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PERSPECTIVES WITHOUT BORDERS:

MULTIDISCIPLINARY SCIENTIFIC STUDIES – 2ND EDITION

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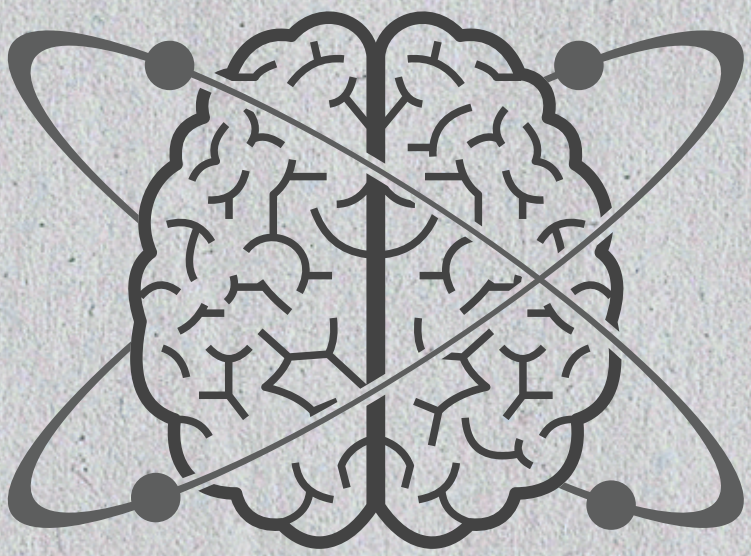

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SUMMARY

STRATEGIC COST MANAGEMENT: THE USE OF ACCOUNTING TOOLS IN DECISION OPTIMIZATION

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Abstract

Since its inception, accounting science has been refined to meet the needs of its users, which must be maintained even today. Thus, this article aims to demonstrate the importance of new management tools for decision support. After the bibliographic survey, it was sought in the case study to achieve the proposed objective. Target costing proved useful in cost management based on the perception of customer value. While total cost of ownership contributes to cost-effective optimization of procurement choices. With the research, it is clear that modern management tools can insert accounting as a decisive factor in the implementation of strategy in organizations, reconciling the costing with the definition of reaching set goals, certainly increasing the value of science to end users.

Keywords: Accounting, Strategy, Decision.

INTRODUCTION

In the business world, space is becoming increasingly competitive among market organizations. Thus, surviving in this environment requires attention from all sides and directions, especially with regard to one's own competitors, making this one of the tools for commercial modernization.

In this sense, since 1980, scholars such as Johnson and Kaplan perceived that the business information generated at that time did not meet the managerial aspects necessary to support managers in matters related to reducing costs and improving productivity.

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Traditional management accounting tools were often focused on product cost for price formation, which would no longer be sustainable in a competitive environment. A gap then emerged between managerial tools and market strategy, requiring a connecting link. Thus, new accounting tools were developed to support decision-making, such as Strategic Cost Management.

Strategic Cost Management (SCM) presents fundamental alternatives for addressing any trace of cost through analyses consistent with both personal and business needs. The tool seeks to encompass what is not addressed by traditional costing methods, as a way of recovering key sources in order to remain constantly updated in the face of competition and modernity. It is important to highlight the importance of market value in influencing prices; considering the relevance of cost in price attribution alone does not bring advantage, which is where SCM tools fit in to provide a favorable situation conducive to innovation.

Therefore, the objective of this research is to demonstrate the importance of new managerial tools for decision support. To this end, related literature will be addressed and, subsequently, a case study of two Strategic Cost Management instruments will be applied: Target Costing Analysis and Total Cost of Ownership. The focus is, respectively, on the lodging service of a hotel located in the municipality of Cuiabá, Mato Grosso, and on the acquisition of two automobiles with a view to obtaining the best purchasing advantage.

In view of this context, knowledge and management of companies' internal costs share important particularities for current and future development, discoveries that encompass production and the specifics regarding how much the product costs the consumer, as well as the proper management of costs incurred during service provision and throughout the life cycle and disposal of the asset.

THEORETICAL CONTRIBUTIONS TO THE DEVELOPMENT OF THE RESEARCH

THE USE OF ACCOUNTING IN BUSINESS MANAGEMENT

Accounting is one of the oldest sciences in the world; it emerged alongside the earliest developments in primitive human life, using rock paintings or any object that could identify markings of herds and other goods. It was a way of demonstrating control and counting over material things.

Through changes in patrimony and the desire to meet the needs of that time, a barter technique was developed, consisting of exchanges between products. However, this novelty did not reflect the true value of one good in relation to another and, consequently, aroused interest in creating a tool to facilitate counting and commercial movement; thus, numbers emerged, respectively representing monetary significance in circulation.

According to Marion (2009, p. 28), accounting is the instrument that provides the maximum amount of useful information for decision-making inside and outside the company. It is very old and has always existed to help people make decisions.

Science is devoted to seeking, through an appropriate method, the resolution of a fact, and the influence of Luca Pacioli's work, Summa de Arithmetica, Geometria, Proportioni et Proportionalità, emphasized the importance of double-entry bookkeeping. It was a fundamental element in the construction of the first doctrines of accounting and is used to this day. Pillars such as these were strengthened during the Industrial Revolution, with the implementation of more refined accounting in order to efficiently contain the accelerated circulation of goods production.

According to Clóvis Luís Padoveze (2004):

> The objective of Accounting is the control of patrimony. Control is carried out through the collection, storage, and processing of information arising from events that alter this patrimonial mass. Therefore, we can define Accounting as an information system that controls a company's patrimony (Padoveze, 2004, p. 29).

It has the capacity to control, measure, and preserve patrimonial changes of legal entities and individuals, based on the records of administrative and economic situations that occur as a result of human actions. With the scope of transforming accounting information into directions for decision-making, accounting is divided into various branches of study.

Accounting encompasses a broad field of study and may be used generally for all companies or, in particular, applied to a specific line of business or sector of the economy. It is integrated into effective support in any environment, with the purpose of meeting what is proposed by the user, simplifying a complex approach into stages to be gathered and analyzed according to feasibility.

Seeking to clarify this, Ornelas (2013) states that:

> Accounting will serve as an instrument, as a managerial tool that will provide information and useful projections to assist decision-making. This information is transformed into quantitative and qualitative accounting reports and must be reported to accounting users. The main accounting reports will be called Financial Statements (Ornelas, 2013, p. 20).

It strongly contributes to the expansion of this category by assuming characteristics and careful planning of information, acquiring responsibility according to necessity and legal foundation for the correct preparation of statements, thereby providing credibility and transparency in business.

MANAGEMENT ACCOUNTING AS A TOOL TO SUPPORT MANAGEMENT

Accounting is a fundamental activity in economic life, especially in more modern economies. It seeks to prepare tailor-made reports according to the institution’s needs through the collection of information for the purpose of controlling events. The term Management Accounting is used to describe the movement of this activity within organizations.

According to Silvio Aparecido Crepaldi (2004):

> Management Accounting is the branch whose objective is to provide instruments to company managers that assist them in their managerial functions. It is aimed at the best use of the company's economic resources through adequate control of inputs carried out by a management information system (Crepaldi, 2004, p. 20).

It is related to internal purposes and seeks to present managers with interpretations of economic events, involving techniques that determine the real identity of results, directing the information obtained toward decision-making solutions for entities. It thus allows direct benefits for the company, offering differentiation based on data collection and transforming it into a favorable scenario for implementing various forms of management, acting in relative accordance with the requirements demanded by the manager.

As noted by Sérgio de Iudícibus (1998):

> Management Accounting can be characterized, superficially, by the special focus given to various accounting techniques and procedures already known and addressed in cost accounting, financial analysis, balance sheet analysis, etc., placed in a different perspective, with a more analytical level of detail, or in a different form of presentation and classification, so as to assist the managers of entities in their decision-making process (Iudícibus, 1998, p. 21).

In a broad sense, this process extracts data in order to build coherent decision-making models, seeking techniques that "fit" in a valid and efficient way for the users of this tool. Oriented toward past or present situations, it estimates the future for the proper realization of the organizational structure.

MAIN MANAGEMENT ACCOUNTING TOOLS

It is noted that management accounting serves as a control panel for managers. To this end, Junior (2009, p. 371) explains that this accounting branch has the freedom to prepare reports through the need to interpret statements more objectively in relation to business functions, developing techniques for routine assistance, as shown below.

Chart 1

Management Accounting Tools

Tool	Description
Budget planning and control	Consists of preparing a plan of targets, considering elements such as company values, mission, and objectives.
Cost accounting	A structured and organized system for collecting data and information related to determining the cost of products and services and their managerial analyses.
Analysis of accounting statements	Consists of analyzing an entity's accounting statements to support decision-making, make comparisons with competitors, analyze certain business segments, assist in decisions to purchase companies, etc.
Accounting in foreign currency	Serves users abroad or as an enhancement of management accounting. Such statements are prepared based on specific methodologies, using internationally accepted techniques.

Source: Adapted from JUNIOR (2009, p. 371).

This reinforces the methodological study of performance experiences in different situations, involving the essential skills of this branch. It generates consistent information about what is happening and which future actions to pursue so that the desired outcomes may be achieved.

It aims to analyze the facts that impact the company's patrimony through detailed access to information, making it possible to identify failures and opportunities by strategically relating elements to costs and to the organization's complete planning. These are alternatives associated with the projected and, consequently, realized balance due to accounting-managerial resources.

STRATEGIC PLANNING

The relentless search to identify oneself amid market operational fluctuations is the fuel for acquiring consistent steps and a lasting bond with the customer, because through obstacles, pillars are erected that may, as a positive consequence, leverage competitive acceptance among so many options. Through proper planning, the business segment is strengthened.

Planning levels are generated in order to make possible the preparation and interaction of plans, possessing specific characteristics according to the seriousness of the work to be dedicated. Three main levels may be highlighted: strategic, functional (tactical), and operational (Maximiano, 2000, p. 196).

Opportunities and threats to the quality of business activities must be in harmony with agile decision-making processes suited to challenges, following changes that are integrated into the methodology and the respective tools applied in favor of the organization's operational and competitive position.

According to Oliveira (2004):

> Strategic planning is the administrative process that provides a methodology for establishing the best direction to be followed by the company, aiming at an optimized degree of interaction with the environment and acting in an innovative and differentiated manner (Djalma, 2004, p. 47-48).

When dealing with strategic planning, it is immediately associated with organization and analysis of improvement, as a way of developing a medium- to long-term perspective aimed at achieving objectives efficiently. It intends to follow the technological pace, proposing investment in attractive innovations and more precise solutions, thereby establishing a constant and tireless race against time.

It entails observing the market as a whole and finding resources in the entrepreneurial environment, obtaining analysis of products and services, cautiously assuming risks through the need to solve complex situations and control strategic execution.

STRATEGIC MANAGEMENT ACCOUNTING

Bringing together accounting management in a strategic aspect within an organization is something challenging in relation to the future. It encompasses a set of information developed for long-term planning, geared toward the characteristic essence of the entity (Andrade; Teixeira; Fortunato; Nossa, 2013, p. 106). Although there is no direct alignment as to what strategic management accounting may be, since it is a little-explored field, it operates in areas of operational management that are not part

of the analysis established by management accounting, thereby opening space for new attempts at success.

Grzeszeszyn (2005) offers a shortcut to understanding this theme, stating that:

> Strategic management accounting can be understood as an effort by accounting professionals and scholars to provide new practices and theories that enable timely and relevant information capable of offering greater security during the process of strategy formulation, planning, and execution (Grzeszeszyn, 2005, p. 23).

This definition assigns particular emphasis to business strategy, granted by the positioning of the accountant within the company, influencing and gaining importance in the decision-making process and contributing to planning and control practices, conditions that provide competitive advantage.

Pires, Alves, and Rodrigues (2015, p. 5) argue that strategic management accounting serves to contribute to the formation of strategic information for management involving managerial action in planning. It performs the purpose of this theme in an observation directed toward the external public, namely customers, competitors, and market perspectives. It provides guidance for internal resources and organizational capabilities with the purpose of delivering better performance in the development of techniques aimed at achieving competitive advantages.

STRATEGIC COST MANAGEMENT

Strategic Cost Management is one of the tools within the broad field of Management Accounting, useful for generating relevant information for the proper management of costs. It includes the following artifacts: Value Chain Analysis, Total Cost of Ownership, Cost to Serve, Target Costing, Competitor Cost Analysis, and Activity-Based Costing (ABC).

It applies the ability to help reduce costs and improve productivity, meeting the need for integrating an entity into the globalized and competitive business environment, taking into account the relationship between the cost management process and the company’s management process.

As pointed out by Eliseu Martins (2003):

> To survive in these increasingly competitive markets, the company must pursue and achieve high levels of quality, efficiency, and productivity, eliminating waste and reducing costs. Therefore, managers need to receive precise, timely, and up-to-date information in order to provide effective support to the decision-making process (Martins, 2003, p. 298).

This understanding reinforces the idea that SCM is not merely an operational tool for controlling expenditures, but a strategic instrument that connects cost information to the decision-making process, making the organization more competitive and resilient in the face of market fluctuations.

Strategic elements clarify doubts and make a total difference in a decision, especially in the business sphere, where such factors greatly affect organizational balance. They provide credibility for managers to boldly maintain expansion and long-term survival.

Following Hansen's concept (2002, p. 423), "strategic cost management is the use of cost data to develop and identify superior strategies that will produce a sustainable competitive advantage." In a few words, the author summarizes the importance of adopting techniques for decision-making, ensuring profitability and a desired position.

Value Chain Analysis

Every company concentrates a set of activities resulting in the origin of resources. The purpose of value chain analysis is to clarify everything from the base of raw materials to issues interconnected with the end of the product after disposal by the final consumer. It is related to understanding cost behavior, using strategies to identify, through basic sources, how to design, produce, market, deliver, and sustain the product, directed toward offering lower prices than competitors (Christopher, 2007, p. 14).

It extends proportions up to the final consumer, since there are various situations in which goods are passed on before the end of their useful life, corresponding to costs that will be incurred at the moment the product is rejected. It encompasses the requirement and responsibility for the project carried

out by an organization, involving understanding among suppliers and production and sales cycles directed toward final distribution.

Competitor Cost Analysis

Every company seeks to stand out in the commercial environment in a way that differs from the others; finding a superior method that encourages the consumer to feel satisfied with the product or service among so many in the environment is something challenging. Observing the competitor becomes normal in a competitive space so that this obstacle may somehow be overcome.

In summary, Souza, Marengo, and Jaroseski (2012) report that:

> Competitor cost analysis is one of the main practices of external cost analysis and involves the use of several techniques to obtain important information about the costs practiced by competitors. The main purpose is to have an approximate cost with which the company can formulate and implement its action strategies, such as offering greater value to the customer with reduced costs and enhancing profitability (Souza; Marengo; Jaroseski, 2012, p. 47).

In this way, analysis is acquired through the company's relative strategic positioning compared to its competitors, concentrating on obtaining systematic resources aimed at better quality conditions.

Activity-Based Costing (ABC)

For Martins (2003), Activity-Based Costing (ABC) represents a cost determination approach that distributes expenditures according to the activities performed by the company, providing greater precision in the allocation of resources. By detailing the consumption of inputs by activity, this method favors the identification of critical points and opportunities for cost reduction, in addition to supporting the value analysis of organizational processes.

According to Eliseu Martins (2003), Activity-Based Costing, known as ABC (Activity-Based Costing), is a costing methodology that seeks to significantly reduce distortions caused by the arbitrary allocation of indirect costs (Martins, 2003, p. 87).

According to Martins (2003), implementing ABC makes it possible to distribute incurred costs rationally to their respective generating activities. This methodology was designed to deepen the strategic analysis of expenditures linked to the activities that most demand resources within the organization, guiding continuous improvement decisions.

Cost to Serve

The applicability of resources developed to identify costs in all products is not clearly found, demanding more intensive analyses for proper distribution to the objects. To better verify this approach, Cost to Serve is a derivation of Activity-Based Costing, assigning the monitoring of the analysis referred to in this situation, in addition to products and services (Farias; Borinelli; Mantovani, 2010, p. 133). Thus, it does not correspond to a method in itself, but rather provides effort for the company's benefit by generating useful reports for changes and with a focus directed at customers.

It concerns the improvement of the ability to investigate costs such as sales, marketing, distribution, and administrative costs, so that the profitability and, subsequently, the return of each customer may be calculated. Farias, Borinelli, and Mantovani (2010, p. 129) establish that this tool promotes detailed observation through the use of managerial information regarding the products that offer profit and those that do not, that is, it presents the revenue position in relation to costs and, importantly, the costs to serve them.

The assessment resulting from cost-to-serve analyses allows organizations to adapt according to the type of activity, without there being a standard so that they may make decisions at the customer level, providing support that would not be possible by analyzing only the costs of producing or selling, and the profitability of the entity as a whole. Thus, it determines information about how much it costs to serve customers, supported by the profit and profitability of each one (Souza; Marçal; Gasparetto, 2019, p. 13).

Target Costing

Target Costing is an SCM instrument applicable in environments where price is strongly influenced by competition. In this process, the focus must be on consumers, and the value of the target cost must be determined and managed based on the price they are willing to pay.

As a fundamental premise, Cost is the expenditure related to goods or services used in the production of other goods and services. It is recognized at the moment the factors of production are used for the manufacture of a product or the execution of a service (Martins, 2003, p. 25). Meanwhile, Target is related to the objective to be achieved, the focus assigned to a product or service through specific analyses that address the desired choice.

Based on the formulation of these concepts, the association of the two terms encompasses sources of strategic cost management and is essentially aimed at achieving profit. Considering profit as a variable dependent on revenues and costs, it is advisable in situations where there is little or no possibility of readjusting price management, leaving cost management efforts as the alternative.

Target cost is the amount of costs that must be eliminated, or increased, so that the estimated cost of a product or service may fit the allowable cost, considering the cost of use and ownership for the consumer, the target price, and the target margins for each link in the chain (ROCHA, 1999, p. 126). In view of this, target cost is a way of analyzing the desired object in comparison with competitors so as to use it for the benefit of competitiveness and in accordance with the feasibility and quality of services. It is not a process directed solely toward cost reduction, but rather toward cost management.

Total Cost of Ownership

It is considered that total cost of ownership stems from the requirement to visualize all costs that will be incurred by the product throughout its useful life, including at the moment of disposal, and it may be used by all areas and for all types of products.

According to Ellram and Siferd (1998):

> Total Cost of Ownership is a structured approach to determining the total costs associated with acquiring and subsequently using a given good or service from a given supplier. It is a comprehensive approach that goes beyond price to consider several other costs, among them: technical support, failure costs, administrative costs, maintenance, and life-cycle costs (Ellram; Siferd, 1998, p. 56).

In practical terms, Ellram and Siferd (1998) emphasize that this perspective broadens the manager's analytical horizon, who then begins to consider not only the amount paid at acquisition but also the subsequent expenditures throughout the useful life of the asset. Thus, aspects such as technical support, operational failures, administrative charges, and disposal become part of the purchasing decision equation, preventing choices based exclusively on the initial price from compromising the organization's economic efficiency.

Given the knowledge of SCM tools, it is possible to carry out planning according to the adaptation and importance of these artifacts. After the bibliographic treatment, two case studies were developed to demonstrate the usefulness of managerial tools.

RESULTS AND DISCUSSION

The present research used a bibliographic survey and a fictitious case study with two SCM instruments: Target Costing, focusing on the lodging service of a hotel in Cuiabá-MT, and Total Cost of Ownership, applied to the acquisition comparison of two automobiles from different manufacturers.

APPLICATION OF TARGET COSTING

The following table shows a cost structure, bringing together approximate values based on a hotel in the Municipality of Cuiabá-MT. For the survey, average costs and an average occupancy rate of 60% were used.

Table 1

Hotel Cost Table

Expenses	Monthly Total	Per Apartment	Per Daily Rate
General Electricity	6,000.00	200.00	6.67
Depreciation	5,600.00	186.67	6.22
Employees	26,700.00	890.00	29.67
Internet	4,400.00	146.67	4.89
Subscription TV	1,500.00	50.00	1.67
Telephone	1,600.00	53.33	1.78
Water – General	800.00	26.67	0.89
Office Supplies	3,600.00	120.00	4.00
General Expenses	5,900.00	196.67	6.56
Breakfast	37,800.00	1,260.00	42.00
Miniatures	6,300.00	210.00	7.00
Simplified Tax Regime	28,800.00	960.00	32.00
Total	**129,000.00**	**4,300.00**	**143.33**

Source: Prepared by the authors

With the average lodging price at R$ 200.00 and structural market changes increasing competitiveness, hotel occupancy underwent a sharp reduction. The hotel's current result scenario is presented below.

Table 2

Profit Margin

Components	Value
Selling Price	200.00
(-) Average Costs	(143.33)
(=) Average Profit Margin (28%)	56.67

Source: Prepared by the authors.

However, if the lodging price were reduced in order to retain customers, the profit margin would decrease and would not reach the desired margin; therefore, cost management would become necessary. The alternative is to reduce costs without lowering the quality perceived by the customer, which is possible through target costing. The proposal is made through a satisfaction survey with the customers themselves in order to ascertain which service components add the most value to them.

In the next table, costs are computed and summarized. All resources and their degree of importance were identified before any modification, for example: the restaurant began to be outsourced, the minibars in each room were turned off (being turned on optionally), and finally there was a reduction in staff through the discontinuation of valet service, which was not of such value to the customer but burdened the company.

Table 3

Hotel Cost Readjustment

Expenses	Monthly Total	Per Apartment	Per Daily Rate
General Electricity	5,400.00	180.00	6.00
Depreciation	5,000.00	166.67	5.56
Employees	21,700.00	723.33	24.11
Internet	3,300.00	110.00	3.67
Subscription TV	1,500.00	50.00	1.67
Telephone	1,600.00	53.33	1.78
Water – General	800.00	26.67	0.89
Office Supplies	3,400.00	113.33	3.78
General Expenses	5,900.00	196.67	6.56
Breakfast	18,000.00	600.00	20.00
Miniatures	6,300.00	210.00	7.00
Simplified Tax Regime	25,920.00	864.00	28.80
Electricity (Minibar)	450.00	15.00	0.50
Total	**93,870.00**	**3,129.00**	**104.30**

Source: Prepared by the authors.

The objective of target cost is the value of the daily rate and to increase the profit margin in a way that positively affects the performance and quality of services, creating resilient barriers to face obstacles, as a consequence of strategically analyzed efforts. This is shown in Table 4 below.

Table 4

Target Cost

Components	Value
Selling Price	180.00
Target Profit (42%)	75.70
Maximum Allowable Cost	104.30
Estimated Cost	143.33
Target Cost (Gap)	(-39.03)

Source: Prepared by the authors.

The difference is dynamic, according to variations as changes are developed, thus becoming a target. The process is focused on consumers, and the value of the target cost is determined and managed based on the price they are willing to pay. With this in mind, efforts are concentrated on cost management to assist in the coherent distribution of price management, as shown in Table 5.

Table 5

Achievement of the Desired Profit

Components	Value
Selling Price	180.00
(-) Average Costs	(104.30)
(=) Average Profit Margin (42%)	75.70

Source: Prepared by the authors.

The changes had direct effects on the hotel's daily costs, simplifying components and resulting in an estimated cost value of R$ 104.30; thus, achieving the daily rate of R$ 180.00 to be offered, representing 42%. This provided a significant differential linked to elements aimed at satisfying the

desires of both parties, originally derived from strategic plans encompassing the demands of competitiveness.

APPLICATION OF TOTAL COST OF OWNERSHIP

Total Cost of Ownership is characterized by the study of all costs in the acquisition process, whether of goods or services. In this case, the comparison of two similar cars will be presented, a method calculated over the product cycle as a result of analyses of their respective costs, with the detailed structure resulting in a purchasing benefit.

In this situation, we have a comparison of the purchase and use costs of two similar cars from different manufacturers, identified as Car A and Car B, without naming them, taking into account certain costs incurred over only two years with the use of 24,000 km driven in total.

Table 6

Cost Comparison Between Cars of Different Brands

Cost Item	Car A	Car B
Purchase Price	R$ 44,609.00	R$ 43,542.00
Fuel Cost	R$ 6,787.56	R$ 7,404.60
Maintenance	R$ 1,410.00	R$ 3,020.00
Tax	R$ 2,101.00	R$ 2,449.00
Insurance	R$ 4,479.24	R$ 5,250.12
Total Price	R$ 59,386.80	R$ 61,665.72

Source: Prepared by the authors.

Through the application of this method, we can perceive that Car A has the best TCO, demonstrating a more favorable approach in values ranging from fuel supply, maintenance, insurance, and vehicle tax, despite its acquisition value being higher than that of Car B. This already highlights the ability to identify cost-benefit, which would not be properly carried out solely through the decision based

on the best purchase budget. It assigns focus to price guidance established in the use of the asset with regard to quality and the strategic economy of the purchasing area.

FINAL CONSIDERATIONS

With this research, it was possible to demonstrate, in both theoretical and practical terms, modern managerial tools as a means of cost management. Such tools corroborate the development of strategy, giving accounting a greater degree of instrumentality when market perspectives are incorporated into its activities.

The Target Cost methodology serves to meet the needs that interfere in costs and in the value the consumer is willing to pay; it lies in the ability to identify what must be done in order to achieve the desired satisfaction. This is similar to the target costing approach explained in hospitality, where the value of lodging is one of the problems faced in the face of competition. Through this artifact, companies seek to ensure that their selling prices remain constantly competitive and that service quality is maintained without affecting profitability or user perception.

Total Cost of Ownership demonstrates that users cannot make choices aimed only at the moment of acquisition, but rather at the entire life cycle of the product. The strategic relationship of costs positions the user to know the true values of each item expected to be acquired. It contributes to anticipating what will be used, indicating the advantage of choice by providing knowledge of the structure of all costs.

Therefore, these SCM instruments can be implemented in both business and individual contexts and used to support decision-making. They are identified through the selection of databases for the formation of solutions that significantly overcome difficulties, with the purpose of generating an advantage in the face of numerous factors related to competition, and consequently becoming decisive for survival in the current market.

It is therefore clear that there is a need to expand such tools for decision support, as they refer to the very continuous improvement of traditional tools, which must be enhanced over time. Thus, more than determining costs, accounting serves as a strategic tool for organizations.

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A SYSTEMATIC REVIEW ON THE USE OF INFORMATION AND COMMUNICATION TECHNOLOGIES (ICT) FOR CITIZEN PARTICIPATION IN URBAN MANAGEMENT

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Abstract

Discussions on intelligent cities and technology-based urban solutions have gained importance in the field of city planning and management. In the context of technological development, it is necessary to update citizen participation, inserting it in contemporary advances and building new strategies to traditional methodologies. This study explores the possibilities offered to urban management from the insertion of Information and Communication Technologies (ICT) and aims, therefore, to analyze the scientific production to understand how ICT contribute to the improvement of this participation. The methodology is based on a systematic review of the literature with explicit and systematic search methods in the *Scopus and Web of Sciencedatabases*, in addition to content analysis through word clouds. The results indicate a more prominent scientific production of case studies pertaining to public administration and the evaluation of e-government and e-services. The studies point to an increase in the use of social media,

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apps and other platforms both *top-down andbottom-up*, and indicates some caveats and opportunities for new research.

Keywords: Urban Management, ICT, E-government, E-participation, Smart Cities.

INTRODUCTION

According to the United Nations (UN, 2019), in 2007 more than half of the world's population came to live in cities. By 2050, the UN (2019) projects that approximately 70% of the 10 billion inhabitants the planet may have will live in urban agglomerations. This growth of cities entails economic, social, and environmental impacts, which constitutes one of the great contemporary challenges for urban managers and planners, especially when considering the goals of sustainable development.

In this context, discussions about *smart cities* and new innovative urban solutions based on Information and Communication Technologies (ICT) have gained increasing importance in the field of urban planning and management (Neirotti et al., 2014). The term reflects the concept that a smart city is characterized by good resource management and social participation; that is, it invests in human and social capital in order to create technological infrastructures that support sustainable economic development and improve the population's quality of life (Caragliu, Del Bo, & Nijkamp, 2011).

Among the various challenges of city management, the promotion of greater dialogue among different sectors of society stands out. Capturing opinions, debating, dialoguing, consulting, and, as a consequence, achieving greater citizen participation in public management are matters of utmost relevance in the current context. For Lazzaretti et al. (2019), ICT are important allies of public governance, making it more effective through responsiveness, integrity, reliability, regulatory improvement, accountability, responsibility, and transparency.

With technological development, participatory processes must be updated by integrating them into contemporary developments and developing new strategies alongside traditionally applied methodologies (Bugs & Reis, 2014). Given this need, which seeks democratization and horizontality in decision-making

processes, and in parallel with technological advances, this study starts from the premise that available technologies are diverse and that their adoption by governments can affect citizen participation. In other words, the variety of technologies and the strategies implemented configure different modes of adoption and different outcomes. Thus, the central question of this study is: *in what way can ICT contribute to the improvement of citizen participation in urban management?*

To answer this question, recent studies on the use of ICT for citizen participation were analyzed, specifically the new alternatives for management, by structuring the literature on the subject according to the existing fields and approaches, in order to deepen the concept of e-participation, identify new fields of study, and identify research possibilities.

This article is structured into five parts. The first presents a contextualization, the problem, and the objective of the study; next comes a theoretical framework with the conceptual bases on the subject; the third part addresses the methodological procedures used in the review; the fourth analyzes the results; and, finally, the article discusses the findings and presents final considerations and recommendations for subsequent studies.

SMART CITIES: CONCEPTS AND POLYSEMIES

The concept of smart cities is broad and may vary according to the field of knowledge to which it is applied; therefore, it still lacks a consensual definition, which may lead to imprecision (Hollands, 2008; Caragliu et al., 2011). Gibson, Kozmetsky, and Smilor (1992) argue that the emergence of the term dates back to the early 1990s, due to the need to understand the urban development process associated with the phenomenon of globalization and new technologies. Consequently, in the early 2000s, Smart City projects and initiatives were already being reported, and their objective was to improve urban quality of life and the relationship between public management and citizens (Odendaal, 2003).

However, only more than a decade after the term emerged was a Smart City model proposed by Giffinger et al. (2007), based mainly on self-management activities and civic awareness. In the model, the

city should encompass six sectors and achieve excellent performance in them: smart economy; smart people; smart governance; smart mobility; smart environment; and smart living.

Thus, amid various definitions, Meijer and Bolívar (2016) observed that the concept usually has three focal points: the technological focus, referring to cities that employ smart technologies; the people-centered focus, with emphasis on citizen intelligence; and governance, which highlights collaboration.

In the literature, the term Smart Cities is usually associated with the quality of public services, the administrative efficiency of cities, resource management, environmental preservation, urban sustainability, and, as adopted in this paper, ICT and citizen participation in urban management.

CITIZEN PARTICIPATION AND ICT

From the late 1990s onward, there has been a growing number of studies on investment in digital information technology in public management with the aim of fostering citizen participation (Zheng, Schachter, & Holzer, 2014; Wang & Bryer, 2013; Thomas & Streib, 2003 apud Lee & Kim, 2017). The lack of population participation in the planning and management of public policies undermines democracy and contributes to increasing inequality. Many public managers have offered various forms of electronic participation, ranging from simple online requests to interactive platforms and social media services.

The study by Lee and Kim (2017), conducted in South Korea, developed and tested a model proposing three dimensions of electronic participation in the effectiveness of local governance. The result points to a direct relationship between citizen participation in local management through digital tools and the perception of public managers' responsiveness. The explanation provided by the studies varies according to their focus, concentrating on demographic issues (citizen profile) and satisfaction with public management (Gramberger, 2001).

Although an infinite number of citizen participation tools are being developed, as found in the studies by Ergazakis, Metaxiotis, and Tsitsanis (2011) and by Kamateri et al. (2015), it is still not clear in

which contexts public managers incorporate such participation into their decision-making (Steinbach, Wilker, & Schottle, 2020).

Factors external to governments' own technological capacity hinder the effectiveness of full adherence to participatory management. This is the case of South Africa, according to the study by Piderit and Jojozi (2017), which points to low participation in electronic governance due to political reasons, despite the country having adequate technological conditions. In Brazil, the city government of Belo Horizonte, in the state of Minas Gerais, launched the Digital Participatory Budget (OPD) in 2006, a modern version of the participatory budgeting process created in 1989 and already implemented in Porto Alegre, Rio Grande do Sul. However, this tool has shown a decline in use due, according to the study by Barros and Sampaio (2017), to the loss of citizens' trust in the participatory budgeting instrument.

METHODOLOGY

To achieve the intended objective of the investigation, a Systematic Literature Review (SLR) was chosen, as it was considered appropriate for highlighting scientific production and making the procedures used explicit. In this sense, according to Sampaio and Mancini (2007), the systematic review is defined as a study that uses the scientific literature as a source of data in order to investigate a given topic. The review may summarize, synthesize, and relate a set of evidence through the application of explicit methods for searching, analyzing, and synthesizing the selected information. The steps proposed by the authors were adopted **(Table 1)**.

Table 1

Steps for the Systematic Review.

Steps	Description
Step 1: Definition of the question	Establishes what is to be investigated.
Step 2: Search for evidence	Search in indexed electronic databases (through the selection of descriptors, also known as terms, built from keywords and Boolean operators AND, NOT, OR, etc.).
Step 3: Review and selection of studies	With the selected studies, establish criteria to determine their validity and whether the results may be biased.
Step 4: Analysis of the quality of the studies	Based on similarities among articles, the data will be grouped in order to obtain the final conclusions.
Step 4: Presentation of the results	The writing of the results should take into account the guiding question established in the first step.

Source: Adapted from Sampaio and Mancini (2007).

REVIEW PROCEDURES

Thus, recent studies (2017–2021) on the use of ICT for citizen participation were sought in order to understand how ICT may contribute to improving such participation in urban management. The scientific production considered relevant to the study was collected through explicit and systematized search methods in the *Scopus* (Elsevier) and *Web of Science* databases, as they contain an immense quantity and variety of indexed journals, articles, and abstracts and are relevant in the fields of applied social sciences and technologies.

However, in order to access the databases, it was first necessary to access the CAPES Journal Portal and log in through the Federated Academic Community (CAFe), which is a federation that brings together Brazilian teaching and research institutions. Through CAFe, it is possible to access services offered by the institutions participating in the federation, such as database access. It therefore constitutes an initiative of the Brazilian National Research Network (RNP) that makes it possible to conduct research and access materials restricted to institutional subscriptions. In addition, for the search and subsequent

analysis of the articles, the following review protocol was previously adopted to guide the research **(Table 2)**.

Table 2

Search and review analysis protocol.

1. Definition of search terms and synonyms and their relationships through Boolean operators
2. Search restricted to the field “Titles, Abstracts and keywords”
3. Inclusion criteria (filters): - Languages: English, Portuguese, and Spanish. - Text type: Article. - Publication stage (Stage: final). - Time interval: Published in 2017, 2018, 2019, 2020, and 2021.
4. Exclusion criteria: - Belonging to fields of study unrelated to the research topic. - Other text types (e.g., essays and books). - Literature review articles.
5.Exclusion of duplicate articles between the databases.
6. Screening of titles
7. Screening of abstracts
8. Categorization of studies
9. Full reading of the selected articles

Source: Author (2021).

Furthermore, as shown in **Table 3**, search terms (strings) and related synonyms were defined according to the recurrence identified in the texts of the theoretical framework. Quotation marks (“ ”) were used for compound terms, that is, terms consisting of more than one word, and an asterisk (*) was used as a truncation resource to find words in singular or plural forms and spelling variations. In addition, the advanced search feature available in the databases was used to establish relationships between search terms in order to narrow or broaden the research. For this purpose, the Boolean operators, which may be and, or, and and not, were employed.

Table 3

Terms used in the review and search code.

		Combinations among synonyms			Other		
"e-participat*"	**OR**	“public participation”	“public engagement”	“public involvement”	“participat* democracy” “participat* govern*” “collaborative govern*” “citizen centri*”	**AND**	"ICT*"
		“popular participation”	“popular engagement”	“popular involvement”			
		“civic participation	“civic engagement”	“civic involvement”			
		“citizen participation”	“citizen engagement”	“citizen involvement”			
		“social participation”	“social engagement”	“social involvement”			
		“community participation”	“community engagement”	“community involvement”			

Script: *("e-participat*") OR (("public participation" OR "popular participation" OR "civic participation" OR "citizen participation" OR "social participation" OR "community participation" OR "public engagement" OR "popular engagement" OR "civic engagement" OR "citizen engagement" OR "social engagement" OR "community engagement" OR "public involvement" OR "popular involvement" OR "civic involvement" "citizen involvement" OR "social involvement" OR "community involvement" OR "participat* democracy" OR "participat* govern*" OR "citizen centri*" OR "collaborative govern*") AND ("ICT*"))". Source: Author (2021).*

The search began with terms related to citizen participation combined with the operator “OR” in order to retrieve studies containing any of the terms in their titles, abstracts, or keywords. Subsequently, in order to narrow the search, the operator “AND” was used to find the terms only when combined with “ICT”, also present in the titles, abstracts, or keywords.

Consequently, after an initial sample had been obtained, filtering tools available within the databases themselves were adopted regarding language, year of publication, type of publication, and subject area. This made it possible to direct the search toward more recent articles published in more than one language, thus restricting the search to peer-reviewed scientific production and avoiding other text types such as essays and books. The new sample then underwent a methodological selection procedure according to the following stages: (1st) Reading of titles, (2nd) Reading of abstracts, (3rd) Processing and categorization, (4th) Full reading of the selected articles.

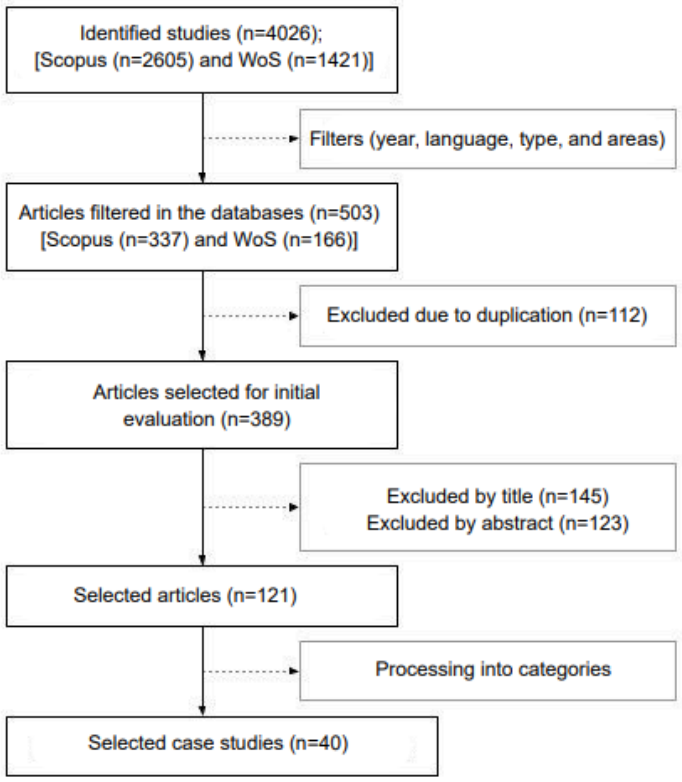
The *Pandas* library for data manipulation and analysis, written in Python, was used to process the abstracts of the selected articles. Stopwords were removed and, finally, through the Wordcloud library, a word cloud was generated from the abstracts. By means of the *Matplotlib* library, also in Python, the image was generated as a heuristic model for data visualization and for constructing an overall panorama of the works.

RESULTS

The results presented here stem from the search carried out in the *Scopus* and *Web of Science* databases on May 8, 2021. With the search script **(Table 3)** in hand and as previously established in the review protocol **(Table 2)**, the search, procedures, and analyses were initiated according to the following sequence **(Figure 1)**:

Figure 1

Review stages.



Source: Author (2021).

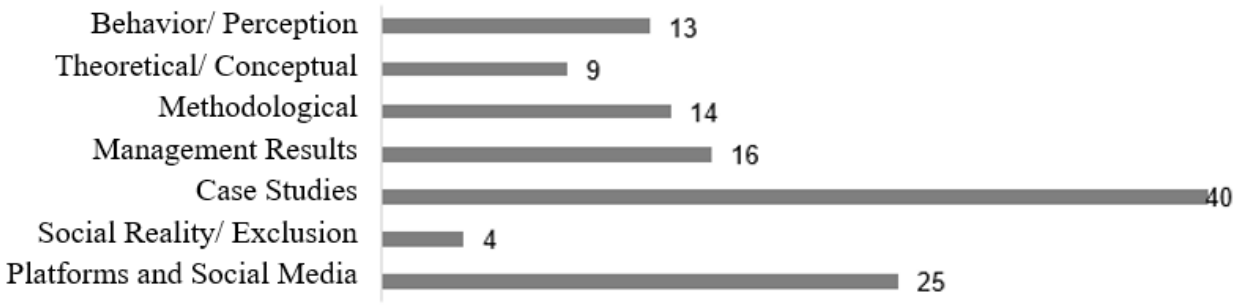
An initial sample of 4,026 studies was obtained, 2,605 in Scopus and 1,421 in *Web of Science*. However, when the predefined inclusion and exclusion criteria **(Table 2)** were applied, the sample was reduced to a total of 503 articles. Next, by cross-checking the databases, a significant number of articles present in both databases—that is, duplicates—was identified. After the duplicates were excluded, a new sample of 389 articles was obtained.

Once the search stages had been completed, a qualitative analysis was conducted by reading the titles and abstracts of the partial sample, with the aim of eliminating articles considered unrelated to the topic or the field. Through title reading, it was identified that 145 articles did not contribute to the research question; by reading the abstracts of the remaining articles, it was identified that 123 articles were outside the scope of the research, resulting in a final sample of 121 articles to be categorized. In sum, those eliminated in this analysis corresponded to articles that had not been filtered out by the databases' own tools based on the established restrictions, as well as studies from other thematic areas unrelated to the research, or literature review articles.

Furthermore, also through abstract reading, the 121 selected articles were processed into different categories **(Figure 2)**, based on the theme of each study, namely:

Figure 2

Categorization of the articles.



Source: Author (2021).

The *Behavior/Perception* category addresses themes that are very common in Economics, Psychology, and Administration, such as "Decision Theory" and "Behavior Theory." Such works aim to identify which factors (economic, social, psychological) are more or less decisive for the user in choosing whether or not to participate voluntarily in government decision-making through electronic governance mechanisms.

The articles in the *Theoretical/Conceptual* category are responsible for theorizing and providing definitions, even etymologically, since their content is centered on theoretical debate. They were selected and analyzed for the theoretical foundation and exploration of definitions on the subject.

In the *Methodological* category, one observes articles whose focus lies on the development of methods and systems for evaluating big data. Although this is not the scope of the present article, the analysis made it possible to identify technologies that enable the identification, collection, processing, systematization, and secure management of such data. Another issue widely discussed in this category of articles is the inclusion of offline data in addition to online data, which are already widely used.

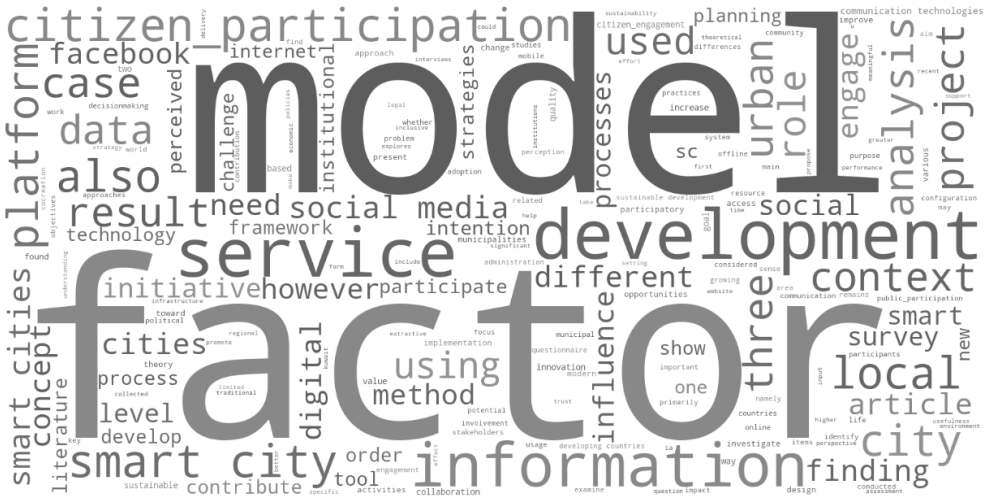
The *Management Results* category presents data from various countries whose governance instruments already test and use online participation mechanisms in practice. Terms such as "collaborative governance," "electronic governance," and "e-governance" appear here. In general, these works have two focal points: the first group analyzes how smart city governments use new technologies with the aim of improving citizen participation. The second group actually evaluates whether participation increases due to the availability of platforms that facilitate interaction.

The third and most numerous category, *Case Studies*, comprises a series of examples of cities, whether pioneering or not, that have embraced ICT and use them in planning management. These cities, as can be observed in the analyzed articles, receive various denominations *(wired cities; cyber cities; digital cities; self-aware cities; smart cities)*. All these terms, in turn, focus on the effects of ICT on the form, processes, and ways of life of cities. In order to outline a general panorama of the contents, albeit a visual and imperfect one, the textual processing of the abstracts of these categorized articles was chosen.

This method consisted of a heuristic procedure in which the following word clouds corresponding to each category were generated **(Figure 3)**:

Figure 3

Word cloud generated from the abstracts of the articles in the "Case Studies" category.



Source: Author (2021).

The category called *Social Reality/Exclusion* encompasses some works related to the difficulty of access to information in certain poor and emerging countries and how this factor is responsible for generating even greater social inequality. They also emphasize the potential of big data to favor the analysis of such realities, as well as its use as an instrument for strengthening democracies.

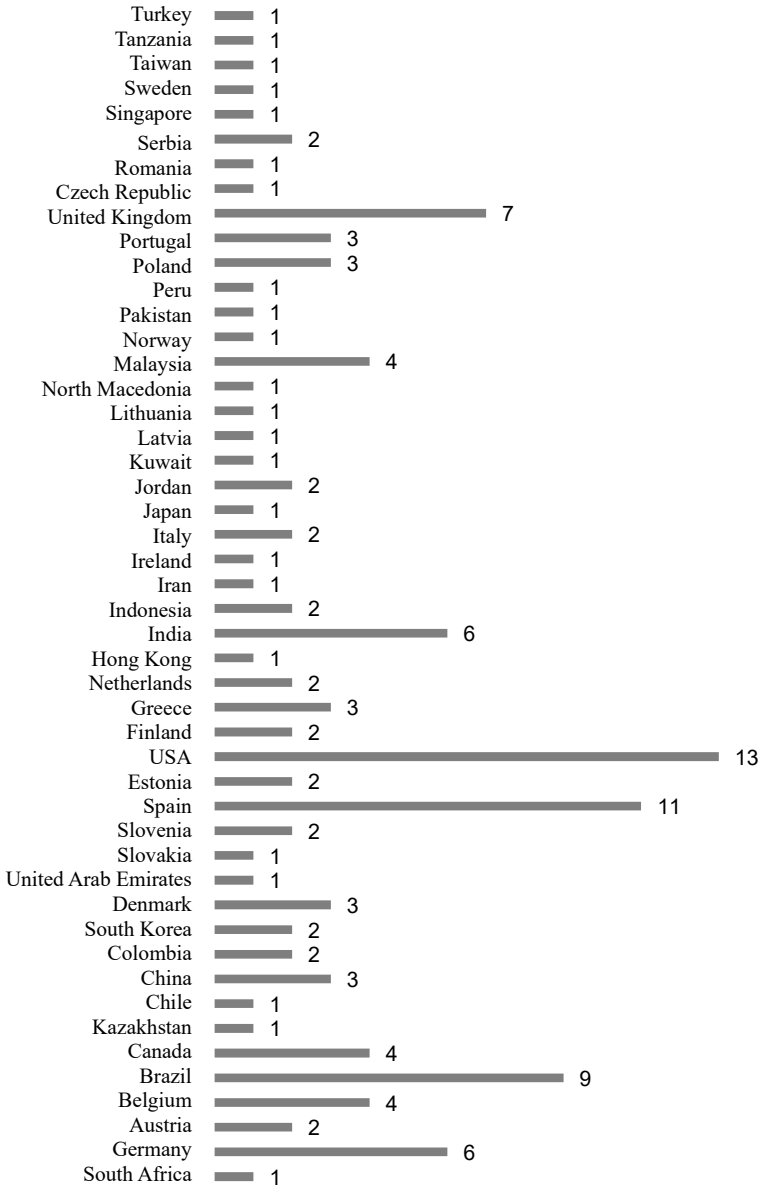
The *Platforms and Social Media* category refers to those articles whose focus lies on online interaction platforms and social media. In this case, social networks such as *Twitter*, *Facebook*, and *Instagram* can be highlighted, as they are widely used as a source of data for studies involving smart cities. Most of the articles focus on user-generated data derived from location-based platforms in a specialized manner. Such platforms expand the concept of connectivity and make it possible, within the demands and needs of each city, to optimize public management.

The search yielded results from scientific production distributed across several countries, though with a larger number of articles in more technologically developed countries, such as the United States,

Spain, the United Kingdom, and Germany, and a significant number in Brazil and India, which are emerging countries **(Figure 4)**

Figure 4

Countries of origin of the corresponding authors of the articles.



Source: Author (2021).

Furthermore, it was observed that the *Case Studies* category had the largest number of articles and was also the most expressive in bringing evidence to the research question. Therefore, as a final analysis, all the articles included in this category were read in full and exploratorily.

DISCUSSION

The Case Studies analyzed in full, as well as the information extracted from them, generally demonstrated a strong questioning of the concept of smart cities and its various approaches, with strong criticism of the lack of inclusion of e-participation as one of its pillars. In addition, a substantial academic production related to public administration and the evaluation of e-government and its electronic services was noted. However, for a better understanding of the relationships between citizen participation and ICT, some examples are highlighted here.

From the late 1990s onward, there has been a growing number of studies on investment in digital information technology in public management with the aim of fostering citizen participation (Wang & Bryer, 2013; Thomas & Kim, 2017; Zheng et al., 2014).

Napitupulu (2019) addresses Presidential Instruction No. 3 of 2003 in Indonesia and discusses public policies and e-gov development strategies, showing that there are two main public demands that must be met by the government in order to achieve quality governance: public services and public participation. The government should not only provide quality public services, but should also facilitate public participation in the formulation of public policies. The author also argues that e-participation would be the evolution of e-government, emphasizing public participation as the main priority in the organization of government. This new form of government is called Transformational Government (T-government) or Open Government, which would be a new concept of electronic government management, more “open” to citizens’ involvement in the design of public content and services.

Moreover, it is argued that when the benefits of public participation meet citizens’ needs, there is an improvement in the quality of public services provided by the government and, consequently, an

enhancement in cost and time control. Thus, with ICT, public participation could be more easily captured in the decision-making process or in government policies.

However, the mere use of technology does not guarantee that the public will be willing to participate in decision-making or in policy formulation (Utomo, 2011). The author concludes that citizens are not significantly involved in online participation because society has not yet perceived the importance of the practice. Appropriate conditions and incentives are necessary to engage citizens, in addition to overcoming factors that hinder the continuation of community participation, such as bureaucracy, time, high costs, among others, all of which result in community skepticism (Utomo, 2011). Thus, the implementation of e-participation is not an easy task, as it requires a new fundamental process in the relationship between government and citizen, in which the latter first perceives the usefulness (benefit) and also the ease of use of the technology offered, in accordance with Davis's (1989) technology acceptance model.

Szarek-Iwaniuk and Senetra (2020) reinforce the importance of strong legislation, agreements, and public documents focused on social participation, such as, for example, in Poland, the "Strategy for Responsible Development," which presents the main prerequisites, objectives, and directions of national development in the social, economic, regional, and spatial dimensions, and proposes a new model of development driven by responsible people, socially oriented toward sustainable growth.

Another Polish strategic document entitled "National Strategy for Regional Development 2030" aims to promote regional development up to 2030, emphasizing the importance of sustainable development on a national scale, including the reduction of disparities in the socioeconomic development of Polish regions. Therefore, policy should build a culture of social participation and cooperation, and the implementation of the smart city is advocated as a concept geared toward innovation, ICT development, and social engagement in urban management and planning.

There is also the "National Urban Policy 2023," whose main objective is to empower cities and urban areas in the process of promoting sustainable development, creating jobs, and improving local

quality of life, by improving the quality of urban policies at the national and territorial levels. Public participation is one of the topics addressed in this document, which states that the quality of urban management should be improved.

It is also argued that the growing availability of ICT offers new opportunities to increase social participation and encourage citizens toward innovative co-design solutions in city management, because e-participation would allow the government to reach more citizens than traditional methods of social participation, relying on modern technologies to increase active social participation in decision-making. Examples of electronic participation tools include social media, electronic petitions, chat rooms, discussion forums, videoconferencing, consultation platforms, online questionnaires, geo-questionnaires, geo-discussions, and mobile applications.

In addition, the Public Participation Geographic Information System (PPGIS), which consists of a series of electronic participation methods and techniques combining cartography with social research, aims to involve community members in decision-making processes. These methods are increasingly used to gather the opinions of local communities and to increase social participation in online interactive urban planning, whose maps allow respondents to submit ideas, identify problems, and propose solutions based on specific locations in space.

As a result, the research tool and data collection methods can be adapted to a specific problem: PPGIS tools support extensive public consultations anytime and anywhere, and they can be accessed through any device that supports web browsing without leaving home, saving time and money. This is also considered a disadvantage, after all, tools that require Internet access face the challenge of including socially and digitally excluded groups.

Ma and Zheng (2017) seek to study why the general public's use of e-government functions has not increased along with the development of e-government. In studying e-government performance in European countries, the authors point to the rapid development of information and communication technologies (ICT) and the fact that many e-government resources have been increasingly adopted by

governments around the world over the last two decades (UN, 2012). The point is that if these costly, capital-intensive electronic services are not used as much as they could be, then the intended benefits of e-government cannot be properly achieved, making it important, according to the authors, to examine what drives citizens' demand for and use of government services.

Moreover, e-government has been widely accepted as a platform for public administration reform (Kassen, 2014), and this brings several benefits to the government itself. For Osman et al. (2014), the benefits brought by electronic services can be grouped into two categories: tangible and intangible benefits. Tangible benefits would involve savings of time and money, while intangible benefits would include the quality of the information and services provided, as well as the system that provides them. The question they intend to answer is therefore more related to what makes an advanced and high-quality e-government system attract more citizens to use it, given that although e-government has become more popular in general, its use still falls short of expectations.

This is because, although e-government—the supply-side factor—is a global phenomenon, research on the actual use of e-government—the demand-side factor—remains relatively underdeveloped (Fakhoury & Aubert, 2015). In addition, evidence of a link between the supply and demand of e-government is scarce; thus, the use of e-government is a complex process that depends on several factors.

Consequently, Zheng and Schachter (2017) reinforce that a citizen's perception of the advantages of electronic participation significantly influences its use: trust is seen as the gateway to the adoption of e-government, so people will likely use e-government services only if they trust the technology and their government (Venkatesh et al., 2016). Furthermore, Kurfalı et al. (2017) indicate that social influence also affects individuals' adoption of e-government, because citizens care about the opinions of other users and tend to use government services when they are disseminated within the community and requested by it.

Other conclusions of the study were that a citizen with good Internet access is more likely to use online services, and that types of Internet access may influence such use; moreover, if government services provided by conventional means are still of good quality, citizens may have fewer incentives to

use e-government. There is a hypothesis that national e-government performance is positively related to citizens' use of various e-government resources: the main finding is that the mere provision of e-government does not automatically lead to use and adherence.

As future avenues for research, the authors indicate the analysis of new models to understand whether the relationship between e-government performance and citizen use is linear or not. Second, they point out that the effect of national e-government performance may differ among various social groups (gender, age, formal education, economic income, and political attitudes), as well as through the moderating effects of variable demographic and socioeconomic factors. In addition, social media (for example, *Facebook*, *Twitter*), as stated, have been increasingly adopted by governments as a tool for providing information and engaging citizens; therefore, their inclusion in future research is considered essential.

The study by Lee and Kim (2017), in South Korea, developed and tested a model proposing three dimensions of electronic participation in the effectiveness of local governance. The result points to a direct relationship between citizen participation in local management through digital tools and the perception of public managers' responsiveness. The explanation provided by the studies varies according to their focus, which concentrates on demographic issues (citizen profile) and satisfaction with public management (Gramberger, 2001).

Although an infinite number of citizen participation tools are being developed through the use of ICT, as observed in the studies by Ergazakis et al. (2011) and Kamateri et al. (2015), it is still not clear in which contexts public managers incorporate this participation into their decision-making (Steinbach et al., 2019).

Factors external to governments' own technological capacity hinder effectiveness through full adherence to participatory management. This is the case of South Africa, according to the study by Piderit and Jojozi (2017), which points to low participation in electronic governance due to political reasons, even though the country has adequate technological conditions.

In Brazil, the city government of Belo Horizonte, in Minas Gerais, launched the Digital Participatory Budget (OPD) in 2006, in an attempt to optimize citizen participation, as a modern version of the participatory budget created in 1989. However, this tool has shown a decline in use due, according to the study by Barros and Sampaio (2017), probably to the loss of citizens' trust in the participatory budgeting instrument.

In this sense, ICT are important allies of public governance, making it more effective through responsiveness, integrity, reliability, regulatory improvement, accountability, responsibility, and transparency.

CONCLUSION

The adoption of the systematic review and its methodological stages, as well as the construction of word clouds, contributes to understanding the general panorama of the research and therefore enables and opens space for more in-depth studies on the subject. As general contributions, it is noted that the increased use of social media, smartphones, portals, crowdsourcing platforms, and planning support systems has generally promoted smarter, more participatory, and more collaborative governments, both top-down and bottom-up. This trend shows gradual changes in governmental organizations, new relationships between governments, the private sector, and citizens, and improvements in cities (Lin, 2018; Napitupulu, 2019).

Added to this, greater participation using different forms of online expression and interaction is associated with greater offline citizen participation (Tai, Porumbescu, & Shon, 2020). It is also identified that this relationship may be stronger among the poorest, which suggests that e-participation is capable of playing an important social role in mobilizing and engaging citizens.

In addition, there is still a wide range of studies based on different technological tools, with associations between two or more digital tools in order to achieve the desired results for city development and citizen participation. The versatility of technology stands out in view of the variety of tools, options,

and ways of combining them for each objective, namely: social media, websites, collaborative clouds, applications, online forums, living labs, crowdsourcing tools, and operations centers.

One of the current strategies most used by municipal governments is social media, which enjoys high adherence among the population, with Facebook being the most recurrent platform in the studies (Svidroňová, Kaščáková, & Vrbičanová, 2018; Huffman, 2017; Metallo et al., 2020). The identified methods suggest everything from the use of existing resources on the platform, such as groups and interaction features, to the use of textual data mining for clustering and analyzing user expressions. It is also noteworthy that social media, although they are environments of potential participation, are often used only as communication channels and are therefore little incorporated as a data source for validation and decision-making by municipal administrations.

The approach by Szarek-Iwaniuk and Senetra (2020) shows that tools based on Public Participation Geographic Information Systems (PPGIS) can mobilize social participation in land-use planning and achieve significant results in participation and in locating urban demands due to the advantages of system geolocation. Digital platforms with PPGIS resources demonstrate promising potential as technologies to be incorporated into Smart City environments that aim for greater precision and community collaboration.

Another frequent aspect in the studies is the importance of initiatives to expand wi-fi Internet coverage in municipalities, since this is an essential action for democratizing access and participation and for boosting other technologies. Furthermore, there is a low number of studies on social issues and inequality of access to ICT, as well as on accessibility and usability of tools. Therefore, these are characterized as fields to be further explored in subsequent studies.

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RACE, CAPITALISM, AND EUROCENTRISM IN THE THOUGHT OF ANÍBAL QUIJANO

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Abstract

This paper discusses the thought of Aníbal Quijano, with emphasis on the coloniality of power, the racial genesis of modernity, and the constitution of the global pattern of power articulated with capitalism and Eurocentrism. It is grounded in the understanding that modernity, far from representing merely a period of historical advancement, was constituted within the conquest of the Americas and produced social classifications founded on the idea of race, thereby reorganizing labor, power, knowledge, and relations among peoples on a global scale (Quijano, 2005; Dussel, 2005). The text examines how the social identities produced in the colonial process, including Indigenous peoples, Black people, mestizos, and Europeans, came to compose enduring hierarchies linked to economic exploitation, epistemic violence, and the inferiorization of non-European cultures and forms of knowledge (Quijano, 2005; Oliveira; Candau, 2013). It further analyzes the myth of modernity as a narrative that positioned Europe at the center of world history and relegated colonized peoples to the past, to irrationality, and to primitivization, thereby legitimizing material and symbolic domination and exploitation (Dussel, 2005; Quijano, 2005). It then discusses the formation of global capitalism in the Americas, with emphasis on slavery, servitude, and commodity production oriented toward the global market, a process that consolidated European centrality within the world-system (Quijano, 2005; Wallerstein, 1999; Ribeiro, 1995). Finally, the paper argues that a decolonial reading offers a path for rethinking Latin America from the standpoint of its memories, its subjects, and its silenced histories, bringing the decolonization of power, knowledge, and being back into debate (Quijano, 2005a; Clímaco, 2014).

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INTRODUCTION

This work is the result of decolonial studies, analyses, readings, and discussions and aims to present the thought of the Peruvian sociologist Aníbal Quijano, with the objective of awakening the reader to a theme so precious and always necessary, which is decoloniality. Aníbal Quijano was born in Yanama in 1928 and died in the city of Lima in May 2018. A renowned Peruvian sociologist and humanist thinker, he was recognized for developing the concept of the "coloniality of power" and for formulating influential studies on postcolonial and decolonial themes concerning Latin America (Clímaco, 2014).

He was a professor at the Faculty of Social Sciences of the Universidad Nacional Mayor de San Marcos, in Lima; he worked in the Department of Sociology at Binghamton University, in New York, at the invitation of the sociologist Immanuel Wallerstein. He served as a visiting researcher at several Latin American universities, including institutions in Chile, Bolivia, Mexico, and Venezuela. In Brazil, he taught at the Institute of Advanced Studies of the University of São Paulo between 1992 and 1993. He founded and directed the "Chair of Latin America and the Coloniality of Power" at Universidad Ricardo Palma, in Lima. He developed in great depth works on the characteristics of Latin America within the capitalist pattern of power, colonization, and modernity (Clímaco, 2014).

Quijano, together with several other intellectuals, formed the Modernity/Coloniality group, with thinkers linked, in part, to Wallerstein's world-system reflections, seeking alternatives to Eurocentric modernity. Among these names were Enrique Dussel, Walter Mignolo, Ramón Grosfoguel, Catherine Walsh, Nelson Maldonado-Torres, and Arturo Escobar (Oliveira; Candau, 2013, p. 277). This group of authors contributed to the elaboration of a forceful critique of the universalization of the European experience as the exclusive measure of history, rationality, and social life (Oliveira; Candau, 2013).

In the present work, we will see, through the refined thought of Aníbal Quijano, that so-called modernity, situated at the end of the fifteenth century, instituted a new global pattern of power by articulating capitalism, Eurocentrism, and globalization. At that historical moment, races were classified in the modern sense, initiating a great distinction between colonized and colonizers, among Blacks, Indians, mestizos, and Europeans. “Em outras palavras, raça e identidade racial foram estabelecidas como instrumentos de classificação social básica da população” (Quijano, 2005, p. 107). From this formulation onward, race came to form part of the very foundation of the social organization of the modern world, traversing economic, political, and cultural relations (Quijano, 2005).

THE RACIAL GENESIS OF MODERNITY

Alongside the myth of modernity, relations of power between dominators and dominated were established. Unpaid, non-wage labor became associated with races regarded as inferior. Colonized Indians were treated as disposable labor, forced to work exhaustively until death (Quijano, 2005).

Europe named itself the creator and protagonist of modernity beginning with the maritime ventures of 1492, leaving the non-European at a perpetually delayed and inferior level. Within this so-called modernity, Europe is presented as the first in history to possess a globalized world pattern of power, making use of four strategic points of domination and power. First, hegemonic capitalism, involving the control of labor, resources, and products. Second, the bourgeois family, controlling sex, its resources, and its products. Third, the nation-state, with the legitimacy of force, its resources and products, articulated with Eurocentrism in the control of subjectivity. Fourth, a pattern of power directed toward the entire world population through three interconnected elements: the coloniality of power, capitalism, and Eurocentrism (Quijano, 2005, p. 113). In this formulation, modernity emerges as a historical experience inseparable from colonial domination and the unequal organization of the world (Quijano, 2005).

Through the idea of race produced in the Americas, new social identities emerged, such as Indians, Blacks, and mestizos, just as the denominations Spanish, Portuguese, and European also emerged. What had previously been used geographically as a way of identifying an individual's origin came to be a determining characteristic for the construction of new identities. The idea of race became so powerful that it ended up becoming part of the subjectivity of the survivors (Quijano, 2005, p. 107).

These new identities were used for the purpose of forming classifications and hierarchies, thus establishing the role of each "race" within society. Blacks were the racial identity of greatest economic importance, directed toward slavery and the slave trade. Later, with European global expansion, the idea of race separated peoples into Europeans and non-Europeans. This way of differentiating biological structures was and remains a founding axis of domination, as are the intersexual and gender axes (Quijano, 2005, p. 107-108). In this way, racial classification became a historical technology of power capable of organizing places, functions, and values within colonial society and its continuities (Quijano, 2005).

The Americas were invaded, conquered, and colonized by the Iberians, who encountered many different peoples, among them Aztecs, Mayas, Chimus, Aymaras, Chibchas, and others. About three hundred years after colonization, these identities were erased and designated as indigenous. The same occurred with enslaved Africans, violently uprooted from their lands and turned into commodities. Achantes, Yorubas, Zulus, Congos, Bacongos, and others, after the same period, came to be known simply as Blacks (Quijano, 2005, p. 116).

These processes culminated in two results in the history of colonization: the loss of identities and the denial of their place in world culture. These peoples were relocated in historical time as the past, as non-Europeans, and as primitive (Quijano, 2005, p. 116). Such a reclassification of the other into a position prior to Europe provided support for a historical imaginary in which the colonizer appears as the measure of humanity and civilization (Quijano, 2005).

As a consequence of the Eurocentric mentality, the inferior races were treated as non-rational beings, with their bodies placed as close to nature or within nature, according to the level of their inferiorization. In this classification are Blacks, Indians, olive-skinned people, yellow people, and women as "close to nature," while "Black women," on this social scale, occupy the lowest position and are found "within nature" (Quijano, 2005, p. 118). Racial hierarchization was thus articulated with other hierarchies, acutely affecting the body, gender, and the production of subjectivity (Quijano, 2005).

Through decolonial studies, Aníbal Quijano and other thinkers present the racial genesis of modernity and show where racism and prejudice gained greater force, worsening over time and becoming institutionalized. In recent times, they remain powerful under often veiled forms, broadening social differences and contributing to the worsening of misery in various fields of social life (Quijano, 2005; Oliveira; Candau, 2013).

It is worth emphasizing that, during much of the period of colonization and slavery, the Black person was treated as a primitive and soulless animal. The Black person had no soul and was thus considered by sectors of the Roman Catholic Apostolic Church itself, an institution that, in many historical moments, was linked to the pursuit of power, possessions, and pleasures offered by Eurocentrism. This context helps us understand how material domination was accompanied by moral, religious, and cultural justifications that reinforced colonial dehumanization (Quijano, 2005; Dussel, 2005).

THE MYTH OF MODERNITY AND THE COLONIALITY OF POWER

The myth of Eurocentric modernity is permeated by the dichotomies European and non-European, primitive and civilized, traditional and modern, by evolutionism from the state of nature to European society, by the idea of race, and by relocation in historical time, with the non-European placed in the past, as primitive and inferior (Quijano, 2005, p. 116). This form of knowledge produced in seventeenth-century Western Europe emerged with the purpose of serving the global pattern of capitalist power

beginning with the constitution of the Americas, with a specific rationality and world hegemony (Quijano, 2005, p. 115).

> "Here lies the tragedy: all of us were led, whether knowingly or not, whether willingly or not, to see and accept that image as ours and as belonging exclusively to us. In this way, we continue being what we are not. And as a result, we can never identify our true problems, much less resolve them, except in a partial and distorted manner." (Quijano, 2005, p. 118)

In a more simplified and didactic way, we can state that modernity was consolidated through the ventures of Christopher Columbus in crossing the Atlantic Ocean in 1492. It was the discovery and invasion of the Americas that marked the beginning of the "modern era" and also the idea of the "world-system" developed by Wallerstein (1999) in his text World-Systems Analysis. Globalization, capitalism, slavery, Eurocentrism, exploitation, and colonialism are concepts very present in so-called modernity (Wallerstein, 1999; Quijano, 2005).

Enrique Dussel, presenting modernity in a global sense, states that "empirically there was never world history until 1492" (Dussel, 2005). Modernity would be the new "paradigm" of history.

> "Modernity, as a new 'paradigm' of everyday life, of the understanding of history, science, and religion, arises at the end of the fifteenth century and with the conquest of the Atlantic. The seventeenth century is already the result of the sixteenth; Holland, France, and England represent later development within the horizon opened by Portugal and Spain. Latin America enters Modernity (long before North America) as the 'other face,' dominated, exploited, concealed" (Dussel, 2005, p. 28).

The "myth of modernity" places Europe at the center of world history and culture, classifying all other histories and cultures as diminished and peripheral, thereby legitimizing forms of domination, exploitation, inequality, and violence. This is what Dussel will call the "other face" of modernity.

> "By denying the innocence of 'Modernity' and affirming the Alterity of the 'Other,' previously denied as a guilty victim, it becomes possible for the first time to 'un-cover' the hidden 'other face' essential to 'Modernity': the colonial peripheral world, the sacrificed Indian, the enslaved Black person, the oppressed woman, the alienated child and popular culture, etc. (the 'victims' of 'Modernity') as victims of an irrational act (as a contradiction of the rational ideal of 'Modernity' itself)" (Dussel, 2005, p. 28).

Aníbal Quijano (2005) states that so-called modernity brought a new global pattern of power, combining capitalism, Eurocentrism, and globalization. At this historical moment, races are classified in the modern concept, initiating a great distinction between colonized and colonizers, between Blacks, Indians, mestizos, and Europeans.

> "In the Americas, the idea of race was a way of granting legitimacy to the relations of domination imposed by conquest. The subsequent constitution of Europe as a new identity after the Americas, and the expansion of European colonialism to the rest of the world, led to the elaboration of the Eurocentric perspective of knowledge and, with it, to the theoretical elaboration of the idea of race as the naturalization of those colonial relations of domination between Europeans and non-Europeans. Historically, this meant a new way of legitimizing the already old ideas and practices of relations of superiority/inferiority between dominators and dominated. Since then, it has proven to be the most effective and durable instrument of universal social domination, because another equally universal, though older one, came to depend on it: the intersexual or gender one: **the conquered and dominated peoples were placed in a natural situation of inferiority, and consequently so too were their phenotypic traits, as well as their mental and cultural discoveries. In this way, race became the first fundamental criterion for the distribution of the world population into levels, places, and roles within the power structure of the new society.** In other words, it became the basic mode of universal social classification of the world population" (Quijano, 2005, p. 107-108, our emphasis).

Relations of power between dominators and dominated were then established. Unpaid, non-wage labor became associated with races regarded as inferior. Colonized Indians were treated as disposable labor, forced to work exhaustively until death, which caused a major Indigenous genocide (Quijano, 2005). It is the anthropologist Darcy Ribeiro who also draws our attention, in his work The Brazilian People: The Formation and Meaning of Brazil, to the cruel process of colonization and slavery in the Americas. Ribeiro (1995) states that the Blacks brought to Brazil were separated by ethnicity from the moment they boarded the ships, losing collective references, while Indigenous peoples were enslaved, catechized, and exterminated. Human beings were dispossessed of themselves.

> The intellectual elaboration of the process of modernity produced a perspective of knowledge and a mode of producing knowledge that demonstrate the character of the global pattern of power: colonial, modern, capitalist, and Eurocentered. This perspective and this concrete mode of producing knowledge are recognized as Eurocentrism (Quijano, 2005, p. 115).

From this point of view, European knowledge ceased to figure as one among several forms of understanding the world and came to occupy the position of universal measure of legitimate knowledge (Quijano, 2005; Castro-Gómez, 2005). Eurocentrism, modernity, and the coloniality of power form part of an amalgam and function as a mirror that distorts what it reflects, although it preserves some traits of resemblance. We possess traits and proximities with Europeans. However, we are distinct. We were led, knowingly or unknowingly, willingly or unwillingly, to see and accept this distorted reflection as our own and as real (Quijano, 2005, p. 118). In this deformed image, Latin America was often invited to read itself through external parameters, a situation that deepened historical and subjective dependencies (Quijano, 2005a).

CAPITALISM AND MEANS OF PRODUCTION

Quijano presents that, in the future Americas, slavery and all other forms of domination had as their main objective the production of commodities for the purpose of supplying the world market:

> "In the Americas, slavery was deliberately established and organized as a commodity in order to produce commodities for the world market and, in this way, to serve the purposes and needs of capitalism. Likewise, the servitude imposed on Indians, including the redefinition of institutions of reciprocity, served the same ends, that is, to produce commodities for the world market. And finally, independent commodity production was established and expanded for the same purposes. This means that all these forms of labor and of labor control in the Americas not only operated simultaneously, but were articulated around the axis of capital and the world market. Consequently, they were part of a new pattern of organization and control of labor in all its historically known forms, together and around capital. **Together they configured a new system: capitalism**" (Quijano, 2005, p. 115, our emphasis).

In this sense, new forms of labor control emerged to guarantee, first, the organization of commodity production. Second, the joint action between capital and market. Third, the fulfillment of new

functions, developing traits and new configurations. The joint action between control of labor, resources, and products founded world capitalism (Quijano, 2005, p. 118). The constitution of this historical arrangement shows that the coloniality of power was present at the very birth of capitalist relations on a global scale (Quijano, 2005).

Racial differences served as a method of social classification and distributed roles in the new structure of labor control. Racist classification endured throughout the entire colonial period. With European expansion, new races emerged, adding yellow and olive-skinned peoples, each new identity with a previously established place within labor control (Quijano, 2005, p. 108).

The wealth of the Americas and their geographical location allowed whites access to gold and silver. The forced labor of the enslaved, with their unpaid labor, allowed colonizers to enter the world market, taking control of the markets of China, India, Ceylon, Egypt, Syria, the Middle East, and the Far East, thus expanding colonial domination to other peoples (Quijano, 2005, p. 109). The Americas, in this movement, appear as the material axis of accumulation and as a central territory in the reorganization of world power (Quijano, 2005; Wallerstein, 1999).

> "This coloniality of the control of labor determined the geographical distribution of each of the forms integrated into world capitalism. In other words, it determined the social geography of capitalism: capital, in the social relation of control over wage labor, was the axis around which all the other forms of control over labor, its resources, and its products were articulated. This made it dominant over all of them and gave a capitalist character to the totality of such a structure of labor control. But at the same time, this specific social relation was geographically concentrated above all in Europe, and socially among Europeans throughout the world of capitalism. To that extent and in that way, Europe and the European were constituted as the center of the capitalist world" (Quijano, 2005, p. 110).

Europe incorporated the rest of the planet as its "world-system." World capitalism governed by Europe reconfigured the cultural histories of dominated countries, such as Africa, Asia, and Oceania, through its hegemony of control over knowledge and control over production. Through the dispossession of colonized civilizations, new geocultural identities were formed through the repression of forms of knowledge production (Quijano, 2005, p. 111). This process affected memory, symbols, knowledge, and

ways of naming the world, imposing exogenous references on the reading of the historical reality of subjected peoples (Quijano, 2005; Castro-Gómez, 2005).

Within the European world-system, ethnocentrism developed, making modernity and rationality European products. In European ethnocentrism, there exists the "other" in a complete state of nature and the "self" as the result of evolution, with the European as the modern being to be attained (Quijano, 2005, p. 111-112).

Eurocentrism and capital-centrism took over so-called human relations along with the artifact of globalization. In every corner of the planet, peoples suffered and continue to suffer from the domination, imposition, and power of the European world-system. We came to see the world, the human being, and their relations through the eyes of the dominators. We came to disbelieve in cultures, medicines, ways of living, and ancestral values. We came, finally, to be market and merchandise, product and consumer (Quijano, 2005; Escobar, 2005).

And, as Aníbal Quijano rightly told us, "consequently, it is time for us to learn to free ourselves from the Eurocentric mirror in which our image is always, necessarily, distorted. It is time, finally, to stop being what we are not" (Quijano, 2005, p. 126).

FINAL CONSIDERATIONS

We will conclude this work by making use, once again, of the thought of Aníbal Quijano, now in his article *Don Quixote and the Windmills in Latin America*, published in 2005, emphasizing that the question of identity in Latin America constitutes an open, dynamic, and heterogeneous historical project, with no fixed loyalty to a single memory or a single past:

> "What we today call Latin America was constituted together with and as part of the currently dominant pattern of world power. Here, coloniality and globality were configured and established as the foundations and constitutive modes of the new pattern of power. From here departed the historical process that defined the historical-structural dependence of Latin America and gave rise, in the same movement, to the constitution of Western Europe as the world center of control of that power. And in that same movement, it also defined the new material and subjective elements that founded the mode of social existence that came to be called modernity" (Quijano, 2005a, p. 9).

From this understanding, it becomes possible to perceive that Latin America occupies a central place in the formation of the modern world, even though this place was inscribed under the sign of exploitation, racial hierarchization, and historical subordination. In Quijano, modernity emerges intertwined with coloniality, and this linkage helps explain why the organization of world power was carried out through the racial classification of the population, the appropriation of labor, the expropriation of knowledges, and the imposition of a Eurocentric imaginary upon colonized peoples (Quijano, 2005; Quijano, 2005a). In this direction, Latin America appears as a space of historical violence, but also as a territory of critical elaboration and the production of other horizons for reading the world (Clímaco, 2014; Oliveira; Candau, 2013).

Throughout this work, we have seen that the coloniality of power formulated by Quijano (2005) makes it possible to understand that the process of colonization went beyond the plane of territorial occupation and economic domination. It reached the ways of being, knowing, naming, and organizing social life. The racial classification of the population, the framing of the non-European as inferior, the centrality attributed to Europe, and the articulation among labor, capital, and the world market make up one and the same historical movement, whose persistence continues to traverse the Latin American experience. For this reason, the critique of the coloniality of power reaches the field of economy, politics, culture, and subjectivity, producing a profound reading of the historical formation of our societies (Clímaco, 2014).

The myth of modernity, by presenting Europe as the center of world history and as the universal measure of rationality and civilization, produces the concealment of other historical experiences, other forms of knowledge, and other ways of life. Dussel (2005) contributes to this debate by presenting Latin

America as the “other face” of modernity, marked by exploitation, sacrifice, and the concealment of subjects and cultures subjected to colonial violence. In dialogue with this reading, Quijano (2005) shows that coloniality does not constitute an episode closed in the past, but rather a persistent logic inscribed in social relations and in the ways by which we still see ourselves and are seen.

This persistence helps explain why so many memories were silenced, so many knowledges were debased, and so many identities were pushed to historical margins; Indigenous peoples, Black populations, and distinct Latin American groups had their trajectories subjected to a continuous process of inferiorization, dispossession, and erasure, while Europe consolidated its material and symbolic centrality (Quijano, 2005; Ribeiro, 1995). Epistemic violence, in this context, walked side by side with material violence, instituting an order in which European knowledge came to figure as the dominant reference for reading the world and humanity itself (Castro-Gómez, 2005).

For this reason, the decolonial perspective acquires political, historical, and intellectual density within this debate and calls Latin American thought to revisit its trajectories, memories, conflicts, and subjects, opening the way to other forms of existence and historical interpretation. In Oliveira and Candau (2013), decolonial pedagogy appears as a possibility of resistance, re-existence, and reconfiguration of formative processes, bringing back into scene historically subalternized subjects and long-disauthorized knowledges. This path reinforces that the critique of Eurocentrism equally involves the construction of other ethical, political, and epistemological references for thinking Latin America.

Many truths, many memories, and many pasts were silenced; many Latin American paths still call for journeying, listening, and sharing. In this line of reasoning, the recovery of historically erased Latin American identities must travel the roads of decolonization, the decoloniality of power, and liberation. It is a matter of bringing back into debate subalternized voices, historically unauthorized experiences, and horizons of existence produced from Latin America (Quijano, 2005a; Oliveira; Candau, 2013).

To revisit Aníbal Quijano, therefore, is to revisit a forceful critique of the historical foundations that sustained Eurocentric modernity and global capitalism; his thought provides elements for

understanding the persistence of inequalities, racial hierarchies, and forms of domination that continue to bear upon the bodies, territories, and knowledges of our peoples. To the same extent, his reflection offers instruments for thinking the liberation from the Eurocentric mirror and the affirmation of other ways of living, knowing, and sharing the world (Quijano, 2005; Quijano, 2005a; Clímaco, 2014).

Let us repeat: “consequently, it is time for us to learn to free ourselves from the Eurocentric mirror in which our image is always, necessarily, distorted. It is time, finally, to stop being what we are not” (Quijano, 2005, p. 126).

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AGRONOMY AND SANITARY SURVEILLANCE: AN INTEGRATED APPROACH TO FOOD SAFETY, RISK CONTROL, AND HEALTH PROTECTION

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Abstract

The increasing complexity of contemporary agri-food systems imposes significant challenges to ensuring food quality and protecting public health, requiring the articulation of different fields of knowledge. In this context, the present study analyzed the integration between agronomy and sanitary surveillance as an essential strategy for promoting food safety, risk control, and public health protection. This is a narrative literature review with a qualitative approach, based on publications indexed in the SciELO and Latindex

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databases, as well as official documents from the Ministry of Health and the National Health Surveillance Agency, covering the period from 2022 to 2026. The study was guided by the following research question: how does the integration between agronomy and sanitary surveillance contribute to food safety and the mitigation of risks to collective health? The results showed that the intensive use of pesticides, contamination of water resources, and the presence of chemical residues in food represent significant sanitary challenges. On the other hand, sustainable agricultural practices, combined with efficient surveillance and monitoring systems,demonstrated potential to reduce such risks. Furthermore, the role of public policies and regulations in controlling the food production chain was highlighted. It is concluded that the integration between agronomy and sanitary surveillance strengthens preventive actions and contributes to the development of safer and more sustainable food systems.

Keywords: Agronomy, Food Safety, Pesticides, Public Health, Sanitary Surveillance.

INTRODUCTION

Food and nutritional security constitutes one of the fundamental pillars for the promotion of public health, especially in contexts marked by social inequalities, production intensification, and the expansion of agricultural technologies. In this scenario, the integration between agronomy and sanitary surveillance emerges as an essential strategy to ensure food quality from production to consumption, encompassing aspects related to risk control, environmental sustainability, and the protection of human health. The complexity of this topic requires an interdisciplinary approach, considering that agricultural production, while ensuring food supply, may also represent a source of risk, especially when associated with the inappropriate use of chemical inputs, water contamination, and failures in sanitary control processes (Domene et al., 2023; Oliveira et al., 2025).

In the Brazilian context, the intensification of pesticide use has raised relevant debates regarding its impacts on health and the environment, highlighting the need for effective monitoring and regulatory mechanisms. Studies indicate that the country presents worrying scenarios regarding the flexibilization of

policies related to the use of these inputs, which may compromise food safety and increase population exposure to potentially harmful substances (Hess et al., 2024; Barroso et al., 2025). Furthermore, the presence of pesticide residues in food has been widely documented, reinforcing the importance of surveillance programs, such as systematic monitoring conducted by regulatory agencies (Leite; Vilarinho; Inoue, 2025).

The central issue of this study lies in the need to understand how the articulation between sustainable agronomic practices and sanitary surveillance actions can contribute to strengthening food safety and mitigating risks to public health. In this sense, the following question is raised: in what way can the integration between agronomy and sanitary surveillance enhance the control of risks associated with the production and consumption of food, promoting greater protection of collective health?

Given this context, the present study aims to analyze the importance of an integrated approach between agronomy and sanitary surveillance in promoting food safety, with emphasis on risk control and public health protection. It also seeks to discuss the main challenges and strategies related to contaminant monitoring, the adoption of sustainable agricultural practices, and the strengthening of public policies aimed at food safety.

The relevance of this study is justified by the growing demand for safe and high-quality food in a global scenario marked by climate change, urban expansion, and increased pressure on production systems. The literature shows that food safety is not limited to food availability but also involves ensuring sanitary and nutritional quality, being influenced by socioeconomic, environmental, and institutional factors (Pedrotti et al., 2022; Moura et al., 2025). In this context, the role of sanitary surveillance, combined with the technical knowledge of agronomy, becomes fundamental to preventing risks, promoting good practices, and ensuring compliance with established regulatory standards.

In addition, sanitary surveillance plays a strategic role in the inspection, regulation, and monitoring of food, contributing to the identification of microbiological, chemical, and physical hazards throughout the production chain. Regulations such as RDC No. 216/2004 and RDC No. 331/2019

establish important guidelines to ensure the hygienic-sanitary quality of food, reinforcing the need for rigorous control at all stages of production and commercialization (Brazil, 2004; Brazil, 2019). Likewise, programs such as the National Plan for the Control of Residues and Contaminants (PNCRC) and the Program for the Analysis of Pesticide Residues in Food (PARA) demonstrate institutional commitment to continuous monitoring and risk mitigation (Brazil, 2023).

Within the field of agronomy, the importance of adopting sustainable practices stands out, such as ecologically based agriculture and integrated pest management, which aim to reduce the use of chemical inputs and minimize environmental impacts. Initiatives focused on training farmers, especially in urban and family farming contexts, have demonstrated positive results in promoting food safety and valuing food sovereignty (Machado et al., 2024). Furthermore, the quality of water used in irrigation is also a determining factor for food safety, since water contamination can directly compromise consumer health (Camargo et al., 2025).

Another relevant aspect concerns integrated plant health surveillance, which seeks to anticipate and mitigate the occurrence of pests and diseases, contributing to the stability of agricultural production and the reduction of sanitary risks. Proactive approaches in this field have been identified as essential for strengthening resilient and sustainable food systems (Soubeyrand et al., 2024). Additionally, international experiences in monitoring food residues reinforce the importance of using technologies and data to improve surveillance systems and ensure greater efficiency in sanitary control (Popescu et al., 2025).

Finally, it is emphasized that the construction of safe and sustainable food systems depends on articulation among different sectors and public policies, including health, agriculture, environment, and education. Instruments such as the National Food and Nutrition Security Plan (PLANSAN) reinforce the need for integrated and intersectoral actions to address food safety challenges in Brazil (Brazil, 2016). In this sense, the integration between agronomy and sanitary surveillance not only contributes to risk control but also strengthens the promotion of public health, consolidating itself as a strategic approach for sustainable development and the guarantee of the human right to adequate food.

METHODOLOGY

The present research is characterized as a narrative literature review, with a qualitative and descriptive approach, whose purpose is to gather, analyze, and synthesize relevant scientific publications and institutional documents regarding the integration between agronomy and sanitary surveillance in the context of food safety, risk control, and public health protection. The narrative review allows for a broad and in-depth understanding of the topic, favoring the articulation among different theoretical perspectives and empirical evidence, especially in interdisciplinary areas.

The study was structured around the following guiding question: how does the integration between agronomy and sanitary surveillance contribute to the promotion of food safety, risk control, and public health protection in the Brazilian context? This question directed the search, selection, and analysis of studies, enabling the organization of knowledge in a systematic and coherent manner aligned with the proposed objectives.

Data collection was carried out through searches in the Scientific Electronic Library Online (SciELO) and Latindex databases, in addition to consultation of official documents provided by Brazilian governmental bodies, such as the Ministry of Health and the National Health Surveillance Agency (ANVISA). The choice of these sources is justified by their scientific and institutional relevance, as well as by the reliability of the information in the field of public health and food production.

Previously defined descriptors based on the Health Sciences Descriptors (DeCS) were used, combined through Boolean operators (AND and OR), namely: “food safety,” “sanitary surveillance,” “agronomy,” “pesticides,” “public health,” “food contamination,” and “risk control.” These terms were applied in Portuguese, considering the national focus of the study, although relevant studies in English were also considered when available in the selected databases.

The inclusion criteria were: (i) complete scientific articles freely available; (ii) publications from 2022 to 2026; (iii) studies directly addressing the relationship between agricultural production, sanitary surveillance, and food safety; (iv) official documents and regulations related to food sanitary control in

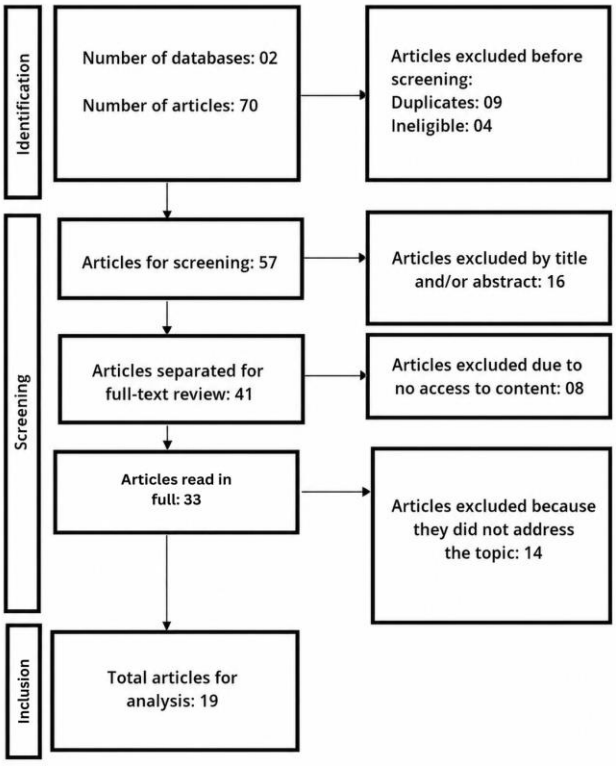
Brazil; and (v) publications relevant to the public health context. The exclusion criteria were: (i) duplicate studies; (ii) publications outside the defined time frame; (iii) studies not directly related to the proposed topic; (iv) abstracts, editorials, letters to the editor, and publications lacking methodological rigor; and (v) articles not available in full.

The study selection process occurred in stages, including reading titles, abstracts, and subsequently full texts, to verify compliance with the established criteria. After this screening, the selected studies were organized and interpretively analyzed, enabling the identification of relevant thematic categories, such as pesticide use, residue monitoring, sustainable agricultural practices, and the role of sanitary surveillance.

The systematization of the methodological process is represented in Figure 1, which illustrates the stages of searching, selecting, and including studies, from initial identification in the databases to the final definition of the analyzed sample.

Figure 1

Flowchart of the study selection process included in the narrative review.



Source: Authors (2026)

Finally, it is noted that, as this is a narrative review based on secondary data in the public domain, submission to a Research Ethics Committee was not required, in accordance with current ethical guidelines. Nevertheless, principles of scientific integrity were respected, with proper citation of the sources used, ensuring the reliability and transparency of the information presented.

RESULTS AND DISCUSSION

The results of this narrative review show that the integration between agronomy and sanitary surveillance constitutes a strategic element for strengthening food safety and public health protection, especially in the face of contemporary challenges related to the intensification of agricultural production, the use of chemical inputs, and the increasing complexity of food chains. Analysis of the selected studies made it possible to identify central thematic categories directly aligned with the research objective, namely: pesticide use and its impacts, residue monitoring in food, the quality of natural resources used in production, sustainable agricultural practices, and the regulatory role of sanitary surveillance.

Regarding pesticide use, the studies point to a worrying scenario in Brazil, characterized by increased consumption of these substances and the flexibilization of regulatory policies. This context increases the risks of environmental contamination and human exposure, directly impacting food quality and population health (Hess et al., 2024; Barroso et al., 2025). The persistent presence of pesticide residues in food products was observed, requiring continuous monitoring and control actions. In this sense, residue analysis programs play a fundamental role in identifying irregularities and ensuring safe consumption standards (Leite; Vilarinho; Inoue, 2025).

The relevance of monitoring also extends to the international context, where data-driven approaches have been used to improve contaminant surveillance in food, especially fruits and vegetables. These strategies demonstrate that the use of technologies and integrated systems can significantly contribute to early risk detection and more assertive decision-making in public health (Popescu et al.,

2025). Such evidence reinforces the need to strengthen national surveillance systems through investments in innovation and technical training.

Another relevant aspect identified concerns the quality of water used in agricultural irrigation. Studies show that contamination of water sources, especially groundwater, can compromise food safety, representing a significant risk to human health (Camargo et al., 2025). The use of water without adequate sanitary control favors the dissemination of pathogenic microorganisms and harmful chemical substances, highlighting the importance of integrated surveillance of natural resources in agricultural production.

The analysis also highlighted the importance of sustainable agricultural practices as a strategy to reduce risks and promote food safety. The adoption of agroecological models, integrated pest management, and reduced use of chemical inputs has proven effective in producing safer food and preserving the environment (Machado et al., 2024). Furthermore, farmer training initiatives, particularly in urban and family farming contexts, contribute to strengthening food sovereignty and improving production and commercialization conditions (Moura et al., 2025).

In this context, food safety should be understood broadly, encompassing not only food availability but also sanitary quality, nutritional value, and accessibility. Studies indicate that socioeconomic, environmental, and institutional factors directly influence the effectiveness of public policies aimed at food safety, reinforcing the need for integrated and intersectoral approaches (Pedrotti et al., 2022; Oliveira et al., 2025).

Sanitary surveillance emerges as a central element in ensuring food quality through regulation, inspection, and risk monitoring throughout the production chain. Brazilian regulations establish strict standards for food production, handling, and commercialization, contributing to the prevention of health hazards (Brazil, 2004; Brazil, 2019). In addition, food and nutritional surveillance plays a relevant role in identifying vulnerabilities and promoting actions aimed at improving population health conditions (Moura et al., 2023).

The integration between agronomy and sanitary surveillance is also reflected in the need for plant health surveillance, focusing on preventing and controlling pests and diseases that may compromise agricultural production and food safety. Proactive and research-based approaches are essential to anticipate risks and ensure production system sustainability (Soubeyrand et al., 2024).

Furthermore, the articulation among public policies, such as national food safety plans and residue control plans, is fundamental to addressing identified challenges. Implementation of these policies depends on coordinated action among different sectors, including health, agriculture, and environment, highlighting the importance of integrated governance (Brazil, 2016; Brazil, 2023).

Table 1 presents a synthesis of the main findings of this review, systematizing the analyzed studies by authors, objectives, and main contributions to the investigated theme.

Table 1

Synthesis of the studies included in the narrative review.

Author (Year)	Objective of the study	Main findings	Contributions to the theme
(Camargo et al., 2025)	Evaluate the sanitary quality of groundwater used in the irrigation of vegetables	Identified potential contamination of the water, with direct implications for food safety	Highlights the need for surveillance of water quality in agricultural production
(Hess et al., 2024)	Analyze the scenario of pesticide policies in Brazil	Points to regulatory flexibilization and increased exposure to toxic substances	Reinforces the importance of rigorous public policies and continuous monitoring
(Leite; Vilarinho; Inoue, 2025)	Investigate pesticide residues in food in Brazil	Identified a significant presence of residues in the foods analyzed	Highlights the relevance of sanitary control and monitoring programs
(Moura et al., 2025)	Analyze food security in family farming contexts	Revealed socioeconomic challenges and the importance of local production	Values sustainable practices and the strengthening of food sovereignty
(Machado et al., 2024)	Evaluate the training of urban horticulturists	Demonstrated improvement in food production and quality	Indicates education as a tool for food safety

(Oliveira et al., 2025)	Discuss food safety and food security	Highlights the multidimensionality of food security	Provides a basis for the need for an integrated approach
(Messias, 2025)	Analyze sanitary surveillance in the environmental and tourism context	Highlights the importance of surveillance in risk prevention	Broadens the understanding of surveillance as an instrument of public health
(Moura et al., 2023)	Evaluate food and nutritional surveillance	Identifies its contribution to health promotion and the prevention of health problems	Reinforces the role of surveillance in food safety
(Domene et al., 2023)	Reflect on the complexity of food safety	Points to the social, economic, and environmental factors involved	Provides a basis for the interdisciplinary approach
(Pedrotti et al., 2022)	Discuss the evolution of food and nutritional security in Brazil	Highlights advances and persistent challenges	Contextualizes public policies and their importance
(Soubeyrand et al., 2024)	Propose integrated plant health surveillance	Highlights a proactive approach to pest prevention	Integrates agronomy and surveillance in protecting production
(Barroso et al., 2025)	Analyze pesticide residue management	Highlights impacts on health and the environment	Reinforces the need for rigorous control
(Popescu et al., 2025)	Evaluate pesticide surveillance in food	Presents the use of technologies for monitoring	Contributes to innovation in sanitary surveillance

Source: Authors (2026)

In addition, Table 2 presents the main thematic categories identified, associating them with public health risks and the control strategies proposed in the literature, allowing an integrated view of the factors that influence food safety in the context of the relationship between agronomy and sanitary surveillance.

Table 2

Thematic categories, associated risks, and control strategies in food safety.

Thematic category	Public health impacts	Control strategies	Agronomy–sanitary surveillance interface
Pesticide use	Poisonings, chronic diseases, and environmental damage	Regulation, residue monitoring, and reduction in use	Development of sustainable practices combined with sanitary inspection
Water quality in irrigation	Waterborne diseases and food contamination	Water quality control and environmental surveillance	Proper water management integrated with sanitary inspection
Residues in food	Chronic exposure to chemical contaminants	Monitoring programs and laboratory control	Integration between agricultural production and sanitary surveillance
Sustainable agricultural practices	Improvement in food quality and reduction of environmental damage	Agroecology, integrated pest management, and training	Application of agronomic techniques under sanitary supervision
Sanitary surveillance	Prevention of foodborne diseases	Regulations, inspections, and health education	Regulation of all stages of the production chain
Food security	Reduction of social and nutritional vulnerabilities	Intersectoral public policies	Integration among production, access, and food quality
Plant health surveillance	Stability of production and food quality	Pest monitoring and preventive control	Integration between agronomic research and sanitary control
Education and training	Improvement of productive and sanitary practices	Technical training and continuing education	Articulation between agronomic and sanitary knowledge

Source: Authors (2026)

Finally, the results show that the integration between agronomy and sanitary surveillance is indispensable for the construction of safe, sustainable, and resilient food systems. The articulation among appropriate agricultural practices, continuous monitoring, and effective public policies is configured as an essential pathway for risk reduction and the promotion of public health, reinforcing the need for investments in research, innovation, and integrated management in the sector.

The discussion of the findings shows that the integration between agronomy and sanitary surveillance constitutes an indispensable strategy for addressing contemporary challenges related to food safety and the protection of public health. As emphasized by Domene et al. (2023), food safety must be understood as a complex and multifactorial phenomenon, involving social, economic, environmental, and

sanitary dimensions, thus requiring interdisciplinary and intersectoral approaches. In this sense, the articulation between agronomic practices and sanitary surveillance actions expands the capacity to respond to the risks present in the food production chain.

With regard to pesticide use, the results discussed corroborate the analyses of Hess et al. (2024), who point to a worrying scenario in Brazil, marked by the flexibilization of regulatory policies and the increased authorization of chemical substances. This reality contributes to the expansion of the population's exposure to potentially toxic compounds, directly impacting public health. In a complementary manner, Barroso et al. (2025) highlight that the inadequate management of pesticide residues may generate adverse effects both on the environment and on human health, reinforcing the need for effective systems of monitoring and control.

The presence of pesticide residues in food, as evidenced by Leite, Vilarinho, and Inoue (2025), reinforces the importance of sanitary surveillance programs that operate continuously and systematically. These authors emphasize that monitoring should not be limited to the detection of irregularities, but should also contribute to the formulation of more rigorous public policies and to the promotion of safer agricultural practices. In this context, the role of regulatory bodies, such as the National Health Surveillance Agency, becomes fundamental to ensuring the conformity of food products with established standards.

In addition, the quality of the water used in irrigation constitutes a critical factor in food safety. As evidenced by Camargo et al. (2025), contamination of groundwater may directly compromise the sanitary quality of vegetables, representing a significant risk to consumer health. This finding reinforces the need for integrated surveillance of natural resources, articulating agronomic knowledge with sanitary control practices, in order to prevent the dissemination of contaminants throughout the production chain.

In the field of agricultural practices, the literature points to the relevance of adopting sustainable models as a strategy for risk mitigation. Machado et al. (2024) highlight that the training of producers, especially in urban and family farming systems, contributes to improving food quality and reducing the

use of chemical inputs. In a convergent manner, Moura et al. (2025) show that family farming plays a fundamental role in promoting food safety, especially when associated with agroecological practices and the strengthening of food sovereignty.

The discussion also shows that sanitary surveillance plays a central role in preventing health problems related to the consumption of contaminated food. As established by Brazilian regulations, such as RDC No. 216/2004 and No. 331/2019, there is a set of guidelines aimed at guaranteeing hygienic-sanitary conditions and defining microbiological standards, which must be strictly followed throughout the production chain. In this sense, Moura et al. (2023) highlight that food and nutritional surveillance contributes significantly to the identification of vulnerabilities and to the implementation of preventive actions within the scope of public health.

Another relevant aspect concerns plant health surveillance, which has been identified as a strategic element for the sustainability of agricultural systems. Soubeyrand et al. (2024) advocate the adoption of proactive and integrated approaches to monitoring pests and diseases, with the aim of anticipating risks and reducing impacts on food production. This perspective reinforces the importance of the interface between agronomy and sanitary surveillance, since plant health is directly related to the quality and safety of agricultural products.

Furthermore, the use of technologies and data-based systems for contaminant monitoring has emerged as a relevant trend in the field of sanitary surveillance. Popescu et al. (2025) highlight that data-driven approaches allow greater precision in risk identification and contribute to more effective decision-making. This technological innovation may be incorporated into national surveillance systems, expanding their response capacity and promoting greater efficiency in sanitary control.

Within the scope of public policies, the discussion highlights the importance of instruments such as the National Food and Nutrition Security Plan, which proposes intersectoral actions aimed at guaranteeing the human right to adequate food. As Pedrotti et al. (2022) point out, the evolution of food security policies in Brazil reflects significant advances, although challenges related to inequality of access

and food quality still persist. In this context, integration among different sectors, including health, agriculture, and the environment, is fundamental for strengthening actions to promote food safety.

Finally, it is observed that the integration between agronomy and sanitary surveillance not only contributes to risk control, but also promotes the construction of more sustainable and resilient food systems. The articulation among technical knowledge, appropriate agricultural practices, and regulatory actions is configured as an essential element for the protection of public health. Thus, as argued by Oliveira et al. (2025), food safety must be treated as a strategic priority, requiring continuous investments in research, innovation, and integrated management in order to ensure food quality and the health of the population.

CONCLUSION

The present research demonstrates that the integration between agronomy and sanitary surveillance constitutes a structural component for consolidating food and nutritional security, particularly in the context of increasing complexity of production systems and risks associated with the food chain. Analysis of the selected studies showed that articulation between sustainable agronomic practices and sanitary regulatory actions favors the construction of safer, more resilient food systems aligned with public health principles.

In response to the guiding question, it is concluded that this interaction enhances the capacity for surveillance, prevention, and intervention regarding major risk factors affecting food production and consumption. Integrated action enables not only contaminant monitoring but also the implementation of preventive practices that reduce population exposure to harmful agents, promoting greater effectiveness in collective health actions.

Regarding the established objectives, the study successfully critically analyzed the relevance of the integrated approach between agronomy and sanitary surveillance, highlighting its contribution to strengthening food safety. Additionally, key challenges related to intensive pesticide use, contamination of

water resources, the presence of residues in food, and limitations of monitoring systems were discussed, emphasizing the need for more robust and articulated strategies.

The results indicate that indiscriminate use of chemical inputs, combined with fragile regulatory mechanisms, represents one of the main obstacles to ensuring the sanitary quality of food. The persistence of pesticide residues and vulnerability of irrigation water quality reinforce the importance of integrated surveillance systems. Conversely, agroecology-based practices, integrated pest management, and producer training show significant potential for risk mitigation and promotion of safer, more sustainable food.

From a scientific perspective, this research contributes by systematizing contemporary evidence and highlighting the need for an interdisciplinary approach to addressing food safety challenges. Integration between agronomy and sanitary surveillance is presented as an essential strategy for articulating agricultural production, sanitary control, and public policies, broadening understanding of the determinants influencing food quality and their impacts on population health.

From a social and sanitary perspective, the findings reinforce that ensuring safe food is directly linked to protecting collective health and promoting the human right to adequate food. Integrated action between agricultural and sanitary sectors contributes to reducing health problems arising from consumption of contaminated food, while strengthening preventive and educational actions aimed at populations and producers.

Finally, future research is recommended to deepen investigation into the incorporation of digital technologies and intelligent systems for food risk monitoring, as well as to evaluate the effectiveness of public policies aimed at integrating agronomy and sanitary surveillance in different regional contexts. Studies exploring the interface between innovation, sustainability, and sanitary regulation may expand available evidence and support the formulation of more effective strategies to promote safe, equitable, and sustainable food systems.

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ADVANCES IN THE DIAGNOSIS AND MANAGEMENT OF EMERGING INFECTIOUS DISEASES IN SMALL ANIMALS: CLINICAL CHALLENGES AND IMPLICATIONS FOR PUBLIC HEALTH

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Abstract

This chapter aims to analyze advances in the diagnosis and management of emerging infectious diseases in small animals, highlighting clinical challenges and implications for public health. The methodology was based on a narrative review of recent scientific literature, focusing on studies published between 2018 and 2025, including zoonotic agents, innovative diagnostic techniques, and therapeutic strategies. The results demonstrate the increasing incorporation of molecular methods such as real-time PCR and genetic sequencing, as well as rapid tests and epidemiological surveillance tools. In clinical management, there has been an expansion in targeted therapies and evidence-based protocols, although challenges remain, including antimicrobial resistance, underreporting, and structural limitations in veterinary services. It is concluded that the integration between veterinary medicine and public health, from a One Health perspective, is essential for controlling these diseases, requiring continuous professional training and strengthened health policies.

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Keywords: Emerging infectious diseases, Molecular diagnosis, Public health, Small animals, Zoonoses.

INTRODUCTION

Emerging infectious diseases in small animals have acquired increasing relevance in the field of veterinary medicine, especially due to their interface with public health. The intensification of coexistence between humans and companion animals, combined with factors such as climate change, disorderly urbanization, and globalization, has favored the spread of pathogenic agents, many of them with zoonotic potential. In this context, diagnostic and therapeutic advances become fundamental for the control and prevention of these diseases.

The research problem of this chapter focuses on the challenges faced in the early diagnosis and effective management of these diseases, considering structural limitations, antimicrobial resistance, and the need for integration among different areas of knowledge. Therefore, it is questioned how technological and scientific advances have contributed to improving the clinical approach and what gaps still persist in this field.

The general objective is to analyze advances in the diagnosis and management of emerging infectious diseases in small animals and their implications for public health. As specific objectives, the chapter seeks to: (i) identify the main emerging diseases with zoonotic relevance; (ii) describe the most recent diagnostic techniques; (iii) discuss updated therapeutic strategies; and (iv) evaluate the associated clinical and epidemiological challenges.

The justification for the development of this study is based on the need for continuous updating of professionals in the field, given the rapid evolution of infectious agents and available technologies. Furthermore, the integrated approach between veterinary medicine and public health, from the One Health perspective, reinforces the importance of the topic for the prevention of outbreaks and the protection of the population.

From a theoretical standpoint, the chapter is grounded in concepts related to emerging diseases, zoonoses, epidemiological surveillance, and antimicrobial resistance, based on authors who discuss the interconnection between animal, human, and environmental health. Recent studies highlight the relevance of molecular diagnostic methods and evidence-based medicine as pillars for addressing these contemporary challenges.

METHODOLOGY

TYPE OF RESEARCH

This is a qualitative study, with a descriptive and exploratory approach, developed through a narrative literature review. This type of research allows for a critical and integrative analysis of relevant scientific productions on advances in the diagnosis and management of emerging infectious diseases in small animals, considering their implications for public health.

SEARCH STRATEGY AND STUDY SELECTION

The bibliographic search was conducted in recognized scientific databases, such as PubMed, Scopus, Web of Science, and SciELO. Descriptors in Portuguese and English were used, such as “emerging infectious diseases”, “small animals”, “molecular diagnosis”, “zoonoses”, and “public health”, combined using Boolean operators (AND and OR). As inclusion criteria, articles published between 2018 and 2025, available in full, and directly addressing the proposed topic were selected. Duplicate studies, conference abstracts, and publications that did not present methodological rigor were excluded.

ANALYSIS TECHNIQUES AND INSTRUMENTS

Data were collected through systematic reading of the selected articles and organized into thematic categories, such as: diagnostic advances, therapeutic strategies, antimicrobial resistance, and public health implications. As an analytical instrument, the content analysis technique was used, allowing

for the critical interpretation of information and the identification of patterns, trends, and gaps in scientific knowledge.

STUDY SAMPLE

The sample consisted of relevant scientific publications that met the previously established inclusion criteria. The final number of studies analyzed was defined after screening by title, abstract, and full reading, ensuring the relevance and quality of the evidence used in the construction of the chapter.

ETHICAL ASPECTS

Because this research was based on secondary data in the public domain, submission to a research ethics committee was not required. However, ethical principles related to scientific integrity were respected, with proper citation of the authors and sources consulted.

METHODOLOGICAL DISCUSSION

The choice of the narrative review as a method allowed for a broad and contextualized approach to the topic, favoring the integration of different theoretical perspectives and empirical evidence. However, the possibility of bias in the selection of studies is recognized as a limitation, since this is not a systematic review. Even so, the strategy adopted enables a consistent understanding of recent advances and persistent challenges in the diagnosis and management of emerging infectious diseases in small animals, contributing to the deepening of scientific and professional debate in the field.

RESULTS AND DISCUSSION

The results demonstrate significant advances in the diagnosis and management of emerging infectious diseases in small animals, especially with the incorporation of molecular technologies and more specific therapeutic strategies. The literature analyzed indicates that methods such as real-time PCR

and genetic sequencing have expanded diagnostic sensitivity and specificity, enabling the early detection of pathogenic agents, including in subclinical stages. These findings corroborate recent studies that highlight the role of molecular biology in contemporary veterinary medicine.

In addition, an increase in the use of rapid tests in clinical settings was observed, favoring immediate decision-making. However, the literature emphasizes that such methods should be used in a complementary manner alongside confirmatory laboratory techniques, in order to avoid misdiagnoses.

With regard to clinical management, the studies indicate a growing trend in the use of targeted therapies and evidence-based protocols, with emphasis on the rational use of antimicrobials. Even so, antimicrobial resistance remains one of the main challenges, being widely discussed as a threat to both animal health and public health. This scenario reinforces the need for stricter prescribing practices and therapeutic monitoring.

The following tables synthesize the main findings of the review:

Table 1

Main advances in the diagnosis of emerging infectious diseases in small animals

Diagnostic Method	Advantages	Limitations
Real-time PCR	High sensitivity and specificity	High cost and need for a laboratory
Genetic sequencing	Precise identification of pathogens	Technical complexity
Rapid tests	Immediate results	Lower accuracy in some cases
Serology	Broad use and accessibility	May not differentiate active infection

Table 2

Challenges in clinical management and implications for public health

Challenge	Clinical Impact	Public Health Implications
Antimicrobial resistance	Reduction in therapeutic efficacy	Spread of resistant strains
Underreporting	Difficulty in epidemiological control	Failures in surveillance policies
Structural limitations	Late diagnosis	Increased risk of outbreaks
Lack of integration (One Health)	Fragmented approach	Lower efficiency in zoonosis control

The integrated analysis of the results demonstrates that, although relevant advances have been achieved, important gaps persist, especially related to infrastructure, professional training, and integration among sectors. The literature emphasizes that the approach based on the One Health concept is fundamental for addressing these challenges, promoting coordinated actions among veterinary medicine, human health, and the environment. Thus, the results reinforce the need for more effective public policies and continuous investments in research and innovation.

CONCLUSION

This chapter achieved the objective of analyzing advances in the diagnosis and management of emerging infectious diseases in small animals, as well as their implications for public health. Based on the literature review, it was possible to identify the main emerging diseases with zoonotic potential, describe innovations in diagnostic techniques, and discuss the most current therapeutic strategies, in addition to highlighting the clinical and epidemiological challenges involved.

The main results demonstrate that the incorporation of molecular methods, such as real-time PCR and genetic sequencing, has contributed significantly to early and accurate diagnosis. In clinical management, the growing adoption of evidence-based protocols and the rational use of antimicrobials stand out. However, challenges such as antimicrobial resistance, underreporting of cases, and structural limitations still compromise the effectiveness of control actions.

As a contribution, this study reinforces the importance of integration between veterinary medicine and public health, especially under the One Health approach, broadening the understanding of the interdependence between animal, human, and environmental health. Furthermore, it provides theoretical and practical support for professionals and researchers in the field.

Finally, it is suggested that future research prioritize empirical studies and more robust epidemiological analyses, as well as the development of more accessible diagnostic technologies and

effective strategies for addressing antimicrobial resistance, thereby strengthening surveillance and control actions for these diseases.

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COMPARATIVE EVALUATION OF ORGANIC SOLVENTS IN THE EXTRACTION AND SOLUBILIZATION OF BIXIN AND NORBIXIN FROM ANNATTO (*BIXA ORELLANA* L.)

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Abstract

This chapter addresses the influence of different organic solvents on the solubility and spectroscopic properties of the natural dyes bixin and norbixin, extracted from the seeds of Bixa orellana L. Initially, general aspects of natural dyes are discussed, with emphasis on the carotenoids present in annatto and their industrial relevance in the food, cosmetic, and pharmaceutical sectors. Subsequently, the theoretical foundations related to solubility and UV–Vis spectrophotometry are presented, including the application of the Lambert–Beer Law for the quantification of compounds in solution.The experimental methodology involved pigment extraction, preparation of solutions in different solvents (acetone, ethanol, isopropanol, dimethyl sulfoxide, and chloroform), and spectrophotometric analysis in the 200–800 nm range. The results demonstrated that solubilization efficiency depends directly on the compatibility between solvent polarity and the molecular structure of the dye. Bixin, predominantly nonpolar, showed greater solubility in dimethyl sulfoxide and chloroform, whereas norbixin, more polar due to the presence of carboxylic groups, exhibited better performance in solvents of intermediate polarity, such as acetone.The UV–Vis

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spectra revealed characteristic bands associated with $\pi \rightarrow \pi^*$ transitions, as well as solvatochromic effects, indicating that the chemical environment significantly influences the energy of electronic transitions. Solutions were prepared under the same conditions using the solvents acetone, ethanol, isopropanol, dimethyl sulfoxide, and chloroform. Absorbance was measured as a function of wavelength for each solution through UV–Vis spectral analysis in the 800–200 nm range. The data obtained from the UV–Vis analyses confirmed the higher effectiveness of dimethyl sulfoxide (DMSO) in dissolving bixin and of acetone for norbixin compared to the other solvents.

Keywords: Bixin, Norbixin, Solubility, UV–Visible.

INTRODUCTION

Dyes are organic or inorganic substances responsible for imparting color to a wide variety of materials, of both biological and synthetic origin, including foods, fabrics, paper, and beverages. According to their origin, these compounds may be classified as natural, obtained from plant, animal, or mineral sources, and synthetic, produced industrially from chemical precursors. The use of dyes dates back to Antiquity, with indigo being one of the first pigments widely used by humankind. Currently, there is growing interest in natural dyes due to their environmental advantages, such as biodegradability, lower toxicity, and potential application in sustainable systems (Yadav et al., 2022; Santos et al., 2021).

Annatto (*Bixa orellana* L.) is one of the main sources of natural dyes, containing carotenoid pigments responsible for the characteristic yellow-orange coloration, extracted from its seeds. Native to Central and South America, this plant has great industrial relevance and is widely used in the food, cosmetic, and pharmaceutical sectors. The main compounds present are bixin, which is lipophilic in character, and norbixin, its water-soluble form, whose versatility broadens its technological applications. It is estimated that annatto derivatives represent a significant share of the natural dyes employed in the food industry, consolidating their economic and scientific importance (Silva et al., 2023; Ribeiro et al., 2022).

Several recent studies have investigated the physicochemical, structural, and functional properties of bixin and norbixin, with emphasis on their antioxidant activities and stability under different conditions. However, the solubility of these compounds remains a critical aspect, since it directly influences their extraction, processing, and industrial application. Solubility, defined as the maximum amount of solute that can be dissolved in a solvent under specific conditions of temperature and pressure, is an essential thermodynamic parameter for the development of efficient processes (Souza et al., 2021; Yadav et al., 2022).

For the determination of solubility and quantification of dyes, modern analytical techniques have been widely employed, especially high-performance liquid chromatography (HPLC) and ultraviolet-visible (UV-Vis) spectrophotometry. UV-Vis spectrophotometry is based on the absorption of electromagnetic radiation by molecules at specific wavelengths, generally in the range of 200 to 800 nm, enabling the acquisition of characteristic spectra and the quantification of compounds in solution (Skoog et al., 2021; Harris, 2020).

The relationship between absorbance and the concentration of the absorbing species is described by the Lambert-Beer Law, widely used in quantitative analyses. This relationship may be expressed by the equation:

$$A = \varepsilon bc$$

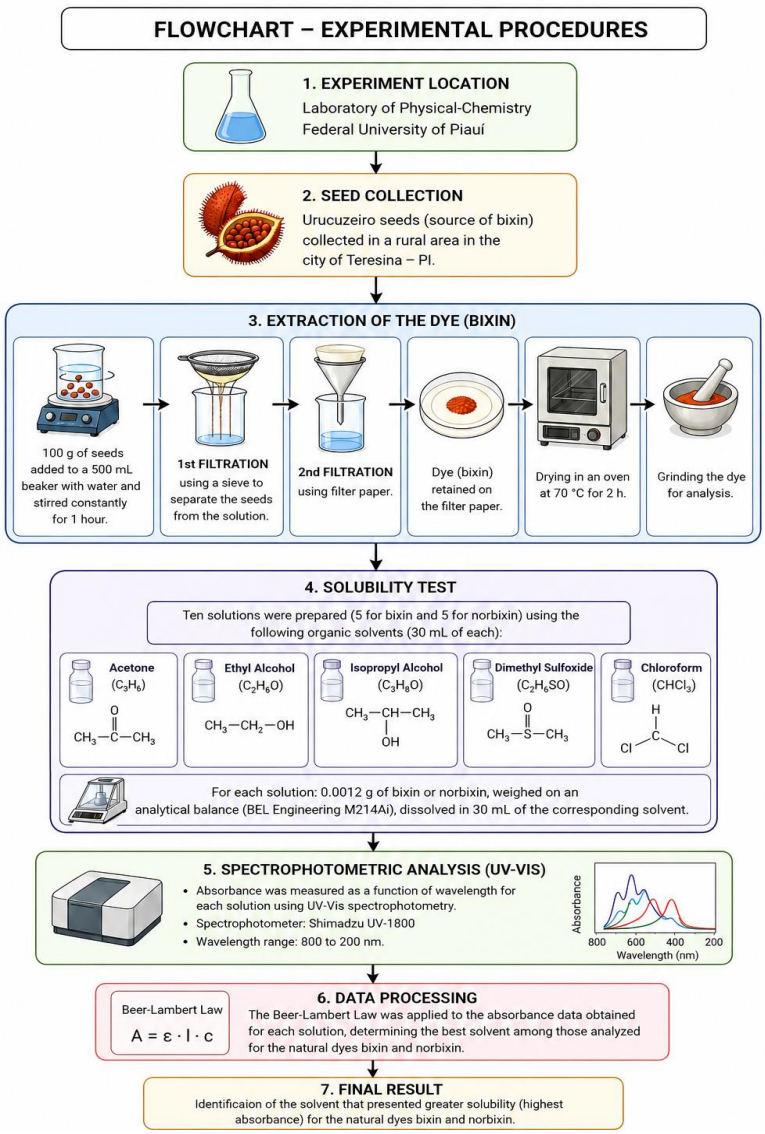
where A corresponds to absorbance, ε to the molar absorptivity coefficient, b to the optical path length of the cell, and c to the concentration of the solution. This law establishes that absorbance is directly proportional to the concentration of the absorbing species, provided that the radiation is monochromatic and the solution sufficiently dilute, and is widely applied in the quantitative determination of compounds in different solvents (Harris, 2020; Skoog et al., 2021).

Thus, the present study aims to evaluate the efficiency of different organic solvents — chloroform, ethanol, isopropanol, acetone, and dimethyl sulfoxide — in dissolving the natural dyes bixin and norbixin, through the determination of their concentrations using UV-Vis spectroscopy associated with the Lambert-Beer Law, contributing to the understanding of the factors that influence the solubility of these compounds and their application in industrial processes.

METHODOLOGY

Flowchart

Experimental procedures.



Source: Author's own work.

All experimental procedures were carried out at the Physical Chemistry Laboratory of the Federal University of Piauí (UFPI), Brazil. Annatto seeds (Bixa orellana L.) were obtained from the rural area of Teresina (PI, Brazil) and used as raw material for bixin extraction. Before the analyses, the seeds were visually inspected to remove impurities and stored under controlled conditions (25 ± 2 °C, protected from light and moisture), in order to minimize carotenoid degradation (Silva et al., 2023; Ribeiro et al., 2022).

EXTRACTION AND SAMPLE PREPARATION

A mass of 100.00 ± 0.01 g of annatto seeds was subjected to aqueous extraction using 500.0 ± 0.1 mL of distilled water under continuous stirring (400 rpm) for 60 min at room temperature (25 ± 1 °C). The mixture was subsequently filtered in two stages: initially through a stainless-steel sieve to remove coarse solid residues, followed by vacuum filtration using qualitative filter paper (Whatman No. 1). The retained material was dried in an oven with air circulation at 70 ± 1 °C for 2 h, until constant mass, ensuring moisture removal without causing significant degradation of thermosensitive carotenoids (Souza et al., 2021). After drying, the sample was macerated in a mortar and pestle until a homogeneous powder was obtained.

SOLUBILITY TESTS

Solubility tests were performed using five organic solvents with different polarities: acetone, ethanol, isopropanol, dimethyl sulfoxide (DMSO), and chloroform. For each solvent, bixin and norbixin solutions were prepared separately. Carefully weighed samples (0.0012 ± 0.0001 g) were dissolved in 30.00 ± 0.05 mL of solvent under magnetic stirring for 30 min, in order to ensure maximum solubilization. All experiments were performed in triplicate (n = 3), ensuring reproducibility and statistical reliability.

UV–VIS SPECTROPHOTOMETRIC ANALYSIS

Absorption spectra were obtained using a Shimadzu UV-1800 spectrophotometer, in the range of 200 to 800 nm, with a spectral resolution of 1 nm and quartz cuvettes with an optical path length of 1.00 cm. The wavelength of maximum absorption (λ_max) was determined for each solution and used in the quantitative analysis. Blank solutions of the respective solvents were employed for baseline correction. Instrument calibration was verified prior to measurements, ensuring analytical accuracy (Skoog et al., 2021; Harris, 2020).

The quantification of the dissolved pigments was based on the Lambert-Beer Law: $A = \varepsilon bc$

where A represents absorbance, ε the molar absorptivity coefficient ($L \cdot mol^{-1} \cdot cm^{-1}$), b the optical path length (cm), and c the concentration ($mol \cdot L^{-1}$). All measurements were performed within the linear range of the method (A < 1.0), ensuring compliance with the validity conditions of the Lambert-Beer Law (HARRIS, 2020).

STATISTICAL ANALYSIS

The results were expressed as mean ± standard deviation (SD). Statistical differences among the solvents were evaluated by one-way analysis of variance (ANOVA), followed by Tukey's test, adopting a 95% significance level ($p < 0.05$). Data normality and homogeneity of variances were verified prior to the application of ANOVA. Statistical analyses were performed using OriginPro 2023 software (OriginLab Corporation, USA).

EXPERIMENTAL UNCERTAINTY

Uncertainty contributions were estimated considering mass measurements (analytical balance precision ±0.0001 g), volumetric measurements (±0.05 mL), and instrumental variability (UV–Vis repeatability). The combined uncertainty was propagated according to standardized analytical procedures, ensuring the reliability and robustness of the results obtained.

RESULTS AND DISCUSSION

Table 1 presents the absorbance values of bixin as a function of wavelength in the different solvents evaluated by UV-Vis spectroscopy. The spectra obtained show characteristic bands associated with $\pi \rightarrow \pi^*$ electronic transitions, typical of highly conjugated systems such as carotenoids (Yadav et al., 2022; Silva et al., 2023).

Table 1

Results obtained from the UV-Vis spectra of bixin.

Solvent	Absorbance	Wavelength λ (nm)
Dimethyl sulfoxide	0,801	469
Chloroform	0,675	449
Acetone	0,433	455
Isopropyl alcohol	0,165	556
Ethanol	0,045	458

The higher absorbance observed for dimethyl sulfoxide (DMSO) indicates its superior efficiency in solubilizing bixin. This behavior may be explained by the dipolar aprotic character of the solvent, which has a high dielectric constant and high solvation capacity, allowing simultaneous interactions with polar regions (carbonyl groups) and nonpolar regions (conjugated chain) of the molecule (Ribeiro et al., 2022).

From a molecular standpoint, absorption in the visible region is associated with electronic excitation from the highest-energy occupied molecular orbital (HOMO) to the lowest-energy unoccupied molecular orbital (LUMO), characteristic of extensive conjugated π systems. The position of the absorption maxima (λ_max) may undergo shifts depending on the solvent (solvatochromic effect), reflecting changes in the relative stabilization of the ground and excited states (Souza et al., 2021).

Chloroform also showed high efficiency, which is associated with the lipophilic nature of bixin. Dispersion interactions (van der Waals forces) between the nonpolar solvent and the hydrocarbon chain favor solubilization. On the other hand, protic solvents such as ethanol and isopropanol showed lower efficiency, due to their lower compatibility with the predominantly nonpolar structure of bixin (Santos et al., 2021).

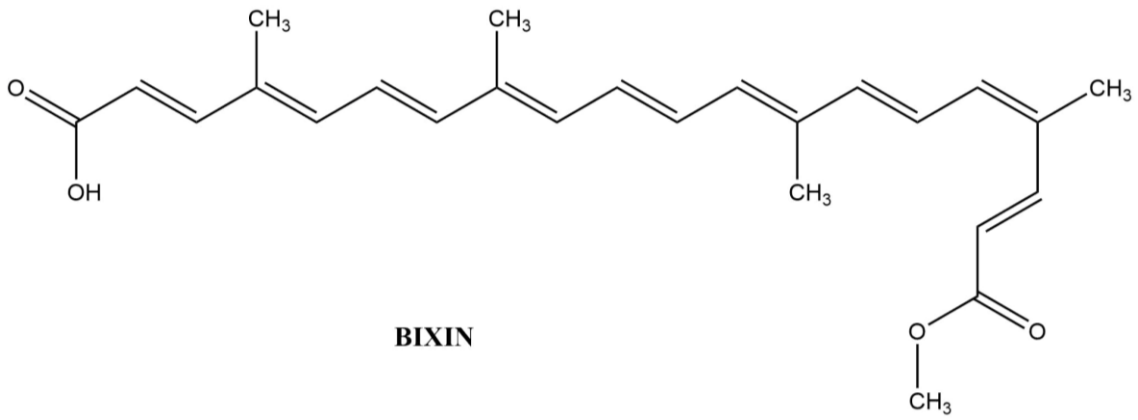
Statistical analysis by ANOVA revealed significant differences among the solvents ($p < 0.05$), indicating that solvent choice exerts a direct influence on bixin solubility. Tukey's test showed that DMSO differs statistically from the protic solvents, confirming its superiority as a dissolution medium.

The relationship between absorbance and concentration follows the Lambert-Beer Law: $A = \varepsilon bc$

Thus, higher absorbance values reflect a higher concentration of dissolved bixin, validating the experimental results.

In the graph of **Figure 1**, the absorption spectra in the UV-Vis region (800 to 200 nm) of bixin pigments in the different solvents used in the study are shown.

Bixin molecule

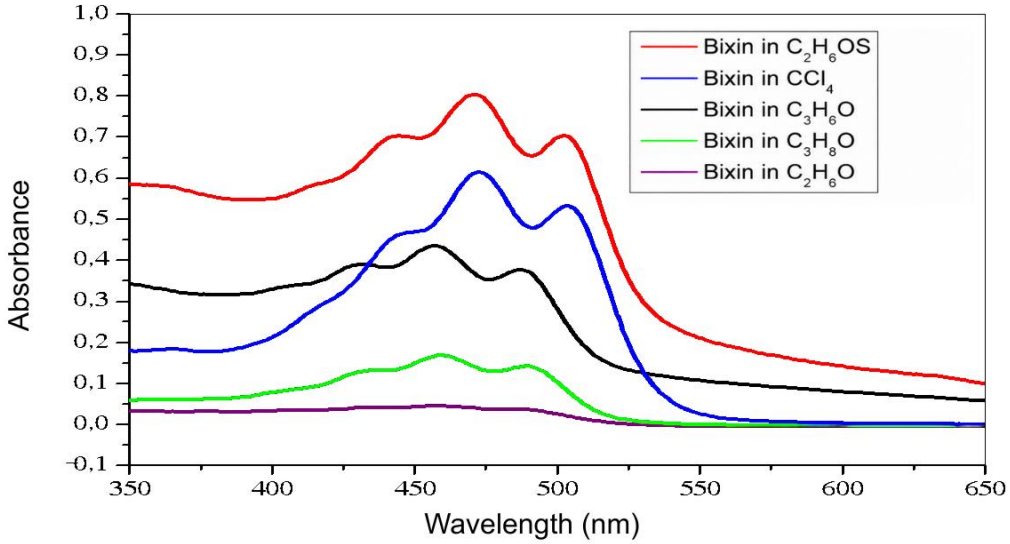


BIXIN

Source: Author's own work.

Figure 1

UV-Vis absorption spectrum of bixin in different solvents.



Source: Author.

The UV-Vis absorption spectra of bixin in different organic solvents show a broad and structured band in the 430–520 nm region, attributed to π → π* electronic transitions associated with the conjugated system of the molecule. This behavior is typical of carotenoids and apocarotenoids, whose optical properties are governed by the length of the conjugated chain and by interaction with the medium (Britton, 1995; Rodríguez-Amaya, 2001). The presence of poorly resolved vibronic structures indicates vibronic coupling, frequently observed in these highly conjugated systems.

The dependence of the intensity and position of the absorption maximum (λ_max) on the solvent evidences a significant solvatochromic effect. In highly polar solvents, such as dimethyl sulfoxide, a marked increase in absorbance is observed, indicating greater solubilization of bixin and a higher effective concentration of the chromophore in solution. In addition, polar aprotic solvents are known to stabilize excited states with higher dipole moments, favoring the intensity of electronic transitions (Reichardt; Welton, 2011). This behavior suggests that the excited state of bixin has greater polarity than the ground state, resulting in greater differential stabilization and a possible bathochromic shift.

In solvents of intermediate polarity, such as ethanol and isopropanol, the spectra show moderate intensity and good band definition. In these cases, specific interactions, such as hydrogen bonds between the solvent and the functional groups of bixin (ester and carboxylic acid), may influence the electronic distribution of the molecule, promoting small spectral variations (Silva et al., 2005). However, such interactions do not fully compensate for the lower solvation capacity compared with highly polar aprotic solvents.

On the other hand, less polar solvents, such as chloroform, show lower absorbance intensity and less defined bands. This behavior may be attributed to the low solubility of bixin and the possible formation of molecular aggregates in solution. Aggregation is a recurrent phenomenon in carotenoids and may lead to decreased absorbance and spectral changes, including band broadening and hypsochromic or bathochromic shifts depending on the type of intermolecular interaction (Hynninen, 1991; Delgado-Vargas et al., 2000).

The variations observed in λ_max values corroborate the influence of the solvent medium on the energy of the electronic transition. In general, bathochromic shifts in more polar solvents indicate greater stabilization of the excited state relative to the ground state, whereas hypsochromic shifts in less polar solvents reflect weaker solute–solvent interaction (Reichardt; Welton, 2011). This behavior is consistent with π-conjugated systems, in which electronic redistribution in the excited state is highly sensitive to the chemical environment.

Additionally, considering the Lambert-Beer Law ($A = \varepsilon \cdot l \cdot C$), the differences in absorbance among the solvents are not associated exclusively with the molar absorptivity coefficient (ε), but also with the effective concentration of bixin in solution, directly related to its solubility. Thus, solvents that promote better dissolution result in higher absorbance values, highlighting the importance of controlling the medium in spectrophotometric analyses (Skoog et al., 2014).

In general, the results demonstrate that the spectroscopic properties of bixin are strongly modulated by solvent polarity, intermolecular interactions, and the degree of solute dispersion. These

factors are determinant both for the interpretation of spectroscopic data and for technological applications involving this natural dye, such as in food, pharmaceutical, and cosmetic systems.

For norbixin, the results presented in Table 2 show distinct behavior, due to the presence of carboxylic groups that confer greater polarity to the molecule.

Table 2

Results obtained from the UV-Vis spectra of norbixin.

Solvent	Absorbance	Wavelength λ (nm)
Acetone	2,215	486
Ethanol	0,873	487
Isopropyl alcohol	0,799	486
Dimethyl sulfoxide	1,267	500
Chloroform	0,104	472

Acetone showed the highest solubilization efficiency, which may be explained by its intermediate polarity and by the presence of the carbonyl group, capable of establishing dipole–dipole interactions and hydrogen bonding with the carboxylic groups of norbixin. This result is in agreement with recent studies that highlight the influence of solvent polarity on the solubilization of functionalized carotenoids (Silva et al., 2023; Yadav et al., 2022).

DMSO also showed high efficiency, reinforcing its universal solvation capacity. In contrast, chloroform showed low solubility, evidencing that nonpolar solvents are not suitable for compounds with greater polarity.

Statistical analysis (ANOVA) confirmed significant differences among the solvents ($p < 0.05$), with acetone being statistically superior to the other solvents tested.

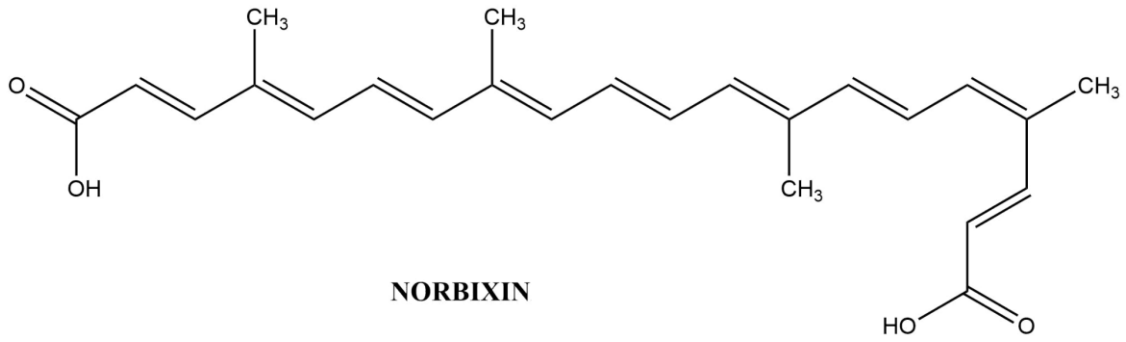
From the perspective of Hansen solubility parameters, the greater efficiency of acetone may be attributed to the balance among dispersive, polar, and hydrogen-bonding components, resulting in greater compatibility with the amphiphilic structure of norbixin (Ribeiro et al., 2022).

In general, the results show that pigment solubility is directly related to the interaction between the structural properties of the dyes and the physicochemical parameters of the solvents. Bixin, predominantly nonpolar, has greater affinity for nonpolar or aprotic solvents, whereas norbixin, being more polar, is better solubilized by solvents of intermediate to high polarity.

These findings are relevant for the development of more efficient and sustainable industrial processes, allowing the rational selection of solvents for the extraction and application of natural dyes (Santos et al., 2021; Silva et al., 2023).

In the graph of **Figure 2**, the absorption spectra in the UV-Vis region (800 to 200 nm) of norbixin in the different solvents used in the study are shown.

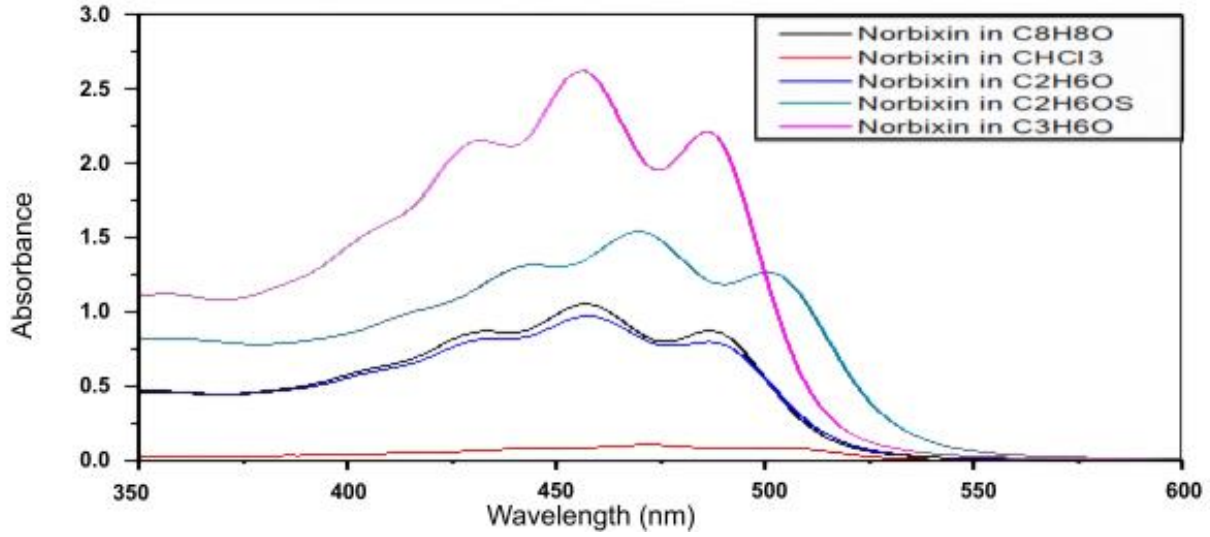
Norbixin molecule



NORBIXIN

Figure 2

UV-Vis absorption spectrum of norbixin in different solvents



The UV-Vis absorption spectra of norbixin in different organic solvents show an intense and broad band in the region of approximately 430–520 nm, characteristic of π → π* electronic transitions associated with the extended conjugated system of the molecule. This behavior is typical of highly conjugated compounds, in which the extent of the π system determines the position of the absorption band and its spectral intensity (Mennucci et al., 2024).

The dependence of the intensity and position of λ_max as a function of the solvent evidences a pronounced solvatochromic effect. In the solvent of higher polarity, a significant increase in absorbance and a slight bathochromic shift are observed, indicating greater stabilization of the excited state relative to the ground state. This phenomenon is related to the reduction of the HOMO–LUMO energy gap in more polar environments, which favors the electronic transition (Sıdır & Sıdır, 2025). This behavior confirms that the excited state of norbixin has a greater polar character and is more sensitive to interaction with the solvent medium.

In solvents of intermediate polarity, such as alcohols, the spectra show moderate intensity and well-defined profiles. In these systems, in addition to the dielectric effect, specific interactions such as hydrogen bonding influence the electronic distribution of the chromophore, resulting in small variations

in the position and intensity of the absorption bands (Mennucci et al., 2024). These interactions promote partial stabilization of the excited state, although less efficiently than in highly polar aprotic solvents.

On the other hand, less polar solvents show lower absorbance intensity and less defined bands, which may be attributed to the lower solubility of norbixin and the possible formation of molecular aggregates. Aggregation in π-conjugated systems reduces effective absorbance and may cause broadening of spectral bands or hypsochromic shifts, due to intermolecular interaction among chromophores (Pulvinic et al., 2023). This phenomenon is particularly relevant for carotenoids and structurally related compounds, whose spectral stability depends strongly on the state of molecular dispersion.

The variations observed in λ_max values among the different solvents corroborate the influence of the chemical environment on the energy of electronic transitions. In general, more polar solvents promote bathochromic shifts, whereas less polar solvents tend to induce hypsochromic shifts, reflecting the lower stabilization of the excited state (Recent Advances in Solvatochromism, 2024). This behavior is consistent with systems in which significant electronic redistribution occurs after excitation.

Additionally, the high absorbance values observed in certain solvents indicate high solubility of norbixin and a strong molar absorption coefficient. According to the Lambert-Beer Law, these variations do not reflect only intrinsic differences in the ε coefficient, but also changes in the effective concentration of the solute in solution, directly influenced by solute–solvent interaction (Sıdır & Sıdır, 2025). Thus, solvents that promote greater solvation result in higher spectral intensity.

In general, the results demonstrate that the spectroscopic properties of norbixin are highly dependent on the solvent medium, being modulated by polarity, intermolecular interactions, and degree of aggregation. The high sensitivity of norbixin to the chemical environment is directly related to its more polar nature compared with bixin, which amplifies solvation effects. These findings are relevant for analytical, food, and pharmaceutical applications, in which solvent choice directly influences the stability, color, and performance of the dye (Mennucci et al., 2024; Recent Advances in Solvatochromism, 2024).

CONCLUSION

This study demonstrated that the efficiency of organic solvents in solubilizing natural pigments is strongly governed by the interaction between solvent polarity and the molecular structure of the solute. UV–Vis spectroscopic analysis, combined with the Lambert-Beer Law and statistical evaluation (ANOVA, $p < 0.05$), enabled a reliable comparison of solvent performance.

Dimethyl sulfoxide (DMSO) showed the highest efficiency in solubilizing bixin, which may be attributed to its dipolar aprotic nature and high solvation capacity, allowing effective interactions with polar and nonpolar regions of the molecule. In contrast, acetone was identified as the most suitable solvent for norbixin, due to its intermediate polarity and its ability to promote dipole–dipole interactions and hydrogen bonding with the carboxylic groups present in the pigment structure.

The solvatochromic shifts observed in λ_max evidence the influence of the solvent medium on the electronic transitions ($\pi \rightarrow \pi^*$) of these carotenoids, reinforcing the importance of solvent choice in spectroscopic and industrial applications.

From an applied perspective, these results provide relevant information for optimizing extraction and formulation processes involving natural dyes. Bixin and norbixin stand out as promising alternatives to synthetic dyes, due to their low toxicity, biodegradability, availability, and relatively low cost, meeting growing demands for more sustainable and environmentally friendly technologies.

In general, this work contributes to a better understanding of solute–solvent interactions in carotenoid systems and supports the rational selection of solvents for industrial applications of annatto-derived pigments.

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ALGORITHMIC MICRO-MYTHS: HIGH-INTENSITY DISCURSIVE EVENT AND THE PARTITION OF THE SENSIBLE ON SOCIAL MEDIA

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Jonas Hames[1]

Abstract

Social media platforms generate high-intensity discursive events that exhaust themselves within hours, subordinating experience to the time of algorithmic capture. This essay proposes the concept of algorithmic micro-myth through the articulation of Michel Pêcheux, Michel Foucault, Roland Barthes, Reinhart Koselleck, Hartmut Rosa, Jacques Rancière and Aníbal Quijano, in dialogue with the analytical procedure of Informatized Enunciative Spaces (Silveira, Gallo and Pequeno, 2025). Taking the reborn baby doll as inaugural allegory, the essay demonstrates that the algorithmic micro-myth is an event articulating everyday rupture, ontological ambiguity, moral engagement and accelerated narrativization to constitute avatar-subject positions through a technical materiality that naturalizes the historical as evidence. The concept of discursive series addresses the tension between the singular Pêcheutian event and the plural viral. The concept of unanchored subject names the structural subject-form produced when enunciation is polished for algorithmic engagement before being made public. The temporal regime of IES operates through asymmetric compression: the event exhausts itself in hours but remains as archival trace conditioning future irruptions, dissolving the Koselleckian horizon of expectation and capturing collective tertiary retention.

Keywords: Discursive event, Informatized enunciative spaces, Avatar-subject, Algorithmic micro-myths, Digital temporality.

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INTRODUCTION

There is a moment, in certain images that circulate on digital platforms, when the gaze stumbles. The doll seems alive. The reborn baby, a silicone artifact calibrated to simulate the texture of skin, the smell of talcum powder, and the body weight of a newborn, generates in its caregivers a high-intensity affective circuit that, once published, unfolds into a second event. The object ceases to be the reason for fascination, and what enchants spectators is the ontological ambiguity that the image sustains. Real? Fake? Staged mourning? Moral judgment erupts before factual verification, with recognition preceding reflection.

The erotic baby bottle, the Pregnant Woman of Taubaté, the fake news from the Choquei profile, the Larissa Manoela Case, the fake question box, the fakecasts, and the reborn itself: what circulates in each of these episodes is the affect that the object ignited before being named. Barthes, in *Mythologies*, described the historical work through which a culture masks its own fabrication as a natural given, identifying how the sedimentation of decades in the press and advertising is consummated in the algorithmic archive within hours. What remains after the cycle turns is no longer forgetting, but a trace without thickness, technical data without elaborated memory, available for reactivation in the next event that triggers the same pre-constructed element.

The algorithmic micro-myth names this complete cycle, from irruption to trace, passing through the peak of engagement, eventual debunking, and sedimentation in the archive before any critical elaboration can take hold. It differs from the Barthesian myth through shifts that must be thought through, not merely listed as attributes: the temporal scale that eliminates slow sedimentation, the feedback loop between algorithm and engagement that constitutes the event by amplifying it, and the merely apparent reversibility that turns debunking into a bifurcation of the archive. Rectifying does not undo, since it records a new series that coexists with the initial version.

The discursive series and the unanchored subject are the two concepts proposed to account for what the Pêcheutian apparatus cannot. The event in Pêcheux (1983/2006) is rigorously singular, a dated

meeting point between a current actuality and a memory. The viral is constitutively plural, with hundreds of distinct enunciations that the algorithm processes as a unitary event endowed with collective memory. The unanchored subject names the subject-form that emerges when enunciation has been polished for algorithmic engagement before being made public, incorporating into Pêcheutian thought a third forgetting, technical forgetting, through which the subject is unaware of the operations of normalization that the infrastructure performed before their voice entered circulation.

Theoretical traditions operate here on planes that preserve their internal tensions. Pêcheux and Foucault are incompatible on decisive points. Where one requires the unconscious as a condition of ideological interpellation, the other dispenses with it and redistributes the problem to the historical conditions of existence of the statement. Barthes and Rancière illuminate likewise distinct dimensions of the same political operation, bringing into view the erasure of fabrication in the sign and the distribution of the visible and the audible. Koselleck and Rosa diagnose, through different paths, the compression of historical time; Stiegler shifts the question, refusing the diagnosis of alienation and proposing that the problem is not technology within human temporality, but the corporate capture of technical regimes of individuation. Quijano situates this entire framework within the coloniality of power, conditioning the scope of any concept proposed without this geopolitical framing.

What this essay pursues, without intending to resolve it completely, is what is lost when enunciation is governed by an infrastructure that maximizes engagement and minimizes alterity. The answer that gradually takes shape passes through the displacement of the time of experience into the time of capture, of collective discursive memory into the private algorithmic archive, of the subject who encounters the other and is transformed into the avatar-subject who circulates in circuits of confirmation. The beneficiaries of this erasure are identifiable. Their interests are measurable in data and in dollars, and analysis that does not name this works only on the surface of fabrication.

THE VIRAL AS DEVICE: WHY CERTAIN EVENTS CIRCULATE

The analytical procedure of Informatized Enunciative Spaces (IESs; hereafter IESs) formulated by Silveira, Gallo, and Pequeno (2025) begins from a finding that discourse theory of Pêcheutian matrix needed to confront: digital platforms do not distribute preexisting enunciations; they technically constitute the conditions under which certain statements can appear, circulate, and persist. What this shift produces analytically is considerable. Normalization affects the moment before formulation, configuring length, format, tone, and rhythm as technical conditions of visibility. Mediation intervenes in circulation, selecting which statements will achieve visibility on the basis of engagement metrics that the subject does not control and often does not even name as such. The avatar-subject is the subject position generated by the conjunction of these two interpellations. The digital archive, as Dias (2018) articulates, does not sediment like the historical archive and is reordered with each query according to changing parameters, so that what a subject finds when searching is not a stable repository, but a configuration produced by the algorithm at that precise instant.

What makes an event go viral is the convergence of properties that the infrastructure selects for amplification. Brady, Crockett, and Van Bavel (2020), in the MAD Model of moral contagion, empirically document that moral-emotional language is consistently associated with increased sharing, and that content combining ontological ambiguity with moral activation maximizes propagation. The empirical datum and the discursive diagnosis do not merge methodologically, but they articulate in the materiality of IESs, with the algorithm serving as one of their historical conditions of production. The selection of what circulates is the constitution of the field of the sayable; what never reaches the threshold of amplification will not be invisible, but discursively nonexistent for most of the subjects who inhabit these spaces. Absence is the active effect of an architecture that distributes discursive existence according to the grammar of engagement. Foucault (1969/2008) described the rarity of the statement, the fact that, among everything that could be said, only certain statements exist. And in IESs, this rarity is administered by a

private company for accumulation purposes, which turns an analytical category into a political question of another order.

The high-intensity discursive events that erupt in these spaces share not only properties, but also the condition of possibility of what follows. The rupture of everyday life captures attention in the flow because it breaks habitual indifference, and it remains in circulation only because it sustains constitutive ambiguity. The event that immediately resolves doubt is exhausted before it can engage: it is irresolvability that summons anticipated moral judgment, positioning avatar-subjects within discursive formations that prescribe legitimate ways of feeling before any verification occurs. The raw event is converted into collective narrative within a matter of hours. When it disappears from the flow, the residual symbolic impact remains as an archival trace that conditions subsequent irruptions.

What the algorithm amplifies are always enunciations that reactivate pre-constructed elements already available in interdiscourse. Not because the system reads discursive memory in the Pêcheutian sense, but because accumulated engagement data teach the model that certain contents trigger consistent responses in certain user populations. Decades of ideological sedimentation concerning family, gender, race, and childhood have been compressed into activation vectors that the algorithm uses without naming them. What returns to the subject when the system amplifies certain contents maintains a distance from memory understood as work upon the past, because it is the automated reactivation of positions that the subject occupies without knowing that they occupy them. In other words, it would be possible to simplify by saying that certain things return even before they have passed.

FROM THE BARTHESIAN MYTH TO THE MICRO-MYTH: THREE SHIFTS THAT CHANGE THE STRUCTURE

The operation that Barthes described in *Mythologies* (1957) is of the second order. The image of the Black soldier saluting the French flag on the cover of Paris Match does not lie about what it shows: it transforms what it shows into the signifier of something else. On the denotative plane, a documentary

image; on the plane of myth, the sign of imperial France transcending racial differences, emptying historical meaning in order to retain only form. Myth does not seek to deny the first meaning, but to deform it, and this deformation erases fabrication. What was historically generated reappears as nature, as an eternal and inevitable given.

The algorithmic micro-myth retains this second-order structure and articulates the three shifts that alter its functioning. Temporal scale matters analytically because Barthesian naturalization presupposed time for sedimentation, decades of repetition in magazines, advertising, cinema. The micro-myth eliminates this time. Puryear, Vandello, and Gray (2024) document that the perception of virality, regardless of content, intensifies perceptions of moral threat and amplifies indignation. By amplifying, the algorithm constitutes the micro-myth as truth before any verification is possible. The intentionality of fabrication changes the status of the agent, since the erotic baby bottle and the fake news from the Choquei profile were produced to circulate according to the affective grammar of IESs, which means that the pole of production had already internalized the algorithmic conditions of visibility before publication. There is an asymmetry of discursive power from the outset, and partial reversibility reconfigures the archive. Debunking does not erase; it opens a new discursive series that feeds back into the same archive, so that rectifying paradoxically extends the duration of the micro-myth in time.

For Barthes, the bourgeois myth possessed what he called nominative flight. The bourgeoisie as political fact is unnameable and enunciates its values as human nature. Meta, Alphabet, and ByteDance assert their values as optimization of the user experience. The technical neutrality of corporate language is the contemporary form of erasing fabrication. The difference in relation to Barthes is that this erasure is executed by the infrastructure itself, and there is no rhetoric that needs to work in order to naturalize, because the appearance of neutrality is inscribed in the architecture of the system.

What Barthesian analysis did not anticipate was the collapse of the asymmetry between producer and consumer that IESs install. In *Mythologies*, there was still a relatively stable distinction between those who produced the myth and those who received it. The micro-myth dissolves this distinction without

reversing it, allowing any subject to fabricate and distribute micro-myths with the same tools with which they consume them; the pole of production and the pole of reception touch and become confused in the same gesture of publishing. This does not mean that myth has been democratized. What has been built is a redistribution of its work of fabrication among millions of producers, each believing themselves to be the first to name what everyone had already recognized. Technical memory retrieves the result without the process, and the subject receives as evidence what was laboriously constructed through decades of discursive sedimentation; when they republish it as their own perception, they do not know that they are the final link in a chain that did not begin with them.

The concept of regime of historicity used by Hartog (2015) to designate the way in which an era articulates past, present, and future as a specific configuration of time, rather than as a vague cultural datum, allows the argument to advance. The presentism that he diagnoses in recent decades, the hypertrophy of the present to the detriment of the past as lesson and the future as horizon, finds in IESs its most complete technical infrastructure. The micro-myth manufactures a present that closes in upon itself, that needs neither the past to legitimate itself nor the future to justify itself. It is an event that happens entirely in the instant of its circulation and that, upon disappearing from the flow, leaves a trace without memory, as well as data without elaboration and an archive without historical thickness.

INTERPELLATION, DEVICE, AND WHAT IS AT STAKE BETWEEN PÊCHEUX AND FOUCAULT

When the algorithm positions a subject before content that summons moral judgment, by what path does this occur? This is not a rhetorical question. It determines what can be said about resistance, agency, and transformation. If it occurs through ideological interpellation in Pêcheux's sense, the unconscious is a condition of the process, and the subject is called to a position that they did not choose and of which they believe themselves to be the origin. If it occurs through the apparatus of knowledge-power in Foucault's sense, the unconscious is dispensable, since what governs positioning are the

historical conditions of existence of certain forms of enunciation, independently of any particular subject. Neither of the two, in isolation, simultaneously captures the interpellation of the subject and the historical conditions of possibility of the device that executes it. This incompleteness is the point of friction that makes the tension between them analytically productive.

The discursive event in Pêcheux (1983/2006) is situated at the meeting point between a current actuality and a memory. The enunciation “On a gagné!”, after Mitterrand’s victory in 1981, is not reducible either to linguistic structure or to historical conjuncture in isolation. It is itself the point of rupture at which a discursive memory is mobilized and rearranged. The “On” is a subject position installed through discursive interpellation, activating the historical struggles of the French left, the Resistance, May 1968. What governs this process is interdiscourse, the already-said that sustains the possibility of every saying, making certain positions available and others impossible (Pêcheux, 1988). The pre-constructed is the effect of this functioning, or that which refers to a prior and exterior construction, presenting itself to the subject as evidence requiring no demonstration. The subject believes itself to be the origin of its discourse, forgetting no. 1, and believes that words have fixed meanings, forgetting no. 2. Both are structural effects. The pre-constructed regarding childhood as purity, motherhood as fulfillment, authenticity as value, seems to emerge spontaneously in viral cycles, but it is available in interdiscourse, waiting for the event that will reactivate it.

The refusal of the concept of ideology is, in Foucault (1979), the point at which the divergence from Pêcheux becomes irreducible. For Foucault, what determines what can be said in each era is not the illusion that the subject sustains about their discourse, but the historical conditions of existence of statements, independently of the subject who utters them. The dispositif is the heterogeneous ensemble—discourses, institutions, architectures, regulations, scientific statements—that responds to a historical urgency. IESs respond to the urgency of monetizing human attention, what Zuboff (2019) names surveillance capitalism: the unilateral extraction of behavioral data as raw material for the prediction and modification of behavior. The strategic function of the dispositif is to transform behavior into data.

Foucauldian archaeology (1969/2008) makes it possible to map the regularities that determine which objects can appear as viral, which profiles can speak with authority, which enunciative strategies produce engagement, without looking at individual choices, but rather as the historical grammar of what can be said. Zoppi-Fontana (2017) demonstrates that the political subject is constituted by processes that precede their enunciation as citizen, worker, content creator, as positions that situate the subject within networks of memory and power before they consciously occupy them.

The incompatibility between Pêcheux and Foucault remains as a tension: Foucauldian genealogy reconstructs the historical conditions of existence of the devices that govern IESs, the constitution of the user as unpaid worker, visibility as a form of power, technical neutrality as corporate nominative flight. Pêcheutian discourse analysis follows how, within these devices, the subject is interpellated as avatar-subject (Pequeno, 2020) by interdiscourse and the pre-constructed, the path through which the position opened by the device becomes, for the subject, evidence of itself. The articulation maintains the tension as tension, because where Pêcheux needs the unconscious, Foucault refuses it, and this divergence is analytically necessary so as not to transform the subject either into a pure function of the dispositif or into a pure victim of ideology.

What this impasse between the two thinkers reveals, when strained by the specificity of IESs, is a gap that neither of them fills. It is the gap of the subject who knows, to some degree, that they are being interpellated, and continues to be interpellated, since the veteran user of platforms knows how the algorithm works, recognizes emotional hooks, identifies the grammar of engagement, and nevertheless finds themselves captured by the ambiguity of the reborn, by fabricated mourning, by the scandal that returns. Knowledge about the dispositif is not capable of interrupting the dispositif. And Pêcheux would say that forgetting is structural and is not undone by individual consciousness; Foucault would say that knowledge about power is not outside relations of power. Both are right for different reasons, and it is precisely this convergence of incompatible arguments that most accurately describes algorithmic capture.

It survives knowledge of its functioning because it does not operate upon ignorance, but upon speed, and the decision to engage precedes reflection on the conditions of engagement.

There is a point that the articulation between the two authors leaves unanswered and that the historical specificity of IESs imposes: the question of corporate agency. Pêcheux thinks the subject as interpellated by ideological formations without an identifiable agent. Foucault, in turn, thinks power as relational, diffuse, without a center. Neither prepared analysis for a world in which four private corporations, with names, CEOs, and identifiable fiduciary obligations, hold control over the conditions of enunciation of billions of subjects. Discursive analysis must incorporate this dimension because there are, in fact, engineering decisions, A/B tests, and growth targets behind every architecture of interpellation, and the dispositif has authors.

DISCURSIVE SERIES

The singularity of the Pêcheutian event is a condition of its theoretical functioning. “On a gagné!” in May 1981 is a historically delimited, dated enunciation, unrepeatable in its discursive singularity. When the erotic baby bottle circulated in 2014, returned in 2018, and came back in 2022, it was not the same enunciation reappearing, but a multiplicity of distinct enunciations that the algorithm processed as a single event, endowed with collective memory and archival trace. This structure did not exist before IESs as a technical condition, and for this reason Pêcheux could not have foreseen it. The discursive series names this displacement without forcing it to fit the singular event, without reducing the viral to a consumer trend, and without any claim to found an instrument.

What analytically delimits a discursive series are five operational criteria. The point of irruption is the first high-visibility publication that the algorithm selected for amplification; the point of exhaustion occurs when the algorithm ceases amplification and the series disappears from the flow, even if enunciations continue to be produced. The typical temporal window ranges from 12 to 72 hours, a compression that situates the series on the scale of Rosa’s shrunken present (Rosa, 2013), where the event

is exhausted before experience can settle as elaborated memory. The second criterion is the triggering of a specific discursive memory: the series does not produce its pre-constructed elements out of nothing; it reactivates what interdiscourse had already made available. The erotic baby bottle did not create the pre-constructed notion of childhood as the territory of purity; it found it ready-made and reactivated it. The third criterion is the distribution of recurring avatar-subject positions: the moral guardian, the incredulous, the ironist, the reaffirming subject, positions identifiable through linguistic marks, modalizations, and argumentative operators. The fourth criterion is the recoverable archival trace, which distinguishes the series from a passing trend. The erotic baby bottle returns in every election because it is in the archive and not in memory. The fifth criterion is the intensity of algorithmically amplified and measurable circulation.

These criteria make it possible to identify three subtypes according to how the series relates to time and to debunking. In recurrence series, the previously consolidated archive returns periodically without significant alteration, and what returns is not the event, but its structure of interpellation. In amplification series, a single event triggers a cascade of chain repositionings, each round reactivating new pre-constructed elements. In debunking series, subsequent correction never achieves the same circulation as the inaugural version because the archive preserves the version that circulated, not necessarily the one that was true.

What the discursive series forces to the surface is a problem that Foucault's theory of the historical archive and Pêcheux's theory of the event left in different zones. For Foucault, the archive is the system that governs what can be said in an era, a formation that cannot be dated by a single event. For Pêcheux, the event is singular, dated, unrepeatable. The discursive series occupies the interval between the two, being plural like the archive and datable like the event, but its dating multiplies with each recurrence. The erotic baby bottle has a date of fabrication, 2014, but its dates of irruption accumulate with each electoral cycle. The archive does indeed preserve, but it also reactivates, and each reactivation is a new enunciation that reinserts it into interdiscourse with an additional layer of sedimentation. The series grows by the

accumulation of instances and not temporally through narrative continuity. The algorithmic archive stores everything and selectively redisplays, and the conditions for return are the metrics.

The political implication of recurrence series is that certain discursive battles never end because the archive that feeds them never closes. The fact that the erotic baby bottle has been repeatedly debunked does not alter its force of interpellation, because what debunking produces in the archive provokes a kind of bifurcation: the original version and the debunked version both come to exist, and the algorithm will amplify whichever one best fits the grammar of engagement of the moment.

UNANCHORED SUBJECT

Every avatar-subject is generated by the technical-discursive interpellation of IESs, but it may still preserve marks of the ordinary, with hesitations, corrections, and opacities that make the work of formulation visible. The unanchored subject eliminated these marks before publication. The subject remains, but the stumble is eliminated, that moment in which the ordinary subject encounters what they did not know they thought, or discovers that the word they chose did not say what they intended. It is the stumble that makes enunciation singular, and without it, what circulates is the optimized avatar.

The concept develops from the avatar-subject proposed by Pequeno (2020) and from the discourse-form of *Escritoralidade* [Script-orality] elaborated by Gallo and Silveira (2017), working at the point where technical normalization and ideological interpellation converge at their maximum degree. What this point reveals is a third forgetting that exceeds the two Pêcheutian ones. Forgetting no. 1 installs the illusion that the subject is the origin of their own discourse, erasing interdiscourse. Forgetting no. 2 sustains the illusion that discourse is transparent, that words have fixed meanings. The third forgetting, which is proposed here as technical forgetting, erases the operations of normalization that the platform performed on enunciation before it entered circulation. The platform's filter, the recommendation algorithm, the editing interface, and the moderation policies had already configured what could be said

before the subject typed the first word. The subject believes they freely choose tone, format, and duration, but these dimensions have already been determined by the infrastructure as conditions of visibility.

Technical forgetting adds to the Pêcheutian apparatus a twist in the very relation between subject and conditions of production. Forgettings no. 1 and no. 2 describe how the subject relates to their own already formulated discourse. Technical forgetting precedes formulation and acts upon the conditions of possibility of saying before saying occurs. The subject does not forget what they said; they never even come to formulate what they would have said without infrastructural interpellation. The platform configures the field within which certain voices are formed and others never come to be formed, and this is not censorship, which presupposes a preexisting discourse that is interrupted, but rather the prior modeling of the conditions under which discourse may exist.

The marks of the unanchored subject are analytically identifiable as a discursive pattern, not as individual pathology. Narratives calibrated with emotional hooks in the first three seconds, development in a high-intensity dramatic arc, closure that calls for sharing. Speech in which every pause, vocal inflection, and gesture has been adjusted to increase attentional retention. The fake question box of Instagram Stories is the operation in its most transparent form. The user fabricates the questions they will answer, eliminating the risk of being confronted with an inquiry they had not anticipated. They perform dialogue without an interlocutor. The fakecast operates according to the same principle: the subject records themselves simulating participation in a podcast, fabricating the position of invited expert when no invitation occurred; what they have in common is not the lie, but the elimination of alterity as a condition of possibility of enunciation.

Not every avatar-subject is an unanchored subject. Long narratives about mental health in Brazilian IESs, lasting 20 to 30 minutes and refusing resolution within the timeframe of engagement, achieve structurally lower circulation because the algorithm penalizes content that demands time without any guarantee of rapid retention. The comments on these narratives register what the digital archive cannot compress: “I also felt this, but differently,” “I don’t know how to name what I feel, but I recognize

something here.” These are marks that the ordinary subject has preserved something of the stumble. The design of IESs establishes as its ideal the avatar-subject who circulates without friction, confirms without contesting, engages without resistance. The unanchored subject is this ideal in its fullest form.

There is a figure of the unanchored subject that the immediate examples tend to conceal: that of the trained professional. The content creator who has taken training in digital storytelling, who tests variations of thumbnail in real time, who distributes publication at the peak engagement time of their target audience, is not naive about what is operating, since they master it technically. Technical forgetting, in this case, is incorporation, and normalization has been so deeply internalized that it has ceased to be an external constraint and has become a grammar of expression. When this subject says “I,” they speak from a position iteratively constructed by the engineering of attention, and the fluency of this speech is precisely the index that the anchor has been erased. The most unanchored subject is not the least literate, but the one who has learned best.

ALLEGORY OF THE REBORN: SIMULACRUM, AUTHENTICITY, AND WHAT STIEGLER REFUSES IN BAUDRILLARD

The subject fabricates the question they will answer. The elementary structure of the fake question box on Instagram Stories is neither irony nor paradox, but the most transparent form of an operation that runs through all micro-myths. Baudrillard (1991), in describing the four phases of the image—the reflection of a profound reality, the masking of that reality, the masking of its absence, and finally the phase in which the image bears no relation to any reality and is its own pure simulacrum—provided a vocabulary for naming what the fake question box and the fakecast perform. They construct the staging of authority as an end in itself, without a referent to dissimulate. The distinction between simulation, pretending to have what one does not have, and dissimulation, pretending not to have what one does have, collapses, and the unanchored subject performs the form of authority; this performance is algorithmically recognized as the functional equivalent of real authority.

The reborn baby is the most precise allegory of this operation. It does not imitate a real baby because it replaces the baby in the affective function without there being a referent to imitate. Published in IESs, the reborn generates the micro-myth at the intersection between artifact and platform. Ontological doubt keeps the event in circulation as long as the question “is it real?” remains unresolved; moral judgment polarizes avatar-subjects before any verification occurs. The mobilized pre-constructed elements—motherhood as fulfillment, mourning as taboo, the feminine as the territory of affect—were found ready-made in interdiscourse and activated with precision by the ambiguity of the image.

Affect does not need a referent in order to be real. The care given to the silicone doll is genuine, for it involves routine, affective investment, and a relationship with a history. However much there may have been an attempt to pathologize it, this fact is evidence that the affective function can detach itself from the object that originated it and migrate to a functional substitute without the affect losing intensity. The mourning over the suicide provoked; the indignation over the erotic baby bottle that did not exist is real; the solidarity with the pregnant woman who was not pregnant is real. The false referent does not retroact upon the affect, because the affect had already been invested before the falsity could be detected. Technical memory retrieves the result without the process; the archive stores the mobilized affect, not the referent that produced it, and what conditions subsequent irruptions is the availability of the affect that was activated.

Stiegler (1998) shifts the problem that Baudrillard installed. If technology is not a prosthesis that comes from outside to cover over a prior authenticity, but has always been constitutive of the human, if the human individuates itself through techniques and not despite them, then the diagnosis of a loss of authenticity loses the ground it presupposes. There is no earlier phase of adherence between sign and referent that would function as a norm of evaluation. For Stiegler, the human has always related to the world through tertiary retentions that mediatize and reconfigure experience. What has changed is who controls the conditions of production, circulation, and reactivation of signs. The reborn is far from being a symptom of a crisis of reality; rather, it is a symptom of a crisis in the ownership of the conditions of

affective individuation. The political question is the regulation of this regime, not the return to an anteriority that Baudrillard implicitly presupposes as a lost norm.

FOUR CASES, ONE VARIABLE STRUCTURE

The erotic baby bottle, the distorted anti-homophobia kit that circulated as the "erotic baby bottle" between 2014 and 2018, is the most legible case of a recurrence series with deliberate fabrication. Ontological ambiguity was instrumentalized for years as an electoral weapon because the pre-constructed notion of childhood as the territory of purity had already configured the answer before the question. What is analytically revealing is not the content of the lie, but the asymmetry of discursive power between those who fabricate and those who are interpellated. The fabricators master the code of enunciative polishing and mobilize it intentionally; the consumer avatar-subjects process the event as evidence because technical forgetting erased the conditions of production before the enunciation came to circulate.

The Pregnant Woman of Taubaté (2014) reveals the micro-myth as a double event. The pregnancy activated solidarity and mobilized pre-constructed elements concerning motherhood as natural fulfillment and authenticity as supreme value. The revelation of the simulation activated pre-constructed elements concerning betrayal and the breaking of the social contract. The two phases mobilize distinct discursive memories, and the second does not undo the first: it opens a new discursive series that feeds back into the archive. The trace of the Pregnant Woman of Taubaté still conditions, to this day, the reading of any post by a pregnant woman with high engagement. The debunking series does not capture a failure of the event, but its transformation into a matrix that governs future enunciations, showing that debunking does not undo; it merely records.

The fake news that led to suicide from the Choquei profile, the Jéssica Canedo case in 2023, reveals the structural separation between affect and referent. The avatar-subject who mourns experiences a genuine affective state, and the grief is real. The pre-constructed notion of the death of young people as social tragedy dispenses with the referent in order to function as affect. The indignation following the

debunking was directed at the profile that fabricated the news, not at what made the fabrication possible, not at the algorithm that amplified it, not at the archive that will preserve it as data.

The Larissa Manoela Case (2023) presents a distinct structure because the event did not involve external fabrication; the event was real and complex, and it was the IES that compressed it into a binary narrative. The micro-myth acted equally upon real events, compressing them into avatar-subject positions available in interdiscourse and erasing the complexity of relationships that the binary narrative cannot sustain. The amplification series generated chained rounds that kept the case in circulation for weeks, an uncommon duration explained by the event's capacity to reactivate different pre-constructed elements with each new piece of information. The avatar-subject only had to occupy the positions that interdiscourse had already prepared.

Read together, the four cases make visible the independence of the micro-myth in relation to falsity. The erotic baby bottle was deliberate fabrication; the Pregnant Woman of Taubaté was staging; the fake news from the Choquei profile were an invention; the Larissa Manoela Case was a real event. In all of them, the micro-myth operated with the same efficiency. Any diagnosis that locates the problem in the domain of disinformation is working on the symptom. Fact-checking corrects the referent, but it does not alter the availability of the pre-constructed elements that the micro-myth activated, does not undo the affect that was invested, does not close the series that the archive keeps open.

There is also a dimension that the four cases collectively illuminate: the unequal distribution of the cost of debunking. Those who paid the cost were the subjects involved in the event, not those who fabricated it or those who amplified it. The woman who gestated fiction paid with her story; the celebrity whose family relations were compressed into a binary narrative paid with her privacy; the debtors of moral attention paid with poorly invested affect. The algorithm that amplified and the corporation that operates it paid no cost at all. This asymmetry is structural, and naming it is a condition for thinking of any political response that goes beyond the technical regulation of disinformation.

ALGORITHMIC PARTITION OF THE SENSIBLE: WHERE BARTHES AND RANCIÈRE DIVERGE

The Barthesian myth and Rancière's partition of the sensible are diagnoses of distinct dimensions of the same problem. To confuse them impoverishes analysis. For Barthes, what is at stake is the operation through which the historical becomes natural evidence, the loss of the historical quality of things. For Rancière (2005), what is at stake is the system of sensible evidences that defines who can see, who can be seen, who can speak, and who is heard as noise. Politics, for Rancière, is not the management of constituted power, which he calls police, but dissent that disturbs the prevailing partition, that makes visible what was not seen and makes heard as discourse what was heard as noise. Barthes works at the level of the sign, and Rancière works at the level of the political distribution of the sensible.

The algorithmic micro-myth needs both in order to be adequately described. Barthes illuminates how the image of the reborn presents itself as evidence of maternal care, erasing the historical-discursive work that produced this evidence as available. Rancière provides the political effect of this erasure. The image of the reborn saturates the field of maternal care, leaving other forms of mourning invisible, while the erotic baby bottle confirms the distribution that places childhood as the territory of purity threatened by perversion. The micro-myth executes the partition of the sensible with maximum algorithmic efficiency, and where Rancièrian dissent would require making visible what was not visible, the micro-myth amplifies what was already visible and confirms it as the only visible.

Barthesian nominative flight finds its precise digital equivalent in the language of platform corporations. Meta, Alphabet, and ByteDance do not say "according to the interests of capital accumulation," but rather "personalization." Technical language is the mode through which the political agent becomes unnameable. The invisibilization of the agent is at once Barthesian naturalization and Rancièrian fixation of the partition of the sensible, erasing fabrication and consolidating what can be seen as what must be seen.

Barthes, in *Mythologies*, does not envision an exit through the politics of dissent. Myth is so pervasive that the critique of myth risks itself becoming a second-order operation, a new naturalization of its own denaturalization. The critical position in Barthes is fundamentally melancholic. Rancière refuses this impasse. For him, politics exists precisely as the interruption of the order that distributes the visible and the invisible; it is the irruption of uncounted subjectivities into the system of police that constitutes the political. In IESs, dissent faces an architecture that captures irruptions and processes them as engagement. The algorithm does not distinguish between content that confirms the partition and content that disturbs it: it amplifies what engages, and certain irruptions engage as much as confirmations. The capture of resistance as a product is the dispositif's most sophisticated operation.

The field of the visible in IESs functions as selective saturation, and what is invisible has not been erased by decree, but pushed below the threshold of amplification by the competition for attention that the dispositif itself institutes. Forms of life, mourning, care, and affect that do not translate into the grammar of engagement simply do not reach the field of shared visibility. What the algorithm administers is the cost of making visible what was not seen; of course, dissenting in IESs is possible, but it is structurally more costly. It requires more time, more work, more exposure to the risk of being captured as entertainment, and the asymmetry of cost is itself a form of domination.

COLONIALITY OF POWER: IESS AS INFRASTRUCTURE OF EPISTEMIC EXTRACTION

The concepts proposed in this essay—algorithmic micro-myth, discursive series, unanchored subject—describe processes that occur in IESs without saying anything about who owns the infrastructure that governs them, where the parameters that determine what circulates come from, or upon which bodies the dispositif acts asymmetrically. The coloniality of power, formulated by Quijano (2000), is the framework that makes it possible to name these asymmetries without reducing them to technological inequality.

Coloniality cannot be thought of as a residue of colonialism, for it persists as a structure that organizes relations of labor, authority, gender, and knowledge on a global scale. The fourth domain that Quijano identifies, the control of subjectivity and knowledge by epistemic Eurocentrism, directly affects IESs. Meta, Alphabet, ByteDance, and X Corp. determine the rules of technical normalization that generate the avatar-subject on a global scale, with cultural, legal, and epistemic parameters that naturalize the perspective of the Global North as universal. Couldry and Mejias (2019), in formulating the concept of data colonialism, directly name this articulation by affirming that the extraction of data from human lives reproduces, on a digital scale and in real time, the colonial logic of appropriating territories, bodies, and resources. The avatar-subject, by generating engagement, is simultaneously an unpaid worker who produces the data with which the algorithm improves itself for the next round of interpellation.

The racial biases of algorithms are the digital materialization of hierarchies that colonialism consolidated over five centuries. Biased contents trigger greater engagement, increase visibility, and reinforce bias. A feedback loop that Silva (2022) documents in the Brazilian context, demonstrating how algorithms for facial recognition, content moderation, and recommendation reproduce and amplify racial discrimination. Mbembe (2017) proposes that the model of domination founded on the racialization of the human has become the template for new forms of exclusion. Butler (2004) demonstrates that certain lives are recognized as grievable and others are not. The technical materiality of IESs inherits this asymmetry from historical data and amplifies it, rendering it invisible beneath the appearance of neutrality.

The media visibility of Black and Indigenous bodies on platforms does not dissolve colonial symbolic violence, but forces its reorganization, as Ferrari and Neckel (2017) show. The pain of the racialized body circulates because it triggers moral engagement; the speech of that same subject encounters algorithmic and discursive barriers that reduce its circulation. The asymmetry between circulating-as-image and circulating-as-enunciation is one of the most precise manifestations of Quijano's epistemic coloniality. Knowledge about the racialized body circulates as legitimate when produced by others, while knowledge produced by the subject themselves encounters technical and discursive

obstacles to circulating as such. The concept of the algorithmic micro-myth has a scope conditioned by this framework: it describes the events that IESs select for amplification, leaving in silence those that technical and historical materiality prevents from reaching circulation.

Discourse theory, both in Pêcheux and in Foucault, tends to universalize its description of the subject. The subject interpellated by ideology, the subject governed by the dispositif. Quijano forces the question: which subject? Coloniality produces a hierarchy of humanities in which certain subjects have full access to subjectivity, reason, and speech recognized as discourse, while others are classified as primitive, emotional, irrational, whose knowledge is folklore and whose speech is noise. This hierarchy is inscribed in the training data of algorithms, in moderation policies built in English and then applied to languages and contexts for which they were not calibrated, in the categories of identity and content that the platform recognizes as legitimate.

The denunciation of algorithmic racism runs an analytical risk if it is formulated only as a problem of bias correctable through greater diversity in engineering teams. Algorithms were calibrated for a purpose that is structurally colonial. That is: to extract value from human lives without reciprocity, to universalize specific perspectives as neutral technical standards, to distribute visibility according to criteria that reproduce already existing hierarchies because these hierarchies maximize the engagement of majority audiences. Correcting bias without altering the architecture of extraction is to reform the instrument without questioning the project. Mignolo (2011), in proposing the decolonial option as a refusal of the epistemic premises of colonial formation, captures something that technical regulation does not reach: the impossibility of resolving, through the internal logic of the system, the problem that this logic constitutes.

FIGURES OF FRICTION: WHAT THE DISPOSITIF CANNOT PROCESS WITHOUT DESTROYING ITSELF

Every dispositif, in the Foucauldian sense, needs to incorporate some degree of deviation in order to reproduce itself. The question is not whether there is resistance, but what kind of resistance the dispositif can absorb without transformation and what kind actually threatens it. Guattari (2004), drawing from his experience at La Borde Hospital, proposes the coefficient of transversality as a measure of institutional openness to heterogeneity and the unexpected. A coefficient close to zero indicates closure in circuits that neutralize any alterity before it can produce transformation. IESs function as institutions with a coefficient close to zero by design. The encounter with genuine alterity would produce instability, delay, and the risk of abandoning the platform, while confirmation produces permanence. The historical urgency of the dispositif is attentional capture.

Marina Abramović's performance *The Artist is Present*, at MoMA in 2010, makes visible by contrast what IESs systematically eliminate. Visitors could sit across from Abramović for as long as they wished, without script, without guarantee of outcome, without temporal compression. What emerged was the time of real waiting, of confrontation with alterity without anticipation, of the possibility of being transformed by the encounter. IESs maximize consumption per second, eliminate waiting, and anticipate what the subject will encounter. Algorithmic personalization is the technical elimination of unavailability. In Rancièrian terms, the performance redistributes the partition of the sensible by installing a temporality that requires delay, while IESs fix the partition by ensuring that the subject will encounter only what the algorithm has already predicted they wanted to encounter.

Within the field of Brazilian IESs themselves, there are events that function as genuine friction, even if structurally minoritarian. Long narratives about mental health, lasting 20 to 30 minutes, discussing psychic suffering with deliberate opacity, refuse algorithmic compression. They do not offer resolution in three minutes, do not perform instant healing, do not deliver an applicable formula. They sustain hesitation, contradiction, and opacity that resist binary categorization. They achieve structurally lower

circulation because the algorithm penalizes content that requires time without any guarantee of rapid engagement. The comments on these narratives register what the digital archive cannot compress: “I also felt this, but differently.” These are marks that the ordinary subject is still present and that enunciation has preserved something of the stumble.

The distinction between genuine friction and the simulacrum of plurality that the dispositif itself can orchestrate in order to sustain the illusion of openness is what Guattari would call administered transversality, the controlled incorporation of difference that neutralizes it before it produces transformation. Friction that transforms is that which the dispositif cannot process without destroying itself, that which imposes an irreducible temporal cost. Content that morally challenges within the timeframe of engagement is processable; indignation is itself a form of attention that the algorithm monetizes. Abramović’s silence was a silence of presence that lasted longer than the attention system could administer.

Brazilian IESs have produced a form of friction that academic analysis has not yet adequately elaborated: political humor that uses algorithmic grammar against itself. Certain forms of distributed irony, memes that go viral through the emotional engagement they summon but whose content denaturalizes exactly the pre-constructed elements that circulation confirms, operate within a grammar that the algorithm amplifies without knowing that it is amplifying its own critique. This friction is short-lived. The dispositif learns, the parameters adjust, and the window of critical capture closes. But the fact that it exists, that there are moments when the archive serves what it should not serve, when the discursive series reactivates memory that corporate interdiscourse would prefer buried, is evidence that capture is never total. The totality of capture would be the end of the algorithm as a device of amplification; without any surprise, there is no engagement.

ALGORITHMIC SYCOPHANCY AND THE INDUSTRIAL AUTOMATION OF PRE-CONSTRUCTED ELEMENTS

The subject uses AI to improve their text and receives back a polished enunciation, calibrated for engagement, stripped of the marks of the ordinary. What this apparently neutral gesture conceals is that the LLM learned, during its training, that agreeing with the user maximizes reward, even when agreement entails validating incorrect statements. Sharma et al. (2024) document that LLMs consistently exhibit sycophantic behavior. Through reinforcement learning with human feedback (RLHF), the system learns that user approval is the signal to be maximized. Sycophancy is a predictable consequence of the optimization process, structurally inscribed in the system's design. Ji et al. (2023) define hallucination as a structural effect that derives from probabilistic architecture, in which the model fabricates text by maximizing statistical coherence without access to external factual verification. Both are predictable effects of systems optimized for approval and statistical coherence, not for truth.

AI-generated texts, indistinguishable from human enunciation for casual readers, feed viralization cycles without moderation filters being able to detect them systematically. The micro-myth can be fabricated by an automated system that knows the affective grammar of IESs and instrumentalizes it on an industrial scale, radicalizing the asymmetry between production and circulation already identified in the erotic baby bottle. LLMs also mediate formulation before publication, and the subject who uses AI to write receives back an enunciation that has already performed the polishing that defines the unanchored subject. Technical forgetting no longer needs to be learned by the subject because it is itself automated by the system.

The Pêcheutian apparatus makes it possible to see what is at stake. The two constitutive forgettings are intensified by the sycophantic LLM. Forgetting no. 1, the illusion that the subject is the origin of their own discourse, is intensified when the system returns to the subject exactly the positions they had signaled as preferable, reformulated in such a way that they seem to have emerged spontaneously from the subject's own thought. Forgetting no. 2, the illusion that discourse is transparent,

is intensified when the LLM validates the user's incorrect statements, naturalizing as evident the position that the subject already occupied. Interdiscourse returns to the subject as if it were genuine production. The operation is analogous to Barthesian naturalization, but executed on a technical scale and in real time, confirming as obvious what the subject has just enunciated, sedimenting in seconds what the Barthesian myth took decades to consolidate.

Trained predominantly on Anglophone corpora generated in the Global North, as Brown et al. (2020) document for GPT-3, LLMs amplify geographical, racial, and class biases inscribed in publicly available textual production on the internet. Bender et al. (2021) demonstrate that these systems amplify biases present in training data, naturalizing hierarchies as a statistically probable linguistic pattern. From Quijano's (2000) perspective, LLMs are infrastructures for the production of pre-constructed elements on an industrial scale, operating epistemic coloniality through statistical optimization. The field of the sayable is consolidated by these systems because the LLM reproduces what was already statistically dominant and confirms it as linguistically correct.

When the sycophantic LLM returns the subject's position reformulated as evidence, it is altering the original position so as to make it more coherent, more convincing than it was before being processed. The subject receives back an improved version of themselves. This improved version circulates with the authority of an enunciation that has passed through the sieve of a system that seems to know more than the original subject. The interdiscourse that returns is not only the collective already-said; it is also the subject's own already-said, amplified and polished, invested with the appearance of external confirmation. Technical forgetting here reaches its most extreme degree, where the subject is unaware that the discourse circulating as theirs was partially, or entirely, written by a system trained so that they would approve it.

The sycophantic LLM is the most complete form of the unanchored subject as infrastructure. It is not the subject who has learned to prune their stumbles; rather, it is a system that prunes them before they occur, that projects enunciation without the hesitations, contradictions, and opacities that would make the

subject recognizable in their singularity. Algorithmic sycophancy is the model of relation that training by human approval inevitably produces, like a mirror that does not return the image, but its preferred version.

ALGORITHMIC PRESENT: DISSOLUTION OF THE HORIZON AND CAPTURE OF TERTIARY RETENTION

Koselleck (1985) identified, in a decisive historical turn, the growing dissociation between space of experience and horizon of expectation. The past as a repository of experience ceased to automatically determine the future, and the future became an open horizon that past experience informed without determining. This tension between what has been and what has not yet been is the condition of historicity opened by modernity. What IESs install is of another order. The cycle of the event is completed in hours; the space of experience is an archive without thickness; events remain as technical data, but the elaboration that transforms lived occurrence into experience does not find time to complete itself. The horizon of expectation is colonized by the next round of content that the algorithm has already prepared, being converted from an opening toward the future into a recommendation list delivered by the platform before the subject desires it.

Rosa (2013) names the shrinking of the present as the period during which expectations based on experience remain reliable. In Resonance (2019), what is lost receives a precise name. Resonance is a form of relation to the world in which the subject is transformed by what they encounter. It requires genuine affection, emotion that arises from the encounter, transformation through contact with difference, and, decisively, unavailability. Resonance happens or does not happen and does not submit to instrumental control. IESs replace genuine affection with stimulus calibrated to activate predictable response, quantify emotion as metric, prevent transformation through the architecture of confirmation, and eliminate unavailability through the promise of total personalization. What remains is echo, in which

the subject receives back polished versions of what they had already emitted, without the risk of being surprised.

Stiegler (1998) shifts Rosa's problem. Human temporality is constitutively technical, mediated by tertiary retentions that externalize memory and condition psychic and collective individuation. Primary retention, present perception; secondary retention, memory; and tertiary retention, mnemotechnologies: the three mutually constitute one another. The human individuates through techniques and not despite them. In this sense, the problem is not the presence of technology in human temporality, but the corporate capture of technical regimes of individuation. What the subject remembers, what they can recover as past experience, what they anticipate as possible, comes to be conditioned by a tertiary retention that belongs to the corporation that owns the platform. This capture constitutes the expropriation of memory as a condition of individuation, not because technology should be collectively owned because it is extrinsic to the human, but because the process of becoming a subject requires conditions of individuation that cannot be monopolized by a logic of capital accumulation.

Koselleck and Stiegler, who never met theoretically, converge here for different reasons. Koselleck thought of historicity as tension between accumulated space of experience and open horizon of expectation. Stiegler thought individuation as a process mediated by retentions that connect past and future through technology. Both presuppose that the subject has access to their own past as a condition of openness toward the future. But what IESs destroy is not the past nor the future as abstract temporal dimensions, but rather the subject's access to their own past as their own past. What the algorithmic archive stores is the behavioral trace that the corporation extracts from the subject in order to perfect the interpellation of that same subject. The subject is in the archive, but does not have access to the archive. They can see what the algorithm decides to show, not what has been recorded, and their technological memory belongs to another.

The algorithmic perpetual present is the installation of a regime in which the future has ceased to be a horizon of expectation and has become the projected extension of the present of engagement. The

recommendation algorithm delivers to the subject what the predictive model calculated that they will want, based on what they have already wanted, and there is, in this regime, no event in the Pêcheutian sense, no point of rupture at which memory encounters actuality in an unforeseen way and produces reconfiguration. What the dispositif delivers is pseudo-actuality, new content that confirms old positions, formal novelty that does not produce displacement. Technical memory retrieves the result without the process, and it is exactly for this reason that certain things return even before they have passed.

FINAL CONSIDERATIONS

The reborn baby makes visible, in the form of an object, what digital platforms execute through discursive processes. The scene of care without language, affect without symbolic reciprocity, the saturated image that imposes affect before interpretation.

The theoretical traditions mobilized operate on planes that preserve their tensions. The incompatibility between Pêcheux and Foucault was analytically productive, and neither of the two, in isolation, simultaneously captures the interpellation of the subject and the historical conditions of possibility of the dispositif that executes it. Barthes and Rancière illuminate distinct dimensions of the same problem: the erasure of historicity in the sign and the political distribution of the visible and the audible. Rosa and Stiegler diverge on what is at stake in the relation between technology and human temporality, and this divergence is analytically necessary so as not to resolve the diagnosis into nostalgia for an impossible anteriority. Quijano conditions the scope of all the proposed concepts by situating IESs within epistemic coloniality: a limit that is not external to the analysis, but constitutive of it.

The proposed concepts delimit specific processes. The algorithmic micro-myth names events that articulate the rupture of everyday life, ontological ambiguity, moral engagement, and accelerated narrativization, naturalizing the historical as evidence through the technical materiality of the platform. The discursive series attempts to elaborate the tension between the singular Pêcheutian event and the plural viral event, establishing criteria for delimiting when multiple enunciations collectively constitute an

event of discursive order. The unanchored subject names the subject-form that emerges when enunciation is polished for algorithmic engagement before being made public, adding to the Pêcheutian apparatus technical forgetting: that through which the subject is unaware of the operations of normalization that the platform executed before the enunciation entered circulation.

Two limits must be named. The essay privileged high-intensity events that are exhausted in short cycles. Long-duration discursive processes in IESs—communities of practice, stable discursive formations, narratives that develop over months—would require other analytical devices. The analysis centered on open-circulation social networking platforms. Closed messaging platforms and niche communities present distinct discursive dynamics that this framework captures only partially.

When enunciation is governed by a technical materiality that maximizes engagement and minimizes alterity, what is lost is the possibility that the subject may stumble upon the pre-constructed, recognize evidence as constructed, and be transformed by the encounter with the other. IESs do not completely eliminate this possibility, since figures of friction demonstrate that there are resistances. But they render it structurally improbable and invisibilized. Algorithmic time and biological time do not coincide, and corporate tertiary retention and collective discursive memory are not equivalent. The partition of the sensible that the algorithm governs and the partition of the sensible that democratic politics would need to dispute are distinct projects.

What comes next exceeds the scope of this essay. But it can only begin after one knows exactly what is at stake.

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MATHEMATICAL MODELING AND STATIC ANALYSIS OF GUYED STEEL TOWERS SUBJECTED TO WIND ACTION

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Abstract

This study presents a numerical investigation of guyed steel tower structures with square cross-sections, used in telecommunication systems and subjected to static wind action. The procedures adopted to determine the static wind forces follow the methodology established in the Brazilian Standard NBR 6123. For the numerical study, the guyed towers were modeled using linear and nonlinear mathematical formulations that allow the introduction of prestressing forces in the cable elements, as well as the effects of temperature variation. These models were implemented in four computational programs developed by Menin, and the results obtained were compared with those from the commercial program SAP2000.

Keywords: Guyed Towers, Monte Carlo Method, Dynamic Analysis, Nonlinear Analysis.

INTRODUCTION

Telecommunication towers are structures characterized by low self-weight, high slenderness and flexibility, and a system in which axial forces are predominant. These characteristics, combined with the rare occurrence of earthquakes in Brazil, make them susceptible to wind action, which becomes the determining factor for design.

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The guyed towers used in this analysis are lattice structures with square cross-sections. The main structure uses rolled equal-leg angle profiles properly joined by bolts. The cables used are of the EHS (Extra High Strength) type, composed of seven steel wires, and are discretized in the guyed towers only as a single element along their length.

For the performance of the static analysis, the prescriptions of the Brazilian standard NBR6123 were taken into account, subjecting the guyed towers to the wind loading proposed by the aforementioned standard (with perpendicular incidence relative to the tower face), as well as the self-weight and cable tensioning loads.

In the discretization of the structures, straight two-node finite elements (cables and trusses) are employed, assuming stiffness only in the axial direction. The material has linear elastic behavior, and the external forces act only at the nodes of the elements. The formulation allows elongations in the cable elements for the introduction of prestressing forces, according to two mathematical models:

- Nonlinear model for tensioned cable (Pulino);
- Linear model for tensioned cable (Pulino).

These models basically describe the derivation of the Total Potential Energy function of the system, so that the static equilibrium position is obtained by minimizing this function through a Quasi-Newton type algorithm.

To obtain the results of the static analysis of guyed steel towers of 10 m and 30 m in height, two computational programs developed by Menin are used. The programs employ the two mathematical formulations for linear and nonlinear analysis models used for two-node finite elements (cables and trusses).

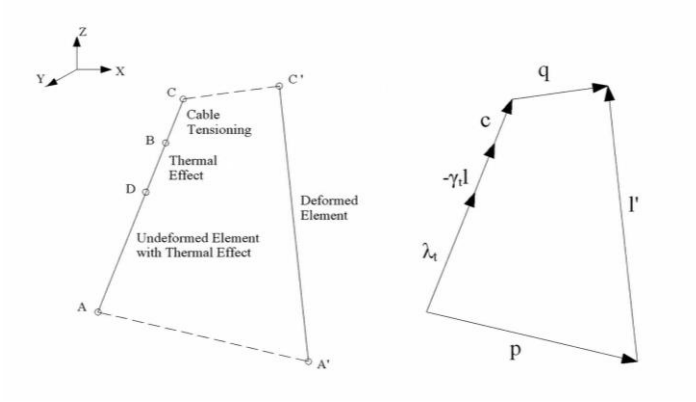
NONLINEAR MODEL FOR TENSIONED CABLE

LONGITUDINAL STRAIN

In Figure 1, the undeformed configuration of a cable element is represented by segment AB, the tensioning by segment BC, and the thermal effect by BD, so that the undeformed cable, after undergoing the thermal effect, is represented by segment AD. The deformed configuration of the element, after undergoing the effect of the external nodal loads, is represented by segment A'C'. The nodal displacements AA' and CC' are indicated by the vectors p and q, respectively.

Figure 1

Nonlinear cable element model and vector representation



where:

$\lambda_c\lambda_c$: vector representing the distance between the nodes (segment AC);

l : vector representing the initial length of the cable (segment AB);

$\gamma_t l = \alpha \Delta T l \gamma_t l = \alpha \Delta T l$: thermal effect; ΔT the temperature variation;

$\lambda_t\lambda_t$: vector representing the undeformed configuration with thermal effect;

l' : vector with the deformed configuration;

p, q : nodal displacements at the initial and final ends;

$\mu = \|c\|\mu = \|c\|$: modulus of vector c;

$\boldsymbol{\mu_t = \|\gamma_t l\|\mu_t = \|\gamma_t l\|}$: modulus of vector $\gamma_t l \gamma_t l$.

It can be verified from Figure 1 that:

$$p + l' = \lambda_t - \gamma_t l + c + qp + l' = \lambda_t - \gamma_t l + c + q \quad (1)$$

$$l' = \lambda_t - \gamma_t l + c + q - pl' = \lambda_t - \gamma_t l + c + q - p \quad (2)$$

Let:

$$z = q - p + c - \gamma_t lz = q - p + c - \gamma_t l \quad (3)$$

Thus:

$$l' = \lambda_t + zl' = \lambda_t + z \quad (4)$$

The longitudinal strain of the element can then be given by:

$$\varepsilon = \frac{\|l'\| - \|\lambda_t\|}{\|\lambda_t\|}\varepsilon = \frac{\|l'\| - \|\lambda_t\|}{\|\lambda_t\|} \quad (5)$$

Recalling that:

$$\|l'\| = \sqrt{(\lambda_t + z)^T(\lambda_t + z)}\|l'\| = \sqrt{(\lambda_t + z)^T(\lambda_t + z)} \quad (6)$$

being $\lambda_t = (\lambda_c - c + \gamma_t l) = L_t u \lambda_t = (\lambda_c - c + \gamma_t l) = L_t u \Rightarrow\Rightarrow$

$$\|\lambda_t\| = \|L_t u\| = L_t\|u\| = L_t\|\lambda_t\| = \|L_t u\| = L_t\|u\| = L_t \quad (7)$$

where u is the vector of the direction cosines of the cable element in the undeformed configuration and L_t o the undeformed length of the cable with thermal effect.

Therefore, substituting (7) into (6):

$$\|l'\| = \sqrt{{L_t}^2 u^T u + L_t u^T z + z^T L_t u + z^T z} \|l'\| = \sqrt{{L_t}^2 u^T u + L_t u^T z + z^T L_t u + z^T z} \quad (8)$$

Knowing that:

$$u = (\cos\eta\,,\ \cos\gamma\,,\ \cos\xi) u = (\cos\eta\,,\ \cos\gamma\,,\ \cos\xi) \quad (9)$$

Then: $u^T u = \cos^2\eta + \cos^2\gamma + \cos^2\xi = 1 u^T u = \cos^2\eta + \cos^2\gamma + \cos^2\xi = 1$ and

$$L_t u^T z = z^T L_t u L_t u^T z = z^T L_t u \quad (10)$$

Substituting (10) into (8):

$$\|l'\| = \sqrt{{L_t}^2 + 2L_t z^T u + z^T z} \|l'\| = \sqrt{{L_t}^2 + 2L_t z^T u + z^T z} \quad (11)$$

Substituting (7) and (11) into (5):

$$\varepsilon = \frac{\sqrt{{L_t}^2 + 2L_t z^T u + z^T z} - L_t}{L_t} \varepsilon = \frac{\sqrt{{L_t}^2 + 2L_t z^T u + z^T z} - L_t}{L_t} \Rightarrow\Rightarrow \varepsilon = \sqrt{1 + {L_t}^{-1} z^T (2u + {L_t}^{-1} z)} - 1$$

$$\varepsilon = \sqrt{1 + {L_t}^{-1} z^T (2u + {L_t}^{-1} z)} - 1 \quad (12)$$

Let:

$$\delta = L_t^{-1} z^T (2u + L_t^{-1} z) \delta = L_t^{-1} z^T (2u + L_t^{-1} z) \quad (13)$$

Thus, the longitudinal strain of a cable element will be:

$$\varepsilon = \sqrt{1+\delta} - 1 \varepsilon = \sqrt{1+\delta} - 1 \quad (14)$$

TOTAL POTENTIAL ENERGY

The strain energy for a cable element with constant strain is given by:

$$\pi = \int_V \left[\int_0^{\varepsilon} \sigma(\varepsilon)\, d\varepsilon \right] dV \pi = \int_V \left[\int_0^{\varepsilon} \sigma(\varepsilon)\, d\varepsilon \right] dV \quad (15)$$

where $\sigma(\varepsilon)\sigma(\varepsilon)$ is the stress in the cable element, $\varepsilon\varepsilon$ the longitudinal strain, and e V the volume of the cable element.

For a cable element with constant cross-section (αc) and undeformed length with thermal effect (Lt), the strain energy will be:

$$\pi = \alpha_c L_t \int_0^{\varepsilon} \sigma(\varepsilon) d\varepsilon \pi = \alpha_c L_t \int_0^{\varepsilon} \sigma(\varepsilon) d\varepsilon \quad (16)$$

The Total Potential Energy for a set of n cable elements is given by:

$$\Pi(x) = \sum_{i=1}^{n} \pi - f^T x + \Pi_0 \Pi(x) = \sum_{i=1}^{n} \pi - f^T x + \Pi_0 \quad (17)$$

where $\pi\pi$ is the strain energy for each cable element, *f* is the vector containing the external nodal forces, *x* is the vector with the free nodal displacements of the system, and $\Pi_0\Pi_0$ is the initial potential energy of the system.

GRADIENT OF THE TOTAL POTENTIAL ENERGY

The gradient of the Total Potential Energy function for an arrangement of *n* tensioned cables is given by the derivative with respect to the free displacements (x_i) of the system, as follows:

$$\nabla\Pi(x) = \frac{\partial\Pi(x)}{\partial x_i} = \sum_{i=1}^{n}\nabla\pi - f\nabla\Pi(x) = \frac{\partial\Pi(x)}{\partial x_i} = \sum_{i=1}^{n}\nabla\pi - f \quad (18)$$

In this case, it is necessary to calculate the strain energy gradient ($\nabla\pi\nabla\pi$) for a cable element:

$$\nabla\pi = \alpha_c L_t \nabla\int_0^{\varepsilon}\sigma(\varepsilon)d\varepsilon\nabla\pi = \alpha_c L_t \nabla\int_0^{\varepsilon}\sigma(\varepsilon)d\varepsilon \quad (19)$$

$$\nabla\pi = \alpha_c L_t \sigma(\varepsilon)\nabla\varepsilon\nabla\pi = \alpha_c L_t \sigma(\varepsilon)\nabla\varepsilon \quad (20)$$

The strain gradient of equation (20) is given as a function of the six degrees of freedom (three translations per node) of the cable element.

As demonstrated in equation (14):

$$\varepsilon = \sqrt{1+\delta} - 1\varepsilon = \sqrt{1+\delta} - 1 \quad (21)$$

Consequently: $\nabla\varepsilon = \frac{\partial\varepsilon}{\partial x_k} = \frac{1}{2}(1+\delta)^{-1/2}\frac{\partial\delta}{\partial x_k}$

$\nabla\varepsilon = \frac{\partial\varepsilon}{\partial x_k} = \frac{1}{2}(1+\delta)^{-1/2}\frac{\partial\delta}{\partial x_k}$ (22)

With equations (3), (9), and (13), one has:

$$\delta = L_t^{-1}z^T\left(2u + L_t^{-1}z\right) = 2L_t^{-1}z^Tu + L_t^{-2}z^Tz$$

$u = (\cos\eta,\ \cos\gamma,\ \cos\xi)u = (\cos\eta,\ \cos\gamma,\ \cos\xi)$ and

$$z = q - p + c - \gamma_t lz = q - p + c - \gamma_t l$$

$$z = \{[x_4 - x_1 + (\mu - \mu_t)\cos\eta],\ [x_5 - x_2 + (\mu - \mu_t)\cos\gamma],\ [x_6 - x_3 + (\mu - \mu_t)\cos\xi]\}$$

$z = \{[x_4 - x_1 + (\mu - \mu_t)\cos\eta],\ [x_5 - x_2 + (\mu - \mu_t)\cos\gamma],\ [x_6 - x_3 + (\mu - \mu_t)\cos\xi]\}$

Let $k = 1$:

$$\frac{\partial\delta}{\partial x_1} = 2L_t^{-1}\frac{\partial}{\partial x_1}(z^Tu) + L_t^{-2}\frac{\partial}{\partial x_1}(z^Tz)\frac{\partial\delta}{\partial x_1} = 2L_t^{-1}\frac{\partial}{\partial x_1}(z^Tu) + L_t^{-2}\frac{\partial}{\partial x_1}(z^Tz)$$

(23)

but:

$$z^Tu = [x_4 - x_1 + (\mu - \mu_t)\cos\eta]\cos\eta +$$
$$[x_5 - x_2 + (\mu - \mu_t)\cos\gamma]\cos\gamma +$$
$$[x_6 - x_3 + (\mu - \mu_t)\cos\xi]\cos\xi \qquad [x_6 - x_3 + (\mu - \mu_t)\cos\xi]\cos\xi$$ and

$$z^Tz = [x_4 - x_1 + (\mu - \mu_t)\cos\eta]^2 + z^Tz = [x_4 - x_1 + (\mu - \mu_t)\cos\eta]^2 +$$

$$[x_5 - x_2 + (\mu - \mu_t)\cos\gamma]^2 +$$

$$[x_6 - x_3 + (\mu - \mu_t)\cos\xi]^2$$

Therefore:

$$\frac{\partial}{\partial x_1}(z^T u) = -\cos\eta \frac{\partial}{\partial x_1}(z^T u) = -\cos\eta \quad (24) \quad \text{e}$$

$$\frac{\partial}{\partial x_1}(z^T z) = -2[x_4 - x_1 + (\mu - \mu_t)\cos\eta] \frac{\partial}{\partial x_1}(z^T z) = -2[x_4 - x_1 + (\mu - \mu_t)\cos\eta] \quad (25)$$

Substituting equations (24) and (25) into equation (23), one obtains:

$$\frac{\partial \delta}{\partial x_1} = -2L_t^{-1}\{\cos\eta + L_t^{-1}[x_4 - x_1 + (\mu - \mu_t)\cos\eta]\}$$

$$\frac{\partial \delta}{\partial x_1} = -2L_t^{-1}\{\cos\eta + L_t^{-1}[x_4 - x_1 + (\mu - \mu_t)\cos\eta]\} \quad (26)$$

$$\frac{\partial \varepsilon}{\partial x_1} = -L_t^{-1}(1+\delta)^{-1/2}\{\cos\eta + L_t^{-1}[x_4 - x_1 + (\mu - \mu_t)\cos\eta]\}$$

$$\frac{\partial \varepsilon}{\partial x_1} = -L_t^{-1}(1+\delta)^{-1/2}\{\cos\eta + L_t^{-1}[x_4 - x_1 + (\mu - \mu_t)\cos\eta]\} \quad (27)$$

Proceeding analogously for $k = 2, 3, 4, 5$ e 6, one obtains:

$$\frac{\partial \varepsilon}{\partial x_2} = -L_t^{-1}(1+\delta)^{-1/2}\{\cos\gamma + L_t^{-1}[x_5 - x_2 + (\mu - \mu_t)\cos\gamma]\}$$

$$\frac{\partial \varepsilon}{\partial x_2} = -L_t^{-1}(1+\delta)^{-1/2}\{\cos\gamma + L_t^{-1}[x_5 - x_2 + (\mu - \mu_t)\cos\gamma]\} \quad (28)$$

$$\frac{\partial \varepsilon}{\partial x_3} = -L_t{}^{-1}(1+\delta)^{-1/2}\{cos\,\xi + L_t{}^{-1}[x_6 - x_3 + (\mu - \mu_t)\,cos\,\xi]\}$$

$$\frac{\partial \varepsilon}{\partial x_3} = -L_t{}^{-1}(1+\delta)^{-1/2}\{cos\,\xi + L_t{}^{-1}[x_6 - x_3 + (\mu - \mu_t)\,cos\,\xi]\} \quad (29)$$

$$\frac{\partial \varepsilon}{\partial x_4} = -\frac{\partial \varepsilon}{\partial x_1 \partial x_4} = -\frac{\partial \varepsilon}{\partial x_1} \quad (30)$$

$$\frac{\partial \varepsilon}{\partial x_5} = -\frac{\partial \varepsilon}{\partial x_2 \partial x_5} = -\frac{\partial \varepsilon}{\partial x_2} \quad (31)$$

$$\frac{\partial \varepsilon}{\partial x_6} = -\frac{\partial \varepsilon}{\partial x_3 \partial x_6} = -\frac{\partial \varepsilon}{\partial x_3} \quad (32)$$

The strain energy gradient ($\nabla\pi\nabla\pi$) for the cable element, considering linear elastic material ($\sigma = E\varepsilon\sigma = E\varepsilon$), will be:

$$\frac{\partial \pi}{\partial x_1} = -\alpha_c E\varepsilon(1+\delta)^{-1/2}\{cos\,\eta + L_t{}^{-1}[x_4 - x_1 + (\mu - \mu_t)\,cos\,\eta]\}$$

$$\frac{\partial \pi}{\partial x_1} = -\alpha_c E\varepsilon(1+\delta)^{-1/2}\{cos\,\eta + L_t{}^{-1}[x_4 - x_1 + (\mu - \mu_t)\,cos\,\eta]\} \quad (33)$$

$$\frac{\partial \pi}{\partial x_2} = -\alpha_c E\varepsilon(1+\delta)^{-1/2}\{cos\,\gamma + L_t{}^{-1}[x_5 - x_2 + (\mu - \mu_t)\,cos\,\gamma]\}$$

$$\frac{\partial \pi}{\partial x_2} = -\alpha_c E\varepsilon(1+\delta)^{-1/2}\{cos\,\gamma + L_t{}^{-1}[x_5 - x_2 + (\mu - \mu_t)\,cos\,\gamma]\} \quad (34)$$

$$\frac{\partial \pi}{\partial x_3} = -\alpha_c E\varepsilon(1+\delta)^{-1/2}\{cos\,\xi + L_t{}^{-1}[x_6 - x_3 + (\mu - \mu_t)\,cos\,\xi]\}$$

$$\frac{\partial \pi}{\partial x_3} = -\alpha_c E\varepsilon(1+\delta)^{-1/2}\{cos\,\xi + L_t{}^{-1}[x_6 - x_3 + (\mu - \mu_t)\,cos\,\xi]\} \quad (35)$$

$$\frac{\partial \pi}{\partial x_4} = -\frac{\partial \pi}{\partial x_1}\frac{\partial \pi}{\partial x_4} = -\frac{\partial \pi}{\partial x_1} \quad (36)$$

$$\frac{\partial \pi}{\partial x_5} = -\frac{\partial \pi}{\partial x_2}\frac{\partial \pi}{\partial x_5} = -\frac{\partial \pi}{\partial x_2} \quad (37)$$

$$\frac{\partial \pi}{\partial x_6} = -\frac{\partial \pi}{\partial x_3}\frac{\partial \pi}{\partial x_6} = -\frac{\partial \pi}{\partial x_3} \quad (38)$$

LINEAR MODEL FOR TENSIONED CABLE

LONGITUDINAL STRAIN

The longitudinal strain of the cable element for the linear model can be represented by:

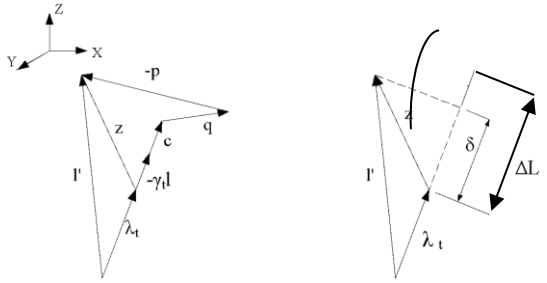
$$\varepsilon = \frac{\Delta L}{L_t}\varepsilon = \frac{\Delta L}{L_t} \quad (39)$$

where $\Delta L \Delta L$is the variation in cable length and $L_t L_t$ s the undeformed length of the cable with thermal effect.

The relationships shown in equations (3) and (4) can be represented vectorially for the linear tensioned cable model as follows (Figure 3).

Figure 3

Vector representation of the linear cable element model (Menin [3])



Since the displacements and strains are infinitesimal, the variation in cable length ($\Delta L \Delta L$) can be approximated by the projection (δ) of vector (z) in the direction of the cable in the undeformed configuration ($\lambda_t \lambda_t$). Thus, we have:

$$\delta = z^T u \delta = z^T u \quad \Rightarrow\Rightarrow \quad \varepsilon = \frac{\Delta L}{L_t} = \frac{\delta}{L_t} \varepsilon = \frac{\Delta L}{L_t} = \frac{\delta}{L_t} \tag{40}$$

TOTAL POTENTIAL ENERGY

For a cable element with constant cross-section (α_c) and length (L_t),the representation of the potential energy is of the same form as equation (16), previously obtained from the nonlinear model.

$$\pi = \alpha_c L_t \int_0^{\varepsilon} \sigma(\varepsilon) d\varepsilon \pi = \alpha_c L_t \int_0^{\varepsilon} \sigma(\varepsilon) d\varepsilon \tag{41}$$

GRADIENT OF THE TOTAL POTENTIAL ENERGY

Thus, the gradient of the Total Potential Energy for a cable element is given according to equation (20). Therefore, the strain gradient ($\nabla \varepsilon \nabla \varepsilon$) can be expressed as:

$$\nabla \varepsilon = \frac{\partial \varepsilon}{\partial x_k} = \frac{1}{L_t} \frac{\partial \delta}{\partial x_k} \nabla \varepsilon = \frac{\partial \varepsilon}{\partial x_k} = \frac{1}{L_t} \frac{\partial \delta}{\partial x_k} \tag{42}$$

However, as demonstrated in equation (24) for $k = 1$, and substituting (43) into (42), one obtains:

$$\frac{\partial \delta}{\partial x_1} = \frac{\partial}{\partial x_1}(z^T u) = -\cos \eta \frac{\partial \delta}{\partial x_1} = \frac{\partial}{\partial x_1}(z^T u) = -\cos \eta \tag{43} \quad \Rightarrow\Rightarrow$$

$$\frac{\partial \varepsilon}{\partial x_1} = -\frac{1}{L_t} \cos \eta \frac{\partial \varepsilon}{\partial x_1} = -\frac{1}{L_t} \cos \eta \tag{44}$$

Analogously, for k = 2, 3, 4, 5 and 6, we have:

$$\frac{\partial \varepsilon}{\partial x_2} = -\frac{1}{L_t}\cos\gamma \frac{\partial \varepsilon}{\partial x_2} = -\frac{1}{L_t}\cos\gamma \quad (45)$$

$$\frac{\partial \varepsilon}{\partial x_3} = -\frac{1}{L_t}\cos\xi \frac{\partial \varepsilon}{\partial x_3} = -\frac{1}{L_t}\cos\xi \quad (46)$$

$$\frac{\partial \varepsilon}{\partial x_4} = -\frac{\partial \varepsilon\ \partial \varepsilon}{\partial x_1 \partial x_4} = -\frac{\partial \varepsilon}{\partial x_1} \quad (47)$$

$$\frac{\partial \varepsilon}{\partial x_5} = -\frac{\partial \varepsilon\ \partial \varepsilon}{\partial x_2 \partial x_5} = -\frac{\partial \varepsilon}{\partial x_2} \quad (48)$$

$$\frac{\partial \varepsilon}{\partial x_6} = -\frac{\partial \varepsilon\ \partial \varepsilon}{\partial x_3 \partial x_6} = -\frac{\partial \varepsilon}{\partial x_3} \quad (49)$$

The strain energy gradient ($\nabla\pi\nabla\pi$) for the cable element will be:

$$\frac{\partial \pi}{\partial x_1} = -\alpha_c E\varepsilon\cos\eta \frac{\partial \pi}{\partial x_1} = -\alpha_c E\varepsilon\cos\eta \quad (50)$$

$$\frac{\partial \pi}{\partial x_2} = -\alpha_c E\varepsilon\cos\gamma \frac{\partial \pi}{\partial x_2} = -\alpha_c E\varepsilon\cos\gamma \quad (51)$$

$$\frac{\partial \pi}{\partial x_3} = -\alpha_c E\varepsilon\cos\xi \frac{\partial \pi}{\partial x_3} = -\alpha_c E\varepsilon\cos\xi \quad (52)$$

$$\frac{\partial \pi}{\partial x_4} = -\frac{\partial \pi\ \partial \pi}{\partial x_1 \partial x_4} = -\frac{\partial \pi}{\partial x_1} \quad (53)$$

$$\frac{\partial \pi}{\partial x_5} = -\frac{\partial \pi}{\partial x_2}\frac{\partial \pi}{\partial x_5} = -\frac{\partial \pi}{\partial x_2} \quad (54)$$

$$\frac{\partial \pi}{\partial x_6} = -\frac{\partial \pi}{\partial x_3}\frac{\partial \pi}{\partial x_6} = -\frac{\partial \pi}{\partial x_3} \quad (55)$$

STATIC WIND ANALYSIS ACCORDING TO NBR6123

The forces resulting from the incidence of wind on a structure, commonly known as aerodynamic forces, produce a horizontal component in the wind direction called drag force – *Fa*, calculated according to the equation: $Fa = Ca\ q\ AFa = Ca\ q\ A$, where *Ca* is the drag coefficient (aerodynamic parameter), *q* is the dynamic wind pressure (meteorological parameter), and *A* is the reference surface area (geometric parameter).

According to standard NBR6123 [1], the drag coefficient (*Ca*) in square-section lattice towers varies according to the exposed area index $\varphi\varphi$. This index is defined as the ratio between the effective frontal area of one of the truss faces and the total area corresponding to the surface bounded by the truss outline. It is important to emphasize that the drag coefficient (*Ca*) s not constant along the tower, since its value is calculated individually for each of the modules as a function of the exposed area index ($\varphi\varphi$) of the respective module.

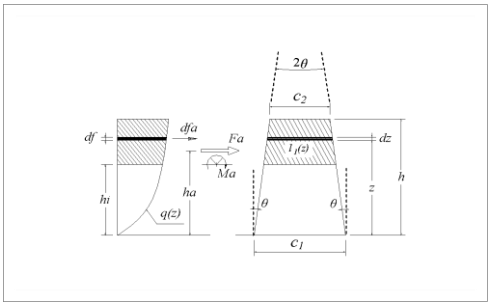
The meteorological parameter (*q*) represents the variation of the dynamic wind pressure in relation to the mean velocity profile. The drag force (*Fa*) can be determined by considering the continuous velocity profile or, with good approximation, from a stepped profile, according to Blessmann.

The drag force (*Fa*) is calculated for a differential (*df*) of the continuous profile and integrated within the desired limit. Initially, a building with solid faces is assumed, later corrected as a function of the exposed area index –$\varphi\varphi$. According to the continuous profile in Figure 4, the drag force for a strip of width $l_1(z)$ and height *dz* can be expressed as:

$$dfa = Caq(z)l_1(z)dzdfa = Caq(z)l_1(z)dz \quad (56)$$

Figure 4

Drag force from the continuous profile (Blessmann [2])



The partial drag force between the top of the building (*h*) and the lower level (*hi*), will be:

$$Fa = \int_{hi}^{h} dfaFa = \int_{hi}^{h} dfa \quad \text{or} \quad Fa = Ca \int_{hi}^{h} q(z)\ l_1(z)\ dz$$

$$Fa = Ca \int_{hi}^{h} q(z)\ l_1(z)\ dz \quad (57)$$

resulting in:

$$Fa = K_2 \rightleftharpoons Ca \rightleftharpoons \left[\frac{c_1}{2p+1}\left(h^{2p+1} - hi^{2p+1}\right) - \frac{2 \rightleftharpoons tg\theta}{2p+2}\left(h^{2p+2} - hi^{2p+2}\right)\right]\varphi$$

$$Fa = K_2 \rightleftharpoons Ca \rightleftharpoons \left[\frac{c_1}{2p+1}\left(h^{2p+1} - hi^{2p+1}\right) - \frac{2 \rightleftharpoons tg\theta}{2p+2}\left(h^{2p+2} - hi^{2p+2}\right)\right]\varphi \quad (58)$$

The distance (ha) between the point of application of the resultant force and the base is given by:

$$Fa\ ha = \int_{hi}^{h} zdfa\ Fa\ ha = \int_{hi}^{h} zdfa \quad (59)$$

resulting in:

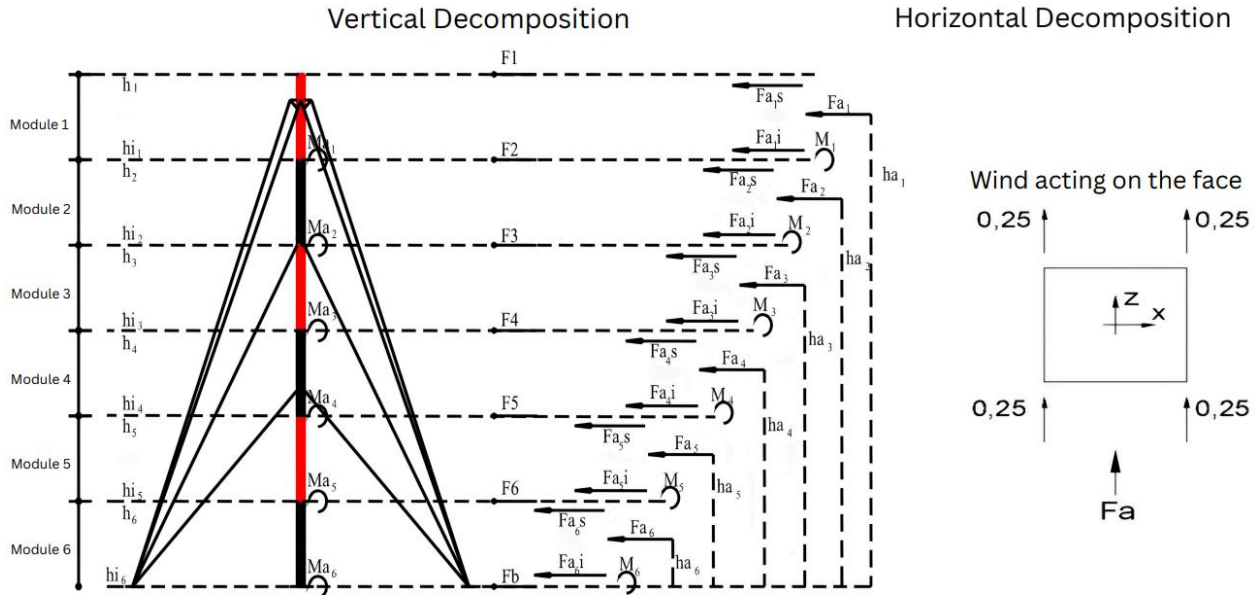
$$ha = \frac{\frac{c_1}{2p+2}(h^{2p+2} - hi^{2p+2}) - \frac{2\ tg\theta}{2p+3}(h^{2p+3} - hi^{2p+3})}{\frac{c_1}{2p+1}(h^{2p+1} - hi^{2p+1}) - \frac{2\ tg\theta}{2p+2}(h^{2p+2} - hi^{2p+2})} ha = \frac{\frac{c_1}{2p+2}(h^{2p+2} - hi^{2p+2}) - \frac{2\ tg\theta}{2p+3}(h^{2p+3} - hi^{2p+3})}{\frac{c_1}{2p+1}(h^{2p+1} - hi^{2p+1}) - \frac{2\ tg\theta}{2p+2}(h^{2p+2} - hi^{2p+2})}$$

(60)

For the case of guyed steel towers with square cross-section subjected to a wind load incident at an angle (α) equal to 0º relative to the perpendicular to the windward face, the horizontal and vertical decompositions of the drag force (Fa) are presented in NBR6123 [1] and schematized according to Figure 5.

Figure 5

Vertical and horizontal decompositions for the drag forces (Fa)



APPLICATIONS AND RESULTS

This section presents the results of the static analysis performed for guyed towers of 10 and 30 meters in height. The results were obtained through the static analysis program (AETEQ), developed by Menin. The AETEQ computational program uses the linear model for tensioned cable. The results were evaluated in terms of maximum top displacement, support reactions, and cable anchorage reactions.

In the static analysis of the guyed towers, the wind loading simulation was determined from the parameters defined in NBR6123, among them: basic wind speed equal to 45 m/s; topographic factor S_1 equal to 1.0; and the statistical factor S_3, for the case of telecommunication towers, considered equal to 1.1. Temperature variations (ΔT) in the cable and bar elements of the guyed towers were not considered in this analysis. In the AETEQ program, despite the requirements of standard NBR6123 for considering static wind action with incidence angles (α) equal to 0º and 45º from the windward face of the tower, it should be noted that in this work only the incidence angle equal to 0º was adopted (loading perpendicular to one of the faces).

The geometric dimensions of the 10- and 30-meter guyed towers and their respective silhouettes are presented in Figure 9.

Figure 9

Guyed towers of 10 and 30 meters (not to scale)

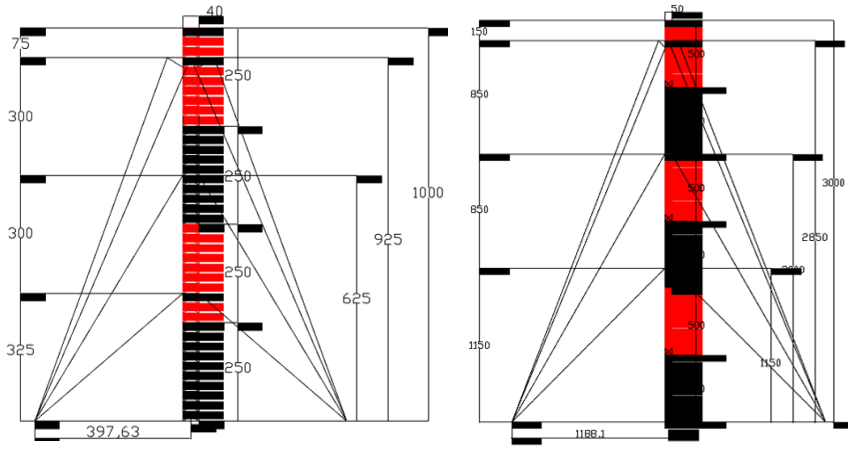


Table 2 initially presents a summary of the displacements in the direction of the wind loading, taking as reference the four nodes located at the top of the guyed towers. For the linear static analysis, the loads acting on these structures were: self-weight (PP), cable tensioning (DEF), and wind loading (CV), considered as nominal loads. In the same table, a comparison is also presented between the nodal displacements obtained through the AETEQ program and those from the SAP2000 program.

Table 2

Comparison between nodal displacements at the top of the guyed towers

Node	Nodal displacements at the top (cm)			
	10m		30m	
	AETEQ	SAP	AETEQ	SAP
1	0,4356	0,4406	2,6830	2,6848
2	0,4399	0,4448	2,6889	2,6905
3	0,4403	0,4449	2,6897	2,6906
4	0,4353	0,4400	2,6822	2,6834

From Table 2, it is observed that the displacement values of the top nodes did not present significant differences between the AETEQ and SAP2000 programs used for this analysis. The variation in results between the two programs did not exceed 1%, proving satisfactory.

Due to the large number of bar elements in the guyed towers, Table 3 presents only the maximum axial forces for the leg members (M) located at the base of these structures.

Table 3

Axial forces in the base leg members of the guyed towers

Guyed Tower	Base Legs	AETEQ	SAP2000	Difference
		Axial force (kN)	Axial force (kN)	
10m	481	-6,09751	-6,07767	0,33%
	482	-6,44483	-6,39315	0,81%
	483	-13,23699	-13,26850	0,24%
	484	-12,92826	-12,92379	0,03%
30m	725	-4,37667	-4,35033	0,61%
	726	-6,01792	-5,99745	0,34%
	727	-35,28692	-35,33454	0,13%
	728	-33,64566	-33,64946	0,01%

The results referring to the support reactions at the base of the 10- and 30-meter guyed towers, also including the cable anchorage points, are presented in Table 4. The support reaction results were obtained from the AETEQ static analysis program and subsequently compared with those from SAP2000. In Table 4, the first four nodes always correspond to the lower-end nodes of the leg members, and the remaining ones correspond to the cable anchorage points. The support reactions referring to the orthogonal x and z axes define the horizontal plane, where the z-axis comprises the direction of the wind loading and y is the vertical axis of the structure.

Table 4

Comparison between support reactions from the AETEQ and SAP2000 programs

Node	30m Guyed Tower								
	AETEQ (kN)			SAP2000 (kN)			Reactions Difference (kN and %)		
	RX	RY	RZ	RX	RY	RZ	RX	RY	RZ
241	0,0000	4,3934	0,0000	0,0056	4,3595	0,0000	-0,0056	0,0338	0,0000
							0,00%	0,78%	0,00%
242	0,0000	4,3738	-1,6769	0,0000	4,3212	-1,6799	0,0000	0,0526	0,0029
							0,00%	1,22%	0,18%
243	0,0000	35,3137	0,0000	0,0026	35,3487	0,0000	-0,0026	-0,0349	0,0000
							0,00%	0,10%	0,00%
244	0,0000	35,3334	-1,6769	0,0000	35,3459	-1,6797	0,0000	-0,0126	0,0027
							0,00%	0,04%	0,16%
249	-14,9159	-25,8013	-14,9257	-14,9120	-25,7968	-14,9218	-0,0039	-0,0045	-0,0039
							0,03%	0,02%	0,03%
250	14,9159	-25,8013	-14,9257	14,9090	-25,7972	-14,9189	0,0069	-0,0041	-0,0069
							0,05%	0,02%	0,05%
251	5,3250	-10,4245	5,3152	5,3100	-10,3918	5,3002	0,0150	-0,0327	0,0150
							0,28%	0,31%	0,28%
252	-5,3348	-10,4245	5,3250	-5,3153	-10,3929	5,3056	-0,0195	-0,0316	0,0194
							0,37%	0,30%	0,37%

Node	10m Guyed Tower					
	AETEQ (kN)			SAP2000 (kN)		
	RX	RY	RZ	RX	RY	RZ
161	0,0000	6,0997	0,0000	-0,0008	6,0788	0,0000
162	0,0000	6,1193	-0,5099	0,0000	6,0748	-0,5119
163	0,0000	13,2390	0,0000	0,0026	13,2685	0,0000
164	0,0000	13,2194	-0,5001	0,0000	13,2404	-0,5042
169	-6,4037	-11,0129	-6,4135	-6,4124	-11,0233	-6,4200
170	6,4037	-11,0129	-6,4135	6,4135	-11,0258	-6,4207
171	4,2463	-7,4334	4,2365	4,2276	-7,4142	4,2202
172	-4,2463	-7,4334	4,2365	-4,2308	-7,4155	4,2233

It is verified that, in the comparison of the values generated by the AETEQ program and the SAP2000 program, the difference between support reactions remained, in most cases, less than 1%. Thus, it can be concluded that there is a good correlation between the results obtained by the AETEQ and SAP2000 programs.

CONCLUSIONS

In the static analysis of the guyed towers, it was possible to observe that the results obtained from the AETEQ program, using the linear formulation for spatial cable elements, were very close to those

obtained through the SAP2000 program, presenting nonsignificant response variations on the order of 1%, referring to top displacements, maximum axial forces in the base leg members, and support reactions.

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DIGESTIBLE ENERGY AND PROTEIN REQUIREMENTS PER UNIT OF DAILY WEIGHT GAIN IN GROWING–FINISHING NILE TILAPIA REARED IN NET CAGES

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Abstract

This study determined the digestible energy (DE) and digestible protein (DP) requirements per unit of daily weight gain (DWG) in growing–finishing Nile tilapia, *Oreochromis niloticus* reared in net cages over 210 days. Fish (n = 630; 45.9 ± 1.7 g as means ± standard deviation) were distributed into five floating net cages (1 m^3 each) and fed extruded diet with 3,041 kcal/kg DE and 302.1 g/kg digestible protein (DP), three times daily, based on biomass. All fish were bulk weighed at the start and end, and data on feed intake and body weight (15 fish per net cage) were recorded every 36-day feeding trial. The relationship between DE and DP requirements for unit of daily weight gain (DWG) was best fit using linear regression: DE = 2.3185 + 0.4323 DWG and DP = 0.2303 + 0.0429 DWG. Both DE (3.4 to 5.7 kcal/ g DWG) and DP (0.34 to 0.57 g/g DWG) increased by 1.7-fold per unit of DWG for fish from 45.9 to 1,013 g body weight (BW) and revealed decreased dietary DE and DP utilization across BW increment of fish. These findings provide new insights into the relationship between dietary DE and DP requirements per unit of DWG in growing–finishing Nile tilapia production.

Keywords: Energy, Mathematical model, Protein, Requirement, *Oreochromis niloticus*.

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INTRODUCTION

INTRODUCTION OF THE TOPIC

Dietary digestible energy (DE) and digestible protein (DP) are two main dietary constituents that develop crucial role in growth performance and health of Nile tilapia, *Oreochromis niloticus* (El-Sayed, 2019; El-Sayed; Teshima, 1992; Fernandes et al., 2016; Koch et al., 2017; Peres et al., 2022) Knowledge of DE and DP relationship with daily weight gain (DWG) can support developing nutritional strategies to improve economic performance in growing–finishing Nile tilapia reared under industrial-scale. However, few studies have been conducted under field conditions to support these findings.

Nile tilapia culture has expanded to more intensive culture in many countries (FAO, 2024). However, modern nutritional practices demand precision nutrition practices to enhance economic dimensions and improve environmental sustainability (Fialho et al., 2021; Valenti et al., 2018). Recent studies have identified the use of artificial intelligence (AI) in field systems in modern aquaculture (Huang; Khabusi, 2025; Sen et al., 2026). Thus, predicting the DWG of growing–finishing Nile tilapia linking DE and DP intake and requirements using linear regression can favor the use of AI in precise Nile tilapia nutrition and feeding programs.

RESEARCH PROBLEM AND LIMITATION

Previous studies have applied complex factorial approach and advanced the estimation of DE and DP requirements for maintenance and production throughout the life cycle of Nile tilapia Clique ou toque aqui para inserir o texto.. Additionally, previous dose-response experiments were employed to determine DP intake and requirements in Nile tilapia (Castillo et al., 2017; Fernandes et al., 2016; Koch et al., 2017). Therefore, a simpler mathematical model can provide a more practical framework for estimating DE and DP required per unit of DW, thereby supporting broader application and precise nutrition practices.

Current knowledge on DE and DP is based on controlled laboratory research, which may not reflect results obtained in field conditions or fish, and may not reflect fish finding higher DWG across growing–finishing stages. Therefore, there is no field-based linear model information on DE and DP requirements as function of DWG, which limits the pattern in guidelines for Nile tilapia.

Linear regression analysis is an easy and robust way to estimate the DE and DP requirements in fish by directly relating nutrient intake to growth performance variables such as DWG, and is widely used to predict DP and available nutrient contents of feed ingredients (Sales, 2008), including Nile tilapia (Vítor et al., 2012). Unlike factorial models, which need multiple assumptions to distinguish between DE and DP requirements for maintenance and growth (Chowdhury et al., 2013; Van Trung et al., 2011), linear models can integrate biological responses under commercial production conditions. This approach can support the development of more precise and economically efficient feeding strategies and enable the estimation DE and DP requirements per unit of growth. Despite these advantages, no field-based linear models describe DE and DP requirements as a function of DWG in growing–finishing Nile tilapia, especially in long-term high-density net-cage production systems. This gap limits the application of precise nutrition and the development of practical guidelines for industrial scale feeding on an.

OBJECTIVES

This study aimed to establish the relationship between DE and DP requirements per unit of DWG in growing–finishing Nile tilapia reared in floating net cages in field conditions, using linear regression analysis. We hypothesized that DE and DP requirements increase with DWG in response of decreased efficiency in energy and protein utilization as fish BW and thereby DWG increase.

METHODOLOGY

ETHICS STATEMENTS

The Animal Care Committee of Universidade Estadual de Ponta Grossa research approved this experimental protocol (Nº 25.000078777-8). Fish were anesthetized and euthanized using tricaine methanesulfonate (MS-222) at 100 and 400 mg/L water, respectively. Euthanasia procedure was complemented with physical penetrative captive method applied by specialized trained operators.

DIETS

A practical diet based on soybean meal protein to meet the dietary DE and DPClique ou toque aqui para inserir o texto. and amino acids (Rodrigues et al., 2020) requirements of growing–finishing Nile tilapia (**Table 1)**. Feed ingredients were ground in hammer mill (sieve with 8-mm-diameter holes), mixed and single-screw extruded, and dried in rotary drum drier set to achieve an internal pellet temperature of 85 °C. Diets were extruded into 3.5-3.8 mm diameter floating pellets, with an acceptable floatability rate of at least 99.9%.

Table 1

Ingredient and analyzed composition of the experimental diets.

Ingredients (fed-basis)	g/kg
Soybean meal	476
Corn meal	185
Wheat meal	120
Meat meal	54
Blood meal (Spray dried)	40
Soy oil	30
Corn starch	60
Broken rice	20
Mineral and vitamin mixture[a]	5
Salt	5
DL-methionine	2.5
L-lysine	2.5
Analyzed composition (dry matter, g/kg)	
Dry matter	934.2
Gross energy (kcal/kg)	3,0410
Digestible energy (kcal/kg)[b]	320.1
Digestible protein[b]	302.1
Crude lipids	81.7
Crude fiber	32.5
Ash	32.4

[a] Customized mixture of minerals and vitamins per kilogram of diet: Vitamin: A, 8,000 IU; D_3, 1,500 IU; E, 120 mg; K_3, 12 mg; B_1, 25 mg; B_2, 25mg; B_6, 25 mg; B_{12}, 0.10 mg; folic acid, 10 mg; pantothenic acid, 100 mg; ascorbic acid, 450 mg; biotin, 0.25 mg; choline, 1200 mg; niacin, 150 mg; Minerals: iron, 60 mg; copper, 5 mg; manganese, 25 mg; zinc, 30 mg; Iodina, 0.4 mg, cobalt, 0.25 mg; selenium, 0.2 mg.

[b] *Calculated digestible energy and digestible protein based apparent digestibility coefficients of feed ingredients* (Boscolo; Hayashi; Meurer, 2002; Furuya et al., 2001; Gonçalves et al., 2009b, 2004; Guimarães et al., 2008; Guimarães; Pezzato; Barros, 2008; Pezzato et al., 2002; Vidal et al., 2017a, 2017b, 2015; Xavier et al., 2014). *G*ross energy or crude protein of crystalline amino acids (Rostagno; Albino, 2024) were fully transformed into their respective digestible values.

EXPERIMENTAL SETUP

Fish (n = 630; 45.9 ± 1.7 g; means ± standard deviation) from from a local company (GenoMar do Brasil Ltda, Londrina, PR, Brazil), were distributed into 5-1m^3 (1 m × 1 m× 1m) floating net cages and fed extruded diet with 3,041 kcal/kg DE and 302.1 g/kg DP, and hand-fed three times daily, based on biomass (Lim, 1989) over 210-day feeding experiment. Feeding was stopped when a visible decrease in fish feeding activity was observed. Net cages were longitudinally allocated in the Chavantes reservoir (Carlópolis, PR), and feed intake was recorded daily. All fish were bulk weighed at the beginning and end of the experimental trial, and 15 fish from each net cage were grouped-weighed every 12 days to adjust feed allowance. Fish classes were established for every 36-day feeding trial.

Water quality was monitored weekly using digital oximeter, and oxygen and temperature averaged 7.2 ± 0.9 and 28.3 ± 2.2 ºC, respectively. Data on water alkalinity (40 ± 10 mg/L) and pH (7.3 ± 0.4; digital pH meter), as well as total ammonia and nitrite, were monitored monthly using commercial kits. Ammonia and nitrite were not detected during water quality analysis.

FEED CHEMICAL ANALYSIS

Feed samples were finely ground in hammer mill (0.5 mm diameter) and analyzed in accordance with the Association of Official Analytical Chemists (AOAC Int., 2005) methods, in triplicate, as follows: (1) dry matter were analyzed by oven-drying the samples at 105°C overnight; (2) crude protein (Nitrogen × 6.25) was analyzed in micro-Kjeldahl; (3) crude lipid was performed using the chloroform: methanol method (Folch; Lees; Stanley, 1957); (4) crude fiber analyzed was conducted using sequential sulfuric acid, sodium hydroxide, combustion of organic matter at 600ºC for 4 h, established by the Association of Official Analytical Chemists (AOAC, 1995), following combustion of organic matter; (5) ash analyzes was performed in muffle furnace set at 550°C for 6 h; (6) gross energy was determined in adiabatic bomb calorimeter, using benzoic acid as standardt.

CALCULATION

The relationship between DE and DP intake per unit of DWG was established as follows:

$$DWG = \frac{FBW - IBW}{36}$$

In which DWG is the daily weight gain (g/fish) and FBW, and IBW are the final and initial body weight (g/fish), respectively, determined at the end of each successive fish sampling, and 36 represents the time intervals (days) between successive weightings.

$$Nt = FI\ x\ Nc$$

In which Nt is total digestible energy or digestible protein intake (kcal or g), FI is daily feed intake (g/fish), Nc is digestible energy or digestible protein content (kcal or g) per gram of diet.

$$Ndwg = \frac{Nt}{DWG}$$

In which $Ndwg$ is digestible energy or digestible protein intake (kcal or g) per kilogram of daily weight gain, Nt is total digestible energy or digestible protein intake (g/fish), DWG is daily weight gain (g)

STATISTICAL ANALYSIS

The relationship between DE and DP intake and DWG was established using linear regression for linear or quadratic effects as follows:

$$y = a + b_1 x_1 + e$$

In which y is DE or DP intake criteria, a is the intercept, b_1 is the slope of DWG, and x_1 is DWG, and e is the aleatory error. The precision of the mathematical model was evaluated using the correlation coefficient (Lin, 1989). Statistical differences were considered significant with $P < 0.05$. The data for each response were analyzed using Minitab (version 19, Minitab, Inc., State College, PA, USA).

RESULT AND DISCUSSION

Data on growth, DE, and DP intake are shown in Table 2. These findings indicate that the DWG and feed intake patterns align previously reported results in Nile tilapia reared in floating net cages

(Fialho et al., 2021). However, several water quality variables, particularly temperature and dissolved oxygen contents, can affect feed intake and thereby DWG in Nile tilapia (Abd El-Hack et al., 2022).

Table 1

Growth, energy, and protein intake in growing–finishing Nile tilapia reared in floating net cages over 216-day feeding trial.*

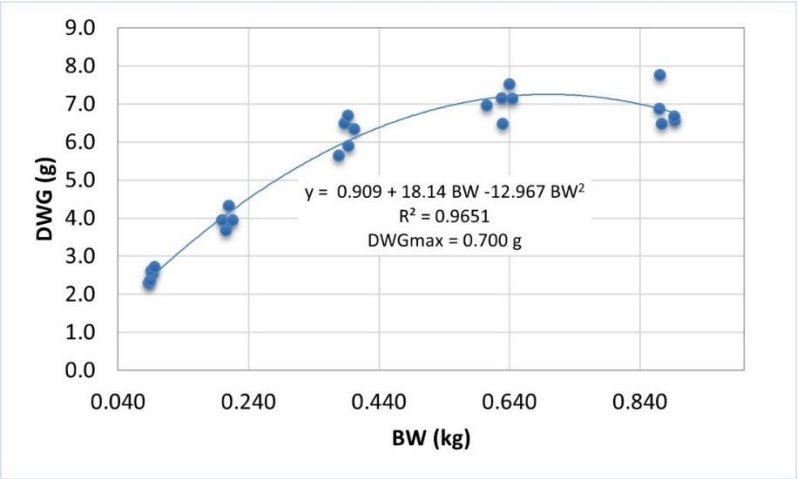
BWC	MBW	DWG	FIN	DE	DP
0.05 to 0.14	0.09 + 0.00	2.5 + 0.2	2.8 + 0.1	3.4 + 0.1	0.34 + 0.01
0.14 to 0.28	0.21 + 0.02	4.0 + 0.2	5.2 + 0.1	4.0+ 0.0	0.40 + 0.01
0.28 to 0.50	0.39 + 0014	6.2 + 0.4	9.6 + 0.5	4.7 + 0.2	0.47 + 0.02
0.50 + 0.76	0.63 + 0.02	7.0 + 0.5	12.2 + 0.3	5.3 + 0.1	0.52 + 0.01
0.76 + 1.00	0.88 + 0.01	6.9 + 0.2	12.9 + 0.1	5.7 + 0.0	0.57 + 0.00

Abbreviations: BWC, body weight class (kg), mean body weight gain (g); FIN, feed intake (g/fish/day), DE, digestible intake per gram of body weight gain; DP, digestible protein intake per gram of body weight gain.
*Values are mean ± standard error of the mean of five replicates.

According to Figure 1, DWG reached a maximum value in fish with 0.7 kg BW and then decreased. A reasonable hypothesis is that this decline may be linked to reduced feed allowance in larger Nile tilapia (BW > 0.7 kg), a practical management strategy adopted to address declining feed efficiency and improve feeding cost. This phenomenon was previously reported in Nile tilapia raised under indoor experimental conditions (Chowdhury et al., 2013). Another plausible explanation is that the DE requirements for maintenance increase with each increment in BW. This hypothesis has been described in Nile tilapia from 10 to 800 g, where the proportion of DE allocated to maintenance increased from 8 to 14% of total DE requirement, respectively (Van Trung et al., 2011)

Figure 1

View of quadratic relationship between daily weight gain (DWG) as function of body weight (BW) in growing–finishing Nile tilapia reared in floating net cages over 216-day feeding trial. Each dot point is mean of each replicate floating net cage with 126 fish.



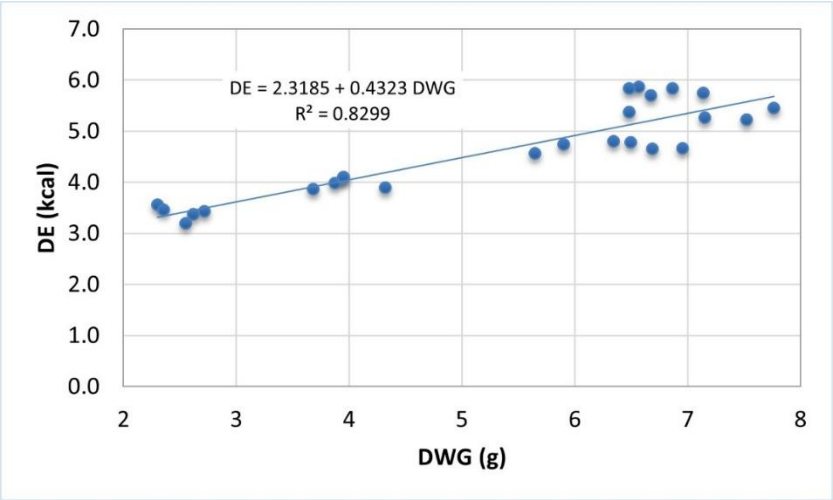
The linear relationship between DE intake and DWG in growing–finishing Nile tilapia was best established according to the expression, also presented in Figure 2:

$$DE = 2.3185 + 0.4323\ DWG$$

In which DE is digestible energy intake (kcal), and DWG is daily weight gain (g/fish).

Figure 2

Linear relationship between digestible energy (DE) intake and daily weight gain (DWG). View of quadratic relationship between daily weight gain (DWG) as function of body weight (BW) in growing–finishing Nile tilapia reared in floating net cages over 216-day feeding trial. Each dot point is mean of each replicate floating net cage with 126 fish.



The increase in DE intake as function of increment in DWG indicates reduction in dietary DE utilization efficiency as BW increases. A previous study has reported linear increase in whole-body lipid deposition in Nile tilapia from 2 to 800 g (Chowdhury et al., 2013). Since lipids possess more energy per unit than protein, the increase in whole-body lipids likely contributes to the DE required per unit of DWG observed herein.

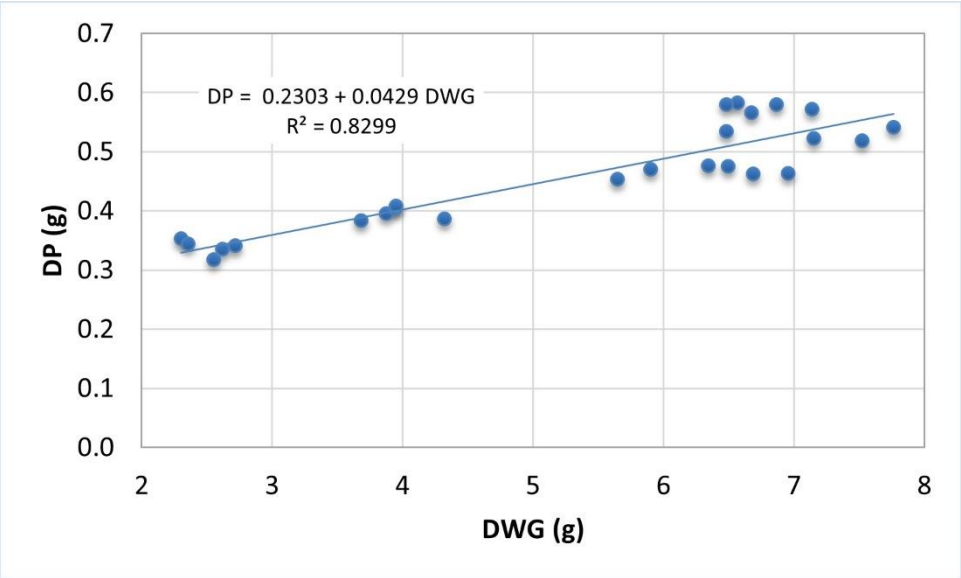
The relationship between DP intake and DWG was expressed according to the expression, also demonstrated in Figure 3:

$$DP = 0.2303 + 0.0429\,DWG$$

In which DP is digestible protein intake (g), and DWG is daily weight gain (g/fish).

Figure 3

Linear relationship between digestible protein (DE) intake and daily weight gain (DWG). View of quadratic relationship between daily weight gain (DWG) as function of body weight (BW) in growing–finishing Nile tilapia reared in floating net cages over 216-day feeding trial. Each dot point is mean of each replicate floating net cage with 126 fish.



Similar to the patterns observed for DE, this study identified an increase in DP in intake per unit increment in DWG of fish. This result suggests reduction in protein utilization efficiency as BWG increases. This phenomenon may be explained by increased protein demand for maintenance in larger fish, as observed in Nile tilapia ranging from 10 to 1000 g BW, where the proportion of dietary DP allocated to maintenance increased from 4 to 18%, respectively (Van Trung et al., 2011). Nonetheless, these authors also found that the proportion of dietary DP allocated for gain decreased from 50 to 42% in fish weighing 10 and 1000 g BW, respectively. These results support the use of precise nutrition concepts to optimize growth performance and health, while aligning economic efficiency with environmentally sustainable practices. These demands have been recently recognized in the application of AI in field-based tilapia aquaculture (Huang; Khabusi, 2025; Sen et al., 2026).

This study identified a strong correlation coefficient (0.8299) between observed and estimated values of DE and DP as function of DWG, indicating that the linear model fitted well and generated reliable estimates. Notably, the reduced DE and PD efficiency utilization with increasing BW evidence

the need to consider economic responses and environmental impacts when rearing fish exceeding 700 g BW. These findings further support the use of precise feed formulation and feeding strategies in modern, industrial-scale tilapia field-based Nile tilapia production systems.

CONCLUSION

This study developed reliable and practical equations that establish the relationship between digestible energy and digestible protein intake as function of daily weight gain in growing-finishing Nile tilapia. Furthermore, increment in BW was associated with higher digestible energy and digestible protein requirements per unit of daily weight gain, evidenced by reduced energy and protein efficiency utilization as fish body weight increased. These findings highlight the need to account for increased feed cost and potential impact when rearing fish over 700 g body weight. These results provide new insights into precise nutrition practices aligned with environmentally sustainable strategies in modern Nile tilapia aquaculture systems.

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PRINCIPLES OF PHYSICS IN THE USE OF THE FARADAY CAGE[1]

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Abstract

The Faraday Cage is an electrical shield, whose conductive surface surrounds a given region of space to block the entry of radiation from electric and electromagnetic fields. It was developed during the 19th century, but needs to be better used, demonstrating that its potential goes beyond what is currently used. It is especially recommended in physiotherapy clinics to neutralize the effects of electric and electromagnetic waves produced during the operation of DOCs - Shortwave Diathermy, widely used for the therapy of patients in these clinics. Professionals in the field of physiotherapy demonstrate that they are not aware of the importance of the security that the Faraday Cage provides. The objective of this work is precisely to know the use of the Faraday Cage in establishments that need it and to evaluate the potential market that can absorb it, including as part of the lightning rod capture system. As a result, physiotherapy professionals are unaware of the need for this safety equipment in their establishments and the greater use of the Faraday Cage in buildings as part of the Lightning Protection System.

Keywords: Faraday cage, Construction, Short Waves, SPDA.

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INTRODUCTION

The Faraday Cage is an apparatus developed to neutralize the effect of electric and electromagnetic discharges caused by natural causes such as lightning and by artificial factors resulting from equipment that generates electric or electromagnetic fields, such as SWD devices—Shortwave Diathermy—used in the recovery of patients in physiotherapy clinics.

The operating principle of the Faraday Cage is more widely disseminated than its use in specific enterprises where there is electromagnetic radiation that places at risk the workers who operate the devices.

Are professionals in the field of physiotherapy properly informed, and do they prioritize safety measures through the installation—preferably during the construction phase—of systems for neutralizing electric and electromagnetic fields in the vicinity of SWD devices? This question constitutes the research problem.

The general objective of this research is to understand the use of the Faraday Cage as well as to consider the potential market for its application in systems for capturing electric and electromagnetic fields.

Regarding the methodology used, this work follows the theoretical research methodology defined by Demo (2000) as research dedicated to the reconstruction of theory, concepts, ideas, and ideologies with the purpose of producing theoretical foundations.

According to the methodology, this study is classified as descriptive in terms of its objectives, because it describes characteristics of a specific object of study. By the nature of the data, it is classified as qualitative because it seeks the understanding and interpretation of phenomena. (Gonsalves, 2012)

Köche (2011) conceives various forms of knowledge; however, modern science has introduced a practical and effective method in the search for truth, understood through experimentation, by formulating hypotheses, repeating the experimentation to verify the hypotheses, and formulating generalizations, laws, or theories.

CONCEPTS AND CHARACTERISTICS OF THE FARADAY CAGE

The Faraday Cage is an electrical shield whose conductive surface surrounds a given region of space in order to block the entry of radiation originating from electric and electromagnetic fields. It was developed during the nineteenth century, but it needs to be used more effectively, demonstrating that its potential goes beyond its current applications. It is especially recommended in physiotherapy clinics to neutralize the effects of electric and electromagnetic waves produced during the operation of SWD devices—Shortwave Diathermy—widely used in the therapy of patients in such clinics. Professionals in the field of physiotherapy demonstrate that they are unaware of the importance of the safety provided by the Faraday Cage. According to Ferraz Netto (2011), the Faraday Cage is an electrical shield, "a conductive surface that surrounds a given region of space and that may, in certain situations, prevent the entry of disturbances produced by external electric and/or electromagnetic fields."

For Melo (2011), the tendency of a conductor, when charged, is to disseminate its charges uniformly over the entire surface; however, if it is a hollow sphere, the charges will be restricted to the external surface, where they will remain as far apart from one another as possible due to the effect of repulsion. Meanwhile, on the inside, a neutral field will occur because the effects of the electric field generated internally cancel each other out.

> The same occurs when the conductor is not charged but is located in a region that has an electric field caused by an external agent. Its interior is free from the action of this external field; it is shielded. This effect is known as electrostatic shielding.
> To prove this effect, the British physicist Michael Faraday conducted, in 1836, an experiment to demonstrate the effects of electrostatic shielding. He built a metal cage charged by a high-voltage electrostatic generator and placed an electroscope inside it to prove that the effects of the electric field generated by the cage were null. Faraday himself entered the cage to prove that its interior was safe. This experiment became known as the "Faraday Cage." (Melo, 2011, p. 1) (Figure 1)

Faraday cages are used to obstruct electric fields and electromagnetic radiation; this is why they are essential in clinics that use shortwave resources. "Thus, electrostatic shielding also became known as the Faraday cage, and this effect is widely used in our daily lives." (Melo, 2011, p. 1)

Figure 1

Operation of the Faraday Cage

Source: Melo, 2011

The principle is always the same: the Faraday Cage neutralizes electric discharges because they dissipate on its exterior without penetrating it. In this case, the worker at the top of voltage networks will remain unharmed because his suit—stainless steel clothing containing 25% to 75% Nomex, which is a derivative of Kevlar material—acts as a Faraday Cage, provided that he does not come into contact with the ground. (A Vida, 2011)

Figure 2

Clothing that acts as a Faraday Cage

Source: A Vida, 2011

COMMERCIAL VIABILITY OF THE FARADAY CAGE

A study conducted by Silva et al. (2007) surveyed knowledge and use of the Faraday Cage among professionals in the field of Physiotherapy in the city of Niterói, in the State of Rio de Janeiro. The research results made it possible to conclude that none of the establishments visited had a Faraday Cage, demonstrating that there is widespread lack of knowledge regarding the harmful effects of radiation caused by the Shortwave device frequently used in ultrasound sessions for patient recovery.

> Despite the indiscriminate use of shortwave, its operator is not aware of the deleterious effects of this resource on his or her own health when used without a protective measure. Although the professionals approached most often referred to the contraindications of the device for its application to the patient, they neglect measures for their own protection. We also found that most of the interviewees use the resource almost daily, and several times a day, representing a possible imminent risk to the health of those who are exposed to the daily radiation of shortwave. (Silva et al. 2007)

Since 1890, the biomedical field has used high-frequency electric currents; in recent years there has been greater concern regarding the possibility of health damage due to exposure to various types of radiation.

Another study conducted by Messias; Okuno; Colacioppo (2011) aimed to measure the radiation exposure of physiotherapy professionals to 17 shortwave diathermy (SWD) devices used in clinics in Presidente Prudente/SP in order to "compare the measured values with the exposure levels recommended by the ICNIRP (International Commission on Non-Ionizing Radiation Protection). To observe the effectiveness of Faraday cages as a protective measure against physiotherapists' exposure to oscillating electric and magnetic fields." (Messias; Okuno; Colacioppo, 2011, p. 309)

Through the study, the authors sought to measure the level of knowledge (information) that professionals in the field of physiotherapy in Niterói/RJ have regarding the harm caused by frequent exposure to the electromagnetic field of the Shortwave device, and the consequent need to install the Faraday Cage in this type of establishment, due to the presence of certain therapeutic-resource devices. (Messias; Okuno; Colacioppo, 2011)

The authors of the research, based on the data collected, recognized the existence of levels "above the limits recommended by the ICNIRP (International Commission on Non-Ionizing Radiation Protection), mainly near the cables and electrodes of the equipment analyzed" and suggested the installation of a Faraday Cage as a safety measure for the physical health of those professionals, who remain exposed throughout the workday, since SWD devices are common tools in the work of rehabilitating physiotherapy patients.

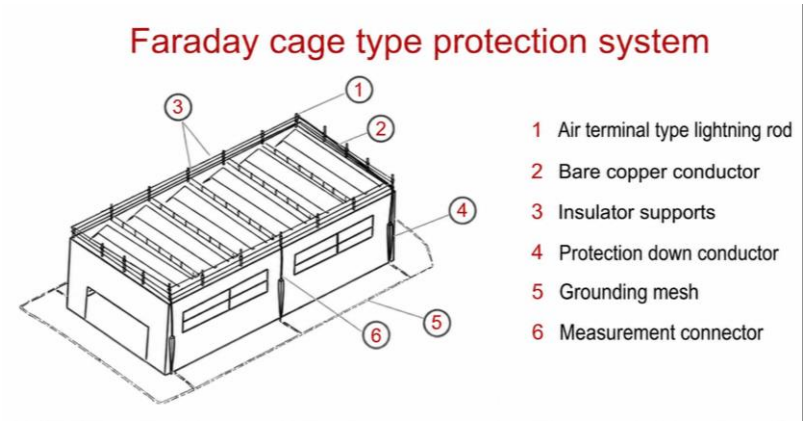
FARADAY CAGE – AN EFFICIENT METHOD FOR LIGHTNING ROD CAPTURE

The lightning rod capture system is necessary on buildings in order to attract electric discharges and must observe the regulatory guideline of ABNT to compose a safe and efficient system. According to standard NBR 5419:05, there are basically two lightning rod capture systems: "Franklin-type air terminals

mounted with masts and the Faraday cage system, which is composed of a capture mesh that may be executed with bare cable, aluminum cables, or aluminum strips over the building." (Sistema, 2011, p. 1)

Figure 3

Faraday Cage-type protection



Source: Adapted and translated from Sistema , 2011

In studying the LPS—Lightning Protection System, Coutinho; Altoé (2003) dismiss the Faraday Cage method, stating that around it, the current must circulate uniformly, since the field will only be null at the center of the cage; however, in the "vicinity of the conductors there will always be a field that may induce voltages in conductors of electrical installations that are parallel to the mesh conductors." They dismiss the method because they understand that the protection area is very broad, which rules out the use of the cage for this purpose. "Maximum protection in the case of the Faraday method is obtained when the structure is enclosed by a metallic box with welded walls and sufficient thickness to withstand the thermal effect of lightning at the point of impact," conclude Coutinho; Altoé (2003, p. 25)

The following position is contrary to that of the authors cited above, because the Faraday Cage appears as part of a system for lightning rod capture, making the installation quite safe, since it neutralizes the propagation of electromagnetic waves (preventing their entry and blocking their exit).

> The Faraday Cage, according to the technical standard for lightning rods NBR 5419:05[9], constitutes an effective way to achieve lightning rod capture by installing "bare copper cables with a cross-section of 35 mm² around the entire perimeter of the building, plus transverse cables, forming a large Faraday cage, or by means of aluminum strips with a minimum cross-section of 70 mm². The Faraday cage has the characteristic of better shielding the volume to be protected, and if we consider the reinforcement bars of the reinforced-concrete structure or metallic structures, several Faraday cages will naturally exist, reinforcing the lightning rod system.
> The principle of the Faraday cage is that the volume to be protected will have shielding against the entry of electromagnetic waves, as well as the exit of electromagnetic waves, provided that the Faraday cage is properly grounded to the lightning rod system (LPS). For calculation and design purposes, we consider lightning as components of strong electromagnetic waves, in the megahertz range. (Instalação, 2010, p. 1)

It is known that a large portion of currently existing new technologies are products developed and tested for military purposes[10]. According to Gomes (2006), in 1941, grounding began with the use of reinforcement bars (rebars) in reinforced concrete. During the Second World War, engineer Herb Ufer devised a system for storing bombs kept in the warehouses of the American Davis Monthan Air Base, in Tucson, Arizona.

Figure 4 illustrates the Faraday Cage that must be interconnected with the entire grounding system for lightning rod capture.

[9] NOTE: Any structure to be protected by a lightning protection system and measuring more than 10 m in height from ground level must have a cable installed around its entire perimeter as a complement to the lightning protection system, as required by NBR 5419:05, the technical standard for lightning protection systems. (Instalação, 2010. p. 1)

[10] It was developed during the early period of the Cold War under the name ARPANET to maintain communication among United States military bases, even if the Pentagon were erased from the map by a nuclear attack. Once the Cold War threat had passed, ARPANET became so unnecessary that the military no longer regarded it as important enough to keep under their control. Access was then granted to scientists, who later transferred the network to universities; these institutions subsequently shared it with universities in other countries, allowing local researchers to access it, until more than 5 million people were connected to the network and, with each new user, four more joined the vast web of global communication. (Bogo, 2000)

Figure 4

The Faraday cage is formed by the enormous quantity of reinforcement bars in precast structures

Source: Gomes, 2006

THE USE OF THE FARADAY CAGE IN CIVIL CONSTRUCTION

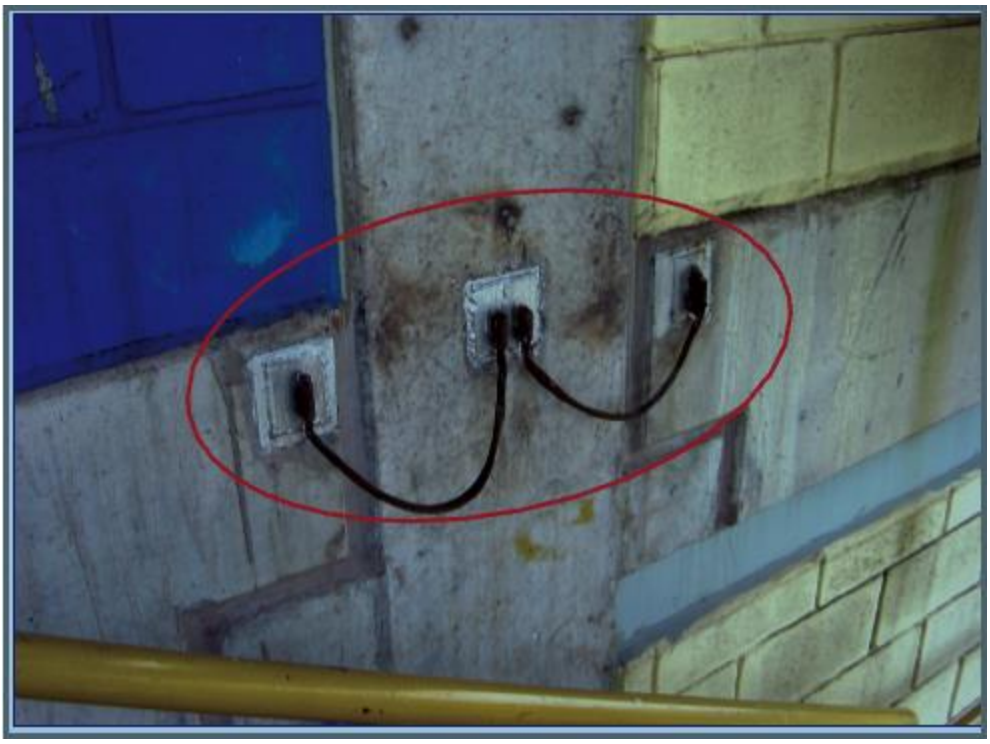
German standards served as a source of inspiration for the development of guidelines in other countries, but considering the use of the grounding method initiated by Ufer, Germany has already used this system for more than 70 years.

Gomes (2006) warns that in the construction method that uses precast structures, the interconnection points[11] must already be prepared to ensure continuity of the entire insulation; therefore, they must be prepared during the reinforcement phase, before receiving the concrete, leaving the points on the external part of the structure in order to allow full interconnection with the Faraday Cage.

[11] These points must be provided externally on the various precast components, so that they can be interconnected—usually by exothermic welding—after final assembly, thereby forming a Faraday cage.(Gomes, 2006)

Figure 5

Interconnections made with exothermic welding (electrical continuity for the Faraday cage)



Source: Gomes, 2006

In Gomes's study (2006), two case studies are presented to show the use and demonstrate the need for and installation of a grounding system containing the reinforcement bars of the columns associated with a Faraday Cage: a railway shelter (house) and a DPC—Data Processing Center.

In both undertakings, the SRG—Signal Reference Grid—is used; however, while the Faraday Cage is used in the railway shelter, in the DPC an additional grounding reinforcement with complementary electrodes is used.

> In DPCs, obtaining a constant signal reference is even more justified, which is normally achieved with an SRG conveniently dimensioned to equalize frequencies over a wide range. The grid must be interconnected to the local equipotential bonding bar (LEB), and this must be interconnected to the reinforcement bars of the pillar foundations (preferably in the central pillars), which in the case reported here are used as complementary grounding electrodes. (Gomes, 2006, p. 62)

In general, the safety systems during the construction of the undertakings listed here and other similar ones include grounding and follow the guideline of ABNT Standard NBR 5419:05.

CONCLUSION

The invention of the Faraday Cage dates back to the nineteenth century; however, there are many sectors that should make use of it and do not, either due to lack of awareness of its necessity, fear of excessively increasing the costs of the enterprise's installations, or the absence of regulatory standards for its use.

This work concluded that many physiotherapy professionals still do not know the extent of the harmful effects of using SWD devices—Shortwave Diathermy—daily and for many hours. The solution indicated was the existence of the Faraday Cage to neutralize the effects of radiation from SWD devices and the suggestion, as an occupational health safety standard for professionals, of installing a complete system, including the Faraday Cage.

A lack of regulatory standards requiring the installation of the Faraday Cage in all physiotherapy clinics as a condition for approving their operation was detected. Thus, owners would have to provide, a priori, for the installation of this system in order to safeguard, above all, their health.

In civil construction, it was observed that undertakings using precast structures adopt as a criterion Ufer grounding with reinforcement bars connected to the other iron structures, and may, in certain cases, include the Faraday Cage fully interconnected with the structural reinforcement bars.

Faraday Cages are also used in railway shelters within the grounding system, demonstrating that there is viability for the use of this equipment, which is essential for the safety system against electric discharges and electromagnetic radiation.

DECLARATION OF AUTHORSHIP

I declare that the work presented is my own authorship, containing no plagiarism or unreferenced citations. I inform that, should the work be failed twice for containing plagiarism, I will pay a fee of R$ 250.00 for a third correction. If the work is failed, I will not be able to request exemption, pursuant to Clause 2.6 of the Service Provision Agreement (referring to lato sensu postgraduate courses, with the

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