Ongoing mitigation strategies and further needs of the United States food industry to control COVID-19 in the work environment

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Abstract

The COVID-19 pandemic has had dire effects on the United States (US) food industry through impacts on workers’ health and wellbeing and supply chain disruptions. The objectives of this study were to determine what the food industry needs to be able to control COVID-19 impacts in the work environment and what mitigation strategies are being implemented. A web-based needs assessment survey was distributed from January to April 2021, via 13 food professional/trade organizations and 2 social networks, targeting management professionals at food (produce, dairy, poultry, and beef/pork) processing facilities and produce farm operations in the US. Statistical analyses evaluated patterns in self-reported adoption of mitigation strategies against COVID-19 in the participants’ facilities/operations and perceived needs of the industry regarding COVID-19. Responses to open-ended questions were analyzed using thematic analysis. In total 145 responses were received, of which 79 were usable, including 38 (48%) from the dairy, 17 (22%) from the fresh produce, and 24 (30%) from a mixture of other food industry sectors. Only two usable responses were from the beef/pork sector and none from the poultry sector. Findings revealed that several social distancing, biosecurity, and surveillance mitigation strategies against COVID-19 are commonly implemented in the participants’ facilities/operations, but their implementation frequency differs by the facility/operation size and industry sector. Also, findings indicated that collaboration between the food industry and government agencies, contingency plans and appropriate training, and new technologies are needed to control COVID-19 in the food industry. Subject to limitations associated with the relatively low response rate (possible selection bias), the findings suggest that the US food industry is prepared to safeguard workers’ health and businesses in the event of a new COVID-19 variant or similar future
disaster, provided that appropriate structures are put in place to ensure coordination and
compliance, both before and during such an outbreak.

Keywords: COVID-19, dairy, fresh produce, mitigation strategies, food industry management

**Introduction**

The COVID-19 pandemic, caused by the SARS-CoV-2 beta-coronavirus virus, has
presented important challenges to the food industry in the United States (US) and around the
world. The food industry has dealt with disruptions in the supply chain [1–5], difficulties
meeting market demands and changes in food consumption patterns [2,6,7], negative effects on
production capacity [8], labor shortages [9], and decreases in productivity due to absenteeism
[10–12], while adopting various public health measures to safeguard its workforce’s health [13].
The US food industry, including transportation and logistics, is more than ever considered
critical infrastructure for the nation because of its key role in feeding the US population [14].
The maintenance of such activities has led to the occurrence of COVID-19 outbreaks across all
industry sectors in the US, including poultry [15], beef/pork [15], dairy [16], and fresh produce
[17]. Indeed, from April 2020 to July 2021, more than 90,000 cases and 450 deaths related to
COVID-19 have been reported across food industry sectors in the US [18]. Some of these
outbreaks have involved widespread transmission of COVID-19 among employees, as was the
case for a central New York State greenhouse in which more than half (171/300) of the workers
tested positive for the virus [17]. Food and agriculture workers are amongst the occupations most
severely affected by excess deaths due to COVID-19 according to a study comparing the total
number of deaths in two scenarios, one theoretical scenario in which COVID-19 never happened
(established based on pre-pandemic data for 2018 and 2019) and one scenario that projected
deaths during the COVID-19 pandemic [19]. To improve the ability of the US food industry to more effectively and quickly respond to COVID-19 related disturbances and similar future disasters, it is essential to understand the needs and concerns of the food industry regarding the ongoing pandemic. This requires understanding the specific needs and concerns of the various industry sectors, as impacts (e.g., COVID-19 related deaths), challenges, and responses to these challenges might be different across food industry sectors. For instance, industry sectors providing employees with housing and transportation might require additional preventive measures to avoid contact between COVID-19 infected and healthy employees [20].

In the US, governmental institutions, such as the Centers for Disease Control and Prevention (CDC) and the Occupational Safety and Health Administration (OSHA) have published guidelines and checklists to inform and guide the US food industry and other businesses about the correct implementation of social distancing, biosafety, and surveillance strategies to assist in preventing COVID-19 cases [20–23]. The guidelines usually recommend the adoption of multiple methods to socially distance workers, sanitize and clean the workplace and workers’ hands, enforce mask-wearing, and apply surveillance tests to identify COVID-19 cases and prevent further spread. These guidelines were established early in the COVID-19 pandemic (around June 2020) [20,23] and prior to the widespread availability of vaccines to reduce transmission in the workplace (late 2020 – early 2021) [21,22]. The proper implementation of these strategies is considered important in reducing the occurrence of COVID-19 cases in the workplace and/or limiting the size of an outbreak; for example, air ventilation and social distancing have been shown to be effective in reducing COVID-19 dissemination among employees in German meat industry facilities in 2020 [24]. Nonetheless, there is a gap in information regarding what the food industry perceives as needed to properly
address COVID-19 transmission in food production facilities and operations. Currently, information about the adoption of mitigation strategies in the US food industry remains scarce and limited to certain sectors, such as the meat [15], poultry [15], and dairy sectors [25]. Although, these studies have provided valuable information, they were performed in a comparatively earlier period in the COVID-19 pandemic (April – July, 2020) when the adoption of mitigation strategies by the US food industry could have been different (e.g., vaccine availability) and information, such as guidelines to implement ventilation in buildings [22] and OSHA’s instructions to prevent COVID-19 transmission in the workplace [21], have not yet been published. In addition, the study by Yung et al. [25] was restricted to dairy farmers in the states of Minnesota and Wisconsin, which represents a small part of the US dairy industry and might not reflect the adoption of mitigation strategies in other dairy facilities and operations in the country.

This information is important as knowing how commonly social distancing, biosafety, and surveillance mitigation strategies were adopted to prevent COVID-19 cases across the US food industry and the reasons behind such adoption or lack of adoption are crucial to identify areas where prevention could be improved. Therefore, the objectives of this study were to identify the needs of the US food industry (targeting produce farm operations as well as produce, dairy, poultry, beef/pork processing facilities) in mitigating the impact of the COVID-19 pandemic on workforce and food production, and to assess the ongoing implementation of COVID-19 mitigation strategies in the work environment. These objectives were addressed through the administration of a needs assessment survey between January and April, 2021, detailed in the “Materials and methods” section.

Materials and methods
A two-part web-based needs assessment survey was developed. Part 1 asked general questions about a survey participant’s overall industry sector (produce, dairy, poultry, beef/pork, or other), and part 2 asked about conditions and COVID-19 mitigation strategies in a food production facility or operation of the participant’s choice (participants who oversee multiple facilities and/or operations were asked to choose one). The wording of questions can be found in S1 Appendix, S1 Table (additionally, the S1 Appendix includes a complete copy of the survey instrument including introduction letter and the consent statement). Briefly, the questions included in part 1 were about a participant’s industry sector, their main role in their organization, how COVID-19 has impacted their industry sector, concerns about COVID-19 control, challenges in maintaining production capacity, needs to successfully mitigate COVID-19, desired features of a computational modeling tool that aids decision making in control of COVID-19, and indicators of a successful response against COVID-19. Part 2 included questions about the industry sector of the participant’s selected facility/operation, maximum tolerable reduction in the production labor force that is compatible with maintaining full production capacity, number and age of employees, availability of employer-provided housing and transportation for employees, importance of different specialized job functions for maintaining production in the event of a COVID-19 outbreak, sources of COVID-19 in the facility/operation, and adoption of COVID-19 mitigation strategies (definitions of mitigation strategies provided to survey participants are shown in Table 1). Part 2 also included several questions applicable only to participants from the produce food sector. Survey questions were initially designed by E.B., R.I., and S.L.-S. The design process included discussing preliminary versions of the survey with A.A., C.Z., D.W., S.D.A., S.I.M., and M.W. until a consensus was reached regarding the
phrasing and content of the questions included in the final version of the survey. The survey was piloted between December 8, 2020, and January 6, 2021, by obtaining anonymous responses from 7 out of 10 members of an advisory council for the authors’ COVID-19 research grant comprised of executive-level managers representing the produce, dairy, beef/pork, and poultry industry sectors. Feedback from the piloting process was incorporated into the final version of the survey.

Table 1. Definitions of social distancing, biosafety, and surveillance mitigation strategies provided to study participants in the needs assessment survey.

| Mitigation strategy                              | Definition                                                                                                                                                                                                 |
|-------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| **Social distancing**                            |                                                                                                                                                                                                          |
| Installed physical barriers                     | Clear plastic partitions preventing employees from getting too close and preventing particles or droplets exhaled by one person from entering the breathing zone of another.                                           |
| Staggered break times                           | Groups of employees have different break times.                                                                                                                                                           |
| Staggered arrival/departure times (staggered shifts) | Groups of employees have a set number of hours to work during the day, but they have different start and finish times.                                                                                  |
| Downsizing operation                            | Reduction of a facility’s production capacity accompanied by a reduction in the number of employees.                                                                                                         |
| Adjusted sick day policy                        | Employee benefits include a paid sick leave granted when an employee is unable to work because the employee is quarantined or isolated due to COVID-19, because of a bona fide need to care for an individual subject to quarantine or isolation, or to care for a child (under 18 years of age) whose school or childcare provider is closed or unavailable for reasons related to COVID-19. (Definition is adapted from US Dept. of Labor "Families First Coronavirus Response Act: Employee Paid Leave Rights"). |
| Spacing workers >6ft during production          | Keeping a space at least 6 feet between employees.                                                                                                                                                        |
| Cohorting employees                              | Establishing groups of employees based on their risk of infection in the company, where each cohort remains as separated from the other cohorts as possible.                                                 |
| **Biosafety**                                   |                                                                                                                                                                                                          |
| Enhanced handwashing                            | Implementation of a set of instructions for employees about                                                                                                                                               |
when and how to wash hands that goes above and beyond instructions that were in place pre-COVID-19.

| Alcohol-based hand rubs | Implementation of a set of instructions for employees about when and how to use. |
|-------------------------|----------------------------------------------------------------------------------|
| Face mask, face shields, and/or goggles | Implementation of a set of instructions about how and when to use face masks, face shields and goggles. Face masks are often referred to as surgical masks or procedure masks. They cover the nose and mouth and are secured under the chin, fit snugly against the side of the face, and do not have gaps. Face shields are secondary protectors intended to protect the entire face against exposure. Goggles shield the eyes against the hazards. |
| Increased air ventilation rates | Increase in the rate at which external air (fresh air) flows into the building. |
| Air cleaning/filtering | Destroying or removing hazards like viral particles from the air. |

**Surveillance**

| Temperature screening and quarantine | Screen for employees with a temperature above 99.5°F (or other cut-off value) and keep identified employees away from the workplace to determine whether they develop COVID-19 symptoms or test positive for the disease. |
| Test for infection and isolation | Test employees for COVID-19 infection (viral test); Isolation: keep away from the workplace an employee who is sick with COVID-19 or tested positive for COVID-19 without symptoms. |
| Contact tracing and quarantine | Contact tracing is a process to identify individuals who may have been exposed to a person with COVID-19. Quarantine is the practice of separating individuals who have had close contact with someone with COVID-19 to determine whether they develop symptoms or test positive for the disease. |
| Return to work post recovery policy | Any strategy implemented for employees returning to work following a COVID-19 infection based on symptoms or doctor’s recommendation. |

The survey was implemented in the Qualtrics survey platform (Qualtrics, Provo, UT) and made available online to survey participants through a link. After clicking on the link participants were shown an introductory letter that provided information about the purpose of the survey and asked to consent to take part in the study. Individuals older than 18 years and affiliated with a produce farm operation or with produce, dairy, beef/pork, poultry, or other food processing facility in the US were considered eligible to participate in the survey; recruitment
targeted management professionals at those facilities and operations. No identifying information was collected from participants and their responses remained confidential. No compensation for participation was provided (S1 Appendix). The survey took approximately 30 minutes to complete.

A number of food industry professional/trade organizations were contacted to request their assistance in disseminating the survey to their management professional members. This resulted in successfully collected responses via 13 organizations, including 3 associated with the fresh produce industry, 5 with dairy, 1 with beef/pork & poultry, and 4 with general processing.

Additionally, the survey was distributed via two social networks of study authors (Table 2). The period for survey distribution started on January 19, 2021, and concluded on April 6, 2021. The study was approved by the Cornell University Institutional Review Board for Human Participants (IRB protocol #2006009660). No power-based sample calculation was conducted due to the preliminary nature of the investigation.

Table 2. Number of needs assessment survey responses (total received and usable) by the industry sector and social media recruitment targets.

| Recruitment target                      | Total responses | Usable responses |
|-----------------------------------------|-----------------|-----------------|
| Fresh Produce                           | 31              | 17              |
| - United Fresh Produce Association      |                 |                 |
| - Produce Marketing Association         |                 |                 |
| - IAFP Professional Development Group (PDG) |             |                 |
| - Fruit and Vegetable Safety and Quality|                 |                 |
| Dairy                                   | 61              | 35              |
| - Northeast Dairy Foods Association     |                 |                 |
| - International Dairy Foods Association |                 |                 |
| - New York State Cheese Manufacturers’ Association | | |
A response was considered usable when participant completed at least part 1 of the survey.

### Data management and statistical analysis

Only responses from participants that completed at least part 1 of the survey were considered usable (Table 2). These were organized in an Excel datasheet (Microsoft, Seattle, WA) for subsequent analysis. Responses to multiple choice and open-ended questions asking for specific numbers were treated as numerical data for statistical analysis. If a participant responded an interval to a question asking for a specific number, then the mean of the interval was used. Incomplete responses or those unrelated to the corresponding questions were included as missing values in the datasheet. Statistical analysis was carried out in R v. 4.0.3 [26]. Responses to the survey questions were summarized and organized in tables and visualized using heatmaps. Responses to numeric open-ended questions were summarized using median, mean, interquartile range (IQR), and range. Levels in Likert items were treated as interval (with assigned values 1-5) or numerical (with assigned values 0, 0.5 or 1) data for statistical analysis, so that the median score of responses to a Likert item could be calculated. Responses to the question Q20
“What was the average number of employees in this facility/operation in 2019?” were transformed from interval to nominal data by grouping responses in the levels “Small” (1-49 employees), “Medium” (50-249 employees), and “Large” (>250 employees) based on criteria established by the Organisation for Economic Co-operation and Development (OECD) [31]; this variable served as a proxy for facility/operation size.

A complete plan of analysis of survey questions can be found in S1 Appendix, S1 Table, including questions identified as the outcomes of interest and independent variables (predictors) in the analysis of associations. As applicable, Kruskal-Wallis, Fisher’s exact, Mann-Whitney U or Spearman’s rank correlation tests were used to identify predictors associated with the outcomes of interest at the bivariable level. Associations were considered significant at \( p \leq 0.05 \). Post-hoc assessment of significant associations was carried out using the Dunn’s test to determine specific statistical differences between variable levels. Obtained \( p \)-values were adjusted for multiple testing using the false discovery rate (FDR) [27]. The data underlying the results presented in the study are available in Zenodo (doi: 10.5281/zenodo.5165334).

**Thematic analysis**

Thematic analysis involves determining common themes or ideas that are repeated across participants’ open-ended responses to a certain question [28]. As a follow-up to certain Likert questions or multiple-choice questions, we asked an open-ended question to gain a deeper understanding of participants’ opinions/perceptions. These open-ended questions were preliminarily assessed to select questions with diverse and informative responses for thematic analysis. In other words, questions with responses that provided new information (i.e., not being accounted for in responses to other questions in the survey) and diverse enough to generate at
least two codes were selected. During the initial assessment, a preliminary codebook was
generated to classify participants’ responses into codes and subsequently identify themes
emerging from those codes. This codebook was further refined through discussions among
authors (S.L.-S., S.I.M., E.B., and R.I.). Theme identification across questions was first carried
out individually by authors (S.L.-S., S.I.M., E.B., and R.I.), and a final consensus was reached
following discussion. Details for codes and themes can be found in S2 Table.

Results

Responses from 79 survey participants could be analyzed, most
being from the dairy industry sector and acting as corporate food
safety and quality managers

In total, 145 survey responses were collected. However, based on the decision to only
include responses from participants that completed at least part 1 of the survey (usable
responses), responses from only 79 participants were retained for statistical (Tables 3-5) and
thematic analysis (Table 6). The following results were obtained from responses to questions in
part 1, where participants answered general questions about the industry sector to which they
belong (Table 3). Among 79 participants, 38 (48%) were from the dairy industry sector, 17
(22%) from fresh produce, and 22 (28%) from other food industry sectors (e.g., chocolate
production, frozen food, prepared food, wine production, cereals) (Q1, Table 3). Only two
responses were obtained from the beef/pork industry and thus were grouped into the “Other”
category for statistical analysis. Three participants self-reported association with all 4 food
industry sectors (i.e., Fresh produce, Dairy, Poultry, and Beef/pork) and thus were grouped in the
“Other” category. No responses were received from the poultry sector. (Note: as stated, Q1 in part 1 asked for the industry sector of a participant, which is different from Q15 in part 2 that asked about the industry sector of a facility/operation the participant chose to describe; this is why responses to Q1 and Q15 are slightly different although they both ask about the industry sector.)

Table 3. Number and proportion of responses among survey participants (N=79) for questions, analyzed as categorical variables, from each of the two parts of the needs assessment survey (part 1: General questions about a participant’s industry sector; part 2: Conditions and COVID-19 controls in a facility or operation of participant’s choice).

| Q | Variable | Response | Number | % |
|---|----------|----------|--------|---|
| Part 1 | | | | |
| Q1 | What industry sector are you in? (select all that apply) | Fresh produce | 17 | 22 |
| | | Dairy | 38 | 48 |
| | | Poultry | 0 | 0 |
| | | Beef/pork | 2 | 3 |
| | | Other | 22 | 28 |
| Q2 | Select your main role within your organization | C-suite | 13 | 16 |
| | | Regional manager | 0 | 0 |
| | | Facility manager | 21 | 26 |
| | | Research and development | 3 | 4 |
| | | Corporate food safety and quality | 29 | 37 |
| | | Other | 11 | 14 |
| | | Prefer not to answer | 2 | 3 |
| Q3 | Did COVID-19 have a significant impact on your industry sector? | Yes | 67 | 85 |
| | | No | 12 | 15 |
| Q4 | In which way(s) has COVID-19 significantly impacted your industry sector? (select all that apply) | Operations/production has been reduced/cut back | 38 | 57 |
| | | Operations/production has expanded | 23 | 34 |
| | | Implemented robotics, sensors, automation, and/or computer modeling | 5 | 7 |
| | | Management/corporate employees working remotely | 52 | 78 |
| Question | Options                          | Yes | No | No response |
|----------|----------------------------------|-----|----|-------------|
| Q15b     | In what industry sector is this facility/operation? | Dairy | Poultry | Beef/pork |
|          | Fresh produce                    | 17  | 0  | 1  |
|          | Dairy                            | 40  | 0  | 0  |
|          | Poultry                          | 0   | 0  | 0  |
|          | Beef/pork                        | 1   | 0  | 0  |
|          | Other                            | 20  | 0  | 0  |
|          | No response                      | 1   | 0  | 0  |
| Q20g     | What was the average number of employees in this facility/operation in 2019? | Small (1-49 workers) | Medium (50-249 workers) | Large (>250 workers) |
|          | Small (1-49 workers)             | 25  | 33 | 16 |
|          | Medium (50-249 workers)          | 33  | 42 | 20 |
|          | Large (>250 workers)             | 16  | 20 | 1  |
|          | Prefer not to answer             | 1   | 1  | 0  |
|          | Missing                          | 4   | 5  | 0  |
| Q22      | Does this facility/operation provide group temporary (seasonal) housing to any of your employees? | Yes | No | No response |
|          | Yes                              | 9   | 67 | 3  |
|          | No                               | 67  | 85 | 4  |
|          | No response                      | 3   | 4  | 0  |
| Q24      | Does this facility/operation provide group transportation services (bus, truck, etc.) to employees to/from work? | Yes | No | No response |
|          | Yes                              | 8   | 68 | 3  |
|          | No                               | 68  | 86 | 4  |
|          | No response                      | 3   | 4  | 0  |
| Q31      | If in the future the available labor force in this facility/operation is affected by a COVID-19 outbreak, what short/mid-term solutions should be considered to maintain production? (check all that apply) | Extend the number of work hours for remaining workers | Backfill with emergency personnel from third-party companies | Backfill by reorganizing personnel in the same facility | No response |
|          | Extend the number of work hours for remaining workers | 59  | 28 | 48 |
|          | Backfill with emergency personnel from third-party companies | 75  | 35 | 61 |
|          | Backfill by reorganizing personnel in the same facility | 59  | 28 | 48 |
|          | No response                      | 7   | 9  | 0  |
| Q32      | To prevent labor shortage in this facility/operation due to a potential future COVID-19 outbreak, should capital investment into mechanization be considered as a long-term solution to maintain production? | Yes | No | No response |
|          | Yes                              | 57  | 13 | 9  |
|          | No                               | 13  | 16 | 9  |
|          | No response                      | 9   | 11 | 0  |
| Q43b     | What was the main reason for your choice to describe conditions and COVID-19 mitigation in this particular food production facility/operation? | I am mostly familiar with this facility/operation | This is our unique facility/operation | This is our typical facility/operation | This facility/operation has been impacted greatly by COVID-19 | This is our strategically important |
|          | I am mostly familiar with this facility/operation | 24  | 5  | 16 | 11 | 13 |
|          | This is our unique facility/operation | 10  | 6  | 20 | 14 | 16 |
|          | This is our typical facility/operation | 16  | 20 | 14 | 14 | 16 |
Table 4. Summary statistics for questions included in part 2 of the needs assessment survey

| facility/operation               | Q16<sup>h</sup> | Q18<sup>h</sup> | Q19<sup>i</sup> |
|----------------------------------|-----------------|-----------------|-----------------|
| How does this facility/operation operate? | Year-round 15 | Seasonally 2 | Grower and Processor 3 |
|                                  | Year-round 15 | Seasonally 2 | Grower and Processor 3 |
|                                  | No response 0 | No response 0 | No response 0 |
|                                  |                |                | Grower operation 0 |
| What role best describes this facility/operation? | Grower 2 | Packing House 2 | Processor facility 3 |
|                                  | Grower 2 | Packing House 2 | Processor facility 3 |
|                                  | Processor 4 | Processor 4 | Processor facility 3 |
|                                  | Grower and Field packer 5 | Grower and Field packer 5 | Grower and Processor 3 |
|                                  | Grower and Field packer 5 | Grower and Field packer 5 | Grower and Processor 3 |
|                                  | No response 0 | No response 0 | No response 0 |
|                                  |                |                | Grower operation 0 |
| Please select which part of your Grower and Processor operation will you describe in the remaining questions? | Processor facility 3 | Processor facility 3 | Processor facility 3 |
|                                  | No response 0 | No response 0 | No response 0 |

<sup>a</sup> Question (Q) number in the needs assessment survey.
<sup>b</sup> Participants were required to answer the question to continue the needs assessment survey.
<sup>c</sup> Two participants from the beef/pork industry were grouped in the “Other” category for statistical analysis.
<sup>d</sup> Participants’ provided responses for the “Other” industry sector (number responses): Food processing (2); Frozen fruits (2); Chocolate (1); Cereal (1); Co-packaging of shelf-stable products (1); Consumer packaged goods with fresh produce (1); Food manufacturing (1); Food service (1); Frozen produce (1); Manufacturing shelf-stable foods (1); Prepared food (1); Restaurants (1); Seafood (1); Spirits (1); Sugar (1); Vegetable processing (1). Additional 4 participants were grouped in the “Other” industry sector for statistical analysis: 1 participant who is an academic affiliated with the food industry and 3 participants who reported affiliation with all 4 sectors (i.e., Fresh produce, Dairy, Poultry, and Beef/pork).
<sup>e</sup> Participants’ provided responses for the “Other” main role within their organization (number responses): Quality assurance manager (3); Sales service (1); Affineur (1); Human resources director (1); Owner (1); Office manager (1); CEO (1); Emeritus professor (1); Grower (1).
<sup>f</sup> Participants’ provided responses grouped under the “Other” industry sector for the described facility/operation of the participant’s choice (number responses): Cleaning and sanitation (1); Restaurants (1); Chocolate (1); Prepared food (1); Food manufacturing (1); Shelf-stable products (2); Frozen Produce (1); CPG sauces (2); Cereal (1); Food processing (2); Beverage, spirits (1); Vegetable processing (1); Frozen fruits (2); Seafood (1); Sugar (1).
Additionally, one participant who answered “Other” specified working in all industry sectors.
<sup>g</sup> Original levels “Less than 10”, “10-49”, “50-99”, “100-249”, “250-499”, “500-999”, “1000-2000”, and “More than 2000” were grouped in the levels “Small” (1-49 employees), “Medium” (50-249 employees), and “Large” (>250 employees) based on criteria established by the Organisation for Economic Co-operation and Development (OECD).
<sup>h</sup> This question was only shown to 17 participants who selected the option “Fresh produce” in question Q15.
<sup>i</sup> This question was only shown to 3 participants who selected the option “Grower and Processor” in question Q18.

Table 4. Summary statistics for questions included in part 2 of the needs assessment survey (that asked about conditions and COVID-19 controls in a food production facility or...
operation of participant's choice), which were analyzed as interval variables (number of
survey participants =79).

| Q\(^a\) | Variable                                                                                                                                   | Number of responses | Mean | Median | IQR   | Range    | No response |
|--------|-------------------------------------------------------------------------------------------------------------------------------------------|---------------------|------|--------|-------|----------|-------------|
| Q26    | What is the largest percent reduction in the general production labor force that this facility/operation could withstand over a period of one week without reduction in the production capacity? | 66                  | 15   | 15     | 10-15 | 5-50\(^b\) | 13\(^c\)    |
| Q21    | What is the approximate proportion (%) of employees in this facility/operation that are between 50-69 years of age?\(^d\) | 66                  | 32   | 28     | 20-40 | 0-100    | 13          |
| Q21    | What is the approximate proportion (%) of employees in this facility/operation that are 70 years old or older?\(^d\)                      | 62                  | 3    | 1      | 0-5   | 0-17     | 17          |
| Q23    | Approximately what proportion (%) of employees in this facility/operation are provided with group temporary housing?\(^e\)              | 7                   | 49   | 35     | 35-70 | 10-100   | 2           |
| Q25    | Approximately what proportion (%) of employees in this facility/operation are provided with group transportation to/from work?\(^f\)     | 7                   | 40   | 28     | 15-63 | 10-90    | 1           |

\(^a\) Question (Q) number in the needs assessment survey

\(^b\) This was a single-choice question with available responses: 5%, 10%, 15%, 20%, 30%, 40%, 50%, and Do not know; thus, the observed range spanned the full range of possible responses.

\(^c\) Nine participants responded “Do not know” and were grouped with “No response” for analysis.

\(^d\) The original question asked about ‘50-69 years of age’ and ‘70 years or older’ but were separated here to more clearly indicate their values.

\(^e\) This question was only shown to 9 participants who selected “Yes” in question Q22: “Does this facility/operation provide group temporary (seasonal) housing to any of your employees?”.

\(^f\) This question was only shown to 8 participants who selected “Yes” in question Q24: “Does this facility/operation provide group transportation services (bus, truck, etc.) to employees to/from work?”.

| Table 5. Significant associations found in the bivariable analyses (p ≤ 0.05) between a specific Likert item (outcome) in a survey question (Q) and independent variables |  |
(predictors) describing “Industry sector” (Q1) and “Facility/operation size” (Q20) after post-hoc analysis and false discovery rate adjustment.

| Likert question (Q) | Predictor | Level* | Median* | IQR* |
|---------------------|-----------|--------|---------|------|
| Q5, Regarding control of COVID-19 in your industry sector, how concerning are the items below? | Limited financial resources Facility/operation size | Small<sup>a</sup> | 3.5 | 2-5 |
| | | Medium<sup>b</sup> | 2 | 2-3 |
| | | Large<sup>b</sup> | 2 | 1-3.3 |
| | Limited financial resources Industry sector | Dairy<sup>a</sup> | 2 | 1-3 |
| | | Fresh produce<sup>b</sup> | 3 | 2-4 |
| | | Other<sup>a,c</sup> | 3 | 2-4 |
| | Supplier management Facility/operation size | Small<sup>a</sup> | 3 | 3-5 |
| | | Medium<sup>a,c</sup> | 3 | 2-4 |
| | | Large<sup>c,b</sup> | 2 | 2-3.3 |
| Q9, Regarding needs to successfully mitigate COVID-19 in your industry sector, how important are the items below? | Easier way to understand regulations Industry sector | Dairy<sup>a</sup> | 4 | 3-4 |
| | | Fresh produce<sup>b</sup> | 5 | 3-5 |
| | | Other<sup>a,c</sup> | 3 | 2-4 |
| Q13, Regarding indicators of successful responses to COVID-19 in your industry sector, how important are the items below? | Established effective risk communication plan Facility/operation size | Small<sup>a</sup> | 3.5 | 3-4 |
| | | Medium<sup>a,b</sup> | 4.0 | 4-5 |
| | | Large<sup>c,b</sup> | 5.0 | 4-5 |
| Q29, Regarding potential sources of COVID-19 infection in this facility/operation, how concerning are the items below? | Indoor common areas Facility/operation size | Small<sup>a</sup> | 2.5 | 1-4 |
| | | Medium<sup>b</sup> | 4 | 3-4 |
| | | Large<sup>a,c</sup> | 3 | 2-4 |
| Q34, Have any of these social distancing strategies been applied in this facility/operation, at any point since the start of the COVID-19 pandemic? | | | | |

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| - **Installed physical barriers** | Facility/operation size | Small<sup>a</sup> | 0 | 0-0.6 |
|--------------------------------|-------------------------|------------------|------|--------|
|                                |                         | Medium<sup>b</sup> | 1   | 0.5-1  |
|                                |                         | Large<sup>b</sup>  | 1   | 0.5-1  |
| - **Staggered break times**    | Facility/operation size | Small<sup>a</sup> | 0   | 0-1    |
|                                |                         | Medium<sup>b</sup> | 1   | 1-1    |
|                                |                         | Large<sup>b</sup>  | 1   | 0.5-1  |
| - **Staggered arrival/departure times (staggered shifts)** | Facility/operation size | Small<sup>a</sup> | 0   | 0-0.5  |
|                                |                         | Medium<sup>b</sup> | 1   | 0-1    |
|                                |                         | Large<sup>b</sup>  | 0.5 | 0-1    |
| - **Adjusted sick day policy** | Facility/operation size | Small<sup>a</sup> | 0   | 0-1    |
|                                |                         | Medium<sup>b</sup> | 1   | 0.5-1  |
|                                |                         | Large<sup>a</sup>  | 0.8 | 0.5-1  |
| - **Spacing workers >6ft during production** | Facility/operation size | Small<sup>a</sup> | 0.5 | 0-0.5  |
|                                |                         | Medium<sup>b</sup> | 1   | 0.8-1  |
|                                |                         | Large<sup>b</sup>  | 1   | 0.5-1  |
| - **Spacing workers >6ft during production** | Industry sector | Dairy<sup>a</sup> | 1   | 1-1    |
|                                |                         | Fresh produce<sup>a,b</sup> | 0.5 | 0.5-1  |
|                                |                         | Other<sup>a,b</sup> | 1   | 0.5-1  |
| - **Cohorting employees**      | Facility/operation size | Small<sup>a</sup> | 0   | 0-0    |
|                                |                         | Medium<sup>b</sup> | 0.5 | 0-1    |
|                                |                         | Large<sup>a,b</sup> | 0.5 | 0-0.6  |

Q36. Have any of these employee biosafety strategies been applied in this facility/operation, at any point since the start of the COVID-19 pandemic?

- **Face mask, face shields, goggles** | Industry sector | Dairy<sup>a</sup> | 1   | 1-1    |
|                                |                         | Fresh produce<sup>b</sup> | 1   | 0.5-1  |
|                                |                         | Other<sup>a,b</sup> | 1   | 1-1    |

- **Air cleaning/filtering** | Facility/operation size | Small<sup>a</sup> | 0   | 0-0.1  |
|                                |                         | Medium<sup>b</sup> | 1   | 0-1    |
|                                |                         | Large<sup>a,b</sup> | 0.5 | 0-1    |

Q38. Have any of these surveillance strategies been applied in this facility/operation, at any point since the start of the COVID-19 pandemic?

- **Temperature screening and quarantine** | Facility/operation size | Small<sup>a</sup> | 0.3 | 0-1    |
|                                |                         | Medium<sup>b</sup> | 1   | 1-1    |
|                                |                         | Large<sup>a,b</sup> | 1   | 0.5-1  |

- **Contact tracing and quarantine** | Facility/operation size | Small<sup>a</sup> | 0   | 0-0.8  |
|                                |                         | Medium<sup>b</sup> | 1   | 1-1    |
|                                |                         | Large<sup>b</sup>  | 1   | 0.9-1  |

- **Contact tracing and quarantine** | Industry sector | Dairy<sup>a</sup> | 1   | 1-1    |
Other statistically significant associations found in this study are presented in S3 Table.

Different letters in superscripts indicate statistically significantly different levels. When two levels of a predictor have different superscript letters, it means that the Likert responses for an outcome variable were significantly different between the two levels of a predictor, while having the same letter means no evidence of significant difference. For example, in Q5, the responses to the underlying Likert item outcome “Limited financial resources” were significantly different between “Small” and “Medium”, as well as between “Small” and “Large” levels of the predictor “Facility/operation size” (indicated by different superscripts, a and b) but there was no evidence of difference between “Medium” and “Large” facilities/operations (indicated by the same superscript, b).

Median and interquartile range (IQR) calculated for the interval (1-5 in Q5, Q9, Q13, and Q29) and numeric values (0, 0.5 or 1 in Q34, Q36, and Q38) that were assigned to the Likert scale responses in each Likert item are included for comparison across facility/operation size and industry sector levels. For Q5 and Q29, values 1 to 5 represented “Not at all concerning” to “Extremely concerning”; while for Q9 and Q13, values 1 to 5 represented “Not at all important” to “Extremely important”. For Q34, Q36, and Q38, the value 0 represented “No” (not implemented), 0.5 represented “Yes, but only partially/temporarily, and 1 represented “Yes”.

Table 6. Themes identified in participants’ responses to selected open-ended questions in the needs assessment survey, the purpose of which was to provide depth to the corresponding Likert items questions.

| Likert question<sup>a</sup> | Corresponding open-ended question (Number (N) of responses) | Themes |
|-----------------------------|----------------------------------------------------------|--------|
| Q5                          | Q6, Regarding control of COVID-19 in your industry sector, are there any other concerns we should consider? (N=19) | Employee fatigue, vaccine hesitancy, health and healthcare access |
|                             |                                                          | Access to COVID-19 preventative measures, guidance and information; difficulties in implementation of mitigation strategies |
|                             |                                                          | Supply chain disruption and management of contractor expectations |
| Q7                          | Q8, Regarding the labor force needed to maintain the production capacity in your industry sector during the COVID-19 pandemic, are there any other challenges we should consider? (N=20) | Downside of COVID-19 mitigation strategies |
|                             |                                                          | Government benefits and regulations |
|                             |                                                          | Labor availability, needs, expectations and behavior |
| Q9                          | Q10, Regarding needs to successfully mitigate COVID-19 in your industry sector, are there | Technology to improve infection prevention, time efficiency and internet access |
|                             |                                                          | Cost-effective mitigation strategies, harmonized |
any other important needs we should consider? (N=8)

| Question |
|-----------------|
| Q32 Q33, To maintain production in the event of labor shortage in this facility/operation due to a potential future COVID-19 outbreak, are there any other solutions we should consider? (N=9) |
| Q34 Q35, For one or more of these social distancing strategies, could you share any reasons for adopting or not adopting it, such as cost, compliance by workers, training requirement, effectiveness in reducing health risks, impact on production capacity, and/or lack of science-based information? (N=12) |
| Q36 Q37, For one or more of these employee biosafety strategies, could you share any reasons for adopting or not adopting it, such as cost, compliance by workers, training requirement, effectiveness in reducing health risks, impact on production capacity, and/or lack of science-based information? (N=10) |
| Q38 Q39, For one or more of these surveillance strategies, could you share any reasons for adopting or not adopting it, such as cost, compliance by workers, training requirement, effectiveness in reducing health risks, impact on production capacity, and/or lack of science-based information? (N=10) |

| Guidance and prioritized vaccination of food industry workers |
|-----------------|
| Consumer education |
| Employee benefits and training |
| Industry collaboration, production adjustment and infrastructure changes |
| Infrastructure, productivity or Union imposed constrains |
| Lack of concern or need |
| Infrastructure constrains |
| Lack of funds, supplies or information |
| Lack of need |
| Cost of implementation |
| Increases worker absences |
| Lack of concern or need |

*a The complete wording of the Likert questions can be found in S1 Table.

The most common roles of the 79 participants in their organizations were corporate food safety and quality manager (29, 37%), followed by facility managers (21, 27%), and c-suite
executive (13, 16%) among others (Q2, Table 3). Most (67/79, 85%) indicated that COVID-19 has significantly impacted their industry sector. The most common ways COVID-19 has significantly impacted their industry sector was through major changes in operational staffing control and protection protocols (54/79, 68%), remote work of management or corporate employees (52/79, 66%), and reduced or cut back operations/production (38/79, 48%) (Q4, Table 3).

Participants’ chosen facilities/operations could withstand up to a median of 15% reduction of the production labor force over a week while still being able to maintain the full production capacity

The following results include responses from part 2 of the needs assessment, which asked about a facility or operation of participant’s choice (Tables 3 and 4). The most common reason for selecting a facility to describe in the survey was participant’s familiarity with the facility (24/79, 30%) (Q43, Table 3). In terms of the average number of employees in 2019, most participants (33/79, 42%) chose to describe a medium size-facility/operation (50-249 employees) (Q20, Table 3). The largest percent reduction in the general production labor force over a week that the participants’ facility/operation could withstand without reducing their production capacity had a median of 15% (IQR: 10%-15%; Q26, Table 4). Only 11% and 10% of the participants’ facilities/operations provided group temporary (seasonal) housing and transportation to employees, respectively (Q22 and Q24, Table 4). Regarding short/mid-term solutions to maintain production and prevent their facility/operation labor force from being affected in the event of a COVID-19 outbreak, most of the participants’ facilities and operations considered extending the number of work hours for remaining workers (59/79, 75%) and/or
backfilling by reorganizing personnel in the same facility (48/79, 61%) (Q31, Table 3). Most participants (57/79, 72%) agreed that capital investment into mechanization should be considered as a long-term solution to maintain production in the face of a future COVID-19-associated labor shortage (Q32, Table 3). Further, participants suggested employee- and production schedule adjustments as additional solutions to maintain production (thematic analysis of Q33, Table 6).

**Ever-changing government regulations and easier ways to understand these regulations as well as establishing risk communication plans were deemed important to participants for successful mitigation of COVID-19 in their industry sector**

Regarding the control of COVID-19 in their industry sector (Q5, Fig 1A), *Labor availability* and *Complex ever-changing government regulations* were considered very concerning (median score = 4) among the majority of participants. Conversely, *Workers’ abuse of control measures, Limited financial resources, and Product quality* were only slightly concerning (median score ≤ 2), according to most survey participants (Fig 1A). Kruskal Wallis tests showed that the reported concern for *Limited financial resources* was significantly higher in small compared to medium (*p* = 0.04) and large-sized facilities/operations (*p* = 0.04) and was also significantly higher in the fresh produce industry sector compared to dairy (*p* = 0.05; Table 5). Similarly, the reported concern for *Supplier management* was also significantly higher in small compared to large-sized facilities/operations (*p* = 0.03; Table 5). In response to the open-ended question about additional concerns regarding the control of COVID-19 in their industry sector, participants stated concerns related to employees, COVID-19 mitigation, and...
supply chain factors (thematic analysis of Q6, Table 6). Regarding employee’s mental health, a participant stated the following:

“Mental health impact on managerial and office staff. In talking with industry colleagues, my experience is that many facilities have cut back on the staff responsible for ensuring that the facility is operating in an efficient and structured manner, while expanding the production capacity of the facility. It leaves many of these employees in a position where they are stretched thin and feel overwhelmed.” Participant ID #75, Other (co-packaging of shelf stable products)

<Figure 1 here>

**Fig 1. Heatmaps representing responses to 5-point scale Likert questions regarding [A] concerns about COVID-19 control and [B] challenges to maintain production.** These Likert questions were included in part 1 of the needs assessment survey asking general questions about a participant’s industry sector. For each item within a Likert question, a median shown to the right of the heatmap was calculated from the interval values (1-5), assigned to answers ranging from “Not at all concerning” to “Extremely concerning” [A] and “Not at all challenging” to “Extremely challenging” [B].

Among challenges associated with the labor force needed to maintain the production capacity (Q7, Fig 1B), most participants perceived that all of the items presented to them were at least moderately challenging (median score ≥ 3), with the *Need to train labor, Access to workers with necessary skills, and Access to number of workers needed* being considered very
challenging (median score = 4). Additional challenges to maintaining the production capacity were related to the COVID-19 mitigation, employee and government factors (thematic analysis of Q8, Table 6). In particular, one participant expressed their frustration when dealing with continuously changing government regulations:

“Government directives and laws regarding labor, time off, and pay rules and the changes in these made managing government special rules a full-time job, rather than managing the pandemic we were managing the labor law compliance tasks.” Participant ID #45, Fresh produce.

In terms of the needs to successfully mitigate COVID-19 in their industry sector (Q9, Fig 2A), most participants indicated that Easier way to understand regulations was the most important (median score = 3.5), being valued as a more important need by the fresh produce industry compared to the dairy industry sector and the group of “Other” industry sectors ($p = 0.05$ and $p = 0.03$, respectively; Table 5). In the corresponding open-ended question participants further stated needs for improved technology solutions, mitigation strategies and consumer education (thematic analysis of Q10, Table 6).

< Figure 2 here>

**Fig 2. Heatmaps representing responses to 5-point scale Likert questions regarding the [A] needs to successfully mitigate COVID-19, [B] preferred features in predictive models, and [C] indicators of a successful response against COVID-19.** These questions were included in part 1 of the needs assessment survey asking general questions about a participant’s industry sector. For each item within a Likert question, a median shown to the right of the heatmap was
calculated from the interval values (1-5), assigned to answers ranging from “Not at all important” to “Extremely important”.

If a computational modeling tool were to be available to predict which COVID-19 mitigation strategies would be the most successful in a given facility (Q11, Fig 2B), all model features proposed in the survey (e.g., ease of use, confidentiality and customization, etc.) would be considered very important (median score = 4). Regarding the question about indicators of successful responses to COVID-19 in their industry sector (Q13, Fig 2C), participants perceived that almost all items listed in the question were very important (median score = 4), including establishment of contingency and risk communication plans, standard operating procedures, training, and investment into technologies that reduce vulnerability to a future pandemic (such as due to a new COVID-19 variant) or similar system wide disruption. Additionally, large-sized facilities and operations were more likely to have Established effective risk communication plans compared to smaller facilities and operations (Q13, \( p = 0.03 \), Table 5).

In terms of the risk of shutdown associated with the facility/operation due to work absences for certain specialized job functions (Q27, Fig 3A), participants indicated that Specialized production line functions, Engineering and/or maintenance crew, and Sanitation and cleaning presented a high risk of shutdown (median score = 4). Regarding potential sources of COVID-19 infection in the facility/operation (Q29, Fig 3B), participants were particularly concerned about Activities in the local community (median score = 4). In addition, respondents from medium-sized facilities/operations were more likely to be concerned about Indoor common areas as a potential source of COVID-19 compared to small and large-sized facilities/operations (Q29, \( p = 0.04 \) and \( p = 0.05 \), respectively; Table 5).
Fig 3. Heatmaps representing responses to 5-point scale Likert questions regarding [A] the risk of shut down due to absenteeism of employees with specialized job functions and [B] sources of COVID-19 in the work environment. These Likert questions were included in part 1 of the needs assessment survey that asked about conditions and COVID-19 controls in a facility or operation of a participant’s choice. For each item within a Likert question, a median shown to the right of the heatmap was calculated from the interval values (1-5), assigned to answers ranging from “No risk” to “Very high risk” [A] and “Not at all concerning” to “Extremely concerning” [B].

Survey participants self-reported a widespread implementation of social distancing, biosafety, and surveillance mitigation strategies in their facilities/operations representing different sectors of the food industry.

Among social distancing measures (Q34, Fig 4A), Installed Physical barriers, Staggered break times, Adjusted sick day policy, and Spacing workers >6 ft during production were all implemented or partially/temporarily implemented by most facilities/operations, followed by Staggered shifts which were adopted or partially/temporarily adopted by about half of the participants’ facilities/operations. Downsizing operations and Cohorting employees were found to be the least implemented social distancing strategies to mitigate COVID-19 transmission (Fig
Small facilities/operations implemented several social distancing strategies significantly less frequently than medium- and large-sized facilities and operations, including installing of physical barriers ($p = 0.005$ and $p = 0.005$, respectively), staggered break times ($p < 0.001$ and $p = 0.004$, respectively), and staggered shifts ($p = 0.02$ and $p = 0.04$, respectively; Q34, Table 5). In addition, medium-sized facilities and operations were more likely to adopt Adjusted sick day policy ($p = 0.003$) and Cohorting employees ($p = 0.02$) as one of their social distancing strategies compared to small-sized facilities and operations (Q34, Table 5). In addition, dairy facilities were more likely to adopt Spacing workers >6ft during production ($p = 0.05$) compared to facilities/operations from the group of “Other” industry sectors (Q34, Table 5). The responses to the corresponding open-ended question revealed that infrastructure, productivity, and union-imposed constraints as well as the perceived lack of need or concern were reasons for non-implementation of social distancing measures (thematic analysis of Q35, Table 6). For example, in the following quote one of the participants expressed a concern about downsizing the operation as a strategy to contain the infection spread:

“If the plant does not run near full production, we are out of business.” Participant ID #56, Dairy.

Fig 4. Responses to questions about the implementation of social distancing [A], biosafety [B], and surveillance strategies [C] in a facility/operation of participant’s choice. For each specific mitigation strategy, a median shown to the right of the heatmap was calculated from the
numerical values, 0, 0.5 and 1, assigned to answers ‘No’, ‘Yes, but only partially’, and ‘Yes’, respectively.

Enhanced handwashing, Alcohol-based hand rubs, and Face mask, face shields, goggles, were the most implemented biosafety strategies among facilities/operations (Q36, Fig 4B). The latter strategy was implemented more in facilities/operations in the dairy and “Other” industry sector group compared with the fresh produce sector (Q36, $p = 0.002$ and $p = 0.05$, respectively; Table 5). Air cleaning/filtering was implemented or partially/temporarily implemented in a little more than half of the facilities/operations, with medium-sized facilities and operations being more likely to adopt it compared to small facilities and operations (Q36, $p = 0.01$; Table 5).

Meanwhile, less than half of the facilities and operations adopted Increased ventilation rates as a biosafety measure to mitigate COVID-19 transmission (Q36, Fig 4B). The responses to the corresponding open-ended question indicated that where biosafety interventions were not implemented, it was due to infrastructure constrains or lack of funds, lack of supplies or information, or due to the perceived lack of need (thematic analysis of Q37, Table 6).

Among surveillance strategies (Q38, Fig 4C), Temperature screening and quarantine, Return to work post recovery policy, and Contact tracing were commonly adopted among facilities and operations, while Test for infection and isolation was less frequently implemented than the rest of the surveillance strategies based on the comparison of medians of Likert responses. Contact tracing and quarantine ($p < 0.001$), Temperature screening and quarantine ($p = 0.006$), and Return to work post recovery policy ($p = 0.002$) were more commonly adopted in medium-sized compared to small facilities/operations (Q38, Table 5). Contact tracing and quarantine were also more commonly implemented in large-sized compared to small
facilities/operations ($p < 0.001$). Additionally, dairy facilities more commonly adopted Contact tracing and quarantine as a surveillance measure compared to the fresh produce sector ($Q38, p = 0.02$; Table 5). The responses to the corresponding open-ended question stated the cost of implementation and the caused increase in worker absences, as well as the perceived lack of concern or need, as the reasons for no implementation of surveillance strategies (thematic analysis of Q39, Table 6). For example, two participants expressed challenges due to increased absences when implementing temperature screening as a surveillance strategy:

“Temperature screenings aren’t sufficient, as they aren’t always going to detect a mild case. Temperature gun is 30 to 60 dollars. On site Covid tests are borderline unavailable to small and medium sized companies.” Participant ID #56, Dairy.

“We do daily employee temperature readings but have had to isolate many employees for symptoms other than low grade fevers such as backaches, coughing, fatigue, etc.” Participant ID #46, Fresh produce.

**Discussion**

This study aimed to identify the needs of the US food industry to maintain production and assure workers’ health during the COVID-19 pandemic and to determine what mitigation strategies are being implemented. Information on this matter is crucial to determine both how the US food industry has already responded to the pandemic and what is still required to enhance its resilience in the face of current and future similar disaster events. The main findings from this study suggest that for the represented sectors of the US food industry: (i) mitigation strategies have been widely implemented in facilities and operations of those who answered our survey, except strategies that reduce productivity, involve major costs, or/and had insufficient
information on cost-effectiveness; (ii) facility/operation size and industry sector may impact decision-making regarding implementation of COVID-19 mitigation strategies; and (iii) there are remaining challenges and opportunities to reduce future impacts of COVID-19 and similar disasters. These findings will be discussed in the following paragraphs.

Before discussing these findings, it is important to consider that survey responses were collected from January 2021 to April 2021, a period in which COVID-19 cases in the US food industry were still occurring but there was a declining trend [18]. Additionally, during this time vaccines were becoming available in the US and access was prioritized for essential non-healthcare workers [29], including food industry employees, and the percentage of fully vaccinated people among those eligible ranged from 0 to 21% during that period [30]. Thus, results presented in this study reflect the state of the US food industry sectors in terms of needs and regarding the impact of COVID-19 pandemic on the workforce, food production, and regarding implementation of COVID-19 mitigation in early 2021.

The US produce growers and food processors widely implemented mitigation strategies except those that would have had negative effects on the production capacity, those that required major investments, and/or those with insufficient information on cost-effectiveness.

The study participants self-reported adopting most social distancing mitigation strategies included in the survey, while those measures that negatively impacted production capacity were scarcely adopted. The widespread adoption of most social distancing strategies across assessed
food industry sectors is not surprising given such strategies’ well-established key role in reducing the occurrence of COVID-19 cases in different work settings [31] and countries [32].

The continuous promotion of such measures since the beginning of the COVID-19 pandemic, as well as the availability of updated guidance on how to implement them, likely facilitated their adoption by food facilities and operations [22,33]. For example, a COVID-19 outbreak that occurred in a Colorado mushroom farm on May 6, 2020, was rapidly controlled and further viral dissemination was prevented based on available public health guidance [34]. Additionally, we hypothesize that the common adoption of social distancing mitigation strategies may be partly due to the availability of funding programs launched by the US federal government to financially assist businesses during the pandemic. These programs include the Coronavirus Aid, Relief, and Economic Security Act (CARES Act), the COVID-19 Economic Injury Disaster Loan, and the Coronavirus Food Assistance Program (CFAP), which provided food facilities and operations with financial resources to implement social distancing [35–38]. Despite this, survey participants expressed concerns about financial challenges that limited their ability to install physical barriers, suggesting that additional sources of funding are necessary to further incentivize the adoption of such measures and that companies need to budget in advance for emergency preparedness and responses. Overall, findings from this study suggest that the common adoption of social distancing strategies and the current availability of detailed guidance for their implementation will contribute to rapid implementation of social distancing controls in response to new SARS-CoV-2 beta-coronavirus variants in the current pandemic, future COVID-19 pandemics, and similar disasters. Additionally, our findings address the gap in terms of currently limited information available [15] about the adoption of mitigation strategies in the US food industry. However, it is important to note that representation for the beef/pork and poultry
industries was barely achieved in our study, thus future studies on COVID-19 adoption of social
distancing mitigation strategies in the US poultry and meat industry sectors are required to
complement and update the information reported by Waltenburg [15].

At the same time, our survey revealed that social distancing measures based on cohorting
employees and in particular, downsizing operations, were rarely implemented. Intuitively, this
may be because businesses avoid strategies that would reduce production capacity or present
organizational disruption [39]. Despite findings in this study, downsizing was an option for some
businesses during the COVID-19 pandemic to prevent further dissemination of the virus in cases
of facility/operation’ outbreaks, even in late 2020 [11]. For instance, capacity reduction in the
Canadian beef/pork industry led to financial setbacks to the business and in turn increased the
cost to maintain animals for an extended period before slaughter [11]. It has been reported that
downsizing operations as well as the increase in sickness-related absences caused an increase in
work-related physical demands and job insecurity, which had negative impacts on employees’
mental health [40]. This is relevant to consider, given that one survey participant in this study
expressed food industry employees’ struggles with mental health issues after downsizing,
particularly due to facilities and operations cutting back management and office staff while
distributing the same weight of responsibilities to a smaller workforce. Thus, if
facilities/operations plan on adopting, or are forced to adopt, downsizing as a strategy to reduce
COVID-19 transmission, measures should be taken not only to prevent downstream food supply
disturbances and production losses to the facility but also to protect employees’ mental
wellbeing. Further studies are needed to determine the specific economic and other effects of
downsizing on the US food industry facilities/operations and their workers prior to and during
the COVID-19 pandemic.
Cheap and easy to implement biosafety mitigation strategies were widely adopted by the survey participants’ produce farm operations and food processing facilities, but more information is needed about cost-effectiveness for air cleaning and air filtering/ventilation. The self-reported use of personal protective equipment (PPE) observed in our study agrees with an earlier report from Waltenburg [15], in which 86 out of 111 (77%) of the meat and poultry processing facilities required workers to wear masks. However, this is in contrast with findings by Yung et al. [25], who indicated that between June and July 2020, only a little more than half (20/37, 54%) of consulted dairy farmers in Wisconsin and Minnesota believed that face masks are being used by workers after the COVID-19 pandemic had started. The authors explain that this moderate use of PPE was due to a perceived safeness against COVID-19 transmission in well-ventilated spaces, and because of the difficulties of using such protection in the hot and humid environment of a dairy farm [25]. The discrepancy in findings between Yung et al. [25] and our study could be because the latter assessed dairy processing facilities rather than dairy farms, and targeting the dairy industry in the US instead of being restricted to Wisconsin and Minnesota. Furthermore, survey participants in the current study mentioned that the lack of access to preventative measures, including PPE, was an important concern in efforts to control COVID-19 in their industry sector. Previous reports indicate that the unavailability of supplies early in the COVID-19 pandemic was a severe challenge for businesses, even for front-line essential workers in healthcare institutions in the US [41] and abroad [41,42]. This shortage in PPE and other hygiene supplies was a consequence of disruptions in the PPE supply chain in the US [43] and elsewhere, whose weaknesses were exposed during this pandemic [44]. The survey findings about the lack of access to preventative measures strongly suggest that establishing a reliable and efficient system to ensure PPE availability and distribution to food facilities/operations is essential for the success
of disaster preparedness plans against future pandemics. Altogether, our findings suggest that
sectors of the food industry represented in the survey are prepared to implement biosafety
strategies in the event of a new variant of the SARS-CoV-2 beta-coronavirus, future COVID-19
pandemics or similar disasters caused by airborne-transmitted pathogens, although the success in
their adoption will strongly depend on the establishment of measures to strengthen the local and
global supply chain of PPE and other relevant resources.

Contrary to other biosafety strategies, the current study revealed that air filtering and
ventilation were scarcely implemented among facilities/operations (at least as of early 2021) due
to the lack of or insufficient information about cost-effectiveness and guidance. These findings
are somewhat unexpected considering that ventilation and air filtering have been recommended
in late 2020 by the CDC as engineering controls (i.e., measures that do not interfere with
employees’ work but prevent their interaction with COVID-19) intended to reduce airborne
concentrations of SARS-CoV-2 beta-coronavirus in indoor environments [22]. Moreover, poor
air quality and air flow inside meat and poultry processing plants have been associated with an
increased risk of workers becoming infected with COVID-19 [24]. Reasons for not
implementing air filtering expressed by survey participants include the disruption of the
controlled environmental conditions required for production, consideration of air filtering as an
unnecessary investment when other mitigation strategies are already in place, and the lack of
guidance in how to properly apply this strategy. The CDC recognizes the challenges associated
with the application of ventilation as a COVID-19 control strategy [22]. Installing air filtering
and ventilation systems is indeed a more complex process compared to other recommended
biosafety strategies to combat COVID-19 since it requires consideration of several additional
factors before their implementation, including the selection of systems adequate to the size,
occupancy level, and specific facilities’ features (e.g., production environment) [45]. Because of the complexity of installing air filtering and ventilation systems [22], and the ongoing discussion about the effectiveness of some of these methods in collecting and/or removing viral particles in the air [46], we hypothesize that facility management might favor other, easier to implement and more commonly advised control strategies to prevent COVID-19 transmission. The survey findings highlight the importance of further research and guidance about the implementation of air filtering and ventilation and the advantages in terms of cost-effectiveness they present over other mitigation measures.

Surveillance strategies were widely implemented by the participants’ produce grower operations and food processor facilities/operations with the exception of testing and isolation due to the cost of detecting positive cases of COVID-19. This finding is not surprising considering that both contact tracing and testing, in conjunction with quarantine, have been proposed as useful methods to prevent COVID-19 transmission in the community [47,48]. These methods have also been promoted by the CDC and OSHA as ways to reduce COVID-19 dissemination in the workplace [33,49]. Indeed, an early report of mitigation strategies used in the food industry pointed out temperature screening as a widely applied method in the US poultry and meat industry sectors [15], and it is currently being recommended by the CDC to be implemented in the food industry facilities and operations [20]. Nonetheless, some survey participants mentioned difficulties in implementing surveillance mitigation strategies due to funding limitations; this is expected as a significant investment is required to continuously test suspected cases among employees and temporarily remove positives from the workforce. Our findings suggest that the US food industry is willing to apply surveillance measures to prevent further transmission of COVID-19 cases in their facilities/operations and underline the need to improve access to these
measures and to strategically apply them to avoid increasing the costs associated with absenteeism and productivity loss.

Regarding temperature screening, some survey participants expressed distrust to use it as an approach to detect mild cases of COVID-19 infection, a topic that has been a matter of discussion throughout the pandemic [50–53]. Slade and Sinha [51] identified issues associated with temperature screening through non-contact infrared thermometers, namely the risk of close interaction between the employees and testers when measuring temperature, the variability in measurements due to lack of training in its application, and the costs associated with hiring employees to continuously measure temperature among workers. Additionally, previous reports have suggested poor specificity [54,55] and sensitivity [56] of temperature screening (both infrared thermometers and thermal imaging cameras) when used to detect mild COVID-19 cases, which results in many false positives, thus leading to an unnecessarily increased absenteeism and the associated rise in costs due to productivity loss. Chen et al. [55] found that specificity for infrared thermometers can range between 61% to 67%, depending on the part of the body being measured (wrist and forehead, respectively). This is an extremely important drawback for labor-intensive sectors of the food industry, which rely on the availability of qualified workers to continue food production. It was proposed that temperature screening has been a valuable and easy to implement tool to reduce COVID-19 cases, particularly at the beginning of the pandemic when the knowledge about the virus and the effectiveness of preventive methods and available guidance was limited [57,58]. However, given the issues associated with this strategy, the increased access to vaccination against COVID-19, and the widespread implementation of other controls in the food industry, we believe it relevant to reevaluate the current role and contribution of temperature screening as a surveillance strategy and how it should be implemented (if its
implementation is needed at all) to avoid increasing absenteeism among workers. Ideally, surveillance methods should be adopted based on tests’ availability, ease of implementation, and accuracy. For the application of temperature screening, maximizing specificity would be crucial to avoid the costs associated with false-positive cases. This can be achieved by raising the cut-off value used to define a positive case (increasing the temperature cut-off), establishing more stringent criteria for diagnosis of COVID-19 cases (e.g., presence of COVID-19 symptoms, recent exposure to the virus through interaction with infected individuals, or the requirement of follow-up testing for confirmation of suspected individuals), or applying temperature screening in series with a second highly specific diagnostic test.

Large and medium-sized food industry facilities/operations have better ability to implement mitigation strategies compared to small businesses. Additionally, there are differences among the dairy and fresh produce industry sectors in their needs and adoption of mitigation strategies.

Large and medium-sized facilities/operations of survey participants more frequently implemented social distancing, biosafety, and surveillance mitigation strategies compared to small businesses. It is also important to consider that, due to scale economies, implementing mitigation strategies might lead to a greater reduction in production capacity for smaller businesses than for larger ones, resulting in greater economic losses that cannot be sustained by those small businesses, as evidenced by studies pointing out their lack of financial resilience to sustain the impacts of COVID-19 [59,60]. For example, the implementation of complex
measures, such as air cleaning/filtering, which entail high fixed costs, is likely to be economically infeasible or even unnecessary for operations that consist of only a few employees.

Findings from the survey reveal that small facilities/operations are more commonly concerned about funding, while participants also mentioned that small facilities/operations struggle to manage COVID-19 related work absences and that better financial support is required to assist small to medium-sized businesses. Because small businesses typically lack access to the types of financial resources readily available to large firms (i.e., institutional funding), research has been directed to develop cutting-edge and low-cost technologies to assist them in responding to the COVID-19 pandemic [61,62]. Our findings suggest that small food industry facilities and operations would benefit from development of low-cost, effective, and flexible mitigation strategies to help maintain production in their operations during the COVID-19 pandemic.

We found that participants’ facilities from the dairy industry sector more commonly adopted specific biosafety and surveillance mitigation strategies compared to the fresh produce industry sector, while the latter was more likely to be concerned about funding and required easier approaches to understand continuously changing governmental regulations. We hypothesize that the comparatively lower adoption of PPE in the fresh produce industry is due to some operations (farms) being conducted outdoors in the field, in which case the use of goggles and face shields might prevent employees from performing their tasks efficiently. Indeed, in contrast to dairy processing plants, the decentralized nature of the fresh produce industry coupled with the significant heterogeneity in operating practices suggest that not all mitigation strategies may be appropriate for some operations. Additionally, reduced implementation may be due to the fact that transmission risk of COVID-19 outdoors is considered lower than indoors. Differences may also exist in how consistently both industry sectors can access mitigation
strategies, as survey participants from the fresh produce sector expressed concerns about funding limitations. Moreover, our survey findings indicate that the fresh produce industry sector also needed easier approaches to understand the continuously evolving governmental regulations, potentially due to the continuous turnover of workers that are incorporated into the workforce seasonally. These findings reveal important differences in terms of challenges and needs of the dairy and fresh produce industries and further suggest that innovative approaches are needed for fresh produce operations to overcome the limitations in PPE use, as well as develop novel strategies to train the newly recruited workforce more efficiently.

To reduce the US food industry’s vulnerability, it is important to establish plans and guidelines to minimize business interruptions, train the workforce about risk and mitigation strategies, and develop new technologies to face COVID-19-related disruptions

The survey participants considered the establishment of plans and guidelines as very relevant for reducing the impact of current and future COVID-19 outbreaks. These approaches would enhance industries’ ability to effectively respond to current and future disruptions in a timely manner, considering the consequences of the COVID-19 pandemic in the US food industry, particularly at the beginning of the pandemic [6]. Our findings are consistent with a previous study calling for the food industry to proactively establish plans and mitigation strategies to assist in building resiliency and ensuring the correct continuation of the productive process [63]. This supports the idea that the development of plans and guidelines to prevent future impacts of the COVID-19 pandemic and similar disasters should be established taking into consideration the complexity of the food supply chain. More specifically, government and
businesses should develop contingency plans to be prepared to effectively address workforce reduction, economic losses, and facility shutdowns as consequences of the simultaneous effects of dramatic changes in products’ demand [64,65], modifications to products’ specifications (e.g., package size) [64,65], government-mandated suspension of operations [64,65], and facility shutdown-related increase in work absences [6].

The survey participants also acknowledged the importance of training employees in risk and mitigation strategies to prevent COVID-19 transmission in their food facilities and operations. This finding was expected given that training has been a fundamental tool to educate the workforce on how to behave during the pandemic, correctly implement mitigation strategies, and understand the current state and federal rules and regulations around the COVID-19 pandemic. Guidelines and training resources made available by the CDC and OSHA have been useful to train employees in the use of PPE, social distancing practices in the workplace, and identification of signs and symptoms associated with COVID-19 cases. Importantly, ensuring access to the internet in facilities and operations located in remote areas is also crucial to allow them to implement training strategies promptly, a need expressed by survey participants. This is essential if novel technologies, such as augmented and virtual reality, are to be implemented for training the workforce on disaster preparedness [66]. Previous reports evidence important advantages of these novel approaches compared to traditional methods for training, including the opportunity to socially distance while allowing workers to immerse themselves in the activity at hand and learn effectively [67].

The development of new technological approaches to respond to the COVID-19 and future pandemic events (e.g., due to new SARS-CoV-2 beta-coronavirus variants) was considered important by the survey participants. The COVID-19 pandemic has resulted in new
technologies being developed at an accelerated pace to promptly assist the food industry in dealing with the COVID-19 pandemic and beyond [66]. Future advances in digitalization and big data analysis will assist the food industry in rapidly responding to COVID-19-related or other similar disruptions through improved access to knowledge for decision-making [5]. For instance, the design of modeling tools to predict impacts of COVID-19, including costs associated with absenteeism, effects on productivity, and the cost-effectiveness of implementing available mitigation strategies would provide useful information to assist the food industry in better managing the ongoing pandemic. Furthermore, improvements in data collection and management, such as shared access to data and data traceability, can facilitate relevant improvements in the efficiency of the food supply chain, while the implementation of automation and robotics technologies could assist in improving food security and facilitate the adoption of social distancing measures to prevent airborne pathogen transmission [5,65]. Unquestionably, the development of new technologies will assist in building resilience to withstand COVID-19-related disruptions in the US food industry. Nonetheless, we suggest that the implementation of novel technological approaches must consider maintaining previous efforts made by the industry sector to improve efficiency, as well as consider the financial investment necessary to implement technological advances, such as automation [6,68]. Further studies are needed to determine the specific technological requirements across industry sectors in the US, the ability of food industry sectors to invest in new technologies, and the mechanisms in which these new advances could contribute to improving resilience in the industry.

**Study limitations**
The major limitation of the conducted needs assessment survey is relatively low number of responses received, and the associated potential selection bias, despite the engagement of a number of professional and trade organizations and the distribution of the survey via social media. The concurrent widespread application of survey-based studies to understand different aspects of COVID-19 in the US food industry might have resulted in the industry’s fatigue and increased reluctance to respond to surveys as the pandemic progresses, particularly given that the survey designed for this study was distributed more than a year after the pandemic has begun. This is relevant, as it may have introduced a non-response selection bias to findings presented here, particularly due to the slim response rate from representatives of the beef/pork and no responses from the poultry sectors. Thus, any generalization of findings to these sectors should be done with caution. The reasons for differential participation of the food industry sectors in this study are unknown. Among responses, almost half were from the dairy industry sector, with a much lower representation from the fresh produce industry sector. Similarly, in line with the targeted recruitment efforts, responses were predominantly from individuals in high managerial positions (c-suite, facility managers, etc.), with only a few responses from non-managerial positions. Although this potentially limits the range of perspectives included in the study, opinions, and perceptions from individuals ‘at the top of the ladder’ were targeted because they can provide valuable insight into facilities and operation’s needs, challenges, decisions, and overall impacts of the COVID-19 pandemic in the US food industry. However, we recognize that this study does not include the complete spectrum of worker positions (particularly non-managerial) and therefore not fully address food industry worker needs. Due to the relatively small number of responses, more elaborate approaches to control for potential confounding of the associations between the outcomes and predictors of interest could not be conducted.
Considering Likert-item responses as interval/numerical data during statistical analysis led to the application of non-parametric methods for statistical assessment of associations, which are less efficient for detecting existing effects than parametric tests. The survey was open for participation for almost 3 months in early 2021, which was a time characterized by great changes concerning the response to the COVID-19 pandemic in the US, such as the implementation of COVID-19 vaccination among essential non-healthcare workers. It is possible that some of those changes may have affected participants’ responses depending on when they completed the survey and might not represent needs of the US food industry and adoption of mitigation strategies early in the COVID-19 pandemic. Additionally, although in open-ended questions participants commented about concerns regarding limited access to COVID-19 vaccines for food industry employees and their vaccination hesitancy, the survey did not include questions about vaccination because vaccines were not available at the time the pilot process was finished and the survey was initially distributed. Thus, timely assessment of the food industry needs regarding COVID-19 vaccination is still needed. Finally, although information about COVID-19 morbidity and mortality in the participants’ facilities and operations could have provided valuable insights, we chose to exclude those to improve the response rate.

Conclusions

Provided that the responses of survey participants are reflective of the wider US food industry, the food industry facilities and operations in the US are broadly prepared to protect their workers and businesses quickly and effectively in the event of a future pandemic due to SARS-CoV-2 or similar airborne pathogens. Future collaborations between the US food industry and federal and state agencies to establish contingency plans and define appropriate training, as
well as the development of food industry-directed technologies will be crucial to build resilience against future COVID-19-related and similar disturbances.

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S1 Table. All questions (Q) included in the needs assessment survey, question type, type of analysis (statistical or thematic) and role in statistical analysis of associations (as an outcome of interest (primary or secondary) or independent variable (predictor). Responses considered usable for analysis were those in which participants completed at least part 1 of the needs assessment survey.

S2 Table. Themes and underlying codes identified in participants’ responses to selected open-ended questions in the needs assessment survey, which were intended to provide depth to the corresponding Likert questions. An example quote is included to illustrate each of the codes identified.

S3 Table. Significant associations found in the bivariable analyses (P ≤ 0.05) using Mann-Whitney U (MW-U) and Spearman’s correlation (SC) tests between a specific Likert item (outcome) in a survey question (Q) and independent variables (predictors).

S1 Appendix. Copy of the needs assessment survey instrument.
Q5. Regarding control of COVID-19 in your industry sector, how concerning are the items below?

| Item                                      | Not at all concerning | Slightly concerning | Moderately concerning | Very concerning | Extremely concerning | Median score |
|-------------------------------------------|-----------------------|---------------------|-----------------------|-----------------|-----------------------|--------------|
| Complex/ever-changing government regulations about COVID-19 | 2                     | 8                   | 22                    | 19              | 25                    | 4            |
| Labor availability                        | 3                     | 7                   | 14                    | 26              | 27                    | 4            |
| Customer expectations                     | 13                    | 18                  | 21                    | 14              | 12                    | 3            |
| Supplier management                       | 6                     | 20                  | 23                    | 11              | 16                    | 3            |
| Production capacity                       | 11                    | 13                  | 26                    | 17              | 9                     | 3            |
| Organizational awareness of the virus     | 18                    | 9                   | 13                    | 17              | 19                    | 3            |
| Workers’ compliance with control measures | 6                     | 19                  | 20                    | 16              | 15                    | 3            |
| Limited financial resources               | 16                    | 24                  | 16                    | 12              | 9                     | 2            |
| Workers’ abuse of control measures        | 15                    | 24                  | 12                    | 13              | 13                    | 2            |
| Product quality                           | 39                    | 14                  | 13                    | 7               | 5                     | 1.5          |

Q7. Regarding the labor force needed to maintain the production capacity in your industry sector during the COVID-19 pandemic, how challenging are the items below?

| Item                                      | Not at all challenging | Slightly challenging | Moderately challenging | Very challenging | Extremely challenging | Median score |
|-------------------------------------------|------------------------|----------------------|------------------------|------------------|-----------------------|--------------|
| Need to train labor                       | 5                      | 16                   | 19                     | 25               | 12                    | 4            |
| Access to workers with necessary skills   | 8                      | 11                   | 20                     | 24               | 14                    | 4            |
| Access to number of workers needed        | 7                      | 11                   | 18                     | 24               | 17                    | 4            |
| Sufficient housing for labor              | 26                     | 11                   | 10                     | 10               | 6                     | 3            |
| Turnover in workforce                     | 10                     | 18                   | 21                     | 16               | 12                    | 3            |
### A. Q9. Regarding needs to successfully mitigate COVID-19 in your industry sector, how important are the items below?

| Item                                                                 | Median score |
|----------------------------------------------------------------------|--------------|
| Easier way to understand regulations                               | 3.5          |
| Better information on cost effectiveness of COVID-19 mitigation strategies | 3            |
| Better and cheaper testing technologies                            | 3            |
| Better technologies to assure social distancing                     | 3            |
| More and better training                                            | 3            |
| Training materials in more languages                               | 2            |

### B. Q11. If computational modeling tools were available to predict which COVID-19 mitigation strategies would most likely be successful in a given facility/operation at a given time, how important would the model features below be for your industry sector?

| Model Feature                                                      | Median score |
|-------------------------------------------------------------------|--------------|
| Ability to customize the model for use in a specific facility    | 4            |
| Ability to use the model confidentially                           | 4            |
| Ease of model use by company personnel                           | 4            |
| Ability of the model to predict infection risk reduction          | 4            |
| Ability of the model to predict initial and ongoing cost of implementation | 4            |
| Ability of the model to predict impact on production capacity    | 4            |

### C. Q13. Regarding indicators of successful responses to COVID-19 in your industry sector, how important are the items below?

| Indicator                                                                 | Median score |
|--------------------------------------------------------------------------|--------------|
| Workforce related contingency plans updated to minimize COVID-19 related business interruptions | 4            |
| Investment made into technologies that reduce vulnerability to a future pandemic or similar system wide disruption | 4            |
| Established effective risk communication plan                           | 4            |
| Standard operating procedures/checklists are in place for mitigation of COVID-19 impacts | 4            |
| Workforce trained about COVID-19 risks and mitigation                   | 4            |
| Digital technologies utilized in planning of facility specific COVID-19 mitigation | 3            |
Q27. How would you describe the risk of a shutdown in this facility operation due to work absences in each of the specialized job functions below?

| Job Function                          | No risk [1] | Low risk [2] | Moderate risk [3] | High risk [4] | Very high risk [5] | Median score |
|---------------------------------------|-------------|--------------|-------------------|---------------|-------------------|--------------|
| Engineering and/or maintenance crew   | 1           | 9            | 21                | 18            | 19                | 4            |
| Sanitation and cleaning               | 3           | 14           | 19                | 21            | 16                | 4            |
| Specialized production line functions | 3           | 9            | 18                | 28            | 13                | 4            |
| Lab personnel                         | 3           | 17           | 17                | 13            | 9                 | 3            |
| Quality control and assurance         | 6           | 20           | 19                | 14            | 12                | 3            |
| Supervisors                           | 2           | 13           | 30                | 21            | 5                 | 3            |

Q29. Regarding potential sources of COVID-19 infection in this facility/operation, how concerning are the items below?

| Source of Infection                  | Not at all concerning [1] | Slightly concerning [2] | Moderately concerning [3] | Very concerning [4] | Extremely concerning [5] | Median score |
|--------------------------------------|---------------------------|-------------------------|---------------------------|---------------------|--------------------------|--------------|
| Activities in the local community    | 6                         | 11                      | 14                        | 21                  | 21                       | 4            |
| Production line                      | 10                        | 21                      | 25                        | 10                  | 6                        | 3            |
| Common production tools/equipment    | 11                        | 22                      | 21                        | 13                  | 6                        | 3            |
| Indoor common areas                  | 6                         | 13                      | 19                        | 25                  | 9                        | 3            |
| Employee transportation conditions   | 28                        | 11                      | 8                         | 10                  | 6                        | 2            |
| Employee housing conditions          | 28                        | 11                      | 7                         | 8                   | 8                        | 2            |
| Outdoor common areas                 | 33                        | 21                      | 10                        | 4                   | 4                        | 2            |
Q34. Have any of these social distancing strategies been applied in this facility/operation at any point since the start of the COVID-19 pandemic?

| Strategy                                      | No | Partially/temporarily | Yes |
|-----------------------------------------------|----|------------------------|-----|
| Spacing workers >6ft during production       | 11 | 15                     | 47  |
| Adjusted sick day policy                     | 15 | 17                     | 41  |
| Staggered break times                        | 13 | 9                      | 51  |
| Installed physical barriers                  | 16 | 20                     | 37  |
| Staggered arrival/departure times (staggered shifts) | 28 | 11                     | 34  |
| Cohorting employees                          | 37 | 16                     | 20  |
| Downsizing operation                         | 54 | 14                     | 5   |

Q36. Have any of these biosafety strategies been applied in this facility/operation at any point since the start of the COVID-19 pandemic?

| Strategy                                      | No | Partially/temporarily | Yes |
|-----------------------------------------------|----|------------------------|-----|
| Face mask, face shields, goggles             | 2  | 5                      | 66  |
| Alcohol-based hand rubs                       | 4  | 6                      | 63  |
| Enhanced handwashing                          | 6  | 3                      | 64  |
| Air cleaning/filtering                        | 15 | 17                     | 41  |
| Increased ventilation rates                   | 41 | 9                      | 23  |

Q38. Have any of these surveillance strategies been applied in this facility/operation at any point since the start of the COVID-19 pandemic?

| Strategy                                      | No | Partially/temporarily | Yes |
|-----------------------------------------------|----|------------------------|-----|
| Return to work post recovery policy           | 6  | 9                      | 58  |
| Contact tracing and quarantine                | 13 | 12                     | 47  |
| Temperature screening and quarantine           | 13 | 10                     | 50  |
| Test for infection and isolation              | 27 | 12                     | 34  |