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Food safety gaps between consumers' expectations and performances toward functional beverages containing botanicals

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Abstract

Purpose – This study aims to modify and validate the Food Safety Gap Scale (FSGS) to assess consumers' expectations and perceived performance regarding functional beverages containing botanicals and to provide evidence-based recommendations for strengthening food safety measures in Thailand.

Design/methodology/approach – The FSGS, comprising four gap dimensions across three key stakeholders, was developed from the original model and relevant literature. Confirmatory factor analysis (CFA), model fit indices and tests of reliability and validity were conducted. Importance-performance analysis (IPA) was applied to prioritize constructs for improvement.

Findings – Based on 470 respondents, the modified FSGS model, consisting of 24 indicators, was reliable and valid. The IPA results indicated significant food safety gaps in commitment and regulation dimensions, highlighting the need for targeted improvements to enhance consumer confidence.

Research limitations/implications – The study was limited to three provinces and may not represent broader national or international contexts. The use of an online survey may have introduced selection bias. A longitudinal approach is recommended to capture evolving consumer perceptions, particularly in risk awareness, knowledge and trust.

Originality/value – This study introduces a novel, product-specific tool for evaluating consumer perceptions of food safety, grounded in real-world practices. The modified FSGS offers actionable insights for policymakers and is adaptable to other high-risk food categories.

Keywords Food safety gap, Importance-performance analysis, Functional beverages, Botanicals, Consumer perceptions and expectations

Paper type Research article

1. Introduction

The functional food market is expanding rapidly, with functional beverages representing the fastest-growing category. These products, defined as conventional beverages offering health benefits beyond basic nutrition, are driven by rising health consciousness—intensified during the COVID-19 pandemic—and growing demand for natural botanical ingredients (Cong *et al.*, 2020; Alongi and Anese, 2021; Colombo *et al.*, 2020). Despite this growth, concerns persist

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regarding food safety, authenticity of health claims, and potential risks such as food–drug interactions and side effects from overconsumption (González-Díaz *et al.*, 2020; Di Fonzo and Liberati, 2020). Strengthening regulatory oversight is therefore essential to protect consumers and sustain trust in this market.

Ensuring food safety requires a robust regulatory framework with coordinated efforts among competent authorities, food business operators, and consumers (Food and Agriculture Organization and World Health Organization, 2023). However, regulatory approaches to functional foods vary. Some countries, including the Republic of Korea, Japan, and Canada, maintain comprehensive systems for definitions, approved ingredients, health claims, labeling, and communication, while regions, such as the European Union and Southeast Asia, face fragmented policies and regulatory ambiguity (Cong *et al.*, 2020; Intrasook *et al.*, 2024). Apart from the regulatory approach, consumer perceptions of safety are also influenced by cultural and national contexts, including knowledge, beliefs, risk awareness, and stakeholder performance, which shape decision-making and trust (Sgroi *et al.*, 2024; Ponte *et al.*, 2024).

To address these challenges, Lin *et al.* (2020) developed a food safety gap assessment tool identifying mismatches between consumer expectations and perceived performance across four gap dimensions: (1) assurance (industry controls), (2) commitment (authority efforts to build consumer trust), (3) regulation (standard setting and enforcement), and (4) consumer-based assessment (perception, experience, awareness, and attitudes). Validated via Confirmatory Factor Analysis (CFA) and prioritized using Importance-Performance Analysis (IPA), this tool guides stakeholders in targeting interventions to strengthen safety and trust (Lin *et al.*, 2020; Choi and Ju, 2022). This study initially developed the food safety gap assessment tool for functional beverages containing botanicals, using Thailand as a case study. The primary objectives were: (1) develop a Food Safety Gap Scale (FSGS) and assess gaps under existing safety measures and (2) provide evidence-based recommendations for enhancing food safety management of these products.

2. Data and methods

Primary data were collected from respondents meeting two inclusion criteria using proportionate stratified non-random sampling. A self-administered online questionnaire was distributed via convenience sampling during COVID-19 restrictions. Data validity, reliability, and internal consistency were assessed, followed by confirmatory factor analysis (CFA) to evaluate construct validity and model fit. Importance-performance analysis (IPA) was then applied to identify gaps across four dimensions and guide targeted recommendations. Each methodological step is detailed in the following section.

2.1 An online questionnaire with the Food Safety Gap Scale (FSGS)

The questionnaire included two sections: demographics and perceptions measured using the Food Safety Gap Scale (FSGS), which comprises four dimensions with 40 indicators rated on a 7-point Likert scale (1 = "strongly disagree," 7 = "strongly agree") (Lin *et al.*, 2020). Prior to participation, respondents were provided definitions and contextual information on functional beverages containing botanicals to ensure comprehension. Data were collected online via Google Forms and distributed through social media to reach diverse participants, including industrial employees, official staff, students, and general consumers. Respondents were assured of confidentiality and that their data would be used solely for anonymized statistical analysis. The FSGS dimensions were linked to three primary stakeholders responsible for food safety, as depicted in Figure 1.

The original FSGS was modified to reflect the context of functional beverages containing botanicals by integrating relevant food safety principles and control measures. According to the Food and Agriculture Organization and World Health Organization (2024), both general

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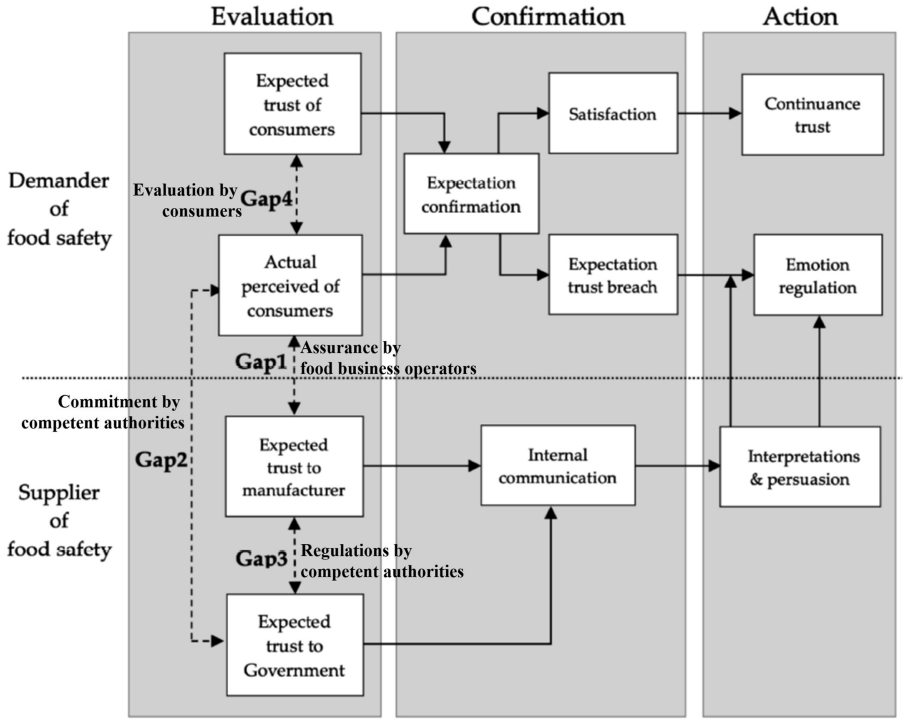

Figure 1. Food safety gap dimensions with three major stakeholders involved in the evaluation process of the Evaluation-Confirmation-Action (ECA) model. Source: Modified from Lin *et al.* (2020)

and commodity-specific measures—such as those for dairy-based beverages—are necessary for ensuring safety based on risk profiles and consumer expectations. For indicator selection, general food control measures from Lin *et al.* (2020) were selected under two conditions: (1) validity and (2) relevance to the safety of functional foods, which influences consumer perceptions, knowledge, and consumption decisions (Topolska *et al.*, 2021; Wu *et al.*, 2021; Zanetta *et al.*, 2022). Specific control measures related to production, product integrity, and presentations were identified from secondary data and aligned with the four FSGS dimensions. The revised model was validated using CFA and assessed through IPA to identify priority areas for improvement (Lin *et al.*, 2020; Lopez *et al.*, 2021).

2.1.1 Assurance dimension. Product assurance positively influences consumer trust in food safety and their willingness to purchase functional foods and beverages (Cong *et al.*, 2020; Wu *et al.*, 2021). To meet consumer expectations, food business operators must implement assurance measures covering production processes, raw material control, and product presentation. Accordingly, ten indicators were developed to represent the assurance dimension (Table 1). These indicators reflect key aspects of quality assurance systems, including hygiene practices during production (Item A1), ethical business operations, particularly under crisis conditions (Items A2-A4), and the provision of accurate, essential product information to build trust and long-term consumer engagement (Item A8). Traceability of product origin (Item A10) was identified as particularly important for strengthening consumer confidence.

Maintaining claimed functionality is essential in functional beverage production, especially for botanical ingredients, which require strict control of plant specifications and phytochemical profiles due to natural variability and potential toxins (Cong *et al.*, 2020; Colombo *et al.*, 2020; Wu *et al.*, 2021). Environmental contaminants, poor post-harvest

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Table 1. Indicators of the assurance dimension (A) of food safety expectation from consumers to food business operators

Indicators		Reference
A1	Thai food producers maintain hygienic controls	Lin *et al.* (2020)
A2	I believe in food safety from food enterprises maintaining a code of ethics	Lin *et al.* (2020)
A3	In the COVID-19 pandemic, a specific hygienic protocol is implemented	Duda-Chodak *et al.* (2020)
A4	Thai producers produce safe food	Lin *et al.* (2020)
A5	Botanicals derived from by-products or wastes are safe	Socas-Rodríguez *et al.* (2021), Wu *et al.* (2021)
A6	Advanced technologies can increase the usefulness of functional beverages containing botanicals	Galanakis (2021)
A7	Mixed botanicals are tested for safety and health benefits	Nazir *et al.* (2019), Schieber (2020)
A8	Food labels provided all the necessary information	Lin *et al.* (2020)
A9	Consumption limit and warning statements are clearly displayed	Tanemura *et al.* (2020)
A10	Traceability information enhances trust in food safety	Iftekhar and Cui (2021), Wu *et al.* (2021)

Source(s): Authors' own work

handling, and inadequate processing can introduce hazards, undermining consumer trust (Items A5–A6). Proper formulation is also critical, as improper combinations or phytochemical interactions may reduce efficacy or pose health risks, necessitating regulatory guidance on intake and warnings (Nazir *et al.*, 2019; Schieber, 2020; Tanemura *et al.*, 2020). Rigorous testing and clear communication of risks are essential for ensuring safety, efficacy, and consumer confidence (Items A7, A9).

2.1.2 Commitment dimension. Competent authorities strengthen consumers' confidence in the safety of functional foods by demonstrating strong and consistent commitments to food safety (González-Díaz *et al.*, 2020; Lin *et al.*, 2020; Wu *et al.*, 2021). Likewise, ten indicators of the commitment dimension are summarized in Table 2. Some validated indicators from Lin

Table 2. Indicators of the commitment dimension (C) of food safety expectation from consumers to competent authorities

Indicators		Reference
C1	Good policies and procedures concerning food safety are in place	Lin *et al.* (2020)
C2	Governments act quickly to correct food safety problems	Lin *et al.* (2020)
C3	When governments make food safety regulations, it ensures that manufacturers follow them	Lin *et al.* (2020)
C4	Governments strive for continuous improvement in food safety	Lin *et al.* (2020)
C5	The food safety level of market products is very poor	Lin *et al.* (2020)
C6	I always stay educated by the governments on food safety	World Health Organization South-East Asia (2022)
C7	I am educated by the government to maintain good hygienic practices for food regarding the COVID-19 pandemic	Ministry of Public Health (2021)
C8	I understand information from governments on food labeling and claims	Cong *et al.* (2020)
C9	Functional beverages containing botanicals are controlled by governments	González-Díaz *et al.* (2020), Wu *et al.* (2021)
C10	Functional beverages containing botanicals differ from medicinal herbal products	Colombo *et al.* (2020)

Source(s): Authors' own work

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et al. (2020) were applied to reflect core responsibilities of authorities in safeguarding consumers (Items C1–C5). Furthermore, governments are expected to continuously improve consumers' knowledge and awareness of food safety in normal situations and during pandemics (Items C6 and C7). For instance, the Ministry of Public Health of Thailand has issued public guidelines on preventive practices during the COVID-19 pandemic, reflecting an active role in consumer education under the national food safety strategy.

For functional beverages containing botanicals, capacity-building programs on food labeling and claims are necessary to improve consumer awareness of safety aspects (Item C8). Transparent communication about governmental monitoring and enforcement further helps align consumer expectations with perceived performance (Item C9). Additionally, clear distinctions between functional beverages and medicinal herbal products must be communicated to prevent consumer confusion and potential misuse (Item C10).

2.1.3 Regulation dimension. Food regulations influence the food safety gap through varying degrees of stringency, enforcement, and public communication. Ten indicators representing the regulation dimension are outlined in Table 3. Consistent with Lin *et al.* (2020), some validated indicators (Items R1 – R4) were selected to capture common regulatory challenges across countries (Nazir *et al.*, 2019; Cong *et al.*, 2020). In the functional food context, regulatory clarity is particularly important. Clear definitions help distinguish functional beverages containing botanicals from other health-related products (Item R5) and prevent misleading claims (Item R6). In contrast, the absence of specific requirements may fuel consumer skepticism and erode trust in authorities (Item R7).

For botanical additions to food, establishing daily intake limits and requiring warning labels builds consumer trust (Item R8). Clear, enforceable criteria for health claims help prevent misinformation (Item R9). Additionally, some countries mandate pre-market authorization to ensure the safety of phytochemical types and concentrations for long-term use (Item R10). Collectively, these regulatory measures strengthen consumer protection and credibility, thereby narrowing the food safety gap.

2.1.4 Assessment dimension. Ten indicators for the assessment dimension are presented in Table 4. Several validated items from Lin *et al.* (2020) (Items E1 – E4) were included to reflect general consumer expectations and perceptions of food safety. Additional indicators were

Table 3. Indicators of the regulation dimension (R) of food safety expectation from consumers to competent authorities and food business operators

Indicators		Reference
R1	Thai authorities enforce strict hygienic standards on food	Lin *et al.* (2020)
R2	I trust imported foods are safe and meet standards	Lin *et al.* (2020)
R3	If a violation has a direct impact on public health, authorities correct it immediately	Lin *et al.* (2020)
R4	Governments communicate in a clear way with food manufacturers about food safety and hygiene	Lin *et al.* (2020)
R5	Food producers know that controlling functional beverages containing botanicals is different from medicinal herbal products	Colombo *et al.* (2020)
R6	Advertisements of functional beverages claiming to treat diseases are illegal	Food and Drug Administration (2021)
R7	A regulation for functional foods is necessary for food safety	Nazir *et al.* (2019), Alongi and Anese (2021)
R8	Daily intake of botanicals and specific warning statements can ensure food safety	Tanemura *et al.* (2020)
R9	The health claim criteria can reduce misleading claims	Di Fonzo and Liberati (2020)
R10	An approval process for the safety and functionality of botanicals can increase confidence in food safety	Mitchell *et al.* (2022)

Source(s): Authors' own work

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Table 4. Indicators of the assessment dimension (E) of food safety expectation of consumers themselves

Indicators		Reference
E1	Consumers are also responsible for food safety	Lin *et al.* (2020)
E2	I usually pay attention to the risks of food	Lin *et al.* (2020)
E3	I know where the food originates from	Lin *et al.* (2020)
E4	Influence from information about quality and safety certification	Lin *et al.* (2020)
E5	My first priority in purchasing functional beverages is the health benefits	Wu *et al.* (2021)
E6	Increasing consumption of functional beverages containing botanicals relates to preventing the COVID-19 disease	Han and Hoang (2020)
E7	Botanicals derived from natural resources are safe	Socas-Rodríguez *et al.* (2021), Wu *et al.* (2021)
E8	Diversity of plants influences food safety	Colombo *et al.* (2020), Vilas-Boas *et al.* (2021)
E9	Some botanicals are hazardous for long-term consumption	Mitchell *et al.* (2022)
E10	Overconsumption of functional beverages containing botanicals may cause adverse health effects	Tanemura *et al.* (2020)

Source(s): Authors' own work

tailored to functional beverages containing botanicals. Perceived health benefits strongly influence consumer attitudes and purchase intentions (Item E5), while risk perception during crises can enhance trust in product safety and functionality (Item E6). For botanicals, their natural sources contribute positively to consumers' trust (Item E7). Consumer knowledge is also crucial, including specific understanding of plant species and phytochemical components (Item E8), traditional uses and their safety implications (Item E9), and awareness of intake limits to prevent adverse effects (Item E10).

2.2 Sampling

The sampling unit comprised consumers who met the study's inclusion criteria. The study focused on residents of Bangkok, Samut Prakan, and Nonthaburi—provinces with high COVID-19 case rates between January 1 and March 22, 2022—to capture heightened health awareness during the pandemic (Department of Disease Control, 2022). Inclusion criteria were age and education: participants were aged ≥20 years and had at least a secondary education, ensuring positive attitudes toward functional foods, independent purchasing decisions, and adequate understanding of nutritional information and health benefits (Topolska *et al.*, 2021). Based on National Statistical Office data (2021), the eligible population in these provinces was 2,138,055, 596,474, and 446,968, respectively. A sample of 400 respondents was calculated using Yamane's (1967) formula with a 5% margin of error. Proportionate stratified non-random sampling was applied to allocate respondents across provinces (Bangkok: 269; Samut Prakan: 75; Nonthaburi: 56), with convenience sampling employed within each stratum.

2.3 Testing the validity, reliability, and internal consistency of the indicators in the FSGS

To assess content validity, the Item-Objective Congruence (IOC) index was applied to all 40 FSGS items, with three experts from government, academia, and industry serving as evaluators. The IOC method evaluates the alignment between survey items and research objectives, using a scoring scale of +1 (congruent), 0 (questionable), and −1 (incongruent). Items with IOC values above 0.5 were considered acceptable (Rovinelli and Hambleton, 1977, cited in Fouzul Kareema and Bt Zubairi, 2022). Internal consistency was examined through a pilot test with at least 30 randomly selected respondents, using Cronbach's alpha with a threshold of $\alpha > 0.70$ (Lin *et al.*, 2020).

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In the preliminary survey, data from at least 200 respondents within the study area were used to perform statistical validation of the FSGS using Cronbach's alpha and CFA (Myers *et al.*, 2011). Model calibration was also evaluated through fit indices, construct reliability, and construct validity (Rodríguez-Mantilla *et al.*, 2019; Lopez *et al.*, 2021). The chi-squared statistic divided by the degree of freedom (χ^2/d.f.) was expected to be less than 5.0 to indicate an acceptable fit between the sample and expected covariance matrices. The Comparative Fit Index (CFI) and Tucker Lewis Index (TLI) were used to evaluate the fit scale between the sample and theoretical covariance matrices, with threshold values above 0.90 considered acceptable. Additionally, the Root Mean Square Error Approximation (RMSEA) was used to evaluate the degree of discrepancy between the sample and model covariance matrices, with values below 0.08 indicating a satisfactory fit (Hair *et al.*, 2014; Lopez *et al.*, 2021). The CFA was estimated for individual dimensions and the full model. The indicators with factor loadings below 0.5 were removed, in line with empirical guidelines for constructs related to personal perception and regulatory concerns (Steenkamp and Maydeu-Olivares, 2023).

Construct reliability was assessed using Composite Reliability (CR), with values $\geq$ 0.60 deemed acceptable. Construct validity was evaluated using convergent and discriminant validity. Convergent validity was evaluated using Average Variance Extracted (AVE), with thresholds of $\geq$0.50, or $\geq$ 0.40 when accompanied by CR $\geq$ 0.60 (Hair *et al.*, 2016; Lam, 2012; Zainudin, 2012). Discriminant validity was tested via the heterotrait-monotrait (HTMT) ratio with values < 0.90 considered acceptable, indicating adequate separation between reflective constructs (Henseler *et al.*, 2015). To further reduce bias, HTMT2 was employed given its robustness in congeneric models with positive and heterogeneous factor loadings (Roemer *et al.*, 2021). Following CFA re-estimation, the final set of indicators was incorporated into the FSGS for Importance-Performance Analysis (IPA) of food safety perceptions of botanical functional beverages among Thai consumers. Analyses were conducted using STATA 17 and IBM SPSS Statistics 26.

2.4 Procedure of IPA

In the final round, the questionnaire was revised into four sections based on the remaining indicators: (1) demographic information, (2) subjective perception, (3) perceived importance, and (4) perceived performance regarding food safety. All perception-related sections employed a 7-point Likert scale ranging from 1 (strongly disagree) to 7 (strongly agree), while demographic information was collected using closed-ended questions. The subjective perception section was analyzed for model reliability and validity, while the importance and performance sections were used to conduct the IPA. Following Lin *et al.* (2020), IPA applies two dimensions and four quadrants to show the performance (perceived) and importance (expected) of various indicators on the x- and *y*-axes, respectively. The four quadrants are: Quadrant I (high expectation/high performance) indicates satisfactory safety performance; Quadrant II (high expectation/low performance) highlights areas needing improvement; Quadrant III (low expectation/low performance) denotes low-priority areas; and Quadrant IV (low expectation/high performance) suggests potential overinvestment. IPA thus provides actionable insights into food safety gaps, guiding stakeholders in prioritizing interventions to strengthen safety systems for functional beverages containing botanicals.

This study was approved by the Research Ethics Review Committee at the Asian Institute of Technology, with certificate number RERC 2023/004, dated January 30, 2023.

3. Results

3.1 CFA

Prior to the pre-test of the FSGS, content validity was assessed using the IOC Index by three experts from the food industry, Thai Food and Drug Administration (FDA), and academia, each with over 10 years of experience in food safety and technology. The experts were briefed

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on the study's objectives, conceptual framework, and scoring criteria. The results showed that all indicators achieved an IOC score above 0.50, with 39 scoring 1.00 and one scoring 0.67, indicating acceptable content validity. Minor typographical corrections were made based on expert feedback, without changes to the indicator set. A pre-test was subsequently conducted with 55 eligible respondents in the target study areas to assess internal consistency. Cronbach's alpha for the four dimensions ranged from 0.82 to 0.89, exceeding the 0.70 threshold, confirming the reliability of the ten indicators per dimension (Table 5).

In the preliminary survey, data from 218 respondents were used to statistically evaluate the structure of the FSGS. As shown in Table 5, Cronbach's alpha values ranged from 0.71 to 0.84 across the four dimensions, indicating acceptable internal consistency for both individual dimensions and the overall questionnaire. Subsequently, the CFA was conducted in two steps. First, each dimension was subdivided into general and specific aspects of functional food safety, based on prior literature. Factor loadings and model fit indices were assessed, and items with loadings below 0.5 were removed to improve model performance. Of the 40 items, 27 met the criteria and were retained for the second-stage CFA.

Second, a first-order CFA using a pooled measurement model was conducted to evaluate the overall FSGS structure. This analysis assessed model fit through goodness-of-fit indices, composite reliability, convergent validity, and discriminant validity. In the full model result, items with factor loading values ≥ 0.50 and meeting construct reliability and model fit criteria were retained. Item E3 (loading = 0.48) and Item R9 were excluded, the latter to improve model fit by increasing CFI and TLI values above 0.90. Upon re-estimation, the revised model retained 25 items with loadings ≥ 0.5, all meeting criteria for model fit and construct validity. These 25 items were included in the final questionnaire used for IPA assessment (see Supplementary Material).

The final survey was conducted between April 1 and September 30, 2023, with a total of 470 respondents—255 from Bangkok, 103 from Samut Prakan, and 112 from Nonthaburi. Although the distribution reflected limitations of the convenience sampling technique, all participants met the inclusion criteria and resided in the designated areas. Thus, all 470 responses were used to refine the FSGS assessment. From the final survey analysis, Cronbach's alpha values for the overall FSGS and three of the four dimensions exceeded 0.70, ranging from 0.75 to 0.86; while the assessment dimension had an alpha value of 0.64 with the item-rest correlation ranging from 0.33 to 0.44 (Table 5). By rule of thumb, this is also acceptable for internal consistency (Hajjar, 2018). Descriptive statistics from both survey rounds are provided in the Supplementary Material.

In the pooled CFA model, Item A6 exhibited a factor loading of 0.41, below the acceptable threshold of 0.50, and was therefore removed. The revised CFA model, comprising the remaining 24 items, was then re-evaluated and confirmed to meet criteria for construct reliability and validity.

Table 5. Results of the reliability test (Cronbach's alpha) of the overall FSGS and by dimension

Dimension	Pre-test FSGS (40 items, $n = 55$)	Preliminary FSGS (40 items, $n = 218$)	Final FSGS (24 items, $n = 470$)
Assurance	0.88	0.77	0.75
Commitment	0.89	0.84	0.86
Regulation	0.85	0.81	0.80
Assessment	0.82	0.71	0.64
Total	0.96	0.91	0.91

Source(s): Authors' own work

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Following the reassessment, the revised FSGS model met all thresholds for model fit, construct reliability, and convergent validity. However, low discriminant validity was identified via the HTMT2 ratio, particularly between general and specific commitment (0.96), and between specific commitment and general regulation (1.04), both exceeding the recommended cut-off of 0.90. The overlap between general and specific commitment is likely due to the similarity in actions by competent authorities across food categories. For example, public education initiatives on hygiene and labeling for functional beverages do not differ significantly from those for conventional food products. Following the recommendation by Lin *et al.* (2020), the two sub-dimensions of commitment were merged to resolve this issue. A subsequent pooled CFA confirmed the revised FSGS model retained acceptable construct reliability and convergent validity (Tables 6 and 7).

In Table 6, the factor loadings of all 24 retained items had factor loadings above 0.50, satisfying the minimum requirement for construct validity. Construct reliability and convergent validity were also confirmed across all dimensions, validating the modified FSGS structure. Although the χ^2/d.f. ratio exceeded the recommended threshold of 5.0. This outcome is common in large samples ($n > 200$), where χ^2 becomes overly sensitive, particularly when degrees of freedom are reduced due to model adjustments. Alternative fit indices were therefore considered. For example, CFI and RMSEA are less sensitive to extraneous variables, whereas TLI and CFI are less sensitive to sample size (Stone, 2021). The results showed that key indices met the acceptable cut-off criteria. The CFI value was 0.934, suggesting that the modified FSGS was a better fit as it was closer to the upper bound of 1. Moreover, the TLI value of 0.921 indicated that the FSGS model was comparatively improved per degree of freedom as an acceptable fitting model. Regarding the residuals, RMSEA was

Table 6. Results for the FSGS items and measurement values

Dimension	Sub-dimension	Remained items	Mean (SD)	Factor loading	Model fit indices	CR	AVE
Assurance (Assu)	Assu_gen	A1	5.22 (0.05)	0.671	RMSEA = 0.053	0.74	0.42
		A2	5.57 (0.05)	0.615	CFI = 0.934		
		A3	5.38 (0.05)	0.632	TLI = 0.921		
		A4	5.28 (0.05)	0.677	χ^2/df = 5.74		
	Assu_ff	A7	5.34 (0.05)	0.727		0.61	0.44
		A9	5.51 (0.05)	0.594			
Commitment (Com)		C1	5.01 (0.06)	0.747		0.86	0.51
		C2	4.52 (0.07)	0.817			
		C3	5.03 (0.06)	0.676			
		C4	5.08 (0.06)	0.696			
		C8	5.10 (0.06)	0.605			
		C9	4.77 (0.06)	0.737			
Regulation (Reg)	Reg_gen	R1	4.74 (0.07)	0.824		0.82	0.54
		R2	5.19 (0.05)	0.631			
		R3	5.21 (0.06)	0.650			
		R4	4.99 (0.06)	0.808			
	Reg_ff	R7	5.74 (0.05)	0.692		0.79	0.56
		R8	5.76 (0.05)	0.783			
		R10	5.91 (0.05)	0.755			
Assessment (Asse)	Asse_gen	E1	5.89 (0.05)	0.640		0.70	0.44
		E2	5.83 (0.05)	0.639			
		E4	5.98 (0.05)	0.702			
	Asse_ff	E6	4.31 (0.07)	0.612		0.77	0.63
		E7	5.00 (0.06)	0.942			

Note(s): Gen = general aspect; ff = functional food aspect
Source(s): Authors' own work

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Table 7. Results for discriminant validity by the HTMT2 ratio

	Assu_gen	Assu_ff	Com	Reg_gen	Reg_ff	Asse_gen	Asse_ff
Assu_gen							
Assu_ff	0.62						
Com	0.63	0.67					
Reg_gen	0.52	0.60	0.94				
Reg_ff	0.35	0.39	0.34	0.40			
Asse_gen	0.31	0.30	0.21	0.30	0.71		
Asse_ff	0.48	0.70	0.55	0.54	0.28	0.22	

Note(s): Assu = assurance; Com = commitment; Reg = regulation; Asse = assessment; gen = general aspect; ff = functional food aspect

Source(s): Authors' own work

0.053, which indicated that the errors of approximation between the sample and covariance matrices were acceptably low (Hair *et al.*, 2014; Lopez *et al.*, 2021). Overall, these results confirm that the final FSGS model demonstrates strong construct validity, reliability, and overall psychometric soundness.

In Table 7, the HTMT2 ratio for most construct pairs satisfied the baseline criteria, indicating satisfactory discriminant validity. However, the HTMT2 ratio between commitment and general regulation dimensions was 0.94, slightly above the 0.90 cut-off, suggesting limited discriminant validity. This overlap likely reflects the dual role of competent authorities in both implementing commitment measures and enforcing general food regulations. Regulatory enforcement and food safety communication, which consumers often perceive as part of a unified function (Lin *et al.*, 2020). The absence of specific functional food regulations in Thailand likely reinforces this overlap, as general measures are applied broadly and enforcement is not distinctly communicated to the public (Intrasook *et al.*, 2024).

While elevated HTMT2 values can result from high factor loadings and inter-construct correlations, ratios below 1.00 remain acceptable at a sensitivity level above 95% (Henseler *et al.*, 2015). In this case, the HTMT2 value is still acceptable, when high loadings for Items R1 (0.82) and R4 (0.81) likely contributed to the elevated correlation (Henseler *et al.*, 2015; Roemer *et al.*, 2021). In contrast, the sub-dimension on functional food-specific regulations demonstrated adequate discriminant validity, with HTMT2 ratio of 0.34 with commitment and 0.40 with general regulation, reflecting its distinct regulatory focus, particularly regarding health claims, which remain unregulated in Thailand. Furthermore, these constructs exhibited AVE values above 0.50, confirming acceptable convergent validity. Collectively, these results affirm that the modified FSGS model, consisting of seven constructs and 24 indicators across four dimensions, is both reliable and valid and suitable for further analysis using the IPA.

3.2 IPA

Table 8 presents mean scores for importance, performance, gap values, and paired *t*-test results for all 24 indicators. The paired *t*-test revealed statistically significant differences between the importance and performance means for each item ($p < 0.05$), with negative gap scores across all indicators. These results indicate that, on average, consumer expectations for food safety in functional beverages containing botanicals exceed perceived performance. The largest gaps appeared in the regulation and commitment dimensions, particularly Items R3 (−2.27), R1 (−2.23), C2 (−2.17), C1 (−2.11), R2 (−2.10), C3 (−2.10), R4 (−2.08), and R8 (−2.08). These findings reflect significant deficiencies in perceived regulatory enforcement and governmental commitment, highlighting areas where improvement should be prioritized.

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Table 8. The IPA result for food safety in functional beverages containing botanicals in three provinces

Construct	Item	Mean Importance (I) (n = 470)	Std. Err	Mean performance (P) (n = 470)	Std. Err	GAP (P-I)	Paired t-statistic	Quad
Assu_gen	A1	6.35	0.0328	4.92	0.0360	−1.44	29.30	I
	A2	6.40	0.0314	4.66	0.0396	−1.75	34.09	I
	A3	6.35	0.0316	4.84	0.0342	−1.51	33.56	I
	A4	6.34	0.0319	4.83	0.0364	−1.52	32.85	I
Assu_ff	A7	6.35	0.0262	4.71	0.0350	−1.64	36.14	I
	A9	6.05	0.0293	4.25	0.0272	−1.80	45.13	III
Com	C1	6.31	0.0301	4.21	0.0396	−2.11	42.16	II
	C2	6.33	0.0318	4.16	0.0396	−2.17	42.29	II
	C3	6.33	0.0326	4.23	0.0393	−2.10	40.87	II
	C4	6.28	0.0322	4.27	0.0410	−2.01	37.58	II
	C8	6.18	0.0335	4.21	0.0401	−1.96	37.95	III
	C9	6.23	0.0322	4.20	0.0406	−2.03	37.97	II
Reg_gen	R1	6.32	0.0313	4.09	0.0398	−2.23	43.26	II
	R2	6.30	0.0311	4.21	0.0340	−2.10	45.84	II
	R3	6.39	0.0317	4.13	0.0403	−2.27	43.91	II
	R4	6.26	0.0321	4.18	0.0395	−2.08	39.08	II
Reg_ff	R7	6.26	0.0320	4.20	0.0388	−2.06	40.20	II
	R8	6.33	0.0327	4.25	0.0374	−2.08	42.06	II
	R10	6.24	0.0329	4.34	0.0422	−1.91	34.39	II
Asse_gen	E1	6.27	0.0329	5.31	0.0417	−0.96	19.29	I
	E2	6.20	0.0331	5.24	0.0413	−0.97	19.17	IV
	E4	6.16	0.0336	5.16	0.0400	−1.00	20.52	IV
Asse_ff	E6	5.19	0.0609	4.65	0.0455	−0.54	8.75	IV
	E7	5.58	0.0524	4.91	0.0427	−0.67	12.50	IV

Note(s): p-value of all items is 0.000, mean of performance = 4.52, and mean of importance = 6.20
Source(s): Authors' own work

Moderate gaps were observed in the assurance dimension (−1.80 to −1.44), suggesting relatively better alignment between expectations and perceived performance of business operators. The smallest gaps were recorded in the assessment dimension, particularly Items E6 (−0.54), E7 (−0.67), E1 (−0.96), E2 (−0.97), and E4 (−1.00), indicating that consumers were satisfied with food safety performance. However, minimal gaps in E6 and E7—relating to risk perception of natural ingredients and botanical claims—may reflect consumer complacency. Given potential risks from unverified claims or weak safety controls, enhanced awareness and regulatory oversight remain essential.

In Figure 2, Items E1 and E2 were positioned in Quadrant I (high importance, high performance), indicating strong consumer awareness of food risks and a sense of personal responsibility in ensuring food safety. In contrast, Items E4, E6, and E7 fell into Quadrant IV (high performance, low importance), suggesting that while consumers feel confident in evaluating product safety, they may undervalue critical food safety attributes—particularly regarding overstated health claims and the safety of natural ingredients. This may reflect growing public trust in botanicals and perceived health benefits during and after the COVID-19 pandemic (Han and Hoang, 2020; Socas-Rodríguez *et al.*, 2021; Wu *et al.*, 2021).

All items related to commitment and regulation were mapped to Quadrant II (high importance, low performance), revealing a significant expectation–performance gap. Consumers expressed dissatisfaction with governmental commitment and regulatory enforcement related to the safety of botanical-based functional beverages. Commitment-related items showed consistently large negative gaps (−1.96 to −2.17), emphasizing the need

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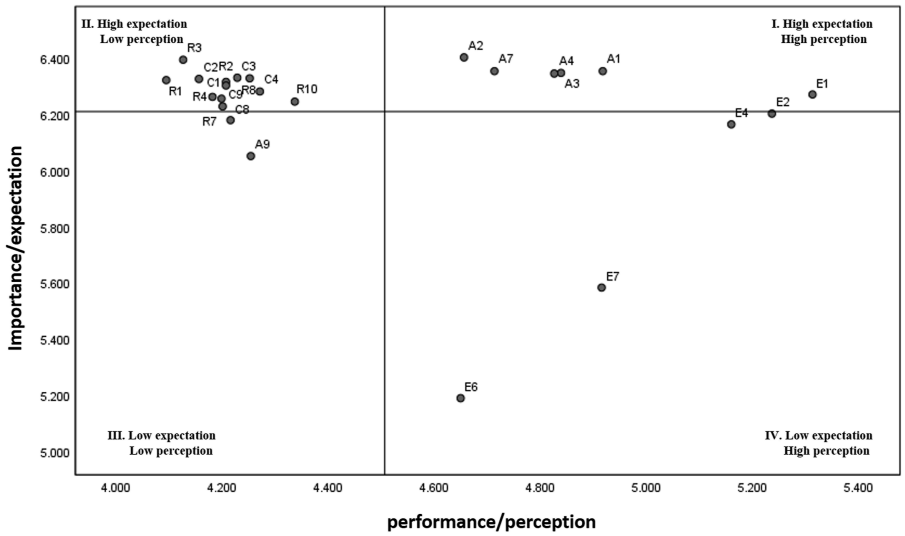

Figure 2. The importance-performance matrix of food safety for functional beverages containing botanicals

for stronger policy development, timely safety responses, and improved public communication. The largest regulatory gaps (Items R3 and R1) highlighted concerns about weak enforcement and slow incident response, while Items R7 and R8 underscored the absence of specific regulations for functional foods. These findings directly support the study's objective by identifying priority areas for targeted, evidence-based improvements in food safety governance, particularly in regulatory development and risk communication surrounding botanical functional beverages.

4. Discussion

This study sought to evaluate and strengthen the food safety performance of key stakeholders involved in safeguarding the supply chain. The findings demonstrate that the modified FSGS tool effectively captures the food safety gap between consumer expectations and actual performance. Consistent with Lin *et al.* (2020), this gap is shaped not only by the actions of regulatory authorities and food business operators but also by consumer-specific factors such as prior experience, attitudes, and access to information, which collectively influence purchasing behavior. By accounting for risk variability across food categories, the instrument provides insights into both general and product-specific safety measures, particularly in the context of functional beverages containing botanicals. This integration enhances the model's capacity to reflect the complexity of real-world food safety systems in countries such as Thailand. Moreover, the modified FSGS constitutes a methodological innovation for analyzing food safety gaps within a product-oriented framework, with applicability across diverse food categories.

To ground responses in lived experience, participants were provided with the scope and concrete examples of functional beverages before reporting their consumption frequency. The sample consisted primarily of healthy individuals with substantial knowledge of botanically enhanced functional beverages. By focusing on consumers with positive perceptions of these products—identified as a high-risk group in risk-based food safety frameworks—the study captured perceptions of safety and the effectiveness of stakeholder practices. Although dietary habits and socioeconomic status were not controlled, these diverse perspectives reflected

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real-world conditions and generated a comprehensive understanding of public attitudes toward functional beverages, consistent with the study's objectives. Nonetheless, methodological limitations warrant consideration. The reliance on an online questionnaire and convenience sampling may have constrained representativeness, particularly older adults with limited knowledge or access to reliable information, which are critical for effective risk communication (Topolska *et al.*, 2021). Furthermore, the absence of controls for dietary habits and socioeconomic status constrained the ability to examine their influence on food safety perceptions (Ponte *et al.*, 2024; Sgroi *et al.*, 2024).

Confirmatory factor analysis (CFA) yielded robust evidence of food safety gaps between consumer expectations and perceived performance regarding botanically enhanced functional beverages, providing a foundation for improving food safety performance. The CFA is widely recommended for validating the unidimensionality of theoretical constructs (Lopez *et al.*, 2021; Steenkamp and Maydeu-Olivares, 2023). Model fit indices enable the elimination of weak variables, strengthening the model's structural integrity (Rodríguez-Mantilla *et al.*, 2019; Lopez *et al.*, 2021). When combined with the importance–performance analysis (IPA), the results highlight priority dimensions across stakeholder groups, offering actionable evidence to guide policymakers in strengthening food safety management, industry practices, and consumer awareness for these emerging products (Lopez *et al.*, 2021; Choi and Ju, 2022).

The IPA results revealed that consumer confidence was lowest in the areas of commitment and regulation concerning functional beverages containing botanicals. Weaknesses centered on policy development, enforcement, timely response to incidents, and public communication. In many countries across Europe and Southeast Asia, including Thailand, policy frameworks for functional foods remain underdeveloped. A clear and comprehensive policy direction is critical for effective management, product innovation, and consumer trust. Experiences from Japan and the Republic of Korea illustrate the value of well-structured, consumer-oriented policies, which emerged partly in response to demographic changes and increasing healthcare costs. These initiatives have clarified regulatory responsibilities, ensured accountability, and spurred market growth. Similarly, Canada's regulatory strategy since 2021 has reduced enforcement costs while protecting consumers from misleading claims (Intrasook *et al.*, 2024). These cases highlight how strong governance and regulatory commitment can strengthen food safety performance, public health, and consumer confidence in the safety of functional foods.

Beyond issues of unclear commitment, this study highlights the need to strengthen regulatory performance. In Thailand, the FDA serves as the primary authority for the formulation and enforcement of food safety regulations (World Health Organization South-East Asia, 2022). Although current regulations exist for enforcement, consumer perceptions of their effectiveness remain low, likely due to limited transparency and weak public communication, a challenge reported elsewhere (González-Díaz *et al.*, 2020; Zanetta *et al.*, 2022). Improving communication through systematic disclosure of enforcement actions, incident responses, and annual surveillance findings is therefore essential. The absence of a specific regulation for functional foods further exacerbates consumer skepticism, leaving ambiguity regarding product scope, health claims, and labeling obligations (Cong *et al.*, 2020; Tanemura *et al.*, 2020). By contrast, Canada and the Republic of Korea require functional foods to display a "*Supplemented Food Facts table*" or a "*Health Functional Foods*" logo, thereby distinguishing them from conventional products, improving consumer awareness, and risk communication (Intrasook *et al.*, 2024). The absence of dedicated policies and specific legislation for functional foods in Thailand reflects both consumer uncertainty and the undifferentiated performance of national authorities, consistent with the low discrimination (HTMT ratio <0.90) observed between the dimensions of commitment and general regulation.

The moderate gap of performances from food business operators can also be reduced by reinforcing assurance mechanisms through the reforming policy and legislation for functional foods. For instance, the placement of Item A9 in Quadrant III of the IPA suggests that low consumer expectations for safety information may reflect insufficient labeling practices. A specific functional food regulation could enforce compliance and improve consumer

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understanding. While consumer-related performance gaps were relatively small, targeted education remains essential to address misconceptions about misleading claims and overstated benefits of naturally derived ingredients (e.g. items E6 and E7 in Quadrant IV) (Di Fonzo and Liberati, 2020). Similar to trends observed in other nations, respondents' positive perceptions of natural ingredients may reflect both individual beliefs and national initiatives promoting Thai herbs for commercial applications (Intrasook *et al.*, 2024). Without clear regulatory boundaries and effective communication, the health risks associated with botanically enhanced beverages may be exacerbated.

Overall, the findings underscore the urgent need for Thai competent authorities, particularly the FDA, to establish a dedicated regulatory framework for functional foods. This framework should integrate clear labeling requirements, transparent processes for safety and claim validation, and proactive public communication to reduce regulatory ambiguity, strengthen enforcement, and rebuild consumer trust. Lessons from countries with well-defined functional food regulations can guide the development of mandatory and voluntary measures suited to the Thai context, while interactive collaboration between regulators and industry is essential to enhance food safety performance (Intrasook *et al.*, 2024; Ponte *et al.*, 2024; Sgroi *et al.*, 2024). Strengthening these mechanisms would reinforce governance, foster innovation and competitiveness in the functional food sector, and ensure consumers receive accurate, science-based information that supports informed decision-making, cautious consumption of botanically enhanced beverages, and greater confidence in the food safety system.

5. Conclusion

This study confirms the interdependence of the four ECA model dimensions—assurance, commitment, regulation, and assessment—each reflecting the roles of key stakeholders: competent authorities, food business operators, and consumers. Enhancing one dimension can reinforce others, emphasizing the need for a coordinated food safety strategy. The modified Food Safety Gap Scale (FSGS), developed and validated in this study, offers a novel, product-specific tool for assessing consumer perceptions. Applied to functional beverages containing botanicals, it effectively identifies critical safety gaps and informs targeted interventions. The integration of Importance–Performance Analysis (IPA) enables prioritization based on consumer expectations and perceived performance. Findings support policy development to strengthen food safety systems, with the tool adaptable to other high-risk food categories. To build consumer trust in botanical functional beverages in Thailand, policy recommendations include clear regulatory frameworks, enhanced enforcement, and reinforced risk communication.

There are some limitations to be addressed. First, the consumer survey was limited to three provinces in Thailand, constraining the generalizability of the findings. Future research should include broader geographic regions to capture variations in risk perception and sociodemographic factors, including beliefs in naturally derived ingredients, that may shape food safety attitudes toward botanical functional foods. Second, the online survey had low participation from older adults, who may perceive risks differently due to health concerns and limited access to risk communication, which could bias the assessment of perceived food safety performance. Future studies should address this bias through on-site data collection and stratified random sampling to improve representativeness. Moreover, a longitudinal approach is recommended to capture changes in consumer behavior and attitudes over time, particularly in risk perception, knowledge, and trust in food safety in response to public crises, regulatory shifts, and production innovations. Lastly, the validity and reliability of the FSGS should be strengthened through stakeholder input (e.g. regulators, industry) and refined using Exploratory Factor Analysis to confirm its structural dimensions.

Supplementary material

The supplementary material for this article can be found online.

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