Journal of Food Protection 87 (2024) 100240

Contents lists available at ScienceDirect

Journal of Food Protection

journal homepage: www.elsevier.com/locate/jfp

Research Paper

Maturity of Food Safety Management Systems in the Vietnamese Seafood Processing Industry

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ARTICLE INFO

Keywords:
Diagnostic instrument
Food safety management system
Seafood processing industry
Vietnam

ABSTRACT

Fifty-nine percent (59%) of the reported food safety issues in Vietnam are related to seafood products, mainly fish and fish products. The international export of seafood products continues to grow due to intensification of the production in the Vietnamese seafood processing industry. To ensure the production of safe food, a company-specific, effective food safety management system is essential. This research explores the maturity of food safety management systems in a convenience sample of the Vietnamese seafood processing industry to identify potential gaps and interventions for improvement. The food safety management system diagnostic instrument was used to assess the context riskiness, maturity of control and assurance activities and food safety performance of 11 companies. Maturity of their food safety management systems was further explored through hierarchical cluster analysis, and the differences in maturity between clusters were statistically tested through Mann-Whitney U tests (nonparametric). The influence of companies' organizational characteristics on the maturity of control and assurance activities was assessed through nonparametric K independent tests. A variability in the maturity of food safety management systems between the eleven Vietnamese companies was measured. Cluster analysis revealed two clusters, Cluster I (six companies) and Cluster II (five companies). The companies in both these clusters operate under a moderate level context riskiness and average to advanced level of food safety performance. However, control and assurance activities are at a lower maturity in Cluster I compared to Cluster II. None of the companies' organizational characteristics (i.e. certification level) have a statistically significant influence on the maturity of control and assurance activities. However, compliance with multiple food safety standards and the presence of physical intervention system(s) have a positive influence on food safety performance.

Ensuring the safety of food presents difficulties in nations across the economic spectrum, spanning from low-income to middle-income and high-income countries. Between 1997 and September 7th, 2023, the Rapid Alert System for Food and Feed has recorded 83,276 food safety issues (RASFF, 1997-2023). The biggest contributors to this number of notifications were fruits and vegetables (18.2%), seafood products (17.5%), and nuts, nut products, and seeds (17.1%) (RASFF, 1997-2023). The majority of the notifications within the category 'Seafood products' are classified as 'Fish and fish products' (RASFF, 1997-2023). Fish and fish products have a high potential for being contaminated by pathogens due to the several factors such as contaminated raw materials, poor fishing practices, poor personal hygiene practices (Luu et al., 2017), and abuse along the food chain for example by interruption of the cold chain (Clayton et al., 2002; Onjong et al., 2014b). The increased (international) trade of food across the years has elevated the potential on cross-border transmission of pathogenic microorganisms, thereby amplifying the risk for human health around the world (Ababouch, 2006; Nychas et al., 2016). This makes food safety problems more frequent while food chains become more complex (Pham & Dinh, 2020). Especially for countries that depend on international trade, such as Vietnam, food safety issues can cause great economic and competitiveness losses (Nguyen-Viet et al., 2018).

Although Vietnam is known for being part of the world's top exporters of seafood products (Ministry of Agriculture and Rural Development, 2021a; Nguyen & Jolly, 2020), 59% of the food safety notifications with Vietnamese origin were related to seafood products (RASFF, 1997-2023). With further globalization, the export of Vietnamese seafood products has continued to surge, driven by intensified production and processing (Ministry of Agriculture and Rural

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https://doi.org/10.1016/j.jfp.2024.100240
Received 17 October 2023; Accepted 8 February 2024
Available online 10 February 2024

Development, 2021b; Nguyen-Viet et al., 2018). The main exported seafood products are Pangasius (*Pangasius hypophthalmus*), better known as 'tra' fish in Vietnam (Noseda et al., 2012; Quyen et al., 2017) and shrimps (Ministry of Agriculture and Rural Development, 2021b; Tran et al., 2013). South Korea, Europe, Japan, China, and the United States are the top five import markets of Vietnamese seafood products (Nguyen, 2023), therefore stimulating the compliance of Vietnamese seafood companies with international food safety and quality standards (Nguyen & Jolly, 2020; Pham & Dinh, 2020). In spite of recent growth, the country is still experiencing export rejections of its products due to failures to meet export requirements regarding food safety and quality (Tran, 2018; RASFF, 1997-2023).

Food business operators must ensure that their company-specific food safety management system (FSMS, based on sector-specific prerequisite programs and on HACCP principles) is operational and effective (Chaoniruthisai et al., 2018; Onjong et al., 2014a). Sector-specific prerequisite programs for the seafood industry are described, e.g. in the Code of Practice for Fish and Fishery Products (FAO & WHO, 2020). Consequently, by implementing an effective FSMS system, the presence of hazards, whether physical, chemical, and/or microbiological, in food products should be reduced to a minimum. Improved food safety levels help combat foodborne diseases and increase consumer trust (Koutsoumanis & Aspridou, 2016).

With the significant amount of food safety notifications relating to seafood, growth of the Vietnamese seafood industry, and international trade, it is evident that there may be underlying issues prompting for a need for deeper investigation. Currently, there is little information about the maturity of food safety management systems in the Vietnamese seafood processing industry, as previous research in this domain has been limited to a single company more than ten years ago (Noseda et al., 2012). Therefore, the objective of this research was to investigate the maturity of food safety management systems in eleven seafood processing companies in the south of Vietnam, region Ho Chi Minh City, by using a validated instrument designed for the purpose of evaluating FSMS maturity (Luning, Marcelis, & Jacxsens, 2009). The first corresponding research question is formulated as follows: "How does the maturity of food safety management systems vary among seafood processing companies in the south of Vietnam, specifically in the Ho Chi Minh City region?". Our hypothesis posits that there will be significant differences in the maturity levels of food safety management systems among the seafood processing companies in the specified region, as assessed using the validated instrument designed by Luning, Marcelis, and Jacxsens (2009). Based on the results, potential routes of improvement can be formulated to avoid food safety issues with Vietnamese seafood companies. Furthermore, the relationship between the companies' organizational characteristics and the maturity of food safety management systems will be investigated. Accordingly, the second research question of this study is "What is the relationship between the maturity of food safety management systems in seafood processing companies in the south of Vietnam and their organizational characteristics?". The hypothesis is that a significant correlation between the maturity of food safety management systems and organizational characteristics will be present. Specifically, it is hypothesized that companies with certain organizational characteristics, such as having multiple certifications in place, will exhibit higher levels of maturity in their food safety management systems compared to those lacking their organizational features.

Material and methods

The food safety management system diagnostic instrument

To assess the maturity of the food safety management systems in the participating seafood processing companies, the food safety management system diagnostic instrument (FSMS-DI) was applied as developed by Luning P.A., Marcelis W.J., and Jacxsens L. in 2009 (Luning, Marcelis, & Jacxsens, 2009). The instrument consists of 58 indicators, classified across four main subjects: context riskiness (17 indicators) (Luning, Marcelis, et al., 2011), control activities (25 indicators) (Luning et al., 2008), assurance activities (nine indicators) (Luning, Marcelis, Rovira, et al., 2009), and food safety performance (seven indicators) (Jacxsens et al., 2010). Luning, Marcelis, et al. (2011) defined context factors as structural elements of the situation that cannot be (easily) changed and affect decision-making activities in the food safety management system and the food safety performance (e.g. sector, vulnerability of raw materials, regulatory requirements). The control activities, aimed at keeping product and process conditions within acceptable safety limits, and assurance activities, aimed at setting systems requirements, evaluating system performance, and organizing necessary changes, together form the food safety management system activities (Luning et al., 2008). The food safety performance was evaluated based on four external and three internal food safety performance indicators, validated to microbiological food safety parameters in previous research (Jacxsens et al., 2009; 2010). Each indicator was evaluated on a grid of three or four levels, depending on the category assessed. For the context riskiness, a grid of three situations was used, representing a low (situation 1), moderate (situation 2), and high-risk situation (situation 3) (Luning, Marcelis, & Jacxsens, 2009). For the control activities, assurance activities, and food safety performance, a grid of four levels (level 0–1–2–3) was used, representing basic (level 1), average (level 2) and high maturity levels (level 3) and with level 0 representing absence of the activity or the situation of the activity not being applicable/relevant for the company.

The general assumption behind the diagnostic instrument is: if the context of a company is riskier (overall context score approaches level 3), then the food safety management system activities (consisting of control and assurance activities) must be more mature (a score approaching level 3) to counter this high-risk situation and realize a good food safety performance (score 3). If a company operates in a low-risk context (score 1), then a basic food safety management system (score 1) is sufficient to realize a good food safety performance (score 3) (Luning, Marcelis, et al., 2011).

The FSMS-DI was preceded by general questions to gain knowledge on companies' organizational characteristics, such as the location of the company, number of employees, product focus, food safety certification status, and major customers. The location of the companies was categorized into 'city', representing Ho Chi Minh City, and 'outside the city', representing provinces around Ho Chi Minh City (respectively Vung Tau, Long An, and Bien Hoa). The size of the company was categorized into 'small-sized', 'medium-sized', or 'big-sized' as the number of employees was ranging from respectively <50, 50–249, and >249 employees. The product focus of a company was categorized into three categories, respectively, 'fresh frozen', 'processed frozen', and 'mix'. For the food safety certification status were two categories created, representing 'single certification' and 'multiple certification'. Companies that were only HACCP, Seafood HACCP Vietnam, and Seafood HACCP United States certified were placed under the category 'single certification'. Companies with additional international GFSI-acknowledged certificates such as BRC, IFS, and/or ISO 22000 were placed under the category 'multiple certification'.

Sample and data collection in Vietnamese seafood industry

A convenience sampling method was used for this study, as study participation was voluntary. The goal was to have a varied sample size, with companies of different sizes, different production processes, and final products. Multiple seafood processing companies across Ho Chi Minh City and surrounding provinces were contacted. Communication was established through both email and phone, effectively conveying the advantages of their participation in this research. After a company

gave confirmation to participate in the research, a company visit was scheduled. During the company visit, conducted by the first author and a representative of the Ho Chi Minh City University of Food Industry (HUFI), an in-depth face-to-face interview was held with the quality manager(s)/responsible(s) for about 1.5–2 h. Therefore, the FSMS-DI was translated into the Vietnamese language to perform the interview. In this interview, each indicator was assessed and scored according to the company' circumstances. In total, eleven companies were visited. For reasons of confidentiality, the identities of the seafood companies (A to K) are withheld. Table 1 gives an overview of the company organizational characteristics of the eleven companies included in the study.

Data and statistical analysis

A database of the FSMS-DI results was created in Microsoft Excel Version 16.64 (2022) containing the levels of the indicators of the context riskiness, control activities, assurance activities, and food safety performance for each company (58 indicators for 11 companies). With the scores of the individual indicators, an overall score was assigned for each part of the diagnostic instrument based on the mean score of the responses (level to which the company's circumstances belong) of the associated indicators (Jacxsens et al., 2010; Sampers et al., 2010). This mean score was converted to an assigned score (Table 2) defined by the work of Sampers et al. (2010) for the context riskiness, the control activities, and the assurance activities, and by the work of Jacxsens et al. (2010) for the food safety performance. When an indicator belonging to the control activities, assurance activities, or food safety performance was evaluated as level 0, the following correction was conducted: if the indicator was rated as level 0 due to the fact that the activity was absent, then, the score 0 was included in the calculation of the mean score. On the other hand, if the indicator was rated as level 0 due to the fact that the indicator was not applicable for the company's circumstances, then the score 0 was not taken into the calculation of the mean score. An example of the latter is the presence of physical intervention system(s) for a company that only executes filleting and portioning of fresh seafood products. For this company, this indicator of physical intervention system(s) is not relevant, and therefore not included in the calculations.

A hierarchical cluster analysis, based on the complete linkage method (also known as the furthest neighbor method) and squared Euclidean distance, was executed in Statistical Package for the Social Sciences (SPSS), version 28 for Windows. This analysis was used to explore the underlying relationship within the dataset where similar data points were grouped together based on their similarities or dissimilarities. These groups are called a cluster. Afterward, the statistical significance of the indicators between the clusters was examined by Mann-Whitney U tests (nonparametric) to gain insight into the similarities and differences in FSMS maturity between clusters (Kussaga et al., 2014). Finally, the influence of the organizational characteristics on the FSMS maturity in the seafood processing companies was also statistically tested with Mann-Whitney U tests or Kruskal-Wallis tests.

Table 2
Transformation to assigned score based on mean score for part I context riskiness (Sampers et al., 2010), part II control activities (Sampers et al., 2010), part III assurance activities (Sampers et al., 2010), and part IV food safety performance (Jacxsens et al., 2010)

Category of indicators in the FSMS-DI	Assigned score	Transformation rule
Context riskiness	Overall score 1	If mean score of activities 1.0 – 1.2
	Overall score 1_2	If mean score of activities 1.3 – 1.7
	Overall score 2	If mean score of activities 1.8 – 2.2
	Overall score 2_3	If mean score of activities 2.3 – 2.7
	Overall score 3	If mean score of activities 2.8 – 3.0
Control activities Assurance activities	Overall score 0	If mean score of activities 0 – 0.2
	Overall score 1	If mean score of activities 0.3 – 1.2
	Overall score 1_2	If mean score of activities 1.3 – 1.7
	Overall score 2	If mean score of activities 1.8 – 2.2
	Overall score 2_3	If mean score of activities 2.3 – 2.7
	Overall score 3	If mean score of activities 2.8 – 3.0
Food safety performance	Overall score 1	If mean score of activities 0 – 1.2
	Overall score 1_2	If mean score of activities 1.3 – 1.7
	Overall score 2	If mean score of activities 1.8 – 2.2
	Overall score 2_3	If mean score of activities 2.3 – 2.7
	Overall score 3	If mean score of activities 2.8 – 3.0

Table 1
Organizational characteristics of participating Vietnamese seafood processing companies (numbered from A to K) in Vietnam (VN) (US = United States)

	Location	Number of employees	Type of product: Raw frozen/Processed frozen/Mix	Food safety certification status	Major customers
A	Ho Chi Minh City	50–249	Mix	Seafood HACCP VN, BRC	Not known
B	Ho Chi Minh City	>249	Mix	HACCP, ISO 22000	Japan
C	Vung Tau	50–249	Raw frozen	Seafood HACCP VN	Korea
D	Vung Tau	50–249	Processed frozen	Seafood HACCP VN	US, Russia, Japan, Germany, China, Indonesia
E	Vung Tau	50–249	Raw frozen	Seafood HACCP VN	Korea, China, United States, Canada
F	Vung Tau	50–249	Processed frozen	Seafood HACCP VN & US	Korea, Europe (mainly Italy), US, …
G	Ho Chi Minh City	50–249	Processed frozen	Seafood HACCP VN, BRC, IFS	Korea, Europe, US
H	Ho Chi Minh City	50–249	Processed frozen	HACCP, BRC, IFS	United Kingdom, United States, Australia, France, The Netherlands
I	Long An	50–249	Raw frozen	HACCP	Korea, Europe
J	Bien Hoa	>249	Mix	HACCP, BRC, IFS	Thailand, China, Spain, Japan, Germany, …
K	Ho Chi Minh City	>249	Processed frozen	HACCP, BRC, ISO 22000	Japan, Korea, Australia, …

For all the statistical analyses, the statistical significance level was established at 5% (P value < 0.05).

Results and discussion

Prevailing maturity of food safety management systems in the Vietnamese seafood processing industry

For the eleven companies (A to K) is the assigned overall score for each of the four sections in the FSMS-DI shown in Table 3. This table shows that there is a range in the assigned scores for each part between the companies.

Context riskiness

Concerning the riskiness of the context, all companies, except for company I, operate in a moderate-risk situation (score 2). Company I operates in a moderate to high-risk situation (score 2_3) (Table 3). Within the dimension of context riskiness, two indicators share the same high-risk score in every company, respectively, 'Risk of raw material' and 'Safety contribution in chain position'. This uniformity arises as all companies start producing from highly perishable raw materials (e.g. fish and shrimps which have a short shelf life due to multiple spoilage mechanisms and with a potential prevalence of microbiological and/or chemical hazards), and they all contribute to the final safety of the products by significant reduction of pathogens to acceptable levels and/or prevention of postcontamination. Maturity of food safety management system activities.

Maturity of food safety management system activities

For the control activities (Table 3), the maturity of respectively seven and four companies is rated as average (score 2) and average to advanced (score 2_3). Three control activities are on an advanced level (level 3) for all the companies, namely the indicators 'Cooling facilities', 'Performance of measuring equipment', and 'Performance of analytical equipment'. The control activities mostly rated as basic (level 1) or not present/conducted (level 0) are 'Packaging intervention equipment', 'Process capability of physical intervention equipment', and 'Process capability of packaging intervention equipment'. For the assurance activities (Table 3), maturity levels in companies range from score 1_2 (e.g. company C) to score 2_3 (respectively company G). Only the indicator 'Record keeping system' is on an average level in all companies (score 2), meaning there is a full registration of critical product and process data in separated systems (not integrated), accessible via specific (authorized) persons.

Food safety performance

Lastly, Table 3 indicates that the food safety performance of the companies fluctuates between average performance (score 2) and average to good performance (score 2_3). In this dimension, almost all indicators are rated as advanced (score 3), apart from the indicators 'Judgement criteria for microbiological results' (score 2) and 'Hygiene & pathogen nonconformities' (score 2).

Patterns in food safety management system maturity

To explore existing patterns in FSMS maturity in the Vietnamese seafood processing industry, the data presented in Table 3 are used to perform a hierarchical cluster analysis. The result is a dendrogram with two clusters: Cluster I and Cluster II at a dissimilarity distance of 25 units (Fig. 1). Cluster I contains six (6) companies, respectively, companies B, C, D, E, I, and K, and Cluster II includes five (5) companies, respectively, companies A, F, G, H, and J. The companies in each cluster should show a similar context riskiness, maturity of control and assurance activities, and food safety performance.

For each cluster is, the overall context riskiness, the overall maturity of control and assurance activities, and the overall food safety performance assigned. Both clusters have an equal moderate context riskiness (score 2). Furthermore, cluster I scores lower than Cluster II on the maturity of food safety management system activities (on both control and assurance activities). This means that the food safety management system activities for companies in Cluster I are less tailored toward the company-specific circumstances than for companies in Cluster II. Cluster I has an average maturity (score 2) while Cluster II has an average to advanced maturity (score 2_3) for the control activities. Moreover, Cluster I has a basic to average maturity (score 1_2) while Cluster II has an average maturity (score 2) for the assurance activities. The assurance activities are executed on a lower maturity level than the control activities in both clusters. Both clusters have an average to good food safety output in their performance (score 2_3).

To visualize the difference in maturity of the control and assurance activities for each cluster, radar charts are drawn up (Fig. 2). A more highly colored radar chart is associated with a more tailored and mature level of control and assurance activities, adapted to the needs of the specific company.

Through statistical indicator analysis (nonparametric), the difference in maturity of FSMS activities between the clusters is further investigated. The outcome of the statistical indicator analysis between the mean scores of the control and assurance activities between both clusters is shown in Table 4. Statistical significance is indicated with a P value < 0.05. The associated P value for each statistically significant indicator is signified in bold (Table 4). For the control activities, there are two indicators statistically significant, respectively, 'Product specific preventive measures' (P value $= 0.04$) and 'Calibration and verification program' (P value $= 0.01$). For the assurance activities, there is one indicator significantly different between the clusters, respectively, 'Validation of preventive measures' (P value $= 0.03$). From these results is concluded that the various companies in both clusters have a minor difference in the maturity of their food safety management system activities, as only three activities out of 42 are statistically significantly different.

Table 3
Assigned scores for the four parts (respective context riskiness, control activities, assurance activities, and food safety performance) of the FSMS-DI for the Vietnamese seafood processing companies (from A to K)

	Context riskiness	Control activities	Assurance activities	Food safety performance
A	2	2	2	2_3
B	2	2	1_2	2_3
C	2	2	1_2	2
D	2	2	1_2	2_3
E	2	2	2	2
F	2	2_3	2	2_3
G	2	2_3	2_3	2_3
H	2	2_3	2_3	2_3
I	2_3	2	2	2
J	2	2_3	2	2_3
K	2	2	1_2	2_3

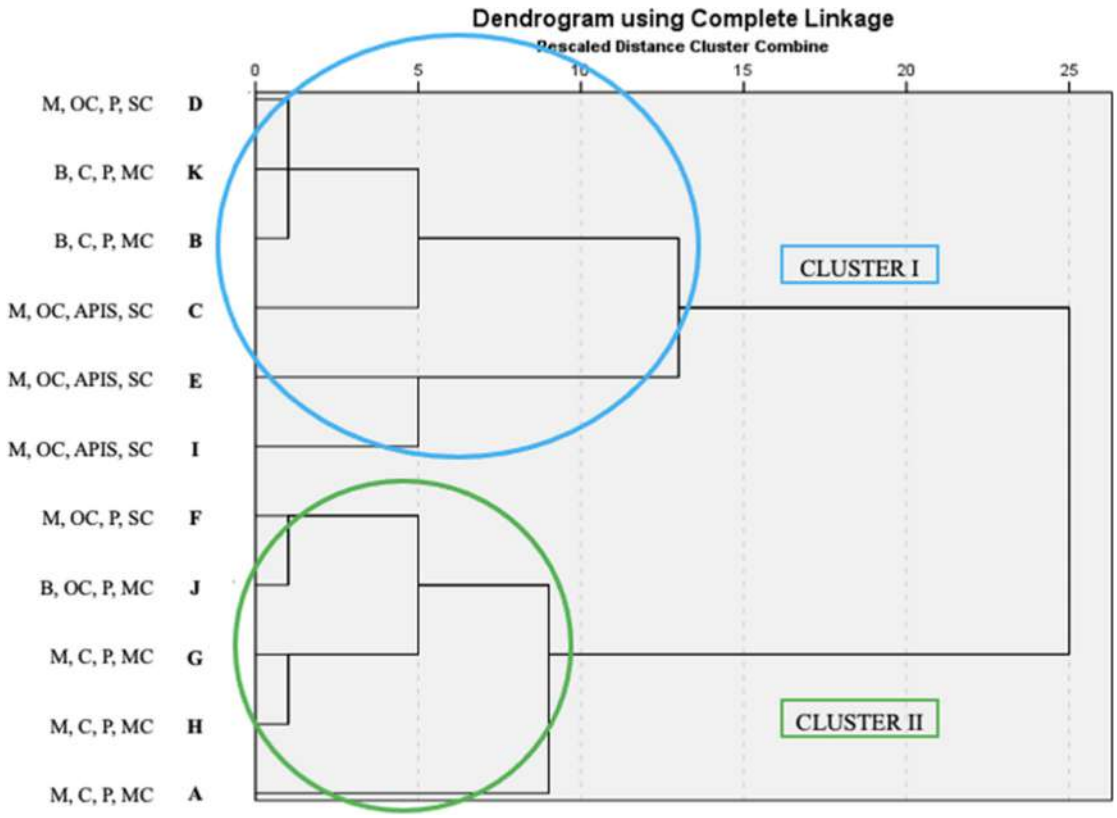

Figure 1. . Clusters obtained by the hierarchical cluster analysis with the complete linkage method using assigned scores of context riskiness, control activities, assurance activities, and food safety performance of the Vietnamese dataset. Blue circle represents Cluster I, and green circle represents Cluster II. The associated seafood processing companies are presented on the left side of the dendrogram, together with their organizational characteristics (from left to right: size of company, location of company, presence/absence of physical intervention system, food safety certification) (M = medium size; B = big size; OC = outside city; C = city; P = physical intervention system; APIS = absence physical intervention system; SC = single certification; MC = multiple certifications).

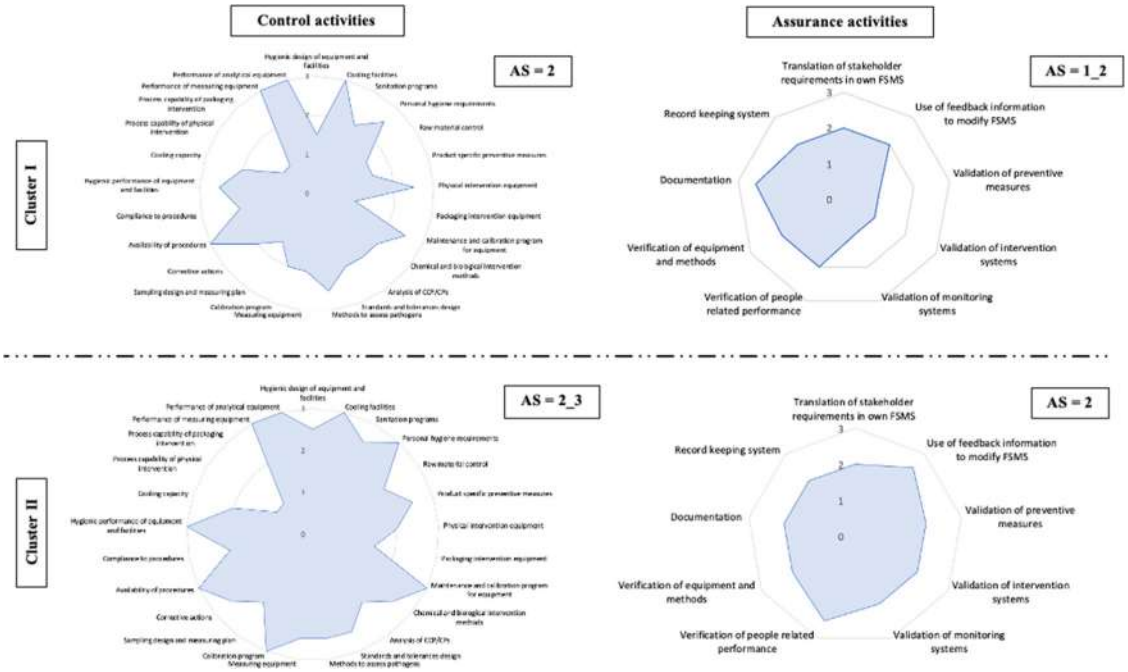

Figure 2. . Radar charts for the control activities and the assurance activities for Cluster I and Cluster II of the Vietnamese dataset. The assigned score (AS) for each dimension per cluster is visualized in the right upper corner.

Table 4
Statistical analysis of mean scores (assigned scores) of indicators of control activities and assurance activities per cluster (score 1 basic level; score 2 average level; score 3 advanced level). *P* value calculated with Mann-Whitney U nonparametric test (n = number of companies in the cluster). Bolded *P* value scores indicate significant differences ($P < 0.05$) between the clusters

	Mean (assigned scores) per cluster		*P* value
	Cluster I ($n = 6$)	Cluster II ($n = 5$)	
CONTROL ACTIVITIES			
Hygienic design of equipment & facilities	1.7 (1_2)	2.4 (2_3)	0.18
Cooling facilities	3.0 (3)	3.0 (3)	1.00
Sanitation programs	1.8 (2)	2.6 (2_3)	0.12
Personal hygiene requirements	2.3 (2_3)	3.0 (3)	0.17
Raw material control	1.5 (1_2)	2.0 (2)	0.08
Product-specific preventive measures	1.3 (1_2)	2.6 (2_3)	**0.04**
Physical intervention equipment	2.3 (2_3)	2.2 (2)	0.87
Packaging intervention equipment	1.0 (1)	1.3 (1_2)	0.85
Maintenance and calibration program	2.7 (2_3)	2.8 (3)	0.64
Chemical & biological intervention methods	1.8 (2)	2.6 (2_3)	0.09
Appropriateness of CCPs/CPs analysis	2.0 (2)	2.0 (2)	1.00
Standards and tolerances design	2.2 (2)	2.6 (2_3)	0.16
Methods to assess pathogens	2.7 (2_3)	2.4 (2_3)	0.40
Measuring equipment	2.0 (2)	2.4 (2_3)	0.10
Calibration and verification program	2.2 (2)	3.0 (3)	**0.01**
Sampling design and measuring plan	1.5 (1_2)	2.0 (2)	0.22
Extent of corrective actions	2.2 (2)	2.6 (2_3)	0.16
Availability of procedures	2.8 (3)	2.8 (3)	0.89
Compliance to procedures	2.0 (2)	2.0 (2)	1.00
Hygienic performance of equipment & facilities	2.3 (2_3)	2.8 (3)	0.28
Cooling capacity	2.0 (2)	2.0 (2)	1.00
Process capability of physical intervention equipment	1.0 (1)	1.0 (1)	1.00
Process capability of packaging intervention equipment	1.0 (1)	1.0 (1)	1.00
Performance of measuring equipment	3.0 (3)	3.0 (3)	1.00
Performance of analytical equipment	3.0 (3)	3.0 (3)	1.00
ASSURANCE ACTIVITIES			
Translation of stakeholder requirements	1.8 (2)	1.8 (2)	1.00
Systematic use of feedback information	2.0 (2)	2.6 (2_3)	0.13
Validation of preventive measures	0.8 (1)	2.2 (2)	**0.03**
Validation of intervention processes	1.2 (1)	2.2 (2)	0.18
Validation of monitoring systems	1.0 (1)	1.8 (2)	0.10
Verification of people-related performance	1.8 (2)	2.4 (2_3)	0.08
Verification of equipment & methods related performance	1.8 (2)	2.2 (2)	0.43
Documentation	2.3 (2_3)	2.2 (2)	0.64
Record keeping system	2.0 (2)	2.0 (2)	1.00

Influence of company characteristics on food safety management system maturity

Influence of company size

The first company characteristic of which the effect on FSMS maturity within the Vietnamese processing industry was investigated is company size. Eight medium-sized companies and three big-sized companies participated in the study. However, the company size has no statistically significant influence on the maturity of food safety management system activities (control activities: *P* value = 0.90; assurance activities: *P* value = 0.19) or the food safety performance of the company (*P* value = 0.24). Moreover, in the literature, no conclusive relationship between company size and FSMS maturity exists (Chaoniruthisai et al., 2018). Some studies have shown that smaller companies tend to have lower levels of food safety performance due to barriers in implementing and maintaining food safety and quality standards, as well as limited organizational support (Chaoniruthisai et al., 2018; Sampers et al., 2012). Jacxsens et al. (2015) found no differences based on company size.

Influence of location of company

For the location of the companies, Cluster I contains two companies inside the city and four companies outside the city. Cluster II contains three companies inside the city and two companies outside the city (Table 1). Upon statistical testing, the location of the company did not have an influence on the maturity of FSMS activities as the *P* value for control activities is 0.83 and the *P* value for assurance activities is 0.56. No relationships between the location of the company and the maturity of food safety management system activities are found in the literature.

Influence of presence of physical intervention systems

All companies produced frozen products, aimed at (international) export, with the main product focus on fresh frozen for three companies, processed frozen for five companies and a mix of fresh and processed frozen for another three companies. Of the companies who produced processed frozen products, respectively, eight companies, all owned physical intervention system(s) aimed at reducing, inactivating, or eliminating pathogens to acceptable levels by physical treatments, such as heat treatments (e.g. blanching, pasteurization, sterilization, cooking, drying), high-pressure processing, or irradiation. The companies without any physical intervention system(s) in place were categorized in Cluster I. This shows that companies that execute physical treatments have more mature FSMS activities. Nevertheless, statistical testing revealed that the presence of physical intervention systems does not have a significant influence on the maturity of control activities (*P* value = 0.14) and the maturity of assurance activities (*P* value = 0.74). The study of Jacxsens et al. (2015) stated

that products produced with the need of intervention systems indicate higher company context riskiness and more robust FSMS activities. In this research, as all seafood companies had a similar context riskiness, except from company I, the presence of physical intervention systems does not have a significant influence on the context riskiness (P value = 0.10). However, the presence of physical intervention systems does have a positive influence on the food safety performance (P value < 0.05, respectively 0.002).

Influence of food safety certification status

Food business operators aimed at export face a range of demands from the export market, including regulatory requirements, microbiological criteria, chemical standards, and inspection requirements. These requirements can vary depending on the importing country and type of product. In addition, to meet the requirements of customers and other stakeholders in the supply chain, companies may also need to comply with international standards related to food safety and/or food quality such as BRC or IFS (Kussaga et al., 2014). Four out of five companies in Cluster II are certified for multiple standards while only two out of six companies in Cluster I are certified for multiple standards. These results suggest that companies with multiple food safety standards are more likely to exhibit a higher level of maturity in their FSMS activities. Following statistical testing, the compliance with multiple food safety standards has no influence on the maturity of food safety management system activities (control activities: P value = 0.33; assurance activities: P value = 0.43). The studies by Hua Yen et al. (2021), Jacxsens et al. (2015), Kirezieva et al. (2015), Nanyunja et al. (2015), Rajkovic et al. (2017), Ren et al. (2022), and Sampers et al. (2012) indicated that compliance with stringent food safety management system requirements/certifications did not generally impact the level of context riskiness but those companies had a more advanced level of food safety management system activities, resulting in a higher level of food safety performance. Upon statistical testing, the compliance with multiple food safety standards has no influence on the context riskiness in this dataset (P value = 0.27) but does have a positive influence on the food safety performance (P value = 0.04). However, even though food business operators comply with food safety standards, it does not guarantee that the food products produced will always be safe. Many foodborne outbreaks were caused by companies that have been verified and received certification due to compliance (Powell et al., 2013; Sawe et al., 2014). Peterson (2001) found, in his ten-year study, that an improved safety performance does not necessarily correlate with high audit scores, but the high audit scores do partially correlate with improved legislative compliance.

General discussion

Summary of the key findings

All eleven Vietnamese companies, except for one, were operating under a moderate risk context (score 2). Following the general concept behind the diagnostic instrument, the maturity of food safety management system activities should be at least average (score 2) to realize a good food safety performance (score 3). This assumption was fulfilled for only six out of eleven companies (55%). The maturity of control and assurance activities varied along the Vietnamese companies. After analyzing the dataset using hierarchical cluster analysis and statistical analysis, valuable insights were obtained regarding the indicators that exhibited statistical significance (P value < 0.05) between the clusters representing less and more mature food safety management systems. Two control activity indicators and one assurance activity indicator showed statistical significance. These indicators highlight areas for further improvement in the respective companies. However, besides these statistically significant indicators, all companies have room for improvement. When examining the results in relation to the companies' organizational characteristics, it was revealed that the compliance with multiple food safety standards and the presence of physical intervention systems had a positive influence on the food safety performance. However, none of the investigated organizational characteristics had an influence on the maturity of control and assurance activities.

Concept of food safety management system diagnostic instrument

The concept behind the diagnostic instrument is that if the context of a company is riskier, the food safety management system activities must be more advanced to counter the high-risk situation and realize a good (stable and predictable) food safety performance (Luning, Marcelis, et al., 2011), due to more insight in the underlying mechanisms and more accurate information (Luning, Jacxsens, et al., 2011). If this assumption is extended to this study, where the majority of the participating seafood processing companies operated in a moderate context riskiness, the food safety management system activities should be at least average (score 2) to realize a good food safety performance. However, the maturity of assurance activities in four Vietnamese companies was basic to average (score 1_2), which can be insufficient to deal with ambiguity, uncertainty, and vulnerability issues in the context characteristics (Onjong et al., 2014a). Especially for company I, as they operate in a moderate to high-risk context (score 2_3), the control and the assurance activities (score 2) seemed to be insufficient to deal with the context riskiness as reflected in the lower food safety output (score 2). By improving food safety management system activities, it could be possible to effectively address the risk situation and achieve a good (stable and predictable) food safety performance. Another way to achieve a better food safety output is by reducing the context riskiness. However, since context factors are defined as structural elements of the situation that cannot easily be changed (Luning, Marcelis, et al., 2011), it is more manageable to improve the maturity of the food safety management system activities. Even though the food safety performance met acceptable standards in all companies to address the context riskiness, except for company I, there is always room for improvement. These companies can continuously endeavor to enhance their FSMS activities, particularly those that have not reached an advanced level.

Positioning of results within the broader context

Upon reviewing the prevalence of seafood safety issues originating from Vietnam and the recent assessment of the maturity of food safety management systems, a pertinent question arises: "What factors are contributing to this issue when the maturity of FSMS activities and food safety performance doesn't appear to be significantly low?". Delving into an analysis of the RASFF database, it becomes evident that seafood products are susceptible to various types of hazards, including (micro-)biological, chemical, or physical hazards. The investigation highlighted the primary contributors to these issues, namely the hazard categories 'Residues of veterinary medicinal products', 'Pathogenic microorganisms', and 'Heavy metals' accounting for 29%, 23%, and 17% of the cases, respectively. Conversely, the 'Biological contaminants' category played a lesser role, contributing only 5% to the total (RASFF, 1997-2023). Analyzing these statistics, it is apparent that attributing the majority of seafood safety issues in Vietnam to the seafood processing industry may not be accurate. Approximately 30% of these issues seem to be linked to residues of veterinary medicinal products, indicating that the root problem may lie more within the aquaculture sector, where adherence to proper aquaculture practices may be lacking. In this context, the presence of veterinary medicinal product residues in final seafood products can be attributed to various factors, such as overdose, unnecessary antibiotic usage, disregarding manufacturer's instructions, the administration of prohibited drugs harmful to humans, failure to adhere to withdrawal periods before slaughter, and the potential contamination of animal feed and water with drugs (Rana et al., 2019; Singapore Government Singapore Food Agency, 2022). It is crucial to emphasize that residues of veterinary medicinal

products in seafood products pose a significant health risk to consumers. These risks include the potential development of multidrug resistance, carcinogenic effects, and disruptions to the normal intestinal microflora (Rana et al., 2019).

Moreover, pathogenic microorganisms can end up in final seafood products due to various factors and contamination sources along the seafood supply chain, such as contaminated water sources, poor hygiene practices, improper storage conditions, use of contaminated ice, infected seafood-producing animals, uncooked or undercooked seafood products, cross-contamination during preparation, inadequate regulatory compliance, and inadequate supply chain control (Novoslavskij et al., 2015; Sheng & Wang, 2020). It is noteworthy that the responsibility for managing pathogenic microorganisms extends across the aquaculture sector, seafood processing sector, distribution sector, and retail sector. Furthermore, consumers also play a pivotal role in ensuring the safe handling of seafood products (Novoslavskij et al., 2015). To mitigate the risks of pathogenic microorganisms in final seafood products, strict adherence to food safety regulations, proper handling practices, and hygiene measures are imperative at every stage of the seafood supply chain. Additionally, employing effective processing and storage methods, coupled with rigorous monitoring and testing protocols, are essential components of ensuring seafood safety (Novoslavskij et al., 2015; Sheng & Wang, 2020).

Factors influencing the data: Study limitations

Like most research studies, this study encounters limitations. An examination of biases and other factors possibly influencing the data is made. These biases stem from a range of contributing factors, including socially desirable responses, the utilization of a convenience sample, and the inherent characteristics of the food safety management system diagnostic instrument. The initial influencing factor investigated pertains to the interviewee's honesty. Socially desirable responses represent a bias characterized by an inclination to exaggerate positive behaviors while downplaying undesirable ones, thereby introducing a source of bias and inaccuracy in the responses (Jespersen et al., 2017; Lalwani et al., 2006). In this study, the awareness of socially desirable responses was illuminated by the research of Lalwani et al. (2006), which revealed that Singaporeans and Asian Americans tend to embrace collectivistic cultures and often perceive themselves as interdependent, sociable, and actively engaged in fostering positive relationships with others. This particular style of socially desirable responding is referred to as 'impression management' (Lalwani et al., 2006). Consequently, the dataset was adjusted by reorganizing the indicators, focusing on a comprehensive discussion of a single subject instead of individually examining each indicator and its associated responses. It is important to acknowledge that even with this reorganization, it is challenging to entirely eliminate socially desirable responses, as some degree of it may persist.

It is crucial to note that the food safety management system diagnostic instrument assesses the performance of food safety but does not provide any information regarding the actual microbiological safety achieved by the implemented system. To take the actual food safety performance into account, microbial assessment scheme (MAS) can be added to the diagnostic instrument. MAS is a vertical microbial sampling plan throughout the production process, from raw materials to final product. This instrument evaluates the performance of the designed and applied control activities in a food safety management system by a systematic analysis of microbial counts (Jacxsens et al., 2009; Tong Thi et al., 2014). In the research of Noseda et al. (2012), about the dynamics of microbiological quality and safety of Vietnamese *Pangasianodon hypophthalmus* during processing, the overall MAS level was slightly lower (score 2) than the self-estimated level of food safety performance (score 2_3). It must also be noted that MAS offers only snapshot analysis of the performance (Jacxsens et al., 2011; Noseda et al., 2012).

Lastly, a convenience sample was utilized due to the constrained timeframe and impracticality of visiting every seafood processing company in Southern Vietnam. While numerous companies were approached, only those that expressed a willingness to assess their system performance for the purpose of improvement were included in the study, potentially introducing a selection bias (Jacxsens et al., 2015; Kussaga et al., 2014). As a result, the findings derived from this dataset may not offer a representative portrayal of the entire Vietnamese seafood processing industry. Consequently, it is not advisable to generalize or make broad statements about the broader population based on these results (Simkus, 2022). To generalize the statements, a broader spectrum of companies from various regions across Vietnam should be incorporated in the study.

Conclusion and perspectives for future research

In light of the considerable number of seafood safety notifications, the burgeoning Vietnamese seafood industry, and the expansion of international trade, the primary objective of this study was to assess the maturity of food safety management systems within the Vietnamese seafood processing sector, specifically in the Ho Chi Minh City region. A similarity in the context of riskiness and food safety performance among the companies have been found. However, notable differences emerged in the maturity of their food safety management system activities. The study, utilizing the instrument developed by Luning, Marcelis, and Jacxsens (2009), revealed distinct levels of implementation of food safety practices, showcasing the variability in practices within the studied companies. Furthermore, contrary to the hypothesis, the investigation into the relationship between the maturity of food safety management systems (FSMSs) in the Vietnamese seafood processing industry and their organizational characteristics yielded unexpected results. While was initially anticipated that a significant correlation would be present, particularly expecting that companies with multiple certifications would demonstrate higher FSMS maturity, findings tell a different story. Surprisingly, having multiple certifications did not show a discernible effect on the maturity of food safety management systems. Instead, the results revealed that having multiple certifications and the presence of physical intervention systems had a positive influence on food safety performance. However, it is important to note that none of the investigated organizational characteristics demonstrated a significant impact on the maturity of control and assurance activities within these companies. This provides valuable insights into the specific dynamics at play in the relationship between organizational characteristics and the maturity of FSMS in seafood processing companies in this region.

In conclusion, the findings of this publication shed light on the maturity of food safety management systems in selected companies in the Southern Vietnam. However, there is still ample opportunity for further research to be conducted in other companies within Vietnam, including the middle and northern regions, to gain a more comprehensive understanding of the maturity of food safety management systems within the Vietnamese seafood processing industry. The diagnostic instrument can therefore be used at the governmental level or by the fishery sector to diagnose companies in vulnerable situations that require support in system design and evaluation. Additionally, exploring a comparative analysis between multiple countries in Asia and other continents would provide valuable insights into the similarities and differences in food safety management systems in the seafood processing industry, fostering cross-cultural learning, and potential improvements in both continents. The potential for future research in this area is significant, as it can contribute greatly to the advancement of food safety knowledge and the improvement of practices on a broader scale.

CRediT authorship contribution statement

Justine Van Durme: Conceptualization, Data curation, Formal analysis, Investigation, Methodology, Project administration, Visualization, Writing – original draft, Writing – review & editing. **Pauline Spagnoli:** Conceptualization, Supervision, Writing – review & editing. **Le Nguyen Doan Duy:** Data curation, Project administration, Writing – review & editing. **Do Thi Lan Nhi:** Data curation, Project administration, Writing – review & editing. **Liesbeth Jacxsens:** Conceptualization, Supervision, Writing – review & editing.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Acknowledgment

We acknowledge and thank the companies and all participants for their input during this study.

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