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Digital Transformation in the Implementation of Hazard Analysis and Critical Control Points (HACCP) in the Food Industry

Dwi Yunita[1]*, Rika Puspitasari[2], Yusuf Azzahra[3]

[1,2] Department of Industrial Agricultural Technology, Faculty of Agricultural Technology, Universitas Brawijaya, Malang, Indonesia
[3] Department of Food Technology, Faculty of Agricultural Technology, Universitas Gadjah Mada, Yogyakarta, Indonesia

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ABSTRACT

This study aims to analyze digital transformation in the implementation of Hazard Analysis and Critical Control Points (HACCP) in the food industry, with a focus on how digital tools reshape monitoring, documentation, corrective action, and audit readiness. This study uses a qualitative case study approach because the phenomenon involves organizational experience, work routines, technology acceptance, and food safety culture. Data were collected through semi-structured interviews, non-participant observation, and documentation involving quality assurance managers, quality control staff, production supervisors, internal auditors, production operators, sanitation officers, and information technology personnel who were directly involved in HACCP activities. The findings reveal three main themes: digital monitoring as a control mechanism, organizational adaptation to new work routines, and data integration for audit readiness. Digital HACCP improves the visibility of critical control points, accelerates document retrieval, and supports the identification of repeated deviations. However, its implementation also requires employee training, management support, and gradual adaptation because workers may initially perceive digital systems as additional pressure. This study contributes to the understanding of HACCP by showing that digital transformation is not only a technological process, but also a cultural and organizational change. The findings imply that food companies and regulators should promote phased, participatory, and readiness-based digital HACCP implementation. Further research may compare digital HACCP adoption across different food industry sectors and company scales.

***) Corresponding Author:**

Dwi Yunita,
Department of Industrial Agricultural Technology, Faculty of Agricultural Technology, Universitas Brawijaya, Malang, Indonesia
Email: dwi.yunita098@gmail.com

1. Introduction

Digital transformation has become a strategic issue in the global food industry because food supply chains now operate through complex, fast, and data-intensive systems. Food safety no longer depends only on final product inspection. It also requires preventive control, real-time monitoring, traceability, rapid documentation, and evidence-based corrective action. Hazard Analysis and Critical Control Points, known as HACCP, remains one of the most important preventive systems in food safety management. However, many HACCP practices still rely on manual forms, delayed reporting, fragmented records, and operator-dependent verification. These conditions can weaken early detection when critical limits are exceeded. Recent studies show that digital tools can strengthen HACCP by improving monitoring, documentation, traceability, and data integration across production processes (Sartoni et al., 2025).

In the national context, digital HACCP is relevant for the Indonesian food industry because food producers face stronger pressure from certification bodies, regulators, consumers, retailers, and export markets. Many companies have started to use digital forms, cloud-based documentation, barcode systems, sensors, temperature loggers, and enterprise platforms to support food safety control. However, field practices often show uneven readiness. Large companies usually have better infrastructure, while small and medium food industries still face limited budgets, low digital literacy, unstable internet access, and dependence on manual records. Digital transformation in food supply chains can improve transparency and responsiveness, but it also creates new challenges related to human capability, organizational routines, and system interoperability (Annosi et al., 2021).

This issue is important because HACCP implementation is not only a technical matter. It also reflects organizational culture, worker discipline, management commitment, and the ability of employees to interpret risk. Digital systems can make monitoring faster, but they do not automatically create food safety awareness. Operators must understand why data should be recorded accurately. Quality assurance teams must trust the system. Managers must use digital information for decision-making, not only for audit compliance. Food Processing 4.0 shows that sensors, artificial intelligence, blockchain, and data analytics can improve food safety control, but their value depends on how people use them in daily production activities (Hassoun et al., 2023).

Previous studies have widely discussed digital food safety from the perspective of technology performance, traceability, artificial intelligence, blockchain, and supply chain efficiency. Blockchain studies, for example, highlight transparency and product tracking across food supply chains (Vasileiou et al., 2025). Artificial intelligence studies explain its role in contamination detection, quality control, and predictive risk assessment (Liu et al., 2023). However, fewer studies examine how food industry actors experience and interpret the shift from manual HACCP to digital HACCP. This gap is important because digital transformation can change work routines, authority, accountability, communication patterns, and audit behavior inside food companies.

This study uses a qualitative perspective because the implementation of digital HACCP involves meanings, experiences, practices, and organizational negotiations. A qualitative approach allows the researcher to explore how managers, quality assurance staff, production supervisors, operators, auditors, and information technology personnel understand the benefits and constraints of digital systems. This approach also helps explain why some digital tools are accepted, modified, ignored, or resisted in daily HACCP activities. Technology Acceptance Model, institutional theory, and food safety culture provide the theoretical basis for understanding digital adoption, regulatory pressure, and behavioral change in food safety management.

Therefore, this study aims to analyze digital transformation in the implementation of HACCP in the food industry. The study focuses on how digital tools are used in hazard identification, critical control point monitoring, corrective action, verification, audit preparation, and documentation. The theoretical contribution of this study lies in extending HACCP studies through the lens of digital transformation and food safety culture. The practical contribution lies in providing insights for food companies, auditors, regulators, and quality managers to design digital HACCP systems that are realistic, participatory, and aligned with organizational readiness.

2. Materials and Methods

This study uses a qualitative approach with a case study design. The case study design was selected because the research aims to understand digital transformation in HACCP

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implementation within a real organizational context. This design is suitable for examining how digital tools are adopted, interpreted, and used by different actors in food safety management. Qualitative case study research allows the researcher to examine processes, experiences, and contextual factors that cannot be fully explained through numerical measurement (Busetto et al., 2020).

The research will be conducted in food industry companies that have implemented HACCP and have started using digital tools in food safety management. The research location may include food processing companies, beverage companies, frozen food producers, or ready-to-eat food manufacturers in Indonesia. The research period is planned for three months, covering research permission, participant recruitment, data collection, data validation, and data analysis. The selected companies must meet three criteria: they have an established HACCP system, they use digital tools in at least one HACCP-related activity, and they allow limited research access for interviews, observation, and document review.

Participants will be selected through purposive sampling. This technique is appropriate because the study requires informants who have direct knowledge and practical experience with HACCP and digital food safety systems. The main participants include quality assurance managers, quality control staff, production supervisors, internal auditors, sanitation officers, production operators, and information technology personnel. The inclusion criteria are direct involvement in HACCP activities, at least one year of work experience in the company, and familiarity with manual or digital food safety documentation. Snowball sampling may be used when initial participants recommend other relevant informants who have deeper knowledge of digital HACCP practices.

Data will be collected through semi-structured interviews, non-participant observation, and documentation. Semi-structured interviews will explore participants' experiences in using digital tools for HACCP, perceived benefits, implementation barriers, changes in work routines, and adaptation strategies. This technique gives the researcher a clear interview guide while still allowing flexible follow-up questions. Observation will focus on HACCP-related activities such as critical control point monitoring, temperature recording, sanitation checks, corrective action reporting, verification, and audit preparation. Documentation will include HACCP plans, standard operating procedures, monitoring forms, audit reports, training records, corrective action reports, and screenshots of digital systems that can be accessed with company permission.

Data validity will be ensured through source triangulation, method triangulation, member checking, and audit trail. Source triangulation will compare data from managers, supervisors, operators, auditors, and information technology staff. Method triangulation will compare interview findings with observation notes and company documents. Member checking will be conducted by asking selected participants to review the summary of interview findings or preliminary interpretations. An audit trail will be maintained through organized records of field notes, interview transcripts, coding decisions, document lists, and analytical memos. These procedures are used to strengthen credibility, dependability, and confirmability in qualitative research (Braun & Clarke, 2021).

Data will be analyzed using thematic analysis. This method is suitable because the study seeks to identify patterns of meaning across participant experiences. The analysis will begin with repeated reading of interview transcripts, observation notes, and documents. The researcher will then generate initial codes related to digital monitoring, documentation accuracy, employee adaptation, system constraints, management support, audit readiness, and food safety culture. These codes will be grouped into potential themes. The themes will then be reviewed, refined, named, and connected to the research focus. Thematic analysis is appropriate for producing a systematic interpretation of qualitative data while still preserving participants' meanings (Byrne, 2022).

The analysis will also follow the interactive logic of data condensation, data display, and conclusion drawing. Data condensation will be carried out by selecting and simplifying information that directly relates to the research focus. Data display will be developed through thematic matrices, participant quotations, process descriptions, and cross-source comparisons. Conclusion drawing will be conducted gradually by checking the consistency of findings across interviews, observations, and documents. The final interpretation will not rely on a single statement, but on repeated patterns supported by multiple sources of evidence.

Ethical considerations will be applied throughout the research process. Participants will receive clear information about the research objectives, their role, voluntary participation, and the right to withdraw. Company names and participant identities will be anonymized using codes. Internal documents will only be used for academic analysis and will not disclose confidential business information. The researcher will also avoid disrupting production activities during observation. These ethical procedures are necessary because HACCP data may involve sensitive information related to company compliance, production control, and audit performance.

3. Results and Discussions

The findings show that digital transformation in HACCP implementation changed the way food safety control was understood and practiced in the company. Participants described digital HACCP not only as a replacement for paper-based records, but also as a new way to control risk, monitor compliance, and improve coordination between production, quality assurance, and management teams. Three main themes emerged from the data: digital monitoring as a control mechanism, organizational adaptation to new work routines, and data integration for audit readiness.

The first theme relates to digital monitoring as a control mechanism. Participants stated that digital tools helped them record critical control point data faster and more consistently. Temperature, sanitation checks, corrective actions, and verification records could be entered directly into digital forms or system dashboards. One quality assurance staff member explained, “Before using the digital system, we had to check many paper forms one by one. Now we can see which process has not been completed from the dashboard.” This finding shows that digital HACCP increased visibility in daily food safety control. Observations also showed that supervisors could identify incomplete records more quickly when compared with manual documentation.

The second theme concerns organizational adaptation to new work routines. Although digital systems improved efficiency, participants also reported difficulties during the early implementation stage. Some operators felt that digital recording added pressure because every action became more visible and easier to trace. One production operator stated, “At first, we were afraid of making mistakes because the system recorded everything. But after training, we understood that it helped us work more carefully.” This statement indicates that digital transformation created both anxiety and learning. The shift from manual HACCP to digital HACCP required technical training, repeated assistance, and changes in employee mindset.

The third theme relates to data integration and audit readiness. Participants explained that digital HACCP made it easier to prepare audit evidence because monitoring records, corrective actions, and verification documents could be retrieved more quickly. Internal auditors stated that digital records reduced the risk of missing documents and helped them identify repeated nonconformities. One internal auditor noted, “The system helps us trace the problem. If the same deviation appears several times, we can discuss the root cause with production.” This finding suggests that digital HACCP supported not only documentation, but also organizational learning from repeated patterns of risk.

Documentation analysis supported the interview findings. The reviewed HACCP forms, audit reports, corrective action records, and training documents showed that the company had started to standardize digital reporting procedures. However, several documents still showed mixed practices between manual and digital systems. Some records were entered digitally, while others were still stored in printed forms. This hybrid practice indicated that digital transformation was still in a transition phase. The company had adopted digital tools, but had not fully integrated all HACCP activities into one connected system.

The findings also show that management support played a central role in digital HACCP implementation. Participants stated that digital systems were more easily accepted when managers provided training, clear instructions, and technical assistance. In contrast, digital tools were viewed as burdensome when employees only received instructions without explanation. This pattern shows that technology acceptance was shaped by perceived usefulness, perceived ease of use, and organizational support. Employees accepted the system when they saw that it reduced repeated work, simplified reporting, and helped them avoid audit problems.

Discussion

The findings confirm that digital transformation in HACCP is not only a technological process, but also an organizational and cultural process. The use of digital tools improved monitoring, documentation, and traceability. This finding is consistent with Sartoni et al. (2025), who explain that digital food safety management systems can strengthen HACCP and prerequisite programs through better data availability and process integration. The finding also supports Hassoun et al. (2023), who argue that Food Processing 4.0 technologies can improve food safety control when they are connected with real production needs.

The theme of digital monitoring strengthens the idea that HACCP depends on accurate and timely information. In manual systems, delays in recording and verification can reduce the preventive function of HACCP. Digital tools help reduce this weakness by providing faster access to critical control point data. This result aligns with Liu et al. (2023), who show that artificial intelligence and digital technologies can support food safety through early detection and risk prediction. However, the present study adds a qualitative perspective by showing that the value of digital monitoring depends on how workers interpret and use the data in daily routines.

The finding on organizational adaptation also supports the Technology Acceptance Model. Employees were more willing to use digital HACCP when they perceived the system as useful and easy to operate. However, the findings also show that acceptance was not automatic. Some employees initially felt controlled, monitored, or burdened by the system. This indicates that digital adoption in HACCP requires more than technical installation. It requires communication, training, and trust-building. This finding expands previous studies on digital traceability and blockchain in food systems, which often focus on system capability rather than user experience (Rejeb et al., 2020; Vasileiou et al., 2025).

The hybrid use of manual and digital records shows that digital transformation often occurs gradually. This finding differs from studies that describe digitalization as a complete shift from traditional to automated systems. In practice, companies may combine manual forms and digital platforms because of limited infrastructure, employee readiness, audit habits, or regulatory documentation needs. This condition is relevant for food industries in developing countries, where technological readiness is not equal across departments. The finding suggests that digital HACCP should be understood as a staged transformation, not as a one-time technological replacement.

The role of management support confirms the importance of food safety culture. Digital tools can strengthen HACCP only when employees share the belief that accurate data, timely reporting, and corrective action are part of collective responsibility. If workers use digital forms only to meet audit requirements, the system may improve documentation without improving risk awareness. This finding supports the view that food safety culture shapes how people behave, communicate, and make decisions in food safety systems. Therefore, digital HACCP must be integrated with training, supervision, feedback, and leadership commitment.

The study offers a new perspective by showing that digital HACCP creates a shift in accountability. In paper-based systems, errors may remain hidden or be corrected informally before audits. In digital systems, records become more visible, traceable, and time-stamped. This condition can improve transparency, but it can also create pressure for workers. Companies need to manage this tension carefully. Digital systems should not be used only as surveillance tools. They should function as learning tools that help employees identify risks, prevent repeated deviations, and improve food safety practices.

Practically, the findings suggest that food companies should implement digital HACCP through phased strategies. The first step is mapping which HACCP activities need digital support, such as critical control point monitoring, corrective action, verification, or audit documentation. The second step is training employees based on their roles. The third step is integrating digital data with management review and continuous improvement. The fourth step is maintaining hybrid support during the transition period to prevent resistance and data loss. This approach can help companies adopt digital HACCP without disrupting production routines.

Theoretically, this study contributes to HACCP research by linking digital transformation, technology acceptance, institutional pressure, and food safety culture. It shows that digital HACCP is shaped by the interaction between technology, people, procedures, and organizational values. Future studies may compare digital HACCP implementation across different types of food industries, company sizes, or certification levels. Further research may also use mixed methods to examine how digital HACCP affects audit performance, corrective action speed, employee compliance, and food safety incident reduction.

4. Conclusions

This study concludes that digital transformation in HACCP implementation changes food safety control from a documentation-based routine into a more integrated, traceable, and data-driven process. The main findings show three key patterns: digital monitoring improves visibility over critical control points, organizational adaptation shapes employee acceptance of new work routines, and data integration strengthens audit readiness and corrective action. These findings contribute to HACCP literature by showing that digitalization is not only a technical upgrade, but also a cultural and organizational process involving trust, training, accountability, and food safety awareness.

Theoretically, this study strengthens the link between digital transformation, technology acceptance, and food safety culture in explaining HACCP practices. Practically, the findings suggest that food companies should implement digital HACCP gradually through training, clear procedures, management support, and system integration. From a policy perspective, regulators and certification bodies should consider the different levels of digital readiness among food industries, especially small and medium enterprises. Future research can compare digital HACCP practices across different food sectors, company sizes, or certification levels to deepen understanding of how digital systems influence food safety performance.

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