frontiers | Frontiers in Sustainable Food Systems

TYPE Original Research
PUBLISHED 02 March 2023
DOI 10.3389/fsufs.2023.1060876

OPEN ACCESS

EDITED BY
Hung Nguyen-Viet,
International Livestock Research Institute (ILRI), Kenya

REVIEWED BY
Puja Dudeja,
Army College of Medical Sciences, India
Delia Grace,
University of Greenwich, United Kingdom

*CORRESPONDENCE
Paul Ebner
✉ pebner@purdue.edu

SPECIALTY SECTION
This article was submitted to Agro-Food Safety, a section of the journal Frontiers in Sustainable Food Systems

RECEIVED 03 October 2022
ACCEPTED 13 February 2023
PUBLISHED 02 March 2023

CITATION
Mosimann S, Ouk K, Bello NM, Chhoeun M, Vipham J, Hok L and Ebner P (2023) Describing capability, opportunity, and motivation for food safety practices among actors in the Cambodian informal vegetable market. *Front. Sustain. Food Syst.* 7:1060876. doi: 10.3389/fsufs.2023.1060876

Describing capability, opportunity, and motivation for food safety practices among actors in the Cambodian informal vegetable market

Sabrina Mosimann[1], Keorimy Ouk[2], Nora M. Bello[3], Malyheng Chhoeun[2], Jessie Vipham[4], Lyda Hok[2,5] and Paul Ebner[1]*

[1]Department of Animal Sciences, Purdue University, West Lafayette, IN, United States, [2]Center of Excellence on Sustainable Agricultural Intensification and Nutrition, Royal University of Agriculture, Phnom Penh, Cambodia, [3]Department of Animal Science, The Ohio State University, Columbus, OH, United States, [4]Department of Animal Sciences and Industry, Kansas State University, Manhattan, KS, United States, [5]Division of Research and Extension, Royal University of Agriculture, Phnom Penh, Cambodia

Introduction: Several Cambodian initiatives seek to improve nutritional outcomes *via* increased production and consumption of nutrient-dense foods, including vegetables. However, food safety gaps in informal markets, where most vegetables are purchased, allow for the transmission of foodborne pathogens and threaten the positive nutritional outcomes associated with vegetable consumption.

Methods: This study describes a tool used to measure perceptions of Cambodians involved with informal vegetable markets regarding their capabilities, opportunities, and motivations to implement food safety practices. The quantitative tool could also be used to assess capability, opportunity, and motivation to adopt a behavior in a wide range of development contexts. To these ends, a questionnaire assessing these perceptions was developed using the Capability, Opportunity, Motivation-Behavior (COM-B) model of behavior and the Theoretical Domains Framework (TDF).

Results: The questionnaire was piloted with vegetable vendors in Phnom Penh ($N = 55$), revised, and subsequently implemented in the provinces of Battambang and Siem Reap with vegetable producers, distributors, and vendors ($N = 181$). Confirmatory factor analysis resulted in a nine-factor model corresponding to TDF constructs with a comparative fit index of 0.91, a Tucker-Lewis index of 0.89, and a root mean square error of ~0.05. Further analysis indicated that vegetable vendors and distributors typically had significantly higher ($p < 0.05$) levels of perceived motivation and capability to implement the target food safety practice (washing surfaces that come in contact with vegetables with soap and water every day) compared to their perceived opportunity to do so. Among farmers, however, levels of perceived motivation were significantly higher ($p < 0.05$) than levels of perceived opportunity and capability. In addition, vendors in Battambang had significantly higher ($p < 0.05$) levels of perceived capability, opportunity, and motivation to implement the target food safety practice in comparison to farmers in either province. Vendors in Battambang had significantly higher ($p < 0.05$) levels of perceived opportunity and motivation than vendors in Siem Reap.

Conclusions: These data suggest that efforts to bolster vegetable vendors' and distributors' perceived opportunity and vegetable farmers' perceived opportunity and capability to implement food safety practices could increase the likelihood of adoption of the target food safety practice.

KEYWORDS

Cambodia, food safety, capability, opportunity, motivation

Introduction

Cambodia has seen rapid economic growth and significant reductions in poverty over the past several decades, to the extent that the World Bank changed its classification of Cambodia from a low income to a lower-middle income economy in 2015 (World Bank Group, 2017). Cambodia's population has also grown in recent years and is currently estimated to be ~16.7 million (National Institute of Statistics and Ministry of Planning, 2020a; Central Intelligence Agency, 2022). Over 60% of the Cambodian population lives in rural areas, and, though the number of individuals primarily employed in the agricultural sector has declined, between 50% (National Institute of Statistics and Ministry of Planning, 2020b) and 80% (National Institute of Statistics and Ministry of Planning, 2020a) of the employed rural population between the ages of 15 and 64 still works primarily in production agriculture (National Institute of Statistics and Ministry of Planning, 2020a).

Despite recent economic improvements, malnutrition remains a problem throughout Cambodia and is of particular concern in rural areas, in households in which the mother has little or no formal education, and in households with incomes in the lowest quintile (National Institute of Statistics, Ministry of Health, and ICF, 2022). The most recent national health survey performed in Cambodia found that 9.6% of surveyed children under the age of 5 experienced wasting and 21.9% were stunted (National Institute of Statistics, Ministry of Health, and ICF, 2022); these incidence rates are considered medium and high, respectively, based on the prevalence thresholds developed by the World Health Organization and UNICEF (de Onis et al., 2018). Both the Cambodian government and international development organizations have taken steps to address these nutritional challenges by implementing various nutrition-focused policies and programs, including those designed to increase local production and consumption of vegetables (Ministry of Agriculture, Forestry and Fisheries, the European Union, and the United States Agency for International Development, 2015; Feed the Future Innovation Lab for Collaborative Research on Sustainable Intensification, 2020; Save the Children, 2020).

Currently, much of the fresh produce sold in Cambodia is sold in the informal vegetable market (Sokhen et al., 2004). The informal vegetable market in Cambodia is similar to informal markets found in countries throughout the world in that it is largely unregulated in terms of governmental monitoring or fee collection (e.g., taxing) and exists in parallel with the formal vegetable market. In Cambodia, the informal vegetable market is composed of a loose network of vegetable farmers, collectors, distributors, and vendors (Sokhen et al., 2004; Desiree et al., 2020). There are typically few to no food safety standards enforced on the farms where vegetables are produced or in the open-air wet markets where vegetables are sold, and poor sanitary conditions are common in both environments (Sokhen et al., 2004; Desiree et al., 2020). In addition, previous research found that raw vegetables and vegetable contact surfaces in open-air wet markets in Cambodia are commonly contaminated with bacterial pathogens (Phoeurk et al., 2019; Desiree et al., 2021; Schwan et al., 2021). These findings indicate that current food safety practices in these markets are not sufficient to mitigate the foodborne disease risks associated with the consumption of raw vegetables. Some of the key food safety gaps in the informal vegetable market supply chain noted by Desiree et al. (2020) included improper manure composting and application, use of poor quality water to irrigate or wash vegetables, failure to regularly sanitize vehicles prior to vegetable transport, scarcity of cold storage, lack of improved sanitation (e.g., toilets, handwashing stations), and the comingling of fresh produce with raw animal-sourced foods, among others. Chemical contamination of food is also of concern in Cambodia, and both chemical and microbial contamination have been linked with foodborne disease outbreaks in recent years (Thompson et al., 2021).

Fresh fruits and vegetables present a particular food safety concern because these foods are often eaten raw and are not typically subjected to high cooking temperatures or other kill steps that reduce or eliminate pathogenic bacteria. Consuming food contaminated with pathogens can cause a variety of foodborne illnesses, of which diarrheal diseases are the most common (Havelaar et al., 2015). Diarrhea is associated with dehydration, malnutrition, decreased economic stability due to lost productivity and healthcare costs, and, in some cases, death (National Institute of Diabetes and Digestive Kidney Diseases, 2016; World Health Organization, 2017; Niyibitegeka et al., 2021). Diarrheal diseases are particularly significant for children's health: among children under 5 years of age, diarrhea is a leading cause of mortality and malnutrition worldwide (GBD 2015 Mortality and Causes of Death Collaborators, 2016; World Health Organization, 2017). In Cambodia specifically, the WHO estimates that 7.4 and 15% of all deaths among children under 5 (0–4 years of age and 1–59 months of age, respectively) are due to diarrhea (World Health Organization, 2018). Furthermore, in a survey performed in 2010, ~15% of all Cambodian children under 5 years of age were reported to have had diarrhea within the past 2 weeks (National Institute of Statistics, Directorate General for Health, and ICF Macro, 2011). While the proportion of diarrheal disease that is caused by foodborne pathogens is unknown, even conservative estimates would suggest that the diarrheagenic diseases caused by microbial contamination of food have significant negative impacts on overall health outcomes (Grace, 2015).

Considering that substantial food safety gaps exist in informal produce markets in Cambodia and that several studies have confirmed the presence of pathogens on vegetables in these markets (Sokhen et al., 2004; Phoeurk et al., 2019; Desiree et al., 2020, 2021; Schwan et al., 2021), it is clear that consuming fresh vegetables puts Cambodians at risk of contracting foodborne illnesses such as diarrhea. Given that the intestinal disruptions caused by foodborne illnesses often result in nutrient malabsorption, it then follows that foodborne illness contracted due to consuming vegetables may negate the nutritional benefits of fresh vegetable consumption. Thus, in order to effectively improve the nutritional status of Cambodian communities, food safety concerns must be addressed alongside nutritional concerns.

Much of the knowledge and technologies needed to mitigate the food safety concerns present in the Cambodian vegetable market, and in many food markets throughout the world, already exists (Standards for the Growing, Harvesting, Packing, and Holding of Produce for Human Consumption, 2015). However, poor food safety is a persistent issue in many nations. Lack of access to resources, insufficient training, regulatory limitations, and the need for significant behavioral change at both individual and community levels may all contribute to implementation gaps between food safety knowledge and food safety practice. Facilitating voluntary behavior change can be especially challenging, even when the change needed appears straightforward to the development organization or government entity promoting it. For this reason, techniques that allow program implementers to more effectively enable behavior change are key to both improving food safety and to facilitating positive behavior change in a variety of development contexts. Using behavior theory to inform program design may be one such technique. Behavior theories are theoretical models intended to explain and predict behavior by identifying and defining the factors that influence behavior and explaining how these factors relate to each other (Kerlinger, 1986, as cited in Glanz et al., 2015, p. 26). By applying a specific behavior theory or theories to their projects, program designers and implementers could position themselves in a clear, operationalizable framework within which they may identify and define potential determinants of behavior. These frameworks may then be used to inform the creation of assessment tools that measure behavioral determinants within particular audiences, thereby increasing program designers' and implementers' capacity to recognize and address audience-specific barriers to and facilitators of behavior change.

Conceptual framework

The Capability, Opportunity, Motivation-Behavior (COM-B) model of behavior (Michie et al., 2011) and the Theoretical Domains Framework (TDF; Michie et al., 2011; Cane et al., 2012) were used in combination as the conceptual framework of this research. Taken together, the COM-B model and the TDF provided a specific perspective by which to identify and define the potential determinants of food safety practice adoption and the relationships between these determinants. The TDF aligns with the COM-B model but provides, in many cases, higher resolution with the three main constructs of COM-B (capability, opportunity, and motivation).

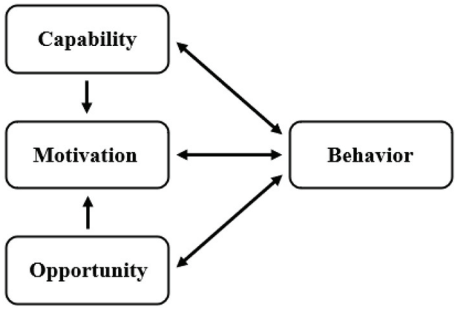

FIGURE 1
The COM-B model of behavior (adapted from Michie et al., 2011).

The COM-B model of behavior proposed by Michie et al. (2021; Figure 1) posits that the combination of an individual's capability, opportunity, and motivation for a behavior determines whether or not the individual will perform that behavior. Capability is defined as the "psychological and physical capacity" to perform a behavior, while opportunity is defined as "all the factors that lie outside the individual that make the behavior possible or prompt it" (Michie et al., 2011). Finally, motivation encompasses all of the mental processes that "energize and direct" behaviors (Michie et al., 2011). In the COM-B model, Michie et al. (2011) suggest that capability and opportunity have the potential to affect motivation and that all three of these behavioral constructs may both influence and be influenced by behavior (Figure 1). The TDF, a synthesis of over 30 distinct behavior theories, further defines and operationalizes capability, opportunity, and motivation by subcategorizing each of these behavioral constructs into measurable domains (Figure 2; Michie et al., 2011; Cane et al., 2012).

Originally, the COM-B model was designed to serve as an improved theory of behavior and to aid in the creation of context-specific interventions that effectively promote behavior change (Michie et al., 2011). In the research presented herein, determinants of food safety behavior change were explored in the context of informal vegetable markets in Cambodia. The results of this research were ultimately intended to inform the design of food safety engagement programs that facilitate the adoption of food safety practices. Thus, the COM-B model seemed well-suited to the purposes of this study. The use of this model in conjunction with the TDF was particularly fitting, as the combination of these frameworks enabled the design of a theoretically grounded quantitative questionnaire that may be used to quantify and assess perceptions of capability, opportunity, and motivation for specific behaviors both among Cambodians involved with informal vegetable markets and in other development contexts.

Research objectives

Informed by the COM-B model of behavior and the TDF, the primary purpose of this research was to develop a validated

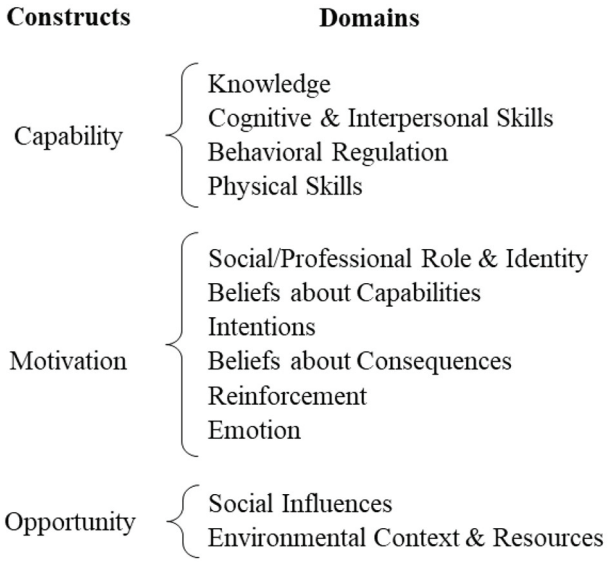

FIGURE 2
The behavioral constructs (capability, opportunity, and motivation) and within-construct domains of the COM-B model and TDF used to create the questionnaire (Michie et al., 2011; Cane et al., 2012). To note, the TDF domains optimism, goals, and memory, attention, and decision processes were excluded from the questionnaire. Optimism and goals are in the motivation construct, while memory, attention, and decision processes is in the capability construct.

instrument that explores, describes, and quantifies the perceptions of Cambodians involved with informal vegetable markets regarding their own capabilities, opportunities, and motivations to implement food safety practices. Specifically, the results of the research were intended to provide quantitative data on the levels of these three behavioral components within each group and to identify which, if any, of these components may be acting as a limiting factor for behavior change within a group. This quantitative data could then be used to tailor food safety programs to specific audiences, with the ultimate goal of increasing both the implementation of food safety practices and the positive outcomes expected to accompany these practices. Additionally, we aimed to create the instrument in a manner that would allow measurement of target audiences' perceptions of their own capability, opportunity, and motivation for specific behaviors across a variety of development contexts, both within and outside of the realm of food safety. Such a questionnaire could facilitate the incorporation of behavior theory into program design and provide development practitioners with quantitative data that could be used to inform and improve the design and implementation of development programs in many fields.

Methods

Ethical approval

All research described here was reviewed by the Institutional Review Board of Purdue University (West Lafayette, IN) and by the Royal University of Agriculture (Phnom Penh, Cambodia) and deemed exempt (IRB-2020-383). No participants received any form of remuneration for participating in the study.

Questionnaire overview

A quantitative questionnaire was designed for the primary purpose of measuring the perceptions of Cambodians involved with informal vegetable markets regarding their own capabilities, opportunities, and motivations to implement a specific food safety practice. However, the questionnaire was designed in such a way so as to be easily adaptable to different target audiences, practices, and geographic locations in order to facilitate its use in other development contexts. The content and structure of the questionnaire was based on the COM-B model of behavior and the TDF in order to ground the proposed research in validated theory. The questionnaire assessed participants' perceptions of the three behavioral constructs identified as the primary determinants of behavior in these models (i.e., capability, opportunity, and motivation) through quantitative questions based on 12 construct-specific domains drawn from the TDF (Figure 2). These domains refined the definitions of capability, opportunity, and motivation, thereby facilitating a comprehensive and precise evaluation of each construct (Figure 2). To note, three TDF domains (i.e., optimism, goals, and memory, attention, and decision processes) were excluded from the questionnaire due to limited applicability to the target behavior or excessive overlap with other domains.

Questionnaire validation

An initial draft of the questionnaire consisting of 68 content (i.e., non-demographic) questions was reviewed for content and face validity. This review was intended to ensure that (1) questions were aligned with the appropriate behavioral construct and construct-specific domain, and that (2) the questionnaire adequately addressed all relevant aspects of the three behavioral constructs with minimal redundancy. Subsequently, a revised version of the questionnaire containing 45 content questions was reviewed by Cambodian university students and Cambodian members of the research team to ensure that all questions were understood easily, understood in the intended way, and culturally appropriate. Following additional revisions, the questionnaire was translated into Khmer by Cambodian members of the research team. Back translation was then performed by an outside translation service to confirm that questions had retained their meaning during the initial translation process. Finally, the research protocol was submitted for ethical approval and the questionnaire was digitized using KoboToolbox (Kobo Inc, 2023) to facilitate field implementation and delivery. The digitized version of this questionnaire served as the pilot questionnaire and consisted of 39 content questions.

Quantitative survey research course

Concurrent with the first steps of questionnaire creation, several members of the research team hosted an online course on quantitative survey research for Cambodian undergraduate students. The course met for ∼1.5 h twice a week for 5 weeks and covered topics including survey question creation, reliability and validity assessments, survey implementation, and data analysis. The goal of this course was to build capacity for future Cambodian-led survey research by training Cambodian students in rigorous quantitative survey research and providing them with an avenue for obtaining certification to conduct human subjects research through the Collaborative Institutional Training Initiative Program (The CITI Program, n.d.). In total, 77 students from the Cambodian Institute of Technology and the Royal University of Agriculture completed the course. The students involved in this course reviewed the quantitative questionnaire developed for this study to ensure that the questionnaire was both easy to understand and culturally sensitive. Several students also received additional training regarding survey implementation and served as survey enumerators during data collection.

Pilot study and questionnaire revision

The pilot study was limited to vegetable vendors in informal markets in Phnom Penh, Cambodia in September 2021 and was intended to assess questionnaire reliability and validity. Vegetable vendors were selected for participation using availability sampling techniques with total sample numbers determined by availability and the questionnaire was administered in-person by Cambodian members of the research team (Daniel, 2012). Survey enumerators read each question and its corresponding answer scale aloud in Khmer to each participant so that participants would have a clear and consistent understanding of the questionnaire's content regardless of literacy level. The food safety practice chosen was "washing surfaces that come in contact with vegetables with soap and water." Two rounds of data collection were performed using the pilot questionnaire. In total, 55 vegetable vendors were approached using availability sampling for participation in the pilot study. Excluding individuals who were approached but declined ($n = 2$) to participate and respondents who answered <50% of the questions on the questionnaire, these selection and sampling methods led to 50 sets of complete responses in the data set. To note, all participants were 18 years of age or older and consented to participate in this research.

Responses collected during the pilot study were evaluated to assess the reliability and validity of the questionnaire using correlation plots, heat maps, and confirmatory factor analysis (CFA) created and performed *via* the corrplot (corrplot package), heatmap (stats package), and cfa (lavaan package) functions of R in RStudio Team (2020). Correlation plots and heat maps enabled visualization of the correlation structure of the data and filtering of questions that did not align with other questions in the same behavioral construct, that correlated negatively with many other questions, or that correlated strongly with questions across multiple constructs. CFA loadings and fit indices were used to evaluate the strength of individual questions and whether or not the theoretical models that informed the design of the questionnaire (i.e., the COM-B model of behavior in conjunction with the TDF) adequately fit the observed data. Based on these analyses and on feedback from survey enumerators regarding their observations of participants' confusion over certain questions, several questions were either removed or revised to improve clarity and alignment with the appropriate construct.

Data collection in the provinces

The final questionnaire consisted of 30 questions surrounding a single food safety practice (i.e., washing surfaces that come in contact with vegetables with soap and water every day). All but two questions asked respondents to indicate their level of agreement with a particular statement (e.g., I would wash the surfaces that come in contact with harvested vegetables with soap and water every day if it helped me to sell my vegetables to new buyers") using a 7-point Likert scale (1 = Strongly disagree; 2 = Disagree; 3 = Somewhat disagree; 4 = Neither agree or disagree; 5 = Somewhat agree; 6 = Agree; and 7 = Strongly agree). The questionnaire was implemented with vegetable farmers, vegetable distributors, and vegetable vendors involved in the informal vegetable market in the provinces of Battambang and Siem Reap during November of 2021. These participant groups were specifically targeted for inclusion in this research as they represented the primary groups involved in the informal vegetable market in Cambodia (Sokhen et al., 2004; Desiree et al., 2020). The provinces of Battambang and Siem Reap were chosen as the geographic focus of the final data collection events because both of these provinces are a part of the current USAID Feed the Future Zone of Influence in Cambodia (United States Agency for International Development, 2014).

Survey enumerators identified potential participants in Battambang and Siem Reap using availability sampling techniques (Daniel, 2012), which dictated the total number of samples collected. A total of 196 individuals were approached for participation in the study. Both men and women were surveyed, but the distribution of responses was not equal across genders because certain participant groups were composed almost entirely of only one gender (e.g., most Cambodian vegetable vendors are female). As such, due to significant differences in samples sizes between male and female respondents throughout the study making statistical analysis inappropriate, data were not disaggregated by gender. All respondents were at least 18 years of age and voluntarily agreed to complete the questionnaire. Excluding individuals who were approached but declined ($n = 5$) to participate and respondents who answered <50% of the questions on the questionnaire, these selection and sampling methods led to 181 sets of complete responses in the data set. Specifically, complete responses were collected from vegetable farmers ($n = 27$), vegetable distributors ($n = 37$), and vegetable vendors ($n = 26$) in Battambang, and from vegetable farmers ($n = 30$) and vegetable vendors ($n = 61$) in Siem Reap. No vegetable distributors were surveyed in Siem Reap as there is no large vegetable distribution center in that province. As before, the questionnaire was delivered in-person in Khmer by native

Khmer-speaking Cambodian national enumerators. Enumerators read each question aloud in Khmer and repeated the corresponding answer scale aloud in Khmer for each question.

Data analysis

Following data collection in Battambang and Siem Reap, response data were cleaned (i.e., questionnaires that were < 50% complete were excluded) and formatted for analysis in RStudio using the mice (mice package); corrplot (corrplot package), heatmap (stats package), and cfa (lavaan package) functions of R (RStudio Team, 2020). The mice function was employed using the predictive means matching method to generate values for missing data points assuming missing values were missing at random (MAR). Correlation plots and heat maps were created to allow visualization of the correlation structure of the data. CFA was also performed in order to assess the level of fit between the theoretical model and the data set. Given that the COM-B model includes three behavioral constructs, initial iterations of CFA were based on a three-factor model. During additional iterations of CFA, questions were further divided based on visual analyses of correlation plots, the structure of the COM-B model and the TDF, and model fit statistics (i.e., the comparative fit index, Tucker-Lewis index, and root mean square error of approximation). To note, the questionnaire included one free response question regarding who, if anyone, required participants to wash vegetable contact surfaces with soap and water every day. Responses to this question were not included in these statistical analyses due to their qualitative nature.

After performing CFA, an ANOVA shell as adapted by Stroup (2013) was used to formalize description of the data generation process and subsequently specify the statistical model to be used for data analysis. A general linear mixed model was fitted to questionnaire responses defined in a 1–7 Likert scale assuming a normal approximation. The linear predictor included the fixed effects of functional group (defined by five levels reflecting the appropriate combinations of participant role and location, i.e., farmers in Siem Reap, farmers in Battambang, vendors in Siem Reap, vendors in Battambang, and distributors in Battambang) and behavioral construct (i.e., capability, opportunity, and motivation) as well as their two-way interactions. Random effects fitted into the model consisted of person nested within functional group and its cross product with behavioral construct in order to properly identify the experimental units for each of the treatment factors, respectively, as well as recognize subsampling in the data collection process. Doing so ensured proper calibration of tests and estimation of degrees of freedom for inference. Model assumptions were evaluated using externally studentized residuals and were considered to be reasonably met.

The statistical model was fitted using the GLIMMIX procedure of SAS® data analysis software (SAS Version 9.4. SAS Institute Inc., Cary, NC, 2023). Variance components were estimated using restricted maximum likelihood, and a Kenward-Rogers approach was used to estimate degrees of freedom and to make corrections to estimated standard errors. Estimated least square means and their corresponding standard errors were calculated at the appropriate level of inference in the factorial treatment structure. Relevant pairwise comparisons were also conducted using a Bonferroni adjustment to avoid inflation of the Type I error rate due to multiple comparisons. Adjusted p-values were used for statistical inference and differences were considered significant at a level of $p < 0.05$.

Results

Pilot study and questionnaire validation/revision

Due to inconsistency in response trends between survey enumerators in the initial data collection event for the pilot study ($N = 30$ participants), additional steps were taken to ensure that the questionnaire was understood clearly and consistently by all enumerators and respondents. These steps included showing respondents a visual representation of the answer scale as well as reading the scale aloud after each question. Inter-enumerator response consistency improved in the second data collection event ($N = 20$ participants), with comparatively less variation in respondents' answers across different enumerators for most questions. For this reason, the correlation plot used to inform the revisions process was created using response data from the second data collection event only.

The pilot questionnaire was revised based on both enumerator feedback and visual evaluations of correlation within and across behavioral constructs. Initial discussions with enumerators led to the exclusion of three capability construct questions that respondents perceived as confusing or illogical. Survey enumerators also noted that some respondents did not understand the purpose of the first two questions on the pilot questionnaire, which asked if and by whom respondents were required to perform the target behavior, making these questions seem strange and slightly off-putting to some respondents. With this in mind, these two questions were relocated to the end of the questionnaire in order to avoid confusing respondents at the outset of the questionnaire. In addition, nine questions that were considered to be outside of the scope of the research or non-essential were removed in order to shorten the questionnaire and minimize respondent fatigue. Specifically, four motivation construct questions that concerned vegetable quality, two questions that referred to participants' "businesses" (one opportunity and one motivation construct question), and three opportunity construct questions that were deemed non-essential were removed in order to focus and shorten the questionnaire.

The correlation plot of response data from the second data collection event of the pilot study indicated that questions in the motivation and capability constructs generally correlated positively with other questions in the same construct. Questions in the opportunity construct, however, tended to correlate positively within their respective TDF domains but not across domains within the same construct. In addition, several questions were found to correlate positively across multiple constructs (Figure 3). Though some positive correlation across different behavioral constructs was expected based on the relationships and interdependencies between capability, opportunity, and motivation described in the COM-B model, two questions in the motivation construct that correlated positively across multiple constructs were re-evaluated for clarity. One question was removed, while the other was re-assigned to a

10.3389/fsufs.2023.1060876

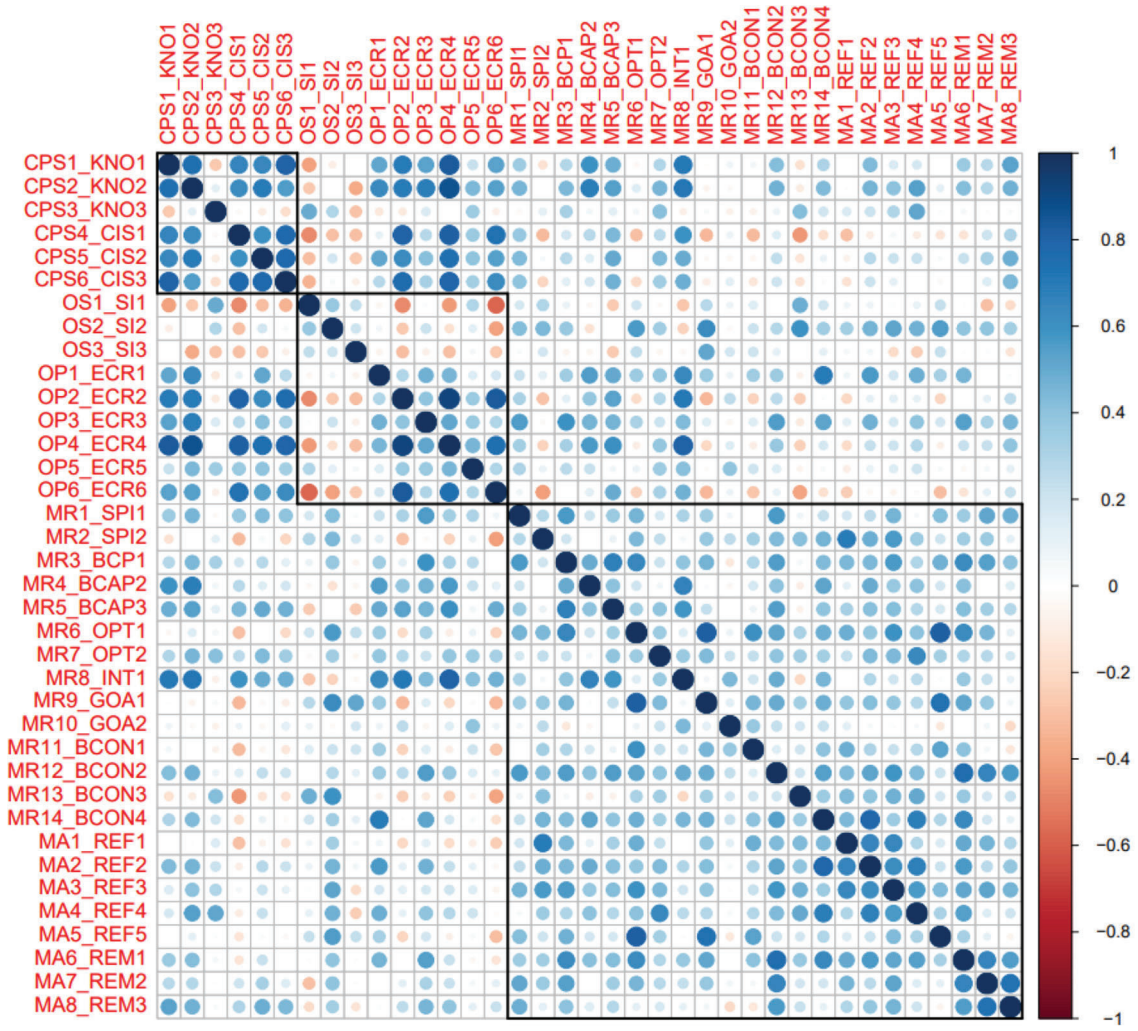

FIGURE 3
Correlation plot of response data collected from 20 vegetable vendors in Phnom Penh during the second data collection event of the pilot study. Question codes (e.g., CPS1_KNO1) indicate the COM-B construct and TDF domain in which the question falls. Black squares indicate questions in the same behavioral construct.

different TDF domain within the motivation construct to better reflect the question's central focus. In addition, one question in the capability construct appeared to correlate weakly with the other capability construct questions. This question was re-assigned to the opportunity construct in order to further refine the TDF domain groupings.

After the removal of all of the aforementioned questions, one additional question in the motivation construct was also re-assigned to a different TDF domain in order to consolidate two single-question domains in the motivation construct (i.e., goals and intentions, see Figure 2). Three questions in the motivation construct were also reworded slightly to improve their alignment with the appropriate TDF domain. Finally, four questions were added in order to support a thorough evaluation of the domains and constructs of the TDF and COM-B model. Two of these questions were added to the capability construct, one to the motivation construct, and one to the opportunity construct. Additionally, the target behavior, "washing surfaces that come in contact with vegetables with soap and water" was amended to "washing surfaces that come in contact with vegetables with soap and water every day" in order to reflect the repetitive, ongoing nature of the target behavior. CFA was then performed to assess the validity of the pilot questionnaire.

Taken together, these revisions resulted in a final questionnaire composed of 30 content (i.e., non-demographic) questions, of which 28 had a 7-point agree/disagree Likert answer scale. Of the two remaining questions, one had a binary yes/no answer scale and the other was a free response question. The final questionnaire had five questions in the capability construct, seven questions in the opportunity construct, and 17 questions in the motivation construct on the final questionnaire. The disparity in the number of questions contained in each construct was due to differences in the number of components required to comprehensively assess each construct as reflected in the TDF model. The free response question was not categorized into a construct. The final version of the questionnaire has been provided under Supplementary material.

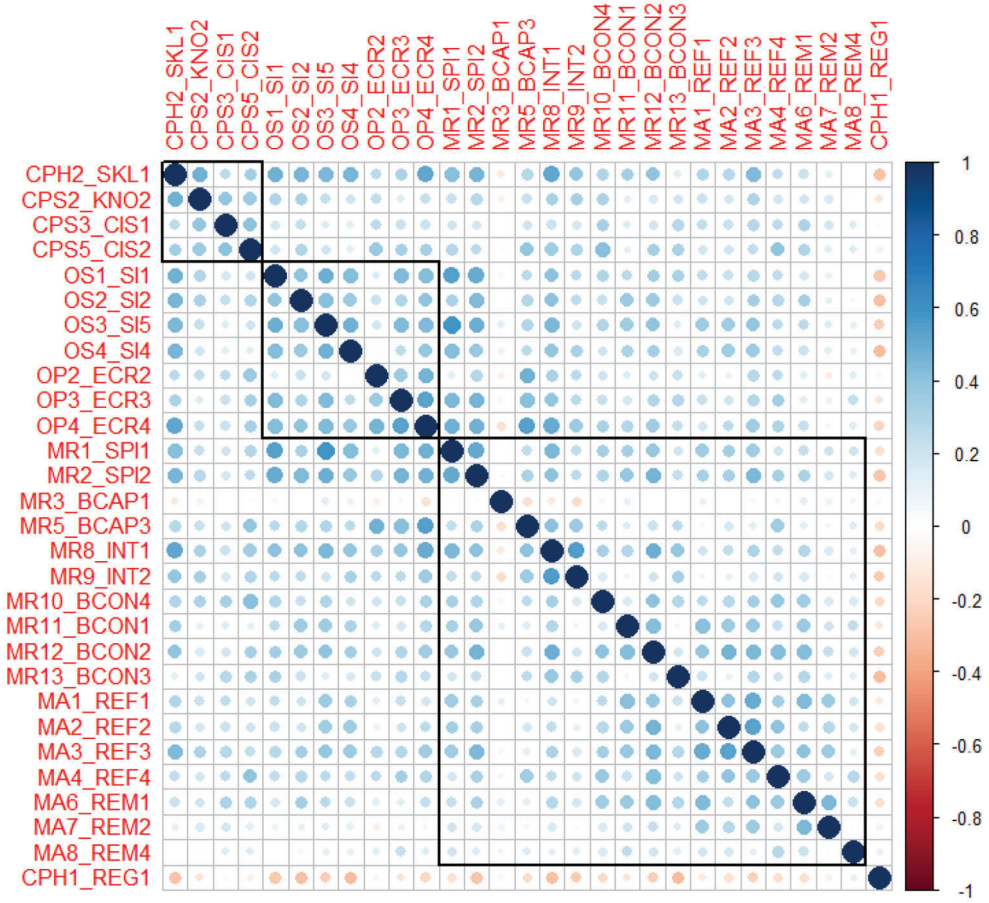

FIGURE 4
Correlation plot of response data collected from vegetable farmers, vendors and distributors in Battambang and from vegetable farmers and vendor in Siem Reap (data from $n = 181$ participants in total). Question codes (e.g., CPS1_KNO1) indicate the COM-B construct and TDF domain in which the question falls. Black squares indicate questions in the same behavioral construct. To note, though not located in the same square, CPH1_REG1 was also included in the group of questions comprising the capability construct (upper lefthand square).

Data collection in the provinces

Visual analyses of correlation plots of response data (Figure 4), qualitative analyses of question suitability, and CFA resulted in the exclusion of data from three questions from the final factor analysis model. One question in the capability construct was excluded because it correlated negatively with virtually all other questions, loaded negatively onto the CFA model (estimated loading of -0.17 ± 0.04 in the first iteration of CFA), had a binary yes/no answer scale rather than a 7-point agree/disagree Likert scale, and was a demographic question. Another question in the capability construct was removed because it was identified as a measurement of the target behavior itself rather than a measurement of participants' perceptions of their capability, opportunity, or motivation for that behavior. Finally, a question in the motivation construct was excluded because it correlated weakly with nearly all other questions, loaded poorly onto the CFA model (estimated loading of 0.085 ± 0.13 in the second iteration of CFA) and involved a double negative that may have made the question difficult to understand clearly and consistently. To note, the correlation plots created using this data set indicated that many questions positively correlated with questions in multiple constructs. As previously noted, this cross-construct correlation was expected to some degree due to the inter-relatedness of capability, opportunity, and motivation within the COM-B model.

CFA was performed iteratively, beginning with a model with three factors. These three factors corresponded to the capability, opportunity, and motivation constructs of the COM-B model and consisted of five, seven, and 17 questions, respectively. Following the removal of the three questions described in the previous paragraph, CFA concluded with a nine-factor model. These nine factors were comprised of nine groups of questions that corresponded to the capability construct ($n = 3$ questions) and to the social/professional role and identity ($n = 2$ questions), beliefs about capabilities ($n = 1$ question), intentions ($n = 2$ questions), beliefs about consequences ($n = 4$ questions), reinforcement ($n = 4$ questions), emotion ($n = 3$ questions), social influences ($n = 4$ questions), environmental context, and resources ($n = 3$ questions) TDF domains. Questions in the capability construct were not divided by their TDF domains during the final iteration of CFA due to the limited number of questions within the construct and because the correlation plot supported grouping these questions by

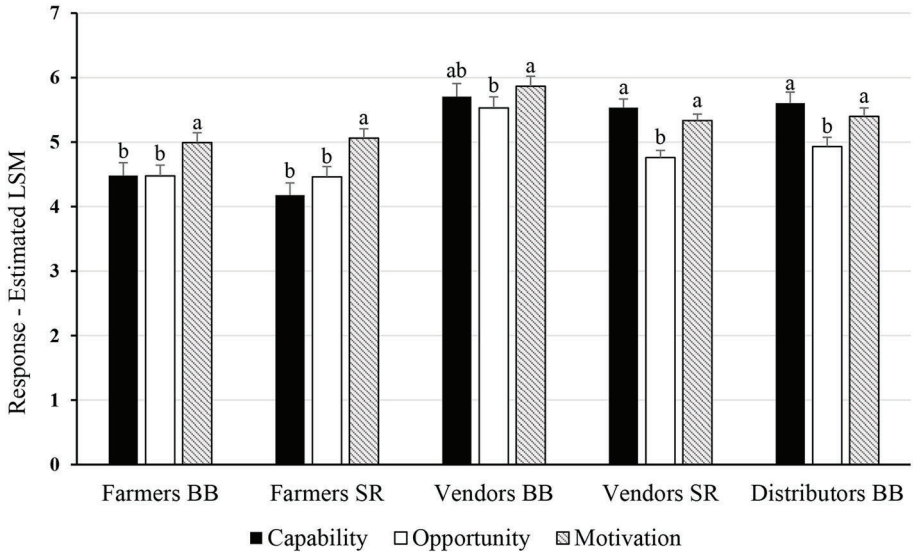

FIGURE 5
Estimated mean responses (and corresponding SE) to the sets of questions comprising the behavioral constructs of capability, opportunity, and motivation for each functional group. Different letters indicate significant differences ($p < 0.05$) between behavioral constructs within a functional group.

construct, among other considerations. The final nine-factor model had a comparative fit index of 0.91, a Tucker-Lewis index of 0.89, and a root mean square error of ∼0.05.

Following these assessments of reliability and validity, differences in levels of perceived capability, opportunity, and motivation within each functional group were investigated (Figure 5), as supported by a significant two-way interaction ($p < 0.001$). To note, the estimated differences in questionnaire responses reported here are meaningful only in relation to one another, not necessarily as absolute values. Farmers in Battambang and Siem Reap reported higher levels of perceived motivation for washing vegetable contact surfaces with soap and water every day than of perceived opportunity ($p < 0.001$ and $p < 0.001$ for Battambang and Siem Reap, respectively) or capability for the same behavior ($p = 0.009$ and $p < 0.001$ for Battambang and Siem Reap, respectively; Figure 5). Among farmers in Battambang, perceived motivation for washing vegetable contact surfaces with soap and water every day was estimated to be 11.6% higher than perceived opportunity and ∼11.4% higher than perceived capability. For farmers in Siem Reap, perceived motivation was ∼13.5 and 21.2% higher than perceived opportunity and capability, respectively. By contrast, levels of perceived capability and opportunity were not found to be significantly different from each other among farmers in either location (Figure 5). Vendors in Battambang also reported significantly higher ($p = 0.04$, 6.1% higher) levels of perceived motivation than perceived opportunity (Figure 5). In this group, levels of perceived capability for the target behavior were intermediate and were not observed to be significantly different ($p > 0.99$ in both cases) from levels of either motivation or opportunity (Figure 5).

Among both vendors in Siem Reap and distributors in Battambang, levels of perceived capability and motivation were observed to be significantly higher ($p < 0.001$, vendors; $p < 0.001$ and $p = 0.001$, respectively, distributors) than levels of perceived opportunity (Figure 5). Specifically, vendors in Siem Reap reported levels of perceived capability and motivation for the target behavior that were estimated to be 16.3 and 12.1% higher, respectively, than the level of perceived opportunity for the behavior; similarly, for distributors, estimates of perceived capability and motivation were 13.7 and 9.5% higher than perceived opportunity, respectively. In both of these functional groups, levels of perceived capability and motivation were not found to significantly differ from each other (Figure 5). To note, levels of perceived motivation for washing vegetable contact surfaces with soap and water every day were higher ($p < 0.05$; ranging from 6.1 to 13.5% higher) than levels of perceived opportunity for this behavior across all functional groups (Figure 5).

In order to further explore the interaction between functional group and behavioral construct, levels of perceived capability, opportunity, and motivation were compared across functional groups (Figure 6). Farmers in both provinces were found to have reported lower ($p \leq 0.001$) levels of capability in comparison to distributors and both groups of vendors (Figure 6). Levels of perceived capability for the target behavior were estimated to be 23.5–36.6% higher among distributors and vendors compared to farmers. No other significant differences in levels of perceived capability were observed across functional groups ($p > 0.99$ in all cases; Figure 6). Analyses of response estimates for perceived opportunity and motivation indicated that vendors in Battambang had significantly higher levels of perceived opportunity ($p < 0.002$) and motivation ($p < 0.05$) for washing vegetable contact surfaces with soap and water every day compared to vendors in Siem Reap and both groups of farmers (Figure 6). In particular, levels of perceived opportunity and motivation were estimated to be 23.5–23.9% and 15.9–17.5% higher, respectively, among vendors in Battambang than among farmers, and ∼16.2 and 10.0% higher,

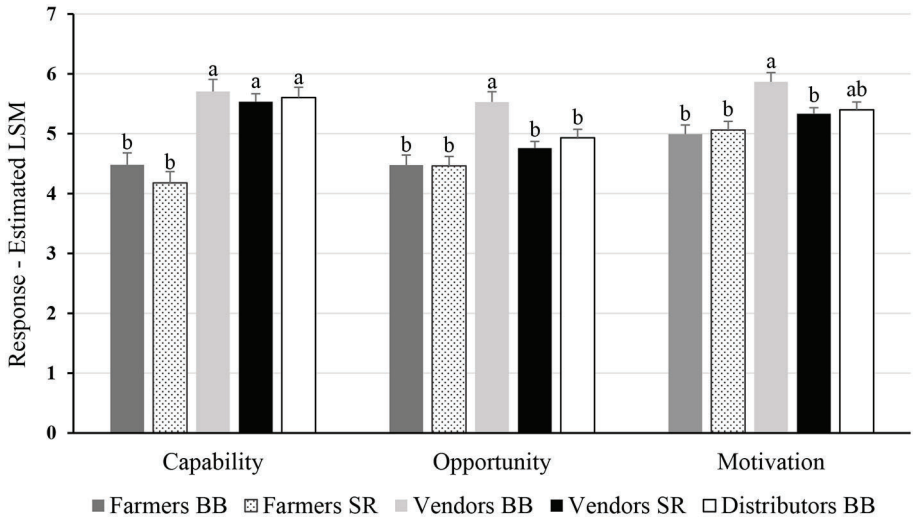

FIGURE 6
Estimated mean responses (and corresponding SE) to the sets of questions comprising the behavioral constructs of capability, opportunity, and motivation for each functional group. Different letters indicate significant differences ($p < 0.05$) between functional groups within a behavioral construct.

respectively, among vendors in Battambang than among vendors in Siem Reap. Levels of perceived opportunity and motivation among distributors in Battambang were not found to significantly differ ($p > 0.05$) from those of any other group (Figure 6).

Discussion

The primary objective of this research was to explore and describe perceptions of capability, opportunity, and motivation for a specific food safety practice among Cambodians involved with informal vegetable markets in order to inform future food safety engagement programs in Cambodia. Toward this end, we aimed to develop a quantitative questionnaire to assess the likelihood of food safety practice adoption based on the COM-B model of behavior (Michie et al., 2011) and the TDF (Michie et al., 2011; Cane et al., 2012). To assess capability, opportunity, and motivation to implement different food safety practices. For the purposes of developing the questionnaire, we chose a single food safety practice (i.e., washing vegetable contact surfaces with soap and water every day); however, the questionnaire was designed such that any practice of interest can be easily interchanged (e.g., washing hands before handling vegetables, separating vegetables from animal sourced foods, etc.).

Developed in 2011 and 2012, respectively, the COM-B model of behavior and the TDF are relatively new behavior theories (Michie et al., 2011; Cane et al., 2012). Since their creation, however, these models have been used in a variety of fields and have been applied most often in research regarding the promotion of health-related behaviors (e.g., dental hygiene, sexual health, weight management, exercise, hand hygiene, smoking cessation, etc.; Cowdell and Dyson, 2019; Buchanan et al., 2021; Greene and Wilson, 2022). The COM-B model and TDF have also been applied, albeit to a much more limited extent, to research on food safety behavior change.

To our knowledge, all of the existing literature in this area focuses on the retail or consumer level (Courtney, 2017; Ipsos MORI, 2017, 2021; Thiavalappil et al., 2018; Wodnik et al., 2018; Yavelak, 2019). Furthermore, we are aware of only five Cambodian development programs to which the COM-B model has been applied in some way (Keats et al., 2018; Bartholomew et al., 2019). In all such programs, the COM-B model was applied following program implementation as a tool to evaluate the interventions and impacts of the program itself rather than being used as a basis for assessing capability, opportunity, and motivation among the target audience in order to inform program design. Thus, it is a clear that capabilities, opportunities, and motivations for food safety practices among food producers and distributors in Cambodia have been significantly underexplored. The research described in this study was intended to address this gap, with the understanding that theoretically grounded, quantitative assessments of these potential determinants of behavior could equip program designers to develop food safety engagement programs that more effectively facilitate the adoption of positive food safety practices.

The results of this research indicated that the perceptions of Cambodians involved with informal vegetable markets regarding their own capabilities, opportunities, and motivations for washing surfaces that come in contact with vegetables with soap and water every day are specific to each combination of functional group (i.e., the combination of a participant's geographic location and role in the informal vegetable market) and COM-B construct (i.e., capability, opportunity, and motivation). Based on these findings, it appears that future food safety engagement programs for vendors and distributors would benefit from addressing the relatively low levels of perceived opportunity for the target behavior observed in these groups, while programs for farmers would be better served by focusing on both perceived opportunity and capability. Additionally, as levels of perceived capability, opportunity, and motivation were found to be higher among vendors in Battambang than among farmers in both Siem Reap and Battambang, there may

be a greater opportunity for increasing the adoption of the target food safety practice among vendors than among farmers.

The Behavior Change Wheel put forward by Michie et al. (2011) at the same time as the COM-B model provides additional guidance for program design by linking the individual components of capability, opportunity, and motivation with specific intervention types. Based on the Behavior Change Wheel and the nature of the target behavior, environmental restructuring-based interventions may be well-suited to addressing perceived deficiencies in opportunity. This type of intervention aims to alter the social or physical context of the audience and could include efforts to make the physical infrastructure of informal vegetable markets more conducive to positive food safety practices. Education- and training-based interventions, on the other hand, may be more appropriate for addressing deficiencies in perceived capability (Michie et al., 2011). Education-based interventions are intended to improve an audience's understanding of the target behavior and could include educational programs that present information about food safety and food safety practices. Training-based interventions involve sharing techniques for performing the target behavior; in this context, hands-on demonstrations of food safety practices could be considered training-based interventions. While bearing in mind that the specific context of the program may make some intervention types more appropriate and feasible than others, program designers could use these recommendations to guide the selection of food safety practices and the development of engagement programs that promote the adoption of such practices (Michie et al., 2011). For vegetable vendors and distributors in particular, for instance, incorporating environmental restructuring-based interventions into engagement programs may be most useful for encouraging the implementation of the target behavior. Of interest are the differences in responses between several of the respondent groups. These differences may result from differences in awareness (e.g., previous food safety education programs in one region but not the other), proximity to agriculture-focused learning institutions or extension services, or even greater interfaces with end-users (e.g., producers vs. vendors). However, hypotheses as to factors influencing these differences remain conjecture at this time and may be the foci of future studies.

The results of statistical analyses investigating the alignment of the theoretical models used to design the questionnaire (i.e., the COM-B model and the TDF) with the response data indicated the theoretical models adequately fit the response data (Lin, 2021). It was therefore concluded that the questionnaire was a valid instrument for assessing Cambodians involved with informal vegetable markets' perceptions of their own capabilities, opportunities, and motivations to perform a specific food safety practice. As the questionnaire was intentionally designed to be easily adapted for use with different audiences and target behaviors and in various geographic locations, the validation of the questionnaire also served to fulfill the second objective of this research, namely, developing a quantitative questionnaire that could be used to assess capability, opportunity, and motivation in a wide range of development contexts.

This research is intended to provide program designers with a starting point for developing food safety engagement programs in Cambodia. However, we acknowledge that the transferability and generalizability of the results in this study are limited. Even within Cambodia, extrapolation regarding the capabilities, opportunities, and motivations of Cambodians involved with informal vegetable markets in other provinces should be done with caution as differences in education, resources, or local norms, among other factors, may impact determinants of behavioral. Research that uses the questionnaire developed in this study to measure Cambodians' capabilities, opportunities, and motivations for other food safety practices (e.g., washing hands after handling money, properly composting manure, etc.) is also needed in order to provide insight into the relative levels of these behavioral components across different food safety practices. With such information, program designers may be able to identify existing or develop new food safety practices and interventions for which Cambodians report higher overall levels of capability, opportunity, and motivation, thereby enabling more informed decisions regarding which practices and interventions are most suitable for inclusion in food safety engagement programs.

Data availability statement

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

Ethics statement

The studies involving human participants were reviewed and approved by Purdue University Institutional Review Board and Royal University of Agriculture Research Council. The patients/participants provided their written informed consent to participate in this study.

Author contributions

SM: responsible for questionnaire design, testing, revision, data analysis, and manuscript preparation. KO and MC: responsible for questionnaire design, testing, revision, and data collection. NB: responsible for data analysis and manuscript preparation. JV and LH: responsible for experimental design and manuscript preparation. PE: responsible for experimental design, questionnaire design, testing, revision, data analysis, and manuscript preparation. All authors contributed to the article and approved the submitted version.

Funding

This study was made possible by the generous support of the American people through the United States Agency for International Development (USAID) though Cooperative Agreement No. 7200AA19LE00003 to Purdue University as

management entity of the Feed the Future Innovation Lab for Food Safety.

Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

Publisher's note

All claims expressed in this article are solely those of the authors and do not necessarily represent those of their affiliated organizations, or those of the publisher, the editors and the reviewers. Any product that may be evaluated in this article, or claim that may be made by its manufacturer, is not guaranteed or endorsed by the publisher.

Author disclaimer

The contents are the responsibility of the authors and do not necessarily reflect the views of USAID or the United States Government.

Supplementary material

The Supplementary Material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/fsufs.2023.1060876/full#supplementary-material

References

Bartholomew, K., Vinh, D., Mao, D., Ek, K., Dip, N., and Lonn, P. (2019). *A Toolbox for Measuring the Effectiveness of Programs Working on Behavioral Change*. Available online at: https://louvaincooperation.org/sites/default/files/2020-10/218_Final%20Report_Toolbox%20for%20BC%20Programs_Kantar_FINAL.pdf (accessed February 19, 2023).

Buchanan, H., Newton, J. T., Baker, S. R., and Asimakopoulou, K. (2021). Adopting the COM-B model and TDF framework in oral and dental research: A narrative review. *Commun. Dentistr. Oral Epidemiol.* 49, 385–393. doi: 10.1111/cdoe.12677

Cane, J., O'Connor, D., and Michie, S. (2012). Validation of the theoretical domains framework for use in behaviour change and implementation research. *Implement. Sci.* 7, 37. doi: 10.1186/1748-5908-7-37

Central Intelligence Agency (2022). *The World Factbook 2021: Cambodia*. Available online at: https://www.cia.gov/the-world-factbook/ (accessed February 19, 2023).

Courtney, S. M. (2017). *Food Safety Attitudes and Self-Reported Behaviours of Undergraduate Students at the University of Waterloo (Ontario, Canada)*, (Master's Thesis), University of Waterloo, UWSpace, Waterloo, On, Canada.

Cowdell, F., and Dyson, J. (2019). How is the theoretical domains framework applied to developing health behaviour interventions? A systematic search and narrative synthesis. *BMC Public Health* 19, 1180. doi: 10.1186/s12889-019-7442-5

Daniel, J. (2012). "Choosing the type of nonprobability sampling," in *Sampling Essentials: Practical Guidelines for Making Sampling Choices* (Thousand Oaks, CA: SAGE Publications, Inc.), 81–124. doi: 10.4135/9781452272047.n4

de Onis, M., Borghi, E., Arimond, M., Webb, P., Croft, T., Saha, K., et al. (2018). Prevalence thresholds for wasting, overweight and stunting in children under 5 years. *Publ. Health Nutr.* 22, 175–179. doi: 10.1017/S1368980018002434

Desiree, K., Schwan, C. L., Ly, V., Hok, L., Bello, N. M., Nwadike, L., et al. (2021). Investigating *Salmonella enterica*, *Escherichia coli*, and coliforms on fresh vegetables sold in informal markets in Cambodia. *J. Food Protect.* 84, 843–849. doi: 10.4315/JFP-20-219

Desiree, K., Schwan, C. L., Ly, V., Hok, L., Nwadike, L., Phebus, R. K., et al. (2020). Defining the flow and food safety behaviors of actors in the Cambodian vegetable value chain. *Food Protect. Trends* 40, 349–362. doi: 10.4315/1541-9576-40.5.349

Feed the Future Innovation Lab for Collaborative Research on Sustainable Intensification (2020). *Feed the Future Innovation Lab for Collaborative Research on Sustainable Intensification Five-Year Final Report*. Available online at: https://www.k-state.edu/siil/resources/SIIL%20Final%20Report%202014-2019-FINAL.pdf (accessed July 6. 2022).

GBD 2015 Mortality and Causes of Death Collaborators (2016). Global, regional, and national life expectancy, all-cause mortality, and cause-specific mortality for 249 causes of death, 1980-2015: A systematic analysis for the Global Burden of Disease Study 2015. *Lancet* 388, 1459–1544. doi: 10.1016/S0140-6736(16)31012-1

Glanz, K., Rimer, B. K., and Viswanath, K. (2015). *Health Behavior: Theory, Research, and Practice, 5th Edn.* Jossey-Bass. Available online at: https://www.google.com/books/edition/Health_Behavior/PhUWCgAAQBAJ?hl=en&gbpv=1 (accessed February 19, 2023).

Grace, D. (2015). Food safety in low and middle income countries. *Int. J. Environ. Res. Public Health* 12, 10490–10507. doi: 10.3390/ijerph120910490

Greene, C., and Wilson, J. (2022). The use of behaviour change theory for infection prevention and control practices in healthcare settings: A scoping review. *J. Infect. Prev.* 23, 108–117. doi: 10.1177/17571774211066779

Havelaar, A. H., Kirk, M. D., Torgerson, P. R., Gibb, H. J., Hald, T., Lake, R. J., et al. (2015). World Health Organization global estimates and regional comparisons of the burden of foodborne disease in 2010. *PLoS Med.* 12, e1001923. doi: 10.1371/journal.pmed.1001923

Ipsos MORI (2017). *Food Handlers and Norovirus Transmission: Social Science Insights*. Available online at: https://www.ipsos.com/sites/default/files/2017-07/food-handlers-and-norovirus-transmission-2017.pdf (accessed February 19, 2023).

Ipsos MORI (2021). *Qualitative Research Into the Consumption of Food With Expired "Use By" Dates*. Available online at: https://www.food.gov.uk/sites/default/files/media/document/fsa_qualitative_research_into_the_consummption_of_food_with_expired_use_by_dates.pdf (accessed February 19, 2023).

Keats, S., Sim, S., and Phon, D. (2018). *Country Report: Scaling Up Home Gardens for Food & Nutrition Security in Cambodia*. Available online at: https://idl-bnc-idrc.dspacedirect.org/bitstream/handle/10625/57265/IDL-57265.pdf?sequence=2&isAllowed=y (accessed February 19, 2023).

Kerlinger, F. N. (1986). *Foundations of Behavioral Research. 3rd Edn*. New York, NY: Holt, Rinehart and Winston.

Kobo Inc. (2023). *KoboToolbox*. Kobo Inc. Available online at: https://www.kobotoolbox.org/ (accessed February 19, 2023).

Lin, J. (2021). *Confirmatory Factor Analysis (CFA) in R With Lavaan*. Available online at: https://stats.oarc.ucla.edu/r/seminars/rcfa/ (accessed June 28, 2022).

Michie, S., van Stralen, M. M., and West, R. (2011). The behaviour change wheel: A new method for characterizing and designing behaviour change interventions. *Implement. Sci.* 6, 42. doi: 10.1186/1748-5908-6-42

Ministry of Agriculture, Forestry and Fisheries, the European Union, and the United States Agency for International Development (2015). *Policy and Strategic Framework on Childhood Development and Protection in the Agriculture Sector 2016–2020*. Available online at: http://extwprlegs1.fao.org/docs/pdf/cam165884.pdf (accessed February 19, 2023).

National Institute of Diabetes and Digestive and Kidney Diseases (2016). *Symptoms and Causes of Diarrhea*. Available online at: https://www.niddk.nih.gov/health-information/digestive-diseases/diarrhea/symptoms-causes (accessed February 19, 2023).

National Institute of Statistics, Directorate General for Health, and ICF Macro (2011). *Cambodia Demographic and Health Survey 2010*. Available online at: https://dhsprogram.com/pubs/pdf/FR249/FR249.pdf (accessed February 19, 2023).

National Institute of Statistics, Ministry of Health, and ICF (2022). *Cambodia Demographic and Health Survey 2021–22 Key Indicators Report*. Available online at: https://nis.gov.kh/nis/CDHS/2021-22/2021-22%20CDHS%20%20Key%20Indicator%20Report_EN.pdf (accessed February 19, 2023).

National Institute of Statistics and Ministry of Planning (2020a). *General Population Census of the Kingdom of Cambodia 2019: National Report on Final Census Results*. Available online at: https://nis.gov.kh/nis/Census2019/Final%20General%20Population%20Census%202019-English.pdf (accessed February 19, 2023).

National Institute of Statistics and Ministry of Planning (2020b). *Report of Cambodian Socio-Economic Survey 2019/20*. Available online at: https://nis.gov.kh/nis/CSES/Final%20Report%20of%20Cambodia%20Socio-Economic%20Survey%202019-20_EN.pdf (accessed February 19, 2023).

Niyibitegeka, F., Riewpaiboon, A., Youngkong, S., and Thavorncharoensap, M. (2021). Economic burden of childhood diarrhea in Burundi. *Glob. Health Res. Pol.* 6, 13. doi: 10.1186/s41256-021-00194-3

Phoeurk, C., Tieng, S., Tan, S., Moeung, S., Cheu, S., Chean, P. R. C., et al. (2019). Prevalence and concentration of E*scherichia coli* and *Salmonella* species in fresh vegetables collected from different types of markets in Phnom Penh. *Cambodia J. Basic Appl. Res.* 1, 75–95.

RStudio Team (2020). *RStudio: Integrated Development for R*. Available online at: http://www.rstudio.com/ (accessed February 19, 2023).

SAS Version, 9.4. SAS Institute Inc., Cary, NC (2023). *SAS and all Other SAS Institute Inc. Product or Service Names Are Registered Trademarks or Trademarks of SAS Institute Inc. in the USA and Other Countries.* ® *Indicates USA Registration*. Cary, NC.

Save the Children (2020). *Improving Nutrition in Cambodia During the First 1,000 Days: The NOURISH Experience 2014-2020*. Available online at: https://resource-centre-uploads.s3.amazonaws.com/uploads/NOURISH-End-of-Project-Report-August.pdf (accessed July 6, 2022).

Schwan, C. L., Desiree, K., Bello, N. M., Bastos, L., Hok, L., Phebus, R. K., et al. (2021). Prevalence of *Salmonella enterica* isolated from food contact and nonfood contact surfaces in Cambodian informal markets. *J. Food Protect.* 84, 73–79. doi: 10.4315/JFP-20-112

Sokhen, C., Kanika, D., and Moustier, P. (2004). *Vegetable Market Flows and Chains in Phnom Penh*. Available online at: https://agritrop.cirad.fr/544875/1/document_544875.pdf (accessed February 19, 2023).

Standards for the Growing, Harvesting, Packing, and Holding of Produce for Human Consumption (2015). *21 C.F.R. § 112*. Available online at: https://www.ecfr.gov/current/title-21/chapter-I/subchapter-B/part-112 (accessed February 19, 2023).

Stroup, W. W. (2013). *Generalized Linear Mixed Models: Modern Concepts, Methods and Applications*. London: Taylor & Francis Group.

The CITI Program (n.d.). *Human Subjects Research (HSR)*. Available online at: https://about.citiprogram.org/series/human-subjects-research-hsr/ (accessed February 19, 2023).

Thiavalappil, A., Waddell, L., Greig, J., Meldrum, R., and Young, I. (2018). A systematic review and thematic synthesis of qualitative research studies on factors affecting safe food handling at retail and food service. *Food Control* 89, 97–10. doi: 10.1016/j.foodcont.2018.01.028

Thompson, L., Vipham, J., Hok, L., and Ebner, P. (2021). Towards improving food safety in Cambodia: Current status and emerging opportunities. *Glob. Food Secur.* 31, 100572. doi: 10.1016/j.gfs.2021.100572

United States Agency for International Development (2014). *Feed the Future Cambodia: Zone of Influence Baseline Report*. Available online at: https://pdf.usaid.gov/pdf_docs/PA00K555.pdf (accessed February 19, 2023).

Wodnik, B., Freeman, M., Ellis, A., Awino Ogutu, E., Webb Girard, A., and Caruso, B. (2018). Development and application of novel caregiver hygiene behavior measures relating to food preparation, handwashing, and play environments in rural Kenya. *Int. J. Environ. Res. Public Health* 15, 1994. doi: 10.3390/ijerph15091994

World Bank Group (2017). *Cambodia – Sustaining Strong Growth for the Benefit of All*. Available online at: https://openknowledge.worldbank.org/bitstream/handle/10986/27149/Cambodia-SCD-May-9-SEPCO-05242017.pdf?sequence=5&isAllowed=y (accessed February 19, 2023).

World Health Organization (2017). *Diarrhoeal Disease*. Available online at: https://www.who.int/news-room/fact-sheets/detail/diarrhoeal-disease (accessed June 10, 2022).

World Health Organization (2018). *Distribution of Causes of Death Among Children Aged <5 Years (%)*. Available online at: https://www.who.int/data/gho/data/indicators/indicator-details/GHO/distribution-of-causes-of-death-among-children-aged-5-years-(-) (accessed June 22, 2022).

Yavelak, M. K. (2019). *Design and Implementation of Population-Specific Interventions to Improve Consumer Food Safety Behaviors (Publication No. 27814978)*. (Master's Thesis, ProQuest Dissertations & Theses Global), North Carolina State University, Raleigh, NC, United States.