Smart Traceability for Food Safety: Managing Food Traceability in the Digital Age

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Abstract

Food safety is essential to protect public health and ensure traceability throughout food chain. The increase in alert systems between 2018 and 2023 has highlighted critical issues in official controls, particularly regarding food traceability.

Data on sanctions and seizures carried out in the Campania region for lack of traceability during the years 2018–2023. These data were analyzed, with prior authorization from the competent UOD.

These data showed that each year, a significant percentage of sanctions (over 10%) is related to traceability issues.

To address these problems, SMART TRACEABILITY was developed, an innovative software designed for bar, restaurants, and other food service establishments. The platform allows for the automated compilation of production records by selecting recipes and photographing lot numbers, reducing manual errors and ensuring compliance with current food safety regulations. Pilot testing in two restaurants showed that, after initial resistance, the system was effectively integrated into their processes, improving operational efficiency and the traceability of ingredients.

Although developed for the restaurant sector, SMART TRACEABILITY could also be adapted for the food industry, introducing advanced features such as monitoring the quantities produced and the recipients of the supplies, this system ensure complete traceability along the entire chain from producer to consumer.

Introduction

In the 1990s, a series of food scandals and health crises such as bovine spongiform encephalopathy (BSE), methanol-tainted wine, avian influenza, and dioxin contamination in poultry and eggs raised serious concerns about food safety in Europe. As a result, the European Union introduced community regulations to ensure food safety at all stages of the chain.

In 2002, Regulation (EC) No. 178/2002 established fundamental principles such as risk analysis, the precautionary principle, transparency, operator responsibility, and food traceability, as well as the creation of the European Food Safety Authority (EFSA).

In 2006, the "Hygiene Package" introduced mandatory HACCP systems.

An innovation was introduced by this legislation, the traceability system, which enables food operators to track products from farm to fork and identify potential issues in real time.

Traceability is essential for ensuring a rapid response in the event of contamination or outbreaks of foodborne diseases, as it allows the source of contamination to be located, dangerous products to be withdrawn, and consumer health to be protected. In fact, with the rise in global food safety risks and the intensification of international trade, the number of rapid alert systems such as the RASFF (Rapid Alert System for Food and Feed) has increased.

The RASFF was created to allow the timely exchange of information on food-related risks. The data comes not only from official controls, but also from company self-monitoring, consumer reports, and clinical cases of foodborne illnesses.

Foodborne illnesses (FBDs) today represent a major public health concern. Every year, millions of Europeans become ill due to infections, food poisonings, and toxic contaminations. The traceability system and the use of RASFF play a crucial role in managing these illnesses, allowing for the rapid identification of outbreak sources, the isolation of contaminated batches, and the prevention of the spread of implicated food products.

The legal requirement of traceability in the food supply chain is essential not only for ensuring food safety but also to avoid administrative sanctions and seizures imposed on food operators. Legislative Decree 190/2006 outlines the penalties for violating the traceability obligations established by Regulation (EC) No. 178/2002.

Failure to ensure product traceability can result in administrative fines ranging from €750 to €4,500. For this reason, data on sanctions and seizures due to lack of traceability in the Campania region between 2018 and 2023 were analyzed.

The data were extracted from the GISA platform, a regional software used by Local Health Authorities (ASL) to manage food safety and veterinary public health in Campania.

These data were analysed with prior authorization from the UOD for Prevention and Veterinary Public Health of the Campania Region.

The data show that each year, a significant percentage of sanctions (over 10%) is related to traceability issues.

The following tables report:

- Table 1: the total number of sanctions issued

by the competent authorities belonging to the Prevention Departments of the seven Local Health Authorities (ASL Avellino, ASL Benevento, ASL Salerno, ASL Napoli 1, ASL Napoli 2, ASL Napoli 3, ASL Caserta).

• Table 2: the number of sanctions specifically related to traceability issues.

• Table 3: the percentage of sanctions related to traceability issues in relation to the total number of sanctions.

The number of sanctions related to traceability has increased in recent years, reaching its peak in 2023. Moreover, data analysis reveals that a significant portion of food seizures is due to traceability violations. In fact, as shown in Table 4, approximately 60% of seizures were carried out due to issues related to the lack of traceability.

Specifically, when businesses do not have an adequate traceability system, they are vulnerable to seizures, which result in significant economic losses and reputational damage.

The data for the years 2018-2023 show an increasing trend in fines and seizures, with a significant rise in 2022 and 2023. This highlights the need to improve traceability systems within food companies to avoid sanctions and issues related to food safety.

The proposal outlined in the thesis concerns an automated production sheet filling system, which could be an effective solution to enhance traceability. An automated system would ensure that every stage of the production chain is properly tracked and documented, minimizing human errors and facilitating compliance with regulations. Such a system would be a valuable tool to reduce the risk of sanctions and seizures, while improving product transparency and quality.

Sanzioni impartite dal 2018 al settembre 2023	
2018	710
2019	964
2020	703
2021	775
2022	1252
2023	1217

Tab n.1: *totale sanzioni (estrapolazione Gisa)*

Sanzioni rintracciabilità dal 2018 al settembre 2023	
2018	88
2019	113
2020	80
2021	43
2022	143
2023	183

Tab n.2: *sanzioni rintracciabilità (estrapolazione Gisa)*

Percentuale sanzioni impartite in tema di rintracciabilità sul totale delle sanzioni	
2018	12,4%
2019	11,7%
2020	11,4%
2021	5,5%
2022	11,4%
2023	15%

Tab n.3 *Percentuale sanzioni impartite in tema di rintracciabilità sul totale delle sanzioni- elaborazione tramite Excel dati Gisa delle tabelle n.1 e 2.*

MATERIALS AND METHODS

SMART TRACEABILITY is an advanced software designed for food traceability management, enabling businesses in the food sector, particularly restaurants and similar establishments, to monitor and track every stage of food production, from raw materials to the finished product.

This software not only ensures food safety but also optimizes operational efficiency and simplifies the management of raw materials and suppliers.

1.   Supplier and Raw Material Management

One of the key features of SMART TRACEABILITY is the comprehensive management of suppliers and raw materials. Users can create a detailed mapping of all suppliers with essential information such as name, address, phone number, and contact details. Each supplier is linked to the raw materials they provide, allowing a clear and immediate view of which ingredients come from which supplier. In case of need, such as a recall or product, users can easily trace back to the supplier. The platform also allows adding new suppliers or removing those no longer in collaboration, keeping the list always up to date. Additionally, each raw material can be associated with its batch origin, enabling tracking of products from the beginning of the supply chain. In case of issues like contamination or defects, the platform allows rapid tracing back to the source of the supply, minimizing risks and economic damage.

2.   Warehouse Management (PRO Version)

The PRO version of the software offers advanced warehouse management, where companies can monitor the entry and exit of raw materials. Every goods loading and unloading operation is recorded with date and time, creating full traceability of the flow of goods. Users can register each delivery, associating the information with the supplier and batches, allowing them to track expiration dates, batch numbers, and other important data.

Another significant feature is integration with the company's ERP system, which allows optimal stock management, automatic ordering in case of overstock or shortages, and continuous evaluation of delivery costs. This enables companies to better manage their resources and optimize raw material procurement.

3.   Use of Raw Materials in the Kitchen

When raw materials are used in the kitchen, SMART TRACEABILITY allows precise tracking of every step in the preparation process. Each dish or recipe is associated with a series of ingredients that come from the suppliers previously registered in the platform. The platform offers over 200 precompiled recipes that users can select, modify, or add according to their needs.

For each recipe, the user selects ingredients from an automatic list that appears once the recipe is chosen, and can select from different suppliers if an ingredient is supplied by more than one. Each time an ingredient is used, the user must take a photo of the batch number and producer details to correctly associate the ingredients with the production. This process ensures that every stage of the preparation is tracked, contributing to complete traceability.

The generated production sheets contain all necessary information, such as batch numbers of ingredients, expiration dates, and packaging dates. The sheets are stored in the system with a certified date, allowing historical consultation of all prepared items.

4.   Advanced Traceability

In the case that it is necessary to reconstruct the history of a food product, for example, in the event of suspected foodborne infections or during checks by the competent authorities, SMART TRACEABILITY allows querying the platform using various filters, such as ingredient, date, recipe, and batch number. This advanced search feature enables real-time access to all information about a product, from its origin to its usage.

Production sheets can be printed at any time to provide detailed and readable documentation. The information, including historical data, remains available in the system, ensuring complete and transparent visibility.

5.   Non-Conformance Management and Supplier Qualifications

SMART TRACEABILITY also offers tools to monitor non-conformities found during procurement or production. Users can record issues with suppliers, such as receiving non-compliant or expired products, and associate detailed information about the supplier, product, date, and the type of problem encountered with each event.

The platform also includes a dashboard for managing supplier qualifications, allowing users to view supplier performance and have a rating system. This way, companies can continuously monitor the quality of products received and improve their procurement decisions.

6.   Supplier Qualification Alert System

To ensure continuous control over supplier performance, the platform provides an alert system that notifies users when a supplier falls below a certain rating threshold. This way, companies can be promptly alerted to any issues and take immediate action to resolve them, preventing a substandard supplier from compromising the final product's quality.

In summary, SMART TRACEABILITY represents a complete and innovative solution for food traceability management. The platform not only ensures compliance with food safety regulations but also offers efficient management of suppliers, raw materials, warehouse operations, and production, improving operational efficiency and minimizing risks related to food safety. With an automated system and constant monitoring, SMART TRACEABILITY is an essential tool for food businesses that aim to optimize the quality and safety of their products, while reducing operational

costs and increasing transparency.

RESULTS AND DISCUSSION

The SMART TRACEABILITY software was tested in two pilot restaurants.

Selection Method and Enrollment Criteria

The criteria used for enrollment were as follows:

- Willingness to participate: Both restaurants voluntarily expressed interest in participating in the trial by signing an informed consent form.
- Menu type: One restaurant with a variable menu (based on seasonality and multiple suppliers) and one with a fixed menu (with stable supplies) were selected to test the software's adaptability to different operational models.
- Absence of significant prior sanctions: To ensure neutral application, restaurants with previous severe food safety violations were excluded.
- Presence of an active HACCP system: This was a necessary condition to evaluate the integration of the software within the existing self-control plans.
- Average size of the business: Both restaurants had a daily seat capacity between 50 and 150, representing a middle range of the restaurant industry.

In the first restaurant, there was initially resistance from the chefs, who were concerned about "time loss" using the system. However, after the first three months, the system was successfully integrated into the business routines, showing that initial concerns could be overcome with an adequate adaptation period. In the second restaurant, adoption was quicker due to the variability of suppliers, and the platform improved traceability and control over ingredient quality.

To evaluate the effectiveness of the software, the following parameters were analyzed, recorded both before and after the six-month trial period:

per. The two selected restaurants had an average daily seating capacity between 60 and 100.

Before the introduction of the software, a thorough assessment of the existing operational flows was conducted, focusing on warehouse management, batch traceability, and manual production sheet completion. This phase highlighted strengths and weaknesses of the existing paper system and allowed the software functionalities to be adapted to actual operational needs.

The involved staff received an initial in-person training lasting four hours, during which the main system features were explained and practical simulations of the most frequent operations were carried out. A simplified user manual was provided to each operator to facilitate daily use of the software. In the first few weeks, continuous technical support was provided via phone and WhatsApp to resolve doubts and address any issues. Throughout the adoption period, monthly in-person updates were scheduled, including monitoring meetings and feedback collection from users. The group of trained operators included the chef, assistant chefs, purchasing manager, and the owners of the two establishments.

The adoption of the software was gradual. During the first month, the system was used for the traceability of only one recipe per day to familiarize with the interface and assess the effectiveness of digital input. In the following months, between the second and third month, the usage was extended to about half of the daily preparations. Starting from the fourth month, the software was used fully for all recipes and warehouse stock management.

Throughout the entire period, data was collected regarding the number of recipes traced, the average time spent on sheet completion (both manual and digital), the number of non-conformities, and the level of system acceptance by staff, assessed via an anonymous questionnaire. This data allowed the

Parameter Evaluated	Restaurant A (Variable Menu)	Restaurant B (Fixed Menu)
Average time to fill production sheets	Pre: 12 min / Post: 4 min	Pre: 9 min / Post: 3 min
Average number of errors per month in traceability (e.g., missing or incorrect batches)	Pre: 7 / Post: 1	Pre: 4 / Post: 0
Percentage of recipes correctly traced	Pre: 68% / Post: 98%	Pre: 75% / Post: 100%
Staff satisfaction (scale 1-5)	Pre: 2.3 / Post: 4.1	Pre: 3.0 / Post: 4.5

During the project, the adoption of SMART TRACEABILITY software was implemented in two pilot restaurants located in the province of Naples. The selection of these establishments was based on specific criteria, including the willingness of the owners to participate, the difference in organizational type (one restaurant with a fixed menu and one with a variable menu), the variety of suppliers used, and the management of traceability still entirely on pa-

quantification of the software's benefits in terms of efficiency, traceability, and user satisfaction.

At the end of the six-month trial, a final meeting was held with the restaurant owners to discuss the results, identify remaining issues, and propose possible improvements. This final phase served as a synthesis and planning moment for future system extensions. In Image 1, there is a flowchart of the software adoption process.

In Image 2, there is a flowchart of the traceability management process before and after the introduction of SMART TRACEABILITY.

PROCESSO DI ADOZIONE DEL SOFTWARE NEI 6 MESI

SELEZIONE DEI RISTORANTI

↓

FORMAZIONE DEGLI OPERATORI

↓

ADOZIONE DEL SOFTWARE

↓

INTEGRAZIONE NELLE ATTIVITA AZIENDALI

↓

VALUTAZIONE INTERMEDIA (a 3 MESI)

↓

VALUTAZIONE FINALE (a 6 MESI)

Immagine n.1 *diagramma di flusso del processo di adozione del software*

Prima

Selezione manuale delle ricette

↓

Inserimento dei numeri di lotto

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Compilazione delle schede di produzione

Dopo

Selezione delle ricette

↓

Acquisizione dei numeri di lotto

↓

Compilazione automatica delle schede di produzione
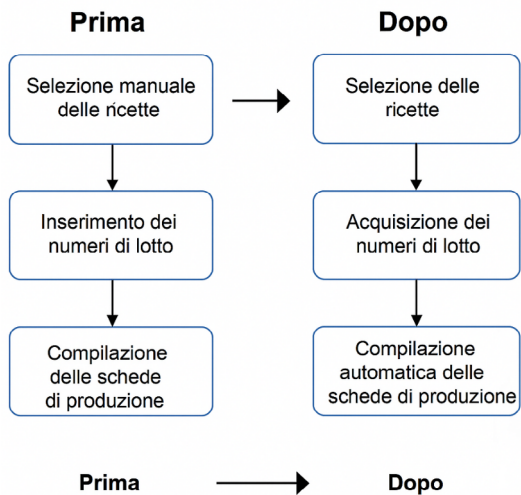
Prima → Dopo

Immagine n.2 *un diagramma di flusso sul processo di gestione della tracciabilità prima e dopo l'introduzione di SMART TRACEABILITY.*

Although no cases of foodborne illnesses or traceability requests occurred, the platform was effective in integrating business procedures, demonstrating its advantages in terms of efficiency and food safety.

Both restaurants appreciated the ease of use, noting that taking a photo is quicker and less time-consuming than manually entering data.

In summary, the trial confirmed that SMART TRACEABILITY is a key step in improving food safety, quality, and traceability in foodservice establishments. Over time, initial resistance was overcome, and the software was effectively integrated into the self-control plans, offering benefits in both prevention and operational simplification. The results support the adoption of the platform in other similar businesses as well.

CONCLUSIONS

The SMART TRACEABILITY project has proven to be an effective and innovative solution for managing food traceability, with a positive impact on food safety, operational efficiency, and regulatory compliance. The introduction of an automated traceability system has simplified business operations, reduced manual errors, and improved raw material management, contributing to greater transparency in the food supply chain. The trial conducted in the pilot restaurants confirmed that, despite initial resistance, the adoption of the platform proved advantageous in terms of operations and food safety.

The results indicate that SMART TRACEABILITY not only facilitates the management of information related to suppliers, raw materials, and production but also provides a valuable tool for prevention in case of health emergencies or official inspections. The system allowed for precise tracking of every stage of the production process, minimizing risks related to contamination and increasing responsiveness in case of intervention needs. Additionally, the data collected during the trial highlighted an improvement in the management of expiration dates and batch numbers, with a significant reduction in traceability-related issues.

The platform also demonstrated significant potential for expansion to larger entities, such as food industries, with the integration of additional functionalities for production monitoring and worker management. Its application could help ensure complete and continuous traceability, from upstream to downstream, further improving food safety and quality on a global level.

In conclusion, SMART TRACEABILITY represents a crucial step toward modernizing and optimizing the agri-food supply chain, with the potential to reduce penalties related to lack of traceability, prevent reputational damage, and ensure consumer safety. Its widespread use could mark a significant turning point in the restaurant industry and beyond, contributing to creating a safer, more transparent environment that complies with food safety regulations. The creation of this software has no promotional or marketing purposes, nor are there any conflicts of interest on the part of the authors.

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