NFS Journal 30 (2023) 8–20

Contents lists available at ScienceDirect

NFS Journal

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

Food integrity culture in food businesses in view of organizational and employees' demographic characteristics

Waeel Salih Alrobaish [a,*], Peter Vlerick [b], Liesbeth Jacxsens [a]

[a] Department of Food Technology, Safety and Health, Faculty of Bioscience Engineering, Ghent University, Coupure Links 653, 9000 Ghent, Belgium
[b] Department of Work, Organisation and Society, Faculty of Psychology and Educational Sciences, Ghent University, Henri Dunantlaan 2, 9000 Ghent, Belgium

ARTICLE INFO

Keywords:
Food integrity climate
Food integrity culture
Food integrity performance
Food fraud vulnerability
Organizational characteristics
Demographic characteristics

ABSTRACT

Scope and approach: The prevailing food integrity culture of four Belgian food companies was assessed through a validated method triangulation. The relation between the perceived food integrity climate, the performed food integrity and the companies' food fraud vulnerability was analyzed in view of employees' demographic characteristics (i.e. age, seniority, job function, contract type) and organizational characteristics (i.e. product type, service type, company size and certifications status).

Results and conclusions: Results from this semi-quantitative study revealed that all the participating companies recorded a positive food integrity culture, as their food integrity climate and performance were medium-high and their fraud vulnerability was medium-low. Minor differences among companies were identified depending on their specific organizational characteristics and employees' demographic characteristics. People integrity was the lowest-perceived food integrity dimension and specific food fraud control measures were lacking in the majority of the participating companies. Managers perceived their company's food integrity climate higher than the operators in contact with food, implying that employees in different job functions may hold differing perceptions of their company's climate. For the other demographic characteristics analyzed (age, seniority and contract type), a statistical correlation with the perceived food integrity climate was not revealed. Results suggest that product type, company size and certifications status may also promote (or hinder) the achievement of a positive food integrity culture. The applied food integrity culture method triangulation has demonstrated to assist food companies in acknowledging potential weaknesses in their food integrity climate, food integrity performance and food fraud control measures, allowing them to improve key human, operational, technical and managerial aspects to achieve an overall consolidated food integrity culture.

1. Introduction

The globalization phenomenon has augmented the risk of unintentional food safety hazards and deliberate food adulteration by increasing the level of competition among (inter)national food businesses and by multiplying the number of intermediaries within the food supply chains [19,32]. Food safety management systems and industry standards that focus on compliance with prescribed product and process requirements are insufficient to assure food integrity, since they are not designed to prevent intentional contamination and counterfeiting acts (i.e. food fraud) and do not consider integrity aspects and values such as accountability, trust and honesty [11,25,31]. Moving from a compliance-based to an integrity-based organizational culture that focuses on all the aspects involved in the food production from farm to fork (i.e. product, process, people and data integrity) as well as on the activities employed in the monitoring of food (i.e. quality, safety, authenticity and defense) has become imperative for food companies to effectively prevent food fraud within the entire food system [2,27].

In the attempt to standardize previous views on food integrity [1,11,19,21,25], Alrobaish et al. [2] defined food integrity as "a multidimensional concept concerning the integrity of product, process, people and data, implying the controlled status of a food product to be intact, safe, of quality and authentic in its claims, as well as sourced, processed and distributed ethically throughout a food supply chain". Culture as a construct describes the history and traditions that give meaning to the underlying values and beliefs held by the members of a social group and guide life in an organization [18,26,29]. In order to reach an organizational culture that promotes and embraces food

* Corresponding author.
E-mail address: waeel.alrobaish@ugent.be (W.S. Alrobaish).

https://doi.org/10.1016/j.nfs.2023.01.001
Received 4 November 2022; Received in revised form 26 December 2022; Accepted 18 January 2023
Available online 25 January 2023

integrity as an integrated and systemic-centric approach, technical, managerial, operational as well as human aspects must be considered [4]. As such, food integrity culture was defined as "the result of the interplay of the food integrity climate perceived by the employees of a food company (human dimension), the food integrity performance of operators in terms of product, process, people and data integrity (operational dimension), and the context in which the company is operating with technical and managerial control measures to prevent potential food fraud vulnerabilities (technical and managerial dimension)" [4].

In accordance with this definition, Alrobaish et al. [4] developed and validated a method triangulation to assess food integrity culture in food organizations including both subjective and objective complementary measurement tools to capture individual as well as organizational aspects. The three methods applied in this triangulation are: (1) the food integrity climate (FIC) self-assessment tool which measures through a questionnaire the subjective perceptions of managers and operators to reveal the human dimension behind a company's food integrity climate [2], (2) a tailor-made key performance indicators (KPIs) interview conducted during an on-site observation which assesses objectively the operators' working mode to verify the food integrity performance on an operational level [4], and (3) the food fraud vulnerability diagnostic tool (SSAFE) which measures technical and managerial aspects of an organization's food fraud vulnerability level through the quality manager's view by means of a questionnaire [32].

To enhance the understanding of food integrity and the factors that promote (or hinder) its fulfillment in food businesses, previous studies at the international level in the context of food integrity climate [3], food safety climate [9], food safety culture [8,15,16] and food safety management systems (FSMS) [12,20,23,28,35] explored whether particular organizational factors and employees' demographic characteristics affect the achievement and administration of food safety and integrity within food companies.

With regard to the demographic characteristics of employees, research found that gender, age, seniority, contract type and training level impacted the motivation of employees' safe food-handling practices [12,15]. In particular, younger employees (< 30 years old) provided a less favorable response when reporting their organization's food safety risk judgment compared to older workers (> 50 years old) [16]. Moreover, employees' evaluations toward factors related to food safety management differed based on their years of experience in the company (seniority) and duration of employment (contract type). In fact, unlike new employees, experienced employees tended to have less favorable perceptions on their managers' commitment in enforcing food safety and on their coworkers' support to ensure safe food production. Finally, part-time employees demonstrated more favorable perceptions on all factors of food safety culture compared to full-time employees [16]. In the context of food integrity, the link with employees' characteristics has not been explored yet.

With regard to the organizational characteristics of food companies, the main findings demonstrated that companies with multiple sites perceived their food safety climate higher than one-site companies [9], and that the implementation of FSMS and HACCP principles appeared more challenging in small and medium-sized food companies than in large companies due to lack of resources and expertise [23,35], indicating that aspects related to the company size are important to consider when assessing food safety and integrity in food organizations. Moreover, it was found that also the certification status is indicative of positive (or negative) food safety and integrity outputs, since companies certified for multiple food standards (particularly ISO 9000, FSSC 22000 and IFS) perceived their food integrity climate higher than companies with only a single or no food certifications [3], and companies that implemented certified self-checking systems (SCS) based upon good practices and HACCP principles had better elaborated and more advanced FSMS than companies not certified for SCS [20]. Similarly, companies' decision to comply to voluntary food safety standards resulted in a more advanced FSMS and better food safety results [28]. Further, additional research demonstrated that companies offering plant-based food products perceived their food integrity climate higher than animal-based food companies [3]. However, animal-based food companies implemented more robust FSMS, control and assurance activities than plant-based food companies due to the higher vulnerability of animal-based food products [20,23]. This highlights that even the sector or production type is potentially related to food safety and integrity performances.

In this paper, the food integrity culture method triangulation proposed by Alrobaish et al. [4] was applied for the purpose of a semi-quantitative case study in four different Belgian food organizations to explore multiple aspects of food integrity culture. In consideration of the lack of scientific evidence on food integrity culture's correlates, this study explores, as first, whether specific employees' demographic characteristics are related to the prevailing food integrity climate and culture of the four participating companies. Further, the organizational characteristics of these companies were investigated to cross-validate and consolidate the findings by Alrobaish, Jacxsens & Vlerick [3], where the relation between employees' perception of food integrity climate of different companies and their organizational characteristics was analyzed statistically.

2. Materials and methods

2.1. Sample selection

Four Belgian food companies with different organizational characteristics were asked to participate to the study based on convenience sampling method. Overall, a total of 115 participating employees with different demographic characteristics took part. The selected companies operate under the same legal requirements in terms of food safety, hygiene and fraud and are located in the same region (Flanders).

2.1.1. Companies' profile

Company A is a small family-owned company with an ethical profile, committed to sustainability, producing vegetarian and organic ready-to-eat dishes. Company B is a family-owned medium-size organization with a conservative profile operative in the meat industry producing ready-to-eat meat products. Company C is a large business producing and distributing a variety of raw materials and ingredients for bakeries and catering such as chocolate and ice cream. Company D is a small company producing traditional beer and distributing nationally as well as internationally. Based on literature review and discussion with subject-matter experts operating in Belgium with expertise on food safety management as well as work and occupational health psychology, four organizational characteristics were deemed relevant for this study, namely product type (plant or animal-based production), service type (B2B or B2C), company size (number of employees) and certifications status (number of food standards implemented). Table 1 offers an overview of the companies' profile based on these four organizational characteristics.

2.1.2. Employees' profile

Based on literature review and discussion with subject-matter experts operating in Belgium with expertise on food safety management as well as work and occupational health psychology, four demographic characteristics were considered relevant for this study, namely age, seniority, job function (managers or operators in contact or not with food) and contract type (permanent or temporary). Table 2 offers an overview of the employees' profile of the participating food companies based on these four demographic characteristics. Participants in each sample group are overall balanced, with the exception that in Company A all operators are in contact with food, meaning that there is no subsample of operators not in contact with food.

Table 1
Overview of the organizational characteristics of the participating food companies ($n = 4$).

COMPANY	PRODUCT TYPE	SERVICE TYPE	SIZE*	CERTIFICATIONS
A	Plant based (ready-to-eat vegetarian food)	Production/ distribution (B2B)	Small (22 employees)	Multiple (FSSC 22000, EU organic label)
B	Animal based (ready-to-eat meat products)	Production/ distribution (B2B)	Medium (59 employees)	Multiple (IFS, Belgian self-checking system)
C	Plant/animal based (preparations for bakery/ catering)	Production/ processing/ distribution (B2B)	Large (300 employees)	Multiple (IFS, Kosher, EU organic and Fairtrade labels)
D	Plant based (traditional beer)	Production/ distribution (B2B)	Small (49 employees)	Single (Belgian self-checking system)

B2B = Business to Business; EU = European.
* Companies size is based on the following classification: small (< 50 employees), medium (50–250 employees) and large (> 250 employees).

2.2. Measurement instruments and data collection

2.2.1. Food integrity climate assessment tool

The concept of food integrity climate was defined by Alrobaish et al. [2] as "the employees' shared perception of leadership, communication, commitment, risk awareness and resources regarding food integrity within the company's working environment in terms of product, process, people and data integrity". To measure the food integrity climate of the four participating food companies, the FIC tool developed and validated in Alrobaish et al. [2] was adopted. The FIC tool allows to measure through employees' subjective perceptions the human dimension behind the company's food integrity aspects through the assessment of twenty indicators obtained by combining five key organizational climate components (i.e. leadership, communication, commitment, risk awareness and resources) [6] with four food integrity elements (i.e. product, process, people and data integrity) [24]. An example of a FIC questionnaire statement is: "In my company, leaders have clear expectations on how to achieve process integrity (e.g. leaders require and trust employees to perform processes according to instructions and standard operating procedures)". The complete English version of the FIC tool is reported in Alrobaish et al. [2]. Indicators are listed in Appendix A. The participating employees in the four companies filled out individually a Dutch version of the questionnaire voluntarily, anonymously and independently. Filling in the questionnaire implied consent and confidentiality was guaranteed. In each company a different number of employees filled out the questionnaire, including operators in daily contact with food as well as managers and operators who have no direct contact with food (e.g. administration, transportation, technical maintenance) (Company A = 14 employees; Company B = 31 employees; Company C = 35 employees; Company D = 35 employees). Respondents were asked to score each of the twenty statements based on a five-point Likert answer scale ranging from "strongly disagree" (1) to "strongly agree" (5), where responses closer to 5 imply a higher perceived food integrity climate. Based on the five-point Likert answer scale on the assessed twenty indicators, the FIC mean scores of the total food integrity climate (from 20 to 100), of the four food integrity elements (five questions each) (from 5 to 25) and of the twenty food integrity climate indicators (from 1 to 5) were calculated for each of the four companies. Higher scores in the FIC tool correspond to a higher food integrity climate. Hence, for the total food integrity climate, results were considered very high if scores were ranging between 90 and 100, high if they were ranging between 80 and 90, medium from 70 to 80, low from 60 to 70 and very low if they were inferior to 60 [4].

2.2.2. Food integrity performance assessment tool

Food integrity performance was described in Alrobaish et al. [4] as the operators' work conduct in terms of compliance to food safety, quality and authenticity standards as well as to the organizational regulations and procedures at the actual operational level. Following the key performance indicators methodology developed and validated by Alrobaish et al. [4], the food integrity performance of the four participating food companies was measured objectively through KPIs interviews designed and tailor-made for each of the four companies addressing the four food integrity elements (i.e. product, process, people and data integrity). The questions and answer keys were defined by the researchers (the authors of this paper) in collaboration with the companies' quality managers based on the specific activities of the organization. Since the selected companies have different organizational characteristics, the four resulting KPIs interviews have different set of questions. An sample question is: "What are the rules regarding the expiry date of this product?". The interviews were conducted in Dutch in a standardized manner during an on-site observation. Informed consent was obtained from the board of directors of the participating companies to conduct the study and publish anonymously the results. In each company a different number of present operators in contact with food were interviewed (Company A = 10 operators; Company B = 22 operators; Company C = 8 operators; Company D = 5 operators). Operators were asked to orally answer to the KPIs questions and, at the same time, demonstrate how to perform the task in question. The scores were assigned by the interviewers (the researchers) by means of a three-point answer scale, corresponding to perfect compliance (1), minor deviation (2) and major deviation (3) based on the correct predefined answer key. A complete English sample of the KPIs interview is reported in Alrobaish et al. [4]. Indicators are listed in Appendix B. Based on the three-point answer scale and the four food integrity elements assessed, the KPIs mean scores of the total food integrity performance (from 4 to 12) and the four food integrity elements (from 1 to 3) were calculated for each of

Table 2
Overview of the demographic characteristics of the participating employees ($n = 115$) per food company.

COMPANY	AGE		SENIORITY		JOB FUNCTION		CONTRACT TYPE	
A	< 30 years old	7%	< 5 years	43%	Management	29%	Permanent contract	79%
	30–50 years old	86%	5–15 years	50%	Operators in contact with food	71%	Temporary contract	21%
	> 50 years old	7%	> 15 years	7%	Operators not in contact with food	0%		
B	< 30 years old	22%	< 5 years	39%	Management	10%	Permanent contract	87%
	30–50 years old	39%	5–15 years	22%	Operators in contact with food	71%	Temporary contract	13%
	> 50 years old	39%	> 15 years	39%	Operators not in contact with food	19%		
C	< 30 years old	34%	< 5 years	37%	Management	6%	Permanent contract	97%
	30–50 years old	34%	5–15 years	43%	Operators in contact with food	83%	Temporary contract	3%
	> 50 years old	32%	> 15 years	20%	Operators not in contact with food	11%		
D	< 30 years old	9%	< 5 years	23%	Management	8%	Permanent contract	97%
	30–50 years old	51%	5–15 years	23%	Operators in contact with food	46%	Temporary contract	3%
	> 50 years old	40%	> 15 years	54%	Operators not in contact with food	46%		

the four companies. Lower scores in the KPIs interview correspond to higher food integrity performance. Hence, for the total food integrity performance, results were considered very high if scores were ranging between 4 and 4.5, high if they were ranging between 4.5 and 5, medium from 5 to 5.5, low from 5.5 to 6 and very low if they were superior to 6 [4].

2.2.3. Food fraud vulnerability assessment tool

Food fraud vulnerability was previously conceptualized by Spink et al. [31] and Van Ruth, Huisman & Luning [32] as the susceptibility of a system to food fraud due to internal or external weaknesses or flaws in such system, resulting from the combination of opportunities and motivations to commit fraud and control measures to counteract it. The SSAFE food fraud vulnerability diagnostic tool was adopted to assess food fraud and its related aspects, and to acknowledge the technical and managerial factors of the four participating food companies potentially vulnerable to food fraud. The SSAFE tool was developed by the international non-profit organization SSAFE [14] and its operationalization is detailed in the research by Van Ruth, Huisman & Luning [32]. The SSAFE questionnaire comprises fifty questions related to opportunities (e.g. "How simple or complex is counterfeiting of your final product?"), motivations (e.g. "How would you describe the ethical business culture of your company?") and control measures (e.g. "Are the fraud monitoring tasks of your raw material control system verified in your company?"), and for each question a three-point answer scale presents descriptions of high, medium or low vulnerability situations to choose from. For the opportunities and motivations a low score (1) implies low vulnerability, whereas for the control measures a high score (3) implies low vulnerability. The complete version of the SSAFE tool is available online at http://www.ssafe-food.org/our-projects in multiple languages. Indicators are listed in Appendix C. Since SSAFE is a diagnostic tool assessing specific organizational technical and managerial aspects, only the principal quality managers of each of the four companies were asked to fill up a Dutch version of the SSAFE questionnaire. Filling in the questionnaire implied consent and confidentiality was guaranteed. Based on the scores given by the quality manager, the mean score for each of the three dimensions was calculated, hence the total food fraud vulnerability level of the participating companies was calculated by applying the following formula: opportunities × motivations × reversed control measures = food fraud vulnerability level, where the highest level of vulnerability would be $3 \times 3 \times 3 = 27$ and the lowest would be $1 \times 1 \times 1 = 1$ [33]. For interpretation, the vulnerability level was considered very low if final scores were ranging between 1 and 4, low if they were ranging between 4 and 7, medium from 7 to 10, high from 10 to 15 and very high if they were superior to 15.

2.3. Data processing and analysis

2.3.1. Method triangulation to assess food integrity culture

Data collected from the questionnaires and interviews were processed statistically through IBM SPSS version 28 to perform descriptive analysis. To assess the prevailing food integrity culture of the four participating food organizations, the results of the three complementary methods were triangulated and compared by means of rankings, similarly to the triangulation methodology previously applied by De Boeck et al. [7] and De Boeck et al. [10] in the context of food safety culture and by Alrobaish et al. [4] in the context of food integrity culture. The four companies were arranged in a ranking order based on the results of the three tools. For each of the three dimension assessed (i.e. food integrity climate, food integrity performance and food fraud vulnerability) a companies' ranking was elaborated, so that the three rankings could be compared and relations among dimensions could be examined.

Specifically, two potential relations were analyzed to determine the positioning of the participating company in terms of food integrity culture: (1) the employees' subjective perceptions on food integrity (FIC tool outputs) were examined against the operators' on-site performance (KPIs interview results) to verify objectively the food integrity indicators for each company; following, (2) the employees' subjective perceptions (FIC tool outputs) were checked also against the organizational food fraud vulnerability level (SSAFE tool scores) to explore the human dimension behind food integrity in relation to the company's technological and managerial strategies to prevent food fraud. Generally, regarding the first relation analyzed, since companies' climate impacts human and organizational performance [18], it is assumed that the association between food integrity climate and food integrity performance is positive, implying that a food organization characterized by a high food integrity climate will likely perform well on the food integrity indicators. Regarding the second relation analyzed, since food integrity and food fraud are opposite concepts [2], it is assumed that the association between food integrity climate and food fraud vulnerability is negative, meaning that the higher is the food integrity climate within a food company, the lower will be its vulnerabilities to commit food fraud, and vice versa.

To facilitate comparison among the four companies, a single value representing numerically the prevailing food integrity culture of each company was obtained by applying the following formula: reversed total climate × total performance × total vulnerability = prevailing food integrity culture, where the best food integrity culture positioning would be $1 \times 1 \times 0 = 0$ and the worst would be $5 \times 3 \times 3 = 45$ (results converted out of their original scores) (adapted from the SSAFE formula reported above). For interpretation, a company's food integrity culture could be considered as positive when the final result was between 0 and 10. As argued by Alrobaish et al. [4], multiple can be the assumptions on how the companies can be positioned in terms of food integrity culture based on the three sets of results. In the best case, the food integrity climate perceived and food integrity performance are high and the food fraud vulnerabilities are low, whereas, in the worst case, the former appear low and the latter high. Food companies may find themselves even in other situations. For instance, on one side, a company that appears very sensitive to food fraud may compensate for its risky situation with a high food integrity climate. On the other side, a company that shows a low potential to commit food fraud may not always have a high food integrity climate.

2.3.2. Assessing the role of employees' characteristics

To examine whether specific demographic characteristics of the participating employees (i.e. age, seniority, job function and contract type) influence their perception of their company's food integrity climate, the analysis of variance (one-way ANOVA) was conducted through IBM SPSS version 28, allowing to verify whether there was a statistically significant relation between employees' characteristics and FIC tool results on the overall sample ($n = 115$ employees) (significance level ≤ 0.05). The statistical basic assumptions to conduct the ANOVA analysis (i.e. the normality of distribution and the homogeneity of variance) were fulfilled.

2.3.3. Assessing the role of organizational characteristics

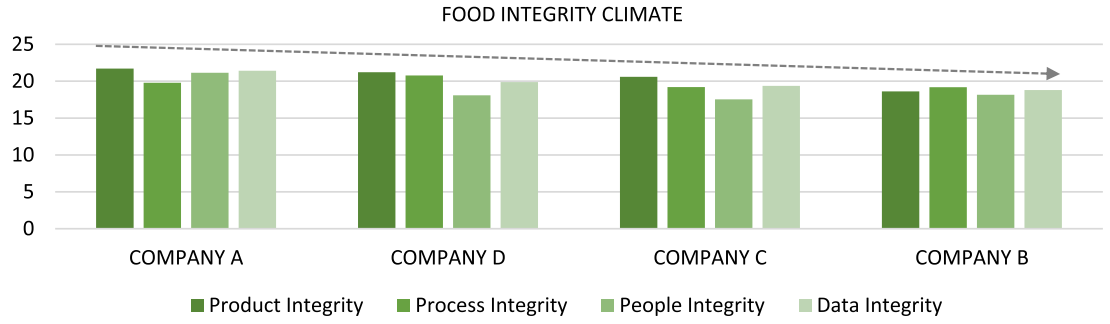
To evaluate whether specific organizational characteristics of the four participating food companies (i.e. product type, service type, company size and certifications status) have an effect or play a role in determining an overall positive (or negative) food integrity culture, the obtained food integrity culture results of the four companies were visually compared against the particular organizational characteristics of each company.

3. Results

3.1. Food integrity culture

3.1.1. Perceived food integrity climate

As represented in Fig. 1, the descriptive results of the FIC tool demonstrated that employees of the four participating food companies



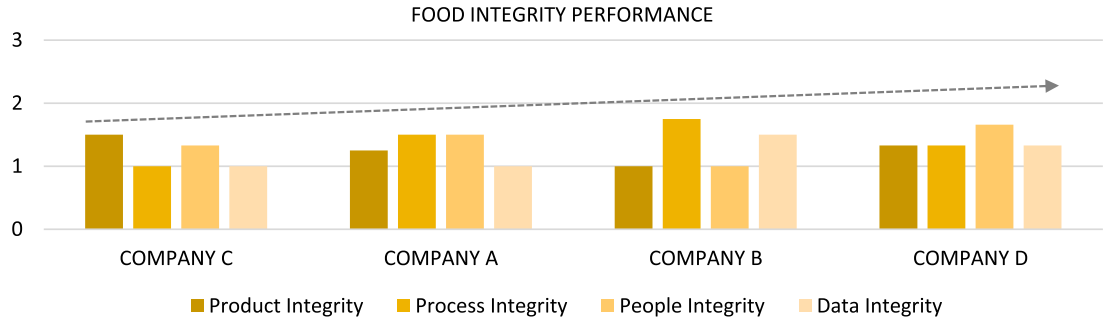
Companies Ranking	N	Product Integrity*	Process Integrity*	People Integrity*	Data Integrity*	Total Food Integrity Climate**
A	14	21.71/25	19.78/25	21.14/25	21.42/25	**84.07/100**
D	35	21.22/25	20.77/25	18.08/25	19.88/25	**79.97/100**
C	35	20.60/25	19.20/25	17.54/25	19.37/25	**76.71/100**
B	31	18.61/25	19.19/25	18.16/25	18.80/25	**74.77/100**

Fig. 1. Graphical representation of food integrity climate descriptive results per company.
Companies are shown in ranking order from the one that perceived the highest food integrity climate (A) to the one that perceived it lowest (B).
Higher mean scores in the FIC tool indicate a higher perceived food integrity climate (a 5-point Likert answer scale is applied).
* The sum scores per food integrity dimension range from 5 to 25.
** The total food integrity climate is the sum score of the 4 food integrity dimensions ranging from 20 to 100.
N = number of responding employees.
/ = out of.

perceived overall a medium-high food integrity climate, with the highest scores found in Company A (mean = 84.07/100) (high climate), followed in order by Company D (mean = 79.97/100) (medium climate), Company C (mean = 76.71/100) (medium climate) and finally Company B (mean = 74.77/100) (medium climate). Differences among food integrity elements were only minor, however people integrity was the lowest-perceived element in three out of four companies (B, C, D) and product integrity was the highest-perceived element in three out of four companies (A, C, D).

3.1.2. *Objective food integrity performance*

As represented in Fig. 2, the descriptive results of the KPIs interviews show that the operators of the four participating food companies demonstrated overall a medium performance in terms of food integrity. Specifically, Company C recorded the highest food integrity performance (mean = 4.83/12) (high performance), followed in order by



Companies Ranking	N	Product Integrity*	Process Integrity*	People Integrity*	Data Integrity*	Total Food Integrity Performance**
C	8	1.50/3	1.00/3	1.33/3	1.00/3	**4.83/12**
A	10	1.25/3	1.50/3	1.50/3	1.00/3	**5.25/12**
B	22	1.00/3	1.75/3	1.00/3	1.50/3	**5.25/12**
D	5	1.33/3	1.33/3	1.66/3	1.33/3	**5.65/12**

Fig. 2. Graphical representation of food integrity performance descriptive results per company.
Companies are shown in ranking order from the highest performing one (C) to the lowest performing one (D).
Lower mean scores in the KPIs interviews indicate an objective better food integrity performance.
* Scores per food integrity dimensions range from 1 to 3 (1 = perfect compliance, 2 = minor deviation, 3 = major deviation).
** The total food integrity performance is the sum score of the 4 food integrity dimensions ranging from 4 to 12.
N = number of responding operators.
/ = out of.

Companies A and B in equal positions (mean = 5.25/12) (medium performance), and finally by Company D (mean = 5.65/12) (low performance). With regard to the food integrity elements, process integrity was the lowest performing dimension overall, whereas data integrity was the highest performing dimension overall, however differences were minimal and varying across companies.

3.1.3. Food fraud vulnerability diagnosed

As represented in Fig. 3, the descriptive results of the SSAFE tool showed that the quality managers of the four participating food companies evaluated their companies overall with a medium-low food fraud vulnerability, with Company C showing the lowest vulnerability (mean = 4.17/27) (low vulnerability), followed in order by Company D (mean = 5.59/27) (low vulnerability), Company B (mean = 6.23/27) (low vulnerability) and finally Company A (7.70/27) (medium vulnerability). Company C showed the lowest vulnerability since the control measures adopted to prevent food fraud recorded a better score than the opportunities and motivations to commit food fraud. The other companies (A, B, D) show a low level of implementation of food fraud control measures as compared to their opportunities and motivations to commit food fraud.

3.1.4. Prevailing food integrity culture

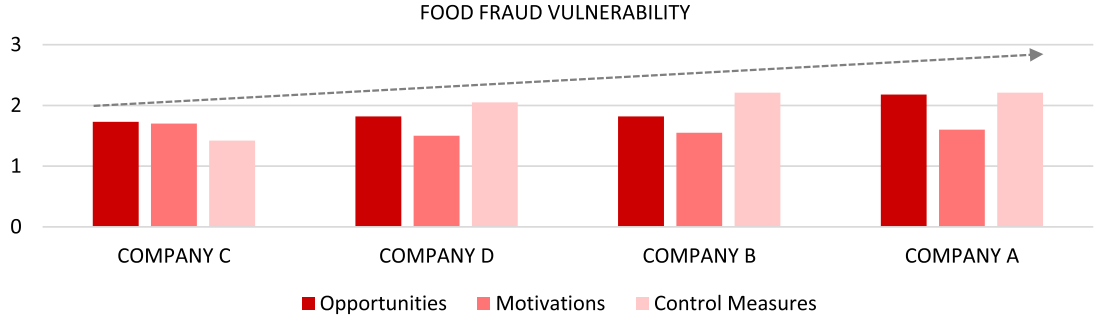
The overall scores of the three assessed dimensions (i.e. food integrity climate, food integrity performance and food fraud vulnerability) for each company were calculated mathematically through the formula above described, and a final score representing the prevailing food integrity culture of each company was obtained. As detailed in Table 3, Company C recorded the highest food integrity culture (mean = 1.18/45), followed in order by Company D (mean = 1.75/45), Company A (mean = 2.00/45) and finally Company B (mean = 2.05/45). Fig. 4 shows the companies positioning in terms of their prevailing food integrity culture. Overall, differences among the four participating food companies were minor and all companies recording a positive food integrity culture with space for improvement in particular areas based on the three dimensions assessed (i.e. food integrity climate, food integrity performance and food fraud vulnerability).

Based on the three sets of scores from the three tools applied in triangulation (i.e. FIC tool, KPIs interview and SSAFE tool), the four participating companies were arranged in rankings (Figs. 1, 2 and 3). The companies ranking order for their KPIs results is not exactly in line with the companies ranking order for their FIC results (Figs. 1 and 2). However, since differences among companies' scores were only minimal, it could be concluded that both the perception of food integrity climate and the objective food integrity performance in the four participating food companies were medium-high. Therefore, the positive relation assumed between food integrity climate and food integrity performance could be confirmed. Minor differences in scores might be due to the fact that the responding employees for the FIC tool and the KPIs interview were different in all the companies, even in their number. In fact the KPIs interview was conducted only with few dedicated operators.

Also the companies ranking order for their SSAFE results is not exactly in line with the companies ranking order for their FIC results (Figs. 1 and 3). However, also in this case, variances in scores were minor and may be attributed to the different organizational characteristics that distinguish each company. Therefore, the negative relation assumed between food fraud vulnerability and food integrity climate could be confirmed, since the overall level of food fraud vulnerability diagnosed by the quality manager of each of the four companies was medium-low, in contraposition to their overall food integrity climate that was perceived by their employees as medium-high.

3.2. Relation between food integrity climate and employees' characteristics

As detailed in Table 4, the results from the ANOVA analysis demonstrated that among the analyzed employees' characteristics (i.e. age, seniority, job function and contract type) only the job function (with subsample groups being managers, operators in contact with food



Companies Ranking	Food Fraud Opportunities	Food Fraud Motivations	Food Fraud Control Measures*	**Total Food Fraud Vulnerability****
C	1.73/3	1.70/3	1.42/3	**4.17/27**
D	1.82/3	1.50/3	2.05/3	**5.59/27**
B	1.82/3	1.55/3	2.21/3	**6.23/27**
A	2.18/3	1.60/3	2.21/3	**7.70/27**

Fig. 3. Graphical representation of food fraud vulnerability descriptive results per company.
Companies are shown in ranking order from the one reporting the lowest food fraud vulnerability (C) to one reporting the highest food fraud vulnerability (A).
Lower mean scores in the SSAFE tool indicate a lower food fraud vulnerability (1 = low vulnerability situation, 2 = medium vulnerability situation, 3 = high vulnerability situation).
The SSAFE tool is filled up exclusively by the quality manager of each company.
* The reported control measures values are reversed, so the higher the reported score, the higher the vulnerability.
** The total food fraud vulnerability is based on the SSAFE formula = opportunities x motivations x reversed control measures.
/ = out of.

Table 3
Food integrity culture descriptive results per company (method triangulation).

COMPANY	TOTAL CLIMATE*	TOTAL PERFORMANCE**	TOTAL VULNERABILITY***	FOOD INTEGRITY CULTURE****
C	2.15/5 x	1.20/3 x	0.46/3 =	**1.18/45**
D	2.01/5 x	1.41/3 x	0.62/3 =	**1.75/45**
A	1.80/5 x	1.31/3 x	0.85/3 =	**2.00/45**
B	2.27/5 x	1.31/3 x	0.69/3 =	**2.05/45**

Companies are shown in ranking order from the one demonstrating the highest overall food integrity culture (C) to the one with the lowest (B).
Lower mean scores indicate a better overall food integrity culture.
/ = out of.
* Total food integrity climate scores (reported in Fig. 1) converted to 5 and reversed.
** Total food integrity performance scores (reported in Fig. 2) converted to 3.
*** Total food fraud vulnerability scores (reported in Fig. 3) converted to 3.
**** Food integrity culture formula (total climate x total performance x total vulnerability = prevailing food integrity culture).

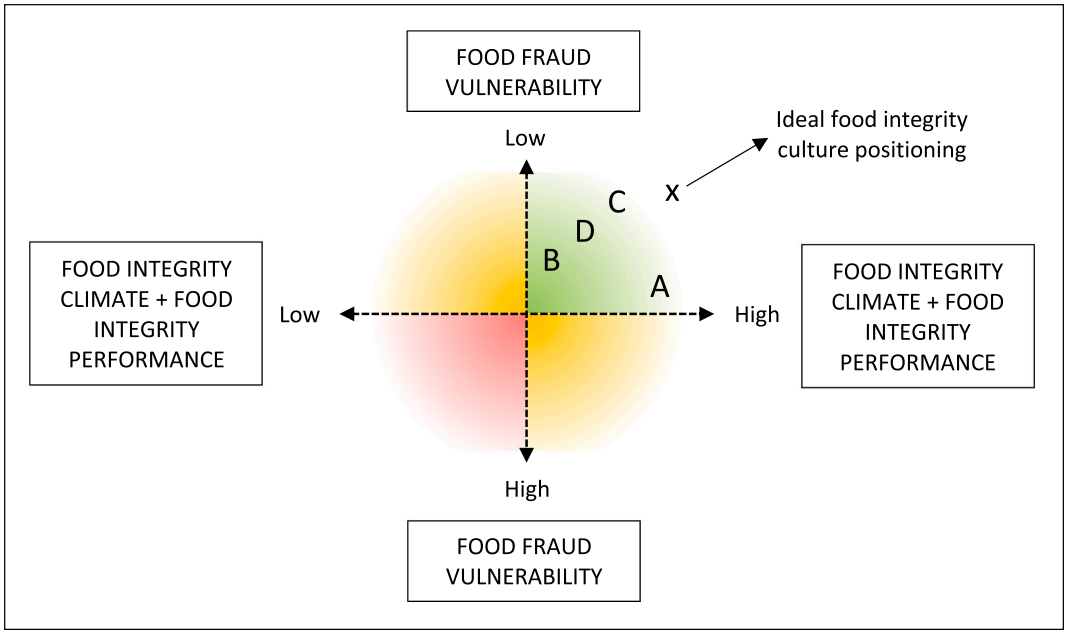


Fig. 4. Companies positioning in terms of their prevailing food integrity culture.
Since food integrity climate and food integrity performance are positively related, they are represented jointly against the food fraud vulnerability (with which they are negatively related).
To position the companies in their exact (indicative) positioning and visualize a comparative positioning of the four companies, the total scores of the food integrity climate (reversed) and of the food integrity performance of each company were combined by mathematical multiplication.

and operators not in contact with food) showed a statistically significant positive relation to the perception of food integrity climate ($F = 3.534$, $p = .032$). Specifically, in all the four participating food companies, the managers perceived their company's food integrity climate higher than the operators not in contact with food and much higher than the operators in contact with food, as illustrated in Fig. 5. In all the four companies this pattern is noticed, even though this difference in food integrity climate perception is more pronounced in Companies C and D, where the managers scored the FIC indicators much higher (respectively mean = 86.50 and 86.67) than the operators in contact with food (respectively mean = 75.41 and 77.19).

3.3. Relation between food integrity culture and organizational characteristics

By interpreting the descriptive results of the three assessed tools and the overall food integrity culture of the four participating food companies in relation to their organizational characteristics (i.e. product type, service type, company size and certifications status) (Tables 1 and 3), it can be argued that Company C recorded the highest food integrity culture as it has the major number of food certifications as compared to the other companies. Company C is also the largest company in the sample, involved in multiple steps of the supply chain (from production to distribution) and the only one offering both plant and animal derived food products. Moreover, Company C recorded the highest score in the food integrity performance and demonstrated the lowest food fraud vulnerability.

On the other side, Company B showed the lowest food integrity culture in the sample, recording the lowest food integrity climate score. It must be noted that Company B is the only animal-based food organization, which may have had an impact on this result. Therefore, even though differences in scores among the companies are small, it is possible to attribute some of these differences to the specific organizational characteristics of each company, mostly to product type, company size and certifications status.

4. Discussion

The food integrity culture method triangulation proposed by Alrobaish et al. [4] was applied in a semi-quantitative case study across four different Belgian food organizations to explore multiple aspects of food integrity culture and to analyze whether employees' demographic

Table 4
ANOVA statistical results of the relation between employees' demographic characteristics and food integrity climate overall.

VARIABLE	GROUPS	N**	FIC MEAN	F VALUE	*P* VALUE
AGE	< 30 years old	23	77.30/100	1.942	0.148
	30–50 years old	53	80.09/100		
	> 50 years old	39	75.79/100		
SENIORITY	< 5 years	39	79.92/100	0.913	0.404
	5–15 years	37	76.84/100		
	> 15 years	39	77.41/100		
JOB FUNCTION	Management	12	84.08/100	3.534	0.032*
	Contact with food	77	76.42/100		
	No contact with food	26	80.23/100		
CONTRACT TYPE	Permanent	106	78.28/100	0.499	0.481
	Temporary	9	75.67/100		

/ = out of.
* $P < .05$.
** N = Total number of employees in the 4 companies filling the FIC tool per demographic group.

characteristics (i.e. age, seniority, job function and contract type) and the companies' organizational characteristics (i.e. product type, service type, company size and certifications status) have an effect or can be associated to the prevailing food integrity culture. To this purpose, the four companies' results of the three tools applied in triangulation (i.e. FIC tool, KPIs interview and SSAFE tool) and the three respective dimensions assessed (i.e. food integrity climate, food integrity performance and food fraud vulnerability) were examined in comparison to study the prevailing food integrity culture in consideration of the different characteristics of the four organizations and of their employees.

4.1. Food integrity culture

With regard to the interconnection among the dimensions of food integrity culture, the positive relation between perceived food integrity climate and objective food integrity performance was confirmed, since in all the four participating food companies both the perception and the actual performance of the food integrity elements (i.e. product, process, people and data integrity) were medium-high. This corroborates the study results of Alrobaish et al. [4], where a similar positive relation was found within the affiliates of a large Belgian meat distribution company. Moreover, in both studies, the food integrity element that was perceived as lowest overall by the participating employees was people integrity. Specifically, the people integrity indicators that were perceived mediocrely by the employees concern the following aspects: leaders motivating and listening to employees' concerns and behaving as role models, leaders encouraging open and honest communication among employees, leaders rewarding employees' positive behavior, employees taking care of each other's well-being, leaders respecting employees and

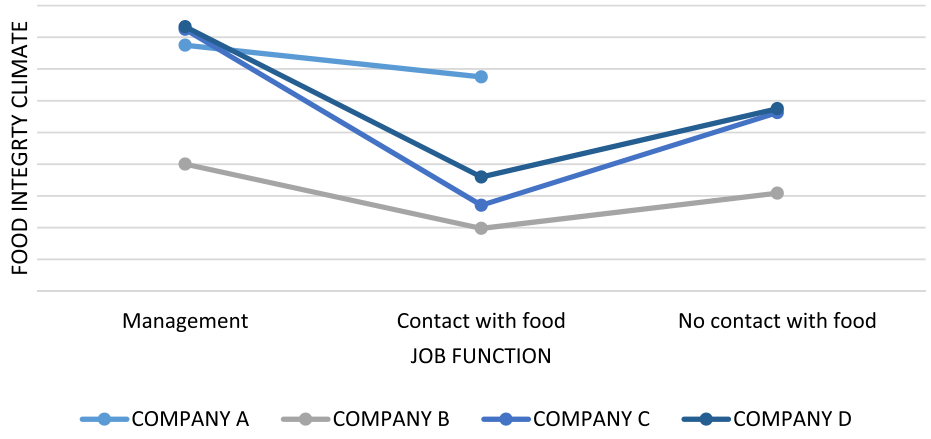


Fig. 5. Graphical representation of the relation between job function and food integrity climate in the four participating companies. In all the companies the management perceived a higher food integrity climate than operators not in contact with food and much higher than operators in contact with food.
* Company A does not have operators that are not in contact with food.
** The food integrity climate mean score is based on the sum score of the 4 food integrity dimensions ranging from 20 to 100.
N = number of employees.
/ = out of.

COMPANY	JOB FUNCTION	N	MEAN**	STANDARD DEVIATION
A	Management	4	85.50/100	2.89
	Contact with food	10	83.50/100	11.91
	No contact with food*	0	-	-
B	Management	3	78.00/100	9.16
	Contact with food	22	73.95/100	11.88
	No contact with food	6	76.17/100	13.00
C	Management	2	86.50/100	12.02
	Contact with food	29	75.41/100	10.94
	No contact with food	4	81.25/100	8.88
D	Management	3	86.67/100	10.69
	Contact with food	16	77.19/100	8.57
	No contact with food	16	81.50/100	7.49

customers' rights, leaders investing in good working conditions, ethical code of conduct and employees' trainings (based on the FIC tool indicators) (Appendix A).

People integrity was the food integrity dimension that obtained the lowest scores also in terms of performance in two out of the four participating food companies, as well as among the operators of the food organization analyzed in the research by Alrobaish et al. [4] (the KPIs interview tool, however, does not allow direct comparison since questions differ and are tailor-made for each company). Also in the research by Zanin, Stedefeldt & Luning [36] where food safety culture was assessed through method triangulation, the element found most in need of improvement was related to people. This highlights the importance of studying the human dimension and the need to acknowledge people-related aspects in food organizations to improve overall food safety and integrity performances. Leaders should motivate their employees, give positive feedback and recognize good behavior, so that employees will be more stimulated to achieve food integrity [18]. In companies with a strong ethical corporate environment (e.g. food integrity culture), employees are strongly committed to adhere to the organizations' rules and regulations, which contributes to limit the risk of unethical behaviors. On the contrary, an organizational culture characterized by demotivation, mistrust and dissatisfaction can be a breeding ground for unethical behaviors among employees [32]. Indeed, recently, Alrobaish et al. [5] found empirical evidence that companies' food integrity climate is positively related to employees' food integrity behavior in food businesses.

The negative relation between food integrity climate (at the individual level) and food fraud vulnerability (at the organizational level) was also verified, since in all the four participating food companies a medium-highly perceived (and performed) food integrity climate corresponded to a medium-low food fraud vulnerability. This confirms the results of the research by Alrobaish et al. [4] in which a similar negative relation was found within the affiliates of a large Belgian meat distribution company. Moreover, commonalities can be found among the samples in both studies regarding the opportunities and motivations to potentially commit food fraud and the control measures to counteract them. In fact, the most common food fraud opportunities detected in all the participating companies in these two studies relate to the fact that technologies and knowledge to adulterate raw materials and final products are generally available, while detection for adulteration requires advanced laboratory analysis, and sometimes tests for counterfeiting are not available at all [30]. Further, the most evident food fraud motivations detected in most of the participating companies in these two studies concern the fact that the sector is highly competitive, there is documented evidence of food fraud activities and the price policy of raw materials and final products varies considerably across countries [14]. For the food fraud control measures, the least developed or completely absent aspects in most of the participating companies in these two studies are related to the fact that there is no verification or monitoring system in place to detect fraud in incoming raw materials and finished products and no integrity screening of employees and suppliers, meaning that these are not selected based on safety, quality and integrity requirements but only on logistic parameters (e.g. availability and cost) (based on the SSAFE tool indicators) (Appendix C). This problematic tends to occur in most food organizations since, while food safety management systems and standards are widely implemented to prevent unintentional food safety hazards, food fraud mitigation and prevention strategies are not yet considered and put in place by industry practitioners to detect and control deliberate adulteration and counterfeiting threats [31,32].

Overall, the prevailing food integrity culture of the four food companies participating in this study could be described as positive, since their food integrity climate and food integrity performance were medium-high and their food fraud vulnerability was medium-low, with space for improvement in particular areas. Specifically, as shown in the companies rankings from Figs. 1 to 3 and represented in Fig. 4, Company C (a large plant and animal-based food processing and distributing food organization) recorded the best food integrity culture positioning within the sample, since its operators performed highly in terms of food integrity (highest food integrity performance in the sample) and the food fraud vulnerability level indicated by the quality manager was low (lowest food fraud vulnerability in the sample), as the multiple and well implemented control measures to prevent food fraud counteract the few opportunities and motivations to potentially commit food fraud detected in the company. Additionally, the motivations to potentially perpetrate food fraud are relative to external factors and fall outside the company's reach and responsibility (e.g. high competition within the industry, high and inconsistent prices of raw materials). Even though Company C obtained the best scores in terms of food integrity performance and food fraud vulnerability, its food integrity climate was not the highest perceived among the four companies, indicating that performance and perception of employees do not always align, as previously demonstrated by Alrobaish et al. [4] in the context of food integrity culture and by De Boeck et al. [10] in the context of food safety culture. The riskiest situation for food companies would be when the perception of food integrity climate is high but the actual performance in terms of food integrity is low, as this poses the danger of optimistic bias and complacency among employees [17]. However, this was not the case of Company C, where the food integrity performance was actually higher than the perceived food integrity climate.

On the opposite side, Company B (a medium-size meat processing and distributing organization) recorded the lowest food integrity culture within the sample, since its food integrity climate was perceived by its employees as lowest among the four companies. However, in terms of rankings, the total scores of Company B were not differing considerably from the total scores of Companies A and D, since the operators in Company D (a small beer producing and distributing organization) performed low in terms of food integrity indicators (lowest food integrity performance in the sample), and Company A (a small plant-based processing and distributing food organization) recorded the highest food fraud vulnerability in the sample, since the lacking food fraud control measures are not able to counteract the multiple opportunities and motivations to commit food fraud detected in the company. Interestingly, while demonstrating the highest food fraud vulnerability, Company A recorded at the same time the highest food integrity climate perceived by its employees among the four companies. This finding is in line with the argument made by Alrobaish et al. [4], stating that not always a high food integrity climate corresponds to a low food fraud vulnerability, or vice versa, as expected, since in some cases food companies that appear very sensitive to food fraud may compensate for their risky situation with a high food integrity climate (Company A), while in other cases companies that show a low potential to commit food fraud may not always have a high food integrity climate.

4.2. *Role of organizational characteristics*

The minor differences described above that were recorded among the companies on the analyzed food integrity and food fraud dimensions (i.e. product, process, people and data integrity on one side and food fraud opportunities, motivations and control measures on the other side) could be attributed to the different organizational characteristics of each company. In fact, as indicated in Table 1, it can be argued that the certifications status may have an impact on the prevailing food integrity culture of a food company, since Company C, that recorded the highest food integrity culture in the sample, has the major number of food certifications implemented as compared to the other companies, including the IFS standard. This observation confirms the statistical findings of the research conducted by Alrobaish, Jacxsens & Vlerick [3], which demonstrated that being certified for multiple food standards is positively associated with a higher food integrity climate (specifically and significantly for IFS, ISO 9000 and FSSC 22000). In the field of food safety, also Jacxsens et al. [20] found that companies that implemented

certified self-checking systems based upon good practices and HACCP principles had better elaborated and more advanced FSMS than companies not certified for SCS. As a matter of fact, food companies that are certified for food standards have specific procedures and systems in place to control and prevent food safety hazards and food fraud risks [13].

The product type seems to be related to a positive (or negative) prevailing food integrity culture, since Company B, which is the only purely animal-based food organization in the sample, demonstrated the lowest food integrity culture among the four participating food companies. As a confirmation to this observation, in the research by Alrobaish, Jacxsens & Vlerick [3] it was found (also in Belgium) that plant-based food companies recorded a higher food integrity climate than animal-based organizations. In line with this, in the study by Jacxsens et al. [20] it was demonstrated that animal-based food products are on a higher-risk level in terms of probability of contamination, since they have intrinsically higher prevalence of pathogens and are often implicated in foodborne outbreaks. On the other side, plant-derived or plant-based products tend to have a lower vulnerability to food fraud as compared to animal-derived or animal-based products [22,34].

The company size appeared to be related to the prevailing food integrity culture of food businesses, since Company C is the largest company in the sample and recorded the highest food integrity culture. In confirmation to this, in the context of food safety climate, De Boeck et al. [7] pointed out that in smaller food companies the people in charge are engaged in multiple simultaneous assignments, and the lack of proper knowledge or technically qualified personnel may represent a challenge for food safety management. Large-scale food organizations require more structured communication that can be managed by more trained people generally available in larger businesses, whereas food safety information in small-scale companies is usually less efficient and structured [23].

There was insufficient evidence in this research to state that the service type could also affect the companies' prevailing food integrity culture since all the participating organizations focus on B2B rather than B2C. Even the previous research by Alrobaish, Jacxsens & Vlerick [3] could not find a statistical relation between supply chain step (i.e. processing, distributing, retail, catering) and the food integrity climate perceived by employees, implying that a company's service type may not affect the achievement of a positive (or negative) food integrity climate and culture.

4.3. Role of demographic characteristics

Some variances in results among the participating companies on the perception of their food integrity climate could be also attributed to the different demographic characteristics of the participating employees. As shown in Fig. 5, the results from the ANOVA statistical analysis demonstrated that the employees' job function in the company is significantly related to their perception of food integrity climate. Specifically, in all the four participating food companies, the managers perceived their company's food integrity climate higher than the operators, especially of those in contact with food. Remarkably, differences in the perception of food integrity climate between managers and operators were also revealed in the research by Alrobaish et al. [2] conducted in a large Belgian meat distribution company. In this latter study, managers perceived product and people integrity higher than operators, while operators scored process and data integrity higher than managers. This could be attributed, in fact, to their different organizational function (e.g. roles and tasks), since, while the management is more involved in the decisions regarding the company's products as well as in the selection and administration of the people within the organization, the operators' work have more to do with the actual execution of the various processes and with the handling of the data relative to the products.

Further statistical correlations between the analyzed demographic characteristics (i.e. age, seniority, contract type) and the prevailing food integrity climate were not revealed in this study, possibly due to the small sample size. On previous related studies, however, the impact of employees' age, seniority and contract type toward food safety was demonstrated (e.g. young, new and full-time employees showed less favorable perceptions of food safety culture factors) [15,16]. Since only four food organizations participated to this semi-quantitative study and not all the employees responded, future research could replicate this study in a more quantitative design with a larger sample to uncover other potential connections between food integrity culture and organizational as well as employees' characteristics, acknowledging the major factors that affect the implementation of an effective food integrity culture within food businesses. Future research might also consider to apply qualitative research methods (e.g. focus group, semi-structured interview, participative field observation) to capture the voice or perceptions of those not willing or not able to participate in the study at hand, in order to have a more representative and nuanced portray of organizations' food integrity culture.

5. Conclusions and future research

The prevailing food integrity culture of four different Belgian food companies was assessed in this semi-quantitative study through the food integrity culture method triangulation developed and validated by Alrobaish et al. [4], analyzing the interplay between the perceived food integrity climate, the performed food integrity and the food fraud vulnerability in view of the companies' organizational characteristics (i.e. product type, service type, company size and certifications status) and employees' demographic characteristics (i.e. age, seniority, job function and contract type).

The results of the three tools applied in triangulation (i.e. FIC tool, KPIs interview and SSAFE tool) demonstrated that overall all the participating companies recorded a positive food integrity culture, since their food integrity climate and food integrity performance were medium-high and their food fraud vulnerability was medium-low, with only minor differences in terms of scores and with space for improvement in some of the specific dimensions analyzed (i.e. product, process, people and data integrity on one side and food fraud opportunities, motivations and control measures on the other side). In particular, people integrity was the lowest-perceived food integrity dimension overall, in some cases also in terms of performance, and specific food fraud control measures were found missing in the majority of the participating companies.

Remarkably, the statistical analysis revealed that the managers in all the four food companies perceived their company's food integrity climate significantly higher than the operators in contact with food, suggesting that the job function has an effect in the perception of the food integrity climate. This reflect that employees across different job functions or roles might hold differing perceptions of the food integrity climate prevailing in their food company. Other demographic characteristics analyzed (i.e. age, seniority and contract type) did not show to have an impact on the prevailing food integrity climate and culture. On the other side, some organizational characteristics could be associated with a positive (or negative) food integrity culture, specifically product type, company size and certifications status.

Despite few research limitations (i.e. small sample size and non-response bias) and due to its strengths (i.e. method triangulation), this study demonstrated the importance of acknowledging and assessing food integrity culture in all its related aspects (i.e. food integrity climate, food integrity performance and food fraud vulnerability) both for practitioners, as a way to enhance food integrity in the food supply chain, and academics, since advancement in this research topic is needed. Food companies would benefit in including regular assessments of their food integrity climate and performance within their standard food safety management systems as well as periodic assessments of potential food fraud vulnerabilities, and managing such human, operational, technical and managerial aspects as strategies of an integrated

system.

Funding

This research has been conducted in the context and under the supervision of Ghent University, Belgium, funded by King Abdulaziz City for Science and Technology (KACST) through the Saudi Arabian Cultural Mission (SACM), the Hague, the Netherlands.

Institutional review board statement

The study was conducted in accordance with the ethical standards of first authors' institutional research committee and with the 1964 Helsinki declaration and its later amendments.

Informed consent statement

Informed consent was obtained from all subjects involved in the study.

Ethical approval

Ethics approval was not required for this research.

CRediT authorship contribution statement

Waeel Salih Alrobaish: Conceptualization, Methodology, Validation, Formal analysis, Investigation, Resources, Data curation, Writing – original draft, Writing – review & editing. **Peter Vlerick:** Writing – review & editing, Supervision. **Liesbeth Jacxsens:** Resources, Supervision, Project administration, Funding acquisition.

Declaration of Competing Interest

All authors state that they have no competing interests to declare.

Data availability statement

The data that support the findings of this study are available from the corresponding author upon reasonable request.

Acknowledgement

We acknowledge and thank all the food companies and employees that participated in the study.

Appendix A

FOOD INTEGRITY CLIMATE (FIC) ASSESSMENT TOOL INDICATORS	
PRODUCT INTEGRITY	1 Leaders set clear objectives (e.g. precise tasks and deadlines to deliver products according to standards)
	2 Clear communication with employees (e.g. understandable information on requirements and recipes)
	3 Importance of product integrity is recognized (e.g. high product standards and customer requirements)
	4 Awareness of hazards and threats (e.g. adulteration, contamination and product counterfeit)
	5 Availability of necessary resources (e.g. good selection of suppliers, raw materials and trained staff)
	6 Leaders have clear expectations (e.g. require and trust employees to operate according to instructions)
	7 Clear communication with employees (e.g. understandable explanations on how to operate and supervise)
PROCESS INTEGRITY	8 Employees act constructively to solve issues (e.g. prepared to face emergencies and correct incidents)
	9 Awareness of hazards and threats (e.g. control of equipment, production line and processing methods)
	10 Availability of necessary resources (e.g. equipment, replacement parts, workspaces and systems)
	11 Leaders continuously improve people integrity (e.g. motivate, involve and listen employees' concerns)
	12 Importance of people integrity is communicated (e.g. open and honest discussions are encouraged)
PEOPLE INTEGRITY	13 Improving people integrity is rewarded (e.g. incentives and positive feedback given to employees)
	14 Employees are alert of hazards and threats (e.g. employees' rights, well-being and consumers' health)
	15 Sufficient investment are made (e.g. good working conditions, ethical code of conduct, employees' training)
	16 Leaders continuously improve data integrity (e.g. verify quality of data and deliver products as promised)
	17 Importance of data integrity is communicated (e.g. clear guidelines and directions on how to record data)
DATA INTEGRITY	18 Leaders set good example (e.g. leaders supervise and participate ensuring product information accuracy)
	19 Employees have a realistic picture of hazards (e.g. false documents, irregular certificates, incorrect labeling)
	20 Sufficient investment are made (e.g. tracking and tracing software, product registration databases)

Appendix B

KEY PERFORMANCE INDICATORS (KPIs) INTERVIEW SAMPLE QUESTIONS	
PRODUCT INTEGRITY	1 Checking requirements of finished products
	2 Rules applied for non-conform products
	3 Products preparation
	4 End of production day activities
PROCESS INTEGRITY	5 Rules followed for waste management
	6 Products expiry dates rules
	7 Hygiene rules for contact with food
PEOPLE INTEGRITY	8 Knowledge on food allergens
	9 New employees training activities
	10 Products lot number registration rules
DATA INTEGRITY	11 Rules followed for start-up controls
	12 Temperatures measurement rules

Appendix C

FOOD FRAUD VULNERABILITY DIAGNOSTIC TOOL (SSAFE) INDICATORS

OPPORTUNITIES		MOTIVATIONS		CONTROL MEASURES	
1	Complexity of adulteration raw materials	12	Supply & pricing raw materials	32	Fraud monitoring system raw materials
2	Technology & knowledge adulterate raw materials	13	Valuable components raw materials	33	Verification of monitoring system raw materials
3	Detectability adulteration raw materials	14	Economic conditions own company	34	Fraud monitoring system final products
4	Technology & knowledge adulterate final products	15	Organizational strategy own company	35	Verification of monitoring system final products
5	Detectability adulteration final products	16	Ethical business culture own company	36	Information system own company
6	Complexity of counterfeiting	17	Criminal offences own company	37	Tracking and tracing system own company
7	Detectability of counterfeiting	18	Corruption level country own company	38	Integrity screening own employees
8	Interference processing lines	19	Financial strains suppliers	39	Ethical code of conduct own company
9	Transparency chain network	20	Economic conditions suppliers	40	Whistle blowing own company
10	Historical evidence fraud raw materials	21	Organizational strategy suppliers	41	Contractual requirements suppliers
11	Historical evidence fraud final products	22	Ethical business culture suppliers	42	Fraud control system suppliers
		23	Criminal offences suppliers	43	Mass balance control suppliers
		24	Victimization of suppliers	44	Tracking and tracing system suppliers
		25	Corruption level country suppliers	45	Social control chain network
		26	Economic conditions branch of industry	46	Fraud control industry
		27	Criminal offences customers	47	National food policy
		28	Ethical business culture branch of industry	48	Law enforcement local chain
		29	Historical evidence branch of industry	49	Law enforcement chain network
		30	Level of competition branch of industry	50	Contingency plans
		31	Price asymmetries		

Note: Opportunities are divided into technical opportunities (in light grey) and opportunities in place and time (in dark grey). Motivations include economic drivers (in light grey) and motivations related to culture and behavior (in dark grey). Control measures are divided into technical (in light grey) and managerial (in dark grey).

References

[1] M.H. Ali, N. Suleiman, Eleven shades of food integrity: a halal supply chain perspective, Trends Food Sci. Technol. 71 (2018) 216–224, https://doi.org/10.1016/j.tifs.2017.11.016.

[2] W.S. Alrobaish, L. Jacxsens, P.A. Luning, P. Vlerick, Food integrity climate in food businesses: conceptualization, development, and validation of a self-assessment tool, Foods 10 (2021) 1302, https://doi.org/10.3390/foods10061302.

[3] W.S. Alrobaish, L. Jacxsens, P. Vlerick, Quantitative study of food integrity climate in Belgian and Saudi Arabian food businesses in view of their organizational characteristics, IFST 57 (2022) 4254–4267, https://doi.org/10.1111/ijfs.15749.

[4] W.S. Alrobaish, L. Jacxsens, P. Spagnoli, P. Vlerick, Assessment of food integrity culture in food businesses through method triangulation, Food Control 141 (2022), 109168, https://doi.org/10.1016/j.foodcont.2022.109168.

[5] W.S. Alrobaish, P. Vlerick, N. Steuperaert, L. Jacxsens, An exploratory study on the relation between companies' food integrity climate and employees' food integrity behavior in food businesses, Foods 11 (2022) 2657, https://doi.org/10.3390/foods11172657.

[6] E. De Boeck, L. Jacxsens, M. Bollaerts, P. Vlerick, Food safety climate in food processing organizations: development and validation of a self-assessment tool, Trends Food Sci. Technol. 46 (2015) 242–251, https://doi.org/10.1016/j.tifs.2015.09.006.

[7] E. De Boeck, L. Jacxsens, M. Bollaerts, M. Uyttendaele, P. Vlerick, Interplay between food safety climate, food safety management system and microbiological hygiene in farm butcheries and affiliated butcher shops, Food Control 65 (2016) 78–91, https://doi.org/10.1016/j.foodcont.2016.01.014.

[8] E. De Boeck, A.V. Mortier, L. Jacxsens, L. Dequidt, P. Vlerick, Towards an extended food safety culture model: studying the moderating role of burnout and jobstress, the mediating role of food safety knowledge and motivation in the relation between food safety climate and food safety behavior, Trends Food Sci. Technol. 62 (2017) 202–214, https://doi.org/10.1016/j.tifs.2017.01.004.

[9] E. De Boeck, L. Jacxsens, A.V. Mortier, P. Vlerick, Quantitative study of food safety climate in Belgian food processing companies in view of their organizational characteristics, Food Control 88 (2018) 15–27, https://doi.org/10.1016/j.foodcont.2017.12.037.

[10] E. De Boeck, L. Jacxsens, P. Vanoverberghe, P. Vlerick, Method triangulation to assess different aspects of food safety culture in food service operations, Food Res. Int. 116 (2019) 1103–1112, https://doi.org/10.1016/j.foodres.2018.09.053.

[11] C. Elliott, *Elliott Review into the Integrity and Assurance of Food Supply Networks*. Final Report: A National Food Crime Prevention Framework, Crown Copyright. Accessed 26/6/2022 from: https://bit.ly/2NA2CGP, 2014.

[12] J.D. Ellis, S.W. Arendt, C.H. Strohbehn, J. Meyer, P. Paez, Varying influences of motivation factors on employees' likelihood to perform safe food handling practices because of demographic differences, J. Food Prot. 73 (2010) 2065–2071, https://doi.org/10.4315/0362-028X-73.11.2065.

[13] M. Esteki, J. Regueiro, J. Simal-Gandara, Tackling fraudsters with global strategies to expose fraud in the food chain, Compr. Rev. Food Sci. Food Saf. 18 (2019) 425–440, https://doi.org/10.1111/1541-4337.12419.

[14] Eurostat, Comparative price levels for food, beverages and tobacco, Accessed 16/7/2022 from: https://bit.ly/2O6lRVe, 2022.

[15] U.Z.A.U. Fatimah, S.W. Arendt, C.H. Strohbehn, Exploring the culture of food safety: the role of organizational influencers in motivating employees' safe food-handling practices, J. Qual. Assur. Hosp. Tour. 14 (2013) 321–343, https://doi.org/10.1080/1528008X.2013.802587.

[16] U.Z.A.U. Fatimah, C.H. Strohbehn, S.W. Arendt, An empirical investigation of food safety culture in onsite foodservice operations, Food Control 46 (2014) 255–263, https://doi.org/10.1016/j.foodcont.2014.05.029.

[17] C. Griffith, Chapter 7: Food safety in catering establishments, in: Safe Handling of Foods, Marcel Dekker, Inc, New York, Basel, 2000.

[18] C.J. Griffith, K.M. Livesey, D. Clayton, The assessment of food safety culture, Br. Food J. 112 (2010) 439–456, https://doi.org/10.1108/00070701011034448.

[19] J. Hoorfar, R. Pruggerl, F. Butler, K. Jordan, Future trends in food chain integrity, in: Food Chain Integrity: A Holistic Approach to Food Traceability, Safety, Quality and Authenticity. Woodhead Publishing Series in Food Science, Technology and Nutrition, Woodhead Publishing Limited, Cambridge, UK, 2011, pp. 303–308.

[20] L. Jacxsens, K. Kirezieva, P.A. Luning, J. Ingelrham, H. Diricks, M. Uyttendaele, Measuring microbial food safety output and comparing self-checking systems of food business operators in Belgium, Food Control 49 (2015) 59–69, https://doi.org/10.1016/j.foodcont.2013.09.004.

[21] E.K. Ling, S.N. Wahab, Integrity of food supply chain: going beyond food safety and food quality, Int. J. Product. Quality Manag. 29 (2020) 216–232, https://doi.org/10.1504/IJPQM.2019.10019297.

[22] P.A. Luning, W.J. Marcelis, J. Rovira, M. Van Boekel, M. Uyttendaele, L. Jacxsens, A tool to diagnose context riskiness in view of food safety activities and microbiological safety output, Trends Food Sci. Technol. 22 (2011) S67–S79, https://doi.org/10.1016/j.tifs.2010.09.009.

[23] P.A. Luning, K. Kirezieva, G. Hagelaar, J. Rovira, M. Uyttendaele, L. Jacxsens, Performance assessment of food safety management systems in animal-based food companies in view of their context characteristics: a European study, Food Control 49 (2015) 11–22, https://doi.org/10.1016/j.foodcont.2013.09.009.

[24] L. Manning, Food fraud: policy and food chain, Curr. Opin. Food Sci. 10 (2016) 16–21, https://doi.org/10.1016/j.cofs.2016.07.001.

[25] L. Manning, Guest editorial, Br. Food J. 119 (2017) 2–6, https://doi.org/10.1108/BFJ-09-2016-0446.

[26] L. Manning, P.A. Luning, C.A. Wallace, The evolution and cultural framing of food safety management systems - where from and where next? Compr. Rev. Food Sci. Food Saf. 18 (2019) 1770–1792, https://doi.org/10.1111/1541-4337.12484.
[27] L. Manning, Moving from a compliance-based to an integrity-based organizational climate in the food supply chain, Compr. Rev. Food Sci. Food Saf. 19 (2020) 995–1017, https://doi.org/10.1111/1541-4337.12548.
[28] J. Nanyunja, L. Jacxsens, K. Kirezieva, A.N. Kaaya, M. Uyttendaele, P.A. Luning, Shift in performance of food safety management systems in supply chains: case of green bean chain in Kenya versus hot pepper chain in Uganda, J. Sci. Food Agric. 96 (2016) 3380–3392, https://doi.org/10.1002/jsfa.7518.
[29] B. Schneider, M.G. Ehrhart, W.H. Macey, Organizational climate and culture, Annu. Rev. Psychol. 64 (2013) 361–388, https://doi.org/10.1146/annurev-psych-113011-143809.
[30] M.A. Sentandreu, E. Sentandreu, Authenticity of meat products: tools against fraud, Food Res. Int. 60 (2014) 19–29, https://doi.org/10.1016/j.foodres.2014.03.030.
[31] J. Spink, D.L. Ortega, C. Chen, F. Wu, Food fraud prevention shifts the food risk focus to vulnerability, Trends Food Sci. Technol. 62 (2017) 215–220, https://doi.org/10.1016/j.tifs.2017.02.012.
[32] S.M. Van Ruth, W. Huisman, P.A. Luning, Food fraud vulnerability and its key factors, Trends Food Sci. Technol. 67 (2017) 70–75, https://doi.org/10.1016/j.tifs.2017.06.017.
[33] S.M. Van Ruth, P.A. Luning, I.C.J. Silvis, Y. Yang, W. Huisman, Differences in fraud vulnerability in various food supply chains and their tiers, Food Control 84 (2018) 375–381, https://doi.org/10.1016/j.foodcont.2017.08.020.
[34] S.M. Van Ruth, O. Nillesen, Which company characteristics make a food business at risk for food fraud? Foods 10 (2021) 842, https://doi.org/10.3390/foods10040842.
[35] E. Walker, C. Pritchard, S. Forsythe, Hazard analysis critical control point and prerequisite programme implementation in small and medium size food businesses, Food Control 14 (2003) 169–174, https://doi.org/10.1016/S0956-7135(02)00061-0.
[36] L.M. Zanin, E. Stedefeldt, P.A. Luning, The evolvement of food safety culture assessment: a mixed-methods systematic review, Trends Food Sci. Technol. 118 (2021) 125–142, https://doi.org/10.1016/j.tifs.2021.08.013.