Portfolio of interventions to mature human organizational dimensions of food safety culture in food businesses

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Abstract

Consensus among academic scholars and practitioners has grown on the principle that established food safety management systems (to control and assure food safety in food businesses) need to be complemented by human components, to develop, nurture and shape a mature food safety culture. This study explores how food safety culture, focused on human organizational elements, can be matured by dedicated interventions. A database of potential intervention strategies was set up through literature reviews. The literature-based database of interventions was enriched with practitioners' insights, through a modified Delphi study with a panel of food safety experts active in the food industry. Combining results, a portfolio is presented consisting of 68 unique and science-based food safety culture interventions. These are ranked by stakeholders based on their perceived effectiveness to improve food safety culture, reported with their most relevant barriers of success, and extra comments concerning their implementation or concept. With this approach, the topic of food safety culture improvement is elucidated through the proposition of tangible and science-based, yet practical and industry oriented, intervention strategies for maturation.

Keywords: Food Safety Culture; Intervention; Delphi Panel; Food Industry; Maturity

1. Introduction

The research field of food safety culture (FSC) has complemented established food safety management systems in food businesses with human components. Sharman et al. (2020) propose the following food safety culture definition, based on the diverse existing definitions in literature: “Food safety culture is defined as a long-term construct existing at the organisational level relating to the deeply rooted beliefs, behaviours and assumptions that are learned and shared by all employees, which impact the food safety performance of the organisation”. Different FSC conceptual models are published, e.g. the model by Nyarugwe et al. (2020) that assesses organizational conditions, technological conditions, and employee characteristics to obtain an indication of the maturity of the prevailing FSC. Spagnoli et al. (2023a), in line with Nyarugwe et al. (2020), present a food safety culture (FSC) conceptual model with three building blocks: the food safety management system (FSMS), a human organizational and a human individual building block. Each building block consists of distinct dimensions. Assessment of food safety culture reveals its maturity, ranging from low to high. After the assessment phase as distinguished in prior research (e.g. de Andrade et al., 2020; Ungku et al., 2014; Jespersen et al., 2016), maturing food safety culture can increase food safety levels (e.g. Wu et al., 2020), which is essential as many foodborne outbreaks and/or recalls in the food system still occur.

The research on food safety culture improvement is limited. Many of the available studies describe the implementation of training to improve FSC. Other studies conclude by identifying goals or offering recommendations, but they often lack clarity on how these goals can be practically achieved. Olsen et al. (2023) focus on food safety culture improvement on a more individual level, by appointing specific employees as culture change agents and subjecting them to individual therapeutic training of sensory and emotional skills. Cotter et al. (2023) reviewed food safety training programs (including media campaigns, food safety films, face-to-face lectures, hands-on activities, and group discussions) with the goal of identifying strategies that positively effect food safety behavior (with behavior being an important dimension in food safety culture (De Boeck et al., 2017)). The study by Cotter et al. (2023) also

48 demonstrates how food safety training fits into a five-stage food safety culture maturity model. Zanin et al.
49 (2022) propose topics to be included in educational actions to improve selected food safety culture
50 dimensions, while Zanin et al. (2021) demonstrate the positive effect on food safety culture maturity of
51 educational actions developed based on educational needs of food handlers and managers. Jia & Evans
52 (2021) present interventions for the food safety management system itself, more specifically the
53 improvement of food allergen management in the scope of food safety culture. da Cunha (2021) selected
54 nine insights from previous literature to improve food safety in food services, highlighting the role of a
55 proactive food safety culture. Frankish et al. (2021) conclude their review with a roadmap for improving
56 food safety culture, suggesting six goals for the horticulture industry (e.g. "harness the power of the whole
57 business"). In this work by Frankish et al. (2021), references are mostly from the food safety (culture)
58 research field, with challenges and opportunities being highlighted but the presentation of actual
59 interventions to achieve the goals remaining limited. Caccamo et al. (2018) and Nouaimeh et al. (2018)
60 respectively describe a case of a five-star hotel and a catering company, in both of which FSC was measured
61 and actions were implemented for improvement. Caccamo et al. (2018) focused on improving both the food
62 safety management system through HACCP, and improving rewards and incentives by make three main
63 changes: renaming and reinventing the incentive scheme, increasing its visibility and transparency, and
64 lastly increasing its focus on safety. Nouaimeh et al. (2018) focused on improving reward, training and
65 communication, consistency and innovation & change. Examples of actions taken by Nouaimeh et al.
66 (2018) to improve these dimensions are: adjusting training to different language requirements of employees,
67 using visual training methodologies, implementation of a daily scoring chart, and implementation of a
68 monitoring system with immediate recognition. Jespersen & Huffman (2014) describe actions taken by
69 Maple Leaf Foods to integrate food safety into the company culture (for example the formation of a
70 leadership and advisory council, and redevelopment of the education program). Sarter & Sarter (2012)
71 propose focus points for interventions (e.g. better knowledge of risks) in small restaurants in Madagascar
72 to promote FSC. Powell et al., (2011) generally discuss possible recommendations to improve food safety
73 culture (e.g. "know the risks associated with the foods they handle and how those should be managed").

74 The goal of this paper is to significantly reduce the existing misalignment between the increasingly more
75 stringent food safety culture demands (from both legislation and private certification schemes), and the
76 presently existing lack of integrated knowledge on how a mature food safety culture can be achieved. This
77 objective is reached by bringing new knowledge to the FSC field in the form of an elaborate portfolio of
78 interventions integrating available knowledge from various relevant research fields and topics. The
79 portfolio contains interventions aiming to mature the dimensions of the human organizational building
80 block from the FSC conceptual model of Spagnoli et al. (2023a) (dimensions included are: 'leadership',
81 'communication', 'risk awareness', 'resources', 'commitment', 'consistency', 'adaptability', 'beliefs and
82 values', and 'mission, vision, strategy'). The human-individual building block of this conceptual model was
83 not selected as the focus. Because a large quantitative study demonstrated that the human-individual
84 dimensions are significantly more mature compared to those dimensions on the human-organizational level
85 (Spagnoli et al, 2023b, Belgian context). The human-organizational building block therefore displayed
86 much more improvement opportunity and urgency. The third (and last) FSC building block in the applied
87 conceptual framework, the food safety management system (FSMS), is already extensively researched in
88 this context (e.g. Manning et al., 2006; Gilling et al., 2001), with the year 2000 as the peak year of HACCP
89 (hazard analysis of critical control points) publications related to food safety (based on Thomson Reuters
90 Web of Science (2023) analysis of publications per year). Food safety expert practitioner's insights
91 concerning interventions' potential and implementation are provided. The proposed intervention portfolio
92 offers a set of evidence- yet practice-based interventions to mature the prevailing FSC in a food business,
93 which might inspire both researchers and practitioners. Future research can apply interventions using the
94 portfolio developed, to empirically test and validate their capacity to mature FSC of food businesses.

2. Material and methods

The portfolio is established by identifying interventions (via scoping reviews) and potential barriers of success from literature. Due to the limited research available in the niche of FSC improvement, interventions were searched in other research fields (for example safety culture in other sectors) with the most experience in implementing interventions for improvement of the included dimensions. To make the translation to the specific context of FSC in the food industry, the identified interventions from literature were presented to stakeholders (food safety practitioners, mainly quality managers in food processing firms). In the stakeholder consultation, executed through a modified Delphi study, the interventions were ranked based on their perceived effectiveness to improve the FSC dimension, and were linked to identified barriers. Furthermore, panelists formulated additional information for implementation.

2.1. Literature review methods to identify studies describing interventions

Scientific literature was collected to find intervention strategies for improvement of the dimensions of the human-organizational building block (dimensions 'leadership', 'communication', 'risk awareness', 'resources', 'commitment', 'consistency', 'adaptability', 'beliefs and values', and 'mission, vision, strategy'). As the goal of this paper was to obtain an overview of a broad arrow of literature, rather than answer answering specific research questions or testing research hypotheses, scoping reviews were selected as the appropriate review method. Two consecutive scoping reviews were done (Figure 1) as per the guidelines of Peters et al. (2015) with review methods established prior to the conduct of the review. Methods applied for these scoping reviews are inline with the PRISMA guidelines for scoping reviews (Tricco et al., 2018). Snowballing using the reference lists of the already included papers was also done. Thomson Reuters Web of Science was used as it the most widely accepted and frequently used database for analysis of scientific publications (van Nunen et al., 2018; Yang et al., 2013).

The first scoping review was executed within the broader safety culture research field focusing on how safety culture improvement is established in organizations (in general, so not dimension specific). Food

safety culture is technically very closely related to safety culture and within the context of a food company both concepts have some overlap (Nyarugwe et al., 2016). Furthermore, previous FSC studies have recommended to learn from the safety culture field in other industries, e.g. healthcare (Nayak & Waterson, 2017). Two reviewers searched Thomson Reuters Web of Science (final search December 2021; validated in 2024) using a predefined search strategy as follows. The search term 'safety culture interventions' was given as input to search all fields of publications, which gave 3064 results. Inclusion criteria were applied as depicted in Figure 1. A selection was made of Web of Science subject categories to further refine results. These subject categories were selected based on Van Nunen et al. (2018) who identified the most relevant categories for safety culture publications, the topic of the present study (food safety culture in the food industry), and because certain categories were the overarching subject categories of many other subcategories. The subject categories included were therefore 'Health care sciences services', 'health policy services', 'Public environmental Occupational Health', 'Nursing', 'Food science technology', 'Industrial engineering' and 'Nuclear science technology'. Selection of these subject categories resulted in 733 retained articles, which were subjected to a title and abstract reading. In this step, it was specifically checked whether the articles contained a described safety culture intervention that could potentially be relevant to food safety culture, as many articles were on the topic of assessment with the conclusion that interventions are needed to improve without elaborating on the interventions itself. Exclusion based on title and abstract reading lead to the retention of fifty-six articles. The next phase entailed a full reading of these fifty-six articles by the two reviewers, resulting in a final 23 retained studies. Two researchers (first author and co-author of this paper) performed exactly the same review process. Intermediate checks on article retention were done, after applying the exclusion criteria, after the title and abstract reading phase and after the full reading phase. Discussions on differing results in article retention were held, until consensus was reached on which articles to include.

As the first review was executed on a more general level (searching for ‘safety culture interventions’), a second review was executed to include relevant research existing on a more specific dimension level (e.g. how to improve leadership). The bibliographic database Thomson Reuters Web of Science (2023) was consulted. In line with the conceptual framework of Spagnoli et al (2023a), each one of the nine food safety culture dimensions in the human-organizational building block was used, one by one, as a term. The dimensions “beliefs and values” and “mission, vision, strategy” were split up into “beliefs”, “values”, “mission and vision”, and “strategy” to facilitate the search. Per dimension, the improvement strategies were searched in publications’ titles using the following search terms: “dimension” and “intervention” (so for example “leadership” and “intervention”, searched in publication titles). If this gave no relevant results, the search term was broadened to "dimension” and "intervention" and “safety”, searched in the topic. Only articles in English were retained. Two researchers (first author and co-author of this paper) performed the review process together. The first reviewer took the dimensions leadership, commitment, resources, and consistency for their account, while the second reviewer did the literature search for the dimensions communication, risk awareness, adaptability, beliefs and values, and mission, vision, strategy.

Lastly, additional articles were found through consulting the reference lists of the already included papers, via Web of Science or Google Scholar, which is called ‘snowballing’ (as was described by Manning et al., 2023). The use of Google Scholar for snowballing is accepted, as previous research has concluded that Google Scholar is valuable for finding specific, known studies (in this case as identified from the reference lists of other included articles) (Haddaway et al., 2015). All articles had to be written in English with full text available. Systematic reviews and articles already included in the first review were excluded.

2.2. Identification and categorization of interventions

Interventions were extracted from the 95 included articles, resulting in a list of 68 unique interventions (Figure 1). The original success or failure of these interventions, as described in the respective articles in their original context, was not considered. Many interventions originated from different contexts and industries, not specifically addressing food safety culture or the food industry. Moreover, not all included studies also implemented an intervention in practice and/or executed a post-assessment for success evaluation. The discussion on the usefulness of the interventions and their potential success is done is the next phase via stakeholder consultation (section 2.4). During these discussions, experts evaluated each intervention's likelihood of enhancing food safety culture, recognizing that many interventions originated from different contexts and industries.

To classify the interventions, each of them was assigned to a dimension of the human-organizational building block (nine dimensions). This categorization was based on the dimensions' definitions and indicators (De Boeck et al., 2015; Spagnoli et al., 2023a), as follows. The first dimension is food safety leadership. Griffith et al. (2010) clarifies that food safety leadership is "a measure of the extent the business's leader(s) is able to engage staff in hygiene/safety performance and compliance to meet the business's goals/vision/standards". Interventions relating most to this definition of leadership were therefore assigned to this dimension. The next dimension, communication is "a measure of the quality of the transfer of food safety messages and knowledge between management, supervisory staff, and food handlers" (Griffith et al., 2010). The third dimension, commitment, is "the extent of engagement and involvement concerning hygiene and food safety of all parties within the organization" (De Boeck et al., 2015). The dimensions resources and risk awareness are respectively defined as "the extent to which physical and non-physical means, necessary to operate in a hygienic and food safe way, are present in the organization (e.g. time, personnel, infrastructure, education/training and procedures)" and "the extent to which the organization is aware of the risks concerning hygiene and food safety and has these under control" (De Boeck et al., 2015). Adaptability refers to "the ability of an organization to adjust to changing influences

and conditions and respond within its current state or move to a new one" (Global Food Safety Initiative, 2018), while consistency in this context is "the proper alignment of food safety priorities with requirements on people, technology, resources and processes to ensure the consistent and effective application of a food safety programme that reinforces a culture of food safety" (Global Food Safety Initiative, 2018). The next dimension is 'beliefs and values'. Normative beliefs "can be expressed by subjective norms, i.e. the individual's perception that most people important to them think they should (or not) perform a behavior" (de Andrade et al., 2021). In this research, normative beliefs are included on the organizational level, not on the individual level, with the most mature or proactive level of this indicator being: "leaders and colleagues believe it is always a priority to operate in the safest possible way, even when there are consequences in other areas such as speed or efficiency" (Spagnoli et al, 2023a). Values "reflect the extent to which safety and quality are seen as core company principles, and how they are directly and indirectly demonstrated in practice"(Taylor & Budworth, 2018). The last dimension is 'mission, vision, strategy". The vision and mission "communicate a business's reason for existence and how it translates this into expectations and specific messaging for its stakeholders" (Global Food Safety Initiative, 2018). Strategy "reflects the plans in place to achieve the company vision, and the extent to which they are communicated and agreed with across the company" (Taylor & Budworth, 2018).

Interventions identified in the second review, discussing a specific dimension in the originial text, were not necessarily categorized to this originial dimension, but were catagorized based on the definitions and indicators of the dimensions of interest as exmplained above. Futhermore, if an intervention was identified that was similar to an already included intervention, multiple references were combined. For example, multiple papers proposed the organization of discussing case studies to increase risk awareness among employees, and were therefore grouped as a single FSC intervention, representing possible approaches. Also, some studies provided multiple interventions, which were attributed to different dimensions. Both the extraction and categorization into these dimensions of the interventions was executed independently by two researchers. Different attributions were resolved through discussion and in all cases consensus was realized.

2.3. Identification of barriers and their classification into themes

Barrier analysis is essential, as a better understanding of barriers will enhance the implementation of the intervention strategies (Emond et al., 2015). Barriers were identified in literature, more specifically the work by Aguirre Velasco et al. (2020), Hearld et al. (2022), Johnson et al. (2011), Lazem & Sheikhtaheri (2022), Lundmark et al. (2020), O'Connell et al. (2022), Saadati et al. (2019), and Young & Waddell (2016) and classified into themes: barriers related to employee characteristics (seven barriers, e.g. low level of education/knowledge amongst employees), management characteristics (seven barriers, e.g. limited management support), assets and tools (six barriers, e.g. lack of financial support) and organizational characteristics (four barriers, e.g. lack of collaboration in the organization) (in line with van Sluisveld et al. (2013). Selection and classification were done by two independent researchers, and consensus was reached in all cases. An overview of the specific barriers per theme is presented in Table 1.

2.4. Stakeholder consultation via a modified Delphi study

2.4.1. Structure of the modified Delphi study

In this study, the Delphi method was applied to gain insights from practitioners who are experts on the matter and the main stakeholders (food safety managers, active in the food industry) concerning interventions' potential in the context of food safety culture and implementation in the food industry. In general, a Delphi study includes at least two rounds of questions. The first round is seen as an exploratory phase in which open questions are often used (Ziglio, 1995). Each subsequent round is an evaluation phase, in which new questions are drawn up based on the results of the previous round (Fletcher & Marchildon, 2014). After each round, the obtained data are presented to all experts in a straightforward way, e.g. graphs, percentages, or frequency distributions (Nasa et al., 2021). This gives the experts the opportunity to revise their answers based on the answers given by the group (Fletcher & Marchildon, 2014). Delphi studies can be used to strive for a (near) consensus between panelists, which is obtained when a specific value (mostly ranging from 50%-97%) of agreement is achieved (Nasa et al., 2021). No specific value was chosen as an

objective for the level of consensus, as the objective of this study was to rank (high to low) the interventions based on this level of consensus.

The applied 'modified' Delphi methodology (the last paragraph of this section discusses why this is a modified Delphi study) was structured to consist of a first round, an intermediate group discussion, and a second round (Figure 2). For each dimension of the FSC organizational building block, the interventions obtained from literature (section 2.1) were presented to the panelists with the full description of the intervention (Appendix A). With this list of interventions for one specific dimension, the Delphi methodology was started each time consisting of the two rounds and intermediate group discussion per dimension. As there are nine food safety culture dimensions for which interventions were collected, nine times two rounds were organized.

The first round was started by introducing the dimension for which the interventions will be discussed. Next, each panelist was asked to respond 'agree' or 'disagree' per intervention to the statement: "this intervention is likely to achieve an improvement of the dimension" (inspired by Revez et al. (2020); Toumbourou et al. (2020)), taking account the food industry as a whole and not only their own organization or their own organization's prevailing food safety culture maturity. In the first round, panelists were also asked to evaluate the relevance of themes of barriers for the dimension at hand as input for the barrier analysis (so not per intervention but for the dimension in general) (based on Toumbourou, 2020). Panelist could answer with 'this theme of barriers is relevant for this dimension', or 'this theme of barriers is not relevant for this dimension' (questions 1a and 1b in Figure 2).

In between rounds, panelists were asked to join a group discussion with all panel members, on all interventions of the dimension. To facilitate discussion amongst panel members, the discussion leader (first author of this article) visually displayed the overall frequency of agreement/disagreement per intervention. The panelists were asked to reveal orally and voluntarily why they agreed or disagreed. Comments about the interventions that came up during these discussions were captured.

In the second round, panel members were asked to reevaluate, based on the intermediate discussion and other panelists' opinions. They were asked to individually make a shortlist for the dimension of three interventions out of the represented list, that they perceive as most effective or most likely to improve the targeted FSC dimension (based on Toumbourou, 2020). Panelists were also asked to list barriers for success (if they thought there were any) for each intervention in their shortlist (questions 2a and 2b in Figure 2). Based on inclusion in these shortlists, or the level of consensus between panelists, a ranking of interventions was made of per dimension. When all panelists have included an intervention in their shortlist, 100% consensus is achieved about the fact that this intervention is amongst the (three) most effective to improve FSC. Next to the level of agreement concerning the inclusion in the shortlist, the frequency of occurrence of barriers was also captured per intervention.

Some modifications were made from the traditional Delphi approach, making the applied methodology a modified Delphi study. "Modified Delphi indicates the process whereby the initial alternatives in response to the researcher's questions are carefully selected before being provided to the panel" (Avella, 2016, 311). In other words, in the first round of the described study, the panel was provided with a structured set of preselected items, rather than open questions (Joyner & Smith, 2015). This was done because the goal was to establish a portfolio of science-based interventions derived from various related research fields, rather than to collect own experiences from the panel. Another modification made from the traditional Delphi approach was that panelists were able to openly share their answers from the first round in the intermediate group discussion (before the second round was started). To allow participants to express themselves freely traditional Delphi studies are mostly done anonymously (Hirschhorn, 2019). However, some researchers argue that openly sharing opinions facilitates discussion and therefore consensus, as interpretation of items can become an issue in anonymous Delphi rounds (Nasa et al., 2021).

2.4.2. Practical organization of the modified Delphi study and panel members

As the goal of the Delphi study was to estimate practical potential for FSC improvement of interventions from a variety of literature and to provide insights on barriers and general implementation, included experts were practitioners from the food industry. In line with recommendations of Olsen et al. (2021), participants of the Delphi study were meticulously selected based on their expertise and experience. Each participant was required to have completed a master's degree with a focus on food safety. Additionally, they needed to be actively engaged in a leadership role where their primary responsibility was food safety management, with a minimum of five years of experience in this capacity. At least one year of this experience had to involve direct, hands-on production experience. Participants were also required to be familiar with current food safety regulation and the common food safety certification schemes, and have practical experience in implementing these. Finally, to ensure a deep understanding of the subject, each participant must have been involved in a food safety culture assessment within their own or another food processing organization. Assessment of these criteria was done via self-reported information provided by the participants, which was verified as much as possible by the authors.

All participants were food safety, quality, or production managers. Additionally, there was a representative of the association of the Belgian food industry ("Fevia"), a representative of a food business innovation platform ("Flanders' Food"), the director of a consultancy organization, and the manager of a company producing cleaning solutions specifically for the food industry. Study participation was voluntary and unpaid.

As 68 unique interventions needed to be discussed, three separate sessions, on three different days, were organized in person to prevent cognitive overload among panelists (Figure 2). In the first session the interventions of the dimensions 'leadership,' 'communication' and 'resources' were evaluated. In the second session, the interventions of the dimensions 'commitment,' 'risk awareness' and 'adaptability' were evaluated. During the last session the interventions of the dimensions 'consistency,' 'beliefs and values' and 'mission, vision, strategy' were discussed. Each time the same group of potential panelists were invited,

however, as these were all active practitioners in the food industry, not all panelists were available for each session. Respectively seventeen, thirteen and seventeen practitioners were present during the sessions (average of 15.7 members). Panelists received the lists of interventions (Appendix A, translated to Dutch) by email, each time about a week in advance, allowing the panelist to prepare and make sure they understand all interventions as some descriptions are quite lengthy or complex. All data were gathered and stored anonymously (participants could openly share their insights with the panel and discuss in between rounds, but notes were taken without mentioning who made each comment).

2.4.3. Data collection and analysis of the modified Delphi study

The interactive platform "Wooclap" was used for data collection (Wooclap, 2023). In the first round of the modified Delphi study two types of output per dimension (Questions 1a and 1b in Figure 2) were generated. One output being a frequency distribution of 'agree' and 'disagree' per intervention (panelists were asked to respond agree or disagree per intervention to the statement: "this intervention is likely to achieve an improvement of the dimension"). The second output of the first round is the frequency distribution of 'relevant' or 'not relevant' for each of the four presented themes of barriers per dimension (e.g. "is the barrier theme 'management' relevant for interventions of this dimension?").

In the group discussion between the two rounds of the modified Delphi study, panelists provided comments. These comments were captured in the form of notes made by researchers during the sessions. Through inductive coding of this collective qualitative data using the software NVivo (NVIVO, 2023), the comments were categorized in four groups: comments regarding intervention implementation, comments regarding intervention concept, comments expressing perceptions on why the intervention does not have potential to improve FSC, and comments describing the panelists' own experiences concerning the implementation of the intervention in their own work environments.

In the second round, each panelist was asked to make a shortlist of the three interventions they believe are the most effective (or are most likely to improve the specific dimension), and to provide barriers potentially

hindering each one of these three strategies (Questions 2a and 2b in Figure 2). For each intervention, a percentage of inclusion in panelists shortlists was calculated, or the level of consensus in the panel on if the intervention is one of the three interventions most likely to improve the dimension (as is common practice in Delphi studies). based on this inclusion in panelists' shortlist, interventions were ranked per dimension (irrespective of the order within the shortlist). Concerning the barriers, results from round two were also calculated in percentages. Per intervention, it was calculated what percentage of panelists, which included this intervention in their shortlist, mentioned a specific barrier. Invalid responses were excluded from further analysis.

3. Results and discussion

3.1. Identification and classification of interventions from included articles

In total, 68 unique interventions were included in the database, extracted from 95 studies. Identified interventions, categorized per dimension, including their references and full descriptions are presented in Appendix A. From the 95 included studies, healthcare was the most frequently studied professional subject category, with 42% of included studies coming from this field. Examples of other consulted subject categories, apart from the food (service) industry (18% of included studies), are road safety (7% of included studies) and education (6% of included studies) (Figure 1). In the first literature review, subject categories were selected to refine results, as indicated in section 2.1. Only seventeen out of 95 articles (18%) had their origin in the food (service) sector (Abushelaibi et al., 2015; Caccamo et al., 2018; Chapman et al., 2010; Cotter et al., 2023; Evans & Redmond, 2019; Ledo et al., 2021; Manning et al., 2021; Massa & Testa, 2009; Moy, 2018; Nouaimeh et al., 2018; Nyarugwe et al., 2020; Powell et al., 2011; Ramdeen et al., 2007; Wiśniewska, 2022; Wu, Hammons, Silver, et al., 2020; Wu, Hammons, Wang, et al., 2020; Yiannas, 2015), which contributed 21 of the 68 interventions.

Although the aim was to assign each of the 68 interventions to a single dimension, four of the 68 unique interventions were assigned to two different dimensions, based on the description given by authors of the intervention source and the dimensions validated indicators and definitions. One of these four interventions is implementing “news food safety info sheets”, chosen here as an example concerning it’s categorization. This intervention is categorized to both the dimensions ‘communication’ and ‘risk awareness’. The description for this intervention is (Appendix A): “Food safety info sheets are standalone communication tools directed at food handlers, designed to be specific to food handler information needs and generate dialogue among food handlers. […] food safety info sheets contained a media story about an outbreak of foodborne illness, graphics, and prescriptive information. The text of food safety info sheets focused on consequences and food handler behaviors. Stories were supplemented with surprising or humorous graphics. Food safety info sheets also contained a section usually entitled ‘‘What You Can Do’’ to connect

364 the outbreak story with behaviors that food handlers could employ during their tasks." (Chapman et al.,
365 2010). This intervention was classified to the dimension 'communication' as it would improve (the
366 regularity of) leaders' communication with the employees about hygiene and food safety, as well as (the
367 regularity of) the visual communication on the importance of food safety. Furthermore, the study describes
368 the intervention as a communication tool designed to generate dialogue among food handlers. For the
369 dimension 'risk awareness', this intervention was relevant as the food safety info sheets contained a media
370 story about a foodborne illness outbreak and its connection with food handler behaviors. Implementing this
371 would have a direct effect on the awareness of risks in the company and employees' alertness for these
372 risks. The other three interventions classified to two dimensions are "Implementation of huddles"
373 ('communication' and 'leadership'), "Include workers in the writing and modifying of procedures, safety
374 policies and practices" ('commitment' and 'consistency'), and "Collect and analyse food safety data"
375 ('commitment' and 'adaptability').

376 As four of the 68 unique interventions are included twice, the total sum of interventions spread accros the
377 nine dimensions is 72. The mean number of interventions per dimension is eight, with the minimum number
378 of interventions (four) in the dimension 'adaptability' and the maximum number of interventions (twelve)
379 in the dimensions 'consistency' and 'communication'. The high number of interventions for the dimension
380 'communication' can be explained by the inclusion of the implementation of several communication
381 techniques as interventions, i.e. DESC script (Hornby & Greaves, 2022), 3-way communication (Schwatka
382 et al., 2019), SMARTT Step back (Roberts et al., 2014) and SBAR communication (Matzke et al., 2021;
383 Randmaa et al., 2014). For the dimension 'consistency', the high number of interventions can be attributed
384 to the inclusion on interventions related to rewards and recognition in line with the definition of the
385 dimension and previous research (six of the twelve included interventions are on this topic). Rewarding
386 employees is an extensively researched topic studied by psychologists, neuroscientists, and others, often in
387 relation to behavioral outcomes and reflects the importance of positive reinforcement of good behavioral
388 conduct (e.g. safety compliance and safety participation) (Hidi, 2016). "Companies invest enormous

financial resources in reward systems and practices to attract, retain, and motivate employees and thereby ensure and improve individual, team, and organizational effectiveness. Organizational rewards comprise financial and nonfinancial rewards, such as appreciation, job security, and promotion" (Antoni et al., 2017). The lower number of interventions for the dimensions 'adaptability' could therefore possibly be explained by the less delineated nature of the topic's research fields. As interventions often relate to multiple, sometimes all indicators of a particular dimension, classification of the interventions on indicator level was not feasible.

3.2. The modified Delphi study

3.2.1. Round 1 of the modified Delphi study to explore the topic and collect panelists first insights

The first round of a Delphi study has the objective of exploring the topic and collecting panelists first insights. This first data collection is then used as input for discussion, mutual comparison of opinions and reevaluation of opinions in round 2. Results of round 1, question 1.a (Figure 2) are displayed in Figures 3 to 5. Overall, there are nine interventions that all panel members evaluated positively (100% consensus) in the first round, namely: visualize training (Emond et al., 2015; Ledo et al., 2021) (based on research from the food (service) industry), implementation of huddles (Ballangrud et al., 2021; Caspar et al., 2017; Khan et al., 2018; Lyren et al., 2013; Matzke et al., 2021), create supportive working conditions (Wong et al., 2021), compentecy/knowledge mapping (Balaid et al., 2012; Manning et al., 2021; Propp et al., 2003) (based on research from the food (service) industry), declare and communicate goals (Pronovost et al., 2017), include "the why" in training (Hill et al., 2020; Rohlman et al., 2020), create shared accountability mechanisms towards goals (Pronovost et al., 2017), have management develop/redevelop the company's mission, vision, and strategy (Almost et al., 2019; Álvarez-Maldonado et al., 2019; Nyarugwe et al., 2020) (based on research from the food (service) industry) and internal dissemination thereof (Kohles et al., 2012; Nouaimeh et al., 2018; Walker, 2012) (based on research from the food (service) industry). These nine interventions are scattered amonst sessions and the different dimensions of the human organisational

414 building block. In the portfolio, 21 of the 68 identified interventions are (partly) derived from prior research
415 in the food (service) industry, while this is the case for four out of nine (indicated between brackets above)
416 of these highest scoring interventions in the first round of the delphi study. This indicates that there is also
417 no clear relationship with whether or not the intervention has a reference from the food (service) sector and
418 high levels of consensus amongst panelists.

419 There are also four interventions that were evaluated positively by less than 20% of panel members (very
420 low perecived potential). These low scoring interventions are: distribution of green and red cards (Caccamo
421 et al., 2018; Nouaimeh et al., 2018), individual reward systems centered around public exposure (Caccamo
422 et al., 2018; Kopelman et al., 2011; Schoonbeek & Henderson, 2011), strategy development through
423 employee storytelling (Kryger, 2017), and wear the insitution's T-shirt conference (Álvarez-Maldonado et
424 al., 2019) (Figure 5). These lowest scoring interventions are all part of the third session of the modified
425 Delphi study, which could indicate that panelists become more critical after having been introduced to more
426 interventions. Brookes et al. (2018) conclude that question order could influence Delphi panel results.
427 Another explanation for the low scores of these specific interventions could be the dimensions itself. The
428 first two low scoring interventions are categorized to the dimension 'consistency', while the other two low
429 scoring interventions are part of the intervention list of the dimension 'mission, vision, strategy'. Maybe
430 panelists find these dimensions generally more difficult to improve and thus less malleable. This is
431 confirmed by Spagnoli et al. (2023b), where 'consistency' and 'mission, vision, strategy' were assessed
432 (amongts the other dimensions of the human-organizational building block of the FSC conceptual
433 framework) in twenty food processing companies. These dimensions were underdeveloped (i.e. a gap) in
434 respectively nineteen and seventeen of these companies (which are the highest frequencies of all dimensions
435 studied), indicating companies struggle with these dimensions. There is also no clear pattern concerning
436 whether or not these low scoring interventions are (partly) based on a reference from the food (service)
437 sector, which is the case for two out of four of these interventions (distribution of green and red cards and
438 individual reward systems centered around public exposure).

In question 1.b. (Figure 2), panelists evaluated the relevance of themes of barriers for each dimension (not per intervention, but for the dimension in general). Results of this barrier analysis in round 1 are presented in Table 2. When the overall mean is calculated for each theme, across all dimensions, the theme 'assets and tools' has the lowest percentage (79.8% of panelists deemed this theme as relevant), and the theme 'management characteristics' has the highest overall relevance (92.8%). It can be concluded that the panelists deemed all themes of barriers as potentially hindering for the succes of food safety culture interventions (as 79.8% is the lowest mean from the four themes), however the impact of assests and tools (e.g. lack of financial support, lack of equipment, lack of time) is estimated as less crucial compared to the theme 'management characteristics' (e.g. limited management support or guidance), which was deemed as most relevant. This is in line with recent studies, which have concluded that senior management commitment is an important challenge for FSC in the context of food processing organizations (Nayak & Waterson, 2017). Additionally, FSC interventions do not perse have to use a lot of time or financial resources. Small actions, e.g. nudges (i.e. small and easily implemented actions) can achieve improvement (Jespersen et al., 2023), confirming the relatively less crucial effect of the barrier theme assets and tools.

3.2.2. Intermediate group discussion between rounds of the Delphi study

In between rounds, panelists were shown results from round one and were invited to discuss their insights and reasons for their first voting (agree or disagree). Comments were captured per intervention through note taking by researchers during the sessions, and are displayed alongside the intervention they specifically addressed in Table 3 (for the top three interventions). Appendix B displays all comments captured in the group discussions for all interventions, classified in the identified themes, regardless of the specific intervention they were addressing. Four themes came up through inductive coding, hereafter recited with an example; own experiences: "in our company, huddles are done by a person from the quality department and the operators", suggestions for implementation in general: "this should be part of validating processes.", suggestions for improvement of the intervention's concept: "maybe it could be an option to, instead of signing a document, all write our names together on e.g. a visual board or a poster", and reasons for why

464 the intervention is not likely to improve the dimension: “in our company this would not be possible,
465 operators would not be able or would not want to write procedures”. Most comments fell into the second
466 category, being suggestions for implementation (Appendix B). The category with the second most
467 comments is suggestions concerning the concept of the intervention. In the dimension ‘communication’
468 there is one recurrent comment in this category, regarding the communication techniques (SBAR, 3-way
469 communication, SMARTT step back, DESC script.): “all leaders should know all useful communication
470 techniques and when to apply them. These could be grouped and taught to leaders as a communication
471 techniques intervention.” Panelists suggested bundling these techniques into one communication technique
472 intervention, rather than separating them and implementing them as different interventions.

473 It can be concluded that the intermediate discussion was a mix of more conceptual arguments and more
474 practical, implementation arguments, which was expected as most panelists are active industry
475 practitioners. These comments should be considered when implementing an intervention, as these contain
476 valuable insights from stakeholders and practitioners and are therefore also included in our presented
477 portfolio.

478 **3.2.3. Round 2 of the modified Delphi study as the final step in the portfolio development**

479 Table 3 displays the portfolio of food safety culture interventions including ranking, barriers, and
480 comments, presenting the three interventions that were most included in panelists shortlists in the second
481 round of the modified Delphi study. These are the three interventions per dimension for which the highest
482 level of consensus was reached in terms of panelists agreeing the intervention is amongst the three most
483 effective. Percentages of inclusion by panelists in shortlists for all dimensions are presented in Figures 3-5.
484 As the number of unique interventions included is 68 and four interventions are included twice, the total
485 number of interventions in Figures 3-5 is 72. Remarkably, for the dimensions ‘leadership’, ‘risk awareness’,
486 ‘adaptability’ and ‘mission, vision, strategy’, 100% consensus is reached regarding the inclusion of an
487 intervention in participants’ shortlists. Respectively, these interventions are: “enable team members to

facilitate sessions on team goal setting," "include the why in training," "collect and analyze food safety data," and "have management develop/redevelop the company's mission, vision, and strategy which includes food safety." For the other five dimensions 100% inclusion is not reached for any intervention, but high percentages were still obtained: 82.4% for the dimension communication (intervention: "visualize training"), 70.6% for the dimension resources (intervention: "create supportive working conditions to enable staff and provide a quality care environment"), 75.0% for the dimension commitment (two interventions have the highest inclusion percentage: "collect and analyse food safety data" and "declare and communicate goals"), 64.7% for the dimension consistency (intervention: "create shared accountability mechanisms towards goals") and 76.5% for the dimension beliefs and values (intervention: "policy statement").

Panelists were also asked to provide potential barriers for success for each intervention included in their shortlist (Table 3, sorted in the four themes of barriers). For these barriers, e.g. 'time,' a percentage of e.g. 75% means that 75% of the panelists that included this intervention in their shortlist are convinced that 'time' is a barrier for this intervention. During intervention implementation, it is essential to take these barriers into account, as ignoring these could hinder the success of the intervention (Emond, 2015).

3.2.4. Comparison between round one and round two

During the course of a Delphi study participants do not only form initial opinions in a first round, but are also invited to reconsider and reevaluate these initial opinions in a second round. Studying shifts between rounds could therefore be interesting. In general, interventions with higher percentages of 'agree' in the first round (i.e. many panelists are convinced that a particular intervention is likely to improve the FSC dimension), are expected to have a higher inclusion in panel members' shortlists in round two. However, exceptions to this hypothesis can be noticed (Figures 3-5), with examples described below. Fish et al. (2020) concluded that time to reflect and vicarious thinking (or trying to understand the importance of an outcome

511 from someone else's perspective) are important reasons for changes in perceptions between rounds of
512 Delphi studies.

513 The intervention "written commitments after training" was judged as likely to improve the dimension
514 commitment by 53.9% of panelists in round one. However, none of the experts included this intervention
515 in their shortlist. This might be due to some clearly voiced negative arguments in the group discussion:
516 several experts indicated that employees might not feel comfortable signing documents because they are
517 afraid of the consequences. Maybe employees' willingness to sign documents is in itself a measure of FSC
518 maturity, with the hypothesis that employees working in companies with a more mature FSC display higher
519 levels of willingness as less fear would exist concerning the consequences (following the experts'
520 comments). In contrast, Stefanidis et al. (2015) concluded that lower levels of general trust in organizations
521 are associated with a higher willingness to sign formal contracts, as a signed document officializes
522 agreements providing more security on the delivery of promises. For the intervention at hand the promise
523 would however be one-sided, as it is only the receivers of training signing to commit to the learnings.

524 Comparable trends are visible for the dimension communication. The strategies of "internal
525 whistleblowing", "newsletters" and "SBAR communication" all had 0% inclusion in shortlists, while
526 respectively obtaining 64.7%, 47.1% and 52.9% of agreement in round one. Concerning the whistleblowing
527 intervention, the reason for the shift could be a comment raised during the group discussion that in a
528 company with a mature food safety culture, there should be no need for such a system as the culture should
529 enable all employees to be able to speak freely. Wiśniewska (2022), however, state that whistleblowing can
530 create a culture of voice. For the SBAR communication technique, the reason for the low inclusion in the
531 shortlists in round two could simply be the fact that the panel urged the combination of these kind of
532 techniques (as discussed in section 3.2.2.), making the inclusion of only one of these in their shortlist
533 unlikely. Indeed, the same trend is apparent for other communication techniques included. The shift for the
534 intervention of newsletters cannot be explained based on the group discussion, as only suggestions for
535 implementation were given. Of course panelists are also forced to make a choice in the second round,

especially for dimensions with many interventions (the dimension communication has twelve interventions, which is the highest number).

Another example is the intervention of "implementing a penalty system" to mature the level of consistency of an organization. Fifty percent of panelists agreed with this intervention in the first round, but there is zero percent inclusion in the shortlists. Several negative comments were given about this intervention in the group discussion. Bolger et al. (2011) conclude that the strongest influence on panelists' opinion change in Delphi studies is the majority opinion. So, when multiple panelists clearly voice a negative opinion in the group discussion and no positive counterarguments are given, this can shift the panel's perceptions.
A last example is the intervention of the "food safety person in charge" (dimension resources). Many panelists (70.6%) agreed with this intervention in round one. However, only one panel member included the intervention in the shortlist. The following comment was made in the group discussion: "there should not be "food safety islands" in your company. Everyone should acknowledge food safety as their own responsibility," meaning that in a company with a mature FSC food safety should be a shared responsibility and should not be assigned to a food safety person. de Andrade et al. (2021) state that sharing food safety responsibilities among all employees is a strategy for a strong food safety climate.

Concerning the barriers, in question 1.b. (Figure 2), panelists evaluated the relevance of themes of barriers for each dimension (not per intervention, but for the dimension in general). In round 2 (question 2.b.) panelists were asked to list relevant barriers for their top three interventions, or the interventions with the most perceived potential for FSC improvement. In round 1, the theme "assets and tools" had the lowest overall percentage concerning its perceived relevance (79.8% of panelists deemed this theme as relevant, on average, Table 2). However, in round two, barriers from the theme "assets and tools", e.g. "lack of time", systematically are (amongst) the most frequently mentioned barriers (Table 3, displaying the three interventions most frequently included in panelists' shortlists of interventions most likely to improve the specific dimension). Additionally, the barrier theme of "management characteristics" (which was evaluated as most relevant in round 1), takes on a much less dominant role in round 2. These results potentially

demonstrate that panelists view interventions they perceive as more resource demanding (assets and tools) but less dependent on management as potentially more effective for food safety culture improvement.

3.3. Application of study results in the food processing industry

A thorough FSC assessment is essential to reveal company specific gaps, before going to the intervention phase. These gaps should be analyzed, in a gap analysis, to ensure a fitting intervention is selected as dimensions can be gaps due to immaturity of different indicators (van Bokhoven et al., 2003). Gaps can be systematically prioritized by the company. After selection of the gap to improve, and with the knowledge from the gap analysis, the company can select an intervention from the presented portfolio, taking into account the formulated barriers and comments from the stakeholders from the food industry. In this process, the highest-ranked intervention might not always be the best choice. The intervention best fitting the company's specific prevailing FSC maturity should be selected (based on the FSC assessment), as different maturity levels can require different interventions. Population characteristics are also essential to consider, e.g. existent subcultures (e.g. described by (Badia et al., 2020). In these cases a tiered intervention approach can be valuable (Cotter et al., 2023). Also, combinations of interventions may be more effective in some cases rather than a single intervention, as a larger variety of barriers for change could be addressed (Emond et al., 2015). After intervention selection, important next steps are designing the intervention program, pretest, adoption, and implementation, and evaluation/monitoring change (van Bokhoven et al., 2003). The degree to which the intervention effect is sustained long term depends on a number of factors and can be influenced through the implementation, e.g. by creating a shared sense of urgency (Willis et al., 2016). Food safety culture also overlaps with safety culture, which are both part of a company's organizational culture (Nyarugwe et al., 2016) and complex relationships between concepts may exist. Interventions, implemented to improve FSC in a food company, might induce organizational changes. Consequently, the strength, type (e.g. communal culture or fragmented culture) and maturity of the organizational culture prevailing in the food organization can facilitate or hinder the acceptance or success of the FSC intervention implied changes (Latta, 2009; Abdul Rashid et al., 2004), therefore influencing FSC maturity.

3.4. Reflections, limitations, and perspectives for future research

Delphi studies are getting increased attention as a research method, with publication numbers continuously rising every year (Web of Science analysis of publications). It is "an efficient, inclusive, systematic and structured approach that can be used to address complex issues" (Mukherjee et al., 2015), and obtain expert opinions (Nworie, 2011). Due to the wide array of Delphi method modifications, credibility of the technique and validity of results have been challenged (Keeney et al., 2001). Results could be influenced by personal factors of experts such as experience and exposure to the problem (Hasson et al., 2011). Therefore, experts in this study were selected for their qualifications and experience, and all of them were acquainted with FSC as they were all part of a guiding committee of a FSC research project. Ono & Wedemeyer (1994) demonstrated the ability of the Delphi method to accurately forecast events. Delphi results do not offer indisputable facts, but provide guidance based on experts' opinions (Hasson et al., 2011).

This study is not without its limitations. First of all, some inclusion criteria were used to select papers to include in the review phase. This of course limits studies included, as for example studies published before 2015 were not retained in the first review to only focus on the latest research. Furthermore, other bibliographic databases could be used to find intervention strategies, such as Scopus. Also, interventions were included in the portfolio from a wide array of contexts, without the consideration of the success or failure of the intervention in its original context. The goal of this study was to offer a comprehensive portfolio of interventions that can be adapted to and tested within the food safety culture domain. By focusing on the potential applicability (via the Delphi study) rather than past performance in other contexts, we can explore a wider range of possibilities and encourage innovation in the relativity novel field of FSC interventions. Therefore, these interventions and the toolbox should be interpreted as illustrative and inspirational rather than offering guaranteed solutions. Implementing food safety culture interventions requires a tailored approach, considering assessments, context, and both facilitating and hindering factors all relating to the company-specific situation. During the three stakeholder consultation panels (Delphi

611 study), each time the same group of potential panelists were invited. However, as these were all active
612 practitioners in the food industry, not all panelists were available for each session causing slight variations
613 in the panel composition between sessions. The study also does not empirically test the developed portfolio
614 yet, to validate the capacity of interventions included, as this was not the scope of the presented article.
615 Lastly, this study focused on improvement of human organizational aspects of food safety culture. Research
616 on improvement of human individual dimensions (for example food safety participation of individual
617 employees) is an important next step to take. These limitations could inspire future research to further
618 explore the potential of food safety culture improvement.

4. Conclusion

The goal of this article was to develop a food safety culture improvement portfolio, containing interventions inspired by various relevant research fields and topics, tailored to the food industry through food safety expert practitioners' insights concerning interventions' potential and implementation. A database of 68 unique interventions is presented based on scoping reviews from the safety culture field and beyond. The interventions are assigned to the 9 included FSC human-organizational dimensions, being "leadership" (8 interventions), "communication" (12 interventions), "resources" (7 interventions) , "commitment" (7 interventions), "risk awareness" (6 interventions), "adaptability" (4 interventions), "consistency" (12 interventions), "beliefs and values" (8 interventions), and "mission, vision, strategy" (8 interventions). The first round of the Delphi study revealed both interventions with low and high perceived potential. The discussion between the first en second Delphi round provided expert practitioners comments regarding intervention's concept, implementation, perceptions on why the intervention does not have potential to improve FSC, and experts' own experiences. In the second round, interventions were ranked based on perceived potential of the panel, and barriers were assigned. Results demonstrated that panelists possibly view more resource demanding interventions that are less dependent of management as potentially more effective for food safety culture improvement. The developed portfolio of interventions expands the research field by bringing forward knowledge and inspiration on how food safety culture, specifically those human dimensions on an organizational level, can be improved and studied. Moving forward, practitioners and researchers can implement the proposed interventions through designing an implementation plan, preceded by a thorough food safety culture maturity assessment and gap analysis. By doing so, the food industry can take it's next step in it's food safety performance journey.

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Conflicts of interest

Declarations of interest: none

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