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Data Visualization Optimization:
A New Dashboard for Decision Making in Quality Control

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Master's in Computer Science and Business Management

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TECNOLOGIAS
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Department of Information Science and Technology

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Abstract

This thesis explores the role of data visualization in the quality control process in the food industry, spotlighting the utilization of a dashboard in real-time to elevate decision-making in this critical domain.

The aim of the study is to develop a dashboard that presents pertinent information to stakeholders in the food supply chain with the means to analyse, evaluate, and monitor the organization's quality control. The examination of KPIs, particularly those linked to food safety and hygiene, enhances stakeholders' decision-making capacities, facilitating the identification of areas for improvement.

For auditors, the dashboard provides explicit specifications on areas requiring enhancement and those that do not meet certification standards, thereby contributing to food safety and hygiene compliance.

Through this real-time visualization, KPIs related to food safety could be easily identified and tracked.

In the creation of the dashboard, the Design Science Research methodology was adopted for the construction and evaluation of the artifact.

Keywords: Food Safety; Business Intelligence; Dashboard; HACCP; KPIs.

Resumo

Esta tese explora a influencia da visualização de dados no processo de controlo de qualidade na indústria de alimentos, destacando a utilização em tempo real de um dashboard para elevar a tomada de decisões nesse domínio crítico.

O objetivo do estudo é desenvolver um dashboard que apresente informações pertinentes aos stakeholders na cadeia de abastecimento de alimentos, proporcionando meios para analisar, avaliar e monitorar o controlo de qualidade da organização. A análise de KPIs, especialmente aqueles relacionados à segurança alimentar e higiene, aprimora as capacidades de tomada de decisão dos interessados, facilitando a identificação de áreas a melhorar.

Para os auditores, o dashboard fornece especificações explícitas sobre áreas que precisam de melhorar a sua qualidade e aquelas que não atendem aos padrões de certificação, contribuindo assim para a conformidade com as normas de segurança alimentar e higiene.

Através dessa visualização em tempo real, KPIs relacionados à segurança alimentar podem ser facilmente identificados e rastreados. Na criação do painel, adotou-se a metodologia de Design Science Research para a construção e avaliação do artefacto.

Palavras-chave: Segurança Alimentar; Inteligência Empresarial; Painel de Controlo; HACCP; Indicadores Chave de Desempenho.

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List of Abbreviations and Acronyms

BI	-	Business Intelligence
DSR	-	Design Science Research
EC	-	Exclusive Criteria
FSMS	-	Food Safety Management System
GDP	-	Good Distribution Practices
GMP	-	Good Manufacturing Practices
HACCP	-	Hazard Analysis and Critical Control Points
IC	-	Inclusive Criteria
ICTs	-	Information and Communication Technologies
IoT	-	Internet of Things.
KPIs	-	Key Performance Indicators
SLR	-	Systematic Literature Review
SS	-	Search string

Chapter 1 – Introduction

Food safety is a constant concern in our society, but it is also a fundamental human right. The lack of food safety carries adverse consequences for both preserving public health and bolstering the nation's economy [1]. To guarantee effective food control, it is imperative to implement rigorous surveillance at every stage of the food supply chain. This encompasses processes from production through processing and distribution to retailers and, ultimately, consumers. Comprehensive monitoring at each phase plays an important role in early identification of potential risks to food safety and in implementing preventive measures, thereby certifying the quality and integrity of food throughout the entire journey [2].

In order to enhance the prevention of foodborne illnesses, it is essential to continually evolve regulatory laws and integrate scientific advancements in food quality monitoring, with a specific focus on the principles of the Hazard Analysis and Critical Control Points (HACCP) system [1], [3].

The use of specialized software for real-time monitoring expands the volume of collected data. The integration of Information and Communication Technologies (ICTs) is crucial in implementing HACCP in food safety as it enhances its effectiveness by simplifying the transmission of the extensive data collected. ICTs strengthen global food safety management, improving compliance with regulations, and fostering efficient communication throughout the supply chain [3].

However, merely implementing ICTs is not sufficient to strengthen food safety in society, the existence of synergy between Business Intelligence (BI) and ICTs is essential. While ICTs provide the tools to collect a large amount of data, BI employ technologies to visualize, interpret, and transform the data into relevant information for decision-making [4].

When they are applied Business Intelligence tools such as dashboards to visualize Key Performance Indicators (KPIs) on an operation, it is possible to identify current issues in quality control measures. This approach empowers stakeholders to make informed decisions regarding quality improvement initiatives [5], [6].

Additionally, it is also identified that the knowledge possessed by stakeholders and their adept utilization of HACCP principles play a vital role in the interpretation of KPIs to the quality control of food [7].

The objective of this paper is to build a dashboard that presents information to stakeholders of a facility in the food supply chain, allowing for the analysis, evaluation, and monitoring of the organization's quality control. KPIs related to food safety and hygiene will be examined to improve stakeholders' decision-making abilities, allowing the identification of areas for

enhancement. In the case of auditors, they will have clear specifications provided by the dashboard regarding what the establishment should improve and what they should not certify, according to food safety and hygiene standards.

The research aims to create a dashboard for organizations for them to improve their consciousness about their food safety and achieve regulatory compliance in terms of food safety and hygiene.

The motivation of this research is to identify KPIs that effectively address quality control. These indicators will be presented in an accessible manner through a dashboard. This achievement will streamline regulatory audits and inspections, enabling proactive risk management within the establishment. As a result, it will reduce the incidence of quality issues and contribute to operational excellence. This improvement enhances the managers' ability to anticipate and mitigate risks related to hygiene and food safety deficiencies. The two problems that the study seek to unravel are described below.

RQ1 What is the dashboard presentation format for data that empower managers in making informed decisions about food safety in establishments?

RQ2 Which dashboard display format of data is the most effective in facilitating auditors' assessment and certification of establishments based on food safety standards?

Chapter 2 – Background

Following the preceding procedure, it is essential to delve more deeply into the key themes that form the basis of this study. This section will offer an in-depth exploration of the relevant literature concerning the subject. The literature review conducted focused on the following subjects:

2.1 – Food Industry

Food sector encompasses an extensive supply chain involving various business processes such as agricultural production, processing, food distribution, retail and consumption. Any failure in one of these processes can have significant impacts on both the sector's economy and society at large scales. The interdependence of these links underscores the critical importance of maintaining efficiency and integrity at every stage, ensuring the continuous supply of safe and high-quality food for the population [1]; [2].

2.1.1 – Hazards in Food Industry

In the food industry, a range of potential hazards can emerge during diverse processes. Biological and chemical contaminations represent a significant threat to food safety, with specific risks outlined in *Table 1*.

Table 1- Hazards in Food Industry

Process in Food Industry	References	Potential hazards
All Processes	[8],[9]	Presence of undeclared allergens.
		Improper handling or storage of food, including cross-contamination and the proliferation of microorganisms.
		Existence bacteria, viruses, and fungi.
Agricultural production	[9]	Chemical contaminations from pesticides, additives, or toxic substances.
Food Processing	[10],[11]	Physical hazards like metal fragments.

Proactive understanding and management of these risks are crucial to ensure the production of safe food and the protection of consumer health. By foreseeing potential hazards, implementing effective control measures, and ensuring stringent adherence to safety protocols, the food industry can consistently uphold the highest standards of safety throughout the entire production and distribution chain.

2.2 – The Importance of Food Safety Information

The importance of Food Safety Information is paramount in ensuring the well-being of consumers and maintaining public trust in the food industry. This critical aspect underscores the need for robust preventive systems and comprehensive management approaches [3].

One such system is the HACCP (Hazard Analysis and Critical Control Points), a preventive system that identifies, evaluates, and controls significant hazards related to food safety. Focused on critical control points during food production and processing, the HACCP aims to prevent health risks to consumers [3].

Aligned with the principles of HACCP is the FSMS (Food Safety Management System), a comprehensive management system that establishes requirements to ensure food safety throughout the entire production chain. Incorporating practices from HACCP, the FSMS sets guidelines for the implementation, monitoring, and continuous improvement of processes related to food safety [12].

Additionally, Good Distribution Practices (GDP) play a vital role in maintaining the integrity and quality of food products during transportation and distribution. GDP aims to prevent contamination or deterioration of food during distribution, maintaining good conditions of storage and proper handling of the food products. [13].

Complementing these systems are the Good Manufacturing Practices (GMP), guidelines designed to guarantee the safe and hygienic production, processing, and packaging of food. Encompassing everything from ingredient selection to manufacturing conditions and quality control, GMP strives to guarantee the consistency and safety of the final products [3];[13].

In essence, the interconnectedness of these systems and practices not only upholds the principles of food safety but also reinforces the dissemination of accurate and impactful information to consumers. This holistic approach from hazard identification to final product delivery highlights the industry's commitment to delivering safe and high-quality food products [12].

2.3 – The Purpose of Information Technology in Food Safety

The integration of ICTs plays a crucial role in advancing food safety practices across the entire spectrum of the food industry. This comprehensive approach is designed to enhance various facets of the food supply chain, ensuring the production and delivery of safe and high-quality food products [14].

One key role of ICTs in the context of food safety lies in their facilitation of effective data management and analysis. These technologies empower stakeholders to manage extensive

datasets generated during production and distribution, enabling real-time processing and analysis. Whether it be monitoring production lines or overseeing supply chain activities, ICTs provide valuable insights into potential risks and areas that warrant improvement [15].

The implementation of advanced traceability solutions is another significant achievement of ICTs. IoT Technology enhance the traceability of food products, allowing stakeholders to trace the origin of ingredients and monitor transportation conditions. This increased transparency not only aids in regulatory compliance but also builds trust among consumers by providing them with valuable information about the journey of the products they consume [16],[17].

2.4 – The Impact of Business Intelligence Technology in Food Safety

The escalating consumer demand for high-quality food has become a motivation for the continuous technology innovation. This demand has led to the ongoing development of real-time and precise tools specifically designed for monitoring food quality [18].

BI introduces technologies to visualize, interpret, and transform the collected data into meaningful information crucial for informed decision-making in the subject of food safety. When we apply Business Intelligence tools, such as dashboards, to visualize Key Performance Indicators (KPIs) in food safety operations, it becomes possible to pinpoint existing issues in quality control measures. This approach empowers stakeholders to make well-informed decisions regarding initiatives aimed at enhancing the quality and safety of food products [5], [6]. The combination of ICTs and BI does not just provide data, it offers a comprehensive understanding of the data, allowing for proactive measures and continuous improvement in food safety practices [4].

2.5 – Dashboards

The primary aim of employing a dashboard for information visualization is to offer a user-friendly means of comprehending and interpreting data. This approach provides several advantages, such as the interactive and personalized presentation of data, enabling users to make informed decisions based on the information presented [19]. Additionally, the dashboard facilitates real-time decision-making with the inclusion of automatic alerts in the event of anomalies which further enhances the dashboard's functionality, allowing for timely responses to potential issues [16]. Another notable advantage lies in its capacity to aggregate and analyse data from diverse and heterogeneous sources, offering a comprehensive visualization [5]. These features collectively contribute to the effectiveness of utilizing dashboards in enhancing data understanding, decision-making, and anomaly detection.

While dashboards offer substantial benefits, it is crucial to acknowledge potential drawbacks. A significant limitation is the requirement for high-quality and accurate data to ensure reliable insights. The effectiveness of the dashboard is inherently tied to the quality of the data it receives [19]. The risk of inaccurate information becomes a concern, particularly when sensors are improperly calibrated, potentially resulting in misinterpretations or decisions based on incorrect data. Therefore, while dashboards serve as a potent data visualization tool, addressing and mitigating these drawbacks is crucial, primarily applicable when data collection relies on sensor technology [16]. Additionally, disadvantages include the need for training to effectively use the dashboard, which may pose a challenge for users less familiar with the technology [20].

Chapter 3 – Related Work

To grasp the findings of prior researchers, a systematic literature review (SLR) was conducted. According to Kitchenham (2009) the most effective methodological approach involves the identification and evaluation of data from all pertinent studies conducted to date within a specific area of interest. Subsequently, we summarize the accumulated knowledge to pinpoint any existing gaps in the literature.

Figure 1 illustrates the various stages of the research process as outlined by Kitchenham (2009). Each phase contributes to the enhancement of study quality through the careful selection of documents based on inclusion and exclusion criteria, as well as the rigorous evaluation of their quality.

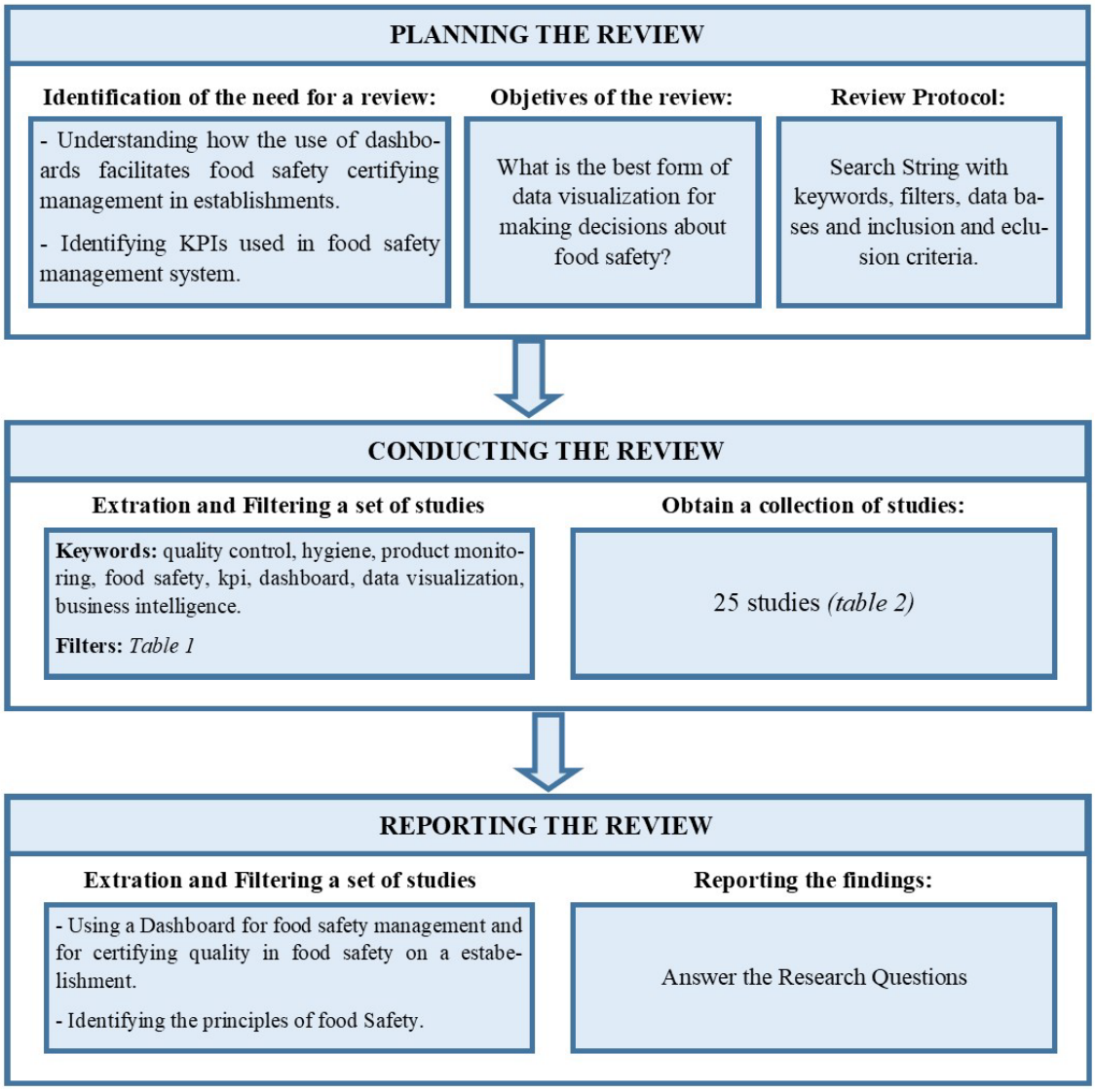

Figure 1 - SLR Stages

The initiation of this research involved the meticulous formulation and application of a strategic search string (SS) that aimed to comprehensively encompass the spectrum of studies related to quality and product monitoring, as well as data visualization and business intelligence.

Search String: ("quality control*" OR "*hygiene*" OR "product monitoring" OR "food safety*") AND (kpi* OR dashboard OR "data visualization" OR "business intelligence"). In this search string, the use of " * " in certain words signifies the inclusion of both prefixes or/and suffixes, expanding the scope to encompass variations crucial for comprehensive selection.

The search string was applied across esteemed article search engines, including *SCOPUS, IEEE, ACM, EMERALD,* and *EBSCO*.

The Inclusive Criteria (IC) and Exclusive Criteria (EC), outlined in *Table 2*, played a crucial role in governing the article selection process represented in *Figure 2*. The inclusivism criteria (IC1 to IC4) aim to ensure the incorporation of relevant articles, while exclusives criteria (EC1 to EC4) are applied precisely to eliminate sources not aligned with the research objectives. The interplay of these criteria, though distinct, plays an essential role in shaping a robust bibliographic foundation adhering to required scientific standards.

Table 2 - Inclusive and Exclusive Criteria

Inclusive Criteria:		**Exclusive Criteria:**	
IC1	Keywords are mentioned on the paper's abstract	EC1	Keywords are not mentioned on the paper's abstract
IC2	Paper is a scientific paper.	EC2	Paper is a non-scientific paper.
IC3	Paper is written in English	EC3	Paper is not written in English.
IC4	Paper was written between 2013-2023.	EC4	Paper was written before 2013.
IC5	Paper is pertinent to the literature review	EC5	Paper is not pertinent to the literature review
IC6	Non-duplicates	EC6	Duplicates

The CI1 and CE1 marked the starting point of this selection, focusing on the identification of the papers that have the pre-defined combination of the keywords of the search string in their abstract and eliminating those papers that did not have these keywords combinations. This strategic refined the initial search of 53 471 papers to 832, as can be observed in the *Table 3*, highlighting studies intrinsically linked to the specific objectives of this research.

Subsequently, CI2, CI3 and CI4 were applied with a focus on selecting scientific papers published in English between 2013 and 2023. This stage established temporal and linguistic parameters, ensuring the contemporaneity and accessibility of chosen documents. In line with CE2, CE3 and CE4, the exclusion of papers was determined by the criteria's stipulation that those that were not align with the CI before mentioned were eliminated.

CI5 ensured that only papers directly relevant to the literature review were retained. This process culminated in a refined selection of 48 papers *(Table 3)* each making a substantial contribution to the research landscape under examination. In adherence to CE5, papers were excluded if they were not pertinent to the literature review.

The final exclusion stage, represented by Exclusion Criterion 6 (CE6), identified and eliminated duplicates, resulting in a final set of 25 papers. The papers included through CI6, in this case, non-duplicates, were considered for the final review of the related work.

Figure 2 illustrates the results of each selection phase across different databases, providing a clear overview of how the selection criteria were applied to narrow down the initial set of articles to the final 25 papers.

Table 3 - Research Results

Data Base	SS applied	CI1 and CE1 applied	CI2 and CE2 applied	CI3 and CE3 applied	CI4 and CE4 applied	CI5 and CE5 applied	CI6 and CE6 applied
Scopus	9 893	278	245	232	181	16	12
IEE	2 817	25	23	23	17	6	6
ACM	761	4	4	4	3	0	0
Emerald	2 000	54	53	53	45	5	4
EBSCO	38 000	471	419	411	341	21	3
TOTAL	53 471	832	744	723	587	48	25

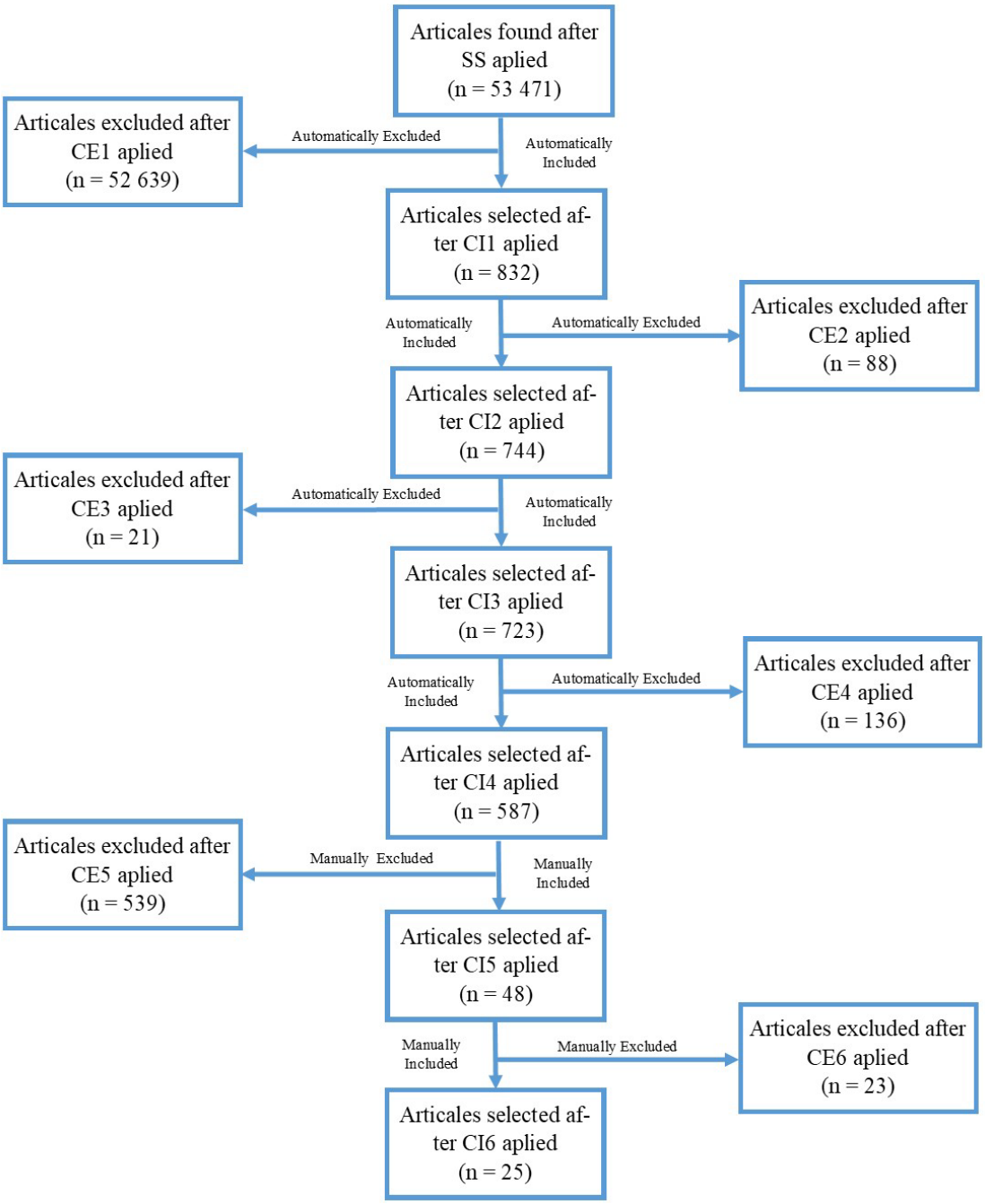

Figure 2 - SLR Flow Chart

The *Figure 3* analyses the distribution of publication years, showing a consistent pattern over time, except for notable peaks in 2023 and 2020. One possible explanation is the growing importance attributed to implementing BI tools to enhance quality control processes in the food industry. The dynamic nature of the sector, along with technological advancements, may have sparked renewed interest in exploring and refining the role of BI tools in quality assurance.

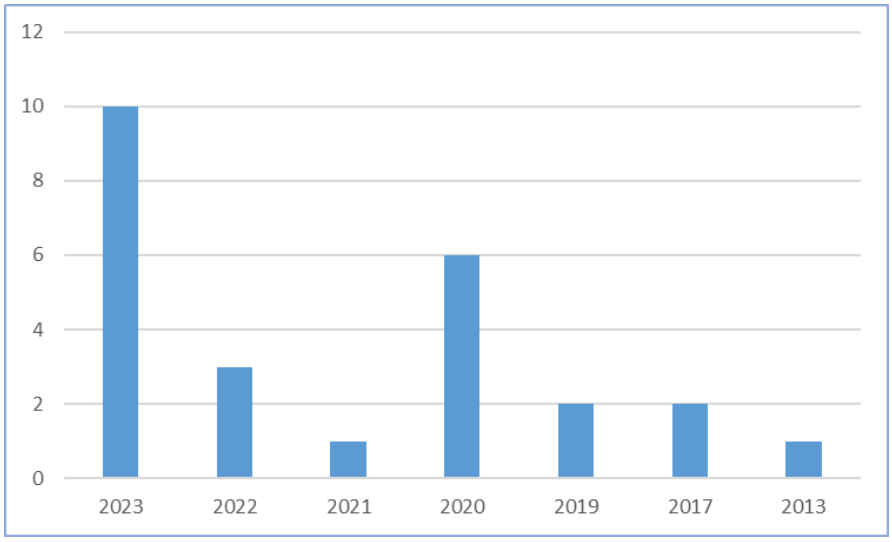

Figure 3 - Publication years of the articles

In *Table 4* the concept-centric of the literature review (LR) in this research encompasses four distinct areas: Data Visualization, Dashboard, Real-Time Monitoring, and Decision Making in Quality Control. The area of Decision Making in Quality Control unfolds into two essential categories: Decision Making in Quality Control Management and Inspections.

While exploring Data Visualization, the reviewed articles provide insights into the effective representation of data relevant to quality. The articles within the Dashboard research vector concentrate on detailing this data visualization format optimizes the presentation of information. In the realm of Real-Time Monitoring, the studies address the importance of real-time monitoring to enable agile responses to critical events throughout the production process.

The section on Decision Making in Quality Control covers two crucial classes: Decision Making in Quality Control Management and Inspections. In the first class, articles explore how data visualization can influence management decisions which directly impact product quality, from production to delivery to the next actor in the supply chain. In the subject of Inspections, articles analyse how data visualization impacts the certification of quality, ensuring compliance and pinpointing areas for enhancement across the business process.

The thematic organization of the articles reflects a notable emphasis on Food Safety, including essential topics such as Food Safety in Cold Supply Chains, Food Safety in Production, Food Safety in Transportation, Pathogens in Food Safety, Food Safety in Warehouses and Temperature and Humidity in Food Safety.

Beyond the specific themes of Food Safety, the research encompasses a diversity of sectors, such as Bioinformatics, Manufacturing Industry, Hospital Services, Public Environment, Public hygiene and Ammunition Industry.

This comprehensive approach emphasizes that quality control is a multifaceted discipline especially in the critical context of food safety across the entire supply chain. Monitoring food quality through data visualization is essential to guaranteeing food safety [21].

Table 4 - Concept Centric – Data Visualization in Quality Control

Subject	Paper	Data Visualization	Dashboard	Real Time Monitoring	Decision Making in Quality control	
					Management	Inspections
Food Safety in Cold Supply Chains	[8]	x		x	x	x
Food Safety in Meet Production	[10]	x	x	x	x	
Food Safety in Transportation	[16]	x	x	x	x	
	[22]	x				x
	[23]	x	x	x	x	
Food Safety in Fresh Production	[24]			x	x	
Pathogens in Food Safety	[25]	x	x	x	x	
Food Safety in Warehouses	[26]	x	x	x	x	
Temperature and Humidity in Food Safety	[21]	x	x	x	x	x
Bioinformatic	[27]	x	x		x	
	[28]	x				
	[18]	x		x		
Manufacturing Industry	[29]	x	x		x	
	[5]	x	x	x		
Hospital - Blood Center	[20]	x	x		x	
	[30]	x		x		
Hospital Hygiene	[31]	x	x			
	[32]	x	x	x	x	
Public Environment	[33]	x	x	x	x	
Air Quality	[19]	x	x		x	
Construction Industry	[34]	x	x		x	
	[35]				x	
Hygiene in Public Bathrooms	[36]	x	x			
Water Sanitation	[37]	x	x	x		
Ammunition Industry	[38]	x	x	x	x	

One of the gaps in the literature study that my thesis seeks to fill is revealed by the examination of *Table 4*. While several papers offer insightful information on topics, such data visualization, real-time monitoring, and quality control decision-making, none of them completely incorporates these elements into a framework designed specifically for food safety institutions. The studies don't look at how dashboards can be designed to support managerial decision-making and inspection-based certification processes in food safety instead, they concentrate on isolated aspects, like data visualization for quality management or real-time monitoring in particular industries, like cold supply chains or hospital hygiene.

Chapter 4 – Research Methodology

As illustrated in *Figure 4*, the research methodology employed in this study is Design Science Research (DSR). This approach fundamentally involves the design, creation, and assessment of the dashboard that is intended for development [39].

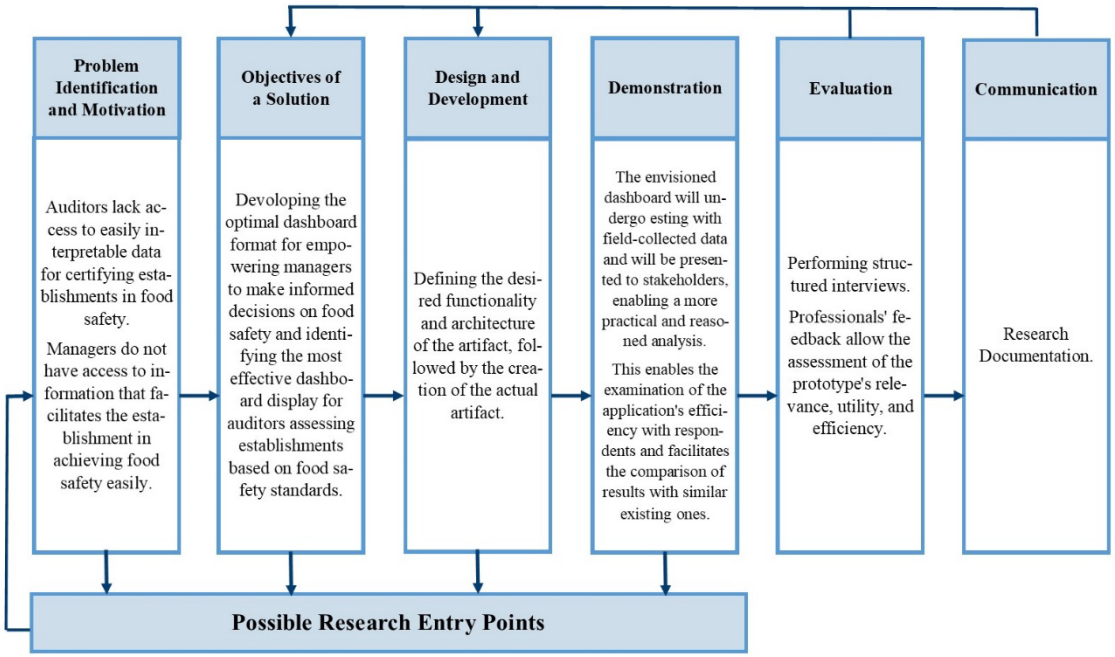

Figure 4 - Application of DSR Methodology Schema

Following this, the implementation phase begins, where the artifact is built and improved in all its versions. The dashboard which is going to be implemented in the food safety sector is the artifact that will be produced and presented to stakeholders (the fourth step). Stakeholders' feedback will be taken into consideration to enhance the artifact and undergo an assessment in the fifth stage of the process. The DSR model may face another iteration to improve the data visualization tool in response to ameliorate in both the dashboard's functionality and requirements. The final phase is dedicated to disseminating the discoveries and outcomes obtained from the developed artifact.

Chapter 5 – Proposal and Evaluation

The proposed dashboard underwent an iterative Design Science Research (DSR) process, involving 4 semi-structured interviews with Quality Control professionals in Food Industry. Each interview constituted a DSR iteration, which contributed to verifying, consolidating, and enhancing the dashboard. *Table 5* aims to introduce the interviewees who participated in this process. The average number of years of experience in the field of food safety field among the interviewees is over 19 years. Moreover, their expertise is not limited to a single organization or sector, most of the interviewees have experience across multiple sectors.

The interviews lasted approximately one hour, during which the interviewees were able to explore all the KPIs and functionalities of the dashboard. This included navigating through different windows and dynamically observing the impact of filters on the dashboard. These iterations throughout the development of the artifact were essential for achieving a refined product that meets the real-world specifications of industries where food safety is applied.

5.1 – First DSR Iteration

Following the DSR methodology, it was conducted 4 iterations to refine the prototype. These iterations incorporated data structure from the food safety system used by some of the interviewees. In this section, during this process was outlined the key aspects of each iteration's three phases: proposal, demonstration, and evaluation. Utilizing a real information system from food safety organization made the respondents more familiar with the data, enhancing their ability to contribute to the development of an effective dashboard for decision support.

Table 5 - Data of the interviewees

DSR Iteration	Gender	Age	Department	Role	Years of Experience
1	Male	52	Food Safety Consulting	Hygiene Protocols Specialist	24
2	Male	26	Food Safety Consulting	Software Developer	5
3	Male	55	Food Safety Consulting	Senior Advisor	26
4	Female	51	Catering	Chef and Food Safety Manager	22
Total		184	N/A		77
verage		46			19,25

5.1.1 – Proposal

To develop the dashboard, several steps were undertaken across three phases. The first phase involved research and analysis, followed by the extraction, transformation, and loading (ETL) processes. Finally, the dashboard was developed, as illustrated in Figure 5.

5.1.1.1 – Research and Analysis

The research and analysis phase were essential for designing and refining the proposed dashboard. This phase was divided into two main sections. The first section focused on researching and analysing the existing information in the AIHACCP database structure to be represented in the proposed dashboard for quality control in the food industry. By developing a dashboard proposal based on real data base structure from a market platform populated by IA generated data, we could effectively demonstrate its value. The second section involved leveraging the extensive data collected from interviews, offering valuable and practical insights. Each interviewee, some with over twenty years of experience in the field, contributed unique perspectives to the project.

The meticulous analysis of public information from regulatory bodies and food safety organizations was crucial not only to identify standard practices but also to determine the KPIs that the dashboard should visualize. Combining this analysis with the insights provided by the interviewees secured a comprehensive approach to designing the dashboard for quality control.

5.1.1.2 – ETL Process

During the ETL process phase, the database structure from the AIHACCP food safety organization's information system was directly extracted in CSV format.

An examination was conducted on the CSV files obtained from AIHACCP data base structure to validate their format and assess the available data and their relationships. After correcting some inconsistencies, the data was imported into the application used to build the dashboard, as shown in *Figure 5*.

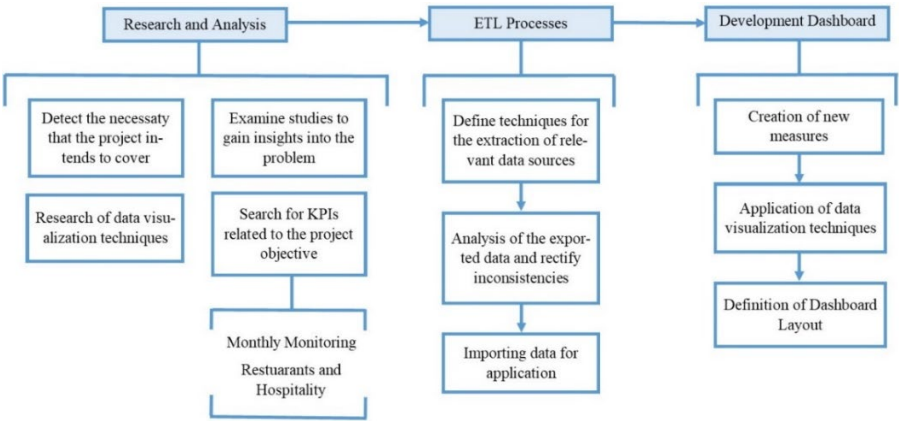

Figure 5 - Proposal Development Workflow

5.1.1.2 – Development Dashboard

During the dashboard development phase, new metrics were created based on the existing measures from the exported files to achieve the idealized KPIs. Some data adjustments were required to standardize the information, aiming for an automated dashboard development process.

5.1.2 – Demonstration

The first iteration of the evolutionary process of developing a dashboard was focused on defining the crucial KPIs and visuals necessary for efficient quality control of food safety organizations.

The primary objective of this initial phase was to develop a dashboard that would facilitate monitoring the planned audit records registered within organization and easily track non-compliance issues related to quality control. To achieve a clear visualization of these two areas of quality control the dashboard was divided into two sections: Monthly Audit Records *(Figure 6)* and Monthly Non-Compliance Issues *(Figure 9).* The dashboard was designed with Portuguese descriptions to streamline testing and future adaptation for the Portuguese market.

For demonstration purposes, the developed artifact was populated with AI-generated information. This allowed interviewees to evaluate it more effectively and provide more insightful feedback.

The Monthly Audit Records section *(Figure 6)* provides a comprehensive overview of audit answers registrations for the selected month and year. Users can choose the audit type from the Dimension of Audit Type, and filter data using the year and month selectors.

At the center of the dashboard, the goals section outlines both daily and monthly targets. Adjacent to this, the dashboard displays the daily average and total number of records for the selected month and year.

A gauge shows the percentage of goals achieved. The gauge includes a gradient of colours ranging from red at 0 (*Figure 6)*, through yellow at 50 (*Figure 7)*, to green at 100 (*Figure 8)*, providing a visual indication of performance against the target.

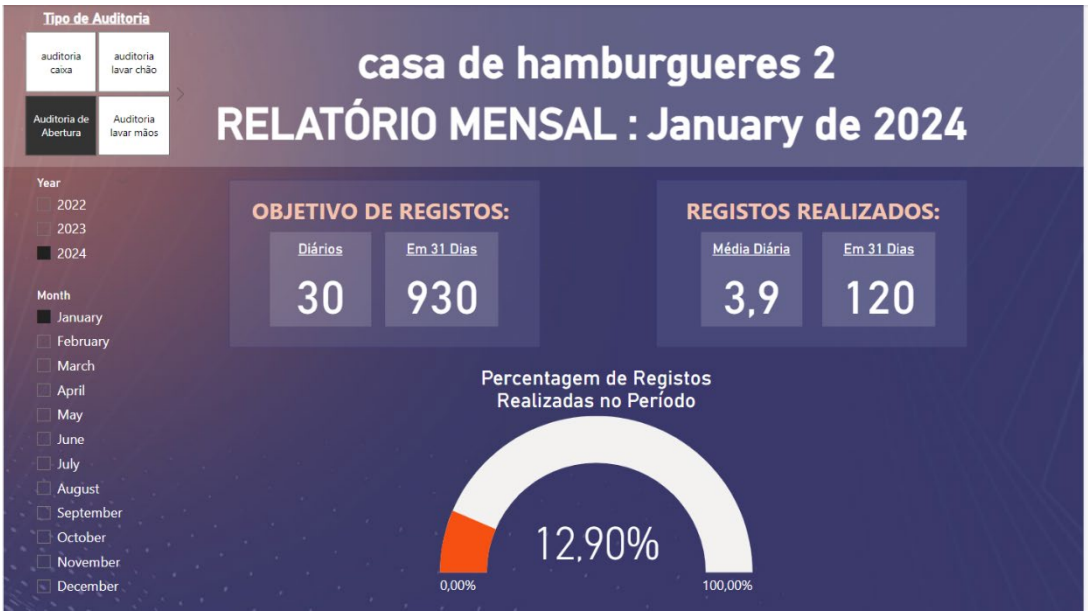

Figure 6 - Dashboard IT1 Monthly Audit Records, Gauge Maximum Values

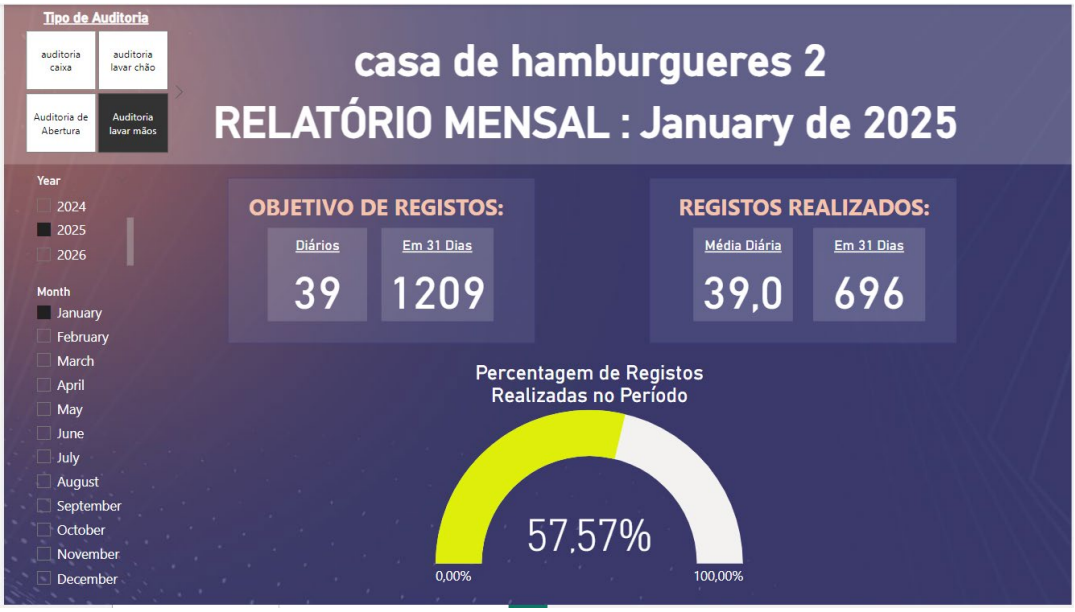

Figure 7 - Dashboard IT1 Monthly Audit Records Gauge at Center Values

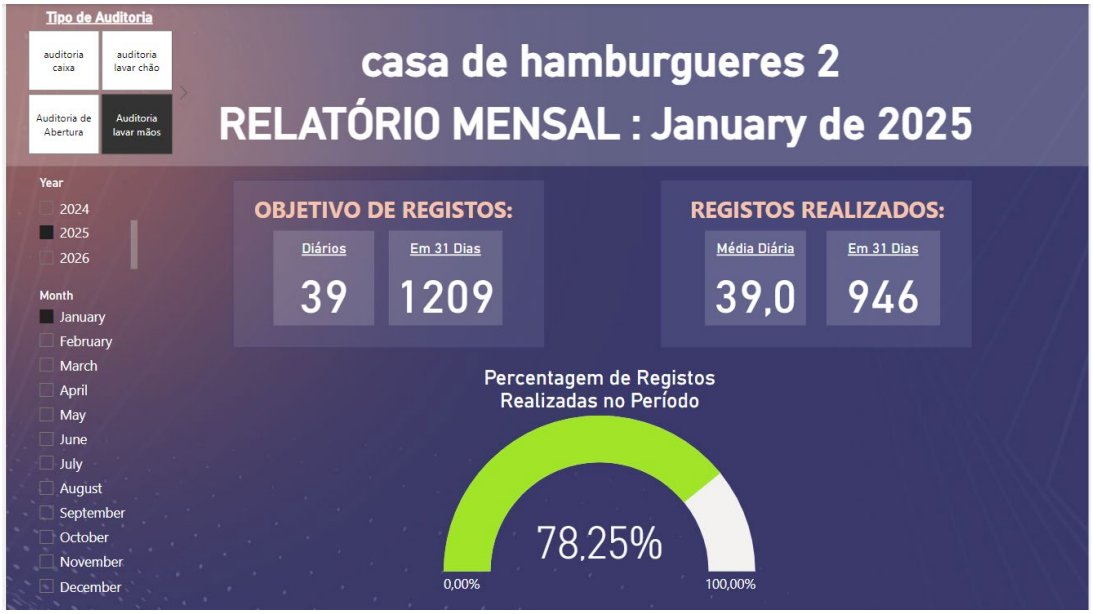

Figure 8 - Dashboard IT1 Monthly Audit Record, Gauge at Maximum Values

The section Monthly Non-Compliance Issues *(Figure 9)* provides a detailed overview of the Non-Compliance Issues registrations for the selected month and year.

The top left section it has the same functionality as in The Monthly Audit Records *section (Figure 6)* and users can also filter the data by year and month.

The dashboard highlights in the center the total number of non-compliance issues registered during the selected month, as well as the average daily registrations. Additionally, it displays the total number of corrections made to non-compliance issues within the month and the average duration, in days, it took to resolve these issues from the time they were registered.

A line graph at the bottom left visualizes the number of non-compliance issues recorded over the days of the selected month and year, displaying the evolution of the registration of throughout the month. On the right, a pie chart illustrates the resolution status of these non-compliances, with resolved shown in green and unresolved shown in red.

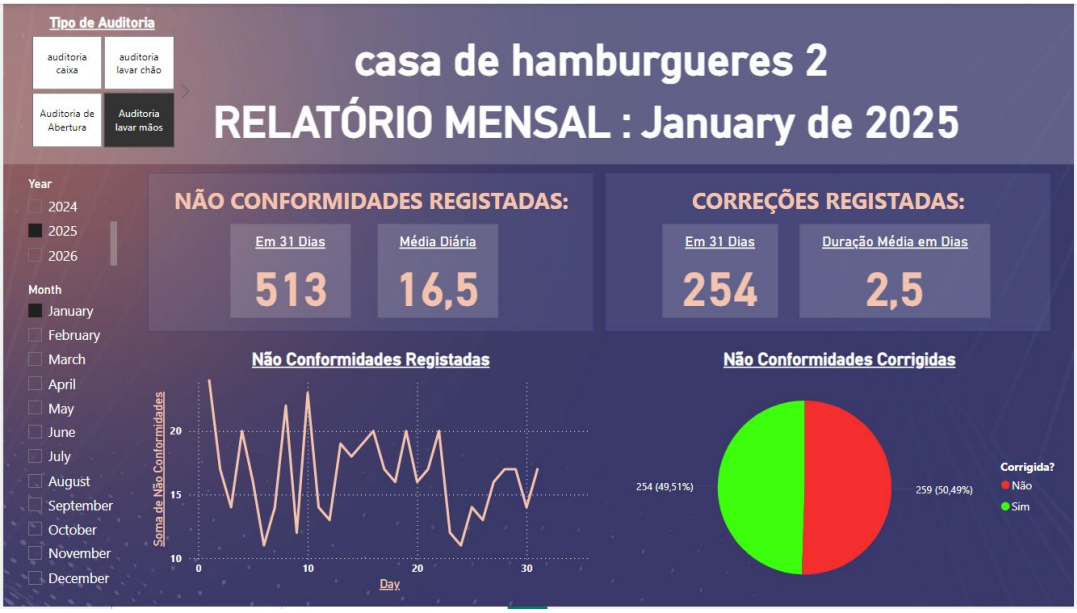

Figure 9 - Dashboard IT1 Monthly Non-Compliance Issues

This dashboard aims to visualize key metrics regarding non-compliances and its corrections, with the objective to provide clear insights into the audit registration performance and the registration of detecting and resolution of non-compliance issues for a specified period.

5.1.3 – Evaluation

After presenting the artifact to the interviewee, the following feedback was obtained: 1 negative aspect, 2 areas for improvement, and 2 positive aspects. These improvements are related to the dashboard filters and the addition of a chart to enhance data comparisons.

The dashboard received positive feedback for its user-friendly presentation of KPIs, making them easy to understand. The selected charts effectively facilitate the interpretation of KPIs and comparisons between recorded data and intended objectives, allowing for quick assessments of quality control management.

However, some areas need improvement. The current filter for selecting data is not ideal. Additionally, the layout and position of the audit type filter need enhancement. In large establishments with more than four audits, a horizontal arrangement reduces clarity.

5.2 – Second DSR Iteration

The Second Iteration was an essential phase in perfecting the functionalities already presented in the dashboard. This phase focused on implementing improvements based on the feedback obtained, as detailed in *Table 6*.

Table 6 - Proposed improvement artefact – 1st Iteration

	ID	Stakeholder synthesis	Stakeholder opinions
PROS	P1.1	"The dashboard features KPIs are easy to understand."	The proposed Dashboards presents the information in a user-friendly manner.
	P1.2	"The selected elements were well-suited to facilitate the interpretation of the KPIs and comparisons between the recorded data and the intended objectives."	The selected charts on the dashboard easily allow comparisons between actual and target performance, enabling a quick assessment of quality control management at this establishment.
CONS	C1.1	"The filter per month and year is not ideal would be better to select a personalized period of time"	Not all external or internal audits related to quality control and food safety, yield ideal one-month periods. Sometimes, shorter, or longer intervals are desired, making it preferable to have the flexibility to freely choose a date range.
PROPOSED IMPROVEMENTS	PI1.1	"The layout and position of the audit type filter are not ideal when there are numerous selections, it would be better in a vertical away."	The position of the 'audit type' filter is not ideal, as in a large establishment there may be more than four audits, as shown in the example, which reduces the clarity of the display. It would be preferable to arrange the filters vertically.
	PI1.2	"Additionally, it would be interesting to have a bar chart which compares the actual number of records to the target for the selected period."	Adding the bar chart on the right side is an improvement to this dashboard, providing a clear visual representation of the number of records in selected period, compared to the registration goals.
	PI1.3	"The KPI labels on the dashboard should be dynamic to reflect the varying frequencies of Audit Type."	Adding dynamic KPI labels based on the audit frequency will make it easier for auditors or managers to analyse the dashboard effectively.

5.2.1 – Proposal

The enhancements on the dashboard aimed to address the identified areas for improvement while maintaining the positive aspects of the initial design. Key changes included refining the dashboard filters for greater flexibility and incorporating a new chart to facilitate data comparisons.

The improvements were then demonstrated in a new session, showcasing the updated dashboard with enhanced data visualization capabilities. The positive aspects (P1) ensured that the KPIs remained easy to understand, while addressing the negative feedback (C1) improved the overall usability and functionality, making the dashboard more effective for quality control management.

5.2.2 – Demonstration

The enhanced dashboard represented in *Figures 10 and 11* incorporates several key improvements in graphical representation and filter functionality.

Firstly, it introduces a personalized date range selection, addressing the need for flexible time intervals. This enhancement is crucial for external and internal audits related to quality control and food safety, which often require shorter or longer periods than the standard one-month intervals, as it was previously identified as a negative point C1.1 during the development of the artifact. By allowing users to freely choose a date range, the dashboard provides a more tailored and relevant analysis, catering to the specific needs of various audits.

Additionally, the layout and position of the audit type filter have been optimized by arranging the filters vertically. This change addresses improvement PI1.1, as it enhances readability and organization. The vertical layout ensures that all filters are easily accessible and clearly displayed, improving the overall user experience. PI1.1 was implemented because it was recognized that with more selection options in the future, the previous filter position would not be visually appealing.

In *Figure 11*, Dashboard Non-Compliance Issues, the improvements arising from C1.1 and PI1.1 have also been implemented.

Moreover, the dashboard (*Figure 10*) now includes a bar chart that compares the actual number of records to the target for the selected period. This addition, which was previously noted as a missing feature, in PI1.2, provides a clear visual representation of performance against goals. Placing the bar chart on the right side of the dashboard highlights the success in meeting registration goals and supports better decision-making by offering an immediate and straightforward means to evaluate performance.

After the implementations related to the C1.1 negative point concerning the date filter, it became evident that including a date hierarchy would further enrich the functionality of the dashboard. By implementing a date hierarchy, users can now seamlessly drill down through different time levels, such as year, quarter, month, and day, providing a more granular and comprehensive understanding of data trends over time. This feature was strategically incorporated into the visual representations within the dashboard to facilitate intuitive navigation and in-depth analysis. Specifically, in *Figure 10*, the bar chart compares the actual number of records to the target for the selected period, allowing users to evaluate performance against goals within the chosen time frame. Similarly, *Figure 11* showcases a line graph where the number of non-compliance issues recorded over a period can be visualized, highlighting patterns and trends that may warrant attention.

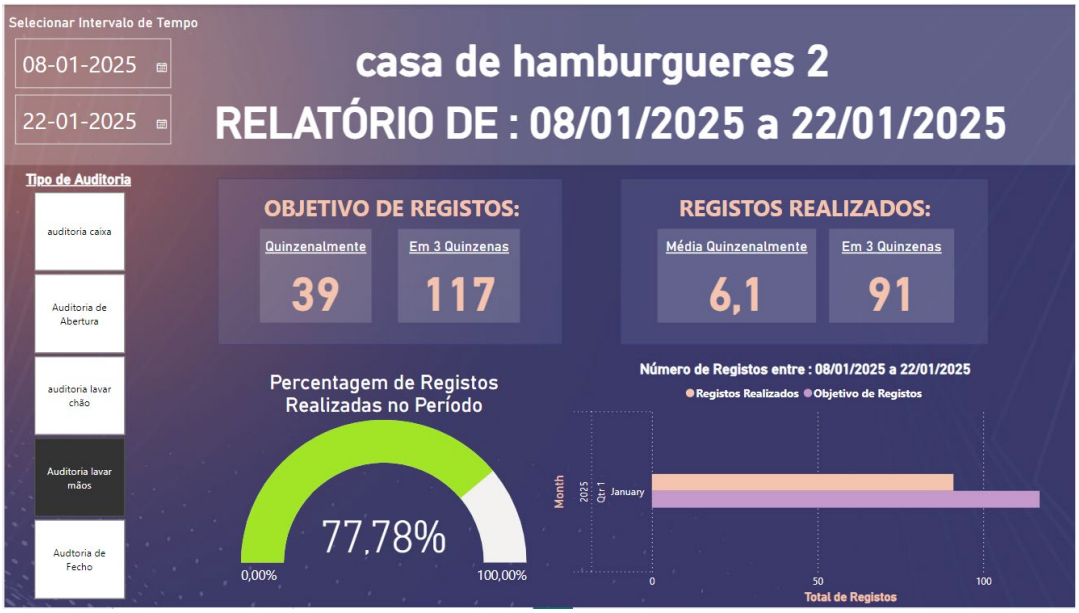

Figure 10 - Dashboard IT2 Audit Records

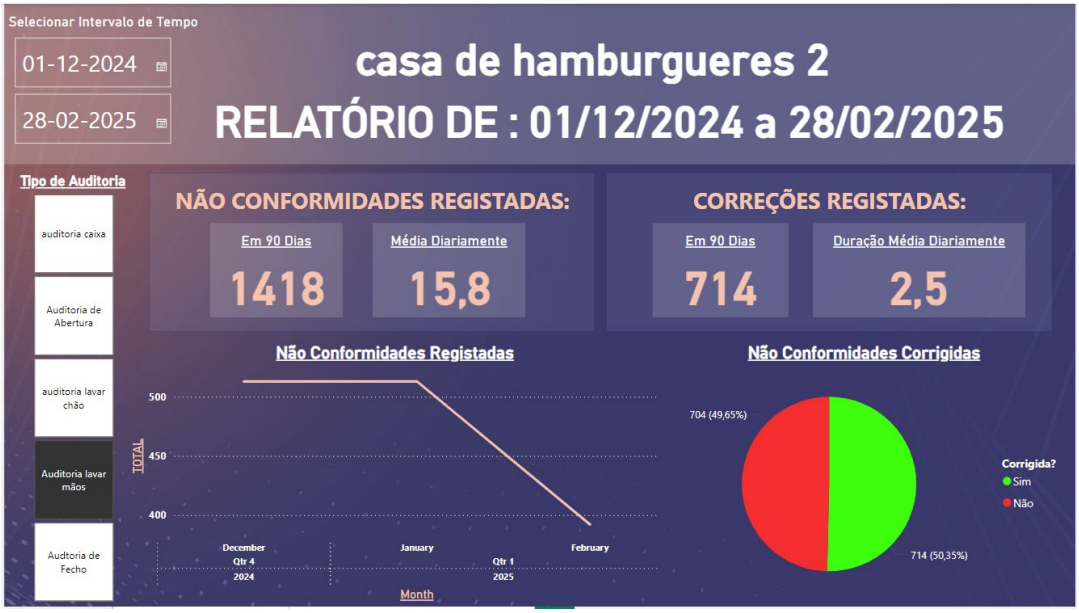

Figure 11- Dashboard IT2 Non-Compliance Issues

To implement the proposed improvement in point PI1.3, the 'Frequency' dimension was added to the model, extracted from the AIHAACP database structure. This addition provides the necessary framework to enable dynamic KPI labels on the dashboard, adjusting according to the frequency of each Audit. As demonstrated in Figures 12 and 13, the descriptions update to reflect the audit frequency based on the selected audit, enhancing the relevance and accuracy of the displayed information.

Figure 12 - Dashboard IT2 Audit Records – Dynamic Legends

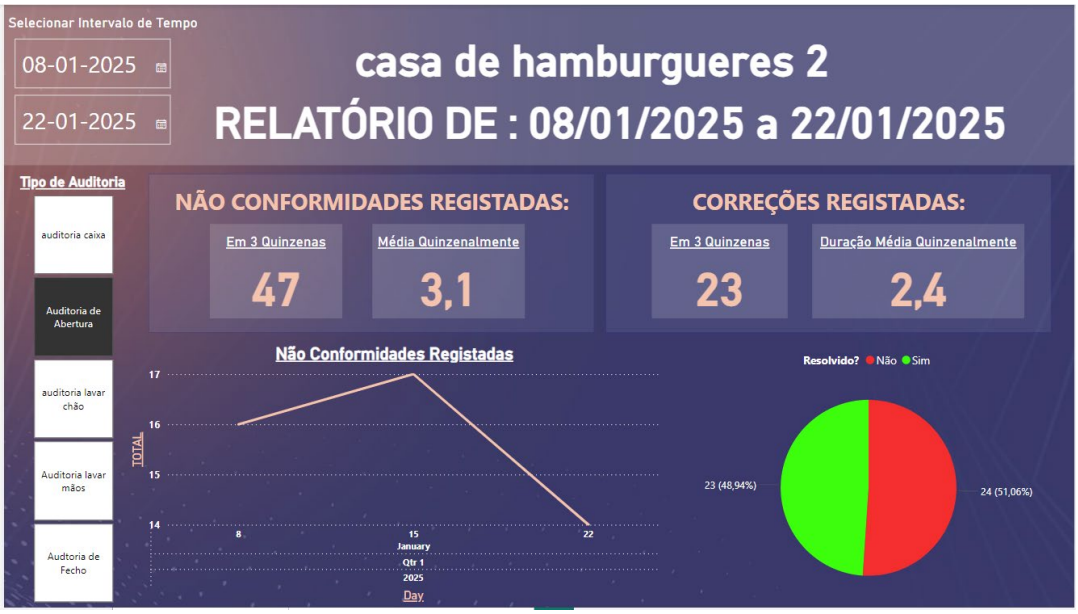

Figure 13 - Dashboard IT2 Non-Compliance Issues - Dynamic Legends

5.2.3 – Evaluation

After presenting the artifact to the interviewee, the feedback included no negative aspects, one suggested area for improvement, and two positive aspects, as detailed in Table 7. The positive feedback highlights the dashboard's emphasis on critical areas, such as non-conformities and correction durations, which spotlight key improvement opportunities. Additionally, the graphs facilitate easy comparison between actual records and target records, allowing for a straightforward assessment of whether targets are being met.

The proposed improvement focuses on a new approach for analysing data by the individuals who made the records, thereby enhancing the dashboard's data visualization and usability. Specifically, it would be valuable to include information about the user who made the entries. Having an overview of all types of entries made by a user over a given period would enable an assessment of an individual employee's contribution to food safety quality control within an establishment.

5.3 – Third DSR Iteration

The Third Iteration involved the proposal of a new visualization dashboard aimed at further enhancing the functionalities and user experience based on prior feedback, as shown on the *Table 7*. This iteration introduced a new panel designed to address the suggested areas for improvement, particularly focusing on providing more detailed insights and better usability. The new panel includes information on audit records and non-conformities by individual collaborators, offering a comprehensive view of each employee's contributions and performance. As with the previous iterations, these new panels were subjected to interviews with key stakeholders to gather comprehensive feedback. This iterative process ensured continuous refinement and optimization of the dashboard, incorporating valuable insights from users to drive ongoing improvements in data visualization and overall effectiveness.

5.3.1 – Proposal

During the evaluation of the second iteration, the points for improvement listed in *Table 7* were identified, and all of them have been successfully implemented.

Table 7 - Proposed improvement artefact – 2nd Iteration

	ID	Stakeholder synthesis	Stakeholder opinions
PROS	P2.1	“The dashboard's emphasis on critical areas, such as non-conformities and correction durations, highlights key improvement opportunities.”	The dashboard highlights critical areas such as non-conformities and the duration of corrections, allowing for focused attention on areas that require improvement.
	P2.2	"These graphs, facilitate easy comparison between actual records and target records, allowing users to drill down into specific time periods for more detailed insights."	The comparison between the objective of records and the number of records achieved allows for a straightforward assessment of whether targets are being met while providing the ability to analyse trends across different time frames.
PROPOSED IMPROVEMENTS	PI2.1	“It would be interesting to see information about the user who made all these registrations, for example, the impact of their registrations over the entire period."	Since all entries are made by a registered user, it would be valuable to have an overview of all types of entries made by a user over a given period. This would enable us to assess an individual employee's contribution to food safety quality control within an establishment.

5.3.2 – Demonstration

In *Figures 14 and 15*, it can be seen that the panels have not suffered any modifications. This decision was made because the last feedback session did not identify any improvements or negative points. Instead, the focus was on maintaining the highlighted strengths from the previous feedback session.

Additionally, after the evaluation of the past iteration, the introduction of the date hierarchy proved to be a valuable enhancement because it provided the ability to analyse trends across different time frames. This addition was beneficial enough that no further changes were needed to the dashboards.

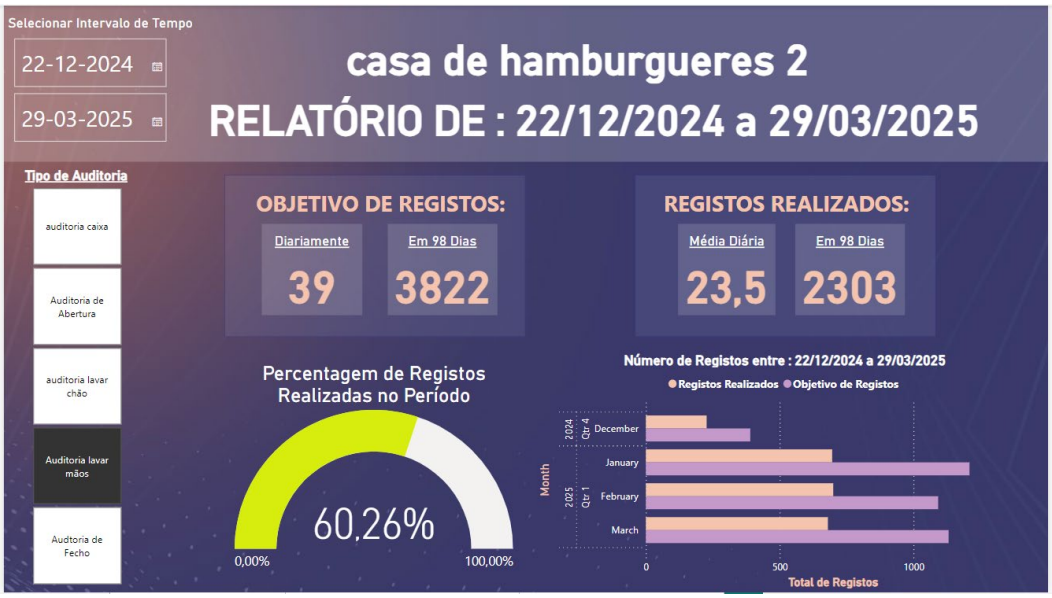

Figure 14 - Dashboard IT3 Audit Records

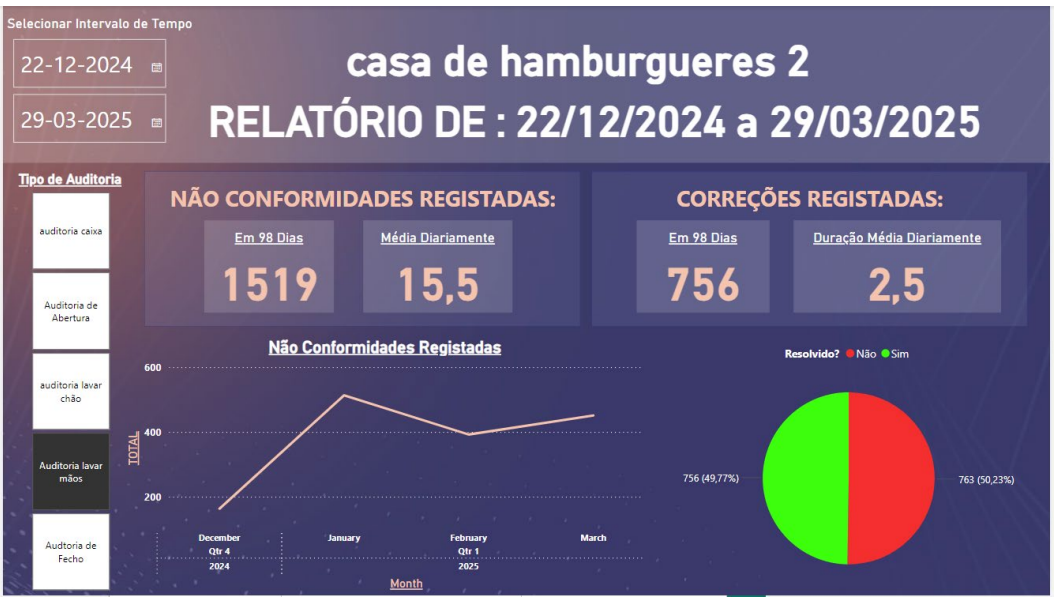

Figure 15 - Dashboard IT3 Non-Compliance Issues

The dashboard presented in *Figure 16* includes several key elements to facilitate data analysis and visualization. It features a date range selection at the top left, allowing users to specify the reporting period and ensuring flexibility in analysing different time frames. Like the other panels, it has a vertical list of audit types on the left side, categorizing the various types of audits conducted. Additionally, this panel includes a dropdown menu labelled "Nome Colaborador" enabling users to select a specific employee and providing insights into individual performance.

The main section of the dashboard includes key metrics that summarize the audit performance: the number of audit registers, the employee's contribution to the registration goal for the audit type, the number of non-conformities registered by the employee, and the number of corrections for non-conformities.

Below the metrics, a bar chart compares the actual number of records uploaded by staff members to the registration goals of the entire establishment, with the x-axis organized by date hierarchy facilitating a straightforward assessment of their performance. Additionally, a pie chart illustrates the resolution status of non-conformities, showing the proportion of resolved and unresolved issues per employee. This comprehensive dashboard provides a clear and detailed overview of an individual employee's contributions and performance in relation to quality control and audit compliance.

Figure 16 - Dashboard IT3 Audit Records per Employee

5.3.3 – Evaluation

The evaluation of the dashboard revealed several positive aspects, areas for improvement, and negative aspects, as represented in Table 8. The interviewee highlighted that the three areas addressed in the dashboard audit records, non-conformities, and records by employee are already detailed with the necessary measures, indicating that no additional measures are needed. However, to improve the clarity of performance metrics, it was suggested to adjust the gauge's colour gradient on the Audit Records Dashboard (*Figure 14*). The current gradient, which ranges from red at 0, yellow at 50, to green at 100, should be modified to transition from red to orange for 0 to 50, yellow from 51 to 89, and green starting from 90. This adjustment will provide a clearer and more accurate visual representation of the performance metrics. Additionally, a central dashboard was suggested to compare the key measures of each area addressed in the dashboard. This central dashboard would serve as an overview, allowing users to quickly assess the main performance indicators and then redirect to more detailed panels for in-depth analysis. These evaluations and suggestions aim to enhance the overall usability and effectiveness of the dashboard in supporting quality control and food safety management.

5.4 – Fourth DSR Iteration

In this section, the fourth iteration of the Design Science Research (DSR) process is outlined, focusing on the continued refinement and enhancement of the dashboard based on previous feedback and evaluations. This iteration seeks to address the identified issues, incorporate user suggestions, and further optimize the dashboard's functionality and user experience adding a new central panel to navigate between panels.

5.4.1 – Proposal

The proposal for the fourth iteration centers on implementing a series of targeted improvements designed to enhance the dashboard's usability and effectiveness. Based on the feedback on the *Table 8*, this proposal outlines the key changes to be made, including the introduction of a central dashboard for comparative analysis, the application of rule-based colour coding for performance gauges, and the addition of navigational elements to streamline the user experience.

Table 8 - Proposed improvement artefact – 3rd Iteration

	ID	Stakeholder synthesis	Stakeholder opinions
	P3.1	“The three areas addressed in this dashboard: audit records, non-conformities, and records by employee, are detailed with the necessary measures.”	The interviewee indicated that there are no additional measures needed in these three areas audit records, non-conformities, and records by employee as they are already detailed with the necessary measures.
CONS	C3.1	“To improve clarity in our performance metrics, we need to adjust the gauge's colour gradient. Instead of the current red at 0, yellow at 50, and green at 100, we should implement a gradient that goes from red to orange for 0 to 50, yellow from 51 to 89, and green starting at 90.”	Currently, the gauge ranges from red at 0, yellow at 50, to green at 100. The suggested improvement is to adjust the colour gradient. The gradient should be red to orange from 0 to 50, yellow from 51 to 89, and green starting from 90. This adjustment will provide a clearer visual representation of the performance metrics.
PROPOSED IMPROVEMENTS	PI3.1	"I propose a Central Dashboard to compare the key measures of each area addressed in the dashboard."	It would be beneficial to add a central dashboard that includes a key measure from the audit records panel and another from the non-conformities panel for comparative analysis. This central dashboard would serve as an overview, allowing users to quickly assess the main performance indicators briefly. Additionally, it should have the capability to redirect users to more detailed panels for an in-depth analysis.
	PI3.2	"It would be more effective to have a title that directly reflects the content and purpose of the report, rather than just the date range, especially since the date filter is already clearly visible on the same line."	It was highlighted the importance of clarity in report titles. It was suggested that the title should directly reflect the subject matter and purpose of the report, rather than simply indicating the date range covered. This recommendation was made in the context of a report layout where the date filter is prominently displayed on the same line as the title.

5.4.2 – Demonstration

In response to the feedback suggesting the addition of a central dashboard for comparative analysis, PI3.1, it was developed a new panel (*Figure 17*) that provides a high-level overview of the key performance indicators from both the audit records panel and the non-conformities panel. The layout maintains the original filter design, ensuring consistency and ease of use. The most relevant KPIs for each theme were identified during the demonstration of the third iteration, focusing on those that are crucial to the overall performance assessment. Additionally, three buttons were integrated into the page, allowing users to quickly navigate to more detailed panels for an in-depth analysis. This enhancement allows users to efficiently assess key metrics at a glance while providing the flexibility to delve into more detailed data as needed, aligning with the improvement points PI3.1 identified.

Figure 17 - Dashboard IT4 Audit Report

As a result of the development of the central dashboard, as suggested in improvement point PI3.1, a button was added to the Dashboards Audit Records *(Figures 18)*, Non-Compliances Issues *(Figures 19)*, and Audit Records per Employee *(Figures 20)* panels. This button redirects users back to the main screen, ensuring easy navigation and a more streamlined user experience across the different sections of the dashboard.

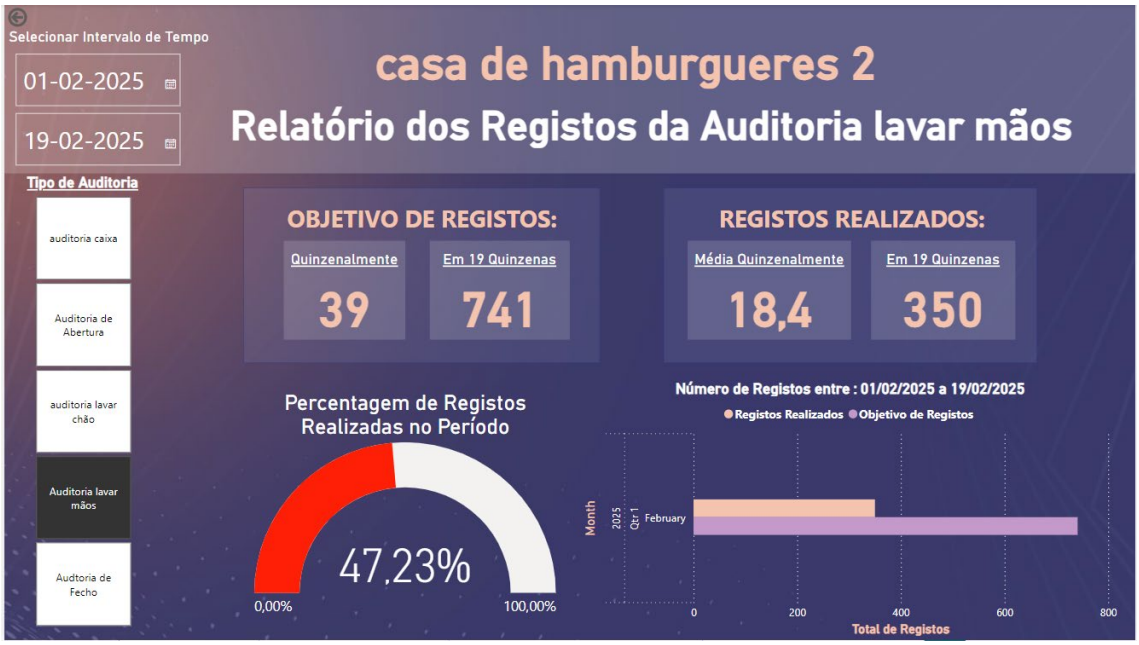

Figure 18 - Dashboard IT4 Audit Records

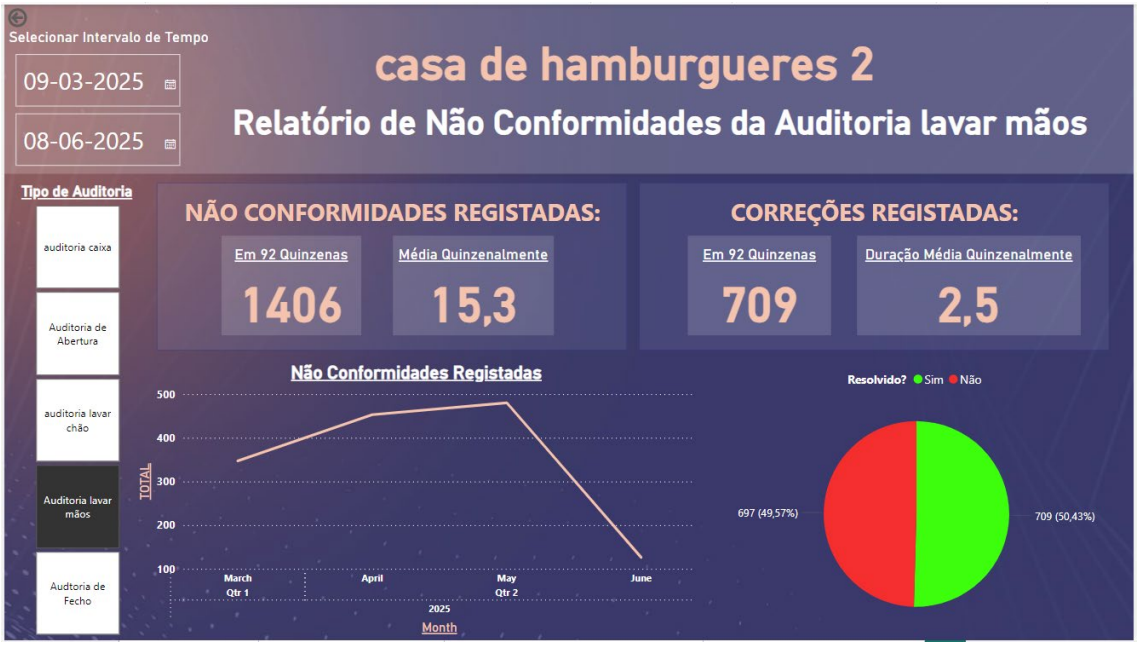

Figure 19 - Dashboard IT4 Non-Compliance Issues

Figure 20 - Dashboard IT4 Audit Records per Employee

The improvements addressing the issue identified in negative point C3.1 were implemented in the gauge of the Audit Records panel. Previously, the gauge used a gradient ranging from red at 0, yellow at 50, to green at 100. To enhance clarity, it was suggested to switch from a gradient to a rule-based color system. The new setup now applies specific rules: red from 0 to 49 *(Figure 21)*, yellow from 50 to 89 *(Figure 22),* and green from 90 to 100 *(Figure 23).* These changes were implemented as shown in the accompanying *Figures 21, 22 and 23*, which demonstrate how the rules were applied in alignment with the suggested improvements to provide a clearer visual representation of performance metrics.

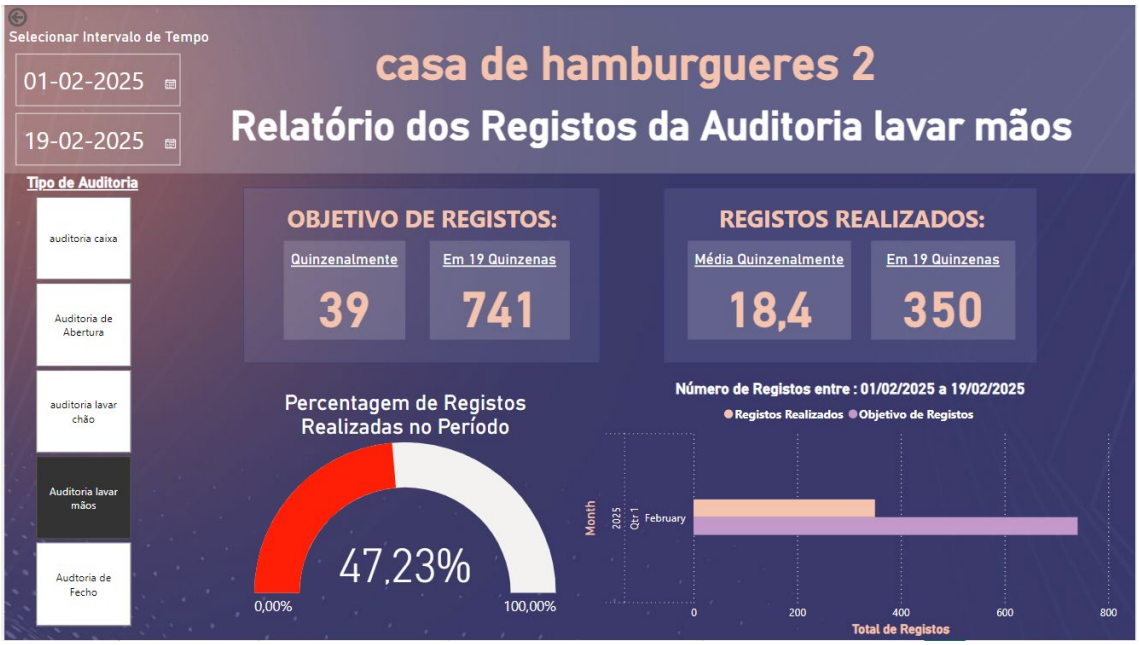

Figure 21 – Dashboard IT4 Audit Records, Gauge 0% - 49%

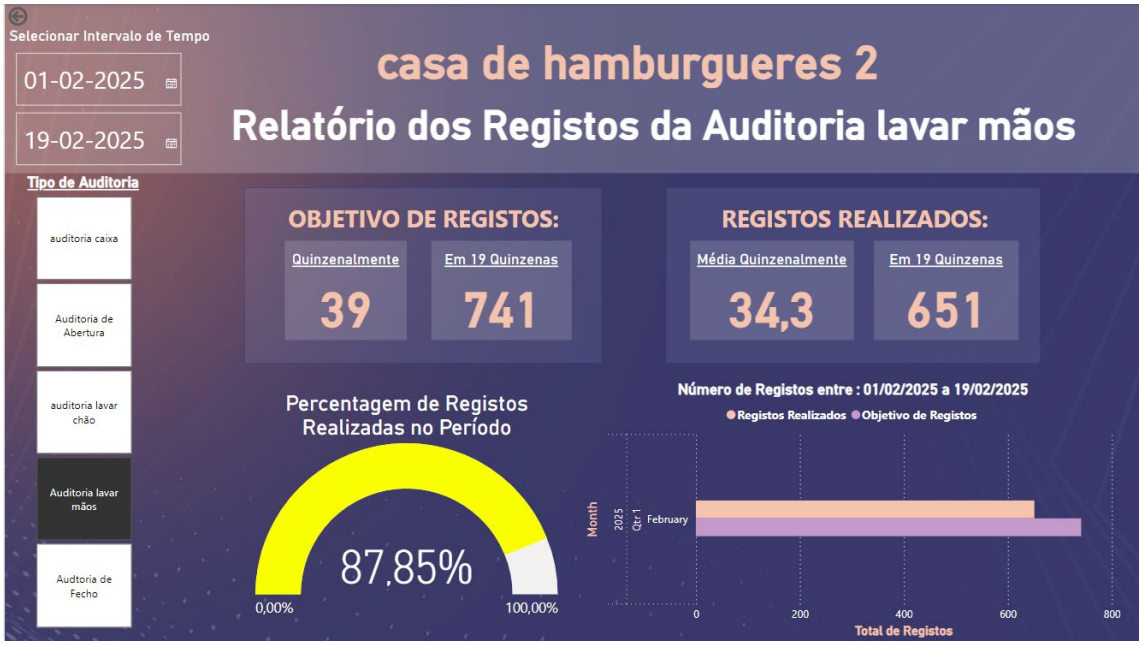

Figure 22 - Dashboard IT4 Audit Records, Gauge 50% - 89%

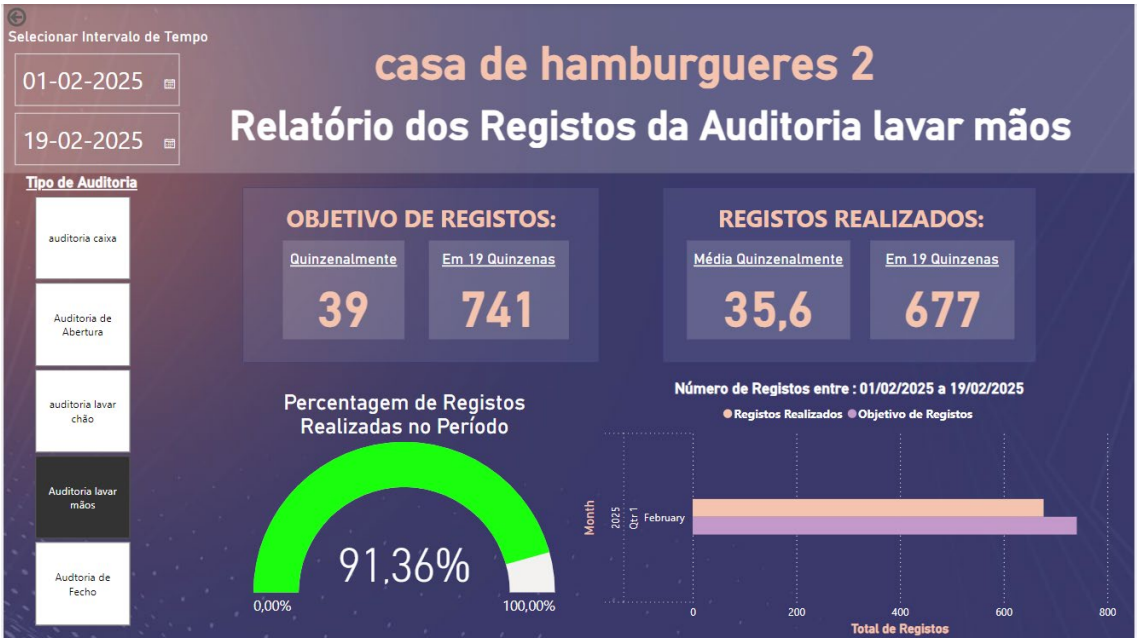

Figure 23 - Dashboard IT4 Audit Records, Gauge 90% - 100%

5.4.3 – Evaluation

During the evaluation of fourth iteration, the feedback was overwhelmingly positive, with no negative points identified by the interviewee. This suggests that the design refinements and enhancements from previous iterations have successfully resolved earlier issues. However, one suggestion for further improvement was brought up during this evaluation. It was proposed that the hierarchy levels in the date selection could be simplified, the interviewee expressed that the current structure, with multiple layers of date filtering, might be overly complex.

Despite this point of improvement, it was decided not to implement this change. This decision was made base on the positive feedback received in the second iteration, where the interviewee praised the current date hierarchy for its effectiveness. Specifically, the existing design allows users to drill down into specific time periods, facilitating a detailed comparison between actual records and target records. This feature was highlighted as a key strength, enabling users to gain deeper insights into performance metrics without overwhelming them with data. Therefore, to maintain this valuable functionality and preserve the intuitive user experience, the current date hierarchy was retained in the final iteration.

Chapter 6 – Conclusion

The objective of this study is to develop a dashboard with KPIs linked to food safety and hygiene that will improve stakeholder decision-making. Managers will be able to make better decisions by recognizing and addressing areas where quality control needs to be improved with the help of this research's artifact. Furthermore, the dashboard's design will give auditors more precise insights into how standards are being implemented, which will enhance their capacity to decide on the certification process with clarity.

Additionally, this study aimed to address two primary research questions: which dashboard display is best for supporting auditors, and what is the most efficient way to deliver data to managers? The dashboard's iterative development, which improved its design in response to stakeholder input, provided answers to these questions. The dashboard that is produced provides managers and auditors with understandable and practical information regarding food safety compliance.

The fundamental finding of this study is the crucial function of dashboards in consolidating and streamlining the copious amounts of data gathered throughout the food sector. Dashboards enable stakeholders to monitor and visualize KPIs in real-time, enabling them to take prompt action in response to non-compliance concerns and track compliance with food safety regulations. Moreover, the incorporation of BI technologies facilitates not only the gathering of data but also the strategic analysis needed for managerial judgment and the auditing procedure.

This study also emphasizes how well contemporary BI tools work when combined with the concepts of HACCP. The study shows how dashboards can convert complicated facts into useful insights that help stakeholders spot patterns, prioritize areas that need to be improved, and manage risks in advance. The dashboard's functionality was improved in multiple ways as a result of the iterative DSR method used in this project, making it more user-friendly and useful for managing food safety. Professionals involved in food safety were directly involved in the dashboard's development, which was fueled by feedback from industry insiders.

According to the study's findings, using dashboards effectively can speed up regulatory compliance procedures and lessen the workload that audits place on businesses. Managers and auditors may evaluate performance and impose corrective steps when needed, thanks to the dashboard's clear visualization of audit records and non-compliance issues. This methodology not only enhances food safety results but also cultivates an ongoing improvement culture in food operations.

By offering a new approach for data visualization and decision-making, this work supports the ongoing efforts to maintain food safety. The dashboard created in this study provides an effective tool for controlling food safety and hygiene in the fast-paced food business of today by bridging the gap between data gathering and real-world implementation. Using comparable BI technologies can help achieve the dual objectives of enhancing food safety protocols and protecting public health. It can also increase operational efficiency.

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