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FOOD SAFETY PROCESS IMPROVEMENT MODEL BASED ON MATURITY LEVELS

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Dissertação submetida ao Programa de Pós-Graduação em Engenharia de Produção da Universidade Federal do Rio Grande do Sul como requisito parcial à obtenção do título de Mestre em Engenharia de Produção, modalidade Acadêmica, na área de concentração em Sistemas de Qualidade.

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Food Safety Process Improvement Model Based On Maturity Levels

Esta dissertação foi julgada adequada para a obtenção do título de Mestre em Engenharia de Produção na modalidade Acadêmica e aprovada em sua forma final pelo Orientador e pela Banca Examinadora designada pelo Programa de Pós-Graduação em Engenharia de Produção da Universidade Federal do Rio Grande do Sul.

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"Cast your cares on the Lord and
he will sustain you; he will never
let the righteous be shaken."
Psalms 55:22

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ABSTRACT

In today's food industry, ensuring the safety of food products is a crucial requirement to ensure regulatory compliance, seek competitive differentiation, and access new markets. Many studies focus on implementing food safety management systems in established processes and evaluating implemented systems. The absence of preventive strategies in process conception and structuring can lead to non-compliance, rework, and non-quality costs. There is a research gap for process development methodologies incorporating food safety requirements. To address this gap, this research aimed to develop and demonstrate a model to guide companies in the adoption of practices for enhancing food safety in processes. Initially, through a systematic literature review, design techniques, trends, challenges, research opportunities and relevant themes in food safety-driven process development were identified. Subsequently, a model was developed to measure food safety maturity in processes and prioritize best practices to improve food processes. It comprises five maturity levels, covering eight key production process areas. The model was tested in three case studies with food producers in Brazil. The results of this study can support food safety-oriented approaches in process development and continuous improvement, ensuring overall food safety standards and regulatory compliance within the industry.

Keywords: Good hygiene practices. Maturity Model. Continuous improvement. Process development.

RESUMO

Na indústria alimentícia atual, garantir a segurança dos alimentos é crucial não apenas para a conformidade regulatória, mas também para alcançar diferenciação competitiva e acessar novos mercados. Muitos estudos se concentram na implementação e avaliação de sistemas de gestão de segurança de alimentos em processos já estabelecidos. No entanto, a falta de estratégias durante a concepção e estruturação de processos pode resultar em não conformidades, retrabalho e custos de qualidade. Constatou-se uma lacuna na pesquisa em metodologias de desenvolvimento de processos que incorporem requisitos de segurança de alimentos. Para preencher essa lacuna, este estudo teve como objetivo desenvolver um modelo para orientar as empresas na adoção de práticas que aprimorem a segurança de alimentos em processos. Uma revisão sistemática da literatura identificou técnicas de design, tendências, desafios, oportunidades de pesquisa e temas relevantes no desenvolvimento de processos com foco em segurança de alimentos. A partir disso, foi desenvolvido um modelo para medir a maturidade em segurança de alimentos nos processos e priorizar práticas para sua melhoria, compreendendo cinco níveis de maturidade e abrangendo oito áreas fundamentais do processo produtivo. O modelo foi testado em três estudos de caso com indústrias alimentícias no Brasil. Os resultados deste estudo podem apoiar abordagens orientadas à segurança de alimentos no desenvolvimento de processos e na melhoria contínua, assegurando padrões gerais de segurança de alimentos e conformidade regulatória dentro da indústria.

Palavras-chave: Boas Práticas de Higiene. Modelo de Maturidade. Melhoria Contínua. Desenvolvimento de Processos.

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SUMMARY

1 INTRODUCTION

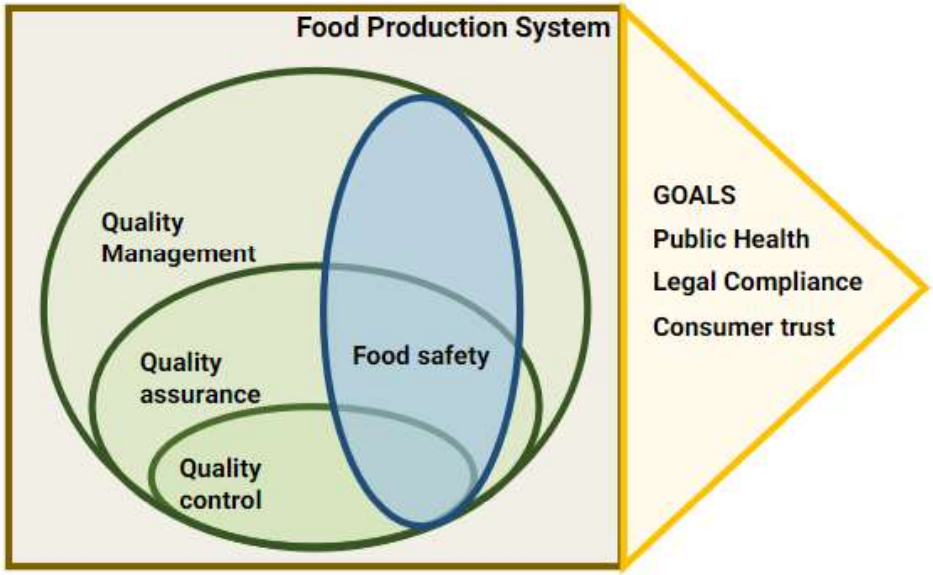
Customers are increasingly concerned about the risks involved in food consumption, and expect food suppliers to demonstrate their capability to effectively manage food safety, aligning with market demands and regulatory requirements (DUONG et al., 2023). As a result, food safety has transcended mere regulatory compliance and has become a critical component in ensuring public health, enhancing consumer trust, and maintaining competitiveness within the industry (FUNG et al., 2018).

Many companies implement food safety management systems (FSMS) to meet these expectations. Within the broader quality context of a company, the FSMS context specifically focuses on factors that impact the safety of food products through various activities and programs (NGUYEN; LI, 2021). These systems can be categorized into obligatory and voluntary systems. Obligatory systems, that comprise Good Hygiene Practices (GHP) and Hazard Analysis and Critical Control Point (HACCP), are mandated by regulations to ensure food safety, primarily emphasizing food safety control practices. These systems require food production facilities to meet minimum food safety standards, but there is usually no explicit requirement for formalized programs with explicitly written procedures and documents (BUCKNAVAGE; CAMPBELL, 2020). In contrast, voluntary systems, like Total Quality Management (TQM) systems and third-party certifications such as ISO, serve to enhance further food safety standards (GEHRING; KIRKPATRICK, 2020), incorporating assurance and management practices (AUNG; CHANG, 2014). These systems apply strategies to enhance auditability and traceability in food production, incorporating formalized procedures and food safety performance indicators. Fig. 1 shows how the food safety dimension is integrated into the food production system.

Several studies focus on food safety systems implementation in ongoing production processes (JACXSENS et al., 2011; CHEN et al., 2019; NGUYEN; LI, 2021), for example, due to customer and trade requirements (PANGHAL et al., 2018). Traditional approaches treat human/behavioral factors separately from process design (EHUWA; JAISWAL; JAISWAL, 2021; MALLHI et al., 2018; YU; SIRSAT; NEAL, 2019). However, the isolated application of such systems on already designed processes can lead to non-compliance, rework, and unnecessary costs. As observed by DA CUNHA et al. (2022), administrative layers of food safety, such as facility design, create latent conditions that influence behavioural layers. For

instance, a process with clearly defined flows and competences supports the reliability of controls and the overall defense system. In this sense, an integrated approach to include a food safety perspective into process improvement may bring promising results.

Figure 1. The food production system, the different levels of adoption of quality and food safety systems, and relevant goals addressed by food safety systems.



Source: the authors.

The design of processes, facilities, and equipment in the food industry should consider eliminating or reducing potential risks and improving production environment conditions. Environmental support (including adequate process design, work conditions, facilities, and equipment) has been identified as a predictor of proper food safety practices (DE ANDRADE et al., 2020; DA CUNHA; STEDEFELDT; DE ROSSO, 2014). Some aspects such as lack of accessible handwashing facilities and sanitation material, improper working surfaces, absence of visibly written rules, and lack of segregated zones may lead to inefficient FSMSs (DA CUNHA et al., 2022; LIN; PAEZ, 2020). Such aspects can also hinder the effectiveness of quality tools like Hazard Analysis and Critical Control Points due to the over- or under-identification of significant risks (WALLACE et al., 2014).

There is a growing recognition of the need for approaches to food safety-driven process design and improvement (ALLENDE et al., 2022). Rather than viewing food safety as a series of isolated implementations, it may be perceived as an ongoing process. Implementing strategies to foster the gradual evolution of FSMSs may contribute to improving company

reputation, employee food safety culture, and sustainable development of production processes (PURWANTO et al., 2021).

1.1 Theme justification

The theme of this dissertation revolves around enhancing processes by integrating food safety practices into process improvement. The significance of this theme lies in response to the growing demand for flexible processes, designed with a preventive logic and avoiding reworks, to enhance sustainability, reduce costs, and improve return on investment on industrial portfolios (MOLINE, 2015; REISINGER et al., 2022; ĐJEKIĆ et al., 2023). Designing food processing facilities should integrate food safety guidelines from the initial process conception, serving as a foundation for continuous improvement and incorporation of innovations and advanced technologies (HASSOUN et al., 2024). There is a research gap for proactive process development methodologies to improve process food safety (ALLENDE et al., 2022).

There are several approaches to the development of processes using GHP as overarching guidelines (KUBO et al., 2021; SINGH; SHALINI, 2014; TALIB; ALI; IDRIS, 2013), but they often lack a concrete intervention strategy to address food safety practices. Food safety is treated as a requirement to be met *a posteriori*; this may lead to missing opportunities for configuration and expansion to prolong the life cycle of processes (REISINGER et al., 2022).

Moreover, several studies propose tools for the diagnosis of FSMSs. The Food Safety Management System Diagnostic Instrument (FSMS-DI) (LUNING et al., 2011) is among the pioneer tools for measuring the implementation of FSMSs. It comprises 51 indicators, including context riskiness, control activities, and assurance activities. Moreover, JACXSENS et al. (2010) present a Microbiological Assessment Scheme (MAS) to allow a self-assessment of FSMSs. The authors encourage the combined application of FSMS-DI and MAS, as has been performed by CHEAH et al. (2021), NGOC et al. (2020), and VAN DURME et al. (2024). While the diagnostic instruments offer insights into the current state of FSMSs, they lack the capability to identify priority interventions for system improvement.

JESPERSEN et al. (2016) present a comparative analysis of systems used to evaluate food safety culture, comprising attitudes, values and beliefs in a particular food handling environment. The authors point out a research gap for unifying food safety dimensions and developing models to assess maturity within organizations based on these dimensions. Food

safety culture diagnosis tools have been referred to as fragmented and vague (JESPERSEN et al., 2016; DE BOECK et al., 2015).

Recently, there has been a growing focus on 'maturity models' and 'readiness models' in various engineering domains, including business process management (TARHAN; TURETKEN; REIJERS, 2016), manufacturing systems (VIVARES; SARACHE; HURTADO, 2018), integrated management systems (DOMINGUES; SAMPAIO; AREZES, 2016; SANTOS et al., 2021) industry 4.0 (LUCATO et al., 2019; PACCHINI et al., 2019; WAGIRE et al., 2020; SENNA et al., 2023), and corporate sustainability (SARI et al., 2020; MACHADO; CARVALHO, 2021). However, maturity models and process improvement models on food safety are still scarce (SANTOS, 2021). Therefore, it is imperative to conduct a comprehensive analysis to identify current techniques and practices for food safety-driven process development and integrate them into a process improvement model. This approach may improve food safety from the early stages of process development, leading to benefits such as lower costs, sustainable development, and fewer non-compliances.

1.2 Research questions

In light of the provided context, two key research questions were developed: (i) What practices, methods, trends, challenges, and opportunities can be identified in process development with a focus on food safety? (ii) How to integrate food safety best practices into a model for process improvement based on maturity assessment?

1.3 Objectives

This research aimed to develop and demonstrante a model to guide companies in the adoption of practices for enhancing food safety in processes. To achieve this general objective, each of the two articles that compose this dissertation approached specific and complementary objectives, as shown below.

Article 1 aimed to gather and analyze design techniques, trends, challenges, and research opportunities for food safety-driven process development. Article 2 aimed to develop and demonstrate a food safety process improvement model to prioritize best practices based on maturity levels.

1.4 Research design

This subsection elaborates on the methodology adopted in conducting the study, focusing on the research method and methodological procedure to achieve the objectives outlined in this dissertation.

1.4.1 Research method

This dissertation can be categorized in its nature as applied research, as it aims to apply knowledge to solve specific problems. To address the outlined objectives, qualitative approaches were employed, which help provide a better understanding of a problem context and deepen the understanding of concepts (GIL, 2017).

Regarding its purpose, this dissertation is categorized as exploratory and prescriptive. The main objective of exploratory research is to facilitate understanding of a context or situation, providing greater familiarity with the issue (MALHOTRA, 2019). In this sense, Article 1 presents a systematic literature review that allows for an understanding of what techniques and practices may be applied to food safety-driven process development, to improve process maturity. Subsequently, Article 2 is a prescriptive study, as it proposes an artifact to assess a company's current food safety process maturity and prioritize best practices to improve food processes. The developed prescription artifact was tested in a case study approach, which allows for the observation of phenomena in real-world settings (AALTIO; HEILMANN, 2010).

Finally, regarding its design, this dissertation used bibliographic research, expert interviews, and case studies. Article 1 provides a systematic literature review (SLR), with the purpose of providing a theoretical foundation for the work, as well as identifying the current stage of knowledge on food safety-driven process design techniques and practices (GIL, 2017). Expert interviews allow for exploring the experience of relevant peers, being useful for the collection of contemporary practices and know-how (MERRIAM; GRENIER, 2019).

Case studies were performed to provide detailed information on the results and limitations of the proposed model, on different scenarios. To foster external validity, three case studies were selected to comprise companies of various products and sizes (FLYVBJERG, 2006). Selection criteria for the case studies included the willingness to participate in the research and compliance with regulations, providing a minimal level of maturity of the FSMS.

The case studies represent a preliminary testing of the model, which may be validated through its application across a broader range of companies.

1.4.2 Methodological procedure

To achieve the outlined objectives, Design Research Methodology (DRM) was employed (BLESSING; CHAKRABARTI, 2009). This methodology encourages the creation and empirical evaluation of a theory or artifact, aiming to produce results applicable in practice. Additionally, DRM emphasizes the iterative nature of the research process, allowing for the improvement of a model through research planning and implementation. DRM comprises four stages: (i) Research Clarification; (ii) Descriptive Study I; (iii) Prescriptive Study; and (iv) Descriptive Study II.

Stage (i) was addressed in section 1.1 of this dissertation, wherein an initial literature review allowed for the understanding of the context and justification of the theme to be explored. This stage has as its primary output a clear definition of the study's objectives.

Stage (ii) accounts for the work presented in Article 1, wherein an SLR allowed for the identification of techniques, trends, barriers, and research opportunities on food safety-driven process development, laying the ground for the elaboration of a process improvement model.

Stage (iii) was approached in Article 2. Food safety practices for different levels of maturity of a company were collected through two Delphi rounds with experts in the field. An additional round was performed for practice prioritization. Identified practices were translated into a questionnaire to assess the current food safety maturity of a company’s processes. Furthermore, a prescriptive model was developed, wherein strategies for process improvement are suggested to the company based on the questionnaire results, drawing from the insights obtained in the previous stage.

Stage (iv) is also addressed in Article 2, wherein the proposed model was tested in three case studies with food producers in Brazil. This allowed to obtain an overview of the current maturity level of these companies, observing how they tailor food safety practices to fit their specific operational contexts. Moreover, it was possible to identify limitations and opportunities for improvement of the proposed model.

The combination of different qualitative approaches, such as systematic literature reviews, expert interviews, and case studies supports a comprehensive understanding of the research problem. The proposal follows a methodological procedure to ensure that the outcomes can be further applied within the food safety sector. This approach incorporates industrial insights into the development of tools for improving food processing.

1.5 Study delimitations

Regarding the object of analysis, study scope delimitations include the geographical context of interviewed experts and studied companies (Brazil), not comprising countries with different social and economic contexts. In this sense, the tool is intended primarily for use within similar geographical contexts. It may need further adaptation for different settings, such as in countries with stricter food safety policies, wherein it may be necessary to review maturity levels to better represent the local regulatory scenario.

Regarding data sources, the performed literature review was directed to sources of the extant academic literature, which excludes food safety-driven techniques and practices available in commercial materials and private websites. The model was tested in a case study approach, which limited the number of participating companies but enabled a more in-depth evaluation of each application. Further studies may focus on applying the tool to a broader range of companies and employing indicators for its validation.

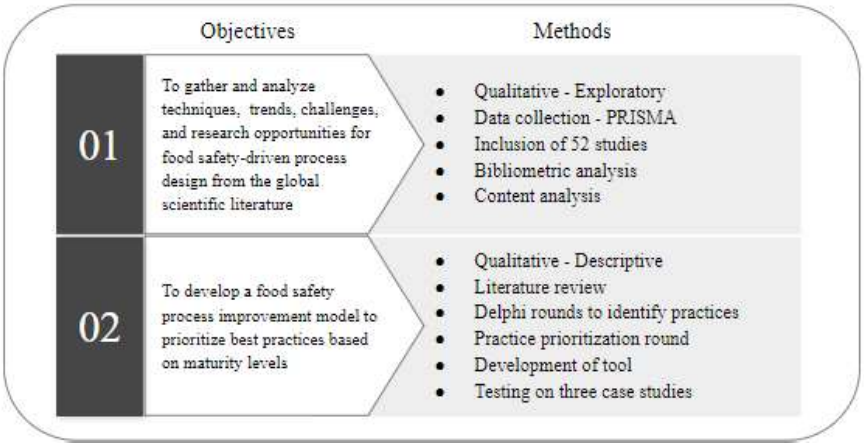
It is emphasized that this dissertation is not exempt from any limitations and does not intend to be exhaustive on the topic covered, as it was based on defined research strategies, databases, and exclusion criteria to approach the proposed research questions.

1.6 Dissertation structure

This dissertation is organized into two articles, as presented in Fig. 2. Chapter 2 presents Article 1, entitled “Towards food safety-driven process design: A systematic review and research agenda,” which was submitted to the journal Critical Reviews in Food Science and Nutrition and is currently under review (status: “with editor”). Chapter 3 presents Article 2,

entitled “A novel model to measure food safety process maturity and prioritize best practices to improve food processes,” to be submitted to the journal Food Control.

Figure 2. Dissertation structure.



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4 FINAL CONSIDERATIONS

In this chapter, the main practical and academic contributions of this dissertation are presented and discussed, along with suggestions for future research on the proposed theme. The general aim of this dissertation was to develop a model to guide companies in the adoption of practices for enhancing food safety in processes. Thus, following the steps of the Design Research Methodology, this dissertation was developed through two articles.

In Article 1 (Chapter 2), the objective was to to gather and analyze design techniques, trends, challenges, and research opportunities for food safety-driven process development. Through a systematic literature review, the results of research and empirical studies were compiled, generating a valuable source of information for food producers who desire to bring the food safety of their processes to the next level. This study provided a bibliometric analysis of the sample, wherein three motor themes and one niche theme were highlighted, giving insight of how assessment, modeling and traceability techniques are being widely used on the field. The content analysis pointed out to the research gap of a holistic model for food-safety oriented process improvement. The collection of relevant practices served as basis for providing recommendations in the subsequently developed model.

Furthermore, Article 2 (Chapter 3) aimed to develop a food safety process improvement model to prioritize best practices based on maturity levels. The model was tested in three food producers, which found the results helpful to their current challenges and proposed improvements to enhance its applicability and scope. The findings suggest that companies may pursue higher maturity levels reactively. The novel model, which proposes proactively planning interventions for food safety maturity progression, could minimize rework and enhance the sustainability of businesses.

In summary, based on the results found in the two developed articles, it can be considered that the two specific objectives proposed in this dissertation were achieved. The results may guide companies in the adoption of practices for enhancing food safety in processes. The guiding research questions were addressed in chapters 2 and 3, which present the elaborated articles.

4.1 Main contributions

The main contributions of this dissertation have both theoretical and practical aspects. Theoretical contributions include an overview of the current research on the field; an analysis of design techniques following the themes of the Codex Alimentarius GHP; and a research agenda for new developments in the field. Furthermore, this research fills the gap for a food safety-driven model for process improvement that encompasses all main themes of the Codex Alimentarius GHP, which may support new developments towards the evolution of FSMSs.

As for practical contributions, this study provides a repository of techniques that companies may select for adoption, as well as a compilation of trends, barriers and research opportunities to be addressed. This research also provides a ready-to-use model to support companies in progressing from an initial process up to a smart integrated FSMS. Additionally, this study provides motivation for new research on the field of food safety-driven process development. A relevant implication of this study is bringing a novel perspective for FSMS models, extending beyond the diagnosis of systems to suggest a prioritization of practices and intervention plan. This enables sequential, incremental enhancements, laying the ground for substantial improvements. The iterative use of the tool may also generate a history of the FSMS implementation through time, preventing the regression into less mature food safety levels.

4.2 Suggestions for future studies

Although the results achieved in this dissertation have been considered satisfactory, one of the limitations encountered was not assessing the context factors of food producers, such as product risk, organizational risk and environment risk. Therefore, one of the opportunities for future work is including context factors assessment into the proposel model, which may draw from existing models in the food sector. This may aid companies in better defining which is the desired maturity level to be achieved in their context. Additionally, this study focused on food producers with already established companies, but it may also be useful for companies during conception phase.

As technologies advance, recommended practices should undergo periodic revision, to match the evolvement of technologies and FSMSs. As a further research opportunity, with the model's implementation in companies and the accumulation of learning from an expanded case repository, a recommendation system may be developed. Algorithms could be used to identify suitable practices, according to the company’s profile and maturity. By analyzing patterns in the data, the model could make tailored suggestions, considering the unique characteristics of

each company. This approach ensures that recommended practices are not only applicable but also remain updated, supporting the continuous improvement of food safety processes.

Future research may advance the topic studied in this dissertation. While Article 1 presents a research agenda for future studies, Article 2 presents a model that may be validated with a broader set of companies from various sectors of the food industry, and adapted to different contexts and challenges. We hope that this research may bring a fresh outlook into the development of FSMSs with more integrated, proactive approaches.