibility and dynamism to support institutions, particularly during times of rapid change and unexpected health crises, enabling swift and effective responses to adversity for survival, growth, and competitive advantage [7]. Beyond mere survival, organizational resilience entails adaptation, proactivity, and seizing opportunities in challenging business environments such as the health sector, rebounding regardless of known or unknown changes [7]. Public health emergencies heighten the complexity of organizational challenges, necessitating a nuanced understanding of global complexities and promoting locally optimal actions, including guidelines for preparing human resources at all levels to cope with health crises.

A key focus of this work is the research on building resilience in health systems [8], with a specific emphasis on preparing human resources. In this regard, the World Health Organization has established the Health Emergency and Disaster Risk Management Framework (H-EDRM) is a mechanism that strengthens an integrated approach to managing health emergencies and disaster risks at national and organizational levels.

In today's knowledge era, human capital, a crucial dimension of intellectual capital, stands as a primary dynamic asset capable of providing a competitive edge. It embodies valuable, rare, inimitable, and irreplaceable attributes that positively influence organizational resilience [9]. Some scholars have expressed concerns about the preparedness of human resources to act effectively in such situations. The collaboration among various stakeholders and the interconnectedness between sectors to overcome challenges and enhance preparedness for future disasters are focal points [10,11].

Additionally, the availability of information, whether through information systems, communication channels, or digital technologies, plays a pivotal role [10-12]. The significance of this study lies in capturing emerging trends and successful practices for the human capital of public health organizations, structuring them systematically to enable managers to make agile and proactive decisions in the face of future health crises.

Therefore, this study aims to identify human resource management strategies that enhance organizational resilience for public health emergency preparedness.

Materials and Methods

The method proposed in this study comprises two complementary parts: a literature review and an environmental scan. In the literature review, we identified challenges and opportunities in human resources management related to disaster preparedness and public health emergencies, drawing insights from recent events, notably the COVID-19 pandemic. The environmental scan allowed us to observe shifts in the external environment and their potential impact on professionals' work. It enabled us to apply these insights effectively in future public health emergency management.

Literature Research

In this study, we conducted a literature search on the Web of Science database focusing on heightened Public Health Emergencies (PHE) between 2016 and 2023. Our search generated 128 titles using a structured search string for the investigated object. After screening and evaluation by the authors, we selected 14 studies for analysis.These studies provided insights into challenges, gaps, and human resource management strategies that can enhance organizational resilience for public health emergency preparedness.

Environmental Scanning

One crucial step in mapping a potential emergency scenario is conducting an environmental scan to identify and adapt to external changes [13]. This management process involves situational analysis of the external environment, aiding decision-making through information acquisition, analysis, and utilization. It provides valuable insights for directing efforts during existing or imminent crisis events, benefiting organizational learning and performance [14]. Using techniques like STEEP (Social, Technological, Economic, Environmental, and Political) analysis facilitates understanding existing conditions and anticipating future adversities and opportunities for innovation, thereby fostering greater organizational resilience [14].

Results and Discussion

In complex PHE contexts, organizational challenges revolve around incorporating ethical values into decision-making processes within complex adaptive systems filled with ambiguities and uncertainties [16].

Strategic resilience hinges on institutional legacies and values to achieve a future vision.

The COVID-19 pandemic highlighted disruptions in health services due to understaffing, emphasizing gaps in HR planning, governance, information systems adoption, and resource allocation [17]. Addressing these challenges requires expanding staff capacity through training, responsibilities review, skills consolidation, PPE utilization, volunteer team organization, and HR plan management [16].

The World Health Organization established the H-EDRM to strengthen health systems' resilience, emphasizing personnel planning, occupational health, security, and capacity building across technical, epidemiological, diagnostic, service, and communication areas [18]. This systemic approach comprehensively tackles human resource planning challenges in PHE.

At the organizational level, it prioritizes occupational health actions, multidisciplinary work, workload adaptation, specific staff hiring measures, and intensifying digital technologies to support productive activities [12].

Interagency coordination, interdisciplinary integration, alignment of guidelines, public-private HR strategy agreements, and breaking silos between government areas are essential for coping with health crises [10,19].

Employees' psychological resilience and organizational culture are crucial in public health crises, necessitating a flexible, continuously trained workforce participating in prevention protocols and post-event learning [8].

Based on identified weaknesses, challenges, and gaps from recent studies outlined prospective strategies for human resource preparation and management at the organizational, actors, and employee levels. Table 1 summarizes these strategies and their alignment with the external environment, guiding organizations toward greater resilience for public health emergency preparedness.

In addition to these initiatives, the environmental scanning brought several contributions and reflections that will guide organizations on the need for articulation for future health emergencies in an anticipated way. Figure 1 illustrates the primary core strategy, contributions, and diagnosis for each scope of the STEEP analysis. Through it, we noticed signs of change in careers, organization operations, and human resources management at work, especially when there is an upcoming health emergency. Therefore, the parameters identified and the diagnoses mentioned should be considered when defining the organizational strategy and updating internal policies for worker protection and actions to increase resilience.

Conclusion

The study emphasizes the critical role of organizational resilience in managing Public Health Emergencies (PHEs), particularly highlighted during the COVID-19 pandemic. It reflects on lessons learned from this crisis, revealing vulnerabilities, opportunities, and positive examples that can guide the development of strategies to enhance organizational resilience. The research underscores the centrality of human resources in organizations, including public health agencies, and how various factors discussed in the literature and environmental scanning analysis can impact professionals in their roles. The environmental scanning process highlighted disruptions across social, technological, environmental, economic, and political dimensions, signaling career changes, human resources management, and internal processes and policies.

The identified strategies and positive practices are crucial for implementation to improve organizational preparedness for future public health emergencies. It is imperative to integrate these lessons learned into organizational strategies and policies to foster greater resilience and effectively navigate similar crises in the future.

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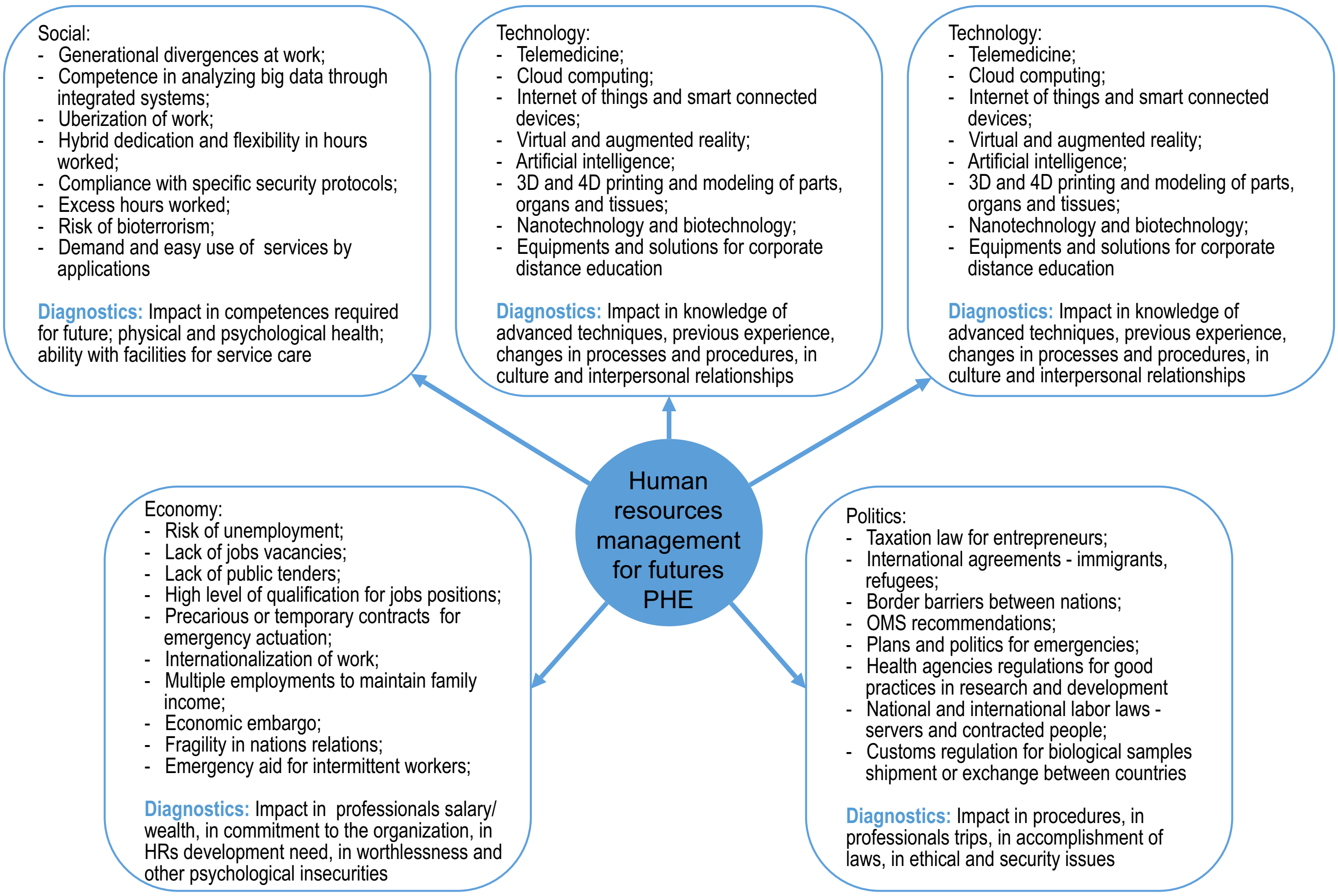
Table 1. Prospective strategies for public health emergency preparedness.

Dimensions	Strategies	Descriptions	References
Organization	Governance & leadership	Integrated structures, partnerships and responsibilities with clear leadership to support a coordinated and interoperable system	[16,20-22]
	Emergency plan and practices and experiences dissemination for preparedness	Develop a plan through a dynamic, collaborative planning process; invest in testing and practicing plans and processes; Gather rules, regulations, unity of purpose and priority for change and action	[16,21-23]
	Risk analysis	Consolidated knowledge of community hazards and risks, systematics and dynamics of risk events, disasters and emergencies	[16,24]
	Surveillance and monitoring	Timely information to provide situational awareness and guide action	[16,21,22,24]
	Resources	Ensure dedicated resource capacity and mobilization capability	[16]
	Communication and dissemination	A strategy to transmit clear and coherent messages on the networks, to the public and between organizational levels;	[16,23]
	Learning and assessment	Evaluation as a strategy to build resilience	[16]
	Digital technologies and agile processes	Use of digital technologies for increasing effectiveness and efficiency, and for coherent data system for situational awareness	[16,20,22,23]
	Future studies - strategic foresight	Perform scanning of the environment, scenarios to identify future opportunities and threats; visioning methods; appreciation request; focus on ambidexterity; road mapping; activity plans for long-term strategies	[20,21]
Actors	Collaborative networks	Develop strong relationships, partnerships and networks; relationships between government, community organizations, customers, institutions and other kind of businesses	[16,19,21-23]
	Community involvement	Understanding and engaging with the community; contribution on preparedness process improvement; community as a partner on solutions development, enhancing knowledge through relational capital	[16]
Employees	Workforce capacity	Develop skills and support knowledgeable, skilled and resilient staff; recruitment and conduction to activities according to education, training and professional development pathway	[16,19,23]
	Staff engagement	Commitment to work; sense of belonging; mission valence	[20,21]
	Creativity and solutions for preparedness and innovation	Stimulate the creativity of professionals; produce a favorable climate for innovation in products, services and processes.	[20,21]
	Workers' health and psychological resilience	Investing in actions that contribute to the professional life quality inside and outside work; support to staff needs	[19,20]

Figure 1. STEEP analysis based on PH manager's multidisciplinary perspectives.



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Massive Open Online Courses (MOOCs) as a Facilitator of Organizational Culture for the Implementation of Key Indicators (KPIs)

Nelson Mendes Nunes[1,2*], Ana Paula Bernardo Mendonça[1,2], José Orbílio de Souza Abreu[1,2], Katharine Valéria Saraiva Hodel[3], Bruna Aparecida Souza Machado[1], Fernando Medina[2]

[1]Postgraduate Program in Industrial Management and Technology, SENAI/CIMATEC University Center; [2]Oswaldo Cruz Foundation (FIOCRUZ); 3SENAI Institute of Innovation in Advanced Health Systems; Salvador, Bahia, Brazil

The study is based on literature reviews focusing on Key Performance Indicators (KPIs), organizational culture, and corporate Massive Open Online Courses (MOOCs). Its objective is to identify synergies and intersections related to these themes and provide guidelines for constructing a learning model centered on MOOCs. The findings suggest that MOOCs can contribute to fostering a performance-oriented organizational culture by enhancing technical and adjacent skills, thus aiding in adopting KPIs within organizations. The study proposes a set of guidelines comprising 10 distinct elements for implementing a learning model based on MOOCs.
Keywords: Organizational Culture. Key Performance Indicators. KPIs. MOOCs. Massive Open Online Courses. Corporate MOOCs.

The increasingly complex and globalized business environment necessitates continuous monitoring of organizational performance to remain competitive [1,2]. Key Performance Indicators (KPIs) are crucial for optimizing resource utilization and enhancing organizational outcomes through ongoing improvements [2,3]. However, selecting appropriate KPIs is often challenging and intricate [1,5].

Organizational culture is a significant factor influencing the development, implementation, and utilization of performance indicators [6-8]. It is recognized as a strategic asset and competitive advantage [9,10], playing a vital role in fostering success by cultivating desired behaviors, skills, and attitudes.

Massive Open Online Courses (MOOCs) emerged as a popular form of digital learning, particularly after platforms like Coursera gained prominence in 2012 [11]. MOOCs offer several advantages, such as cost-effectiveness, broad accessibility, flexibility, adaptability, and agility [12-14]. They provide focused, short-term learning opportunities aimed at developing specific skills. Given MOOCs' capacity to enhance technical and adjacent skills, including digital and social skills, they hold the potential to be facilitators for implementing KPIs within organizations. They can influence organizational culture by continuously developing behaviors and attitudes in the workplace at a reduced cost.

This article aims to explore the synergies and intersections among KPIs, organizational culture, and MOOCs through a literature review. It also intends to provide guidelines for constructing a learning model based on MOOCs, assisting Human Resources managers or training program administrators in organizations.

Materials and Methods

The method approach for conducting the literature reviews involved qualitative research to synthesize the findings from selected studies. This process was structured into five distinct steps, as outlined below:

<u>Step 1: Selection of Databases</u>

The first step involved identifying and selecting relevant databases for the literature review process.

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Address for correspondence: Nelson Mendes Nunes. Avenida Orlando Gomes,1845, Piatã. Salvador, Bahia, Brazil. Zipcode: 42701-310. E-mail: nelson.nunes@aln.senaicimatec.edu.br.

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Databases such as the CAPES journals portal and other pertinent academic platforms were chosen to ensure comprehensive coverage of the literature related to KPIs, organizational culture, and MOOCs.

Step 2: Definition of Inclusion and Exclusion Criteria

Clear criteria were established to determine which studies would be included or excluded from the review. Inclusion criteria focused on studies directly related to the corporate context and accessible through the selected databases. Exclusion criteria were applied to studies that did not meet these criteria or lacked relevance to the research topic.

Step 3: Establishment of Search Descriptors

Specific descriptors and keywords were defined to conduct targeted searches within the selected databases. These descriptors were carefully chosen to capture the essential aspects of KPIs, organizational culture, and MOOCs, ensuring relevant literature was identified.

Step 4: Study Selection Process

The selection process involved analyzing the titles and abstracts of identified studies against the predefined inclusion and exclusion criteria. Studies that did not align with the corporate context or were inaccessible through the CAPES journals portal were excluded from further consideration.

Step 5: Full Study Analysis

Selected studies underwent a thorough reading and analysis to extract relevant aspects and identify intersections and synergies among KPIs, organizational culture, and MOOCs. This analysis aimed to identify insights and findings that could contribute to the development of guidelines for implementing a learning model based on MOOCs.

Overall, this methodological approach ensured a systematic and rigorous review of the literature, enabling the synthesis of key findings and the development of actionable guidelines for leveraging MOOCs in organizational learning models.

Table 1 shows the topics studied, the databases consulted, the inclusion criteria adopted, and the descriptors used in the research.

Table 1. Topics, databases, inclusion criteria, and descriptors.

Topics	Database	Inclusion Criteria	Descriptors
KPIs	CAPES journals portal	2017-2022 peer-reviewed articles English	Key performance indicators, kpis, performance indicators, extraction, development, selection, prioritization and identification
Organizational Culture	CAPES journals portal Web of Science Google Scholar Scopus	2017-2022 peer-reviewed articles English	Organizational culture, pharmaceutical industry e performance indicators
MOOCs	Web of Science Scopus Scientific Electronic Library On-line Scielo (SciELO) ERIC	2017-2022 peer-reviewed articles English / Portuguese / Spanish	Corporate university, corporate learning, workplace learning, professional learning, mooc, massive course, massive open online course

Results and Discussion

Data has been identified through the literature review, highlighting synergies, intersections, and other relevant aspects among the themes of KPIs, Organizational Culture, and MOOCs (Table 2).

The primary objective was to address the research question concerning how MOOCs could drive changes in organizational culture to facilitate KPI implementation. Additionally, the study aimed to propose a set of guidelines for developing an "Online, Flexible, and Technology Enhanced."corporate learning model.

Based on the literature, it is evident that assigning technical skills to the development and selection of suitable KPIs is crucial. This necessitates influencing employee behavior to align organizational culture with performance values.

MOOCs, as highlighted Farrow [22], can facilitate this transformation. By serving as a learning model for employee qualification, MOOCs offer cost-saving advantages through their online format, eliminating travel expenses [12-14].

By leveraging MOOCs, organizations can disseminate technical knowledge and foster adjacent skill development continuously, reaching a larger employee base at reduced costs. Given these benefits, MOOCs have the potential to effectively shape organizational culture, aiding in the adoption of appropriate KPIs.

However, critical factors such as a proficient training program planning, well-defined objectives and expectations, and a secure digitalplatform are essential [13].Therefore, adhering to a set of guidelines (Table 3) is vital for creating a learning model that ensures the successful implementation of KPIs and the effective use of MOOCs for employee qualification strategies.

Conclusion

This study delved into the intricate dynamics involving organizational culture, KPI implementation, and employee qualification through MOOCs. Adopting guidelines for implementing an "Online, Flexible, and Technology-Enhanced"

Table 2. Relevant aspects, intersections, and synergies about KPIs, organizational culture, and MOOCs.

Relevant Aspects	Intersections	Synergies
KPIs help to identify gaps between current and desired performance [5,15,16].	One of the factors influencing the development, implementation and use of performance indicators is organizational culture [6-8].	In addition to technical skills, MOOCs promote the development of fundamental skills for the socialization of knowledge [22].
The process of selecting, prioritizing and developing suitable KPIs is a complex and subjective task, so specific technical knowledge is required [5,17-19].	The successful implementation of a measurement program requires a performance-oriented organizational culture [20].	The strategic implementation of MOOCs makes it possible to contribute, among other things, to improving organizational performance [13,14-23].
Due to the dynamics of today's world, both professionals and organizations have invested in continuous qualification and retraining through MOOCs [12].	Performance comes from interdependent behaviors such as cooperation, knowledge sharing and mutual assistance [21].	Organizations are diversifying the options for the hybrid online-to-offline (O2O) training model [14].

Table 3. Guidelines for implementing a learning model based on MOOCs.

Identify the challenges and opportunities related to organizational culture and the implementation of KPIs.
Identify the gaps in knowledge, technical skills (competencies) and what attitudes (adjacent skills) need to be developed [23-24].
Clearly define the objectives, goals and expected results in the course plan [13].
Design focused short courses based on real cases and problem situations [25].
Adopt the hybrid learning model (O2O) [14].
Promote engagement through non-monetary incentives such as participation in special events, courses, meetings, gifts, among others [24].
Enabling adaptable (flexible) learning paths according to participants' needs [25].
Select a learning platform with clear rules on data use and privacy [13].
Implement course evaluation and monitoring indicators [13].
Promote the course openly, without restrictions or prerequisites for the entire organization [13-22].

learning model based on MOOCs could shift organizational culture toward valuing performance monitoring and easing KPI implementation.This is primarily due to MOOCs' capacity for widespread knowledge dissemination and continuous technical and related skills development.

The research uncovered the convergence of KPIs, organizational culture, and MOOCs, identifying barriers, drivers, and practical strategies. It also proposed guidelines for establishing a corporate learning model to assist human resources managers and MOOC developers in transforming training and development programs through technology-driven continuous learning. It is worth noting that the literature review on MOOCs in organizational contexts needs more empirical studies. Therefore, evaluating MOOC initiatives in this context presents a promising area for future research.

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Enhancing Anaerobic Digestion Process: A Comprehensive Optimization Study

Camila Santos Oliveira[1*], Luciano Sergio Hocevar[1], Jadiel dos Santos Pereira[1], Felipe Andrade Torres[1], Carine Tondo Alves[1]
[1]Federal University of Recôncavo da Bahia; Feira de Santana, Bahia, Brazil

Anaerobic digestion constitutes a series of chemical reactions facilitated by anaerobic microorganisms, wherein organic matter is converted into biofuels. We did a bibliometric study to comprehend the factors influencing the optimization of this process. This investigation underscored crucial parameters affecting methane and biogas production: temperature, pH, hydraulic retention time (HRT), carbon-to-nitrogen ratio, and sample preparation and treatment procedures. We recommend an average of parameters as T = 35°C, pH = 6, HRT = 21 days, and total chemical oxygen demand > 8.5 COD/m³.d to attain optimal outcomes, it is recommended to maintain. By adhering to these guidelines, the process can be enhanced, thereby fostering greater efficiency in biogas production.
Keywords: Anaerobic Digestion. Biogas. Biomethanogenesis.

Anaerobic digestion is a metabolic process that decomposes organic matter in an oxygen-free environment. It involves a series of chemical reactions (Figure 1) facilitated by anaerobic microorganisms, which thrive in environments devoid of oxygen [1]. This natural process occurs in specific soils and sediment at the bottom of water bodies where oxygen cannot penetrate. Additionally, it finds practical applications in various industries, such as producing dairy products, beer, ethanol, and silage. Anaerobic digestion also plays a pivotal role in sewage treatment plants (ETEs) and serves as a renewable energy source by generating biogas. The process can be divided into four phases: hydrolysis, acidogenesis, acetogenesis, and methanogenesis [1].

Hydrolysis constitutes a fundamental step in anaerobic digestion, wherein high molecular mass compounds such as lipids, polysaccharides, and proteins are broken down into more straightforward and soluble organic substances (monomers). This pivotal process is facilitated by hydrolytic bacteria that secrete extracellular enzymes [1,2]. When addressing complex and recalcitrant organic matter, hydrolysis is critical in the overall degradation rate and may be considered a limiting factor [3].

Transitioning to Acidogenesis, the monomers produced during hydrolysis serves as a substrate for diverse anaerobic and facultative bacteria, culminating in forming short-chain organic acids. For example, carbohydrates like glucose undergo degradation into pyruvate, subsequently transformed into lactic acid by Lactobacillales and further metabolized into ethanol through yeast action. This intricate series of reactions yields acetate, ammonia, carbon dioxide, and hydrogen sulfide as products [4].

The third stage, executed by a group of bacteria known as acetogens, assumes critical significance in anaerobic digestion. In this phase, long-chain acids are converted into one or two-carbon atom acids, namely formic and acetic acids, concurrently generating hydrogen and carbon dioxide as byproducts. The reaction equilibrium's direction, involving hydrogen and carbon dioxide consumption for acetate production, is regulated by homoacetogenic bacteria [5].

Lastly, methanogenesis represents the ultimate phase and occurs exclusively under anaerobic conditions. During this stage, carbon within the biomass is transformed into carbon dioxide and methane through the enzymatic activity of

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Address for correspondence: Camila Santos Oliveira. Av. Centenário, 697 - Sim. Zipcode: 44085-132. Feira de Santana, Bahia, Brazil. E-mail: camilaoliveira@aluno.ufrb.edu.br.

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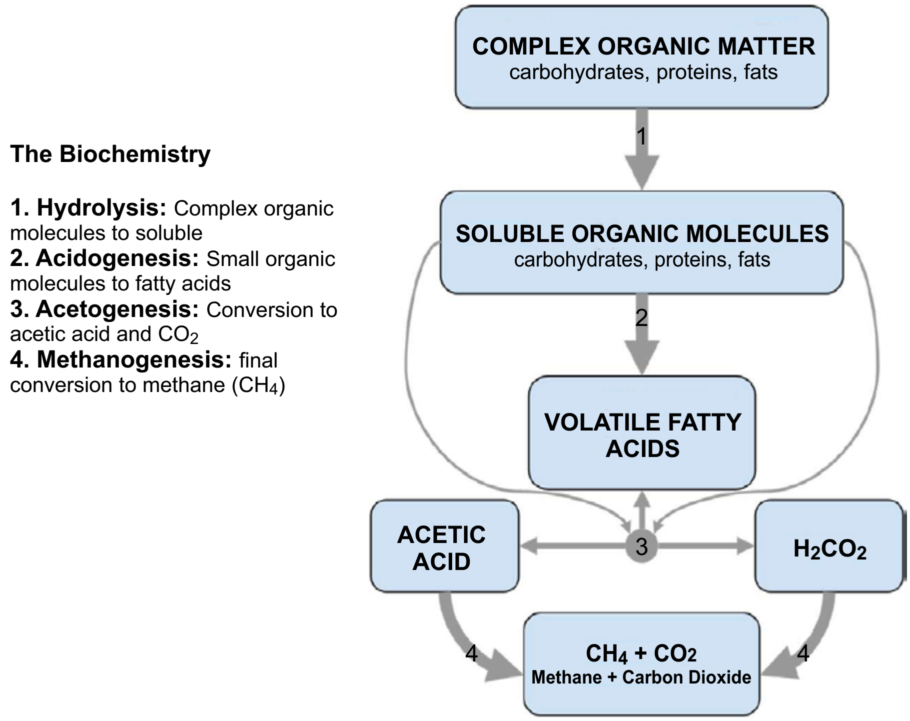
Figure 1. Anaerobic digestion scheme.



methanogenic archaea [6]. Optimizing parameters within the anaerobic digestion process is paramount for maximizing biogas production efficiency. Several vital factors significantly influence the system's performance, including feedstock selection, operating temperature, hydraulic retention time (HRT), pH level, and organic loading rate (OLR). Properly managing and controlling these parameters create favorable conditions for the diverse microbial community responsible for anaerobic degradation. Optimal conditions facilitate the breakdown of complex organic matter into valuable biogas, predominantly methane, thereby enhancing production.

Moreover, fine-tuning these parameters increases biogas yield mitigates process instability and prevents potential inhibition or failure. Effective management and optimization of these factors are crucial for sustainable biogas production, offering a renewable energy source while promoting waste valorization and environmental benefits.

A rigorous exploratory research was conducted to comprehensively understand these influential factors, employing a bibliometric review on the Google Scholar platform. This systematic investigation utilized carefully selected keywords, specifically "anaerobic digestion AND optimization." The study analyzed a wide range of scholarly articles, publications, and academic resources by employing bibliometric techniques.

This approach synthesized and analyzed relevant and up-to-date information regarding anaerobic digestion process optimization, revealing crucial insights and trends in the field. Using Google Scholar, a reputable academic search engine, ensures access to a diverse array of scholarly works, contributing to the robustness and validity of the research findings.

Materials and Methods

A bibliometric search was conducted on Google Scholar using the search terms "anaerobic digestion AND optimization." The search encompassed a broad timeframe without specific publication date restrictions, facilitating a comparison between newer and older information. The results returned 11,100 articles in Portuguese and 235,000 articles in English. Among these, the top 10 articles from each search, ranked by relevance, were selected for further analysis. Remarkably, all the top 10 articles from the Portuguese search were authored in Brazil. In comparison, 50% of the top 10 articles from the English search originated from Asia, with the remainder originating from North America and Europe. In this review, article selection criteria were based on relevance, as determined by the platform and their alignment with the proposed research theme.

The abstracts of the top 10 articles from each search were meticulously examined, and those deemed most pertinent to the research were included in this review, while others were excluded. The excluded articles focused on related subjects, particularly optimizing anaerobic digestion using algorithms.

Results and Discussion

A series of biodigestion experiments should be conducted, where all other variables are kept constant while selectively altering the parameter under scrutiny. This approach allows for the comprehensive assessment of the variables that significantly influence optimal reactor production

The bibliometric review encompassed publications presenting outcomes of studies within this genre, elucidating various investigations in this area. Throughout biodigestion experiments, crucial data are collected and analyzed to comprehend how specific factors influence reactor performance.

These factors may include temperature, pH levels, organic loading rate (OLR), hydraulic retention time (HRT), and the type of feedstock used. Researchers can derive valuable insights into their effects on biogas production efficiency and the overall process by systematically changing and observing these variables.

Through this bibliometric review, a significant volume of pertinent literature was surveyed, presenting diverse findings from various studies focused on optimizing reactor performance. Examining these publications enables researchers and practitioners to comprehensively understand the key factors influencing biodigestion and identify successful strategies for enhancing biogas yields and process stability (Table 1). With access to the data and outcomes of these biodigestion experiments through the reviewed publications, future researchers and industry professionals can leverage a wealth of knowledge to effectively optimize their reactor systems and contribute to the sustainable utilization of anaerobic digestion for biogas production.

Leite and colleagues [7] conducted a study to ascertain the most influential parameters for anaerobic co-digestion of cassava wastewater and coffee husks, utilizing bovine manure as an inoculum. Over 15 days, the researchers monitored biogas production from the mixture of inoculum and substrate, incorporating micronutrients into the process. Employing a Büchner flask as a reactor equipped with a gasometer coupled to a PVC hose, separate tests were conducted to evaluate the impact of various variables on reactor optimization.

The findings underscored the significance of both physical reaction conditions, such as acidity and temperature, and the concentrations of the inoculum and substrate, alongside nutrient addition. Through rigorous analysis, optimal values for the process were determined: 40 mL of cassava wastewater, 95 mL of coffee husks, and 40 mL of bovine manure. Maintaining a pH of 6 was identified as crucial, adding 1.5x106 UFC. mL^{-1} of bacterial inoculum and a temperature of 30°C Additionally, including 46.97 $mg.L^{-1}$ of $FeSO_4.7H_2O$ and 4.41 $mg.L^{-1}$ of $MnSO_4.H_2O$ proved beneficial for maximizing biogas production.

These results illuminate the intricate interplay of various variables in anaerobic co-digestion processes, emphasizing the importance of optimizing substrate and inoculum concentrations, physical reaction conditions, and nutrient supplementation. By identifying these optimal values, the study offers valuable insights for enhancing biogas production efficiency and guiding future research in biogas technology.

Reichert [8] conducted a comprehensive study investigating the correlation between various key variables in anaerobic digestion, focusing on waste composition, volatile solids, feed rate/organic load rate (TCO), pH, temperature, Carbon/Nitrogen ratio, mass residence time in the reactor, and reactor mixture. Reichert continuously analyzed several ETE reactors, utilizing sewage from different treatment plants as inoculum and organic material as substrate without additional additives. The study provided crucial insights into factors significantly influencing anaerobic digestion, identifying optimal points for these variables. TCOs above 8.5 COD/m³.d were advantageous for enhanced biogas production, along with the use of organic wet residues with lower lignin and cellulose content, leading to a higher rate of biodegradable volatile solids.

The pH range of 5.5 to 8.5 and temperature between 30 °C and 35 °C were conducive to maximizing biogas production. A Total Hydraulic Retention (THR) of 14 days was ideal for digestion. Additionally, the study assessed the advantages and disadvantages of each reactor type used, providing valuable insights into suitable reactor configurations for specific applications.

Reichert's [8] study significantly advances our understanding of anaerobic digestion processes by elucidating critical variables and their optimal points. The findings offer practical guidelines for optimizing biogas production, which is essential for developing more efficient and sustainable waste treatment systems.

In another study by Deodato [9], WWTP sludge was used as inoculum and a hydrolyzate of the Organic Fraction of Urban Solid Waste along with pure glycerol and glycerol of industrial origin as substrate. Methanogenesis reactors were employed, and parameters including temperature, pH, and redox potential were measured over 6 months, with a Total Hydraulic Retention (THR) of 21 days. Co-digestion with pure glycerol showed potential for achieving an optimized carbon/nitrogen ratio, which is theoretically advantageous for maximizing biogas production. The study demonstrated promising results, with biodegradable volatile solids reaching approximately 6% m/v ST and about 4.5% m/v SV.

Deodato's [9] research contributes valuable insights into anaerobic digestion, particularly in co-digestion with glycerol-based substrates. The findings underscore the importance of exploring diverse substrates and inoculum combinations to enhance biogas production efficiency, promoting sustainable waste treatment solutions. These studies collectively play a pivotal role in advancing renewable energy production and waste management practices worldwide.

Several works have predominantly focused on algorithmic optimization and code construction. In cases where experimental data were provided, they often presented qualitative and quantitative information from reviews rather than experimental research. However, certain studies, such as the one conducted by Meegoda and colleagues [10], delved into essential variables such as chemical oxygen demand, carbon-nitrogen (C/N) ratio, theoretical methane yield, volatile solids, hydraulic retention time (HRT), total solids, temperature, and mass pre-treatment. Optimal points identified in their study included C/N ratios of 25:1 for mesophilic digesters and 35:1 for thermophilic digesters, HRT between 15-30 days, pH levels between 5-7, and temperatures ranging from 30-50 ºC. Similarly, Bandgar and colleagues [11] addressed the importance of temperature, C/N rate, organic load rate, HRT, pH, and alkalinity in controlling the anaerobic digestion process.

However, explicit parameters were not established in their review article. Conversely, Srivastava [12] considered a range of AD process optimization variables, including pH, temperature, supply rate, C/N rate, solids liquids rate, alkalinity, HRT, fixed and volatile solids, number of stages, sludge characteristics from sewage treatment plants (WWTP), and substrate pre-treatment, with an HRT of 40 days.

Table 1 compares the most cited parameters standard to many articles. A relatively large discrepancy can be observed in the recommended temperature ranges. This variation arises from the different experimental regimes used, i.e., mesophilic or thermophilic, which promote the proliferation of distinct bacterial communities at varying temperatures. Additionally, authors who mentioned the addition of a catalyst noted its beneficial effect on methane production. Deodato [9] worked with manure and others using sewage treatment plant waste in their studies.

Temperature exerts a significant influence on the anaerobic digestion process. Firstly, it directly correlates with the composition of the active microbial consortium, as each species thrives within a specific temperature range. Two main ranges are recognized: Mesophilic, spanning 20–45 °C, and Thermophilic, ranging from 45–0 °C, with optimal values cited as 35 °C and 55 °C, respectively. Elevated temperature accelerates reactions, consequently enhancing biogas production.

Furthermore, temperature impacts reactor acidity. Decreased temperature leads to higher volatile acid concentrations, potentially reducing the anaerobic process's buffering capacity and lowering pH. pH fluctuations significantly affect anaerobic digestion microorganisms, particularly methanogenic bacteria, are susceptible to extreme acidity. Thus, maintaining pH stability is imperative [7]. However, Deodato [7] notes that the pH range may be adjusted depending on the reaction phase, creating a favorable environment for specific microorganisms. For instance, maintaining a pH range of 5.5 to 6.5 during acidogenesis facilitates initial acid formation, while a range of 6.5 to 8.2 during acetogenesis and methanogenesis optimizes subsequent reaction phases. Hydraulic retention time (HRT) denotes the duration of liquid remains in the reactor, representing the time required for complete substrate digestion. It is computed as the ratio of digester volume to flow rate. Shorter HRTs are less efficient for lignocellulosic material digestion but are cost-effective [11].

Leite and colleagues [7] incorporated $FeSO_4.7H_2O$ and $MnSO_4.H_2O$ into their reactor as nutrients, providing sustenance for microbes. Adding nutrients can bolster microbial growth, enhancing anaerobic digestion by improving carbon and nutrient balance. There are optimal dosages for such additions, as excessive metals can become inhibitory or toxic. However, the study revealed that the highest CH_4 yields were achieved at high and low concentrations.

Deodato [9] utilized pure glycerol and glycerol of industrial origin. Glycerol inherently possesses high biodegradability and carbon content, achieves an optimized Carbon/Nitrogen

Table 1. Parameters that appeared most frequently and their values.

Authors	Temperature (°C)	Catalyst	pH	HRT	Reference
Leite and colleagues	30	$FeSO_4.7H_2O$ $MnSO_4.H_2O$	6	15	[7]
Reichert GA	30 – 35	-	5,5 – 8,5	14	[8]
Deodato AM	50 ± 1	Pure glycerol	6,5 – 8,2	21	[9]
Meegoda and colleagues.	30 – 55	-	5 – 7	15 - 30	[10]
Bandgar and colleagues	35 – 55	Biochar	5,5 – 6,5	-	[11]
Srivastava SK	19.85	-	~8	30 – 40	[12]

ratio theoretically, facilitating enhanced biogas production.

Bandgar [11] employed Biochar, a form of biomass originating from plant material processed through pyrolysis. Biochar is rich in monovalent and divalent cations, accelerating carbonation reactions between CO_2 and water and forming carbonic acid. Its high porosity and extensive contact surface also enable it to serve as a CO_2-sequestering medium during anaerobic digestion.

Conclusion

The bibliometric review has proven highly effective in identifying relevant articles pertinent to the study. From the extensive literature surveyed, several critical parameters have emerged as pivotal for optimal Anaerobic Digestion (AD) process performance. These parameters encompass temperature, pH, Hydraulic Retention Time (HRT), Carbon/Nitrogen (C/N) ratio, sample preparation, and treatment procedures. It is advisable to adhere to average values for these identified parameters to enhance the efficacy of AD processes. Specifically, maintaining the temperature at 35 °C, pH at 6, HRT of 21 days, and Total Chemical Oxygen Demands (TCOs) above 8.5 COD/m³.d can significantly improve outcomes.

To further advance our comprehension and practical implementation, it is proposed that future studies focus on analyzing the efficiency of the suggested processes for each specific variable. Conducting practical experiments enable researchers to gain valuable insights into the impact of these parameters on biogas production and the overall process optimization. Overall, the findings from this bibliometric review offer valuable guidelines for optimizing AD processes, providing a foundation for further research and application in the field. By considering and fine-tuning these key parameters, we can enhance the efficiency and sustainability of biogas production, thereby contributing to a more environmentally friendly waste management solution.

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Characterization of Sludge for Biogas Production Using Anaerobic Digestion: A Literature Review Approach

Evily Ribeiro Moura[1*], Val Machado[1], Luciano Sergio Hocevar[1], Jadiel dos Santos Pereira[1], Felipe Andrade Torres[1], Carine Tondo Alves[1]
[1]*Federal University of Recôncavo da Bahia;Feira de Santana, Bahia, Brazil*

This article conducts bibliographic research to characterize sludge for biogas production. The focus is on identifying key components such as organic matter, nutrients, pH, and chemical composition. Additionally, parameters such as the carbon/nitrogen ratio, inhibitory compounds, and biological activity are explored to assess their impact on anaerobic digestion performance. This bibliographic approach seeks to establish optimal parameter ranges for sludge utilization in biogas production. By comprehensively understanding the composition and properties of the sludge, this study contributes to enhancing the efficiency and effectiveness of anaerobic digestion processes.
Keywords: Sludge. Biogas. Anaerobic Digestion.

The process of globalization has significantly impacted the environment, presenting both challenges and opportunities. However, it has also facilitated increased interconnectivity between nations, fostering knowledge sharing to address global environmental issues. In 1995, the Conference of the Parties (COP) was established as an annual meeting for signatory countries of the United Nations Framework Convention on Climate Change (UNFCCC), with the primary objective of achieving greenhouse gas emissions neutrality in the atmosphere within a timeframe that allows for the natural adaptation of terrestrial ecosystems. Noteworthy accomplishments of the COPs include the adoption of the Kyoto Protocol in 1997, which currently boasts adherence from 192 countries, and adopting the Paris Agreement in 2015, with participation from 196 countries [1]. Implementing technological waste management and bioenergy recovery mechanisms is vital in mitigating greenhouse gas emissions and promoting the transition to a circular economy [2]. Among the various clean and renewable energy sources, biogas has emerged as a prominent contender. Biogas can be utilized in electric power generators and refined into biomethane, a promising alternative to conventional vehicular natural gas (CNG) for light vehicles and cargo transport trucks [3].

Biogas production is derived from a biological process known as anaerobic digestion (AD). This process involves the synergistic action of anaerobic microorganisms, whether strict or facultative, to decompose complex organic molecules present in waste, such as carbohydrates, proteins, and lipids, primarily resulting in the production of methane (CH_4) and carbon dioxide (CO_2) [4]. The AD process occurs in four phases: hydrolysis, where lipids, polysaccharides, and proteins are broken down; acidogenesis, where hydrolysis byproducts are transformed into more minor short-chain compounds like butyric, propionic, and acetic acids, alcohols, nitrogen oxides, hydrogen sulfide, hydrogen, and carbon dioxide; acetogenesis, where the acids from the the previous phase is further converted into one- or two-carbon atom acids like formic and acetic acids, hydrogen, and carbon dioxide; and finally, methanogenesis, where methane is produced through the activity of methanogenic archaea, utilizing the carbon present in the biomass. Figure 1 illustrates different sources of organic matter for biogas production.

To enhance the performance of the anaerobic digestion (AD) process, studies are undertaken to

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Address for correspondence: Evily Ribeiro Moura.Av. Centenário, 697 - Sim. Zipcode: 44085-132. Feira de Santana, Bahia, Brazil. E-mail: evilymoura@aluno.ufrb.edu.br.

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Figure 1. Sources of organic matter.

elucidate the influence of process parameters on the degradation of organic matter and biogas production. These parameters encompass temperature, pH, nutrients, and the Carbon/Nitrogen ratio. Moreover, endeavors are made to surmount inhibitory factors that impede anaerobic microorganism activity. The primary objective of these studies is to investigate the operational conditions of the AD process, ultimately aiming to maximize efficiency and biogas production. This article distinguishes itself by aspiring to conduct a comprehensive bibliographic study on global advancements in biogas production through anaerobic digestion, with a specific emphasis on inoculum development (sludge).

Materials and Methods

Anaerobic digestion is a widely acknowledged and sustainable approach for converting organic waste into valuable biogas. The effective operation of anaerobic digesters hinges upon various factors, prominently the characterization of sludge. Such characterization is pivotal in comprehending its composition and properties, which influence biogas production's efficiency and productivity.

The present study adopts a systematic approach to identifying and analyze pertinent literature sourced from diverse scientific databases, including but not limited to ScienceDirect, Scielo, Scopus, and Web of Science. Employing a search strategy encompassing keywords such as "co-digestion" and "biogas," this methodology not only enriches the research process but also bolsters the quality and reliability of the study's findings, thus contributing to the advancement of knowledge in the field of anaerobic digestion for sustainable biogas production.

The scarcity of studies unearthed on the topic of co-digestion and biogas within the selected databases underscores a gap in the existing literature. However, this paucity offers an opportunity to focus on a specific aspect, such as the role of sludge in achieving high-efficiency anaerobic digestion. By narrowing down the study's scope, it becomes feasible to delve deeper into this particular area and potentially furnish new insights or perspectives.

Results and Discussion

An essential aspect of sludge characterization involves determining its chemical composition. This encompasses analyzing the content of organic matter, nutrients, and trace elements in the sludge. Organic matter is a substrate for microbial activity during anaerobic digestion, while nutrients such as nitrogen and phosphorus are crucial for microbial growth and metabolism [5]. Moreover, trace elements, including iron, cobalt, and nickel, can be cofactors for specific enzymes involved in the anaerobic degradation process [6].

Physical characteristics of the sludge, such as particle size

distribution, settleability, and moisture content, also significantly impact

biogas production. Particle size distribution influences the accessibility of microorganisms to organic matter, thereby affecting the degradation rate. Well-settling sludge facilitates the practical separation of solids, ensuring efficient retention time and contact between biomass and substrate [7]. Additionally, the moisture content of the sludge influences the overall digestion process, with optimal moisture levels promoting microbial activity and gas production [8].

Furthermore, the microbial community present in the sludge plays a pivotal role in anaerobic digestion. The diversity, abundance, and metabolic capabilities of microorganisms profoundly impact the efficiency of biogas production. Various microbial groups, including hydrolytic, acidogenic, acetogenic, and methanogenic bacteria, collaborate synergistically to convert complex organic compounds into biogas [9]. Understanding the microbial community structure through molecular techniques like DNA sequencing can provide insights into microbial dynamics and aid in optimizing the digestion process [10].

The selection of the inoculum and substrate is a critical factor that significantly influences the performance of anaerobic digesters [11]. "Inoculum" refers to a specific set of bacteria selected from the ecosystem and introduced into the system, along with the initial quantity used during operation. The inoculum plays a vital role in reducing the lag phase of the system, which is the period during which microorganisms adapt to the environment before initiating multiplication. Utilizing an appropriate inoculum helps prevent issues related to the accumulation of substances that inhibit microbial development at different stages of anaerobic digestion. When the inoculum is well-suited to the substrate employed in the process, it establishes synergy more rapidly, leading to quicker stability in biogas production [11]. pH is one of the critical factors that significantly influences biogas production in anaerobic digestion when using sludge as the inoculum [12]. Research has demonstrated that pH variations can affect the system differently, as different groups of microorganisms respond diversely to pH changes. The optimal pH range for this process, as indicated by studies on chicken waste, is between 6.7 and 7.5. Methanogenic archaea, crucial for biogas production, are particularly sensitive and function best within this pH range.

Different pH levels will result in the production of specific compounds. Lower pH values lead to the production of acetic and butyric acids, while a pH close to 8.0 produces acetic and propionic acids [12]. The decomposition of organic matter in anaerobic digestion occurs through various phases, and facultative and strictly anaerobic microorganisms play vital roles in breaking down organic molecules of different complexities. These microorganisms form an ecosystem that can thrive in a balanced state without exposure to toxic environments [13]. Table 1 presents some characteristics, and Table 2 presents some properties of the aerobic digestion steps.

The pH control mechanism in anaerobic digestion is intricately linked to carbon dioxide (CO_2) and bicarbonate concentration. A significant decrease in pH prompts more CO_2 dissolution in the medium, while an increase in pH leads to CO_2 dissolving to form carbonic acid, subsequently releasing hydrogen [1]. Achieving pH control necessitates an appropriate ratio between intermediate alkalinity,

Table 1. Steps and characteristics of the aerobic digestion process [8].

Step	Characteristics
Hydrolysis	The AD process's initial phase involves converting complex organic matter, such as carbohydrates, proteins, and lipids, into simpler compounds like sugars, amino acids, and peptides. One material is converted into another through the action of exoenzymes excreted by hydrolytic fermentative bacteria.
Acidogenesis	The step is in which acidogenic fermentative bacteria convert organic matter from hydrolysis into several more straightforward products. These products include volatile fatty acids (VFAs), H_2, CO_2, acetate, glucose, alcohols, lactic acid, NH_3, and H_2S. These bacteria are called acidogenic because AGVs are the primary metabolic products they produce.
Acetogenesis	Acetogenic bacteria play a crucial role in the breakdown of products formed by acidogenic bacteria. These acidogenic bacteria are responsible for degrading at least 50 % of the biodegradable Chemical Oxygen Demand (COD), converting it into propionate and butyrate.
Methanogenesis	Methanogenic Archea plays a crucial role. Depending on the species, these Archea can use acetate to produce CH_4 and CO_2, or they can consume H_2 and CO_2 to form CH_4. In addition to these substrates, methanogenic Archeas can utilize formic acid, methanol, methylamines, and CO. Although they represent a smaller proportion of the other methanogenic Archea species, the acetoclastic are normally the predominant microorganisms in AD and are responsible for approximately 60 to 70 % of all CH_4 production.

provided by bicarbonate alkalinity, and partial alkalinity, determined by the alkalinity of volatile acids. This control mechanism facilitates the correction of pH fluctuations within the reaction [2].

The composition of nutrients in the inoculum is another critical consideration for anaerobic digestion. Anaerobic microorganisms rely on nutrients like phosphorus, nitrogen, and sulfur for proper digestion. The presence of sulfur ions, potassium, calcium, magnesium, chlorine, and sulfate is necessary for optimal microbial function [12]. Additionally, nutrients such as copper, iron, magnesium, molybdenum, vanadium, and zinc are essential for microbial growth. However, specific ions like Cu^{++}, Zn^{++}, alkali metal, alkaline earth metal ions, and NH_4^+ can act as inhibitors [12]. Sulfur compounds may precipitate nutrients, resulting in harmful copper, iron, molybdenum, and nickel levels.

The Carbon/Nitrogen (C/N) ratio is a crucial aspect of substrate composition, directly impacting biogas production and forming desirable bacterial cells. An ideal C/N ratio falls between 20 and 35, ensuring a balanced environment. Carbon molecules in the substrate play a pivotal role in methane formation. However, a high C/N ratio may impede bacterial cell renewal and formation due to limited nitrogen availability. Conversely, a low C/N ratio combined with excessive ammonium (NH_4) can create a toxic environment for the microbial community during anaerobic digestion. Furthermore, the presence of nitrite significantly affects the substrate solubilization, hydrolysis, and organic acidification due to its redox properties.

Temperature is another influential factor affecting microbial growth, sludge characteristics,

Table 2. Characterization of inhibitors.

Operational Conditions	Characteristics	Reference
Temperature (°C)	25-35 hydrolysis	[12]
	25-35 acidogenesis	
	32-42 methanogenesis	
ph	6.7-7.5	[11]
C:N	Hydrolysis and Acidogenesis 10-45	[12]
	Methanogenesis 20-30	
S	1-25 mg S\L	[14]
Temperature for growth of microorganisms	Thermophiles 60°C	[12]
	Mesophilic 37°C	
	Psychrophiliacs 15°C	
AI/AP Ratio	Overload reactor >0.4	[12]
	Optimal Range 0.3-0.4	
	Underload reactor <0.3	

substrate solubility, and ionic balance. Bacterial growth and metabolic activity are temperature-dependent, influencing the quantity and types of biogases produced [15]. Light metal ions, such as calcium, magnesium, potassium, and sodium, are also prevalent in anaerobic digestion. These ions can be released during organic matter degradation or utilized for pH adjustment and microbial growth [10]. However, their effects can vary based on concentration, potentially inhibiting or delaying growth and exhibiting toxicity towards the inoculum. Table 3 presents an overview of metals in aerobic digestion and their causes and effects [10].

Indeed, sludge characterization is indispensable for biogas production through anaerobic digestion. We examined sludge's chemical composition, physical attributes, and microbial composition, yielding crucial insights for optimizing processes, formulating substrates, and controlling operations. This understanding of sludge's distinct features empowers operators and researchers to improve the efficiency and reliability of anaerobic digesters, thereby maximizing biogas production from organic waste.

Conclusion

Sludge characterization is a pivotal aspect in the quest for efficient biogas production through anaerobic digestion. Through meticulous research and analysis, we have garnered invaluable insights into the requisite attributes of sludge and refined its utilization. Our findings underscore the imperative of conducting a comprehensive assessment of sludge, considering factors such as pH, nutrient composition, and temperature. The pH level of sludge profoundly influences the phases and metabolic processes of microorganisms engaged in biogas production. A nuanced understanding of pH requisites and their interplay with acidogenesis is paramount for optimizing biogas yield. Moreover, the availability of essential nutrients, notably carbon and nitrogen, assumes critical significance as they serve as sustenance for microbial

Table 3. Light metal ions, causes, and effects [10].

Metal ions	Causes	Effects
Aluminum	Competition with iron and manganese or their adhesion to the microbial cell membrane or cell wall.	It may affect microbial growth.
Calcium	Carbonate and phosphateprecipitation.	Fouling reactors and pipes, fouling biomass, reducing methanogenic activity, losing buffering capacity and essential nutrients for anaerobic degradation.
Magnesium	Stimulate the production ofindividual cells.	Inhibition of the growth of microorganisms, loss of acetoclastic activity.
Potassium	Passive influx of potassium ions that neutralize the membrane potential, extractors for metals bound to exchangeable sites in the sludge.	The most pronounced inhibitory effect is in the thermophilic temperature range.

populations. A balanced ratio of these nutrients is indispensable for fostering optimal microbial activity. Excessive nutrient levels can precipitate the accumulation of free ammonia, impeding reactions and hampering biogas production. Temperature emerges as a pivotal determinant in microbial proliferation and activity. Maintaining an optimal temperature range supports robust microbial function, ensuring efficient biogas generation. Vigilant monitoring and stringent temperature control throughout the anaerobic digestion are imperative for nurturing stable microbial communities and fostering biogas production. To uphold the standards of high-quality biogas production, meticulous sludge analysis prior to commencing anaerobic digestion is imperative. Furthermore, continuous monitoring throughout the reaction period is indispensable to evaluating and upholding desired production parameters. By steadfastly implementing these measures, we can augment the efficiency and efficacy of biogas production, heralding a transition towards a more sustainable and renewable energy paradigm.

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Development of Hydrophobic Fabrics Modified with Graphene: A Systematic Review

Rodrigo Denizarte de Oliveira Polkowski[1*], Pollyana Silva Melo[1],
Leonardo Freitas[1], Katielly Vianna Polkowski[1]
[1]*TRL9 TECH Research and Experimental Development in Physical and Natural Sciences Ltda; Salvador, Bahia, Brazil*

Pursuing fabric with hydrophobicity and self-cleaning properties has been a focal point across various applications. Graphene has emerged as a prominent contender for fabric modification to augment hydrophobicity. This study endeavors to conduct a systematic review of fabrics imbued with graphene for hydrophobic applications, concentrating on the most recent five years and employing the PRISMA method (Preferred Reporting Items for Systematic Reviews and Meta-analyses). Articles were curated from reputable databases, including Scopus, Web of Science, and Science Direct. Following meticulous inclusion/exclusion criteria, thirty-seven studies were deemed eligible for inclusion in the review.
Keywords: Graphene. Fabric. Textile. Hydrophobic. Nanocomposite.

In recent years, nanotechnology has allowed the incorporation of nanoparticles into multifunctional textiles, adding new physical and chemical characteristics to fibers, threads, and fabrics. Fabrics with hydrophobic properties similar to lotus leaf surfaces have recently drawn the attention of researchers due to their significant potential for scientific and industrial applications [1-3].

Graphene has stood out recently due to its remarkable properties, such as fracture resistance, thermal conductivity, impermeability, and hydrophobicity. In addition to these applications, a wide range of graphene applications includes electrical conductivity [2-4], usage as flame retardants [5], energy storage and conversion [6], dye removal [7], and antibacterial function [8]. However, applying graphene to a polymeric matrix (fabric) remains a significant challenge for researchers, particularly when considering high-scale production and low cost.

PRISMA, a reporting guideline for systematic reviews and meta-analyses, was developed to improve reporting quality. It helps plan and document review methods [10]. Systematic reviews synthesize knowledge in afield, identifying research gaps and evaluating theories [11,12]. Our study systematically reviews graphene coated fabrics for hydrophobic applications, focusing on graphene incorporation into fibers and its uses. We consider publications from 2018 to 2023.

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Address for correspondence: Rodrigo Denizarte de Oliveira Polkowski. Rua Mundo, No. 121, 409C, Bahia Technology Park, Trobogy, Salvador - BA, Brazil, Zipcode 41745-715. E-mail: rodrigo@trl9.tech.

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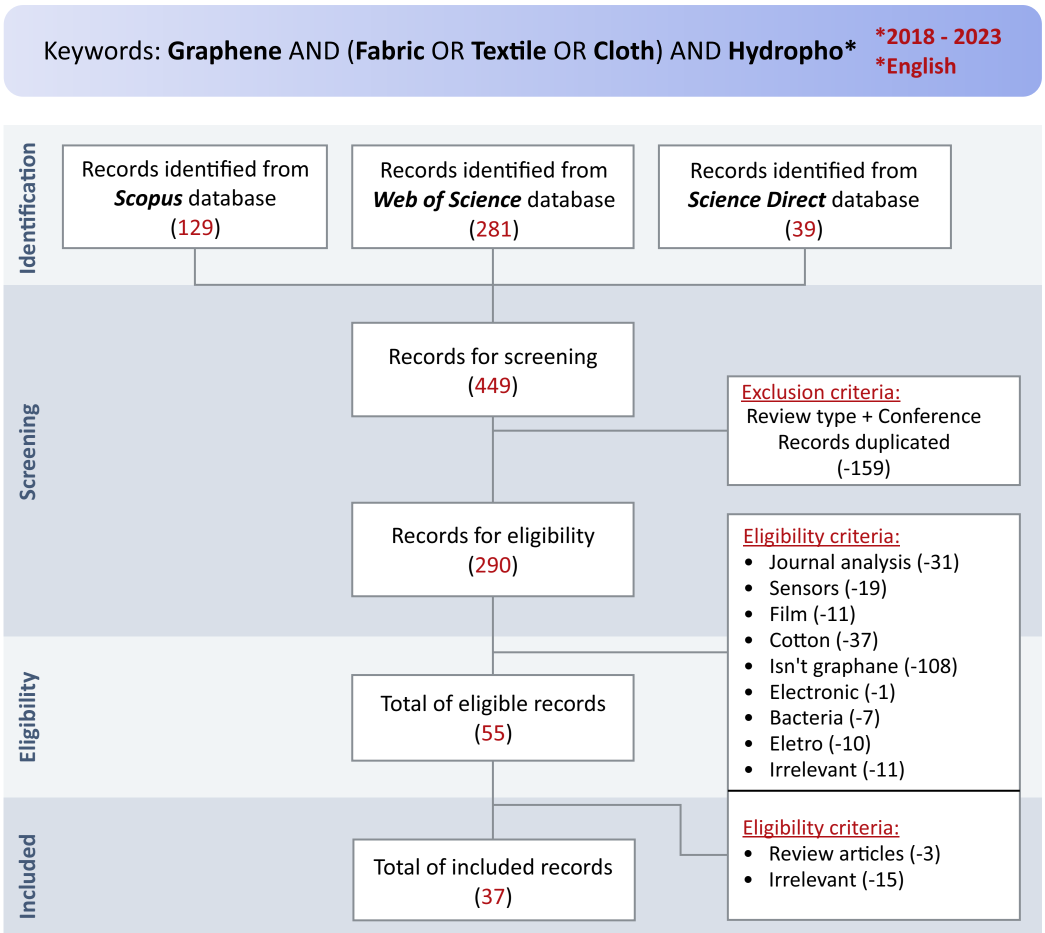
Materials and Methods

In this study, we performed a systematic review using the PRISMA method [10]. We searched Scopus, Web of Science, and Science Direct for articles in English published between 2018 and 2023, using keywords like graphene, fabric, textile, cloth, and hydrophobic. lnitially, we found 449 studies. Two reviewers independently assessed the relevance of titles and abstracts, excluding conference papers, review studies, and duplicates (159), resulting in 290 studies for further analysis. Figure 1 depicts the study selection process following PRISMA guidelines.

After the initial selection, exclusion criteria were applied based on the absence of graphene impregnation (108), studies related to sensors (19), films (11), electronics (1), biological applications (7), and electronic devices (10), resulting in a total of 55 studies deemed relevant to the subject under analysis. The identified articles underwent independent evaluation of their titles and abstracts to assess their suitability, leading to a total of 37 articles that were included in this study.

Figure 1. Systematic review flowchart according to the PRISMA protocol.



Results and Discussion

Figure 2 presents a graph containing data obtained through the PRISMA protocol, showing an increase in studies related to fabrics coated with graphene over the last five years. Until this research, when the data was compiled, there were already 3 articles in this area, and more studies are expected. The highest number of studies was recorded in the years 2019 and 2022. ln 2019, there was an increase of approximately 122% compared to the previous year, while in the period from 2020 to 2021, the number of registrations remained the same as in 2018. The most significant increase in registrations was identified in 2022, with a 155% increase compared to 2018, 2020, and 2021.

The systematic review focused on evaluating graphene synthesis methods, particularly emphasizing the chemical reduction of graphene oxide (GO) for fabric applications. Among the reviewed studies, GO was prevalent, featuring 25 studies related to hydrophobic fabrics, while other types of graphene (sheets, reduced, and quantum) were identified in 12 studies. GO is distinguished by its numerous oxygen-based functional groups on its surface, providing active sites for chemical functionalization and developing specific properties. The synthesis of GO can be achieved through three primary methods: Brodie's, Staudenmaier's, and Hummer's methods, with the latter being the most frequently cited in this study [2,4,13-18]. The studies were further categorized

Figure 2. Studies published in this systematic review by (a) year since 2018, (b) year since 2008, and (e) by graphene type.

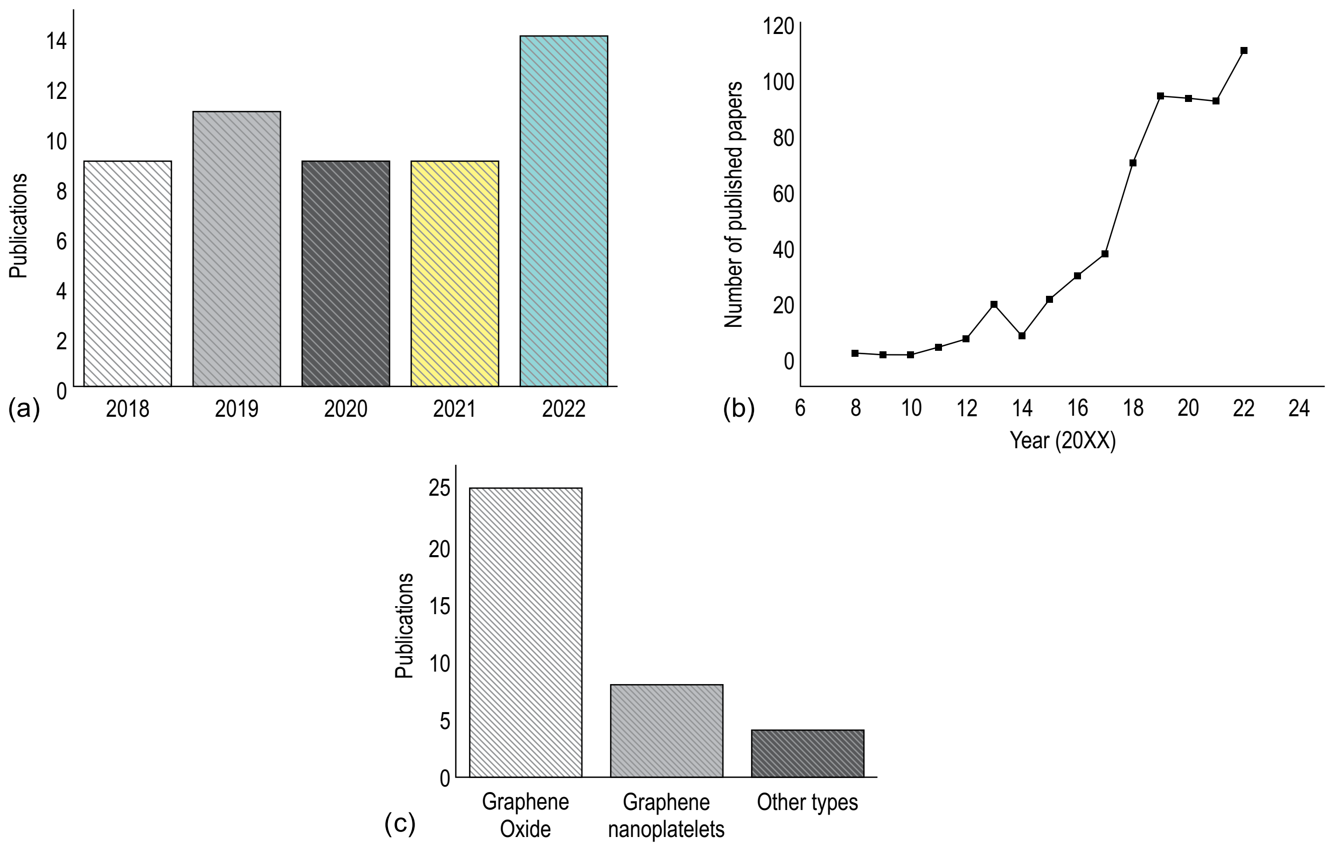
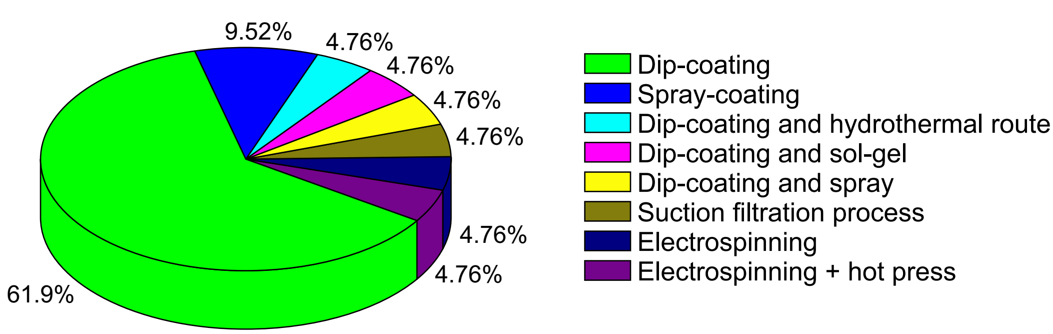


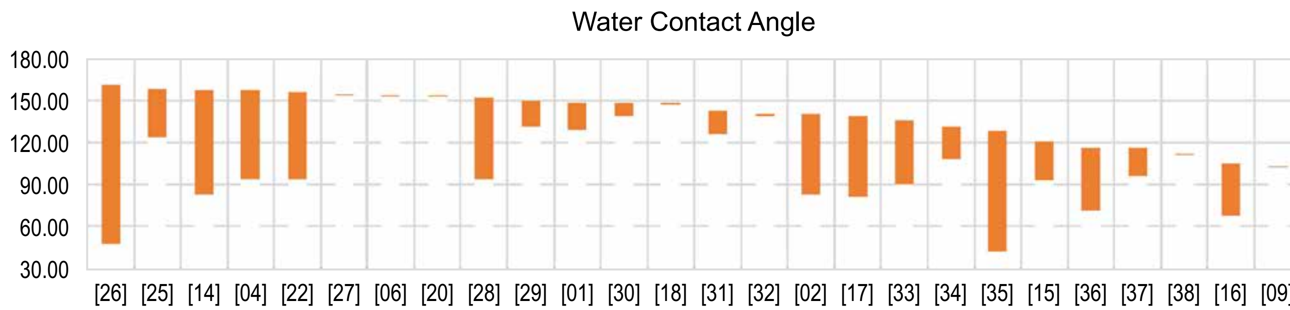
Figure 3. Studies published in this systematic review by application method.



based on the method of graphene application onto the fabric surface, with the dip-coating technique emerging as the most commonly mentioned (15 studies) due to its efficacy in achieving aligned and layered structures for high-quality coatings (Figure 4).

Dip-coating is a widely utilized process for dyeing, printing, or applying various chemical finishes to textile materials such as fabrics, knits, yarns, and nonwovens. This technique has gained prominence in fabric applications owing to its simplicity, strong adhesion, easy availability, and potential for large-scale production [1,5,6,19-23]. Fang and colleagues (2019) studied the preparation of glass fibers coated with graphene and high electrical conductivity through the sol-gel and dip-

Figure 4. Studies published in this systematic review by water contact angle.



coating techniques, and they reported that the dip-coating method achieved the best properties [16].

The studies included in this systematic review employed various analyses, such as scanning electron microscopy (SEM), thermogravimetry (TGA), Fourier-transform infrared spectroscopy (FTIR), dynamic mechanical analysis (DMA), X-ray diffraction (XRD), and X-ray photoelectron spectroscopy (XPS), to evaluate the efficiency of graphene incorporation into the fabric's structure. However, these studies' primary property and objective were hydrophobicity. The "Lotus Effect," described by Oles and colleagues (2000), refers to the physical properties that characterize a superhydrophobic and self-cleaning surface. This property is typically assessed through contact angle analysis, where a contact angle less than 90º indicates a hydrophilic surface, meaning the liquid can wet it. Conversely, a contact angle greater than 90º indicates a hydrophobic surface, with a contact angle exceeding 150º termed superhydrophobic. In this systematic review, 35 studies evaluated hydrophobicity through contact angle measurements. Figure 5 illustrates the relationship between the highest contact angle values achieved after the incorporation or coating of the fabric with graphene.

Out of the total of 35 studies that evaluated the contact angle of the fabric after graphene modification, 28 studies successfully modified the fabric surface to achieve a hydrophobic classification [1,2,3,6,9,14-18,20,22,25-38].

Various resin matrices, including PET, PU, PP, and polyester, were examined in multiple studies. The focus was on functionalizing graphene, not resin synthesis. For instance, Achagri and colleagues (2020) achieved a 148º contact angle on PET fabric using dip-coating [1]. Atighi and colleagues (2022) and Wang and colleagues (2018) also obtained contact angles exceeding 100º for PET matrices. PET exhibits partial hydrophilic properties due to its oxygen-containing groups, resulting in a 71.4º contact angle. Coating with graphene oxide increased the angle to 116.3º [36].

Among the studies in this review (37), 65% focused on developing fabrics for oil-water separation applications. Other applications included flame retardancy [38], catalytic activity [21], self-cleaning [4], and anticorrosive coatings [26,28,39].

Conclusion

The systematic review presented in this article provides a comprehensive overview of recent studies focused on fabric modification with graphene for hydrophobic applications. The reviewed works demonstrate a significant enhancement in fabric hydrophobicity following graphene modification in various forms. Dip-coating emerged as the predominant and favored approach among the different application methodologies explored in the reviewed studies.

Notably, graphene oxide was found to be the most commonly utilized variant of graphene, significantly surpassing other graphene forms in frequency of usage.

The integration of the dip-coating technique with graphene oxide infusion was of particular significance. This combined approach resulted in a consistent and notable improvement in hydrophobic properties across the reviewed studies. The synergistic effects of dip-coating and graphene oxide infusion consistently yielded superior results, substantially enhancing the materials' ability to resist wetting and repel water.

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Polymeric Walls: Technologies and Fire Safety in Non-Conventional Building Systems

Moisés Silva[1*], Ryan Carvalho[1], Mariana Novaes[1], Ariane Rubin[1], Adriano Puglia[1], Juliana Guerreiro[1], Luciano Pisanu[1], João Jesus[1]
[1]SENAI CIMATEC University Center; Salvador, Bahia, Brazil

This article analyzes the use of plastic materials in civil construction, especially in wall sealing systems. Plastics offer easy assembly, quick execution, reduced physical effort, and recyclable and durable, thus reducing environmental impacts. The incorporation of flame-retardant treatments is necessary to meet fire safety criteria. Materials such as vermiculite, ceramic fiber, and fiberglass show heat resistance, contributing to safety in fire situations. Despite the challenges, using plastics in civil construction is promising, allowing the replacement of traditional materials and providing greater agility in construction works.
Keywords: Polymeric Wall. Fire Resistance Requirements. Unconventional Construction Systems.

In order to meet the growing demands of society, several materials have been developed or modified, aiming to improve performance and/or expand their applications. Construction materials play a significant role in this context, emphasizing polymeric materials like plastics.

Plastic materials are used in civil construction, mainly as reinforcement or bonding material (screens, blankets, and tapes), conduits for installations (electrical conduits and pipes), protection (covering for metal wires), and, more recently, used as part of wall systems, providing some advantages over traditional masonry models. These advantages include easily assembled and quickly executed construction modules, reduced physical effort required by labor, excellent finishing, and being recyclable and durable, contributing to minimizing environmental impacts [1,2].

Plastics can adapt to dry construction systems, which, given the aggravated environmental challenges in recent decades, also present ecological advantages. Dry construction technologies lead to lower energy and water consumption, reduce material waste, and enable the use of recycled materials [1,2]. Additionally, sustainability certification entities, such as the US Green Building Council, responsible for LEED certification, support the adoption of recycled plastic materials in construction systems.

Furthermore, incorporating plastic in civil construction increases the material's lifespan, especially when using non-biodegradable materials in short-term activities, such as disposable bottles, which increase post-consumer waste, whose degradation occurs exceptionally slowly. The production of solid waste in Brazil has exceeded 78 million tons. Among these, 14% corresponds to plastic waste, positioning the country as one of the largest global producers of this type of residue [3]. Interestingly, the packaging industry stands out as the main responsible for transforming virgin plastic into products, despite contributing to a shorter lifespan of these items (Table 1).

Another relevant factor consists of the numerous cases of natural disasters caused by climate change, which have been affecting Brazil and the world, making it necessary to adopt construction techniques that are safe, comfortable, and can be built in a short period in order to shelter the victims permanently or in emergencies. A tragic example was the flood in Santa Catarina 2008, which affected 60 cities and 1.5 million people and left 80 thousand homeless, demonstrating the unpredictability of these events and post-disaster control measures [4].

Polymeric structures enable the production of parts with complex geometries thanks to

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Address for correspondence: Moisés Silva. Av. Orlando Gomes, No. 1845 - Piatã, Salvador -Bahia, Brazil. Zipcode: 41650-010. E-mail:moises.silva@fieb.org.br.

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Table 1. Plastic production and recycling in the world

Country	Total plastic waste	Total waste incinerated	Total waste recycled	Recycling VS plastic production
United States	70,782,577	9,060,170	24,490,772	34.60%
China	54,740,659	11,988,226	12,000,331	21.92%
India	19,311,663	14,544	1,105,677	5.73%
Brazil	11,355,220	0	145,043	1.28%
Indonesia	9,885,081	0	362,070	3.66%
Russia	8,949,132	0	320,088	3.58%

their rheological and processing properties. Additionally, they offer hardness and impact resistance, allowing them to meet the requirements of sealing systems. However, other essential characteristics are necessary in polymeric structures, such as low flammability, high resistance to ultraviolet (UV) rays, and thermal and acoustic insulation, to achieve such a purpose.

Therefore, considering the mentioned demands, this article aims to evaluate aspects encompassing the science of plastic materials, considering the requirements established by NBR 15575 [5] for housing wall systems in fire situations.

Materials and Methods

An advanced investigation was conducted using available academic and technical publications to understand the progress and obstacles related to the production and application of polymeric structure systems, including sealing, partition, panel, or structural wall. Keywords, combined and isolated, were used as the selection criteria for the studies in the Scopus database [6], aiming to obtain a comprehensive overview of the information totaling 133 documents. The utilized words are described below.

- Sandwich panels – painéis sanduíche;
- Panels – painéis;
- Walls – paredes;
- Partitions – divisórias;
- Sandwich panels – painéis sanduíche;
- Polymers – polímeros;.
- Modular construction – construção modular;
- Composite – compósitos

The Bibliometrix tool [7] was used to enable the analysis of information from the selected documents, allowing us to understand the importance of the subject regarding the challenges of civil construction, the predominant study approaches, and the frequently employed terms.

Relevance of the Topic to the Scientific Scenario

Figure 1 presents the frequent words associated with the subject. Thus, one can observe the predominance of sandwich-type enclosures, in which polymers are used for the panels and the filling materials. Another approach used is the implementation of honeycomb geometry within the sandwich walls, significantly increasing the system's rigidity and saving on filling materials. Fibers are also associated with using polymers in enclosures to enhance their mechanical characteristics.

Figure 2 shows the terms associated with the previously mentioned keywords. The terms in the first quadrant have higher relevance, indicating the interest of technological and scientific institutions in this subject. The terms "concrete," "foam," "precast," and "glass" are related to the materials used in association with the polymer to compensate for the limitations of its physical

Figure 1. World cloud about the theme.

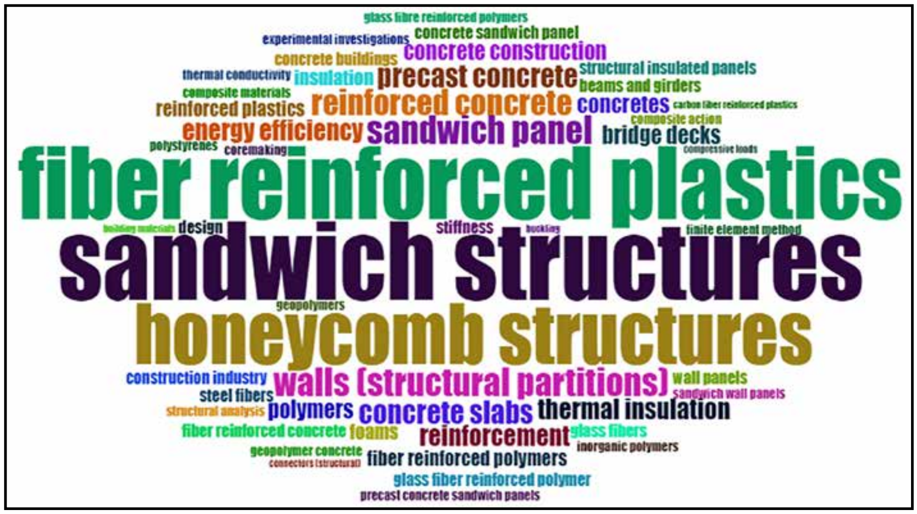
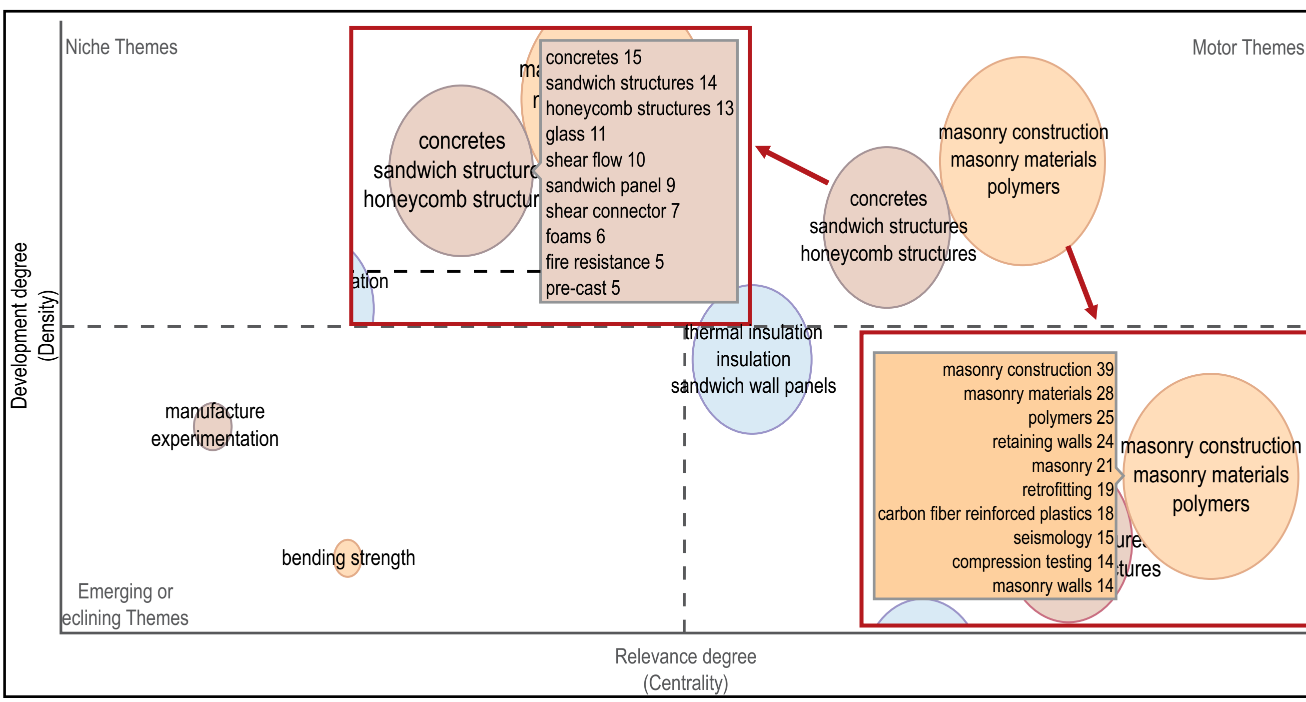


Figure 2. Study density and relevance topics.



and chemical properties, especially regarding its fire performance. The other terms demonstrate the primary applicability of polymers, used as raw materials for specific components, such as connectors for sandwich panels. In the fourth quadrant, relevant terms are found; however, they still have a low volume of academic production, showing the gap relevant to the topic. Polymer materials are currently being used in retrofit works and seismic-resistant to wall systems.

Results and Discussion

Namely, regarding the behavior of polymers under fire, there is a significant challenge related to their compatibility with wall systems, as plastic materials are easy to burn. When heated, they form combustible substances, which generate molten droplets in the presence of oxygen and an ignition source. During combustion, polymers release a considerable amount of heat (highly exothermic reaction) and toxic smoke (CO, CO_2), limiting their areas of application [8]. However, concerning the current regulations in Brazil, they establish that wall systems must meet the criteria below, regardless of the material, when exposed to fire situations:

1. Make it difficult for the fire to start
2. Facilitating the user's escape
3. Reduce widespread inflammation
4. Make it difficult for the fire to spread.

Most materials used in civil construction are typically thermoplastics; therefore, when subjected to a heat source, they soften, become fluid, and then flow. Such a situation compromises their use in wall systems, as plastics do not maintain tightness, insulation, and structural capacity in the face of fire situations, failing to meet requirements 1 and 2. Thus, the association of the material with other efficient flame-retardant treatments is being discussed to make its application viable. Generalized ignition (3) and fire propagation (4) are avoided through flame-retardant additives incorporated into the polymeric matrix; however, this situation is associated with the high cost of raw material production.

The technical tests described by NBR 15575-4 [5] must be carried out to verify compliance with fire safety requirements (Table 2).

Furthermore, for implementing polymer wall systems in Brazil, it is necessary to comply with the recommendations of the National System of Technical Evaluations for Innovative Products and Conventional Systems (SiNAT) through its guidelines. These documents expand on the guidelines provided by NBR 15575 [3]. A Technical Evaluation Document (DATec) is issued in cases of innovations to demonstrate compliance with the guidelines for buildings. This document is valid for 2 years, and it is the responsibility of the constructor to seek its renewal. Table 3 presents all valid DATecs that use polymeric materials as construction elements in sealings.

To comply with the presented regulations, wall systems can use some tactics to enhance their effectiveness in a fire, highlighting fire-retardant coatings and filling elements in sandwich panels, such as fibers, clay materials, and expanding solutions. There is also the possibility of using fire-resistant paints, such as intumescent paints, which serve as an alternative to preventing the generation and spread of flames in plastic materials. These paints can be applied directly to the material's surface, making their use even more practical.

Investigating additional alternatives to safeguard the polymer in fire situations, the following materials renowned for their remarkable heat resistance are revealed:

1.Vermiculite - material calcined at 900ºC to form expanded vermiculite, which, due to the release

Table 2. Normative requirements and their respective technical tests.

Test method	Requirement	Standard
FIRE SAFETY		
Evaluation of the reaction to fire of the internal face of vertical fencing systems	8.2	NBR 9442
Evaluation of the reaction to fire of the external face of the vertical fences that make up the facade	8.3	NBR 9442
Fire resistance of structural and subdivision elements	8.4	NBR 14432 and NBR 5628

Table 3. Normative requirements and their technical tests.

Datec	Description	Guideline SINAT	Evaluated Requirements
Nº 005-C	The system idealized by HOBRAZIL consists of solid walls molded on-site using lightweight concrete with polymer and fiberglass reinforcement protected with polyester for detached and semi-detached houses, single-story and two-story.	Nº 001	Walls are composed of non-combustible materials.
			Appropriate characteristics in terms of smoke development.
			Fire resistance (tightness, thermal insulation, and structural stability) of the walls for 30 minutes.
Nº 017-A	Constructive System developed by Global, in partnership with other companies, consisting of walls made of PVC panels filled with concrete.	Nº 004	Fire reaction of PVC profiles.
			Fire resistance of the walls for 30 minutes.
Nº 038	Modular construction system "Fischer Houses," composed of prefabricated panels made of thin sheets linked by a rigid thermal insulating core.	Nº 010	Reaction to fire of wall panels.
			Fire resistance of the walls for 30 minutes for the panels installed in the kitchen area.

of water between its layers, causes expansion, increasing the original particle size by up to 30 times. The expanded vermiculite particles are lightweight and porous, with low thermal conductivity and a small capacity for noise propagation [9].

2. Ceramic Fiber - obtained from the electrofusion of silica and alumina at high temperatures (approximately 2000°C). With this fiber, different refractory components, such as blankets, modules, boards, tapes, and other products, have various applications in industries ranging from construction to the aerospace sector. The main characteristics of materials produced with this fiber are the high melting point and low thermal conductivity, making it an excellent thermal insulator with high fire resistance [10].

3. Fiberglass - fibers manufactured from chemical compounds are also used for glass production, such as sand, magnesium, and calcium oxide. Since the Second World War, fiberglass has been extensively studied as a reinforcement for polymeric matrices and ceramic materials, allowing the production of filters for thermal and acoustic insulation, threads for fabric manufacturing, special blankets, and structural components for vessels and aircraft [9]. Fiberglass fibers have softening points close to 850°C and a melting point at 1070°C, demonstrating the capability of this material to withstand extreme temperatures [11,12].

Conclusion

A methodical overview was conducted to understand the primary hurdles associated with utilizing plastics in civil construction, focusing on delineating the essential criteria and prerequisites for an avant-garde sealing system, particularly emphasizing fire safety. Thus, relevant information was systematized, mainly for designers and builders, who must ensure compliance with the normative criteria of the designed or built sealing systems. The primary normative texts are the Performance Standard, ABNT NBR 15575 - Part 4, and the National System of Technical Evaluations of Innovative Products and Conventional Systems (SiNATI) guidelines. Furthermore, given the number of criteria to consider, it became necessary to synthesize and organize this information in tables, facilitating the work of designers and builders. In addition, it was possible to verify the main tests or analyses relevant to the determination of the fire performance of the seals.

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Challenges of Innovation in the Health Economic-Industrial Complex: A Case Study on Implementation of Research Results in a Brazilian Science and Technology Institution

Marcelo Santos Ramos[1,2*], Ângela Maria Andrade Scavuzzi[1,2], Daniela Cerqueira Moraes[1,2], Valdeyer Galvão dos Reis[1,2], Camila de Sousa Pereira-Guizzo[2]

[1]Oswaldo Cruz Foundation FIOCRUZ; [2]SENAI CIMATEC University Center, Salvador, Bahia, Brazil

In addition to advancing scientific knowledge, science and technology institutions (STIs) must translate research outcomes into practical applications, thereby addressing societal needs and challenges. Consequently, this study examines the outcomes produced by a public STI, employing the morphology of the Health Economic-Industrial Complex (HEIC) as an analytical framework. Notably, 77.8% of these outcomes have benefited populations marginalized by public policies. The research underscores a robust correlation between the institution's capacity for technological innovation and the chemical and biotechnological industrial subsystems, particularly in diagnostics and diagnostic services. Significantly, the primary impact of these innovations manifests in formulating and enhancing public health policies, thereby directly influencing governmental initiatives aimed at bolstering the Unified Health System.

Keywords: Innovation; Health Economic-Industrial Complex; Scientific Evidence; Public Health.

The World Health Organization (WHO) defines health innovation as the development of policies, systems, products, technologies, services, and health methodologies aimed at improving the well-being of populations. It emphasizes that such innovations encompass preventive, promotional, therapeutic, rehabilitation, and/or assistive measures [1]. These innovative endeavors are closely intertwined with the scientific sector, as they rely on the flow of information to catalyze breakthroughs in medical practices and healthcare. This encompasses new drugs, equipment, clinical procedures, prophylactic measures, and informational resources [2].

In Brazil, specific challenges hinder health innovation, including difficulties in identifying pertinent research problems, limited engagement of critical stakeholders in scientific research outcomes, lack of collaboration between researchers and knowledge users in the investigative process, and constrained research budgets, particularly for implementing research findings [3]. Against this backdrop, the Health Economic-Industrial Complex (HEIC) concept has gained prominence as a model for scrutinizing the political institutional dynamics underpinning the production and provision of healthcare goods and services.

It is noteworthy that the dynamics of health innovation entail a complex network of institutional arrangements comprising industrial firms, healthcare service providers, academic and scientific institutions, technology and innovation entities, research funding bodies, civil society organizations, and healthcare regulatory agencies, as well as the enactment of industrial, scientific, and technological policies, healthcare policies, and intellectual property regulations [4,5].

Understanding this innovation process within its ecosystem is pivotal for devising organizational strategies and public policies capable of identifying potential barriers to health innovation.

This study aims to analyze the challenges confronting health innovation in Brazil by examining the contextual determinants influencing the adoption of research findings within a public science and technology institution, employing the morphology of the Health Economic-Industrial Complex as an analytical framework.

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Address for correspondence: Marcelo Santos Ramos. Rua Rodrigo Argollo, 237. apt. 401, Rio Vermelho, Salvador, Bahia, Brazil. Zipcode: 41940-220. E-mail: marcelo.ramos@aln.senaicimatec.edu.br

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Materials and Methods

This study constitutes a case investigation involving a public Science and Technology Institution (STI) in Bahia. Fifteen volunteers were selected from a pool of 25 researchers within the institute, chosen based on their status as laboratory leaders or recipients of research productivity grants from the National Council for Scientific and Technological Development (CNPq). The research adheres to ethical principles governing studies involving human subjects and received approval from the Research Ethics Committee of SENAI CIMATEC - Opinion No. 5,096,148. Primary data collection involved:

We are conducting semi-structured interviews. The content analysis technique is employed as delineated by Bardin [6].

We are adopting the Consolidated Framework for Implementation Research developed by Damschroder and colleagues [7], focusing on intervention characteristics. During the interviews, volunteers were tasked with recounting two research cases: one wherein outcomes were effectively implemented to enhance population health and another where potential innovations had yet to be realized despite being within reach. Furthermore, the morphology of the Health Economic-Industrial Complex served as a model for scrutinizing the locus of implementation for identified innovations and evaluating outcomes with potential for such implementation.

Results and Discussion

Twenty-four instances of scientific research outcomes were identified, wherein the interviewees directly participated. Among these, nine cases (37.5%) saw successful implementation, while 15 (62.5%) held innovation potential. Data analysis in Table 1 reveals that 79.2% of the reported research outcomes pertained to product development projects encompassing diagnostics, drugs, medications, and vaccines alongside clinical investigations. The latter category may encompass endeavors focused on product development, novel treatments, or clinical-epidemiological assessments, all of which hold promise for contributing to enacting public policies aimed at directly or indirectly benefiting the health of the Brazilian populace and fortifying the Unified Health System.

By focusing the analysis on the innovations emanating from the studied STI, Table 2 reveals that 44.5% of the cases targeted diseases categorized as neglected by the World Health Organization (WHO): tuberculosis (1), Chagas disease (1), leprosy (1), and HTLV (1). Furthermore, three cases (33.3%) were dedicated to addressing diseases prevalent among socially vulnerable populations, including leptospirosis (1), hemoglobinopathies (1), and child nutrition (1). Notably, 77.8% of the innovations generated by the STI benefited populations marginalized by governmental public policies and/or investments in research, development, and innovation within the pharmaceutical industry. Additionally, two more cases were reported, one of HPV and another of hepatitis C. Regarding the application sites of these innovations within the Health Economic-Industrial Complex (HEIC), Table 2 underscores the STI's robust technological prowess, particularly within the chemical and biotechnological-based industrial subsystems for diagnostics and diagnostic services, where 5 cases (55.6%) were identified. The nascent Information and Connectivity subsystem accounted for 3 cases (33.3%), while the chemical and biotechnological-based subsystem for vaccines featured in 1 case (11.1%) of research conducted by a multinational pharmaceutical industry in collaboration with an STI researcher serving as the lead investigator in a phase III clinical trial. The STI's capacity to innovate for the betterment of public health is underscored by the impact of its innovations on the formulation and/or enhancement of public health policies, as evidenced by 6 cases (66.6%) directly influencing governmental action in favor of public health at national, regional, and local levels. It is worth

Table 1 . Distribution of research results implemented or with potential for innovation reported by STI researchers.

Research Areas	Incidence (N)	Incidence (%)	Implanted (N)	Implanted (%)	Not Implanted (N)	Not Implanted (%)
Research and Development of Diagnostics	7	29.2%	4	57.1%	3	42.9%
Clinical Research and Clinical Trials	5	20.8%	2	40.0%	3	60.0%
Research and Development of drugs and medicines	4	16.7%	0	0.0%	4	100%
Research and Development of Prophylactic and Therapeutic Vaccines	3	12.5%	1	33.3%	2	66.7%
Genetics and Molecular Epidemiology in Health, Pharmacogenetics	2	8.3%	1	50%	1	50%
Entomology, Biology and Reservoirs of Infectious Agents	1	4.2%	0	0.0%	1	100%
Epidemiology, Statistical and Quantitative Methods	1	4.2%	1	100%	0	0.0%
Public Policies, Planning and Management in Health	1	4.2%	0	0.0%	1	100%
Totals	**24**	**100%**	**9**	**37.5%**	**15**	**62.5%**

noting that being a public health-oriented STI, its outcomes are closely intertwined with the state's role in promoting health. Furthermore, it is pertinent to mention that scientific evidence produced and implemented within the mechanical, electronic, and materials-based industrial subsystem still needs to be identified.

Table 3 showcases 15 research outcomes with the potential to instigate innovation yet remain unimplemented. A notable socio-sanitary inclination is evident within the STI under study, with 66.7% of the cases focusing on neglected diseases as classified by the WHO. Among these, ten cases encompass leishmaniasis (7), Chagas disease (2), and dengue (1). Additionally, two scientific findings pertain to pathologies that, while not categorized as neglected by the WHO, predominantly afflict socially vulnerable populations: leptospirosis (1) and sickle cell disease (1). Combining these two cases with the preceding ten, we observe that 80% of the potentially innovative scientific outcomes target neglected diseases and/or socially vulnerable populations. According to Decit, neglected diseases are those that not only prevail in conditions of poverty but also perpetuate inequality, serving as formidable barriers to a country's development. Moreover, Garcia and colleagues assert that neglected diseases commonly exhibit high endemicity in rural and underprivileged urban areas of developing nations, coupled with a paucity of research endeavors for the development of new drugs, particularly by transnational pharmaceutical corporations [8,9].

About the contextual determinants of health innovation, the interviewed volunteers cited 65 aspects perceived as barriers to the process of implementing the scientific evidence produced. Table 4 shows that 8 categories of barriers were identified, with greater relevance given to the following challenges to be faced: Cooperation

Table 2. Research Results that generated innovation reported by STI researchers studied.

Search Results	Disease	Kind of Innovation	Application Locus at HEIC
Leprosy sub-registration	Leprosy	Service	Information and connectivity subsystem State> promotion + regulation Others: Public Policy with an impact on Public Health
Neonatal screening for hemoglobinopathies	Hemoglobinopathies	Service	Service subsystem: Diagnostics Others: Public Health Policy
Impact of Vitamin A on infant nutrition	Infant Nutrition	Service	Information and connectivity subsystem State> promotion + regulation Others: Public Policy with an impact on Public Health
BCG revaccination	Tuberculosis	Service	Information and connectivity subsystem State> promotion + regulation Others: Public Policy with an impact on Public Health
Rapid Test for the Diagnosis of Leptospirosis	Leptospirose	Product	Subsystem based on chemistry and biotechnology: Reagents for diagnosis Service subsystem: Diagnostics
Molecular diagnostic test for Hepatitis C	Hepatitis C	Service	Subsystem based on chemistry and biotechnology: Reagents for diagnosis Service subsystem: diagnostics
Testing for HTL-V in prenatal care	HTL-V	Service	Subsystem based on chemistry and biotechnology: Reagents for diagnosis Service subsystem: diagnostics Others: Public Health Policy
Diagnostic potential of Trypanosoma cruzi recombinant proteins	Human Chagas disease	Product	Subsystem based on chemistry and biotechnology: Reagents for diagnosis Service subsystem: diagnostics
HPV vaccine	HPV	Product	Chemical and biotechnological base subsystem: Vaccines

Table 4. Contextual determinants for health innovation: barriers.

Categorization	Definition	Examples of Reports	Nº	%
Cooperation and Restricted Partnerships	Refers to the need to strengthen institutional dialogues with public and private entities to expand strategic collaborations, formal and informal, intra and extramural, in support of the implementation of the results of the scientific evidence produced by the STI	"It is not understood that these public-private partnerships are important. There is a crooked look at researchers who seek private initiative to develop their projects"	13	20%
Lack of Training and Development of Skills for Innovation in STI	Refers to the need to improve the process of recruiting, developing and retaining human resources to act in the implementation of research results	"We researchers do not have training for innovation, so it is very difficult today to be a researcher in Brazil"	12	18.46%
Financing in Limited ST&I	Refers to insufficient financial resources for research, development and innovation.	"There is a need for new funding to implement research results"	10	15.38%
Low Institutional Competence to Deal with Regulatory Bodies	Refers to limited institutional competence to deal with the complexity of normative and legal requirements by regulatory bodies, which would facilitate KT	"It needs a lot more resources, it needs people who understand regulatory issues, lack of trained staff"	10	15.38%
Insufficient Technical Support for innovation	Refers to the need for human resources with specialized technical knowledge to support innovation in STI	"Lack of support from a group that spoke look we identified a series of potential products or potential ideas to be translated and sold"	8	12.31%
Culture of Insufficient Creativity and Innovation	Refers to the need to encourage a culture of creativity and innovation among STI managers and researchers, as well as to strengthen closer ties with government, industry, society and other stakeholders to promote the generation of ideas, knowledge, products and services, expanding the ability to innovate	"You have to take a deeper look at innovation"; "there is no culture of entrepreneurship"	6	9.23%
Little technical-scientific criteria in the definition regarding the vocation of physical spaces	Refers to the need for definition regarding the vocation and use of equipment and physical spaces, according to technical criteria that ensure greater quality to scientific experiments	"There is no proper culture room to work in. There is no division by viruses, bacteria, parasites, etc. segmented culture rooms"	3	4.62%
Conflict between Research and Management Macroprocesses	It is about the incompatibility of the national public management model with the specificities of scientific research institutions, in addition to a misaligned culture between management and research that is not always able to respond with agility and efficiency to the strategic demands of middle and end activities	"We have many restrictions within the public environment. It was not in vain that foundations were created"	3	4.62%
		Totals	**65**	**100%**

and Partnerships 13 (20%), Lack of Training and Development of Skills for Innovation in STI 12 (18.46%), Limited ST&I Financing 10 (15.38%), Low Institutional Competence to Deal with Regulatory Bodies 10 (15.38%) and Insufficient.

Conclusion

The potential of the STI to foster innovations benefiting socially vulnerable populations is evident, given its primary focus on neglected diseases in its scientific investigations. There exists a palpable necessity for heightened political-institutional collaboration among the State, STIs, and various subsystems within the health productive sector, as delineated in the morphology of the Health Economic-Industrial Complex (HEIC). This imperative stems from the interconnectedness and interdependence of these stakeholders in the health innovation process, characterized by a pronounced degree of innovation and intensity in producing and disseminating scientific and technological knowledge. The recent enactment of Brazil's new legal framework for science and technology (Law 13.243/2016) and its accompanying Decree 9.283/2018 mark significant strides by the Brazilian state in promoting and regulating research and development (R&D) activities within the country, with a particular emphasis on fostering collaboration and interaction between the public and private sectors. These legislative measures provide legal clarity for fostering strategic partnerships among key players involved in the innovation process within the Health Economic-Industrial Complex. These partnerships can be facilitated through technology transfer agreements, research and development partnership agreements, and technological procurement arrangements, among other formal mechanisms to incentivize public-private collaboration for health innovation in Brazil. However, it is imperative to cultivate technical expertise to bolster innovation capabilities and capitalize on successes in addressing the challenges.

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