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Literature Study

Food Safety Management System in Edible Bird's Nest Industry: A Review

Sistem Manajemen Keamanan Pangan di Industri Pencucian Sarang Burung Walet: Review

Siti Gusti Ningrum

Faculty of Veterinary Medicine, Wijaya Kusuma University, Surabaya-Indonesia

ABSTRACT

Background: Food safety management systems such as ISO 22000:2018 have many advantages in solving this newcomer industry's problems. It has enabled the edible bird's nest industry to plan, implement, operate, maintain, and update an FSMS providing edible bird's nest products and safe services. **Purpose:** This review article delineates the role of the food safety management system (FSMS) in improving quality control, production performance, and economic effects in the edible bird's nest industry. **Methods:** This study was a literature review that collected sources from books and journals. **Result:** Hence, the evaluation and assessment could be adequate to meet regulatory food safety requirements. FSMS possess division properties such as quality control, production, marketing, purchasing, general affair, human resources, warehouse, and maintenance. They also have veterinary control numbers and animals quarantine installation, enhancing the edible bird's nest industry's overall quality control and production performance in Indonesia. **Result:** The findings of the current review depicted the tremendous potential of cleaning development, which could be explored with the recent advancements in science and technology. The advantages of compelling communication of food safety issues from the FSMS ensure that the edible bird's nest industry conforms to its stated food safety policy and relevant interested parties in fulfilling the trade requirements set by the export/importing destination country.

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***Correspondence:**
Siti Gusti Ningrum
E-mail: sitiningrum@uwks.ac.id

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ABSTRAK

Latar Belakang: Sistem manajemen keamanan pangan seperti halnya ISO 22000:2018 memiliki banyak keunggulan dalam menyelesaikan permasalahan industri baru. Sistem ini memudahkan industri pencucian sarang burung walet dalam perencanaan, operasi, *monitoring* dan pembaharuan sistem manajemen keamanan pangan untuk produk sarang burung walet dan pelayanan yang aman. **Tujuan:** Studi literatur ini bertujuan untuk mengungkapkan peran sistem manajemen keamanan pangan dalam perbaikan pengendalian kualitas, performa produksi, dan dampak ekonomi di industri pencucian sarang burung walet. **Metode:** Studi ini menggunakan metode *literature review* dengan mengambil sumber dari buku dan jurnal. **Hasil:** Evaluasi dan penilaian dapat digunakan untuk memenuhi peraturan terkait persyaratan keamanan pangan. Perangkat divisi sistem manajemen keamanan pangan di antaranya adalah pengendali kualitas, produksi, penjualan, pembelian, urusan umum, sumber daya manusia, gudang, dan pemeliharaan. Selain itu, nomor kontrol veteriner dan instalasi karantina hewan meningkatkan pengendalian kualitas dan performa produksi industri pencucian sarang burung walet Indonesia secara keseluruhan. **Kesimpulan:** Pengembangan pencucian sarang burung walet perlu eksplorasi lebih jauh dengan melibatkan kemajuan terbaru dalam ilmu pengetahuan dan teknologi. Keunggulan komunikasi isu keamanan pangan dalam sistem manajemen keamanan pangan perlu dipastikan bahwa industri sarang burung walet yang ada sudah sesuai dengan kebijakan keamanan pangan yang ditetapkan dan pihak terkait yang berkepentingan dalam memenuhi persyaratan perdagangan yang ditetapkan oleh negara tujuan ekspor/impor..

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Kata kunci: Sarang burung walet, Keamanan Pangan, Veteriner

INTRODUCTION

A food safety management system (FSMS) is vital for the food industry to perform hazard analysis and critical control points. Also, it enables the food safety team to eliminate or reduce the potential hazard to ensure product quality (Milios et al. 2014, Allata *et al.* 2017, Chen *et al.* 2019, Chen *et al.* 2020, Dzwolak, 2019). The food safety system is planned, operated, updated, and incorporated into the overall management activities within the structured management system framework. It benefits the organization and its linked parties (Panghal *et al.* 2018). They are components of FSMS, including scope, normative references, terms and definitions, the organization's context, leadership, planning, support, operation, performance evaluation, and improvement. Internal and external pressures also influence the understanding how an FSMS is developed and implemented (Escanciano and Santos-Vijande, 2014). It then interacts with the food safety culture, which is critical to consistently achieving food safety requirements (Manning *et al.,* 2019). ISO 22000:2018 was adapted for a food company such as the edible bird's nest (EBN) industry to meet the food chain needs (Tarnagda *et al.* 2020).

The popularity of EBN as a food source has made it challenging for the EBN industry to ensure the quality of EBN (Tay *et al.* 2015) from farm to the consumer since EBN comes from animal origin. Indonesia has become the leading producer of edible bird's nests in Southeast Asia, exporting over 2,000 t/year, Malaysia 600 t/year, and Thailand 400 t/year (Ito *et al.* 2021). From the literature, many activities have been adapted to provide and enhance the quality of EBN (Jong *et al.* 2013). They performed the fuzzy Failure Mode and Effect Analysis (FMEA) methodology for EBN processing. It was adapted in Malaysia's EBN production processes to replace the conventional risk assessment, which established effective management for swiftlet cultivation and EBN food processing. In the edible bird's nest industry, FSMS is implemented as a strategic decision that can improve the edible bird's nest industry's overall food safety performance (ISO, 2018). FSMS has a higher ability to consistently provide safe foods and products than conventional risk assessment (Luning *et al.* 2015). A decline in foodborne outbreaks and pathogen contamination in foods suggests that FSMS effectively improves food safety (Papademas and Bintsis, 2010). A previous study (Ningrum *et al.* 2023) found Aspergillus fumigatus in edible bird's nests from various warehouses in Indonesia. It is well known that this fungus is zoonotic, so mitigation of the risk in the first line of the edible bird's nest industry, such as warehouses, is urgently needed.

Hence, the implementation of FSMS could help address risks and demonstrate conformity to specified FSMS requirements in the edible bird's nest industry. However, each company has its own unique FSMS because it depends on which QA standards and guidelines they use and how they translate and adapt them to specific circumstances (Luning *et al.* 2015). This paper explains the FSMS processes as routine EBN manufacturing operations, including QA standards. As the first-ranked resource area for EBN production globally, Indonesia has adapted FSMS for the EBN industry. The elements of FSMS adopted by most of the EBN industry in Indonesia are quality control, purchasing, warehouse, production, marketing, human resources, general affairs, and maintenance. A food safety team leader leads the FSMS to ensure the FSMS has performed well in a food company. The food safety team should list all of the hazards that may reasonably be expected to occur at each step according to the scope, from primary production, processing, manufacture, and distribution until the point of consumption (Kafetzopoulos *et al.* 2013). Thus, this review article delineates the food safety management system (FSMS) to improve quality control, production performance, and economic effects in the edible bird's nest industry.

METHODS

Using key databases like Google Scholar, ResearchGate, PubMed, Science Direct, and the Google search engine, a thorough search was undertaken to identify relevant research and data published between 1990 and 2023. Several criteria, such as legislation, food safety from farm to fork, and the effects of FSMS on EBN's industry, were explored to locate relevant papers. Due to the lack of edible bird's nest literature, the current research evaluated edible bird's nest laws written in Bahasa Indonesia and conference papers. However, papers published in languages other than English and those that were not peer-reviewed were eliminated from the study. First, the abstracts of 3580 published article titles were examined. Following the screening, 100 articles were selected for full paper evaluation. In conclusion, 69 publications with high-quality data were obtained for this investigation.

DISCUSSION

Regulations And Policies Related to Edible Bird's Nest Trade

An edible bird nest, well-known as the "East's Caviar" (Lee *et al.* 2019), was produced by dried swiftlet saliva and formed a white nest (figure 1). EBN can be consumed by humans for a long time ago, mainly by the Chinese (Tai *et al.* 2020). With high demand from People's Republic of China (Thorburn, 2014), swiftlet farming and the EBN industry have emerged as a rising food industry among Southeast Asia countries, including Indonesia. The increased demand for high-quality EBN is challenging for swiftlets farming and the EBN industry (Lee *et al.* 2017). EBN processing involves farming, harvesting, sorting, cleaning, deep cleaning, drying, shaping, redrying, storing, steaming, packaging, and chilling. Normative references are different for some countries. In Indonesia, two regulations organize the food safety system, from swiftlets farming to the EBN industry, veterinary control number and animals quarantine installation.

Food products have met the elements of food safety marked by the veterinary control number. A veterinary control number is a certificate as legal written evidence that hygiene and sanitation requirements are fulfilled as basic eligibility for animal origin food safety assurance in the animal origin food business unit (Niami *et al.* 2019). The objectives of carrying

Figure 1. Edible bird nest.

out the Veterinary Control Number certification are to implement a legal and administrative order to manage the animal-based food products business. It ensures the business unit meets hygiene-sanitation requirements and applies suitable production methods. Also, the Veterinary Control Number makes it easier to trace back in case of food poisoning of animal origin. The veterinary control number certification authority for animal product business units is delegated to Provincial Veterinary Authority (POV) officials. The validity period of the veterinary control number in this regulation is limited to five years, so every five years, it must be recertified by POV officials with surveillance every year (Peraturan Menteri Pertanian, 2020). Therefore, business actors who wish to obtain veterinary control number certification should apply to the provincial office's head by attaching the required requirements online. If the conditions are declared complete, the government will forward the request to the POV Officials to be followed up by deploying the veterinary control number auditor team based on an assignment from the head of the provincial service. Besides, the export of EBN to the People's Republic of China requires tracing the edible bird nest's origin (Yeo *et al.* 2021). This tracing of EBN is proven by determining the swiftlet house by the Agricultural Quarantine Agency. The Animal Quarantine Center has issued various guidelines and technical/implementation instructions in the edible bird's nest quarantine sector, with the following guidelines for examination of edible bird's nest nitrite content for exportation to the People's Republic of China, guidelines for heating edible bird's nest for exportation to the People's Republic of China, guidelines for quarantine monitoring of export of edible bird's nest to the People's Republic of China, guidelines for animal quarantine requirements and measures for exportation of edible bird's nests from the territory of the Republic of Indonesia to the People's Republic of China, technical instructions for handling and inspection of swallow and sriti bird nests, guidelines for animal quarantine measures for importation and exportation of animal products within the territory of the Republic of Indonesia, guidelines for monitoring of materials of animal origin and products of materials of animal origin, guidelines for verification of edible bird's nest heating for exportation to the People's Republic of China 2018, and regulation of the Minister of agriculture No. 26/2020 concerning animal quarantine measures for the importation and exportation of edible bird's nests to and from within the territory of the Republic of Indonesia.

Therefore, the business actor must consider three main conditions: traceability, clean EBN with a nitrite content of less than 30 ppm (Yusuf *et al.* 2020), and heated to 70˚C for 3.5 seconds (Badan Karantina Pertanian, 2018). Also, the clean EBN should be negative for avian influenza virus by PCR and negative for other pathogens such as Salmonella. Indonesia's standards of EBN for export to People's Republic of China are listed in table 1.

Tabel 1.
Indonesia standards of EBN for export (BSN, 2021)

Category	Parameters	Tolerance level
Physical	Feather and dirt contamination	Looks clear of feathers and visual debris from the naked eyes at a distance of 20–30 cm
	Metal and wood contamination	Nil from the naked eyes at a distance of 20–30 cm
	Color	White, yellow, red, orange
	Moisture	Less than 18%
Microbiology	Total Plate Count	≤1 × 10^6 cfu/g
	Coliforms	≤100 cfu/g
	Escherichia coli	≤10 cfu/g
	Salmonella sp.	Negative
	Staphylococcus aureus	≤100 cfu/g
	Avian Influenza	Negative
	Yeast and fungi	≤10 cfu/g
Residue	Nitrite	≤80 mg/kg
	H_2O_2	Negative

Hygiene Personal

Personal hygiene in the EBN industry is the primary key to mitigating contamination from humans to edible bird nests. People who work around open food may contaminate the food or surfaces that the food may contact. Almost all humans, not machines, carry out practically all production stages. Personnel are both reservoirs and vectors of microorganisms and can act as a source of microbial contamination for food products. Direct contamination may arise from contact between the body, which acts as a reservoir of microorganisms, and the food product. The face, neck, hands, and hair contain more transient microorganisms and a higher general bacterial density. Therefore, washing hands is the first thing all workers must do to maintain food safety. Indirect contamination involves people acting as vectors, transferring contamination from one area or surface to another, for example, by moving product soil and microorganisms on the sole

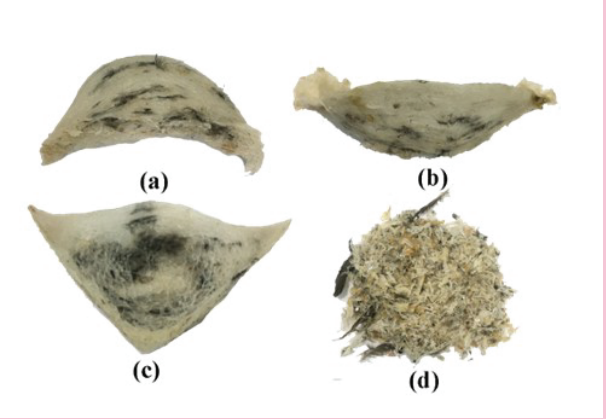

Figure 2. a) Cup-shaped, b) Strip-shaped, c) Corner-shaped, d) Crumble-shaped.

of footwear to different parts of the food factory. This indirect mode also includes contamination in food processing areas if factory clothing is allowed in the canteen, toilets, or home (Margas and Holah 2014).

Moreover, worker health is also the primary key to avoiding human-to-product transmission of disease agents (Holmes *et al.* 2017). Therefore, every worker in the EBN industry must have an excellent medical history, as shown by the results of a medical checkup approved by a doctor in a hospital or clinic. The parameters tested include a physical examination, a thorax examination, an eye health test, and a blood test (Nasrolahei *et al.* 2017). This medical checkup is done at the beginning of work and is repeated yearly. In addition, routine randomized tests are carried out once a year on the hygiene of worker's hands and clothes by swabbing for microbiological testing for suspicion of high total microbes and the presence of pathogenic bacteria (Novakovic and Grujic, 2017).

Sanitation

Sanitation in the EBN industry depends on the QC plan (table 2). Cleaning and sanitizing the processing unit is critical in reducing the risk of transferring pathogenic organisms to food and consumers between different runs (Stoica, 2018). Cleaning and sanitizing procedures should actively destroy the vegetative cells of hazardous microorganisms (Ziyaina and Rasco, 2021) and substantially reduce the population of other undesirable microorganisms without adversely affecting the food product's quality or its safety for the consumer. For example, the primary sanitation in the EBN industry lies in washing production equipment that uses hot water to kill microorganisms and remove dirt attached to the equipment. At the same time, cleaning reagents used in the EBN industry have specific criteria, namely being colorless and odorless. Color and odor-cleaning reagents can adversely affect the EBN product quality.

Grading Control

Every EBN industry must undergo the quality control (QC) stage. Grading is the first mandatory inspection step for quality control. Grading is an activity to sort out the bird's nest's shape and the feathers' quantity. Expert panels inspect and grade raw edible bird nests visually (Saad *et al.* 2012). There are four primary forms of raw material: cup, strip, corner/-head, and cake/biscuit (Xing *et al.* 2012) (see figure 2). In general, cups and corners/heads have a higher quality than strips, cake/biscuits.

Regarding the total number of feathers, bird's nests can be divided into bald, light, medium, and heavy (figure 3). Each industry can have different standard operating procedures (SOPs). For illustration, industry A can accept all types of raw material types in shape and number of feathers. But in industry B, SOPs could be different, only to take cup-shaped bird nests with light feathers. There is nothing wrong with these two types of industries. The difference can be seen in the following process. Industry A has a heavier and more diverse job because it has many bird nest variants that a QC staff for quality must control compared to industry B. Industry B tends to be easier to manage, especially traceability, so this industry is preferred. Apart from being based on physical examination, QC staff must also take a sample from each batch to check for nitrite levels (Merino *et al.* 2017).

Checking the nitrite level in the raw material is needed (Poretti, 1990) to determine the nitrite level before washing. Nitrite levels that are too high in the raw material will cause rework. The washing technique with potable water flowing for a few seconds cannot ultimately reduce the nitrite level (Yusuf *et al.* 2020). Therefore, raw material grading is effective in overcoming high nitrite levels. It can eliminate raw materials not entering industry standards to meet market needs. The grading system will set the market price of EBN (Jamalluddin *et al.* 2019). For example, raw materials with heavy feathers will provide higher nitrite levels than shaved ones. Also, the bird's nest color determines the nitrite levels. A white bird's nest will give you lower nitrite levels than a yellow, brown, or red one (Paydar *et al.* 2013). The cave nests with darker and redder colors had higher nitrite and nitrate contents than the brighter and more yellow house nests. This likely suggests that the nitrite and nitrate contents have correlations with the edible bird's nest color (Quek *et al.* 2018). Recording the

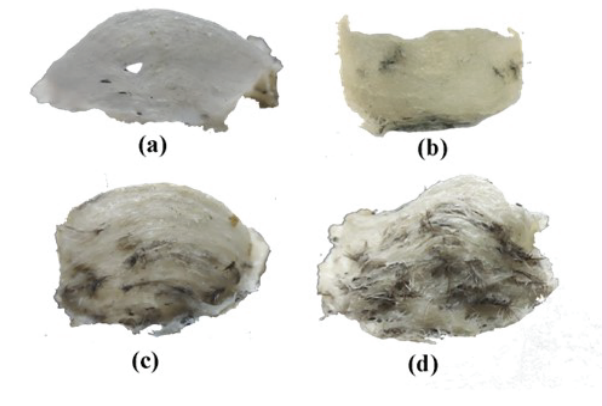

Figure 3. a) Bald feather bird nest, b) Light feather bird nest, c) Medium feather bird nest, d) Heavy feather bird nest.

Tabel 2.
The quality plan in the EBN industry.

Process	Checkpoint		Standard	Measurement tool	Sample		PIC	Quality report	Response if not conform
	Process	Product	Check		Quantity	Frequency			
Incoming material	The arrival of EBN raw materials	EBN	EBN raw material specification	Visual	All	Every arrival	Warehouse and QC staff	Warehouse reports	Report to QAQC manager
	Primary packaging arrival	Primary packaging	Food grade statement	Visual	All	Every arrival	Warehouse and QC staff	Warehouse reports	Report to QAQC manager
	Secondary packaging arrival	Secondary packaging	Material safety data sheets	Visual	All	Every arrival	Warehouse and QC staff	Warehouse reports	Report to QAQC manager
Production	Brushing result	EBN	EBN cleanliness	Visual	All	Every processing	Production and QC staff	Daily reports	Report to QAQC manager
	Feather removal result	EBN	EBN cleanliness	Visual	All	Every processing	Production and QC staff	Daily reports	Report to QAQC manager
	Cleaning result	EBN	EBN cleanliness	Visual	All	Every processing	Production and QC staff	Daily reports	Report to QAQC manager
	Drying result	EBN	EBN cleanliness	Visual	All	Every processing	Production and QC staff	Daily reports	Report to QAQC manager
	Reshaping result	EBN	EBN cleanliness	Visual	All	Every processing	Production and QC staff	Daily reports	Report to QAQC manager
	Regrading result	EBN	EBN cleanliness	Visual	All	Every processing	Production and QC staff	Daily reports	Report to QAQC manager
	Steaming result	EBN	Time and temperature reached	Thermometer dan stopwatch	All	Every processing	QC staff	QC reports	Report to QAQC manager
	Nitrite test result	EBN	Less than 30 ppm	Spectrophoto meter	Minimum six (n) sample per batch	Every processing	QC staff	QC reports	Report to QAQC manager
	Chiller temperature	EBN	3-5°C	Thermometer	All	Everyday	Production and QC staff	Daily reports	Report to QAQC manager
Finished product	Packing result	EBN	Finished product specification	Visual	All	Every packing	Production and QC staff	Finished product reports	Report to QAQC manager

Source. QC plan of PT. Nanyang Boga Jaya Industri. Note: person in charge (PIC)

nitrite content of raw material can also determine the supplier's quality. Several countries have different policies regarding the levels of nitrite in the EBN. The People's Republic of China has set the maximum amount of nitrite in the finished product of EBN to be 30 ppm (Gan *et al.* 2017). According to (Ningrum, 2021), Indonesia has a good record of nitrite in the finished product, which is at a low concentration (10.752 ± 1.515 ppm). With tight market demand, the industry should tighten the selection of raw material suppliers. Despite this, raw materials of excellent quality are scarce these days.

Bird's Nest Cleaning Process Control

The cleaning process is at the core of the EBN industrial activities. White nests are often cleaned by hand to preserve their shapes (Tan *et al.* 2013). Therefore, the washing process is in the public spotlight because the human handle is almost 100% and can only use running water for a few seconds. This is the traditional method most commonly used in the EBN industry (Farhani *et al.* 2015). Although the cleaning process is the core of the EBN industry's activities, it is not necessary for the cleaning process to be a critical control point (CCP). It is because nitrite levels will not be entirely removed by washing (Susilo *et al.* 2016). Therefore, it is essential to grade raw materials to achieve the allowable nitrite content target. This cleaning process begins with cleaning manually using a stainless steel knife. The aim is to remove pieces of wood attached to the bird's nest (Shim *et al.* 2017) without changing its shape. The safety team chooses stainless steel because it has essential corrosion resistance and toughness (Patel Ad, 2015). Cutters are strictly prohibited because they break easily during the cleaning process, creating a risk of cuts to the worker's hands and becoming a physical hazard to the product. In this step, raw bird nests will be soaked in clean water for further cleaning (Hong *et al.* 2020). During the process, most dust or surface impurities will float; the bird's nest starts to absorb the water and expand in size, increasing its original weight (Ma and Liu, 2012). The nest's condition appears soft and sticky (Hong *et al.* 2020). Therefore, it is easier for the workers to pick out the feathers with forceps or tweezers. This process may take 20 to 30 minutes for a skilled worker to do, depending on the cleanliness of the raw bird nest (Hong *et al.* 2020).

The washing technique commonly used in the EBN industry is for potable water to flow briefly. Although insignificant, this application can reduce nitrite levels, so this method is inappropriate for yellow, brown, and red bird nests. The nitrite content in the color group tends to be very high (Ismail *et al.,* 2011). Therefore, EBNs with this color group are rarely found in industrial EBNs. Also, because this process uses time, the timer must be calibrated annually at an accredited institution. It can be calibrated monthly by QC staff who have attended calibration training and have a certificate from an accredited calibration institute. After washing, the QC staff must take a sample from the batch to check for nitrite content. If the nitrite content in the sample exceeds the acceptable level, the washing process must be repeated until the nitrite level is below the threshold. The longer the bird's nest is exposed to water, the less nitrite content will decrease (Susilo *et al.* 2016).

Drying Process Control

A cleaned bird's nest should be dried for 24 hours to restore its original dry shape. Currently, the edible bird's nest processing industry mainly applies conventional convective drying by fans. It is conducted in continuous mode with constant air temperature and airflow. However, (Gan *et al.,* 2017) found that supplying heat for the batch drying process by fan drying increases the energy cost and depletes the quality of fried products, especially the color change nitrite content of dried edible bird's nest. Because fan drying uses a long processing time, thus lowering bioactive ingredients and significant color change and nitrite content change due to the growth of nitrobacteria (Grundmann *et al.* 2000) and long duration of chemical reactions on the bio-active ingredients (Lim *et al.* 2011). The quality of fried food is an essential issue of public concern. Discoloring, aroma loss, textural changes, nutritional value, and changes in physical appearance and shape are the main changes in the food properties during drying. New developments in heat pump drying, such as heat pump drying systems, were introduced to increase energy efficiency. It has been reported that heat pump dryer offers advantages such as higher energy efficiency due to a high coefficient of performance and better product quality with fewer flavor and color change. Due to accurate control of drying conditions and drying can be conducted at relatively low temperatures and independent of the ambient weather conditions (Law and Mujumdar, 2008).

A QC staff must ensure daily cleanliness by inspecting and palpating the fan for dust. Dust is a physical hazard threatening product quality (Jayadi *et al.,* 2018). Also, room temperature is critical to ensuring temperatures ranging from 16-25˚C with 40-60% RH (Atkinson, 2014). With this temperature range, product quality will be well maintained. Besides, because the number of fans used is vast, the maintenance of an electricity flow must be considered every day to ensure no short circuit can help a fire. If a fire occurs, QC staff and other food safety teams must carry out an emergency response to the product (Nikou and Selamat, 2013).

Reshaping Process Control

The dried bird nest shape can change from the desired specification. Then it needs to be reconstructed in the reshaping room. Not many shapes can be adjusted to clarify the existing forms. In the shaping process, the hands are the primary tool for reshaping. Therefore, workers are advised to use nitrile-free gloves or wash their hands thoroughly with soap for at least 20 seconds to reduce microorganism contamination (Burton *et al.,* 2011). Also, workers are prohibited from touching their noses, coughing, eating, and drinking while working (Tan *et al.,* 2013). Besides hands, some industries use stainless steel knives (Dewangan *et al.,* 2015) for reshaping. Wood-based reshaping tools are prohibited in the food industry because the wood has pores contaminated with the presence of microorganisms (Ismaïl *et al.,* 2013) trapped in these pores. Auxiliary material in the form of water is also used in reshaping. The water softens the dried bird nest to be easily shaped and prevents cracking during reshaping (Jong *et al.,* 2013). In general, water is prepared in a clean spray bottle. The critical point at this stage is the cleanliness of the bottles and water used. A QC staff must ensure that the bottles used are transparent, clean, and moss-free. The water must be potable, clean, colorless, and tested in an accredited laboratory (Meneses *et al.,* 2017). After reshaping, the EBN will be dried again in the drying room overnight. If you do not use water, the EBN can be immediately re-graded and stored in a temporary storage warehouse. EBN may be stored in a temporary warehouse for four days. A QC staff must check daily the temperature and humidity listed on the calibrated thermometer.

Steaming Process Control

In edible bird's nest manufacturing, steaming is a critical control point to fulfill a trading permit. Some countries have applied heating as a condition for EBN trade permits, such as People's Republic of China, Canada, Australia, and America (Chen *et al.,* 2015). Meanwhile, Singapore and Hong Kong apply heating depending on customer demand, and most of these two countries do not apply heating for trade. The heating temperature for each country is also different. For example, in People's Republic of China, the heating application must be applied the EBN core temperature must reach 70˚C for 3.5 seconds (Badan Karantina Pertanian, 2018). Therefore, to the Chinese import and export standards of EBN, E. coli, and Salmonella should not be detected (Zhang *et al.,* 2020). Besides, in Australia, the general policy for EBN trade is heated to a minimum core temperature of 100˚C. This regulation is due to the risk mitigation of the potential dangers of *Clostridium botulinum*.

The heating process uses a heating machine and a steamer which verification must verify appointed directly by the Animal Quarantine Agency. This verification ensures that the temperature applied can reach the target core temperature requested by the destination country. The steaming process is a critical control point step, which means that steaming can eliminate microbial pathogens to ensure food safety. The

steamer must be verified by an official verification once a year. A QC staff must test the presence of microbiological contaminants in TPC, *E. coli,* Salmonella, and Avian Influenza in an accredited veterinary laboratory every six months.

On the other hand, many works found alternatives for steamer usage in the EBN industry since steaming reduces the physical value of EBN. The previous work (Than *et al.,* 2018) designed the microwave applicator structure for an industrial sterilization device that is an integral part of the current manufacturing process and can be used to sterilize EBN products. The microwave applicator structure can eliminate two pathogens, Salmonella and *E. coli*, and reduce energy consumption.

Packaging Process Control

Packaging is a crucial final production step (Shukri *et al.* 2018). This location is arguably the location that must be the cleanest because it is the endpoint of production that humans handle. Water use should not be done in the packaging process because there is a risk of pathogen contamination from water or water containers to the bird's nest. Other risks are from the contaminant air (high microorganisms, dust), primary packaging (non-food grade materials) (Geueke *et al.* 2018), and the poor personal hygiene of workers. Therefore, the primary packaging must be stored in a room free of dirt and dust (Holah, 2014). A QC staff must ensure the cleanliness of the packaging room and temperature every day since high temperatures can increase the growth of microorganisms in the room. The temperature in the packaging room must reach a minimum of 16˚C to control the growth of microorganisms that generally grow optimally at 37˚C. Thus, air swabs should be carried out in the packaging area to ensure no air contamination of pathogenic organisms (Demina *et al.* 2021). Besides, the primary packaging used must pass QC selection. Primary packaging must have a food-grade certificate that ensures no migration of hazardous materials (Nemati *et al.* 2018) from the primary packaging to the edible

Storage Control

Storage used in the EBN industry is a chilling room with temperatures ranging from 3-5˚C. The chilling room stores the finished goods for up to four years. To maintain product quality, a QC staff must ensure that the chilling room shows a temperature between 3-5˚C. The generator must immediately ensure the chilling room works correctly if there is a sudden power cut. This room must be locked to avoid theft, and CCTV should be added to this area. Current research indicates that vacuum cooling may be used with various products. Recent trends in the food industry and non-conventional processing techniques have heightened interest in vacuum cooling in applications. Vacuum cooling is a rapid evaporative cooling technique that can be applied to specific foods, particularly vegetables. Increased competitiveness and more significant concerns about product safety and quality have encouraged some food manufacturers to use vacuum cooling technology. The advantages of vacuum cooling include shorter processing times, consequent energy savings, improved

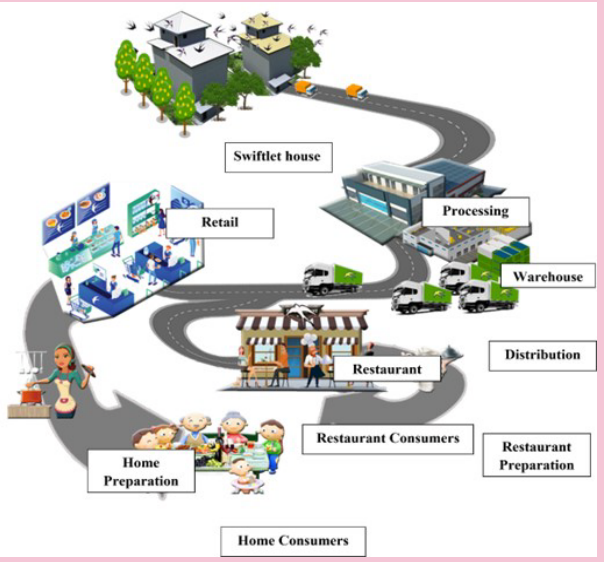

Figure 4. a) Cup-shaped, b) Strip-shaped, c) Corner-shaped, d) Crumble-shaped.

product shelf life, quality, and safety. However, the cooling technique has limited applications (McDonald and Sun, 2000).

The impact of FSMS on Production Performance in the EBN Industry

Environmental control is one of the vital impacts of FSMS on production performance in the EBN industry, from the swiftlets farming process to the customer (figure 4). The food industry's temperature and air quality are associated with the risk of contamination (Zhang *et al.* 2014). Maintaining both parameters can lower pathogen bacteria's threat in the air and surfaces. Besides, pest control inhibits the invasion of pests (Stejskal *et al.* 2019) into the EBN industry. This elimination can increase the production and quality of clean EBN. For facility maintenance in the EBN industry, most EBN industries rely only on the local wired electricity supply. Thus, corrective action such as external power supply is considered to avoid the failure of the power supply (Falck *et al.* 2018) since it can threaten the safety and security of the EBN industry. In addition, predicting when a power failure will occur in advance is difficult. Therefore, FSMS eliminates all risks that can threaten public health in production (Aik *et al.* 2020). The application of CCP is the priority in the FSMS. Any complaint associated with the chance that harmful to humans indicates a failure of the CCP. FSMS only applied safety tools with food-grade certificates (Chaoniruthisai *et al.* 2018). This application can increase the safety of the finished product and customer perception.

The Economic impact of FSMS implementation in the EBN industry

Proper handling in the EBN industry may increase food safety and quality, resulting in economic raises and positive effects on food availability. However, as the market price of clean EBN constantly fluctuates (Tan *et al.,* 2014), quality losses have a lower economic impact than the average trading

prices. The retail price of EBN can reduce by 50% due to the non-standardization of the cleaning process and the lack of proper cleaning guidelines (Hong *et al.*, 2018). Besides, the nutritional value of EBN showed a substantial reduction in fat and ash contents and high moisture contents (Quek *et al.*, 2018). However, meeting the standard requirement of FSMS could be challenging for the actual good product to be preserved during production. Therefore, FSMS plays a significant role and is the primary concern for the stakeholders of industries to obtain the permit from the importer, market share, and value of the EBN products.

CONCLUSION

The growing demand for good-quality EBN is currently a big challenge for the EBN industry. EBN presents a potential frontier of a superfood, rich in collagen and high price in the market. However, this product is not easy to produce at a high cost due to human handling. On the other hand, it is fundamental for the EBN industries to conduct a standard FSMS. This standard should meet the importer's requirements to control the described risks. As for all the reviews, the EBN industry has one critical control point: the steaming process. Besides, a specific traceability system can record unfavorable findings for consumer safety and complaints. The new system should address personal and public control to improve the food safety of the whole production chain to ensure safe products on the market. This paper suggests strategies to orient the development and improvement of a specific traceability system for the emerging production chain in the EBN industry, with paperless effects on workers to mitigate contamination. In particular, this review suggests cutting off paper use with a faster traceability system and considering developing effective machines for EBN industries.

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CONFLICT of INTEREST

The authors declares that there is no conflict of interest.

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