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# Covid-19 pandemic effects on food safety - Multi-country survey study

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ABSTRACT

This study provides an important insight into the response of food safety systems during the first months of the pandemic, elevating the perspective of preventing Covid-19 within conventional food safety management systems. A multi-country survey was conducted in 16 countries involving 825 food companies. Based on the results of the survey, it is obvious that the level of maturity of a food safety system in place is the main trigger in classifying companies and their responses to the pandemic challenge.

Staff awareness and hygiene are the two most important attributes in combating Covid-19, opposed to temperature checking of workers in food establishment and health protocols from the World Health Organization, recognized as attributes with limited salience and importance. Companies confirmed implementation of more restrictive hygiene procedures during the pandemic and the need for purchasing more additional personal protective equipment. Retailers were identified as the food supply chain link mostly affected by the pandemic opposed to food storage facilities ranked as least affected. During this challenging period, all companies declared

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that food safety has not been compromised at any moment. It is important to note that less than a half of the food companies had documented any emergency plans associated with pandemics and health issues in place.

## 1. Introduction

Since January 2020, when the World Health Organization (WHO) declared that the new coronavirus disease (Covid-19), officially named as severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2), is a public health emergency of international concern (WHO, 2020a), all dimensions of life have experienced risks and opportunities. One of the industrial sectors that had to overcome different challenges during the pandemic is the food sector, striving to produce and secure sufficient and safe food. Food security, food safety and food sustainability are recognized as strongly affected dimensions of food systems during the Covid-19 pandemic (Galanakis, 2020).

An interesting approach in paving the way during post-Covid-19 era was proposed by Rowan and Galanakis (2020) focusing the agri-food sector in sustainability and new (green) innovative technologies. Non thermal technologies have sustainability potentials in terms of decreasing processing time of foods and reducing the environmental footprint joint with preventing negative effects of heat on food properties, assuring food safety and maintaining sensorial food characteristics (Rezek Jambrak, Vukusic, Donsi, Paniwnyk, & Djekic, 2018). Some of the latest studies confirm this potential such as work of Bursać Kovačević et al. (2018) that applied "green" pressurized hot water extraction or Barba, Galanakis, Esteve, Frigola, and Vorobiev (2015) improving recovery of high-added value compounds using pulsed electric technologies and ultrasounds. Finally, food ingredients and bioactive compounds supporting immune functions in humans, such as vitamin D, polyphenols and flavonoids have also been in research focus in terms of both preventing and treating Covid-19 as outlined in the review by Galanakis, Aldawoud, Rizou, Rowan, and Ibrahim (2020). A multi country study in 16 countries identified health as one of six determinants in eating behaviors (Guiné et al., 2020), so scientific evidence of the promising effects of food supplements and nutraceuticals can help citizens in protecting themselves during the pandemic and post-Covid-19 era.

To support the food supply chain, the WHO has developed two main guidance documents. One document addressed the food companies and the other the authorities responsible for national food safety systems (WHO, 2020b; 2020c). In parallel, various other guides have been developed and updated in light of new knowledge on local or international levels from governments and/or various food associations, helping the food sector (BRCGS, 2020; EC, 2020; Nakat & Bou-Mitri, 2021). In spite of the big health threat that SARS-CoV-2 virus poses, European Food Safety Authority (EFSA) believes that there is still no scientific evidence that food is a risk or transmission route (EFSA, 2020), basically because coronaviruses have poor survivability on surfaces, such as food products or packaging (CDC, 2020). Yekta, Vahid-Dastjerdi, Norouzbeigi, and Mortazavian (2020) develop scenarios on possible carry-through or carry-over contamination routes associated with food, such as contamination from meat/meat products due to some evidences suggesting that this virus can be transpired in pigs and rabbits (carry--through) or by spreading Covid-19 from personnel to food products/food contact surfaces (carry-over). It is important to mention that the first COVID-19 cases are officially linked to the Wuhan's Seafood market selling exotic/wild animals (Ceylan, Meral, & Cetinkaya, 2020). However since the main transmission mode is "human-to-human" (WHO, 2020b) it has an indirect effect on the entire food business.

Starting from the introduction of good hygiene practices (GHP) and establishment of hazard analysis and critical control point (HACCP) system (CAC, 2003), the food safety management systems (FSMS) have evolved in the last two decades. In spite of different FSMS standards and approaches developed by the British Retail Consortium (BRC, 2018), International Featured Standards (IFS, 2017) or Safe Quality Food (SQF, 2019), they all have several common elements: (i) prerequisite programs (PRPs) are the basis of any FSMS, (ii) HACCP or similar hazard-based approaches are important for identifying, controlling and decreasing food safety risks in the food supply chains; (iii) food safety legal compliance is necessary; and (iv) food-based crisis management is important to anticipate and respond to various threats such as incidents associated with the product (like recalls, withdrawals and food fraud), or emergencies affecting food companies such as natural disasters, food safety issues and food defense. Although food legislation specifies that food companies are responsible for HACCP programs and its implementation, governmental inspection services are responsible for evaluating their effectiveness (Djekic, Tomasevic, & Radovanovic, 2011).

The main objective of this multi-country survey study was to assess the response of food companies to the pandemic in terms of food safety, analyze attributes arising from the Covid-19 pandemic associated with food safety, and position the role of pandemics in emergency responses. The results were deployed through four demographic categories - country where the companies operate, food business type, size, and FSMS status.

## 2. Materials and methods

### 2.1. Survey characteristics

Data used in this study were collected from the food industries of 16 countries in the period from May to August 2020. Companies were contacted in advance to analyze availability for participating in the survey. The only criterion was that the food establishments operate in at least one part of the food supply chain: primary production, food processing, storage/distribution, retail and wholesale covering companies from both animal origin and plant origin food sectors.

The survey has been performed using a questionnaire developed in English language and was translated to local language of the participating countries using the back translation method to ensure accuracy. Due to different Covid-19 restrictions, questionnaires were either sent to companies asking them to answer to all the questions or filled using an online platform (Slido®). Persons answering the questionnaires were food safety/HACCP team leaders (49.0%), production managers (19.3%) or members of top management (31.8%). A total of 825 food companies from 16 countries were included in the survey. The company characteristics are presented per country in Table 1.

### 2.2. Questionnaire used for the survey

A questionnaire has been developed to analyze whether the pandemic associated with Covid-19 has affected food safety in food companies. The set of answers gave the possibility to analyze opinions of companies related to the pandemic, recognize Covid-19 attributes associated with food safety, evaluate emergency preparedness within companies and identify weakest links in the food supply chain. For this purpose, five sections were developed.

The first section consisted of information related to the companies (country of origin, size, type of activity and status of the food management system).

The second section explored nine food safety statements: three statements related to their food safety preparedness plans and six associated with Covid-19. The respondents had the option to rate their degree of agreement according to a five-point Likert scale from 1 'strongly disagree', 2 'disagree', 3 'no opinion', 4 'agree' to 5 'strongly agree'.

Priorities in preventing pandemic effects in food companies were

**Table 1**
Company characteristics per country (n = 825).

| | Overall n (%) | BE (n = 32) | BA (n = 55) | CN (n = 51) | CR (n = 54) | CY (n = 51) | DE (n = 52) | GR (n = 59) | IT (n = 60) | PL (n = 36) | PT (n = 58) | RO (n = 50) | RU (n = 63) | RS (n = 55) | SL (n = 32) | SP (n = 63) | UA (n = 54) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Size | | | | | | | | | | | | | | | | | |
| Small[a] | 368 (44.6%) | 23 (71.9%) | 32 (58.2%) | 22 (43.1%) | 19 (35.2%) | 31 (60.8%) | 14 (26.9%) | 24 (40.7%) | 38 (63.3%) | 12 (33.3%) | 33 (56.9%) | 12 (24.0%) | 10 (15.9%) | 17 (30.9%) | 18 (56.3%) | 39 (61.9%) | 24 (44.4%) |
| Medium[b] | 237 (28.7%) | 4 (12.5%) | 13 (23.6%) | 19 (37.3%) | 15 (27.8%) | 17 (33.3%) | 17 (32.7%) | 22 (37.3%) | 8 (13.3%) | 13 (36.1%) | 14 (24.1%) | 23 (46.0%) | 17 (27.0%) | 13 (23.6%) | 11 (34.4%) | 13 (20.6%) | 18 (33.3%) |
| Big[c] | 220 (26.7%) | 5 (15.6%) | 10 (18.2%) | 10 (19.6%) | 20 (37.0%) | 3 (5.9%) | 21 (40.4%) | 13 (22.0%) | 14 (23.3%) | 11 (30.6%) | 11 (19.0%) | 15 (30.0%) | 36 (57.1%) | 25 (45.5%) | 3 (9.4%) | 11 (17.5%) | 12 (22.2%) |
| Food business | | | | | | | | | | | | | | | | | |
| Animal* | 414 (50.2%) | 25 (78.1%) | 18 (32.7%) | 23 (45.1%) | 18 (33.3%) | 31 (60.8%) | 33 (63.5%) | 21 (35.6%) | 35 (58.3%) | 16 (44.4%) | 19 (32.8%) | 18 (36%) | 51 (81%) | 24 (43.6%) | 8 (25.0%) | 41 (65.1%) | 33 (61.1%) |
| Plant** | 260 (31.5%) | 5 (15.6%) | 30 (54.5%) | 11 (21.6%) | 23 (42.6%) | 9 (17.6%) | 14 (26.9%) | 34 (57.6%) | 14 (23.3%) | 13 (36.1%) | 23 (39.7%) | 29 (58%) | 7 (11.1%) | 20 (36.4%) | 13 (40.6%) | 13 (20.6%) | 2 (3.7%) |
| Service*** | 151 (18.3%) | 2 (6.3%) | 7 (12.7%) | 17 (33.3%) | 13 (24.1%) | 11 (21.6%) | 5 (9.6%) | 4 (6.8%) | 11 (18.3%) | 7 (19.4%) | 16 (27.6%) | 3 (6.0%) | 5 (7.9%) | 11 (20.0%) | 11 (34.4%) | 9 (14.3%) | 19 (35.2%) |
| FSMS status[d] | | | | | | | | | | | | | | | | | |
| No system | 104 (12.6%) | 3 (9.4%) | 11 (20.0%) | 15 (29.4%) | 9 (16.7%) | 1 (2.0%) | 1 (1.9%) | 2 (3.4%) | 6 (10.0%) | 2 (5.6%) | 1 (1.7%) | 0 (0%) | 7 (11.1%) | 5 (9.1%) | 2 (6.3%) | 22 (34.9%) | 17 (31.5%) |
| HACCP | 183 (22.2%) | 5 (15.6%) | 17 (30.9%) | 2 (3.9%) | 10 (18.5%) | 11 (21.6%) | 3 (5.8%) | 10 (16.9%) | 13 (21.7%) | 4 (11.1%) | 24 (41.4%) | 4 (8.0%) | 25 (39.7%) | 13 (23.6%) | 10 (31.3%) | 13 (20.6%) | 19 (35.2%) |
| FSMS | 538 (65.2%) | 24 (75%) | 27 (49.1%) | 34 (66.7%) | 35 (64.8%) | 39 (76.5%) | 48 (92.3%) | 47 (79.7%) | 41 (68.3%) | 30 (83.3%) | 33 (56.9%) | 46 (92.0%) | 31 (49.2%) | 37 (67.3%) | 20 (62.5%) | 28 (44.4%) | 18 (33.3%) |

Legend: n represents the number of companies; (%) represents their share in the sample.
Country codes: Belgium - BE; Bosnia and Herzegovina - BA; China – CN; Croatia – HR; Cyprus – CY; Germany – DE; Greece – GR; Italy – IT; Poland – PL; Portugal – PT; Romania – RO; Russia – RU; Serbia - RS; Slovenia – SL; Spain – SP; Ukraine – UA.
Size of company: [a] Small company (<50 employees), [b] Medium-size company (51–250 employees); [c] Big company (>250 employees).
Food business type: * Animal origin food covers primary production and food processing of meat and poultry, fish, dairy and eggs; ** Plant origin food covers primary production and food processing of fruit, vegetables, cereals and beverages; *** Food service covers storage, distribution, wholesale, retail and food service establishments.
[d] Food safety management system (FSMS) status: No system – company declares they don't have any food safety system in place: HACCP – company has implemented only a HACCP based system; FSMS – company has certified its FSMS (e.g. ISO 22000; BRC, IFS, GlobalGAP).

analyzed in the third section which focused on nine attributes associated with Covid-19 (Table 2) using Best-Worst scaling (most influential was considered as "best", least influential as "worst"). The choice of attributes was made in line with recommendations made by the World Health Organization (WHO, 2020b) as well as prerequisite programs (PRP) outlined in good hygiene practices (CAC, 2003). 'Hygiene of the object' is the first attribute developed from a PRP also known as cleaning and sanitation and is the basic hygiene principle in all food safety standards (BRC, 2018; IFS, 2017; ISO, 2018). Hygiene training, together with development of work instruction are requirements of good hygiene practice (CAC, 2003). Also, the WHO recommends that food workers are aware of Covid-19 symptoms (WHO, 2020b), so we develop the second attribute named 'staff awareness'. As fever (high temperature – 38 °C or above) is a typical symptom of Covid-19 we also introduced 'temperature checking of workers' as the third attribute. Although personal hygiene (and hand washing) is a typical PRP in all food establishment (CAC, 2003), based on WHO recommendation about hand washing as the most important preventive measure (WHO, 2020e), we developed the fourth attribute 'frequent hand washing'. Physical distancing in the working environment (at least 1 m) joint with the use of protective personal equipment (PPE) such as face masks and disposable gloves recognized as measures that slow down the spreading of Covid-19 (WHO, 2020b), so we developed two more attributes 'use of masks and gloves' and 'physical distance between workers'. To adhere to the physical distancing recommendation, we also developed another attribute 'prevent/limit visits to the object', which was also a recommendation outlined by governments during lockdown. Based on the fact that during the first months of the pandemic, several countries experienced shortage in supply of masks, gloves and cleaning chemicals, we have developed another attribute - 'sufficient stock of gloves, masks, sanitizers and cleaning chemicals'. Finally, since during the pandemic the world suffered an overabundance of (dis)information with the potential of undermining the public health response (WHO, 2020d), we developed the final attribute 'health protocols from WHO/government'.

As recommended in the work of Merlino, Borra, Girgenti, Dal Vecchio, and Massaglia (2018) a range of 3–5 attributes should be included in each set of choices, with each attribute being available 3–5 times. In this survey we chose 4 attributes per subset (Table 3) having each presented at least 3 times within the questionnaire (attribute 'use of masks and gloves' was available 4 times). Finally, seven sets have been created

The fourth section was dedicated to identifying food safety systems within the food supply chain that were mostly affected due to Covid-19 pandemic.

Finally, in the fifth section, companies were asked to answer whether they have documented any emergency plans in place that have an impact on food safety. Within this section, a set of nine potential emergencies have been selected based on FSMS requirements for having an effective emergency preparedness and response (ISO, 2018) and/or management of incidents of potential emergency situations (BRC, 2018; IFS, 2017) with the following potential emergencies identified: natural disasters, environmental pollution, fire, pandemics and health issue, bioterrorism, failures in energy supply, contamination of water, ingredients and packaging and transportation accidents.

**Table 2**
Covid-19 attributes associated with food safety used for Best – Worst analysis.

| Covid-19 attributes |
|---|
| Hygiene of the object |
| Staff awareness |
| Frequent hand washing |
| Health protocols from WHO/government |
| Temperature checking of workers |
| Sufficient stock of gloves, masks, sanitizers and cleaning chemicals |
| Physical distance between workers |
| Use of masks and gloves |
| Prevent/limit visits to the object |

Who – World Health Organization.

**Table 3**
Example of attributes subset. Respondents were asked to indicate which of the four presented attributes they considered most influential (Best) and least influential (Worst).

| Most influential | Attribute | Least influential |
|---|---|---|
| ☐ | Hygiene of the object | ☐ |
| ☐ | Sufficient stock of gloves, masks, sanitizers and cleaning chemicals | ☐ |
| ☐ | Frequent hand washing | ☐ |
| ☐ | Physical distance between workers | ☐ |

### 2.3. Data processing and statistical methods

Data obtained from the Likert scale were considered as ordinal values with non-parametric statistical tests used. To classify the observed statements, a two-step cluster analysis has been employed using country type, company size, food sector and FSMS status as categorical variables. The Kruskal-Wallis H test was used to uncover statistically significant differences among the clusters.

Best-worst scores (BWS) were calculated in two ways: (i) by counting the number of times each attribute was chosen as best/worst across the series of seven sets presented to each respondent, and (ii) as a standardized "score" for each attribute. The score was calculated as presented in equation (1), based on works of Merlino et al. (2018) and Wittenberg, Bharel, Bridges, Ward, and Weinreb (2016).

$$BWS = \frac{F_B - F_W}{a\ x\ n} \quad (1)$$

where $F_B$ - frequency of being chosen as best; $F_W$ - frequency of being chosen as worst; a – availability in the series of seven sets (in our case attribute "use of masks and gloves" was available in four sets, all other attributes in three sets); n – number of respondents (in case of the entire population – 825; in case of clusters – the number of companies per cluster). BWS methodology was also used for analyzing food safety systems that were "mostly affected" and "least affected" in the food supply chain due to Covid-19 pandemic.

A principal component analysis (PCA) was applied on whether companies have documented any of the nine presented emergency preparedness plans. Bartlett's test was used to identify whether data are likely factorizable. The number of PCA components was determined by calculating eigenvalues. The level of statistical significance was set at 0.05.

## 3. Results and discussion

### 3.1. Company characteristics

The demographic portfolio of the companies and countries that participated in the survey is displayed in Table 1. The number of companies per countries was in the range between 32 and 63. The majority of companies were classified as small with below 50 employees (44.6%), followed by medium sized companies (28.7%), and big companies with over 250 employees (26.7%).

Companies operating in the animal origin food supply chain (primary production and food processing of meat and poultry, fish, dairy and eggs) represented half of the sample (50.2%), followed by companies operating in the plant origin food supply chain (primary production and food processing of fruit, vegetables, cereals and beverages) with 31.5% and food service companies (storage, distribution, wholesale, retail and food service establishments) with 18.3% of the sample.

Regarding the food safety system implemented, 65.2% of companies responded that they have a certified FSMS according to any standard

recognized within the Global Food Safety Initiative such as FSSC 22000, BRC, IFS, GlobalGAP or similar (GFSI, 2020). The HACCP system alone was operative and implemented in 22.2% of companies while 12.6% of companies declared that they did not have any food safety system in place.

### 3.2. Statements related to FSMS and pandemic

Based on the Likert scale used (from 1 'strongly disagree' to 5 'strongly agree), companies strongly agreed that they have implemented more restrictive hygiene procedures during the Covid-19 pandemic (4.5). Hygiene controls within food companies are implemented to prevent cross-contamination of food by any pathogen, including risks of food contamination by Covid-19 (EC, 2020). Also, they confirmed that they had to purchase more additional personal protective equipment (4.4). Although usage of PPEs is advised by the WHO, its role in food companies is twofold – to reduce spreading of Covid-19 and to prevent any cross-contamination (Nakat & Bou-Mitri, 2021; WHO, 2020b). An important highlight is that companies clearly stated that food safety was not compromised at any moment during the pandemic (4.4). They also responded that their staff and food safety team were additionally trained, as proposed by the latest BRC guide (BRCGS, 2020). However, it's unclear whether they made additional investments in cleaning and sanitation equipment (3.6).

A two-step cluster analysis (Table 4) revealed three clusters named 'basic', 'on-the-way' and 'mature', mainly depending on the level of FSMS in place. The 'basic' cluster consists of 285 companies, mostly small in size (41.3%), with a higher share having no FSMS in place (53.8%), operating in the animal origin food supply chain (38.4%) and the majority of surveyed companies coming from Belgium, Croatia, Poland, Portugal, Russia, Spain and Ukraine. The second 'on-the-way' cluster with 289 companies, mainly have a standalone HACCP system in place (43.7%), they are operating in plant origin food supply chain (38.8%) and coming from Bosnia and Herzegovina, Germany, Greece,

**Table 4**
Description of the three clusters in terms of country, company size and food sector (N = 825) – nine statements.

| Company characteristics | | Cluster 1 (n = 285) | Cluster 2 (n = 289) | Cluster 3 (n = 251) | Total (825) |
|---|---|---|---|---|---|
| Country | Belgium | 18 (56.3%) | 10 (31.3%) | 4 (12.5%) | 32 (100%) |
| | Bosnia and Herzegovina | 12 (21.8%) | 32 (58.2%) | 11 (20.0%) | 55 (100%) |
| | China | 19 (37.3%) | 10 (19.6%) | 22 (43.1%) | 51 (100%) |
| | Croatia | 20 (37.0%) | 16 (29.6%) | 18 (33.3%) | 54 (100%) |
| | Cyprus | 12 (23.5%) | 16 (31.4%) | 23 (45.1%) | 51 (100%) |
| | Germany | 16 (30.8%) | 25 (48.1%) | 11 (21.2%) | 52 (100%) |
| | Greece | 19 (32.2%) | 28 (47.5%) | 12 (20.3%) | 59 (100%) |
| | Italy | 20 (33.3%) | 26 (43.3%) | 14 (23.3%) | 60 (100%) |
| | Poland | 14 (38.9%) | 10 (27.8%) | 12 (33.3%) | 36 (100%) |
| | Portugal | 21 (36.2%) | 20 (34.5%) | 17 (29.3%) | 58 (100%) |
| | Romania | 10 (20.0%) | 8 (16.0%) | 32 (64.0%) | 50 (100%) |
| | Russia | 32 (50.8%) | 22 (34.9%) | 9 (14.3%) | 63 (100%) |
| | Serbia | 14 (25.5%) | 26 (47.3%) | 15 (27.3%) | 55 (100%) |
| | Slovenia | 1 (3.1%) | 11 (34.4%) | 20 (62.5%) | 32 (100%) |
| | Spain | 34 (54.0%) | 13 (20.6%) | 16 (25.4%) | 63 (100%) |
| | Ukraine | 23 (42.6%) | 16 (29.6%) | 15 (27.8%) | 54 (100%) |
| Size | Small | 152 (41.3%) | 135 (36.7%) | 81 (22.0%) | 368 (100%) |
| | Medium | 69 (29.1%) | 78 (32.9%) | 90 (38.0%) | 237 (100%) |
| | Big | 64 (29.1%) | 76 (34.5%) | 80 (36.4%) | 220 (100%) |
| Food business type | Animal | 159 (38.4%) | 143 (34.5%) | 112 (27.1%) | 414 (100%) |
| | Plant | 82 (31.5%) | 101 (38.8%) | 77 (29.6%) | 260 (100%) |
| | Service | 44 (29.1%) | 45 (29.8%) | 62 (41.1%) | 151 (100%) |
| FSMS status | No system | 56 (53.8%) | 35 (33.7%) | 13 (12.5%) | 104 (100%) |
| | HACCP | 74 (40.4%) | 80 (43.7%) | 29 (15.8%) | 183 (100%) |
| | FSMS | 155 (28.8%) | 174 (32.3%) | 209 (38.8%) | 538 (100%) |
| **Food safety statements** | | **Mean ± StD[1]** | **Mean ± StD[1]** | **Mean ± StD[1]** | **Mean ± StD[1] &tnqh_02502 Mode[2]** |
| Within our FSMS, we have documents associated with emergency preparedness and response/incidents affecting food safety | | $3.9 \pm 0.8^{a}$ | $4.0 \pm 1.1^{a}$ | $4.7 \pm 0.7^{b}$ | 4.2 ± 1.0 &tnqh_02502 5.0 |
| Pandemic was identified as one of potential emergency situations/ incidents within our FSMS | | $3.4 \pm 0.9^{a}$ | $3.5 \pm 1.2^{a}$ | $4.5 \pm 0.8^{b}$ | 3.8 ± 1.1 &tnqh_02502 4.0 |
| Food safety team in our company was trained how to react in case of pandemic | | $3.5 \pm 0.8^{a}$ | $3.4 \pm 1.2^{a}$ | $4.5 \pm 0.8^{b}$ | 3.8 ± 1.1 &tnqh_02502 4.0 |
| When pandemic of Covid-19 was announced, we had to additionally train our staff | | $3.6 \pm 0.8^{a}$ | $3.8 \pm 1.0^{b}$ | $4.8 \pm 0.6^{c}$ | 4.1 ± 1.0 &tnqh_02502 4.0 |
| During the pandemic of Covid-19 we implemented more restrictive personal hygiene procedures (hand washing, physical distance, …) | | $4.0 \pm 0.6^{a}$ | $4.7 \pm 0.8^{b}$ | $5.0 \pm 0.2^{c}$ | 4.5 ± 0.7 &tnqh_02502 5.0 |
| During the pandemic of Covid-19 we had to purchase additional personal protective equipment (masks, gloves, protective clothing) | | $3.8 \pm 0.7^{a}$ | $4.5 \pm 1.0^{b}$ | $4.9 \pm 0.6^{c}$ | 4.4 ± 0.9 &tnqh_02502 5.0 |
| During the pandemic of Covid-19 we had to adjust sanitation/cleaning practices associated with hygiene of the object | | $3.6 \pm 0.7^{a}$ | $4.0 \pm 1.1^{b}$ | $4.8 \pm 0.5^{c}$ | 4.1 ± 1.0 &tnqh_02502 4.0 |
| When pandemic of Covid-19 was announced we had to invest in sanitation/cleaning equipment | | $3.3 \pm 0.9^{a}$ | $3.4 \pm 1.3^{a}$ | $4.3 \pm 1.1^{b}$ | 3.6 ± 1.2 &tnqh_02502 4.0 |
| During the pandemic of Covid-19 food safety in our company was not compromised at any moment | | $4.0 \pm 0.7^{a}$ | $4.5 \pm 0.8^{b}$ | $4.7 \pm 0.7^{c}$ | 4.4 ± 0.8 &tnqh_02502 5.0 |

Size of company: Small company (<50 employees), Medium-size company (51–250 employees); Big company (>250 employees).
Food business type: Animal origin food covers primary production and food processing of meat and poultry, fish, dairy and eggs; Plant origin food covers primary production and food processing of fruit, vegetables and beverages; Food service covers storage, distribution, wholesale, retail and food service establishments.
Food safety management system (FSMS) status: No system – company declares they don't have any food safety system in place: HACCP – company has implemented only a HACCP based system; FSMS – company has certified its FSMS (e.g. ISO 22000; BRC, IFS, GlobalGAP).
The Mean values ± Standard deviations[1] and modes[2] were obtained from the raw data. Note: Items denoted with different letters are significantly different at the level of 5%. Likert scale: (1) "Strongly disagree", (2) "Disagree", (3) "No opinion", (4) "Agree", (5) "Strongly agree".

Italy and Serbia. The third 'mature' cluster with 251 companies had certified FSMS (38.8%), they are mainly medium-sized (38.0%) and big companies (36.4%), operating in the food servicing sector (41.1%) and located in China, Cyprus, Romania and Slovenia.

The 'mature' cluster had highest scores on all nine statements compared to cluster 'basic' which achieved lowest scores for all statements. A Kruskal-Wallis H test showed that there was a statistically significant difference between the clusters ($p < 0.05$). Cluster 'on-the-way' for the first three statements analyzing *ex-ante* readiness for the pandemic had similar results as the 'basic' cluster which showed a limited level of readiness for food safety emergencies and pandemics. Out of the other six statements, for five of them all three clusters showed statistically significant differences in answers ($p < 0.05$).

### 3.3. Best-worst scores

Best-worst methodology allowed to identify most influential Covid-19 attributes considered by food companies during the pandemic. The number of times that an attribute was selected as the most influential (best) or least influential (worst) as well as the average score for each attribute, for the entire sample and per cluster, are depicted in Table 5. For easier interpretation, the "rule of the thumb" in which a score indicates the relative strength of influence or salience of an attribute across the sample was used. In this way, "0" indicated no salience and towards "±1.0" the increasing/decreasing salience (Wittenberg et al., 2016).

Considering the entire sample, it is obvious that 'staff awareness' (0.400) is recognized as the most influential attribute, followed by 'hygiene of the object' (0.175). Both are highlighted as top priority by WHO, recommending that FSMS/HACCP teams should raise awareness and strengthen food hygiene and sanitation practices (WHO, 2020b). Similar reaction was observed in meat sector in Serbia upon mandatory HACCP implementation, when the main improvement was related to process hygiene indicators in meat establishments (Tomasevic et al., 2016). Within clusters, 'staff awareness' had the highest average score (0.429) in cluster 1 and the lowest in cluster 3 (0.348). 'Hygiene of the object' scored highest (0.248) in cluster 2, compared to cluster 3 with the lowest score (0.116). In both cases, salience is lower in the 'mature' cluster with FSMS fully operational. Duda-Chodak, Lukasiewicz, Zięć, Florkiewicz, and Filipiak-Florkiewicz (2020) emphasize risk of indirect transmission that may occur in food company mainly from food contact surfaces as most of the people touch different things besides their face during the day and infected workers (both presymptomatic and asymptomatic) can unknowingly contaminate these surfaces with Covid-19 virus which may be transferred to other workers.

'Temperature checking of workers' was recognized as attribute with limited salience and importance (−0.314) followed by 'health protocols from WHO/government' (−0.218). For both attributes, cluster 2 had the lowest scores, −0.339 and −0.233, respectively. It is important to recall that health status control is a PRP (personal hygiene) not allowing disease carriers or ill workers to enter any food handling area (CAC, 2003). Therefore, due to staff awareness raised during the pandemic, companies didn't emphasize temperature checking as important understanding, as personal responsibility should prevail and sick workers won't come to work. As for the low importance of adhering to 'health protocols from WHO/government', two main reasons may be outlined. On one side, all protocols directed to food companies had limited GHP requirements that could be considered new (such as physical distancing or temperature checking of workers), opposed to the importance of keeping working environment clean (WHO, 2020b). On the other side, "infodemia" of rumors and misleading information slightly undermined the authority of WHO and/or national authorities (WHO, 2020d), so social networks such as Facebook launched their program of spreading accurate and scientifically proven information on the Covid-19 (Tasnim, Hossain, & Mazumder, 2020).

Protection of workers with PPEs such as face masks, face shields and gloves (Nakat & Bou-Mitri, 2021) joint with clean uniforms is emphasized in several guide documents (BRCGS, 2020; WHO, 2020b). However, in our case 'use of mask and gloves' was recognized as an attribute indicating no salience. One of the reasons may be the use of various PPEs (depending on the food sector), already before the pandemic.

The same methodology was employed to analyze food safety systems in the food supply chain that were 'mostly affected' and 'least affected' during the pandemic Covid-19 (Table 6). According to respondents it turned out that food safety systems were most affected by the pandemic in retails, while storage was identified as the least affected link. Our study showed that households indicate no salience. Fei, Ni, and Santini (2020) share Chinese experience in mitigating the negative impacts of Covid-19 in distribution and sales of agricultural products, where the government established service alliance and joint platforms supporting the supply-demand matching and keeping the food market operating. In order to prevent risks in the food supply chains that may occur in urban cities from future pandemic outbreaks, Galimberti et al. (2020) identify the need for helping small food producers as key stakeholders in feeding cities. It is of note that limited advices have been developed for food preparation at households during the pandemic, since main attention is focused on mask wearing (during shopping). However, Duda-Chodak et al. (2020) emphasize that upon shopping, it is necessary to remove food packaging and then wash hands and (if possible) wash the purchased products.

A different approach in analyzing safety measures needed in the food sector during the pandemic, identifies consumption phase as most critical. This emphasizes the need for all preventive measures to be critically necessary at the last stage of the food supply chain (Rizou, Galanakis, Aldawoud, & Galanakis, 2020). Nakat and Bou-Mitri (2021) propose creating a Covid-19 task force in food companies as part of business continuity plans for analyzing and if necessary, improving effectiveness of implemented measures, along with contact (person – to – person) tracing. The justification for such a conclusion is the fact that at the end of the food supply chain, more people as potential sources of infections are involved.

Global food companies, in line with their corporate social responsibility programs, have developed several initiatives in combating Covid-19, such as Nestle joining forces with International Federation of

**Table 5**
Subjective priority of Covid-19 attributes: Best-Worst scaling report - frequency counts and standardized average score considering the entire sample and for the three clusters representative.

| Attributes | Number of Best | Number of Worst | BW average score | Cluster 1 | Cluster 2 | Cluster 3 |
|---|---|---|---|---|---|---|
| Hygiene of the object | 812 | 380 | 0.175 | 0.152 | 0.248 | 0.116 |
| Staff awareness | 1326 | 335 | 0.400 | 0.429 | 0.418 | 0.348 |
| Frequent hand washing | 613 | 339 | 0.111 | 0.142 | 0.087 | 0.104 |
| Health protocols from WHO/government | 383 | 922 | −0.218 | −0.208 | −0.233 | −0.211 |
| Temperature checking of workers | 246 | 1024 | −0.314 | −0.331 | −0.339 | −0.267 |
| Sufficient stock of gloves, masks, sanitizers and cleaning chemicals | 561 | 618 | −0.023 | −0.023 | −0.043 | 0.000 |
| Physical distance between workers | 553 | 844 | −0.118 | −0.119 | −0.114 | −0.120 |
| Use of masks and gloves | 709 | 531 | 0.054 | 0.004 | 0.056 | 0.108 |
| Prevent/limit visits to the object | 572 | 782 | −0.085 | −0.047 | −0.098 | −0.113 |

**Table 6**
Subjective priority of food safety system in the food supply chain: Most-Least scaling report - frequency counts and standardized average score considering the entire sample and for the three clusters representative.

| Attributes | Number of Most affected | Number of Least affected | Most-Least average score | Cluster 1 | Cluster 2 | Cluster 3 |
|---|---|---|---|---|---|---|
| Primary | 123 | 236 | −0.137 | −0.158 | −0.149 | −0.099 |
| Food processing | 127 | 102 | 0.030 | −0.017 | 0.045 | 0.0678 |
| Storage | 21 | 156 | −0.164 | −0.172 | −0.166 | −0.151 |
| Transport/distribution | 179 | 91 | 0.107 | 0.144 | 0.079 | 0.096 |
| Retail | 290 | 125 | 0.200 | 0.207 | 0.214 | 0.175 |
| Household | 85 | 115 | −0.036 | −0.003 | −0.024 | −0.088 |

the Red Cross (Nestle, 2020), the Coca-Cola Company ensuring product safety and availability and supporting local communities (TCCC, 2020) or Mondelez International promoting active, healthy lifestyles and providing various types of aid supporting disaster response and relief efforts (MI, 2020).

### 3.4. Emergency preparedness plans

Food companies had the option to identify which emergency preparedness plans exits within their FSMS. All FSMS standards have requirements associated with emergencies (BRC, 2018; IFS, 2017; ISO, 2018) but without defining what types of emergencies need to be addressed. Characteristics of all types of emergencies are their suddenness, uncertainty, and potential complication (Song et al., 2020). Plans usually consist of implementing means of preventions where applicable, instructions how to manage potential emergency situations and accidents, reporting protocol, and *ex post* (root cause) analysis with revision of plans if necessary (ISO, 2018; Motarjemi & Wallace, 2014). GHP requirements (and HACCP based food safety systems) do not specifically require companies to manage their emergency situations (CAC, 2003).

Based on the multiple-choice responses (data not shown), top three emergency plans are: plans in case of water contamination (549 responses; 66.5% companies), followed by contamination of ingredients or packaging (464 responses; 56.2%) and pandemics and health issues (366 responses; 44.4% companies).

Data from the survey were subject to PCA analysis, and the outputs are presented in Fig. 1. Bartlett's test of sphericity displayed statistically significant differences ($p < 0.0005$), indicating that data were likely factorizable. Having the criteria of eigenvalues >1 (Cattell, 1966), the PCA extracted two components separating the emergency plans into two distinct directions that have been recognized as: (i) 'food-environment dimension' (PC1) directed towards emergencies and incidents associated with food and/or environment and (ii) 'vis-major dimension' (PC2) as a dimension focused towards irresistible occurrences that can arise and cause damage or disruption and that are neither caused by nor being preventable by humans. A loading plot (Fig. 1a) provides a summary of the results, showing that the 'food-environment dimension' (PC1) was loaded heavily (>0.6) with food contamination from ingredients, packaging and water, as well as environmental pollution and energy failure. When it comes to the 'vis major' dimension (PC2), the highest positive loadings (>0.6) are for natural disasters and vehicle accidents. By building on the extant literature that supports FSMS and its development in various directions such as food safety culture (Tomasevic et al., 2020), the affirmation of these two dimensions, may contribute to the future analysis of effectiveness of FSMS in emergency situations.

The scores plot displayed in Fig. 1b shows relationships between food companies. As it can be observed, big and small companies were opposed to each other, representing companies with different approaches in documenting emergency preparedness practices. A similar pattern is observed regarding FSMS status. Companies with only HACCP based food safety systems are on the side of small companies, as opposed to companies with FSMS connected with medium-sized and big companies. This agrees with the findings revealed by Dzwolak (2014) and Violaris, Bridges, and Bridges (2008) who emphasized that small companies with lack of human, financial and technical resources experience difficulties in implementing food safety requirements compared to medium and big-sized companies. Based on their activity, Fig. 1b displays that companies are located close to center indicating that they shared similar emergency plans.

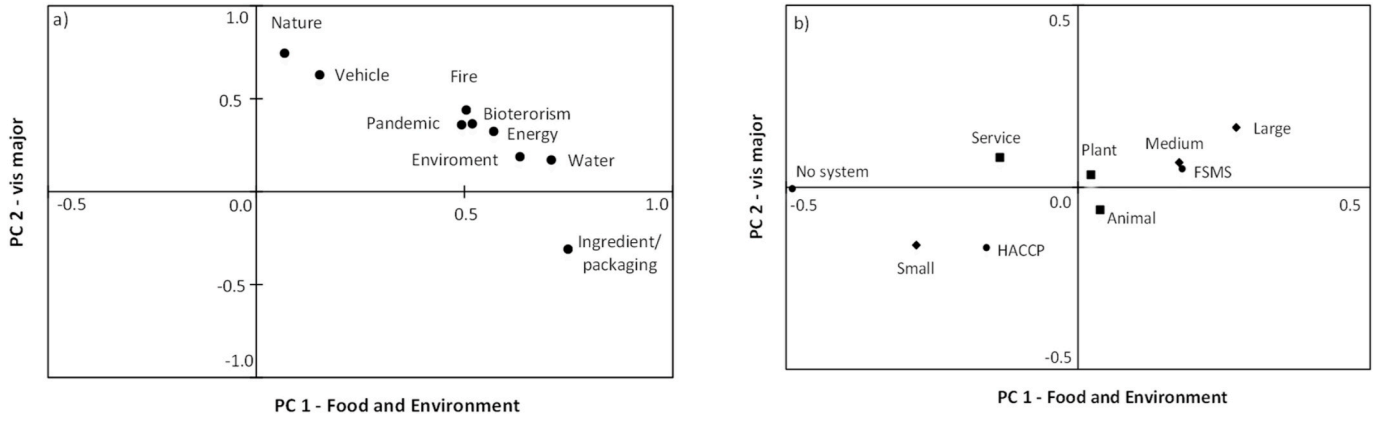


**Fig. 1.** Principal component analysis loadings (a) and scores (b) plots for the nine factors influencing emergency preparedness deployed by size of the companies, their activities in the food sector and their food safety systems. Factors: Nature - Natural disaster; Bioterrorism; Fire; Ingredient/packaging - Ingredient/packaging contamination; Water - Water contamination; Pandemic - Pandemic and other health issue; Vehicle - Vehicle accident; Energy - Energy failure; Environment - Environmental pollution. Size of company: Small company (<50 employees), Medium-size company (51–250 employees); Big company (>250 employees). Food business type: Animal origin food covers primary production and food processing of meat and poultry, fish, dairy and eggs; Plant origin food covers primary production and food processing of fruit, vegetables and beverages; Food service covers storage, distribution, wholesale, retail and food service establishments. Food safety management system (FSMS) status: No system – company declares they don't have any food safety system in place: HACCP – company has implemented only a HACCP based system; FSMS – company has certified its FSMS.

## 4. Conclusions

This research shows the responses of food safety systems during the Covid-19 pandemic and promotes FSMS maturity as the main trigger to rank companies based on their response to the pandemic challenge. It has been confirmed that companies with FSMS have implemented more rigorous preventive measures in combating Covid-19 within their operating facilities.

Staff awareness and hygiene are two of the most important attributes derived from the Covid-19 pandemic affecting food safety. On the other side, temperature checking of workers and health protocols developed by the World Health Organization or national authorities have been rated as attributes of limited salience and importance. In order to combat this pandemic crisis, food companies confirmed the implementation of more restrictive hygiene procedures as well as additional purchase of PPEs. Despite of all the challenges, food safety has not been compromised at any moment. When it comes to emergency plans, almost half of the companies confirmed to have plans for pandemics and health issues.

The limitation of this study is that this research was focused on companies' perceptions and beliefs related to their food safety in the pandemic environment with no on-site assessments performed. Therefore, it was not possible to evaluate the effectiveness of food safety systems as well as emergency preparedness plans in place associated with this pandemic. Future research should explore Covid-19 pandemic effects on food fraud, food defense and food security.

## CRediT authorship contribution statement

**Ilija Djekic:** Conceptualization, Methodology, Formal analysis, Writing - original draft, Writing - review & editing, Supervision. **Aleksandra Nikolić:** Investigation, Data curation. **Mirza Uzunović:** Investigation, Data curation. **Aluwé Marijke:** Investigation, Data curation. **Aijun Liu:** Investigation, Data curation. **Jiqin Han:** Investigation, Data curation. **Mladen Brnčić:** Investigation, Data curation. **Nada Knežević:** Investigation, Data curation. **Photis Papademas:** Investigation, Data curation. **Katerina Lemoniati:** Investigation, Data curation. **Franziska Witte:** Investigation, Data curation. **Nino Terjung:** Investigation, Data curation. **Maria Papageorgiou:** Investigation, Data curation. **Kyriaki G. Zinoviadou:** Investigation, Data curation. **Antonella Dalle Zotte:** Investigation, Data curation. **Erika Pellattiero:** Investigation, Data curation. **Bartosz G. Sołowiej:** Investigation, Data curation. **Raquel P. F. Guiné:** Investigation, Data curation. **Paula Correia:** Investigation, Data curation. **Alexandrina Sirbu:** Investigation, Data curation. **Liliana Vasilescu:** Investigation, Data curation. **Anastasia A. Semenova:** Investigation, Data curation. **Oksana A. Kuznetsova:** Investigation, Data curation. **Urška Vrabič Brodnjak:** Investigation, Data curation. **Mirian Pateiro:** Investigation, Data curation. **Jose Manuel Lorenzo:** Investigation, Data curation. **Andriy Getya:** Investigation, Data curation. **Tetiana Kodak:** Investigation, Data curation. **Igor Tomasevic:** Writing - original draft, Writing - review & editing, Validation, Supervision.

## Declaration of competing interest

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

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