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Diagnosis of hygiene practices and food safety constraints within the agri-food industries of the Bamako district, Mali

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ABSTRACT

Food safety is a major public health and socio-economic development issue. The agri-food industry (AFI) in Bamako and its surrounding areas impacts GDP, employment, and consumer health. Non-compliant products lead to serious health risks and economic losses (absenteeism, healthcare costs). AFI companies must ensure self-monitoring and risk management at all stages of production and marketing. This study identifies the food safety constraints limiting the production of quality food and proposes avenues for improvement. To achieve this objective, an evaluation was conducted with 187 AFI companies using a questionnaire administered to directors, quality managers, and employees. Indicators included: regulatory knowledge, quality policy, infrastructure (premises, equipment), staff monitoring (medical check-ups, training), waste management, finished product testing (external laboratory), traceability, and product withdrawals/recalls. The results reveal widespread non-compliance. 58.82% of companies lack suitable buildings to prevent cross-contamination; 50.80% do not conduct medical examinations for their staff. 91.44% lack quality certification; 69.96% lack regulatory frameworks; 52.94% lack a formalized quality policy. 81.82% lack external control of finished products; 85.56% lack a withdrawal/recall system; and 80.21% lack traceability. These shortcomings require regulatory strengthening, training, and technical support to secure the food chain and promote sustainable development.

Keywords: Food safety, Food industry constraints, Food, Bamako and surrounding areas

1. Introduction

Globally, food safety represents a major public health challenge. The consumption of substandard food directly threatens the health of millions of people. It is estimated that approximately 600 million people fall ill each year as a result of consuming contaminated or spoiled food (Sankara et al., 2024) [1]. This health crisis places a heavy burden on healthcare systems, reduces economic productivity, and hinders overall socioeconomic development, trade, and tourism (FAO and WHO, 2018) [2].

According to World Bank data, annual production losses due to these illnesses in low- and middle-income countries amount to $95.2 billion, while the annual cost of medical treatment is estimated at $15 billion [3]. More than 200 diseases, ranging from acute diarrheal syndromes to oncological conditions, are directly caused by the ingestion of food contaminated with biological agents (bacteria, viruses, parasites) or chemical substances such as heavy metals (WHO, 2024) [3]. Although gastrointestinal symptoms predominate, severe neurological, gynecological, and immunological manifestations are also documented. Furthermore, the

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burden of disease associated with diarrheal illnesses is disproportionately borne by middle-income countries and by children under 5 years of age (GOUE, 2017) [4].

In recent years, Mali has witnessed the emergence of numerous very small, small, and medium-sized agri-food industries (AFIs). This sector plays a leading role in job creation and income generation, and contributes operationally to the national economic development policy. Local processing of agricultural products is a crucial link in the sustainability of food systems, ensuring year-round food supplies. Furthermore, it reduces post-harvest losses, increases food availability, and extends shelf life, thus establishing itself as a powerful factor in regulating the agricultural market to guarantee food and nutritional security (FAO, European Union, and CIRAD, 2022) [5].

The Malian agri-food industry is therefore a major economic pillar due to its significant contribution to the Gross Domestic Product (GDP), exports, and the social fabric. However, this dynamic faces the critical challenge of the distribution of products that may not comply with national and international health standards. Food safety—understood as the absence of contaminants, adulterants, or toxins that could render food harmful to health, whether acutely or chronically—is now a key factor directly influencing the profitability and sustainability of small and medium-sized enterprises (SMEs) in this sector.

In this era of globalization, ensuring the safety and wholesomeness of food products is more crucial than ever for all countries. Eliminating or controlling food risks at the source (a preventative approach) is indeed more effective and less expensive than controlling the finished product (verifying final quality) for reducing or eliminating the risk of adverse health impacts, particularly on human health.

For its part, ensuring the microbiological quality of food aims to prevent or limit the presence and proliferation, within the food matrix, of bacteria that are pathogenic to humans, as well as spoilage bacteria [6].

The development of the agri-food sector depends on establishing a relationship of trust between businesses and consumers. To build this trust, consumers primarily demand the safety and wholesomeness of the product offered for sale, meaning the assurance that the food will not cause any harm to their health. To this end, a multitude of standards and frameworks, both private and intergovernmental, have emerged to specify the required conditions within production facilities. These standards include ISO 22000, IFS (International Featured Standards), BRC (British Retail Consortium), HACCP, AIB (American Institute of Baking), and PIAQ (Integrated Quality Improvement Program). In recent years, these private frameworks have become increasingly important in the overall governance of the agri-food chain [7].

Among these tools, the HACCP (Hazard Analysis Critical Control Point) system is an excellent way to ensure customer satisfaction and combat food poisoning. This food safety management protocol is recognized by the international community as the global guideline for controlling foodborne hazards [8]. It is a dynamic tool that allows for hazard assessment and the implementation of control systems focused on prevention rather than on analyzing the finished

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product. Any HACCP system must be able to evolve and take into account progress made, particularly in equipment design, processing methods, and technological innovations [9].

Although the international regulatory framework is clearly defined, the effective application of these preventive standards remains a complex challenge for developing food processing industries, particularly at the local level where structural, technical, and financial constraints are numerous.

Our research is situated within this global context. The overall objective of this study is to identify, evaluate and analyze the critical constraints that hinder the food safety of products from the agri-food industries in the Bamako district.

2. Methodology

The study population consisted of dairy units, bakeries, juice production units, and restaurants. To maximize the comprehensiveness of the sampling frame, it was established by cross-referencing lists from the National Directorate of Industry (DNI), the Center for Agri-Food Development (CDA), the National Federation of Processors (FENATRA), the NGO CAB DEMESO, and data from our own research on the agri-food industries (AFI).

From this consolidated database, simple random sampling was applied to select a sample of 100 bakeries, 100 restaurants, 80 dairy units, and 50 juice production units for survey. A total of 187 units responded to the questionnaire out of a total of 330 units (response rate of 56.66%).

A standardized and structured questionnaire was developed in accordance with the General Principles of Hygiene (GPH) and food safety standards. This questionnaire aimed to assess the compliance of practices within the selected units.

The survey was conducted through direct (face-to-face) interviews with key respondents qualified to represent the establishment: promoters, quality managers, or managers.

The raw data collected were centralized, coded, and entered. Statistical processing and descriptive analysis of the data were performed using Microsoft Excel and R software.

3. Results and Discussion

We collected a significant volume of data on food safety from the agri-food industries (AFI) in the Bamako district and surrounding areas.

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We collected a significant volume of data on food safety from the agri-food industries (AFI) in the Bamako district and surrounding areas.

3.1. Analysis of Survey Data

3.1.1. Availability of Regulatory and Legislative Texts

Of the 187 companies surveyed, 114 (60.96%) did not have the Malian regulatory and legislative texts for their sector. Conversely, 74 companies (39.04%) did.

Bakeries and pastry shops had the worst rate: 54 companies (98.18%) did not have these documents, compared to only 1 company (1.82%) that did.

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Dairy industries were the most compliant: 49 companies (84.48%) had the documentation, while 9 companies (15.52%) lacked it.

Restaurants show a significant gap: 34 restaurants (85%) do not have the required documentation, while only 6 (15%) do. The juice industry is split 50-50: half have the documentation, and half do not.

3.1.2. Availability of a Food Safety Quality Policy

Of the 187 companies surveyed, 99 (52.94%) do not have a formal food safety quality policy. Conversely, 88 (47.06%) do.

Dairy companies lead the way: 43 (74.14%) have a quality policy, compared to 15 (25.86%) that do not.

Bakeries and pastry shops have the worst rate: 44 (80%) do not have a formal policy, compared to 11 (20%) that do.

Restaurants show a significant shortfall: 24 (60%) do not have one, while 16 (40%) do.

Juice companies are slightly in the majority: 18 (52.94%) have one, compared to 16 (47.06%) that do not.

3.1.3. Availability of GMP, GHP, and GLP Guides in Your Sector

Of the 187 companies surveyed, 116 (62.03%) have Good Manufacturing Practices (GMP), Hygiene Practices (GHP), and Laboratory Practices (GLP) guides. Conversely, 71 (37.97%) do not.

Bakeries and pastry shops show full compliance: 55 (100%) have these guides.

Juice industries have a high rate: 22 (64.71%) have them, compared to 12 (35.29%) that do not.

Dairy industries show a shortage: 35 (60.34%) do not have the guides, while 23 (39.66%) do.

Restaurants present a similar shortage: 24 (60%) do not have them, compared to 16 (40%) that do.

3.1.4. Availability of a Quality Certificate

Of the 187 companies surveyed, 171 (91.44%) do not hold any quality certification. Only 16 (8.56%) have at least one.

Bakeries and pastry shops show a complete absence: 55 (100%) are not certified.

Restaurants follow closely behind: 38 (95%) are not certified, compared to 2 (5%) that are.

Dairy industries have a low rate: 6 (10.34%) are certified, while 52 (89.66%) are not.

Juice industries have the highest rate: 8 (23.53%) are certified, compared to 26 (76.47%) that are not.

3.1.5. Availability of Raw Material Specifications

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Of the 187 companies surveyed, 139 (74.33%) have specifications for their raw materials. Conversely, 48 (25.67%) do not.

Bakeries and pastry shops excel: 54 (98.18%) have this document.

Restaurants follow closely behind: 34 (85%) have them.

Juice industries are moderately formalized: 20 (58.82%) have specifications.

Dairy industries have the worst rate: only 31 (53.45%) have them, compared to 27 (46.55%) that source their raw materials without specifications.

3.1.6. Availability of Contracts with Suppliers

Of the 187 companies surveyed, 120 (64.17%) do not have formal contracts with their suppliers. Only 67 (35.83%) have one.

Dairy businesses have the worst rate: 46 (79.31%) operate without a contract.

Bakeries and pastry shops follow: 40 (72.73%) lack formalization.

Restaurants are the most formalized: 22 (55%) have a contract.

Juice producers are close behind: 18 (52.94%) have a contract.

3.1.7. Availability of a building to prevent cross-contamination

Of the 187 companies surveyed, 110 (58.82%) do not have facilities that effectively prevent cross-contamination. Only 77 (41.18%) have a compliant building.

Juice processing plants are the best structured: 29 (85.29%) have a suitable design, the highest rate.

Bakeries and pastry shops pose a problem: 51 (92.73%) lack adequate facilities, presenting a major health risk.

Restaurants show a deficiency: 22 (55%) have an inappropriate design.

Dairy processing plants are not far behind: 32 (55.17%) do not comply with this requirement.

3.1.8. Availability of a Waste Management Plan

Of the 187 companies surveyed, 109 (58.29%) have a waste management system. Conversely, 78 (41.71%) do not.

Juice processing companies show near-total compliance: 33 (97.06%) have such a system, the highest rate.

Dairy companies are also well-equipped: 50 (86.21%) have formalized their waste management. Restaurants largely adopt this practice: 26 (65%) have one. Bakeries and pastry shops are lacking: 55 (100%) have no formalized system.

3.1.9. Availability of materials/equipment made with smooth, corrosion-resistant surfaces

Of the 187 companies surveyed, 157 (83.96%) have smooth, corrosion-resistant materials and equipment. Only 30 (16.04%) lack them.

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Bakeries and pastry shops show full compliance: 100% have equipment suitable for cleaning and hygiene.

Juice processing companies maintain a high level of compliance: 31 (91.18%) are compliant.

Restaurants are well-equipped: 31 (77.5%) have compliant equipment, compared to 9 (22.5%) that do not.

Dairy companies have the worst rate: 18 (31.03%) have non-compliant equipment.

3.1.10. Existence of Medical Examinations for Staff in Contact with Products

Of the 187 companies surveyed, 95 (50.80%) do not conduct medical examinations for staff in contact with products. Conversely, 92 (49.20%) do.

Bakeries and pastry shops apply this measure almost systematically: 53 (96.36%) conduct medical examinations, the highest rate.

Juice processing companies show the worst rate: 29 (85.29%) do not conduct these checks, compared to 5 (14.71%) that do.

In the dairy industry, 39 (67.24%) do not conduct the examinations, while 19 (32.76%) do.

Restaurants show a similar shortfall: 25 (62.5%) do not, compared to 15 (37.5%) that comply.

3.1.11. Application of GHP and GMP Measures

Of the 187 companies surveyed, 175 (94.59%) effectively apply Good Hygiene Practices (GHP) and Good Manufacturing Practices (GMP). Only 10 (5.41%) do not implement them.

Bakeries and pastry shops achieve near-perfect compliance: 100% apply these measures.

Juice processing companies are almost perfect: 33 (97.06%) are compliant.

Restaurants follow closely behind: 37 (92.5%) apply GHP and GMP.

Dairy processing companies have the most deficiencies: 6 (10.71%) do not implement them, compared to 50 (89.29%) that do.

3.1.12. Availability of a suitable handwashing station

Of the 187 companies surveyed, 101 (54.01%) have a suitable handwashing station. Conversely, 86 (45.99%) lack one.

Bakeries and pastry shops show a complete deficiency: 100% do not have a suitable station.

Juice processing companies excel: 31 (91.18%) are compliant.

Restaurants are well-equipped: 31 (77.5%) have a suitable station.

Dairy companies follow: 39 (67.24%) have one, compared to 19 (32.76%) that lack one.

3.1.13. Staff training on quality

Of the 187 companies surveyed, 130 (69.52%) have trained their staff on quality. Conversely, 57 (30.48%) did not.

Bakeries and pastry shops excel: 100% have trained all their staff.

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Restaurants follow closely behind: 32 (80%) have provided quality training.

Juice industries show a majority: 19 (55.88%) have trained their staff.

Dairy industries have the worst rate: 34 (58.62%) have not trained their staff, compared to 24 (41.38%) that have.

3.1.14. Availability of a Quality Manager

Of the 187 companies surveyed, 131 (70.05%) have appointed a Food Safety Quality Manager. Conversely, 56 (29.95%) do not.

Bakeries and pastry shops are fully compliant: 100% have appointed this manager.

Juice processing companies follow suit: 28 (82.35%) have a dedicated manager.

Restaurants are also well-organized: 32 (80%) have a dedicated manager.

Dairy processing companies lag significantly behind: 42 (72.41%) do not have one, compared to only 16 (27.59%) that do.

3.1.15. Identification of Potential Hazards Related to Production

Of the 187 companies surveyed, 166 (88.77%) identified the hazards related to their production process. Only 21 (11.23%) did not.

Bakeries and pastry shops excel: 100% carried out this identification.

Juice processing companies confirm this high level: 33 (97.06%) are compliant.

Restaurants follow closely behind: 35 (87.5%) have identified the risks.

Dairy industries are the least advanced: 15 (25.86%) have not identified the hazards, compared to 43 (74.14%) who have.

3.1.16. Implementation of Measures to Prevent Potential Hazards

Of the 187 companies surveyed, 167 (89.30%) have measures in place to prevent and control potential hazards. Only 20 (10.70%) do not.

Bakeries and pastry shops are fully compliant: 100% implement these measures.

Juice processing companies also excel: 32 (94.12%) have such measures in place.

Restaurants follow closely behind: 34 (85%) have formalized measures.

Dairy companies have more deficiencies: 12 (20.79%) do not have such measures, compared to 46 (79.31%) that do.

3.1.17. Existence of an Internal Laboratory for Finished Product Testing

Of the 187 companies surveyed, 172 (91.98%) do not have an internal laboratory for testing finished products. Only 15 (8.02%) have one.

Bakeries and restaurants are completely lacking in this area: 100% do not have an in-house laboratory, which is common for SMEs.

Dairy industries show the best capacity for self-monitoring: 13 (22.41%) have one, compared to 45 (77.59%) that do not.

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Juice industries have a very low rate: only 2 (5.88%) have a laboratory, compared to 32 (94.12%) that do not.

3.1.18. External Laboratory Testing of Finished Products

Of the 187 companies surveyed, 153 (81.82%) do not have their finished products analyzed by an external laboratory. Only 34 (18.18%) do. Bakeries never use this type of testing: 100% do without it.

Restaurants follow: 37 (92.5%) do not conduct external analyses.

Dairy industries are the most committed: 24 (41.38%) use an external laboratory.

Juice industries have a moderate use of external laboratories: 7 (20.59%) do.

3.1.19. Availability of suitable means of transport for finished products.

Of the 187 companies surveyed, 101 (54.01%) have suitable means of transport for their finished products. Conversely, 86 (45.99%) do not.

Juice industries excel: 25 (73.53%) have appropriate transport.

Dairy industries follow: 36 (62.07%) are adequately equipped.

Restaurants are close behind: 24 (60%) have suitable means of transport.

Bakeries and pastry shops pose a problem: 39 (70.91%) lack adequate transport, compared to 16 (29.09%) who have it.

3.1.20. Existence of a product traceability system

Of the 187 companies surveyed, 150 (80.21%) do not have a traceability system to track their finished products. Only 37 (19.79%) do.

Bakeries and pastry shops are completely without one: 100% lack traceability.

Restaurants follow: 35 (87.5%) do not have a system.

Dairy industries are the most advanced: 22 (37.93%) have a formalized system.

Juice industries have a moderate level of implementation: 10 (29.41%) have one.

3.1.21. Existence of a system for withdrawing/recalling non-compliant products

Of the 187 companies surveyed, 160 (85.56%) do not have a withdrawal or recall procedure. Only 27 (14.44%) have a formalized procedure.

Bakeries and pastry shops are completely lacking: 100% have no procedure.

Restaurants follow: 34 (85%) do not have a system for non-compliant products.

Juice industries are the most proactive: 9 (26.47%) have a procedure in place.

Dairy industries have a moderate level of implementation: 12 (20.69%) have one.

3.2. Summary of Constraints by Food Industry Category

3.2.1. Bakeries and Pastry Shops

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The survey reveals critical and systemic shortcomings within the bakery and pastry sector, as shown in Table 1. We observed a 100% non-compliance rate regarding the availability of quality certificates, the organization of external testing of finished products by an independent laboratory, and the implementation of a traceability system. This complete lack of evidence and verification mechanisms means that companies are unable to prove the quality of their products and, even more seriously, are unable to manage an effective recall in the event of a health crisis.

Furthermore, the regulatory aspect is almost entirely ignored, with an alarming non-compliance rate of 98.18% concerning knowledge and availability of Food Safety (FS) regulations. This results in a near-total ignorance of the legal framework, which translates into a complete absence of operational verification and crisis management systems.

The supply chain also presents a significant risk: 70.91% of entities are non-compliant regarding the availability of adequate means of transport. This logistical deficiency creates a significant risk of contamination and breaks in the cold chain during product transport.

We observe an extremely high rate of non-compliance concerning premises: 92.73% of establishments have unsuitable premises that do not prevent cross-contamination. This situation poses a major health risk to manufactured products.

This risk is exacerbated by the complete absence of internal quality control. Indeed, 100% of companies do not have an internal laboratory to carry out tests on finished products or raw materials.

3.2.2. Dairy Industries

Our study reveals significant constraints within the dairy industry (Table 2). We observed a non-compliance rate of 89.66% for the availability of a quality certificate. This finding confirms a very low certification rate, despite the formal organization of this sector.

Risk and crisis management is severely compromised: 62.07% of companies do not have a traceability system, and 65.52% do not have an established procedure for recalling non-compliant products. This dual deficiency results in a critical inability to trace the product and remove it from the market in case of a problem, highlighting a near-total ignorance of the legal framework for Food Safety.

Infrastructure and internal controls also present major shortcomings. The majority of companies, 77.59%, do not have an in-house laboratory to carry out essential quality controls. This lack of oversight is compounded by the fact that 72.41% of companies do not employ a dedicated quality manager to supervise these processes.

Furthermore, 55.17% of companies lack suitable premises, increasing the risk of cross-contamination. Health monitoring of staff is also neglected, as 67.24% of companies do not conduct medical examinations for their employees.

Finally, vulnerability to raw material issues is extremely high, since 79.31% of companies do not have a formal contract with their suppliers. This situation indicates that the upstream portion of the milk supply chain is not contractually controlled, exposing the industry to unforeseen risks regarding the quality of its raw materials.

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3.2.3. Juice Production Industries

As shown in Table 3, our study highlights major health constraints within the juice production industry. We observed non-compliance with quality controls, particularly the lack of internal audits. Indeed, 94.12% of companies do not have an in-house laboratory to test finished products and raw materials. Consequently, the vast majority do not conduct any internal quality control of their products.

This deficiency is confirmed by the absence of external verification, as 79.41% of companies do not have their products tested by an independent third-party laboratory. This means that the vast majority do not have the sanitary quality of finished juices verified by an independent third party, nor do they conduct sufficient internal verification.

As for formal recognition of quality, it is very low: 76.47% of companies do not have a quality certificate, indicating that the majority of companies are not certified. The ability to manage an incident is severely compromised. With a 70.59% non-compliance rate, the majority of companies lack an established traceability system. This translates into a significant inability to identify the origin of a product defect in the event of a health issue, rendering crisis management ineffective.

Finally, employee health and safety are largely neglected, as 85.29% of companies do not conduct medical examinations for their staff, posing a risk to both employees and product safety. The juice industry presents a very high level of risk due to the near-total absence of internal (94.12%) and external (79.41%) controls, and a low recognition of quality standards, creating a major vulnerability in the event of contamination.

3.2.4. Restaurants

Our study reveals constraints at the restaurant level (as illustrated in Table 4). Formal commitment to quality is very low, or even nonexistent: 95% of the restaurants surveyed do not have a quality certificate, demonstrating a widespread lack of certification. This finding is consistent with the fact that 90% of businesses do not have a formal quality policy. This lack of formalization makes food hygiene and safety dependent on individual initiatives rather than structured procedures.

Furthermore, knowledge of the legal framework is very insufficient, since 85% of businesses do not have the applicable regulatory and legislative texts, revealing a significant lack of awareness of the legal framework applicable to the restaurant industry.

Control mechanisms are virtually nonexistent. We observe total non-compliance (100% of restaurants) regarding the absence of an in-house laboratory for testing finished products and raw materials. This lack of internal verification is compounded by the fact that 92.5% do not submit their products to an external laboratory. As a result, almost all restaurants do not have the food safety of their dishes or ingredients verified by an independent third party.

Crisis management is severely compromised: 87.5% of establishments do not have a traceability system for finished products and raw materials. This major deficiency translates into a functional inability to identify the source of a product defect in the event of a health alert.

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Finally, employee health monitoring is also inadequate, with 62.5% of businesses not conducting medical examinations for their employees, posing an additional risk to food safety.

3.3. Major constraints relating to food safety for the agri-food industries (IAA) of the Bamako district and its surroundings.

Constraints with more than 50% non-conformity were considered major; these figures are shown in the table below. Analysis of the data in Table 5 reveals a critical situation regarding quality control within the sectors studied. Indeed, the overall non-conformity rate is particularly alarming for several key indicators, highlighting that companies are largely failing to control the structural and organizational aspects of quality management:

✓ Lack of internal controls (91.98%) and lack of a Quality Certificate (91.44%): These are the two most critical issues overall.
✓ Food safety systems: The absence of a withdrawal/recall system (85.56%) and traceability (80.21%) indicates a major vulnerability in the event of a health crisis.
✓ External controls: 81.82% of establishments do not use external laboratories to validate their products.

Key findings by sector:

✓ Bakery and pastry: This sector has a 100% non-compliance rate across four major criteria: Quality Certificate, external control, withdrawal/recall system, traceability system, and internal control. This sector appears to be the least administratively structured.
✓ Dairy Industry: It stands out positively due to a better understanding of legislation (only 15.52% non-compliance) and a better quality policy (25.86%) compared to others. However, it struggles with the presence of dedicated quality managers.
✓ Restaurants: They have very high non-compliance scores for internal control (100%) and quality certificates (95%).
✓ Juice Industry: It stands out for its excellent management of its infrastructure, with the lowest rate of unsuitable premises (14.71%), but lags significantly behind in internal control (94.12%).

The p-value (0.001565) is a robust statistical indicator, reflecting the probability of observing the data under the null hypothesis of no intersectoral difference. Being well below the conventional significance threshold $\alpha = 0.05$ ($p < 0.001$), it allows for the formal rejection of H_0 in favor of the alternative hypothesis, confirming a highly significant difference (heterogeneity) between the evaluated industrial sectors.

Two categories of risks emerge: operational (traceability/removal ≈ 82.9%, impairing responsiveness to contamination) and hygienic (unsuitable premises 58.82%, lack of medical visits 50.80%, promoting cross-contamination). Statistical significance ($p << 0.05$) implies differentiated intervention strategies by sector, rather than uniform ones, to optimize compliance policies and minimize health vulnerabilities.

3.4. Comparison of the agri-food industries.

3.4.1. Comparison of Bakeries and Pastry Shops and Dairy Industries.

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The statistical analysis using Fisher's exact test revealed a p-value of 0.834, greater than the critical threshold of 0.05, which leads us to not reject the null hypothesis (H0). This result confirms the absence of statistical significance in the association between the bakery and pastry sector and the dairy industry. The constraint profiles observed in these two sectors are statistically independent: the intensity of constraints within the dairy industry does not allow us to predict that of the bakery and pastry sector, thus confirming the absence of a structural relationship between their respective profiles.

3.4.2. Comparison of Juice Production Industries and Restaurants

Statistical analysis using Fisher's exact test reveals a p-value of 0.0311, below the critical threshold of 0.05, demonstrating statistical significance at the conventional 5% level. This low probability value leads to the rejection of the null hypothesis (H0), thus confirming the existence of a real and significant association between the juice industry and the restaurant sector. In the context of health and safety constraints, these results indicate that the profiles observed in restaurants are closely linked to those in the juice industry. The identification of a high level of constraint in one of these sectors is accompanied, in a statistically significant manner, by a similar trend in the other, suggesting a functional dependence potentially attributable to shared factors such as common regulatory frameworks or similarities in supply chains.

3.4.3. Comparison of Bakeries and Restaurants

Statistical analysis using Fisher's exact test reveals a p-value of 0.123, exceeding the critical threshold of 0.05, indicating a lack of statistical significance at the conventional 5% level. This probability value leads us to not reject the null hypothesis (H0), confirming the absence of a significant association between the constraints observed in the bakery and restaurant sector. The variations observed between these two sectors show no statistical dependence and are therefore explained by sampling fluctuation or chance rather than by the existence of a structural link.

3.4.4. Comparison of Juice Production Industries and Dairy Industries

Statistical analysis using Fisher's exact test reveals a p-value of 0.196, exceeding the critical threshold of 0.05, demonstrating a lack of statistical significance at the conventional 5% level. This probability value leads us to not reject the null hypothesis (H0), confirming the absence of a significant association between the constraints of the juice industry and those of the dairy industry. Although both sectors fall under the agri-food domain, the specific nature of their respective health and technological challenges, such as pasteurization and starter culture management for dairy products, as opposed to acidity regulation and bottling line requirements for juices, coherently explains this statistical independence. The variations observed between these sectors are thus attributable to sampling fluctuations rather than the existence of a functional link.

3.5.Correlation of Sanitary Constraints

Analysis of the correlation matrix of sanitary constraints (Table 6) highlights the associations between businesses.

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The results reveal three distinct links:

✓ The strongest correlation: Juice and Restaurants (0.68).

The score of 0.678 is a strong positive correlation and confirms the significance test (P = .031). The sanitary constraints of the juice and restaurant industries evolve together in a very coherent manner.

✓ The "average" correlation: Bakeries and Restaurants (0.52).

This explains why P = .123 (close to the threshold of 0.05 but not quite). There is a moderate link, but there is too much "noise" or too many exceptions for it to be statistically certain at 95%.

✓ Weak or non-existent correlations

o Dairy Industry / Restaurants (0.15): Almost no link.

o Bakery / Dairy (-0.08): Close to zero. The minus sign (-) even indicates a very slight inverse trend, but at this level, it is purely due to chance. This confirms the p-value of .834.

o Negative correlation: Bakery / Juice (-0.14)

The score is negative, meaning that when a constraint increases in one sector, it tends to decrease very slightly in the other. However, the value is so small that we conclude there is complete independence.

3.6. Discussion

3.6.1. Lack of Regulatory and Legislative Texts

The results of our study, which indicate that 60.96% of companies do not have the regulatory and legislative texts relevant to their sector of activity, reveal a major problem of potential non-compliance and risk management. This high rate of non-compliance suggests that the majority of companies operate in a zone of legal uncertainty, which constitutes a serious threat to their sustainability and credibility.

This lack of compliance is an indicator of weak management commitment and internal controls.

The contrast with the doctoral research of El Ammari (2016) in Morocco [10] on Moroccan agri-food companies is striking. While 74% of companies had full compliance with the regulatory texts and 17% had partial compliance, our study shows that more than 60% of companies are completely lacking in compliance [9].

This contrast could be explained by the fact that El Ammari's (2016) study focused specifically on large agri-food companies, while our sample includes a majority of SMEs, which often have fewer resources for regulatory monitoring.

National legal frameworks are a crucial pillar for an effective food control system. In all countries, food is governed by a complex set of laws and regulations that stipulate the government requirements that food chain operators must meet to ensure safe and high-quality food (Traore et al., 2022).[11]

The absence of rigorous regulatory monitoring and the implementation of these regulations exposes companies to high risks of non-compliance. Without a precise understanding of

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applicable standards, it is difficult to ensure that finished products are safe and of high quality, which can lead to public health problems.

3.6.2. Lack of Quality Certification and Quality Policy

The observed rate of 91.44% lack of certification (ISO 22000 or other) contrasts sharply with the findings of El Ammari (2016) in Morocco[10], which reported that 62% of companies were certified and 16% were in the process of certification. This significant gap highlights a considerable divergence.

The very low certification rate, combined with the absence of a clearly established quality policy (observed in 52.94% of cases), is a strong indicator of a lack of commitment and an underdeveloped quality culture.

This gap could be due to regulatory or economic differences, or to the level of development of the agri-food industry.

The absence of a clear quality policy, supported by management, demonstrates a profound lack of commitment to food safety.

In many cases, certification helps improve the organization and internal operations of the company. It is only one component of management. Like any improvement initiative, a certification process has positive effects on an organization's profitability and productivity (Cattan, 2009).

Companies can demonstrate their compliance to external stakeholders by obtaining private management standards, such as the International Organization for Standardization (ISO) family of quality certifications (King et al., 2005).

In fact, obtaining ISO certification has become a popular strategic management tool for companies worldwide for over a decade (Ullah et al., 2014).

3.6.3. Lack of Medical Checkups

Our study indicates that 50.80% of companies do not conduct any medical checkups for staff in contact with products, a finding corroborated by the study by Traore et al. (2022)[11], which reports a 43.3% non-compliance rate regarding medical checkups in the dairy sector in Burkina Faso.

The lack of regular medical checkups could lead to the detection of asymptomatic carriers of pathogens (such as Staphylococcus aureus, Salmonella, or parasites) that can subsequently contaminate food.

Implementing PRPs ensures safe and hygienic food production, making it an essential step in guaranteeing the safety and quality of your agri-food products (ISO 22000:2018).[12]

Good Agricultural Practices (GAP), Good Hygiene Practices (GHP), and Good Manufacturing Practices (GMP) are the rules to be followed to produce safe food. Their adoption is a prerequisite for the introduction of a HACCP system; they are fundamental for all companies in the sector (FAO and WHO, 2005). [13]

3.6.4. Inadequate Premises (Risk of Cross-Contamination)

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The results of our study, which reveal that 58.82% of companies do not have a layout that effectively prevents cross-contamination, highlight a major infrastructural deficiency. This high percentage indicates that more than half of the production units are structurally vulnerable to the transfer of hazards, whether microbiological, physical, or chemical.

It is interesting to note the contrast with the work of (Traore et al., 2022) [11] which indicates that 90% of dairy industries do not adhere to the forward flow principle. The inadequate design of the premises makes cross-contamination (between raw and finished products, or between zones) almost inevitable, compromising the effectiveness of all other hygiene measures. The lack of suitable premises for food processing is a major constraint for many businesses. Suitable premises are not simply a physical space; they must meet strict hygiene and safety standards to prevent food contamination. A poorly designed building is a direct source of cross-contamination, jeopardizing product safety.

3.6.5. Lack of Final Inspection of Finished Products

Our study shows that 81.82% of the companies examined do not conduct any final inspection of finished products by an external laboratory, while 91.98% do not have an in-house laboratory. These results contrast sharply with those of El Ammari (2016) [10], who recommends establishing a sampling plan for microbiological and physicochemical analyses, based on a risk analysis and formalized by a contract with an analytical laboratory.

The sampling plan must:

- ✓ cover finished products (and possibly raw materials or work-in-progress);
- ✓ Refer to the standard analytical methods applied, which must be at least equivalent to those prescribed by national regulations or standards.
- ✓ Refer to qualitative microbiological criteria (list of generic flora or microbial species sought) and quantitative criteria (maximum tolerated limit for the presence of these microbial contaminants).

3.6.6. Lack of a Withdrawal/Recall and Traceability System

Our study reveals that 85.56% of companies do not have a withdrawal/recall procedure, which contrasts sharply with the requirements of ISO 22000:2018. This standard explicitly states that the organization must be able to ensure the withdrawal/recall within a reasonable timeframe of any batch of finished products identified as potentially dangerous, by naming the competent person(s) empowered to initiate and implement the withdrawal/recall (ISO 22000:2018). [12]

Withdrawal (or recall) procedures, to be applied in emergencies, must be defined in advance and available within the establishment, in case a batch of food products is likely to pose a risk to the consumer.

The lack of traceability in 80.21% of the companies surveyed constitutes the "weak link" in the chain. This result is more pronounced than that observed in the agri-food industries of Senegal or Côte d'Ivoire, where recent studies show a slight increase due to export requirements. The lack of traceability prevents any effective product recalls in the event of a crisis, thus increasing the risk of large-scale foodborne illnesses.

4. CONCLUSION

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This study, conducted with 187 agri-food businesses in and around the Bamako district, highlights a critical paradox: while the agri-food sector is booming, food safety management remains largely inadequate. The near-universal absence of certified management systems (91.44%), the lack of finished product control (81.82%), and major shortcomings in traceability (80.21%) expose Malian consumers to significant health risks.

The study of the relationship between the different sectors of activity reveals a unique and significant link between the juice industry and restaurants. With a p-value of 0.031 and a strong correlation coefficient of 0.68, these two sectors exhibit closely related variations in constraints. This association suggests a functional correlation potentially attributable to common factors such as shared supply chains, similar consumption patterns, or comparable hygiene requirements for fresh produce. Conversely, the other sectors exhibit notable statistical independence. The comparison between bakeries and pastry shops and the dairy industry shows a complete lack of correlation ($p = 0.834$; $r = -0.08$), confirming that the constraints of one sector do not predict the intensity of those of the other. Similarly, the relationships between bakeries and restaurants ($p = 0.123$; $r = 0.52$) and between the juice industry and the dairy industry ($p = 0.196$) are considered non-significant at the 5% level. These results highlight that health challenges, such as managing pasteurization for milk or acidity for juices, are distinct issues specific to each sector.

Ultimately, the identified constraints are not only technical, but also structural and organizational. Without a paradigm shift involving both industry promoters and public authorities, the competitiveness of Malian products on the regional and international market will remain compromised.

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Table 1: Evaluation of the constraints of bakeries and pastry shops

Major constraints for bakeries and pastry shops	Non-Compliance Rate (%)
Quality Certificate	100
External audit	100
Availability of a traceability system	100
Internal laboratory control	100
Regulatory texts	98.18
Inadequate premises (risk of cross-contamination)	92.73
Adequate means of transport	70.91

Table 2: Assessment of constraints on the dairy industries

Major Constraints in the Dairy Industry	Non-Compliance Rate (%)
Quality Certificate	89.66
Supplier Contracts	79.31
Internal Laboratory Control	77.59
Quality Manager	72.41
Staff Medical Examinations	67.24
Product Withdrawal and Recall Procedures	65.52
Availability of a Traceability System	62.07
Inadequate Premises (Risk of Cross-Contamination)	55.17

Table 3: Evaluation of constraints on juice production industries

Major constraints in the juice production industry	Non-compliance Rate (%)
Internal laboratory control	94.12
Employee medical examinations	85.29
External laboratory control	79.41

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Quality certificate	76.47
Availability of a traceability system	70.59

Table 4: Evaluation of restaurant constraints

Major constraints for restaurants	Non-Compliance Rate (%)
Internal laboratory control	100
Quality certificate	95
External laboratory control	92.50
Availability of a traceability system	87.50
Regulatory texts	85
Staff medical examinations	62.50
Quality policy	60
Inadequate premises (Risk of cross-contamination)	55

Table 5: Major constraints related to food safety identified

Constraints	Non-compliance rate of industries in %					p-value
	Bakery and pastry shop	Dairy industry	Juice Industry	Restaurants	Overall non-compliance rate	
Lack of legislation	98.18	15.52	50	85	69.96	0.001565
Lack of quality certification	100	89.66	76.47	95	91.44	
Lack of a quality policy	80	25.86	47.06	60	52.94	
Lack of medical examinations	3.64	67.24	85.29	62.50	50.80	
Inadequate premises (risk of cross-contamination)	92.73	55.17	14.71	55	58.82	
Lack of external laboratory testing	100	58.62	79.41	92.50	81.82	
Lack of a withdrawal/recall system	100	65.52	73.53	85	85.56	
Lack of a traceability system	100	62.07	70.59	87.50	80.21	

Lack of supplier contracts	72.73	79.31	47.06	45	64.17	
Lack of internal controls	100	77.59	94.12	100	91.98	

Table 6: Correlation matrix of health constraints

Sector of activity	Bakery and pastry shop	Dairy industry	Juice Industry	Restaurants
Bakery and pastry shop	1	-0.08	-0.14	0.52
Dairy industry	-0.08	1	0.45	0.15
Juice Industry	-0.14	0.45	1	0.68
Restaurants	0.52	0.15	0.68	1