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Implementation of Environmental Monitoring Programs in Food Processing Plants in Colombia

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Abstract: To prevent cross contamination of food, in those environments with microbial sensitivity, it is suggested to designing an environmental monitoring program (PMA) in food processing plants. The safety control is given by monitoring raw materials and product processing; however, environmental monitoring in the plant, process areas, surroundings and anything that may cause cross contamination is ignored. In the current context of food exports, Colombian food producers face international regulations such as the FDA's FSMA (Food Safety Modernization Law), whose purpose is for the industry to use measures to prevent contamination in food. The methodology for the design of the guide was carried out in 4 phases: bibliometric review, a survey of requirements for food processing plants, design of sampling plans and creation of the manual for environmental monitoring programs. The analysis of results is a documentary and procedural guide with: logistical, microbiological and chemical requirements for the characterization of food risks in the plant; a sampling plan according to the requirements established in the food industry, according to its classification by zones and a work methodology with the plan. The implementation of this improvement plan will increase the quality of the products, making it new since standardized protocols are established, which can easily be executed in any dairy industry.

Keywords: food, environmental monitoring, guide, program.

哥伦比亚食品加工厂中环境监测计划的实施

摘要：为了防止食物的交叉污染，在那些具有微生物敏感性的环境中，建议设计食品加工厂中的环境监测计划。安全控制是通过监视原材料和产品处理给出的；但是，植物中的环境监测，过程区域，周围环境以及任何可能导致交叉污染的事物都被忽略了。在目前的食品出口背景下，哥伦比亚食品生产商面临国际法规，例如食品药品监督管理局的食品安全现代化法，其目的是使行业采取措施防止食品污染。指南设计的方法是在四个阶段进行的：文献计量审查，对食品加工厂的要求，采样计划的设计以及创建《环境监测计划手册》的调查。结果分析是纪录片和程序指南，其后勤，微生物和化学要求对植物中食物风险的表征进行表征；根据食品行业在食品行业中建立的要求，根据该地区的分类以及该计划的工作方法。该

改进计划的实施将提高产品的质量，这使其成为新的，因为建立了标准化协议，可以在任何乳制品行业中轻松执行。

关键词：食品、环境监测、指南、程序。

1. Introduction

To prevent cross-contamination of food, safeguarding its safety, in those with microbial sensitivity, it is necessary to establish the environmental monitoring programs in food processing plants. Currently, safety control is carried out through basic monitoring of raw materials and product processing; however, the environmental monitoring of the food plants is left aside, which refers not only to the process areas but also to those areas that can significantly influence cross-contamination, as well as the importance of prevention incited by actors as important as the Food Handler [1-5].

The International Commission for Microbiological Specifications for Foods, for its acronym in English ICSMF, in its books: 5- Characteristics of microbial pathogens; 6- Microbial ecology of food products; 2- Sampling methods for microbiological analysis: principles and specific applications; 7- Microbiological analysis in food safety management; 8- Use of data to evaluate process control and product acceptance [6 - 11], direct the management of food processing towards compliance with the safety objectives that they must meet and are the basis in the exercise of inspection, surveillance and control, of the governmental authorities, exercised in Colombia through INVIMA and the departmental health secretaries, especially those considered to be of high microbiological sensitivity, in order to reduce the risk of disease in the population due to consumption of contaminated food, thus impacting public health.

In the current context of economic openness and exports, Colombian food producers face international regulations such as FSMA (Food Safety Modernization Law) of the FDA, where its objective is for the industry to use measures in the prevention of food contamination and not combat it as is regularly done [12].

The correct and efficient application of good manufacturing practices (GMP) programs and hazard analysis and critical control points (HACCP) are essential in the production of food that meets quality and safety parameters..

The FDA Food Modernization Act (FSMA) [12-14] is transforming the food safety system in the United States, breaking the paradigm of implementing corrective measures to mitigate foodborne illnesses preventive and predictive measures, promoting prevention as the engine of continuous improvement.

The United States Congress enacted the FSMA as preventive measures to the current changes in the world food system and, therefore, to foodborne diseases and the consequences that involve human life, affecting the food value chain. in technological, financial and environmental aspects.

The Manual [1] entitled ENVIRONMENTAL MONITORING MANUAL FOR THE FOOD AND BEVERAGE INDUSTRIES provides a peer-reviewed study by Cornell University and 3M Food Safety, offering strategies accompanied by 3M technologies to achieve effective implementation, transforming the monitoring of corrective food tests on raw materials and final products to preventive measures mitigating negative impacts on the processes, using as an example a food company in the United States, suggests relevant guidance for the implementation of an environmental monitoring plan.

The NTC 5230 standard, specific according to ICONTEC [15], SPANISH [16], a horizontal method for sampling techniques used to determine the presence of microorganisms on work surfaces, utensils and various equipments present in the food chain (process areas), allows determine the degree of contamination of said environment. This standard is essential for evaluating sampling areas of process areas, as well as the determination of equipment and surfaces contained in the sampling.

According to [17], considering the findings of the presence of *Listeria monocytogenes* in artisanal fresh cheese from the Department of Quindío. In their study, the presence of this microorganism was detected in 53.6% of the samples analyzed, determining, among other causes, the poor cleaning and disinfection procedures on the different surfaces and the possible cross-contamination with the raw material affecting the final product.

The theoretical and conceptual support elements for this project are supported by national and international regulations, framed in the principles of good manufacturing practices and food safety:

The HACPP (Hazard Analysis and Critical Control Points) system aims to prevent, eliminate, or reduce microbiological, physical and chemical hazards to acceptable levels. Concerning microbiological hazards, in many processes, the critical control points (CCPs) include lethal treatments for the microorganisms of interest: ultra-pasteurization, sterilization, among others, but in foods that are minimally processed, the

CCPs can be based on manipulation and control of factors such as conservation at low temperatures, the reduction of water activity or acidic pH, to control the growth of pathogenic microorganisms [9].

At the international level, the regulation on good manufacturing practices, hazard analysis and risk-based preventive controls for food for human consumption, the Food Safety Modernization Act (FSMA) of the FDA, has the purpose of guaranteeing the manufacture/processing, packaging, and holding of safe food products for human consumption in the United States [18]. Products exported to this country must comply with this regulation.

Several of the problems in a food company corresponding to quality and safety are due to failures in the prerequisite programs supported by good manufacturing practices (GMP), currently legislated in Colombia by resolution 2674 of 2013 [19]. Usually, these faults are found in the environment of the processing plants or near them, for which it is necessary to assess the danger, establish the hygienic zoning of the Plant, the latter determined by the level of risk of cross-contamination of the product and the sampling areas of the process lines [2].

According to the environmental monitoring manual for the food and beverage industries [1]:

The failures are due to the lack of validation and verification of the prerequisite programs, particularly the sanitation program. Examples of food safety and quality problems caused by prerequisite program failures include listeriosis outbreaks associated with ready-to-eat foods, where contamination could be traced to locations in the plant environment. elaboration. This occurs in growth niches where *Listeria monocytogenes* could survive over time and contaminate the finished product.

The environmental monitoring programs (PMA) aim to validate and verify the effectiveness of sanitary controls, for which it is necessary to form an interdisciplinary team to identify those "blind" points in which pathogenic microorganisms can be harbored, or alterations in the products depending on the characteristics of the production process.

The PMAs cover several programs such as ATP Bioluminescence, allergenic protein residues, indicator microorganisms, pathogens and altering or deteriorating microorganisms that, through a sampling plan that describes the points, frequencies and validations of the same, can be evaluated the different surfaces of the hygienic areas of the processing plant [1].

The hygienic zoning of the processing plant is critical since it defines the requirements of each area, considering the risk of product contamination. Therefore, it is necessary to identify and classify the areas depending on their level of risk [20]:

The main environmental pathogenic

microorganisms to evaluate in a processing plant are: *Listeria* spp and *Salmonella* spp [6].

The indicator microorganisms, although they are not pathogenic, do indicate their possible presence in the process and food areas; additionally, they reveal the effectiveness of cleaning and disinfection programs, among these microorganisms we find Enterobacteria, Total Coliforms and *E. coli*; an example of the above is that Enterobacteriaceae can be used as an indicator of the presence of *Salmonella* in the poultry industry [7].

A preventive approach that allows validating, verifying, or monitoring the proper implementation of Good Manufacturing Practices and Food Safety or HACCP Plans through tests in the food processing environment, can help identify and correct potential problems before they occur. that they become an important impact that threatens public health or implies a withdrawal of the product from the market, negatively affecting the image of the processing company [21]. Therefore, the current article specifies the different items that an environmental monitoring program contemplates in food processing plants.

2. Materials and Methods

2.1. Methodological Design

The development of the research is presented in the following flowchart, shown in Figure 1.

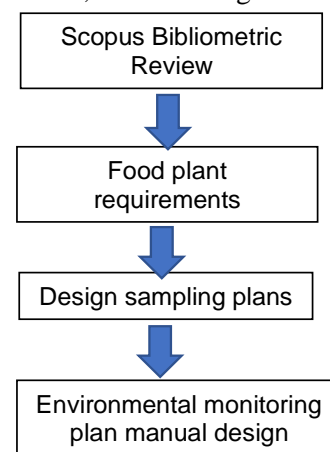


Fig. 1 Methodological diagram

2.1.1. Phase 1

Inquiry and documentation of conceptual and application information of environmental monitoring plans, supported by specialized databases.

2.1.2. Phase 2

The work areas required for the preparation of sampling procedures are established according to the physical and operational characteristics of the plant processes [9].

2.1.3. Phase 3

The following will be defined: the sampling areas, the methods or procedures to prevent them from being

affected by procedures and materials used in cleaning and disinfection processes, the specification of materials, elements and equipment used. Figure 2 shows the classification by zones.

2.1.4. Phase 4

It is intended to prepare a guide document that specifies the use of activities with the allocation of resources by work areas, as well as the use of sampling methods, materials and equipment to consolidate an environmental monitoring plan in food plants.

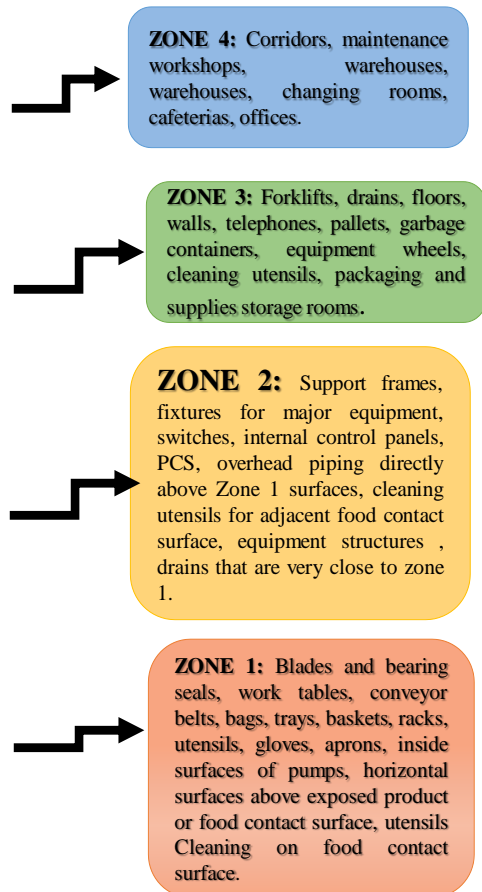


Fig. 2 Classification by zones

3. Results and Discussion

3.1. Bibliometric Analysis

Table 1 shows the bibliometric analysis carried out descriptively, where a numerical distribution of the bibliography consulted for the preparation of the degree work was carried out [22, 23].

Table 1 Descriptive bibliometric analysis

Category/Years	2000–2010	2010–2022
Articles in indexed magazine		10
Degree and thesis work	7	
Opinion articles	1	4
Reflection articles		3
Brief communications and notes		3
Books	5	3
National-international regulations	1	5
Total	14	28

Figure 3 shows the descriptive and analytical analysis around the bibliographic reviews consulted.

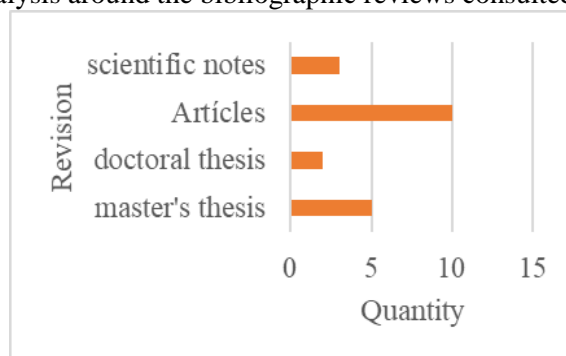


Fig. 3 Bibliometric analysis

Of the theses consulted, two are doctoral and the rest are master's.

- 10 articles from indexed journals related to the line of food science were investigated, being the most relevant.
- The books consulted cover implementations and conceptualizations of the HACCP system, Food Safety, among others.
- The opinion articles are related to options and suggestions about the concepts that should be known about an environmental monitoring program and some examples of how to implement them.
- The notes category contains two implementation manuals for environmental monitoring programs from companies such as Almond and 3M.

Regarding the current regulations, it was reviewed both nationally and internationally, showing the most relevant results in Figure 4.

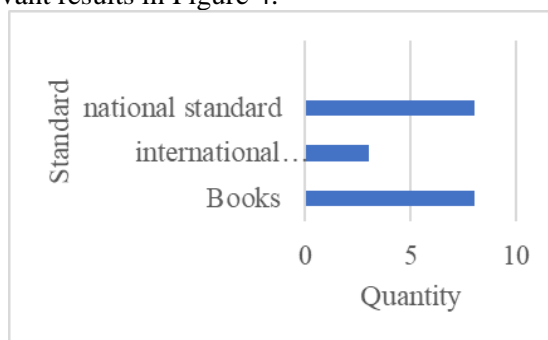


Fig. 4 Valid normative

3.2. Survey of the Requirements for Food Processing Plants

The logistical, technical (chemical and microbiological) requirements to establish the work areas required in the elaboration of sampling procedures according to the physical and operational characteristics of the processes in food production plants [1, 2], must be determined. according to the risk level of the food groups. To limit these risks, the following must be carried out as the first step.

3.2.1. Determination of the Work Team for the PMA

This kit must include:

- Managerial level responsible for quality control of the processing plant (preferably bacteriologist or microbiologist)
- Maintenance staff
- Production personnel responsible for the process areas in the plant
- Equipment and process operators
- Personnel responsible for sanitizing the plant and nearby areas.

The determination of the team is fundamental for the determination of responsibilities, zoning of the areas and determination of the sampling points of interest in the development of the PMA. It is important to determine the work team because a preventive quality culture must be generated in the interdisciplinary team, focused on validating the effectiveness of the frequencies of the cleaning and disinfection processes and interventions, and in the programs that support good manufacturing practices. This allows the microorganisms that are established within the production line to be systematically located, acting as a source of contamination [1, 2, 24, 25].

3.2.2. PMA Relationship with the HACCP System

This relationship is important because the identified safety hazards and the corrective actions obtained as a strategy to mitigate the hazards affecting food safety must be linked [20, 26]. Some of these reasons are important:

- Determination of possible indicator, altering, or pathogenic microorganisms in the process areas of the food industry.
- Definition of critical points to prevent microbiological hazards in places and surfaces in contact with final products and raw materials. Each food industry will have different microbiological hazard points, each case must be analyzed according to the nature or specificity of the process.

- Include tests that verify the effectiveness of the cleaning and disinfection processes in controlling indicator organisms and any other particular organisms.

However, three types of monitoring must be specified to adjust the plan with the frequency monitoring that needs to be implemented in the plant:

- Research monitoring. It is carried out to detect or identify the critical areas of the line, process, or the installation, with the greatest risk of contamination.
- Routine monitoring. It is the monitoring at certain frequencies of points of greatest danger that have been determined in the research monitoring, plus some control points. This type of monitoring allows preventive measures to be taken in each season and to management the history of the facilities.

- Sanitization monitoring. It allows verifying the quality of cleaning and disinfection, in addition to validating the effectiveness of the sanitization plan.

In Figure 5, the PMA is related to the HACCP

system of a food plant.

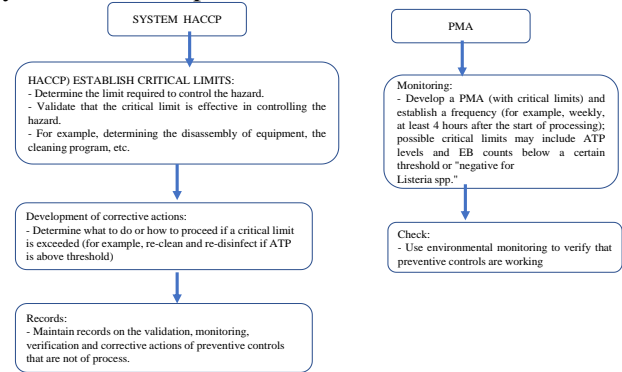


Fig. 5 PMA relationship - HACCP system

3.2.3. Design of Sampling Plans

To establish these work zones, activities such as:

- Preparation and/or review of plans and process flow diagrams, indicating potential areas of contamination by pathogens.
- Accompany the previous activity with on-site reviews of the demarcated process areas to verify and contrast potential hazards with Operators and Supervisors of process areas; this could be accompanied, for example, by a checklist of potential hazards or another record to collect possible findings that also allow their respective analysis.

Finally, based on the bibliography consulted on environmental monitoring plans and pathogenic microorganisms that can generate episodes of contamination in food, the zones must be defined according to the level of risk. Figure 6 shows the zoning of the processing plant, which is different from the hygienic zoning, important because it defines the requirements of each area, considering the risk of contamination of the product. Therefore, it is necessary to identify and classify the areas depending on their level of risk.

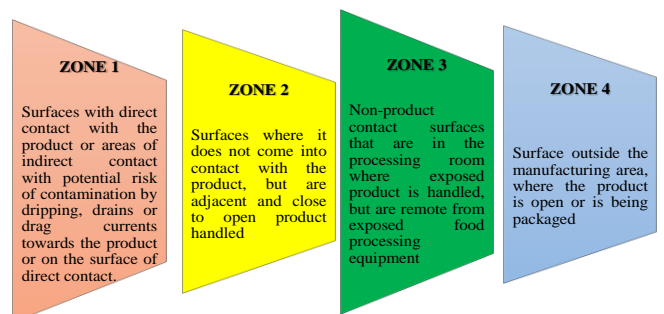


Fig. 6 Classification by zones

Sampling in the process areas previously defined in plans or flow diagrams clearly defines the processing areas where the preventive measures will be applied. This defines a working map for sampling, where points obtained from zones 1 and 2 provide data that can be used to detect a loss of process control or conditions that can lead to product contamination [27].

It can also be used to define the appropriate execution times in the different process lines and to

support the safety of processes with long execution times. Additionally, the indicator tests at points in zones 1 and 2 represent a method to monitor equipment conditions and establish the frequency of preventive and/or predictive maintenance. Reference may be made to cases where trends in the presence of a greater number of indicator microorganisms in certain places will point to the need to replace parts in equipment that generally show wear in rotating work-in-process shifts. When evaluating the sources of elevated levels of indicator microorganisms, it is also important to consider that any independent activity outside the process flow of the products may be occurring in the facilities (civil and/or electromechanical works, implementation of projects aimed at the elaboration of new products in an adjacent line, etc.) [28].

The monitoring of the other areas also helps reviewing exogenous preventive measures that do not allow the generation of external factors that can become internal risks due to various factors of food contamination.

Sampling frequency should be based on risk, depending on factors such as the type of product being produced (ready-to-eat, ready-to-cook, raw, etc.), its microbial susceptibility, the microbial load of ingredients, raw materials and inputs, the level of risk during each phase of the process and other considerations specific to the production environment, such as the microbial lethality of the production process, the frequency of sanitation or the potential for cross-contamination. An approach based on the selection of samples taken according to the level of risk should allow checking only a part of the available sampling points in the area and even then it should be possible to verify the control of the environment or the sanitation procedures.

When microbiological controls are used to verify the effectiveness of cleaning and disinfection, sampling should be carried out after each sanitation cycle and before production start-up, to assess the trend of the results and for the early identification of problems.

If production equipment is complex or contains hard-to-reach areas, it may also be useful to take samples while the equipment is not running, before food processing begins.

Certain equipment (for example, conveyor belts) must be used for a certain time before sampling. This will increase the likelihood that residual microbial populations left behind after sanitization become accessible for sampling [29].

For each sampling point, the acceptance parameters of indicator or altering microorganisms must be established. These limits can be determined in many ways, either by reference levels or by using historical analysis of available data. After sanitization, it is considered that the level of indicator or spoilage microorganisms on the surface should be low or absent.

If the results are outside the established parameters, it is necessary to implement corrective measures.

Significant deviations in the result of the PMA analysis should lead to a reassessment of the sampling plan and sample collection. Once the corrective actions have been implemented, an additional sampling of the area where the problem has been detected must be carried out, to guarantee the effectiveness of these [30, 31].

It should not be forgotten that the objective of sampling is to search for, reduce and/or eliminate the presence of microorganisms on surfaces, especially pathogens or indicator microorganisms [32].

Therefore, this sampling must be carried out in relatively large, strategic areas and in places where the investigative sampling has shown us that they are of greater danger and incidence, such as:

- Large surfaces such as conveyor belts, hoppers, tanks, filling tables, the sample must be taken using 10x10 cm templates as a reference, although for large surfaces, the optimum is to take from 30x30 centimeters.

- On irregular or small surfaces, a novel alternative is the rinse water for analysis. Additionally, the use of sampling material such as swabs is effective in taking samples from these surfaces.

- For long surfaces (Example: rollers) it may be advisable to repeat the sampling operation on three portions of the same surface along the entire length of the roller.

- For walls, tables and long bands, it is recommended to conduct this operation at 4 different points on the surface, covering a surface of 250 cm² at each point to complete a sampled surface of 1 m².

The sample should preferably be taken with a sponge or "pad," a medium with which it is more likely to extract bacteria that may be adhered to. The horizontal, vertical and diagonal movement scheme must be followed throughout the surface to be sampled (for example, the use of 25x25 cm templates) [33].

To determine the periodicity according to the risk level of each area or zone to be sampled, the matrix in Table 2 can be used.

Table 2 Risk probability matrix

		Probability		
		Under	Medium	High
Gravity	High Zone 1			
	High Zone 2			
	High Zone 3			
	Under Zone 4			

3.3. Creation of the Guide for Environmental Monitoring Programs

In this design stage, a practical guide for the implementation of the environmental monitoring program is prepared and documented, where the use of activities by work zones is specified, as well as the use

of sampling methods, materials, and equipment that plants can adapt, food, also based on the recommendations of [34, 35], as also stated in Figure 7.

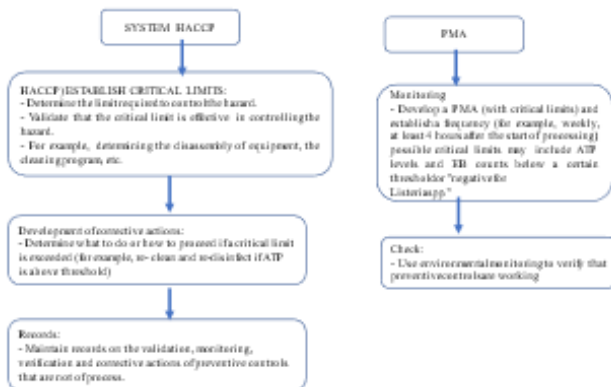


Fig. 7 Basic structure of the PMA guide

4. Conclusions

The main finding is that the environmental monitoring program (PMA) becomes the communication bridge between customer satisfaction and food safety, presenting them in a union of trust to offer the market competitive products with the added value of the quality as the support of food safety.

This reflects in the processing plants, as in the case of our region and country, strategic opportunities to enter local markets with protective food safety barriers supported by international regulations renewed at annual frequencies in terms of food processing.

When analyzing with other similar studies, cost savings were found in the process because a PMA helps optimize plant operations and therefore to work with a risk-based approach, allowing rapid preventive and systemic detection of food safety problems in the plant. Also, improving relationships with suppliers, promoting innovation in the work team, generating a perception in the community of quality, safety and reliability.

A PMA guide implies a baseline in itself that allows comparing the effectiveness of the strategies implemented in processing plants with respect to their good manufacturing practices, validating the effectiveness and efficiency of human resource training, the proper use of cleaning techniques and disinfection, as well as other operational methods in the plant.

As a strength, there are positive consequences for the lessons learned aimed at mitigating microbiological contaminants through corrective, preventive and improvement actions combined with the experience of human resources in the plant, promoting a culture of quality based on the identification of deficiencies, in the strategies implemented in the PMA.

As research limitations, the identification and development of new action methodologies aimed at strengthening safety in the processes and stages of supply and distribution of safe products and raw

materials must be analyzed in studies in any food industry.

It is recommended to continue with the implementation of this type of management plans, which favors safety and opens up future lines of R&D in food processes.

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