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Advanced Risk and Hazard Analysis in the Egg Sorting-Packing Station Industry from Supplier Selection to Delivery in Chain Stores under GFSI Integrated Food Safety Programs

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Abstract: This study outlines a comprehensive examination of risks and hazards in three egg sorting and packing stations, covering the entire process from supplier selection and evaluation to egg delivery in chain stores. The analysis is conducted within the framework of Codex Alimentarius and GFSI-integrated food safety programs. Salmonella is the greatest significant threat. To enhance the Hazard Analysis of Critical Control Points (HACCP), preparatory programs were incorporated into the quality management system (QMS) by monitoring and assessing the biological, chemical, and physical threats according to Code Alimentarius and further integrated into GFSI food safety programs, including food authenticity and food defense. The procedure offered sophisticated preventive tools, hand-on at any time, for eliminating, reducing, or mitigating the risks encountered in egg packing and sorting facilities.

Keywords: PRP; GHP; HACCP; ISO 22000; FSSC 22000; IFS Food; GFSI; food safety management; food control

1. Introduction

There is an increasing demand for eggs from farms that prioritize animal welfare among consumers. Consumers perceive eggs produced in non-cage environments as food that not only meets ethical standards but also provides improved acceptance, nutritional content, and taste. The table egg is the most affordable kind of animal protein, rich in nutrients, and has only 75 calories per egg. Due to their optimal amino acid composition and efficient digestion, they serve as a highly commendable protein source for human consumption. Given that it is not forbidden by the majority of religions, it is a fundamental dietary staple that is consumed globally. Asia, with a dominant share of 53.3% in global production in 2018, has emerged as the greatest producer worldwide, surpassing both the United States (8.6%) and the European Union (10% of global production) [1,2].

Laying hens can consume contaminants such as dioxins, heavy metals, dioxins, dl-PCBs, cleaning and sanitizing chemicals, or veterinary pharmaceutical treatments from the environment, water, soil, and feed [3]. These contaminants can then be transferred to the eggs. Due to their elevated fat content, eggs can harbor a substantial amount of persistent organic pollutants (POPs), such as dioxins and polychlorinated biphenyls (PCBs), which pose potential health risks to individuals. *Salmonella* is the most prevalent pathogen associated with eggs and egg products. Additional

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pathogens that become significant when the process of egg production is transformed into liquid egg products encompass *Bacillus cereus* and *Listeria monocytogenes* [4]. EFSA states that eggs can be stored for an extended duration when chilled in both retail and domestic settings. The danger appears to be primarily impacted by factors such as the size and density of the farm, as well as the hygiene habits of the farmer. EFSA recommends that future monitoring programs systematically record the housing style of laying hens to assess its impact on the prevalence of *Salmonella* [4,5]. The chief factors contributing to the contamination of eggs and egg products during the initial stage of egg processing are the utilization of inappropriate disinfectants, flawed cleaning processes, and ineffective candling and sorting methods. Effective sanitation and processing techniques are necessary for proper handling, sorting, and cleaning. Implementing sound processing techniques, such as regular maintenance and prompt equipment repairs, along with visual inspections of goods, seem to be efficacious measures in averting the occurrence of physical hazards. In addition, it is necessary to use certain measures in accordance with good manufacturing procedures (GMP), such as the utilization of strainers, metal detectors, or magnets to detect and mitigate physical hazards throughout the processing phase [6].

Conventional methods are ineffective in managing initial process risks to guarantee the hygienic integrity of the end goods [7]. To maintain food safety, it is imperative to adhere to Good Manufacturing Practices (GMP), Good Hygiene Practices (GHP), and the principles of Hazard Analysis of Critical Control Points (HACCP) [8]. The important control points idea is founded on the assessment of food safety concerns through the utilization of a control system [7,9]. This preventive approach assesses the comprehensive dangers to the entire food chain, including those of a physical, chemical, and biological nature. Multiple publications [7,10–12]examined the effects of implementing Hazard Analysis and Critical Control Points (HACCP) on the microbiological safety of food products. All small- and medium-sized food enterprises operating in the European Union (EU) must adhere to the Hazard Analysis and Critical Control Points (HACCP) system, which is recognized as a worldwide standard for mitigating the hazards related to foodborne illnesses[13]. The ideas of the Codex Alimentarius guidelines were included into the international standard ISO 22000:2018 [14]. Implementing HACCP systems does not inherently lead to the creation of a traceability system through the documentation procedures. However, it is particularly vital to implement such a system. Although Principle 7 of the HACCP system mandates precise documentation and record-keeping processes, traceability solutions are not obligatory [15]. ISO 22000 mandates that enterprises perform a risk analysis in order to identify significant dangers. One of the crucial steps in the food industry's HACCP application procedures was the identification of hazards. Furthermore, it is in accordance with the initial tenet of ISO 22000:2018 and Codex HACCP, which mandates the performance of hazard analysis. The objectives of HACCP systems are to identify, evaluate, and control risks . ISO 22000 has not been adopted as a standard reference for food manufacturers by the Global Food Safety Initiative (GFSI) because to its lack of relevant PRP (prerequisite program) information. ISO22000:2018 provides improvements that largely concentrate on the identification of a PRP (pre-requisite program) and the CCP (critical control point) for key risks, employing risk-based thinking and risk reduction as guiding principles [12,14–16].

Both the FSSC 22000 and the IFS Foods are GFSI recognized. FSSC 22000 is based on ISO 22000:2018, Pre-requisite: ISO/TS 22002-1:2009, FSSC22000 additional requirements: Part II 2.1.4 (March 2020). The standards have the same objectives, so their requirements are similar and have a certain level of identity, much of the difference is at the audit level, which uses different levels, system points and categories. These standards come with additional requirements regarding genetically modified organisms, food fraud, food defense.

The objective of this study was to comprehensively examine the entire process involved in the selection and evaluation of suppliers, as well as the delivery of eggs to chain stores. This included conducting a detailed analysis of risks and hazards in three specific areas related to egg sorting and packaging. The study focused on establishments that had implemented various food safety management systems. The objective of this project is to facilitate the exchange of technological information to benefit both egg safety scientists and the economic environment (Figure 1).

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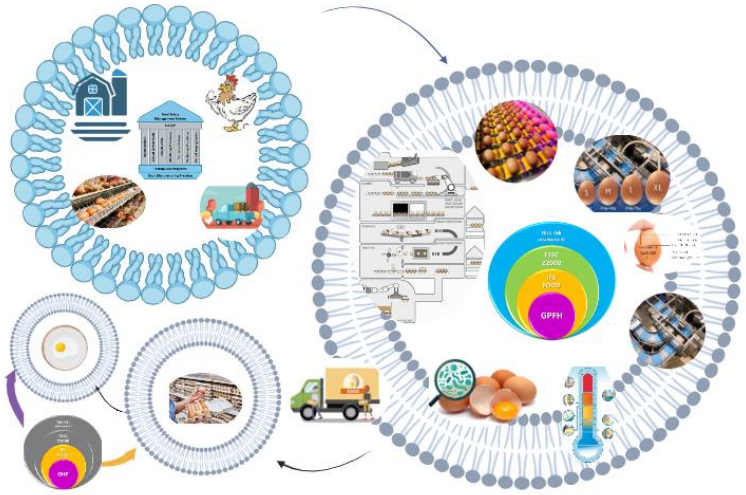

Figure 1. Implementation of food safety systems from the farm to the consumer.

2. Materials and Methods

2.1. Materials

The study specifically examined three separate breeding units of laying hens situated in different counties in Romania.

Farm A breeds a combined total of 190,000 chickens, with an equal distribution of 50% Lohman Brown and 50% ISA Brown. Production occurs within enlarged enclosures, with each hen assigned a space of 850 cm². The farm consistently achieves an egg yield of over 85%, leading to a daily output of 160,000 eggs, which amounts to an annual production of 58,400,000 eggs.

The MOBA 2500 harvesting and sorting equipment, which originates from the Netherlands, automatically collects the eggs from the sheds. This device has a throughput of 30,000 eggs per hour.

Items are categorized and graded based on their size as follows: size S refers to items weighing less than 53g, size M includes items weighing between 53g and 63g, size L includes items weighing between 63g and 73g, and size XL refers to items weighing more than 73g.

The eggs are enclosed in cartons containing 30 eggs of different sizes, guaranteeing superior packaging to maintain their integrity. Eggs derived from hens confined in battery cages are designated with the code 3.

The adoption of the IFS Food system on this farm represents a significant advancement in the dedication to guaranteeing food safety. Implementing the IFS Food system in the consumer egg sorting factory is a strategic strategy aimed at upholding the utmost standards of safety and quality. This comprehensive strategy systematically tackles every vital area of the egg handling and packaging process. This procedure ensures rigorous oversight and control, commencing from the initial acquisition of the eggs until their ultimate packaging, effectively minimizing the risk of contamination and assuring a uniform standard of quality. Robust and effective procedures and defined system benchmarks are essential to ensure that eggs provided to customers adhere to stringent safety and quality criteria. Consequently, this enhances consumer trust and upholds our exceptional standing in terms of food safety superiority.

Farm B encompasses 20 hectares of land and houses a total of 18 shelters dedicated to the rearing of laying hens. In 2012, the birds underwent modernization to comply with the European Union's regulations on the birds' mobility space and degree of freedom. The annual production capacity for eggs intended for consumption has been augmented to 75 million. Sorting and packing are carried out at a rate of 45,000 eggs per hour, utilizing state-of-the-art technology.

Inside the Constanța farm, there is a designated hall for the purpose of breeding free-range laying hens. Each individual hen is allocated a 4 m2 outside area.

The purpose-built facility accommodates 7,000 chickens in a dedicated and uniform area. Hence, two-thirds of the available area is allocated for the purposes of relaxation and nourishment.

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Furthermore, this area serves as a designated space for the purpose of nesting and egg-laying. It is equipped with two inclined planes that automatically elevate at 18:00, effectively removing both the hens and the eggs from the nest using a conveyor belt. One-third of the hall is allocated for slaughter purposes, with a platform positioned 1 meter below the feeding area and furnished with ruminants. Additionally, the shed is equipped with conventional windows on one side, enabling the birds to access the meadow adjacent to the farm.

The sorting station utilizes the FSSC 22000 technology. This approach, well acknowledged worldwide, employs a rigorous and all-encompassing technique for controlling food safety hazards. It is specifically tailored to tackle the unique difficulties related to managing eggs. By adhering to FSSC 22000 standards, the facility may guarantee systematic identification and control of potential hazards, such as biological pollutants and risks of cross-contamination. Accurate control is essential in egg processing as it is vital to precisely mitigate the risk of salmonella and other infections. Furthermore, the FSSC 22000 system's emphasis on ongoing enhancement and regular inspections enables the facility to not just uphold, but also elevate food safety standards throughout the course of time. The implementation of this method showcases a strong commitment to producing secure and high-caliber eggs, fostering consumer trust, and adhering to stringent worldwide food safety standards.

Farm C operates a sustainable chicken farming system, where the eggs produced are labeled with the number 0. Currently, the farm possesses three poultry shelters, each capable of accommodating 3000 birds. The breeding process involves using traditionally raised 16-week-old chicks. A 6-week conversion period is observed, during which the chicks are fed. The birds are kept for up to 80 weeks, with an average egg production rate of 70% on the farm. Each hen produces an average of 120 eggs each year.

The eggs are gathered automatically and sent to the sorting room, where they are manually arranged in 30-piece casings, with each casing being supplied to the marking machine.

The latest farm that was inspected features a sorting and packing facility equipped with Good Practices for Food Handling (GPFH). The GPFH system is designed expressly to address the unique challenges associated with egg handling, ensuring that each egg is treated with utmost care to maintain its integrity and safety. By following the requirements outlined in the Good Practices for Food Hygiene (GPFH), the facility establishes a robust framework for upholding cleanliness, regulating temperature, and averting contamination. These attributes are essential for the proper management of eggs. This method efficiently reduces the probability of bacterial growth, such as salmonella, and the spread of disease-causing microorganisms between diverse sources, therefore guaranteeing the safeguarding of public health. Furthermore, the GPFH system improves efficiency in the sorting and packaging process, leading to decreased occurrences of breakage and waste. Furthermore, it ensures the ability to systematically trace and supervise each stage of the egg handling procedure, which is crucial for swiftly addressing any problems related to food safety. Implementing the GPFH quality system enhances the eggs' quality and safety, while also cultivating consumer trust and faith in the products, which is highly advantageous for any food enterprise.

2.2. Methods:

2.2.1. Evaluating the food risk assessment scheme in three egg sorting/packing units with regards to the implemented food safety initiatives

The risk assessment techniques emphasized in egg sorting and packing stations include the General Principles of Food Hygiene or Good Hygiene Practice (GHP), Good Veterinary Practice (GVP), Good Distribution Practice (GDP), and Good Commercial Practice (GTP). The mentioned standards are Hazard Analysis and Critical Control Points (HACCP), ISO 22000, IFS Food v8 2023, FSSC 22000 v6 April 2023, and GFSI recognized standards.

Food risk can be categorized into two primary categories: food safety and food quality, which are associated with the concept of food integrity as described by Codex Alimentarius 2023 [17] . Food integrity can be categorized into three primary components: food safety, food quality, and food

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authenticity (non-food fraud). The food risk summary, contingent upon the implementation of food safety programs or systems, can assist entrepreneurs in categorizing which risks constitute food safety hazards for the purpose of identifying and evaluating them in the food safety risk assessment.[18]

2.2.2. Elaboration of PRPs

The performance of PRPs (GMPs, GHPs, GVPs, GDPs, GTPs, SSOPs) was carried out according to the methods given by Cusato and in compliance with the provisions of the Codex Alimentarius of 2023 [17,19,20].

2.2.3. Elaboration of the HACCP Plan

The HACCP plan was developed using the framework established by Muresan et al [20], but it was modified to meet the specifications of the updated editions of Codex Alimentarius 2023 [17], FSSC 22000 v6 (April 2023)[21], and IFS Food v8 (April 2023) [22].

2.2.3. Analyses

Residues of antibiotics, Charm II System, for Betalactams (in compliance with EU Reg. 1644/2022, DC 657/2002) and Charm II System, for Macrolides (in compliance with EU Reg. 1644/2022, DC 657/2002/ EC Reg. 37/2010/EC). Antimicrobial residues (b-lactams, macrolides, and tetracyclines) were qualitatively detected using the Charm II test following the methodology described by Adesiyun A. et al. [23].The relative humidity, pH of the yolk, pH of the white, and temperature were determined according to the guidelines set by the EFSA BIOHAZ Panel (EFSA Panel on Biological Hazards), 2014 [4]. Heavy metal residues have been determined using Graphite furnace atomic absorption spectrometry (GFAAS) technique following the methodology outlined by Szkoda J. et al. [24]. Dioxin residues have been detected using the method presented by Ten Dam G, et al. [25]. Perfluoroalkyl and polyfluoroalkyl substances were quantitaive determined using LC-MS/MS technique following the method mentioned by Therillat X. et al.[26]. For melamine determination, LC-MS/MS technique mentioned also by Wang P.C. et al. [27], was used. Fipronil residues have been determined via LC-MS/MS analysis following the methodology outlined by Charalampous A. C. et al. [28].

3. Results and discussion

3.1. Materials

The process of sorting and packing eggs involves several processes to ensure the precise quality, integrity, and categorization of the eggs. After being received and stored initially, eggs undergo a subsequent quality examination. Subsequently, they are classified according to their dimensions and mass. The egg packing process involves meticulously arranging them in cardboard boxes or trays, ensuring their security and easing their transportation. The product is then maintained in a controlled environment, where temperature and humidity are regulated, until it is delivered. This ensures that the eggs remain fresh and safe for human consumption.

During the early stage of the technological process, we obtained not only chicken eggs but also packaging materials like PET trays and cardboard packaging, as well as auxiliary materials such as food-grade printing ink, detergents, cleaning utensils, machine components, vaselines, and food-grade oils. The protocols for acquiring, handling, preserving, and conveying table eggs were established with the objective of mitigating any possible contamination or damage to the eggs or their shells. Particular attention was dedicated to the variables of temperature and time, with a specific concentration on fluctuations in temperature. In order to accomplish this goal, the collection equipment must be made of non-toxic materials and must be designed, constructed, installed, maintained, and operated in a way that encourages proper hygiene practices. Moreover, it is crucial

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to regularly cleanse and sanitize the apparatus and receptacles utilized for egg retrieval. If necessary, they should be regularly replaced to minimize the possibility of contamination in table eggs.

The technology present in the unit is long-lasting, impervious to corrosion, and can be effortlessly cleaned and disinfected. In order to reduce food risks, risk-based control procedures have been put in place to ensure full adherence to process and product standards. These procedures effectively identify and manage hazards that may be present in or on eggs that are meant for human consumption.

The criteria for accepting eggs include several factors, such as the general health of the flock (including the presence of disease-causing organisms), the amount of pathogens present in or on the eggs, the use of agricultural and veterinary chemicals, the age of the eggs, the handling procedures, and any treatments used to kill microorganisms.

During the process of transporting the eggs to the sorting chamber and placing them on the belt, they were handled with great care to prevent any harm, reduce the moisture level on the shell, and prevent any contamination. Therefore, eggs that have been cracked have been separated from those intended for business use (lower quality eggs, grade B, and confiscated eggs), or classified as animal waste in category III. During this phase, eggs that are broken or leaking, as well as eggs that are not acceptable for eating, are identified and deemed unfit for human consumption. The eggs underwent disinfection by the use of UV rays, with close supervision to minimize any harm to the shell and prevent any contamination of the egg's contents.

The next stage entails ovoscoping the eggs to inspect and measure the air cell, guaranteeing its compliance with the European-level criteria. The eggs were confiscated at this level due to the presence of abnormalities in the structure and/or freshness of the product, which were identified within 24 hours. The assessment of weight and subsequent classification of eggs was carried out in accordance with internal procedures for egg categorization, following the currently applicable European standards (Class A: XL: > 72 g; L: 63 – 73 g; M: 53 – 63 g; S: < 53 g). Class B quality eggs are eggs that do not match the quality criteria established for class A eggs, or they are class A eggs that have been demoted and intended for use in the processing industry. Eggs that did not fall into either of the above described categories were categorized as non-compliant and unfit for human consumption.

The process of marking or printing eggs entails affixing them with distinct information, such as the date, farm identity, and quality grade. In this stage, edible inks that are safe for human consumption were used. Eggs are packaged and labeled using board formworks and PET casseroles, which are specifically engineered to protect the eggs throughout shipment. The packaging of these boxes provides comprehensive information on the eggs' source, dimensions, expiry date, and quality, ensuring transparency and adherence to food safety regulations.

The product collective packaging entailed the consolidation of eggs into larger units to optimize the effectiveness of distribution. Once the eggs were organized into pallets, they were secured using pallet strapping. The eggs that had been divided into categories A and B were placed in a facility with controlled temperature to minimize the growth of harmful germs and limit the chances of biological hazards. The temperature range in egg storage rooms, normally ranging from 5°C to 18°C, is optimal for inhibiting the proliferation of infections.

In essence, the procedure of transporting grade A and B eggs from an egg sorting center include distributing the eggs into different package sizes (4, 6, 10, or 30 eggs) during the transportation process. Maintaining the correct temperature is essential as a fundamental control measure to prevent the presence of biological hazards, particularly the contamination caused by pathogenic bacteria. The transportation temperature has been controlled to maintain the air temperature within the range of 5 to 18 degrees Celsius. Ensuring the temperature remains within this range is crucial to ensure the safety and quality of eggs until they reach retail stores or end consumers.

Accumulation of garbage in the egg processing area, storage facilities, other workstations, and nearby areas was severely banned in order to ensure proper disposal and management of waste.

3.2. Evaluating the risk factors associated with eggs at three sorting and packing stations that have implemented distinct food safety protocols.

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Table 1 provides a comparison of food risk assessment schemes, specifically focusing on IFS Food v8 (April 2023), FSSC 22000 v6 (April 2023), and GPFH (GHPs HACCP, Codex 2023).

The initial column displays the identified risk factors in the egg sorting and packaging stations. The issue of contaminants involves both the safety and quality of food. They are included in all food safety analysis systems. Additionally, we can highlight the following shared elements: sanitation and sterilization, detailed product and process descriptions, meticulous operational control and monitoring, corrective measures in the event of process malfunction, validation and verification procedures, record-keeping practices, identification of hazards and their sources, assessment of their likelihood and severity in the absence of control.

The impression of control measures, control limits, corrective actions, and specific features such as fraud assessment, food defense, or incident management may vary depending on the applied system.

Table 1. Elements of the risk assessments applied in the studied egg sorting and packaging stations A, B, C, according with GPFH [GHPs, HACCP], FSSC 22000, and IFS Food scheme requirements.

Item	Requirements		
	2 GFSI schemes		
	Station A: IFS Food v8, April 2023	**Station B: FSSC 22000 v6, April 2023**	**Station C: GPFH [GHPs HACCP, v. 2023]**
Contaminants	- food safety and food quality in PRPs;	- food safety and food quality in ISO 22002-X;	- food safety and suitability in GHPs;
Cleaning and disinfection	- PRPs	- ISO 22002-X;	- GHPs and higher focus;
Product description	- HACCP;	- hazard control plan;	- GHPs;
Process description	- HACCP;	- hazard control plan;	- GHPs;
Operational control	- HACCP;	- hazard control plan;	- GHPs;
Operational monitoring	- PRPs;	- ISO 22002-X;	- GHPs;
Corrective actions in case of process failure	- PRPs;	- ISO 22002-X;	- GHPs;
Validation	- PRPs and cleaning;	- ISO 22002-X and cleaning;	- GHPs and cleaning;
Verification	- PRPs;	- ISO 22002-X;	- GHPs;
Records	- PRPs;	- ISO 22002-X;	- GHPs;
Hazards	- physical [metal, plastic, hard plastic, etc.]; - chemical [inclusive allergens, radioactivity, contaminants as melamine, fipronil, heavy metals, eggs fraud, etc.]; - biological [*Enterobacteriaceae, Salmonella spp*];	- physical [metal, plastic, hard plastic, etc.]; - chemical [inclusive allergens, radioactivity, contaminants as melamine, fipronil, heavy metals, eggs fraud, etc.]; - biological [*Enterobacteriaceae, Salmonella spp*];	- physical [metal, plastic, hard plastic, etc.]; - chemical [inclusive allergens, radioactivity, contaminants as melamine, fipronil, heavy metals, eggs fraud, etc.]; biological [*Enterobacteriaceae, Salmonella spp*];

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Item	Requirements		
	2 GFSI schemes		
	Station A: IFS Food v8, April 2023	**Station B: FSSC 22000 v6, April 2023**	**Station C: GPFH [GHPs HACCP, v. 2023]**
Hazard sources	- unintentional [farms, transport]; - intentional [economic motivation gain related with egg fraud – mislabeling];	- unintentional [farms, transport]; - intentional [economic motivation gain related with egg fraud – mislabeling];	- unintentional [farms, transport];
Occurrence in absence of control	- hazard analysis as HACCP Codex Alimentarius 2023;	- hazard analysis as ISO 22000 requirements;	- hazard analysis [3x3 matrix];
Severity in absence of control	- hazard analysis as HACCP Codex Alimentarius 2023;	- hazard analysis as ISO 22000 requirements;	- hazard analysis [3x3 matrix];
Significant hazard	- hazard analysis as HACCP Codex Alimentarius 2023 [with scientific or industry practice justification];	- hazard analysis as ISO 22000 requirements [with scientific or industry practice justification];	- simple qualitative hazard analysis with scientific or industry practice justification
Control measure	- point of attention / control point; - critical control point;	- operational prerequisites program; - critical control point;	- critical control point;
Control limit	- observable and / or measurable parameters;	- observable parameters for OPRP and measurable parameters for OPRP or CCP;	- observable and measurable parameters;
Limit control definition	- critical limit;	- action criteria; - critical limit;	- critical limit;
Monitoring	- critical limit;	- action criteria; - critical limit;	- critical control point;
Correction	- direct action [immediately];	- in time / promptly action for critical control point;	- not mentioned;
Corrective action	- root cause analysis and prevention of recurrence;	- root cause analysis and prevention of recurrence;	- critical control point;
Validation	- critical control point;	- operational prerequisites program; - critical control point;	- critical control point;
Verification	- calibration; - raw material [eggs], - packaging materials [carboard working forms and PET casseroles], in process product, finish product testing; - environmental testing; - monitoring; - corrective action;	- calibration; - raw material [eggs], - packaging materials [carboard working forms and PET casseroles], in process product, finish product testing; - environmental testing; - monitoring; - corrective action;	- calibration; - raw material [eggs], - packaging materials [carboard working forms and PET casseroles], in process product, finish product testing; - environmental testing; - monitoring; - corrective action;

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Item	Requirements		
	2 GFSI schemes		
	Station A: IFS Food v8, April 2023	**Station B: FSSC 22000 v6, April 2023**	**Station C: GPFH [GHPs HACCP, v. 2023]**
Test reports	- on annual base; - at changes;	- on annual base; - at changes;	- appropriate period - at changes;
Records keeping	- one year + egg shelf life [28 days from lying period]	- one year + egg shelf life [28 days from lying period];	- appropriate period;
Recall	- in the management system part	- in the management system part;	- GHPs;
Input raw material and auxiliary risk assessment	- hazard analysis [3x3 matrix] at reception step	- hazard analysis [3x3 matrix] at reception step;	- hazard analysis [3x3 matrix] at reception step;
Fraud assessment	- fraud occurrence, detection based on criteria established by the company [f.e.: history, economic gain, access to supply chain, the possibility to be frauded – nature of the product, credibility of the suppliers, etc.]	- fraud occurrence, detection based on criteria established by the company [f.e.: history, economic gain, access to supply chain, the possibility to be frauded – nature of the product, credibility of the suppliers, etc.]	- not mentioned;
Threat assessment / Food defense	- emphasize the evaluation of specific areas and the consequences of success, such as suspending production, causing harm to the company/product [egg], and consumer health;	- emphasize the evaluation of specific areas and the consequences of success, such as suspending production, causing harm to the company/product [egg], and consumer health;	- not mentioned;
Supplier control	- supplier selection and evaluation or HACCP;	- supplier selection and evaluation or HACCP;	- GHPs and HACCP;
Incoming inspection	- incoming inspection;	- Incoming inspection	- GHPs and HACCP;
Quality control	- PRPs; - product safety and quality operational control plan;	- as ISO 9001;	- GHPs;
Incident management	- centered on intentional occurrence, sabotage, and cyberattack, connected to the recall process;	- covered by the requirements for emergency preparedness and response;	- not mentioned;

3.2. Assessment and Implementation of the PRPs

Contemporary approaches to guaranteeing the safety of food for consumers encompass many initiatives for managing food safety, which include regulations aimed at protecting against potential acts of food terrorism. The implemented PRPs in egg sorting and packaging units include personnel hygiene, space and building hygiene, means of transport hygiene, egg hygiene, disinfection and cleaning, prevention of cross-contamination, maintenance of a cold chain during food storage, pest control, equipment maintenance, quality control of eggs, packaging and raw materials inspection upon reception, water supply management, waste and wastewater disposal, storage and transport procedures, management of finished products, and supply management. These programs are

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executed according to a clearly defined strategy. PRPs, or Protection and Response Programs, are essential and conceptual programs designed to set security baselines. HACCP is built upon a foundation of various essential programs and supplementary programs. The programs are founded on GMP (Good Manufacturing Practices) and GHP (Good Handling Practices) for products, encompassing the handling and delivery of finished products. These programs are designed to adhere to the ISO 22000:2018 standard, which focuses on food safety management systems.

An evaluation was conducted to analyze the application of PRPs in relation to buildings, facilities, equipment, utensils, food handlers, production, food transportation, and documentation. After the evaluation and identification of deviations, operational protocols were implemented. Training in the deployment of food safety systems is the crucial stage. Observations were made on the implementation of theoretical and practical training in order to modify habits and behavior related to Good Manufacturing Practices (GMP) and Good Hygiene Practices (GHP) [29].

3.3. Implementation of HACCP plan

The implementation of the HACCP plan respects the 12 essential steps.

Preliminary steps to enable hazard analysis (Step 1-6) include:

Food safety teams

The teams responsible for ensuring the quality and safety of the eggs in the 3 stations are multidisciplinary, thoroughly trained and are made up of: HACCP team leader, technological engineer, test laboratory head, hygiene manager, mechanical engineer, supply manager, distribution manager, HACCP team secretary .

Specifications and intended purpose of the product

Prior to providing a comprehensive description of the eggs, the food safety team identified their exact composition as stated in the technical sheet. Table 2 provides a concise overview of the attributes of eggs and their suggested use for all population segments, except individuals who are sensitive due to egg allergies.

Table 2. Eggs product description.

Specification	Description	Mentions
Product name	Eggs – category A	
Technical quality conditions	The eggs come from hens farms that are sanitary and veterinary authorized for consumption. Hens for consumption eggs are raised in batteries or on the ground in compliance with the legal requirements regarding the welfare of the consumption egg hens.	
Qualitative characteristics	Shell and cuticle: clean, intact, normal; Air chamber: the height does not exceed 6 mm, immovable; however, for eggs marketed with the mention "extra", it must not exceed 4 mm; Yolk: visible in the beam of light only as a shadow, without a precise outline; when the egg is turned, the yolk is slightly mobile and returns to the central position;	Tolerances for category A quality defects: At the packing center, just before shipping - 5% of the eggs have quality defects; In the other stages of marketing - 7% of the eggs have quality defects; For eggs with the mention "extra", no tolerance for the height of the air chamber is allowed during the inspection carried out during packaging;

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	Albumen: clear, translucent; Foreign bodies: no foreign bodies; Foreign odor: no foreign odor.	The percentages are doubled when the controlled lot contains less than 180 eggs.
Classification of eggs according to weight	XL - very large - weight greater than or equal to 73 g; L - large - weight less than 73 g and greater than or equal to 63 g, M - medium - weight less than 63 g and greater than or equal to 53 g; S - small - weight less than 53 g	Tolerances for egg weight A batch can contain no more than 10% of eggs from the weight categories close to the one marked on the package, but no more than 5% from the weight category immediately below. When eggs of different sizes are packed in the same package, the minimum net weight of these eggs is indicated in grams, and the mention "eggs of different sizes" is applied on the outside of the package. Category A eggs are neither washed nor cleaned, neither before nor after classification. Eggs should not be washed or cleaned, as this can cause damage to the shell, which due to its antimicrobial characteristics represents an effective barrier against bacterial contamination.
Physical - chemical characteristics	The protein content of the albumen: 11 – 12 % pH albumen: 7.8 – 9.3 The protein content of the yolk: 16 – 17 % pH yolk: 5.6 – 7	
Microbiological conditions	Salmonella (Spp/25 g): absent	According Reg. 1441 / 2007 [30]
Maximum contaminant limits	Sum of dioxin – max 2.5 pg/g fat Sum of dioxins and dioxin-like PCBs – max 5.0 pg/g fat	According Reg. 915 / 2023 [31]
Residues of medicine	≤ 200 - Chlortetracyclin, Oxytetracycline, Tetracycline, Tylosin; ≤ 150 - Erythromycin; ≤ 400 - Neomycin; ≤ 1000 - Tiamulin	According DC 657/2002/EC [32]; Reg. 37 / 2010 [33]
Residues of pesticides	absent	According Reg. 396 / 2005 [34]; Reg. 710 / 2023 [35]; Reg. 1049 / 2023 [36]; Reg. 1042 / 2023 [37]
Radioactive contamination	absent	According Reg. 52 / 2016 [38]
Melamine	max 2.5 mg/kg	According Reg. 915 / 2023 [31]
Rules for checking quality	Checking the quality of the eggs is carried out according to the "Monitoring and measuring" procedure. Each batch is examined with an ovoscope before marking and packaging.	The verification of the microbiological and physico-chemical conditions is done by collecting samples, according to the self-control program and analyzing them in authorized laboratories with which the unit collaborates.
Marking and packaging	Eggs are packed in formwork, they are palletized and wrapped. Eggs are marked in an automated system with	Marking of packages containing category A eggs:

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	the code of the farm of origin and the expiration date. Sale of eggs in bulk: information are communicated visibly and perfectly legibly, information regarding: quality category; weight category; the way of raising chickens; manufacturer code; explanation of the meaning of the manufacturer's code; minimum validity date. The bands and labels for category A eggs will be white, and the indications will be printed in black.	- the packages containing category A eggs have written on the outside, easily visible and perfectly legible; - packaging center code; the meaning of the code is explained on the outside or inside the packaging; letters and numbers of at least 2 mm; - Quality category category A or by the letter A accompanied or not by the mention "fresh"; - Weight category; a 12 mm circle around the mark for the weight class, consisting of letters at least 2 mm high; - Storage conditions "keeping eggs in the refrigerator after purchase"; - Method of raising chickens: "eggs raised in batteries"; - Minimum validity date: it must be a maximum of 28 days calculated from the laying date; letters and numbers of at least 2 mm including the day and month; for packaging "to be consumed, preferably, before..."; for the egg, the date of minimum durability followed by the date, the day, expressed in numbers from 1 to 31 and the month expressed in letters from 1 to 12 or 4 letters from the alphabet; - The "extra" mentions can only be used on packages containing category A eggs until the 9th day after laying; the laying date and the 9-day period must be written; - The way of feeding the chickens can also be indicated. Tolerances regarding the marking of packaging and eggs A tolerance of 20% is allowed for eggs bearing illegible markings during batch and packaging control.
Storage, transport, documentations	5 – 18°C, in clean spaces, free of pests. Eggs should not be refrigerated in spaces with a temperature <5 °C.	Eggs are transported with properly equipped, authorized and well-sanitized means of transport. During transport, the cold chain must be maintained. Eggs are delivered according to the "Product release" procedure. Documents: The transport of eggs is accompanied by the following documents: shipping notice, declaration of conformity
Terms of validity	28 days from the date of laying.	
Intended use	Chicken eggs are widely used in many types of food, both sweet and	The average weekly consumption of eggs should be reduced to 4 pieces.

	salty, including baked ones. Eggs can be scrambled, fried, boiled, soft-boiled and pickled. They can also be eaten raw, although this is not recommended for people who may be particularly sensitive to salmonellosis.	Eggs are part of the group of potentially allergenic foods, they can cause allergies.

Flow diagram

The flow diagram encompasses all the stages of the technological process at the three egg sorting and packaging stations. The diagram illustrates not only the various stages of the technological process, but also includes the processes leading up to the final delivery of the product to the consumer. Providing this material is crucial to enhance the presentation of the situations that may impact the safety and security of the product. These aspects should be taken into account because of their significance [39]. The food safety team conducted on-site verification of the flow charts. Figure 2 illustrates the several stages involved in the egg producing process.

The concepts of the HACCP plan (Steps 7-12)

Assessing risks and establishing permissible thresholds

Hazard identification and assessment is a fundamental principle in all HACCP systems [40] and is necessary to safeguard public health. In order to complete this stage, the food safety team has established a procedure that clearly outlines the hazard analysis approach, as outlined in Table 3. The hazard analysis is conducted throughout the entire process, starting from the eggs' production on the farm and continuing until their delivery. Hazards might exert either a direct or indirect influence on the eggs. These methods rely on the utilization of PRPs and have the objective of detecting CCPs.

The risks that have been identified are categorized into diseases (biological hazards), poisonous chemicals (chemical hazards), and foreign particles (physical hazards). These hazards arise from contamination, proliferation, and persistence[12]. The HACCP team is responsible for identifying and analyzing potential risks related to eggs at every stage of the manufacturing process.

Evaluating the potential risks in egg sorting and packing facilities by considering the seriousness of known health impacts on consumers (severity) and the probability of these hazards occurring. The probability (P) is influenced by the historical data and the knowledge of the units. Every potential danger is assessed and assigned a numerical rating ranging from 1 to 3. A hazard is deemed significant if the hazard rating (HR), obtained by multiplying the likelihood by the severity, exceeds 3 [8,12,13]. A hazard of significant magnitude is one that must be eliminated or reduced to an acceptable level in order to ensure the production of safe eggs.

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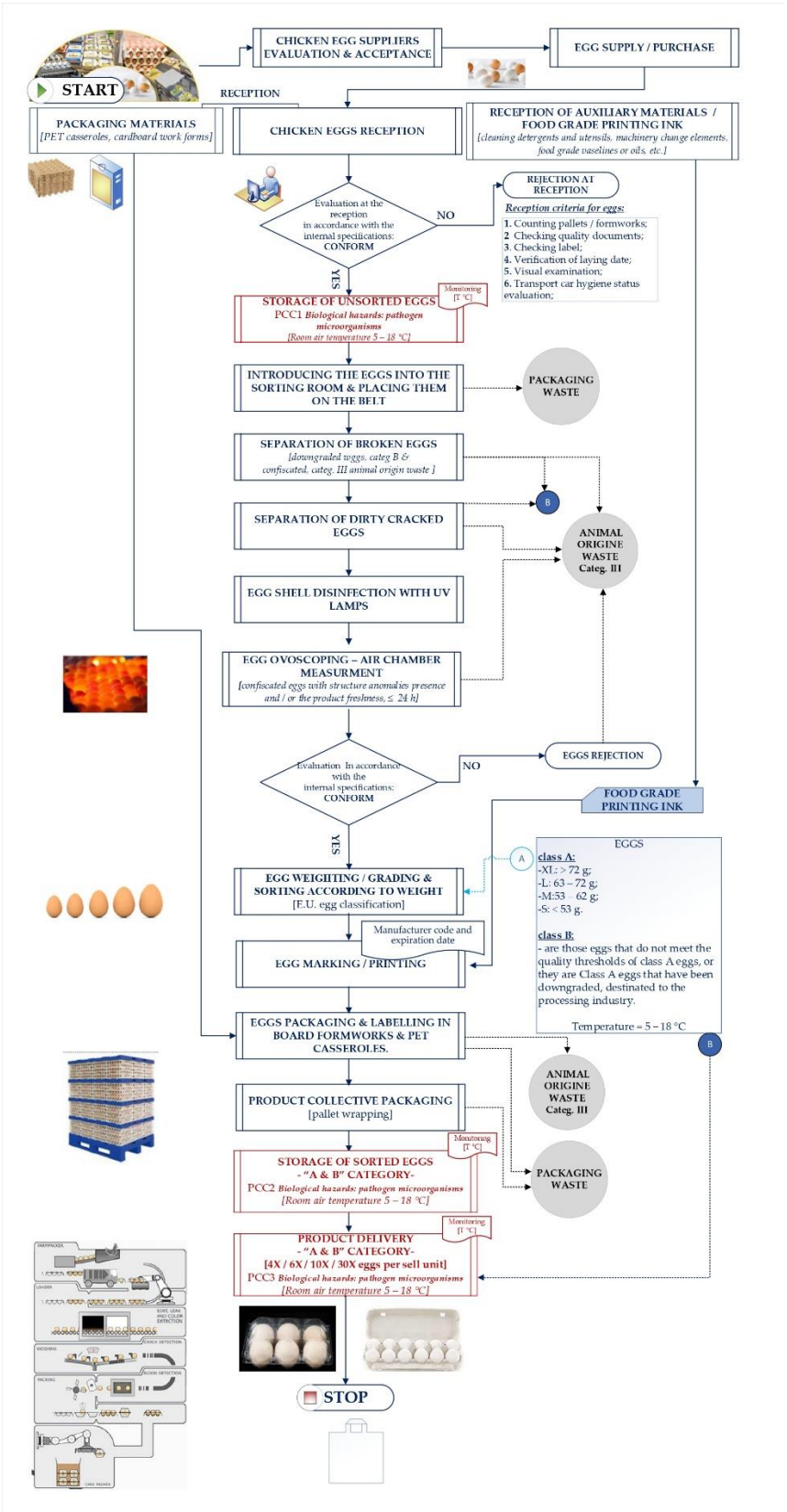

Figure 2. Flow diagram.

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Table 3. Hazard analysis and assessment.

The step of the technological process	Identify potential hazards introduced, controlled, or improved at this step		Does this potential hazard need to be addressed in the HACCP plan? Yes/No	Justify your decision	Hazard assessment			What measure(s) can be applied to prevent or eliminate the hazard or reduce in to an acceptable level?
					S	P	HR	
General, for all steps	**B**	Human diseases such as the SARS-CoV-2 virus or different zoonosis	Yes	It can lead to comsumer health impact	3	1	3	- checking the employees upon entering the unit, measuring the body temperature, and observing their health status, including the presence of symptoms characteristic of the SARS CoV-2 virus; - applying disinfection and hand hygiene rules for all personnel upon entering the unit, wearing a face mask and disposable gloves; - supervision of the personnel who handle the eggs, inclusive health status verification (2x/year parazitologic, bacteriologic, and clinic general exams); - compliance with the principle "FEFO" and stock rotation; - appropriate hand hygiene, according to the Hand Washing SOP (changing min. 1x/hour of the dirty gloves for the people handling eggs or when necessary, plus washing and disinfecting hands at entering each time the production area); - wearing appropriate work equipment for protection (white for production employees and dark blue for the maintenance staff), with a minimum of three complete rows of equipment for each employee; - washing of all work equipment by an external service provider (1x/week collecting); - checking the washing efficiency for the work equipment by taking internal sanitation tests for the washed protective equipment 1 x/week (RLU reading → directly proportional to the amount of ATP collected from the sample) and externally, accreditating ISO 17025 test reports at a frequency of 2 x/year for the following parameters: aerobic total viable count (TVC) and coliforms; - restricting staff access to the areas in accordance with the job description; - personal training with the specific SOP (Standard Operational Procedures), as follows: HACCP system and CCP monitoring, personal hygiene, sanitation program, measuring and monitoring devices, production, reception, storage, allergen management, food fraud, food defense, foreign body management, and management of transport;
	C	Chemical residues of substances used inside the facility	No	It can lead to comsumer health impact	2	1	2	
	P	Foregn bodies from company infrastructure	No	The presence of these hazards have low impact; in general lead to damages of the egg, which will not be delivered to the consumer	2	1	2	
Egg supplier election	**B**	Presence of *Salmonella spp.* and *Campylobacter jejuni* for the supplied eggs	Yes	It can lead to comsumer health impact	3	1	3	- defining criteria for approving egg suppliers based on internal supply protocols;

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The step of the technological process		Identify potential hazards introduced, controlled, or improved at this step	Does this potential hazard need to be addressed in the HACCP plan? Yes/No	Justify your decision	Hazard assessment S	P	HR	What measure(s) can be applied to prevent or eliminate the hazard or reduce in to an acceptable level?
Egg supply	**C**	Pesticide residues, mycotoxins, heavy metals, drugs, hormones, dioxines, radioactivity, allergens (other than eggs protein).	Yes	It can lead to comsumer health impact	3	1	3	- writing the technical specifications and establishing acceptability criteria for eggs; - analysis of the product in accordance with established criteria (legal base); - evaluation of egg suppliers according to internal supply / purchase procedures; - training of purchase department employees in order to understand and respect the acceptability criteria; - application of the provisions of the allergen management procedure and vulnerability study; - identification of allergenic products according to Reg. E.U. 1169/2011 (at reception, if that is the case); - re-evaluation of suppliers where non-conformities were identified at the reception; - removing from the list of accepted suppliers those who do not meet the acceptance conditions established by the supply procedure after complaint management and recurrence of the same issue;
	P	Presence of insects, rodent droplets, plastic, glass.	No	The presence of these hazards have low impact; in general lead to damages of the egg, which will not be delivered to the consumer	2	1	2	
		Fraud	No	97% of the eggs come from own farms; exception → station A with 5 external suppliers, and the matrix does not lead itself to fraud	2	1	2	
	B	Development of pathogenic microorganisms due to improper transport temperature *(Salmonella spp.* and *Campylobacter jejuni).*	Yes	It can lead to comsumer health impact	3	1	3	- supply only from evaluated and accepted suppliers, which have been previously evaluated and signed the quality and food safety annex related to the cold chain maintenance; - the transport of eggs with isothermal vehicles, authorized sanitary-veterinary, properly sanitized; - training of employees from the reception to check elements of compliance related to transport temperature, hygiene, and egg quality conditions;
	C	Chemical residues of substances used to sanitize means of transport.	Yes	It can lead to comsumer health impact	2	1	2	
	P	Contamination with foreign bodies during transport: minerals, insects parts, rodents, dust	No	The presence of these hazards has a low impact; in general, they lead to damage to the egg, which cannot be processed further or delivered to the consumer.	2	1	2	

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The step of the technological process		Identify potential hazards introduced, controlled, or improved at this step	Does this potential hazard need to be addressed in the HACCP plan? Yes/No	Justify your decision	Hazard assessment S	P	HR	What measure(s) can be applied to prevent or eliminate the hazard or reduce in to an acceptable level?
Reception	**B**	Development of pathogenic microorganisms due to farm conditions and / or improper transport: *Salmonella spp., Campylobacter jejuni;*	Yes	It can lead to comsumer health impact	3	1	3	- reception of egg batches on an arranged and boulded ramp (with temperature control); - reception of eggs in accordance with the established criteria [f.e., 1 x/month externally accredited ISO 17025 test reports for the biological hazards *Salmonella spp.* and *Campylobacter jejuni*]; - training of employees from the reception to check elements of compliance (transport temperature inside the vehicle and sanitization status, correctness and legibility of the inscriptions on the quality documents and/or label applied to the pallets, and the declaration of conformity, shelf life of the product);
	C	Pesticide residues, mycotoxins, heavy metals, melamine, drugs, hormones, dioxins, radioactivity, allergens (eggs protein), chemical residues of substances used to sanitize farms and means of transport;	Yes	It can lead to comsumer health impact	3	1	3	- receipt of eggs in accordance with the established criteria [for example, 1x/year carried out accredited ISO 17025 test reports from each egg supplier for the chemical hazards: mycotoxins, heavy metals, drugs, hormones, dioxins, radioactivity, allergens (other than egg protein), chemical residues of substances used to sanitize the farms (e.g., fipronil) or means of transport, and once per year, the same parameters measured and assessed by the company in accordance with the autocontrol program]; - rejection at the reception of egg batches for the following reasons: improper temperature, improper status of truck hygiene; - rejection at the reception of the suspicious eggs that exceed the first 1/3 of the shelf life (eggs ≥ 10 days from lying), eggs that present sensory parameters changed and are contaminated with pest signs;
	P	Presence of minerals, insects, rodents, rodent drops, plastic, glass, metals, etc. Contamination with foreign bodies during transport:	No	It can lead to comsumer health impact	2	1	2	- compliance with the monthly disinsection and deratization program in the outside yard and reception ramp; - protected lights on the ramp and compliance with the annual maintenance of burdock loading (functionality and integrity); - training of the internal person responsible for pest control activities, the person who maintains the relationship with the service provider; - monitoring of the plastic elements from the burdock unloading ramp;

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The step of the technological process	Identify potential hazards introduced, controlled, or improved at this step		Does this potential hazard need to be addressed in the HACCP plan? Yes/No	Justify your decision	Hazard assessment			What measure(s) can be applied to prevent or eliminate the hazard or reduce in to an acceptable level?
					S	P	HR	
Reception of packaging [cardboard packaging, paper rolls, PET casserols, PP bags], labels, and food-grade ink	-	Food fraud	No	97% of the eggs come from own farms; exception → station A with 5 external suppliers, and the matrix does not lead itself to fraud	2	1	2	- rejection at the reception of egg batches without provenance documents whose origin cannot be traced; - application of the provisions of the vulnerability study; - reevaluation of the supplier and decision-making about keeping it or closing collaboration with it in case of fraud;
	-	Food Defence	No	It can lead to comsumer health impact	2	1	2	- application of the Food Defense Plan as a result of the assessment: 24/7 surveillance cameras, controlled access inside the site yard, control access systems for employees according to job descriptions, and mitigation strategies related to employee release;
	B	Presence of *Total viable count* (TVC) and *coliforms*	Yes	It can lead to comsumer health impact	3	1	3	- supplying only from accepted suppliers, GFSI-certified (Global Food Safety Initiative); - completing the supply order with quality and food safety requirements (microbiological parameters); - transport carried out with properly sanitized vehicles; - internal sanitation test at each reception (RLU) and external accreditated test reports min. 1x/year for microbiological criteria specified by Romanian Ministry of Health Order No. 976/1998 [41] and Regulation (EC) No. 1935/2004 [42];
	C	Components that can migrate into the product (global migration, heavy metals), toxic substances in the marking ink	Yes	It can lead to comsumer health impact	3	1	3	- checking the supplied products and accepting only those that meet the quality and food safety requirements, accompanied by appropriate documents. → for packaging: Declaration of Conformity at each delivery; Compliance Declaration; Migration Test Reports (global migration of the components, organoleptic modifications, specific heavy metal migration); and Technical Data Sheet (min. 1x/year); → for ink: use of food-grade ink; acceptance criteria as described in Reg. (EC) No. 2006/2023 [43] regarding the good manufacturing practices for materials and articles intended to come into contact with food, and Reg. (EC) No. 1935/2004, art. 3; - rejection at the reception in case of non-conform packaging and/or ink; - compliance with the reception SOP;
	P	Presence of metals, glass, dust, insects, rodents traces	No	It can lead to comsumer health impact	2	1	2	- protection of lighting sources from the outside ramp; - checking the integrity of transport packaging; - checking the presence of traces of insects or rodents inside the vehicle;

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The step of the technological process	Identify potential hazards introduced, controlled, or improved at this step	Does this potential hazard need to be addressed in the HACCP plan? Yes/No	Justify your decision	Hazard assessment S	P	HR	What measure(s) can be applied to prevent or eliminate the hazard or reduce in to an acceptable level?
Storage of unsorted eggs	**B** Proliferation of pathogenic microorganisms in favorable temperature conditions results in the formation of condensation on the eggshell. Contamination from the storage space *Salmonella spp, Campylobacter jejuni, TVC, Moulds)*	Yes	It can result an unsuitable product or possibly have a health repercussion leading to various illnesses.	3	1	3	- stablishment of storage conditions: temp. of 5–18°C, and temperature and storage time monitoring; - appropriate sanitation of the storage warehouse, in accordance with GMP and GHP; - metrological checks at least annually of measuring and control devices (externally) and monthly (internally with calibrated standard equipment), plus annual checks of the warehouse storage climate unit; - enhancing the efficiency of refrigeration systems by preventing excessive load on the storage warehouse; - personal training with the storage SOP (standard operational procedure) and sanitation of the warehouse SOP; - externally accredited ISO 17025 sanitation tests (1x/3 months) for surfaces [from storage rakes, around sinks, corners, and under the cooling system] and for the air; - application of batch sheets and verification of shelf life;
	C Residues from pest control activities and/or cleaning chemicals	No	The presence of this hazards can cause illness and injury to the consumer	2	1	2	- compliance with the monthly disinsection and deratization program of the company yard and reception ramp (chemicals used, concentrations, frequency); - compliance with the internal annual sanitation program; - training by the service provider of the internal responsible for pest control activities; - prohibition of storing products or other substances than eggs in the storage warehouse;
	P Cracked egg. Contamination with foreign bodies during storage and internal manipulation from the storage: glas, parts of insects, hard plastic, dust	No	The presence of these hazards has a low impact; in general, they lead to damage to the egg, which cannot be processed further or delivered to the consumer.	2	1	2	- training of the responsible staff with the Foreign Body Management SOP; - monitoring the integrity of lighting, hard plastic transport egg forms, hard plastic electrical systems, and plastic pallets; - monitoring of all entries and openings (completely sealed doors, good nets at windows); - presence of EFK (electro-fly killers with glue tape) at all entries;

The step of the technological process	Identify potential hazards introduced, controlled, or improved at this step		Does this potential hazard need to be addressed in the HACCP plan? Yes/No	Justify your decision	Hazard assessment			What measure(s) can be applied to prevent or eliminate the hazard or reduce in to an acceptable level?
					S	P	HR	
Storage of packaging	**B**	Contamination from the storage space (*TVC, Moulds*)	No	It can lead to comsumer health impact	2	1	2	- sanitization of storage warehouses according to a daily, monthly, and annual sanitization program; - complying with storage rules: on shelves, pallets with the batch label; the packaging is stored in the warehouse in designated areas that are specifically marked and separated between different types of packaging; - personal training with the requirements of the packaging storage SOP (ambiental temperature and RH max. 40%); - compliance with the „FIFO" principle;
	C	Residues from pest control activities and / or clenning chemicals	No	The presence of this hazards can cause illness and injury to the consumer	2	1	2	- compliance with the monthly disinsection and deratization program of the storage area (chemicals used, concentrations, frequency); - compliance with the internal annual sanitation program; - training by the service provider of the internal responsible for pest control activities; - prohibition of storing products or substances other than packaging materials;
	P	Presence of glass, insects, rodents, dust	No	It can lead to comsumer health impact	2	1	2	- keeping the packaging protected against dust contamination and other foreign bodies by ensuring the integrity of the protective packaging; - checking the integrity of individual packaging during storage, at least once a week, and eliminating non-compliant packaging: deformed, dusty, broken, or contaminated with foreign bodies; - applying a distance of 50 cm free from the wall for all pallets; - compliance with the monthly disinsection and deratization program in the storage warehouse; - protection of lighting installations; - monitoring of all entries and openings (completely sealed doors, good nets at windows); - transparent foil appliance on all windows; - all entrances to the exterior are protected against the penetration of insects (presence of EFK: electro-fly killers at all entries) and pests (internal rodent traps); - training of the responsible staff with the Foreign Body Management SOP; - restricting staff access to the storage space;

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					S	P	HR	
Introducing eggs for sorting	**B**	Contamination from personnel, MOBA work line or working space (*TVC, Moulds, Staphylococcus haemolyticus, Staphylococcus coagulase positive, Enterobacteriacea)*	No	It can lead to comsumer health impact	2	1	2	- personal health status check at a daily frequency at the pre-operational control (drawn up by the occupational medicine doctor); - proper handling of the eggs to prevent breakage; - removing the packaging film used for the protection of the pallets without making contact with the eggs and removing them from the sorting room; - establish and follow the MOBA packaging line sanitization program (concentrations, operating time, frequency) according to the GHP and producer guidelines from the technical book; - daily check of the ventilation system to prevent condensation and its removal in case of appearance; - personal training with the egg sorting SOP; - weekly internal sanitation tests for surfaces (RLU); - biannually, the company makes externally accredited ISO 17025 test outcomes for operational surfaces, individuals' health conditions, and working microaeroflora.
	C	Residues from pest control activities and / or clenning chemicals	No	The presence of this hazards can cause illness and injury to the consumer	2	1	2	- compliance with monthly disinsection and deratization program of thesorting area (chemicals used, concentrations, frequency); - compliance with the internal annual sanitation program; - training by the service provider of the internal responsible for pest control activities; - prohibition of storing products or substances other than eggs; - application of the provisions of the Allergen Management Procedure for the people: lunch area; - uses of food grade vaselines for greasing equipment (NSF);
	P	Presence of glass, metal, insects, rodents or rodents traces	No	It can lead to comsumer health impact	2	1	2	- collection of animal and non-animal waste in labeled containers and their removal from the sorting area at the end of the program; - sorting the eggs, removing the cracked, broken, and dirty ones: dirty eggs are placed on the formwork, and broken eggs are collected in containers provided with PP or PET bags, which, after filling, will be tied to the mouth and then stored in the refrigerated space [temp. 5 – 18 ^{0}C] for non-compliant products, with a view to delivery for neutralization or further industrial processing – external plant;

The step of the technological process	Identify potential hazards introduced, controlled, or improved at this step		Does this potential hazard need to be addressed in the HACCP plan? Yes/No	Justify your decision	Hazard assessment			What measure(s) can be applied to prevent or eliminate the hazard or reduce in to an acceptable level?
					S	P	HR	
Separation and removal of confiscated, dirty and cracked eggs	**B**	Contamination from machinery, and personnel; Contamination due to breaking eggs	No	It can lead to comsumer health impact	2	1	2	- ensuring and recording the temperature in the sorting room [temp. of 10–12 °C for max. 5 h]; - broken eggs are collected in containers provided with PP or PET bags, which, after filling, will be tied to the mouth and then stored in the refrigerated space [temp. 5–18 °C] for non-compliant products, with a view to delivery for neutralization or further industrial processing at an external plant; - use of clean, single-use formwork; - identification of sorted eggs by the label corresponding to each category [A and B]; - preparation and compliance with the MOBA equipment and installation maintenance program;
	C	Contamination with oils used to lubricate equipment. Contamination with residues and substances used for sanitation and pest control activities	No	the presence of residues of oils used for greasing or washing substances cannot cause serious illness	2	1	2	- the use of food grade lubricating oils; - personal training with the Egg sorting, marking and packaging SOP; - for MOBA parts in contact with the products, the company use only food grade vaselines for greasing equipment (NSF);
	P	Presence of glass, metal, parts from other eggs	No	It can lead to comsumer health impact	1	1	2	- monitoring of the semifinished products (sorted, unpacked eggs, clean and conform as shape and structure); - monitoring the integrity of MOBA line elements and of the production environment;
Disinfection with UV lamp	**B**	Inefficient disinfection [for Total viable count of germs (TVC), coliform bacteria]	No	It can lead to comsumer health impact	2	1	2	- preparation and compliance with the UV lamp maintenance program in accordance with the manufacturer's technical data sheet; - checking the operation efficiency through external test reports (min. 1 x 3 months); - replacement of lamps after 10,000 hours of functioning (aprox. 1 year);
	C	-	-	-	-	-	-	-
	P	Presence of: glass, hard plastic, metal	No	It can lead to comsumer health impact	2	1	2	- daily check of the UV integrity lamp (before and after batch finishing);

The step of the technological process	Identify potential hazards introduced, controlled, or improved at this step	Does this potential hazard need to be addressed in the HACCP plan? Yes/No	Justify your decision	Hazard assessment S	P	HR	What measure(s) can be applied to prevent or eliminate the hazard or reduce in to an acceptable level?
Egg ovoscopy and air chamber measurement	**B** Inappropriate removal of eggs with dirty shell, broken	No	It can lead to comsumer health impact	2	1	2	- daily check of ovoscopy operation: eggs whose air chamber is movable and/or exceeds 6 mm in height are removed, classified as category B eggs, and stored in formwork together with cracked and dirty eggs, which further will be delivered to industrial enterprises for processing; - use of clean, single-use formwork; - identification of sorted eggs by labeling corresponding to each category; - exercise caution when handling the eggs to prevent any inadvertent breakage; - compliance with the autocontrol program for sanitation tests in the working flow;
	C Contamination with residues and substances used for sanitation and pest control activities or oils used to lubricate equipment.	No	the presence of residues of oils used for greasing or washing substances cannot cause serious illness	2	1	2	- the use of food-grade lubricating oils; - personal training with the Egg Ovoscopy SOP; - for ovoscope parts in contact with the products, the company uses only food-grade vaselines for greasing equipment (NSF); - complying with the ovoscope maintenance program; - compliance with the monthly disinsection and deratization program of the company yard and reception ramp (chemicals used, concentrations, frequency); - compliance with the internal annual sanitation program;
	P Presence of metals, glass, plastic	No	It can lead to comsumer health impact	2	1	2	- preparation and compliance with the maintenance program for utilities and installations; - ensuring and recording the integrity of ovoscope and of equipment lighting system;

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The step of the technological process	Identify potential hazards introduced, controlled, or improved at this step		Does this potential hazard need to be addressed in the HACCP plan? Yes/No	Justify your decision	Hazard assessment			What measure(s) can be applied to prevent or eliminate the hazard or reduce in to an acceptable level?
					S	P	HR	
Weighing eggs and sorting according to weight	**B**	Development of pathogenic bacteria in favorable temperature conditions. The formation of condensation on the egg shell. Contamination from machinery or working area.	Yes	It can lead to comsumer health impact	3	1	3	- ensuring the maintenance of the cold chain and recording the temperature in the sorting room to prevent the formation of condensation on the egg shell; - monitoring of the temperature and documenting the information inthe file working sheet, inclusive the packing report with information about the lot no. of each packagin used; - checking the weighing and sorting processes according to 4 categories applied: XL, L, M, S; - checking the weighing and sorting machine with standard calibrated weights, minimum 1 x / month; - completing the egg weight check register and tracking of mass balance; - internally performed sanitation tests for the working surfaces (RLU expresed) are done every month, and externally accredited ISO 17025 sanitation tests are performed every three months for surfaces, including weighted lines or air; - reception of eggs in accordance with the established criteria [f.e., 1 x/month externally accredited ISO 17025 test reports for the biological hazards *Salmonella spp*. and *Campylobacter jejuni*];
	C	Residues of chemical substances used for sanitation of MOBA equipments; lubricants	No	It can lead to comsumer health impact	2	1	2	- establishing and following the Sanitation Program (concentrations, action time, frequency) according to the internal sanitation equipment (MOBA) program; - internal pH test of the rinse potable water taken from the cleaned line (conform rinse potable water pH between 6.5 and 9.5);
	P	-	-	-	-	-	-	-
	B	**-**	-	-	-	-	-	
Marking eggs/Printing	**C**	Heavy metals in the substances used for marking/ printing [Pb, Cd, As, Hg)	No	It can lead to comsumer health impact	2	1	2	- checking the automatic egg stamping correctness and legibility of marking and shelf life; - supplier compliance declaration for the ink used; - accreditated ISO 17025 test reports for heavy metals presence in eggs [min. 1 x / year] and from the supplier [in ink]; - compliance with the maintenance program of the MOBA printing part;

The step of the technological process	Identify potential hazards introduced, controlled, or improved at this step		Does this potential hazard need to be addressed in the HACCP plan? Yes/No	Justify your decision	Hazard assessment			What measure(s) can be applied to prevent or eliminate the hazard or reduce in to an acceptable level?
					S	P	HR	
	P	Presence of glass, metal, insects, rodents	No	It can lead to comsumer health impact	2	1	2	- personal training with the SOP for foreign bodies monitoring related equipment [f.e., displaies, hard plastic from carcasses, conveyor belts, etc.]; - monitoring the integrity of marking and printing MOBA parts equipment; - visual inspection; - compliance with the monthly disinsection and deratization program of the company yard and reception ramp (chemicals used, concentrations, frequency);
Egg packaging in formwork and labeling	**B**	The development of pathogenic bacteria in favorable temperature conditions. The formation of condensation on the surface of the eggs. Contamination from packaging materials.	Yes	It can lead to comsumer health impact	3	1	3	- using approved single-use packaging for the food industry; - checking the microbiological load of packaging through sanitation tests (internal sanitation tests, RLU) and externally accredited ISO 17025 sanitation tests (TVC and Coliforms); - maintainance of the temperature of the sorting and packaging area between 5 – 18 ^{0}C, monitoring it and documenting it in the temperature sheet file: for avoidance of condensation on the egg shell; - checking the cleaning status of formwork, casseroles, and pallets for egg class A: weights S, M, L, and XL;
	C	Chemical components that can migrate from the packaging to the product. Residues from substances used for sanitation and pest control activities.	No	It can lead to comsumer health impact	2	1	2	- annualy migrations test for all packagings used from the suppliers (global migration of the components, organoleptic modifications, specific heavy metal migration); - uses only of food garde vaselines / lubricants (NSF); - compliance with the monthly disinsection and deratization program from the packaging area; - compliance with the internal annual sanitation program;
	P	Presence of glass, metal, insects.	No	It can lead to comsumer health impact	2	1	2	- visual inspection of packaged products; - compliance with the maintenance program of MOBA equipment; - proper intermediary storage of eggs during the working shift, handling, collection of packaging, and correct disposal of packaging waste; - avoidance of prolonged storage of packaged products; - monitoring the integrity of hard plastic objects of the line and from the packaging area; - compliance with pest control activities;

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The step of the technological process	Identify potential hazards introduced, controlled, or improved at this step	Does this potential hazard need to be addressed in the HACCP plan? Yes/No	Justify your decision	Hazard assessment S	P	HR	What measure(s) can be applied to prevent or eliminate the hazard or reduce in to an acceptable level?
Storage of sorted eggs, category A and B	**B** Development of pathogenic bacteria, due to improper storage conditions (*Salmonella spp., Campylobacter jejun*, Aerobic TVC, Moulds, Coliforms)	Yes	it can lead to obtaining an inappropriate product or even to a health impact causing different diseases.	3	1	3	- establishment of storage conditions: temperature of 5–18 °C, monitoring it, and documenting it in the temperature sheet file; - precooling the warehouse before introducing and storing the eggs; - avoidance of placing pallets in front of the air cooling system; - observing the formation of condensation, its removal, and the backup movement of the final product in the second warehouse while the company makes a backup check of the cooling system; - compliance with the annual disinfection program for the warehouse spaces; - checking the microbiological load of surfaces through sanitation tests 1 x / week (internal sanitation tests RLU) and external accreditated ISO 17025 sanitation tests 2 x /year: warehouse microaeroflora (*Aerobic TVC, Moulds*) and 1 x/trimester for surfaces (*Aerobic TVC, Coliforms*);
	C Residues of chemicals from cleaning operations and / or pest control activities	Yes	It can lead to comsumer health impact	2	1	2	- compliance with the sanitation program for spaces and with the monthly pest control program (chemicals, concentrations, frequency); - checking the efficiency of rinsing after cleaning, pH of rinse water, sample taken from the warehouse walls during drying time (conform rinse potable water pH between 6.5 and 9.5); - training of the employees responsible for sanitation activities at the final product warehouse storage facility;
	P Presence of glass, plastic, insects, rodents	No	It can lead to comsumer health impact	2	1	2	- training of the employees with the Foreigh Bodies management SOP; - monitoring the integrity of equipment; - transparent foil to all windows; - the sorting plant strictly prohibits the use of hard plastic (exceptions: MOBA component parts) or glass utensils, only allowing the use of bendable plastic;

The step of the technological process	Identify potential hazards introduced, controlled, or improved at this step		Does this potential hazard need to be addressed in the HACCP plan? Yes/No	Justify your decision	Hazard assessment			What measure(s) can be applied to prevent or eliminate the hazard or reduce in to an acceptable level?
					S	P	HR	
Product delivery A and B category	**B**	Development of pathogenic bacteria as a result of non-compliance with storage temperatures or the formation of condensation on the surface of the eggshell (*Salmonella spp., Campylobacter jejuni,* Aerobic TVC, Moulds, Coliforms)	Yes	It can lead to obtaining an inappropriate product or even to a health impact causing different diseases.	3	1	3	- checking the state of hygiene of the means of transport; - checking the temperature in the truck transport room; - temperature monitoring during transport – visual inside driver cabin, thermogram printing at the end of the journey, and 1x/year-blind verification of the transport service providers through dataloger insertion inside the pallet with the eggs (during the summer period); - loading for delivery at the appropriately arranged ramp or burdock loading ramps, sanitized according to the Cleaning annual program; - before loading, checking the integrity of the packaging and the product shelf life; - drivers with up-to date checks for health status; - conducting the transportation using vehicles that have been authorized by the Food Safety Authority and that are able to maintain the required temperatures throughout the whole journey;
	C	Residues of chemicals from cleaning operations, fuel residue, or other residue from products transported	No	It can lead to comsumer health impact	2	1	2	- conducting the transportation using vehicles that are properly cleaned, with no smells; - the transportation exclusively contains eggs and does not involve the movement of other goods utilizing a coupling mechanism;
	P	Presence of impurities: metal, plastic protection lamps, and stitches from windows	No	It can lead to comsumer health impact	2	1	2	- verification and monitoring of the hygiene and integrity of means of transport; - careful handling of products to preserve the integrity of protective and transport packaging; - verification of the technical condition of the means of transport; - check inside the truck to not be transported other than eggs;

*[1]S, Severity; [2]P, Probability; [3]HR, Hazard Rating; [4]B, Biological; [5]C, Chimical; [6]P, Physical.

After conducting the hazard analysis, the hazard rating (HR) is determined. Control measures are implemented using PRP for hazards with an HR value of 2 or below, which are classified as low or nearly non-existent hazards, without the requirement of CP or CCP [40,44].

The occurrence of potential chemical hazards in eggs, such as residues of veterinary drugs, food additives, migration residues from packaging materials, heavy metals, and air compressor oil, as well as potential biological hazards, is mitigated by the implementation of PRP to minimize the chance of their presence.

While chemical and biological dangers are typically prioritized, it is crucial to recognize that physical hazards in eggs hold comparable significance. Physical risks can arise from failure to comply with PRPs, unintentional contamination , and are associated with interaction with different objects, improper packaging, or inaccurate labeling [29,45].

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Cleaning is not considered in the assessment of units evaluated when HR is equal to or more than 3 (CCP or CP). However, periodic inspections are conducted to verify the absence of foreign particles. (glass, plastic, wood, metal, etc.) [45]

When risks with a Hazard Ranking (HR) of 3 or above are detected, a decision tree called the 4Q is utilized to determine if the hazard should be classified as a Critical Control Point (CCP) or a Control Point (CP), as outlined in Table 4. While the usage of the decision tree technique CCP decision from ISO 22000:2018 is not obligatory, it is recommended in Codex Alimentarius 2023. The decision tree is a visually analytical tool that is clear, well-organized, and easy to comprehend. It should be employed for determining CCP [44].

Table 4. CCP / CP identification.

Process step	Significant hazard	Q1[1]Q2[2]Q3[3]Q4[4]	CCP/ CP YES / NO
Egg supplier election	**B** [f.e.: *Salmonella spp.* and *Campylobacter jejuni*]: the supplied eggs	Yes No No -	**CP 1**
	C [f.e.: pesticide residues, mycotoxins, heavy metals, drugs, hormones, dioxines, radioactivity, allergens (other than eggs protein).]: eggs can be contaminated from the farm;	Yes No No -	
Egg supply	**B** [f.e.: *Salmonella spp.* and *Campylobacter jejuni*]: eggs can be contaminated from improper transport temperature;	Yes No No -	**CP2**
Reception	**B** [f.e.: *Salmonella spp, Campylobacter jejuni, TVC, Moulds*]: egg supplier election	Yes No No -	**CP 3**
	C [f.e. Pesticide residues, mycotoxins, heavy metals, melamine, drugs, hormones, dioxins, radioactivity, allergens (eggs protein), chemical residues of substances used to sanitize farms and means of transport]: egg supplier election	Yes No No -	
Reception of packaging materials, labels and ink	B [f.e. TVC, coliforms]: contamination from the manufacturer or transport;	Yes No No -	**CP 4**
	C [chemicals residue, overall migration limit (OML) for plastic packaging > 60mg/kg food, or 10 mg/dm^2 of the contact material]: contamination from the manufacture;	Yes No No -	
Storage of unsorted eggs	**B** [f.e.: *Salmonella spp*]: contamination due to the improper temperature [limits → 5 – 18 ^{0}C];	Yes No Yes No	**CCP - 1**
Weighing eggs and sorting according to weight	**B** [f.e.: *Salmonella spp., Campylobacter jejuni, TVC, Coliforms*]: contamination of eggs due to improper temperatures, condensation or equipment;	Yes No No -	**CP - 5**
Egg packaging in formwork and labeling	**B** [f.e.: *Salmonella spp., Campylobacter jejun, TVC, Coliforms*]: contamination of eggs due to improper temperatures, condensation or equipment;	Yes No No -	**CP - 6**
Storage of sorted eggs, category A și B	**B** [f.e.: *Salmonella spp., Campylobacter jejun*, Aerobic TVC, Moulds, Coliforms]: contamination due to the improper temperature [limits → 5 – 18 ^{0}C];	Yes No Yes No	**CCP - 2**
Product delivery A and B category	**B** [f.e.: *Salmonella spp., Campylobacter jejun*, Aerobic TVC, Moulds, Coliforms]: contamination due to the improper temperature [limits → 5 – 18 ^{0}C];	Yes No Yes No	**CCP - 3**

[1]Q1 - Do control measure(s) exist for the identified hazard? [2]Q2 - Is the step specifically designed to eliminate or reduce a hazard to an acceptable level. [3]Q3 - Could contamination occur at or increase to unacceptable level(s). [4]Q4 - Will a subsequent step eliminate or reduce the likely occurrence of the hazard to an acceptable level?

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The initial critical control point (CCP) identified pertained to the storage of unsorted eggs. Failure to adhere to the specified settings during this stage may result in the proliferation of harmful bacteria, hence posing potential health risks to customers.

The second CCP is designated for the storage of categorized eggs, specifically those classified as category A and B. The current temperature in the technical process ranges from 5 to 18°C. Elevated temperatures can result in an escalation of the microbial burden, or temperature variations that result in condensation and subsequently toxins. Strict regulation of time and temperature can effectively manage bacterial development. Hence, it is imperative to meticulously monitor both the duration and the degree of heat during the storage procedure. The distribution and sale stages must adhere to same stringent requirements, as specified by CCP 3 [46–48].

Table 5 provides detailed information on the critical limits, monitoring methods, and necessary actions to be conducted in the event that the critical limits or action limits or action criteria are exceeded, following the successful execution of the CCPs.

In order to assess the effectiveness of the HACCP plan, the food safety team devised a verification plan in Table 6. This plan outlines the scope, frequency, and assigned duties for the verification activities.

The research utilizes the documents and records generated throughout the execution of the plan to fulfill the final principle of the HACCP plan. These records serve as proof of the use of HACCP principles, surveillance of CCP parameters, and suggested remedial measures. The materials are categorized into instructions and processes and are comprised of evidence-based documents. Their components consist of a title, purpose, application/scope, definitions, abbreviations, authority, duties, description of operations, records, linked papers, references, and annexes.

Table 5. Identifying critical limits, monitoring procedures and corrective actions.

CCPs	Significant hazard (s)	CCP parame-ter	Value pro-gramme d and validate d	Critical limits	Monitoring procedure				Correction and Corrective action	Records
					What ?	How?	When - frequency?	Who?		
Storage of unsorted eggs **CCP – 1** **Storage of sorted eggs, category A and B** **CCP - 2**	**Biological hazard**: Proliferation of pathogenic microorganisms in favorable temperature conditions, formation of condensation on the eggshell; Contamination from the storage space.	Temp. in the storage room	5 – 18 °C	> 18°C for more than 3 hours	Air temp.	Reading and recording storage space temperature Checking/ validation of the internal system with the ethalon thermometer [standard measuring and monitoring devices].	Continue through electronic systems and physical by the stockkeeper 2 x/ day from Monday to Sunday.	Monitoring: the stockkeeper and the person responsible for security during the weekend; Verification: Quality Assurance Manager and Production Responsible; Corective action: Production Responsible and/or Administrator;	**Correction** If the temperature is near the critical limit (> 15 °C), immediate notification of the technical department and production responsible is done. During storage, a free space is ensured between the formwork / boxes, sufficient for the circulation of cold air. If the defect cannot be fixed and there is a danger that the temperature of the egg warehouse [at	Online system database and temperature sheet

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CCPs	Significant hazard (s)	CCP parame-ter	Value pro-gramme d and validate d	Critical limits	Monitoring procedure				Correction and Corrective action	Records
					What ?	How?	When - frequency?	Who?		
									reception or at delivery] will exceed the value of 18 °C, the eggs should be urgently inserted for sorting if possible or transferred to another space with a corresponding temperature of 5–18 °C [case of CCP1], and / or delivered urgently or transferred to another space with a corresponding temperature of 5–18 °C [case of CCP2]. If the temperature of the air warehouse has reached > 18 °C for more than 3 hours, the product lots are identified as potentially unsafe and treated according to the procedure "Control of non-compliant products [quarantified, externally tested reports for Salmonella and sensoy parameters, and the decision of the Food Safety Team]. Sorting, packaging, and commercializati on within a maximum of 3 days of eggs that have been stored at a	

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CCPs	Significant hazard (s)	CCP parame-ter	Value pro-gramme d and validate d	Critical limits	Monitoring procedure				Correction and Corrective action	Records
					What ?	How?	When - frequency?	Who?		
									temperature < 5 °C. Moldy, rotten, cloudy, or even opaque eggs, without separation between white and yolk, or those with dark spots on the inner side of the shell, produced by various molds or bacteria, are confiscated and destined for denature. **Corrective action** Maintaining the annual verifications of the cooling system according with the internal schedule for preventive measures. If the electricity supply stops, the electric group will be automatically turned on to ensure the appropriate conditions. Establishment and application of equipment maintenance program Establishing and following the specific training of the employees (on food safety and on technical part).	
Product delivery CCP - 3	**Biological hazard**: Development of pathogenic bacteria as a	Temp. during product deliver	5 – 18°C	> 18°C for more than 3 hours	Air temp.	Reading and recording the temperature inside the truck at	Continue through electronic systems.	Monitoring: the driver;	**Correction** The product is not loaded in the truck until the temperature	Thermodiagrame picture at delivery

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CCPs	Significant hazard (s)	CCP parame-ter	Value pro-gramme d and validate d	Critica l limits	Monitoring procedure				Correction and Corrective action	Records
					What ?	How?	When - frequency?	Who?		
	result of non-compliance with storage temperatures, or the formation of condensation on the surface of the eggshell; contamination from the means of transport.	y [inside the truck]				product loading; Automatic system, checking the thermodiagrame before unloading the product	Visualisation every 2 hours during transport [inside the driver cabine]	Verification: Logistic Responsible Corective action: Logistic Responsible and / or Administrator;	of the truck-transported room is max. 10 °C. In case of failure of the system, the truck will be changed (maximum 3 hours) or will be redirected nearest the closest refrigerated warehouse [due to our networking partners and collaborations]. **Corrective action** Revision in time on all trucks and on all refrigerated systems. between If the temperature are not in the range 5 – 18°C Compliance with GMP, GHP measures and staff training. Respecting the product legal parameteres and compliance with product technical parameters; Corect sanitation of the transport trucks after easch delivery [thawing process and sanitation];	

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Table 6. Establishing verification procedures.

No. crt.	Field of verification / item	Frequency	Responsible for verification
1.	Verification of compliance with the procedure for selecting suppliers;	Annual or at introduction of a new supplier in the system	Purchase Responsible
2.	Checking the quality and safety of eggs: - quality parameters (pH, sensory) → once every 3 months; - safety parameters: veterinary residue, mycotoxins, PCB, heavy metals, drugs, hormones, dioxins,melamine, radioactivity, allergens (other than egg protein), chemical residues of substances used to sanitize the farms (e.g., fipronil) → annual. - Sallmonela spp., Campylobacter jejuni: monthly	Annual, biannual and / or monthly	HACCP team leader
3.	Checking the conformity of transport at reception (daily or each reception) and at delivery (each delivery);	Daily or each reception / each transport	Stockkeeper Logistic responsible
4.	Checking the temperature and hygiene conditions from storage warehouses and transport, until sale;	Daily / as long the product is kept into the storage or transported	Logistic Responsible Production Responsible Stockkeeper Driver
5.	Potable water supply check	Annual	Hygiene Responsible
6.	Verification of compliance with the stages of the technological flow	Monthly	Technological engineer
7.	Verification of compliance with equipment maintenance	Annual, biannual and / or monthly	Maintenance manager
8.	Verification of calibration of measuring and control device	Annual or when it is necessary.	Maintenance responsible
9.	Checking the hygiene of production protective equipment, spaces, annexes, and social groups	Internal (weekly) External (1x/ 3 months)	Hygiene Responsible HACCP Team leader
10.	Checking the control of the health of the staff	Biannual	Production Responsible
11.	Checking the hygiene of the work equipment	Internal (weekly) External (1x/ 3 months)	Hygiene Responsible HACCP Team leader
12.	Checking efficiency for waste disposal	Monthly	HACCP team leader
13.	Verification of compliance with the pest control procedure	Monthly	Hygiene Responsible
14.	Verification of CCP records; deviations from critical limits; execution of corrections and / or corrective actions	Daily	HACCP team leader
15.	Checking CP records	Daily	Production responsible HACCP team leader
15.	Checking the efficiency of employees training	Once every three months	HR Manager Production Responsible HACCP team leader
16.	Checking the quality control and safety of the finished eggs	Internal (daily) External (monthly)	Production Responsible HACCP team leader
17.	Checking the registration activity	Monthly	HACCP team secretary
18.	Checking the registration and settlement mode of complaints, trend analysis conclusions	Monthly	HACCP team leader
19.	Checking team biovigilance	Annual	TACCP team
20.	Checking the fraud vulnerability	Annual	VACCP team

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3.4. Findings and discourse on the analysis

3.4.1. Evaluation of quality parameters

Concerning the assessment of the quality criteria of eggs from farms A, B, and C, by Regulation (EU) 589/2008, the following table emphasizes that the majority of the examined eggs were categorized as high quality and safe for human consumption. Thus, less than 1% of all farms were found to have eggs with abnormal shapes, indicating that most of the eggs have a typical shape. The percentage of dirty eggs exhibited a slightly elevated number, particularly in farm C, indicating that while the majority of eggs are clean, there is still a need for improvement in the handling procedures to mitigate the incidence of dirty eggs. The studied farms reported a percentage of damaged eggs below 2%, which complies with the regulations requiring eggs to be free from dirt and damage.

A small proportion of the eggs had an air cell height that was beyond 6 mm, adhering thus to the requirement that the air cell height should not exceed 6 mm. The occurrence of yolk abnormalities was not significant, in farm A having a higher frequency than farms B and C. However, all farms had an incidence below 0.2%, suggesting that the majority of yolks had no signs of significant abnormalities. Cloudiness or lack of transparency was rarely observed in the egg whites from farm A, occurring in less than 0.1% of the cases. This indicates that nearly all of the eggs had clear and transparent whites.

According to the Table 7, there were no detected (nd) cases of germ growth or the presence of foreign matter, which complies with the accepted standards. Farm B experienced two cases of foreign smells that resulted in the rejection of eggs at reception. This fact also suggests the implementation of efficient quality control procedures to identify and eliminate eggs that do not match the requirements established by European laws. Based on the research, the data shows a significant level of compliance to EU regulations, while there are certain places where improvements in the technological flow might be implemented.

Table 7. Evaluation of quality parameters**.**

Eggs quality parameters		**Station A**	**Station B**	**Station C**	**Referince description [Reg. E.U. 589 / 2008] [49]**
(a) shell and cuticle:	irregular shape (%)	0.31	0.26	0.16	normal shape, clean and undamaged;
	dirty (%)	0.81	1.15	1.98	
	damaged (%)	1.49	1.53	1.27	
(b) air space:	height > 6 mm (%)	0.37	0.44	0.28	height not exceeding 6mm, stationary; however, for eggs to bemarketed as ‘extra’, it may not exceed 4mm;
	for extra eggs: height ≤ 4 mm (%)	nd	nd	nd	
(c) yolk:	abnormalities presence at yolk	0.16	< 0.1	< 0.1	referince values: visible on candling as a shadow only, without clearly discernible outline, slightly mobile upon turning the egg, and returning to a central position;
(d) white:	unclear, nontranslucent	< 0.1			clear, translucent;
	development	nd	nd	nd	imperceptible development;
(f) foreign matter	presence	nd	nd	nd	not permissible
(g) foreign smell	presence	nd	presence 2 cases / rejection at reception	nd	not permissible

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3.4.2. Evaluation of veterinary drugs

The following data shows that after conducting analyses on the egg sorting station, no antibiotic residues were found in eggs from farms A, B, and C for chlortetracycline, erythromycin, oxytetracycline, tetracycline, and tylosin. The absence of antibiotic detection in the examined eggs indicates that their levels are below the detectable threshold of the used testing procedures, confirming their compliance with the maximum residue limits (MRLs) set by Regulation (EU) 37/2010 [33]. Regarding Neomycin, and Tiamulin, the designation "not applicable" (na) indicates that the determinations for these antibiotics were not relevant in relation to the waiting period of 0 days. However, it should be noted that these antibiotics do have established Maximum Residue Limits (MRLs). The current Maximum Residue Limit (MRL) is implemented for egg-laying poultry farms through national-level monitoring programs. Thus, the responsibility of the farmer is to conduct tests to confirm to validate the clearance of antibiotics from the body. The lack of detectable residues in the examined samples indicates that the egg sorting centres guarantee the safety of the eggs for human consumption in relation to the specified antibiotics. The reference to withdrawal periods for specific antibiotics underscores the significance of practicing responsible usage of veterinary drugs in poultry farming. In this context, a specific time frame must pass between the final administration of the antibiotic and the collection of eggs intended for human consumption. This precaution is taken to guarantee that antibiotic residues remain below the permissible threshold (Table 8).

Table 8. Evaluation of veterinary drugs.

Veterinary drugs	Station A	Station B	Station C	Reference values	Observations
	X±sx	X±sx	X±sx	[Reg. E.U.37 / 2010. max. µg/kg] [33]	
Chlortetracyclin	nd	nd	nd	≤ 200	waiting period 6 days
Erythromycin	nd	nd	nd	≤ 150	waiting period 4 days
Neomycin	na	na	na	≤ 500	for this type of antibiotic no waiting period is required
Oxytetracycline	nd	nd	nd	≤ 200	waiting period 4 days
Tetracycline	nd	nd	nd	≤ 200	waiting period 4 days
Tiamulin	na	na	na	≤ 1000	for this type of antibiotic no waiting period is required
Tylosin	nd	nd	nd	≤ 200	waiting period 4 days

X - the average of the determined value; sx - standard deviation; nd – not detected; na - not applicable.

3.4.3. The egg quality and safety characteristics

The egg quality and safety characteristics at farms A, B, and C comply with the reference values established by the European Food Safety Authority (EFSA) [4] and Regulation 589/2008 [49]. This suggests that these farms employ efficient management and monitoring systems.

The relative humidity (RH) in all three farms examined falls within the optimal range of 70-80%, in accordance with the recommendations specified in the EFSA study of 2014. Furthermore, this suggests that the eggs remained fresh and of high quality during the whole testing period.

The pH level of both the yolk and white plays a crucial role in determining the quality and freshness. The pH levels of the yolk exhibit variation, but they typically hover around the ideal range of 6 throughout all farms. The pH of albumen displays significant variability, yet it consistently remains close to an optimal value. The observed discrepancy can be ascribed to natural fluctuations in the composition of eggs and the circumstances in which they are stored and handled prior to being examined.

Moreover, the temperature of the eggs is vital in maintaining their quality and freshness. According to Regulation 589/2008 [49], the temperatures recorded at all farms fall within the range of 5 to 18°C. Farm C displayed a higher average temperature, falling within the range of 5-18°C. This suggests the need for more care to ensure proper storage conditions.

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The obtained results underscore the importance of continuous monitoring and adherence to established standards to ensure the safety, quality, and freshness of eggs intended for human consumption (Table 9).

Table 9. The egg quality and safety characteristics.

Parameter	Station A	Station B	Station C	Reference values
	X±sx	X±sx	X±sx	
RH	76.8±1.33	73.2±2.13	79.1±1.02	70-80% [4]
pH yolk	6.3±2.14	6.2±1.46	6.4±1.62	6 [4]
pH white	7.8±1.09	7.1±2.03	7.2±2.59	7.6 [4]
Temparature	5.6±2.53	5.1±1.36	7.2±3.02	5 - 18 °C [49]

X - the average of the determined value; sx - standard deviation.

3.4.4. The contamination of the eggs

The monitoring results from farms A, B, and C (Table 10) confirm adherence to the predetermined threshold limits for various pollutants that could potentially be found in eggs meant for human consumption. This showcases the application of effective strategies for managing the presence of substances that could be harmful to customers and the safety of food.

The cumulative amounts of dioxins and dioxin-like PCBs detected in eggs obtained from all farms are determined to be lower than the reference criterion of 5.0 pg/g fat. Station A has the most minimal average concentration compared to all the other farms. The quantities of non-dioxin-like PCBs detected in all farms were well below the reference limit of 40 ng/g fat. This suggests that the management procedures are successfully executed, hence preventing contamination with these persistent organic pollutants.

The levels of perfluoroalkyl and poly-fluoroalkyl chemicals (PFOS, PFOA, PFNA, and PFHxS) found in eggs from the examined farms are far lower than the reference value of 1.7, suggesting that there is very little risk to human health. These pollutants are a concern because they persist for a long time and have the potential to negatively impact human health. Farm B demonstrates the lowest average concentration, suggesting the successful implementation of effective management practices.

Table 10. Contamination from the 3 egg sorting and packaging stations.

Parameter	Station A	Station B	Station C	Reference values
	X±sx	X±sx	X±sx	
Sum of dioxins (pg WHO- PCDD/F- TEQ/g)	1.7±.03	1.2±0.21	1.6±0.02	2,5 pg/g fat [31]
Sum of dioxins and dioxin-like PCBs (pg WHO-PCDD/ F-PCB-TEQ/g)	2.6±0.34	3.2±1.29	3.4±1.25	5,0 pg/g fat [31]
Sum of non dioxin-like PCBs (ng/g)	28±1.32	27.1±2.38	30.2±2.61	40 ng/g fat [31]
Sum of PFOS, PFOA, PFNA and PFHxS (Perfluoroalkyl and polyfluoroalkyl substances)	0.9±0.34	0.2±0.21	0.3±0.07	1.7 [31]
Melamine	1.9±0.05	2.1±1.36	1.9±1.01	2.5 mg/kg [31]
Fipronil (sum Fipronil + Fipronil sulfone)	< LOD	<LOD	<LOD	LOD = 0.005 mg/kg [34]

X - the average of the determined value; sx - standard deviationl; LOD – limit of detection.

4. Conclusions

The risk and hazard analysis conducted in the three egg sorting and packing stations adheres to the GPFH (GHPs HACCP, v. 2023), FSSC 22000 V6, and IFS Food V8 standards. This study encompasses the entire process, starting from the assessment and selection of suppliers and ending with the distribution of eggs to chain stores. Salmonella poses the greatest substantial risk. The study presented offered advanced preventive measures readily available to avoid, minimize, or alleviate

the risks observed in egg packing and sorting operations. The units equipped with the FSSC and IFS systems possess comprehensive analysis tools for genetically modified organisms, food fraud, and food defense. These tools assist scientists and processing units via the transfer of technology.

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