การพัฒนาเครื่องมือสำรวจการบริโภคสาหร่ายทะเลเพื่อประเมินการได้รับสัมผัสโลหะหนักในอาหาร

ดลรตี จันทร์แจ้ง[1] ครรชิต จุดประสงค์[2] ศรัณยา กิจดำรงธรรม[3] ปราณี พัฒนกุลอนันต์[3] ปรัญรัชต์ ธนวิยุทธ์ภัคดี[3,*]

[1]หลักสูตรพิษวิทยาและโภชนาการเพื่ออาหารปลอดภัย สถาบันโภชนาการ มหาวิทยาลัยมหิดล,

[2]หน่วยเคมีทางอาหาร สถาบันโภชนาการ มหาวิทยาลัยมหิดล,

[3]หน่วยพิษวิทยาทางอาหาร สถาบันโภชนาการ มหาวิทยาลัยมหิดล

บทคัดย่อ

สาหร่ายทะเลเป็นผลิตภัณฑ์ที่นิยมบริโภคเนื่องจากมีคุณค่าทางสุขภาพ แต่อาจปนเปื้อนโลหะหนัก เช่น ตะกั่ว และแคดเมียม ที่สะสมในสิ่งแวดล้อมทางทะเล เพื่อประเมินการได้รับสารปนเปื้อนจากอาหารอย่างแม่นยำ จำเป็นต้องมีข้อมูลเกี่ยวกับรูปแบบ ชนิด และปริมาณการบริโภคสาหร่ายทะเลอย่างละเอียด อย่างไรก็ตาม ข้อมูลเหล่านี้ยังมีจำกัด เนื่องจากการศึกษาก่อนหน้านี้ไม่ได้แยกความแตกต่างระหว่างสาหร่ายทะเลแต่ละชนิด ทำให้การจำแนกแหล่งที่มามีความซับซ้อน โดยเฉพาะอย่างยิ่งในการแยกความแตกต่างระหว่างสาหร่ายน้ำจืดและสาหร่ายทะเล การศึกษานี้จึงมุ่งเน้นไปที่การพัฒนาและการตรวจสอบความถูกต้องของแบบสอบถามความถี่การบริโภคกึ่งปริมาณ (SQ-FFQ) สำหรับการประเมินรูปแบบของการบริโภคสาหร่ายทะเล เพื่อเติมช่องว่างดังกล่าว การดำเนินการประกอบด้วย 4 ขั้นตอน ได้แก่ (1) การสำรวจตลาด (2) การรวบรวมรายละเอียดสาหร่ายทะเลแต่ละชนิด ผลิตภัณฑ์จากสาหร่ายทะเล และเมนูอาหารที่บริโภคโดยทั่วไป (3) การพัฒนา SQ-FFQ ออนไลน์ผ่าน google form และ (4) ความตรงเชิงเนื้อหาถูกประเมินด้วยดัชนีความสอดคล้อง (IOC) โดยผู้เชี่ยวชาญ และความน่าเชื่อถือภายในวัดด้วยค่าสัมประสิทธิ์แอลฟาของครอนบาช (α-coefficient) ผลการสำรวจตลาดพบสาหร่ายโนริ 103 รายการ จีฉ่าย 5 รายการ และวากาเมะ 29 รายการ ซึ่งจากข้อมูลนี้ ได้คัดเลือกเมนูอาหาร 16 รายการที่มีส่วนประกอบของสาหร่ายทะเล เพื่อนำไปใช้ในแบบสอบถาม ซึ่งประกอบด้วยเมนูที่ทำจากสาหร่ายโนริ 10 รายการ จีฉ่าย 1 รายการ และวากาเมะ 5 รายการ ส่วนผล SQ-FFQ แสดงให้เห็นถึงความตรงของเนื้อหาที่ยอมรับได้ (IOC = 0.6-1.0) และมีค่าความน่าเชื่อถือสูง (α = 0.954) ซึ่งเป็นการยืนยันว่าเหมาะสมสำหรับการประเมินการบริโภคสาหร่ายทะเลในการบริโภคโลหะหนัก

คำสำคัญ: สาหร่ายทะเล แบบสอบถามความถี่การบริโภคกึ่งปริมาณ ความตรงเชิงเนื้อหา ค่าดัชนีความสอดคล้อง ความเชื่อมั่นและค่าสัมประสิทธิ์แอลฟาของครอนบาช

รับบทความ: *25 กรกฎาคม 2568* ***แก้ไข:*** *18 กันยายน 2568* ***ตอบรับ:*** *6 ตุลาคม 2568*

[*]ผู้รับผิดชอบบทความ

ปรัญรัชต์ ธนวิยุทธ์ภัคดี

หน่วยพิษวิทยาทางอาหาร สถาบันโภชนาการ มหาวิทยาลัยมหิดล ถ. พุทธมณฑล สาย 4 ต. ศาลายา อ. พุทธมณฑล จ. นครปฐม ประเทศไทย 73170

อีเมล: pharrunrat.tan@mahidol.ac.th

Development of a Seaweed Consumption Survey Tool for Dietary Exposure Assessment to Heavy Metals

Dolratee Janjang[1] Kunchit Judprasong[2] Sarunya Kitdumrongthum[3] Pranee Pattanagulanan[3] Pharrunrat Tanaviyutpakdee[3,*]

[1]Master of Science Program in Toxicology and Nutrition for Food Safety, Institute of Nutrition, Mahidol University
[2]Food Chemistry Unit, Institute of Nutrition, Mahidol University
[3]Food Toxicology Unit, Institute of Nutrition, Mahidol University

Abstract

Seaweed products are widely consumed due to their perceived health benefits. Nonetheless, they can serve as sources of toxic contaminants, particularly heavy metals such as lead and cadmium, which may accumulate from their aquatic environments. To accurately assess dietary exposure to these contaminants, it is essential to obtain detailed information on seaweed consumption patterns, including type and quantity consumed. However, existing data often lack such specificity, as prior studies did not differentiate between seaweed types, thereby complicating the classification of sources, particularly in distinguishing between freshwater and marine varieties. This study focused on the development and validation of a semi-quantitative food frequency questionnaire (SQ-FFQ) for evaluating seaweed consumption patterns. To fill the gap, the four steps were performed: (1) conducting a market survey (2) compiling a detailed list of seaweed types, seaweed-based products, and commonly consumed menus, (3) developing an online SQ-FFQ via google form, and (4) evaluating the tool's content validity through expert review using the Index of Item-Objective Congruence (IOC), as well as assessing internal consistency reliability with Cronbach's alpha coefficient (α-coefficient). The market survey identified 103 nori items, 5 zi-cai items, and 29 wakame items. Based on this, a total of 16 seaweed-based menu items were selected and incorporated into the questionnaire, comprising 10 nori-based menus, 1 zi-cai-based menu, and 5 wakame-based menus. The SQ-FFQ showed acceptable content validity (IOC = 0.6-1.0) and high reliability (α = 0.954), confirming its suitability for assessing seaweed consumption in dietary exposure to heavy metals.

Keywords: Seaweed, Semi-quantitative food frequency questionnaire, Content validity, Index of item-objective Congruence, Reliability and Cronbach's alpha coefficient

Received: *25 July 2025,* ***Revised:*** *18 September 2025,* ***Accepted:*** *6 October 2025*

[*]**Corresponding author**
Pharrunrat Tanaviyutpakdee
Food Toxicology Unit, Institute of Nutrition, Mahidol University, Phutthamonthon 4 road, Salaya, Nakhon Pathom, Thailand 73170
E-mail: pharrunrat.tan@mahidol.ac.th

Introduction

Seaweeds have been a part of the diet in many Asian countries for decades. Especially, brown seaweed (*Phaeophyceae*) and red seaweed (*Rhodophyta*) are commonly consumed in China, Japan, and South Korea, often served in popular dishes such as soups, salads, and sushi. Among them, nori and zi-cai (red seaweed) and wakame (brown seaweed) are the most popular varieties[1]. These seaweeds are readily available and affordable through various distribution channels in Thailand, making them highly accessible to consumers, as confirmed by our market survey. Previous studies have reported that heavy metals from human activities such as mining, industry, farming, and community waste can pollute water. These metals can accumulate in sea plants, and animals over time. When people consume seafood or seaweeds, they may be exposed to these harmful substances[2,3], including lead (Pb), and cadmium (Cd), which can pose health risks to consumers. These toxic elements have been associated with adverse effects, including neurological damage, kidney dysfunction, and cancer[4]. In children, long-term Pb exposure can harm intellectual development, reduced IQ, and an increased risk of cerebral palsy[5]. In adults, increased systolic blood pressure can lead to adverse health effects on the cardiovascular system[6]. Chronic exposure to Cd can lead to its accumulation in various organs, especially the kidneys, resulting in kidneys toxicity. Besides, Cd has been classified as a Group 1 carcinogenic to humans, with strong evidence of lung cancer via inhalation[7]. Consequently, assessing heavy metal exposure from seaweed consumption is a key step in monitoring food safety and protecting public health. According to the risk assessment framework recommended by Codex Alimentarius and the Joint FAO/WHO Expert Committee on Food Additives (JECFA), chemical risk assessment involves four major steps: (1) hazard identification, (2) hazard characterization, (3) exposure assessment, and (4) risk characterization. Among these steps, exposure assessment is especially critical, as it estimates the level of chemical exposure resulting from food consumption[8]. In the case of heavy metals, accurate exposure estimation depends on reliable contamination levels in food and consumption data. An additional rationale for conducting this study is the absence of detailed information on seaweed types in the current food consumption data available from the National Bureau of Agricultural Commodity and Food Standards (ACFS)[9]. The existing data do not distinguish between freshwater and marine seaweed, which affects exposure assessment outcomes. To address this limitation, this study was undertaken to develop a validated tool for collecting seaweed consumption data. The

resulting data will be used to estimate dietary exposure to heavy metals from marine seaweed. The semi-quantitative food frequency questionnaire (SQ-FFQ) is a widely used tool for collecting consumption data, which is used to estimate habitual long-term dietary intake. It is reliable, suitable for large populations, and easy to administer[10]. Moreover, to ensure the questionnaire is effective and aligned with the study objectives, it should be revised and evaluated for validity and reliability[11,12]. Generally, the SQ-FFQ validated for one population cannot be used for another population[13]. To ensure the effectiveness of the tool used for collecting seaweed consumption data, expert review is necessary to confirm the relevance of the listed items. Additionally, reliability testing was used to verify the consistency and validity of its repeated application. Without proper validation and reliability testing, these tools may provide unreliable data, which could lead to inaccurate exposure assessments. To fill the gap, this study focuses on the process of developing and evaluating the content validity and reliability of the SQ-FFQ for estimating heavy metal exposure among adults aged 18 years and older.

Materials and Methods

The development of the SQ-FFQ followed a stepwise process. Ethical approval was first obtained from the Mahidol University Central Institutional Review Board (MU-CIRB), with COA No. MU-CIRB 2025/113.1004. Next, a market survey was conducted to identify the main seaweed species available in the market and their common culinary applications. This information was used to generate culturally relevant food items and dish examples to be included in the questionnaire. Based on these findings, an online version of the SQ-FFQ was constructed, and the instrument subsequently underwent validity and reliability testing (Figure 1). The details of each step are described below.

Market survey of seaweed varieties, seaweed-based products, and related dishes

A survey of seaweed products was conducted in Bangkok and the metropolitan areas. There are two distinct components to obtain the data on seaweed in the markets, including:

1) Market survey for sample collection: The purpose of the market survey was to identify the main seaweed species available in the Thai market. Three commonly consumed species were identified, namely zicai (*Porphyra spp.*), nori (*Porphyra spp.*, processed sheets), and wakame (*Undaria pinnatifida*). Representative dried samples of each species were then collected from popular e-commerce platforms to determine the concentrations of Pb and Cd.

2) Market survey for seaweed-based products and related dishes for tool development: During the market survey, in addition to obtaining information on the types and species of seaweed, data were also collected on the types of dishes prepared and sold from seaweed. Hence, the popular dishes were selected to be included as menu items in the SQ-FFQ.

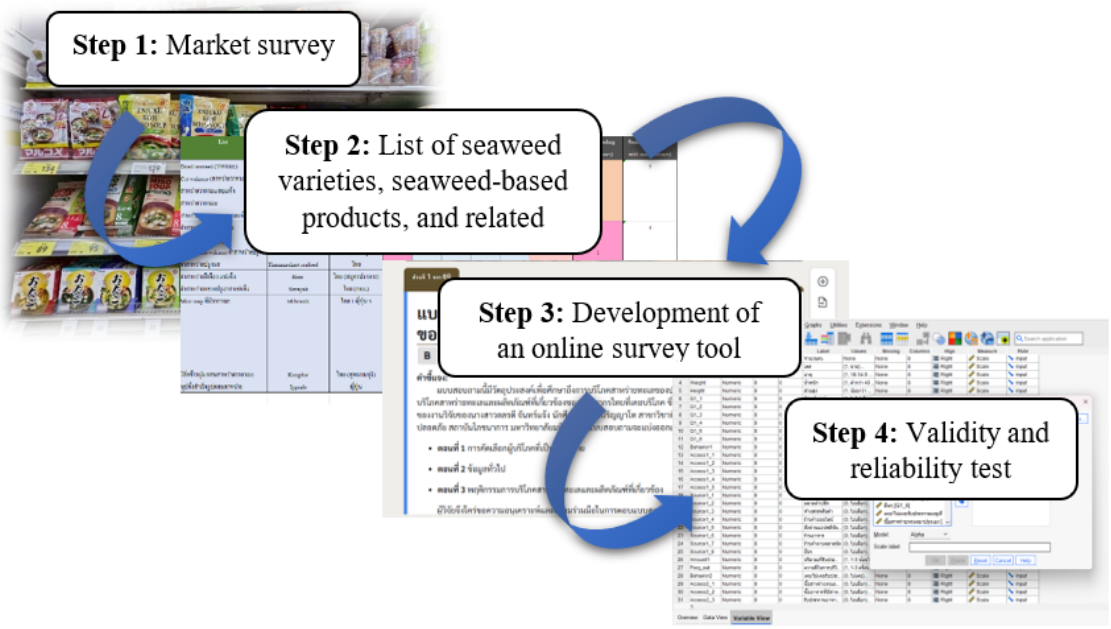

Figure 1. The research process for developing a SQ-FFQ

List of seaweed varieties, seaweed-based products, and related dishes

This part was explained in relation to the linkage of the market survey to the SQ-FFQ development. In addition to collecting seaweed types or species for laboratory analyses, the identified seaweed species were further reviewed for their common culinary uses and inclusion in seaweed menus. A summary table was constructed to illustrate the types of dishes prepared from each species (e.g., soups, salads, sushi, or snacks). These dish names were subsequently included in the SQ-FFQ to facilitate participants' recall and to improve the accuracy of reporting habitual consumption of seaweed-containing foods, as shown in Table 1.

Table 1. Grouping of seaweed products and related menus from a market survey

Group	General name	Commercial products	Popular menus
Red seaweed (*Rhodophyta*)	Nori	Roasted/grilled seaweed with seasoning (i.e., small, medium, big, roll sizes)	Sushi, rice roll, wrap, maki, onigiri
		Flake/topping	Nori shrimp nugget (nori shrimp with pork roll)
		Seasoning/flavor in many snacks (i.e., biscuits, crackers, chips)	Gimmari (deep-fried seaweed rolls)
		Seaweed-wrapped snack	Seasoning/flake/topping
		Crispy seaweed with flavors (frying process)	Thai-style salad rolls with nori
			Snacks
	Zi-cai	Dry seaweed	Soup
Brown seaweed (*Phaeophyceae*)	Wakame	Dry seaweed	Wakame salad
		Instant rice porridge with wakame	Miso soup with tofu
		Instant miso soup with wakame	Boiled wakame seaweed (i.e., sukiyaki, shabu)

As depicted in Table 1, seaweed is classified into two groups: red seaweed (*Rhodophyta*), which includes nori and zi-cai, and brown seaweed (*Phaeophyceae*), such as wakame. Red seaweed is typically consumed as part of snacks and meals, but brown seaweed is primarily consumed in main dishes. For the questionnaire, the list of commonly consumed menu items and product types corresponding to each seaweed species was based on the sixteen menu items identified under the *"Popular Menus"* category, providing participants with options to facilitate accurate and consistent data collection. Participants were also allowed to add any additional seaweed-containing dishes that were not included in the predefined list.

Development of a tool for seaweed consumption survey via an online platform

The SQ-FFQ was designed using google forms, consisting of three parts as follows:

1) Inclusion screening questions for participant selection

The first part of the question was designed to screen out participants. The inclusion criteria for study participants were Thai citizens aged 18 years and above who had previously consumed seaweed or seaweed products. Conversely, the exclusion criteria covered non-Thai citizens who were under 18 years old, did not consume seaweed, were unwilling to provide information, or were unable to complete the online questionnaire, as shown in Figure 2.

2) The questions regarding general participant information

The second part of the questionnaire was designed to collect demographic data, including age, gender, body weight, and height, as shown in Figure 3**.** The most important data is body weight, which will be used for calculating exposure to the chemical of interest.

3) The question of seaweed consumption

The final part of the questionnaire was designed to obtain the consumption data. The SQ-FFQ was selected as a tool for collecting consumption data, including both amount and frequency of consumption, due to its suitability for assessing habitual dietary consumption within the past month. In the development of the SQ-FFQ, each menu item was attached with a representative image to assist participants in recalling their consumption. For amount, a standard portion size (with a unit of “pieces”, “sheets”, and “tablespoons) was provided for each item to facilitate more accurate estimation of the quantity consumed (Figure 4). For frequency of consumption, the five defined categories were established to ensure consistency in reporting and to support accurate dietary intake estimation. The categories included: “very often or every day” (with an additional prompt for participants to indicate the number of times per day the item was consumed), “5–6 times per week”, “3–4 times per week”, “1–2 times per week”, and “1–3 times per month or rarely”. In this section, participants were asked to report their consumption of the sixteen most popular items of the seaweed-based menu. Furthermore, they were asked to specify any other seaweed-containing dishes they had consumed that were not included among the primary sixteen items by an open-ended question.

The application of the obtained SQ-FFQ data

The present SQ-FFQ was developed not only as a dietary assessment tool but also as a foundation for toxicological applications. The tool provides essential information on the habitual consumption of seaweed-containing foods, which is directly relevant to toxicological research. In particular, these data can be used to estimate long-term dietary exposure to contaminants such as Pb and Cd, thereby supporting risk characterization and food safety evaluation. It should be noted that most exposure and risk assessment studies tend to emphasize the analytical aspects, including the determination of contaminant concentrations, method validation, and the reporting of LOD or LOQ values to appropriately handle non-detected results in order to avoid assuming zero risk. However, much less attention has been paid to the robustness of dietary assessment tools, despite their critical role in generating reliable consumption data for exposure estimation. By developing and validating the SQ-FFQ, the present study contributes to filling this gap and provides a methodological foundation that strengthens the accuracy and reliability of long-term dietary exposure and risk assessment. In this study, the SQ-FFQ will be used for risk assessment processes as follows;

1) Estimation of the daily consumption of seaweed (g) at both the individual and population levels

2) Calculation of the dietary exposure to heavy metals (mg/kg BW/day) using consumption amount, concentration of chemicals, and body weight

3) Identification of high-risk groups of the population based on demo-graphic characteristics or consumption patterns by comparing with health-based guidance values

As part of this study, the SQ-FFQ will also be used to collect data on demographic characteristics (age, gender, body weight) and dietary intake, including food items, portion sizes, and consumption frequency. The chemical concentration data will be obtained from laboratory analysis. The data presented in Table 2 also serve as illustrative examples to demonstrate the completeness of the expected results and to facilitate the application of these findings in estimating dietary exposure to heavy metals from seaweed consumption. As shown in Table 2, all relevant variables, such as age, sex, and body weight, are identified for each participant. The SQ-FFQ (Part 3) collected information on food items, standard portion sizes, and frequency of consumption. The frequency of consumption was subsequently converted to a daily

equivalent using a frequency factor (*e.g.*, consumption of three times per week is converted to a daily factor of 3 ÷ 7 = 0.43). The estimated consumption amount or intake will then be calculated as described in Equation 1.

Once the consumption amount, chemical concentration, and body weight are obtained, the dietary exposure can be calculated using Equation 2.

Validity and reliability testing

1) Content validation of the questionnaire using the index of item objective congruence (IOC)

Content validity was evaluated using the IOC by five experts, consisting of a toxicologist, a nutritionist, a food scientist, a food-nutrition data specialist, and a general person.

Five experts independently evaluated each item of the question by rating a score of +1 (clearly relevant), 0 (uncertain), or -1 (not relevant). The scores were then used to calculate the IOC value for each item by Equation 3 below[14].

According to the IOC criteria, an item with an IOC value between 0.5 and 1.0 is considered acceptable for use. If the IOC value is below 0.5, the item requires revision, and reexamination by the experts.

Estimated daily intake (g/day) = Portion size (g/serving) × Frequency factor (day)……..…..… (1)

Exposure (mg/kg BW/day) = [Consumption amount (kg/day) × Chemical concentration (mg/kg)] ÷ BW (kg)..... (2)

Index of item objective congruence (IOC) = ΣR ÷ N ……..……..… (3)
Where ΣR = Sum of scores from all experts, N = The number of experts

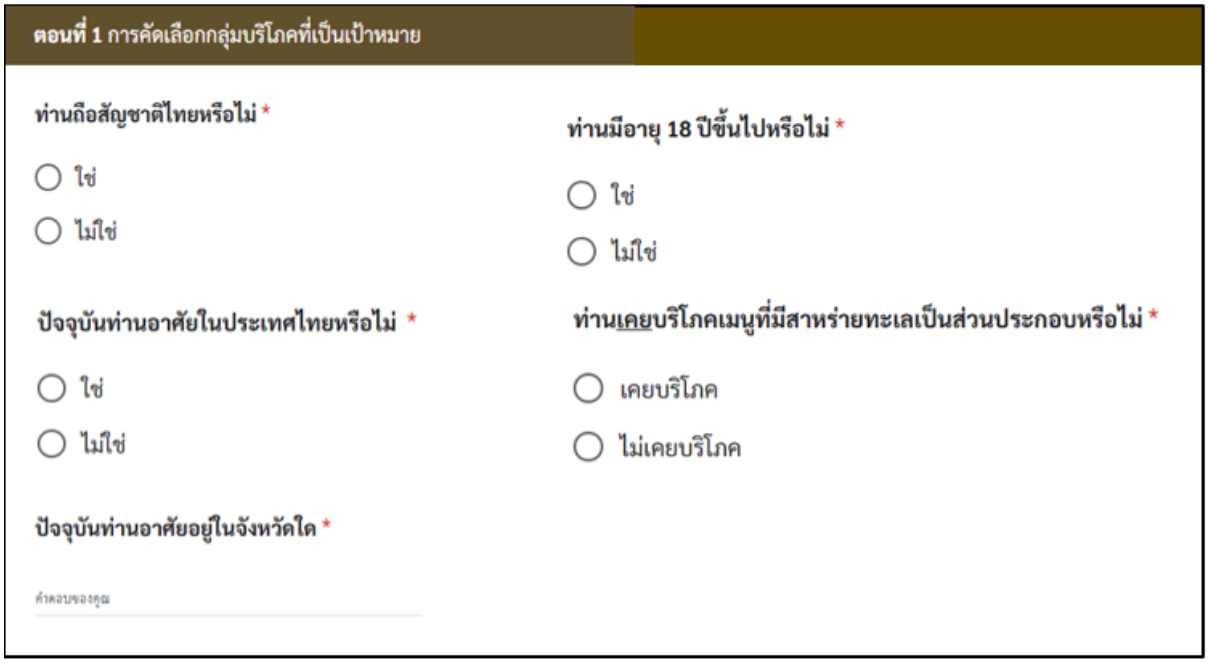

Figure 2. Inclusion screening questions for participant selection

Figure 3. Questions regarding general participant information

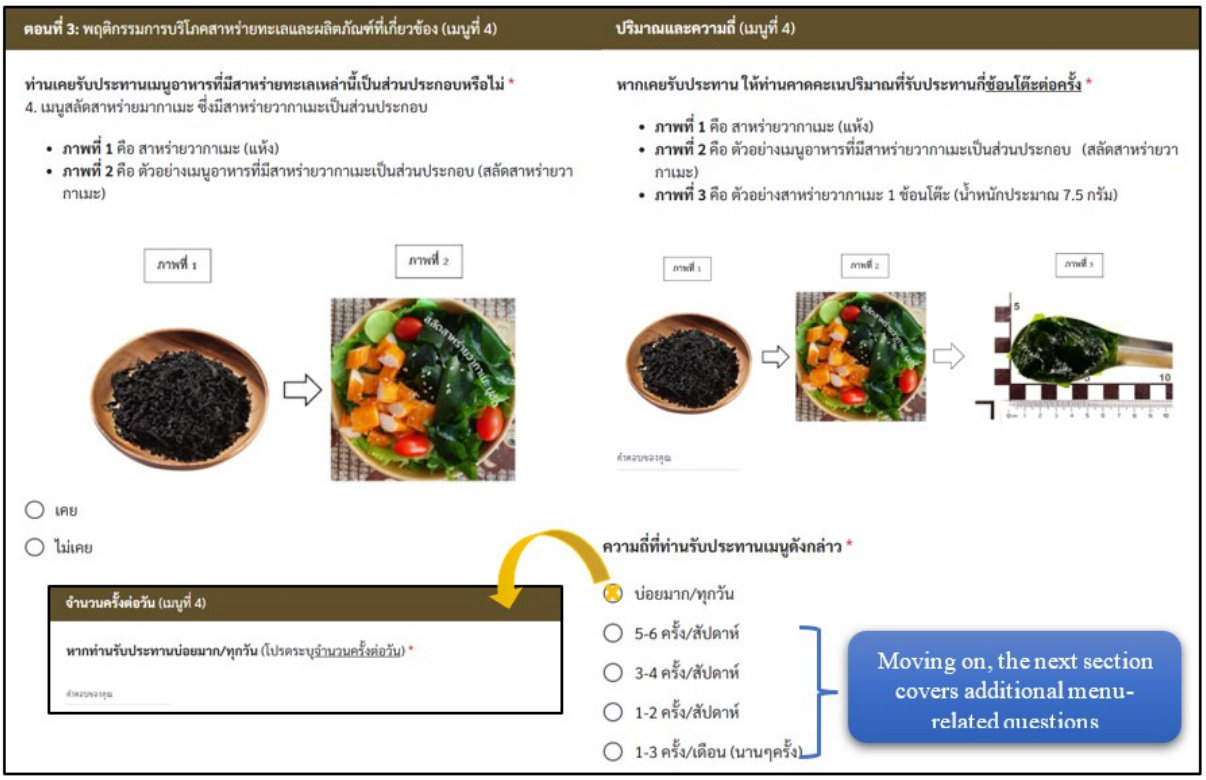

Figure 4. The question on seaweed consumption

2) Reliability test using Cronbach's Alpha coefficient

The pilot study serves as an initial trial conducted before the main survey of data collection. Its primary purpose is to test the feasibility, clarity, and functionality of the research tool, including the questionnaire design, item wording, format, and overall structure. Importantly, the pilot study provides the chance to collect trial data that can be used to calculate α-coefficient. This test enables researchers to assess the internal consistency of the item before it is used in a large-scale study[15]. In this study, a sample size of 30 participants was used as a pilot study to test the reliability of a tool for seaweed consumption survey[16]. Mostly in various studies, α-coefficient is commonly used as a tool to measure the reliability of internal consistency. This coefficient ranges from 0 to 1, with a value of 0.7 or above generally considered acceptable in most studies[17].

Statistical analysis

1) Descriptive statistics

The participant characteristics, such as age, weight, height, and dietary behavior data, including consumption amounts and frequency of consumption obtained from the SQ-FFQ were summarized as mean and standard deviation (SD).

2) Inferential statistics

The Wilcoxon Signed-Rank Test was used to compare IOC scores between the first and second validation rounds, based on assessments from five experts. A *p*-value lower than 0.05 (p-value < 0.05) was considered statistically significant.

The α-coefficient was analyzed for reliability using IBM SPSS Statistical for Windows, version 30.0 (IBM Corporation, Armonk, NY, USA) software.

Table 2. Example summary output from applications obtained from SQ-FFQ

Age	Gender	BW (kg)	Food item	Portion size (g/serving)	Frequency (times/week)	Frequency factor (day)	Consumption amount (g/day)	Chemical Conc. (mg/kg)
20	F	57	Seaweed A	14	3	3/7	14 × (3/7)	0.23
25	M	70	Seaweed B	7	2	2/7	7 × (2/7)	0.12

Note: “F” is Female; “M” is Male; “Chemical Conc.” is Chemical concentration; “BW” is Body weight.

Results and Discussion

Survey of seaweed varieties, seaweed-based products, and related dishes

The findings indicated that seaweed market trends in Thailand, as observed from both retail and wholesale sources, comprise a diverse range of seaweed products**,** mainly distributed types being nori or zi-cai, and wakame. Total nori products were found 103 items, divided into nori, with roasted (35 items) or grilled (26 items), fried (19 items), seasoned flake (17 items), unseasoned flake (3 items), and snack (3 items), while total zi-cai products were found only 5 items as dried seaweed. A total wakame products were found 29 items, consisting of dried (5 items), fresh (4 items), frozen (2 items), and ready-to-eat (18 items). However, for practical reasons, not all items were included in the SQ-FFQ. Instead, a subset of representative and commonly consumed dishes was selected, comprising 10 nori-based, 5 wakame-based, and 1 zi-cai-based dishes. This selection was made to ensure that the SQ-FFQ captures the most popular and culturally relevant menu items, thereby improving recall and response accuracy while minimizing respondent burden.

List of seaweed varieties, seaweed-based products, and related dishes

Based on the results of a preliminary market survey, sixteen commonly consumed seaweed-based menu items were identified and selected for inclusion in the SQ-FFQ. These items were compiled into a comprehensive list to support the assessment of seaweed consumption patterns and to enhance respondents' ability to recall their related dietary intake. Each item on the list was presented in the questionnaire with a corresponding image (Figure 5) and a predefined standard portion size (e.g., piece, sheet, tablespoon) to ensure consistency in reporting. Respondents were required to indicate whether they had consumed each item, the typical amount consumed per occasion, and the usual frequency of intake within the specified reference period. This approach was intended to capture detailed consumption patterns and reduce recall bias during dietary assessment.

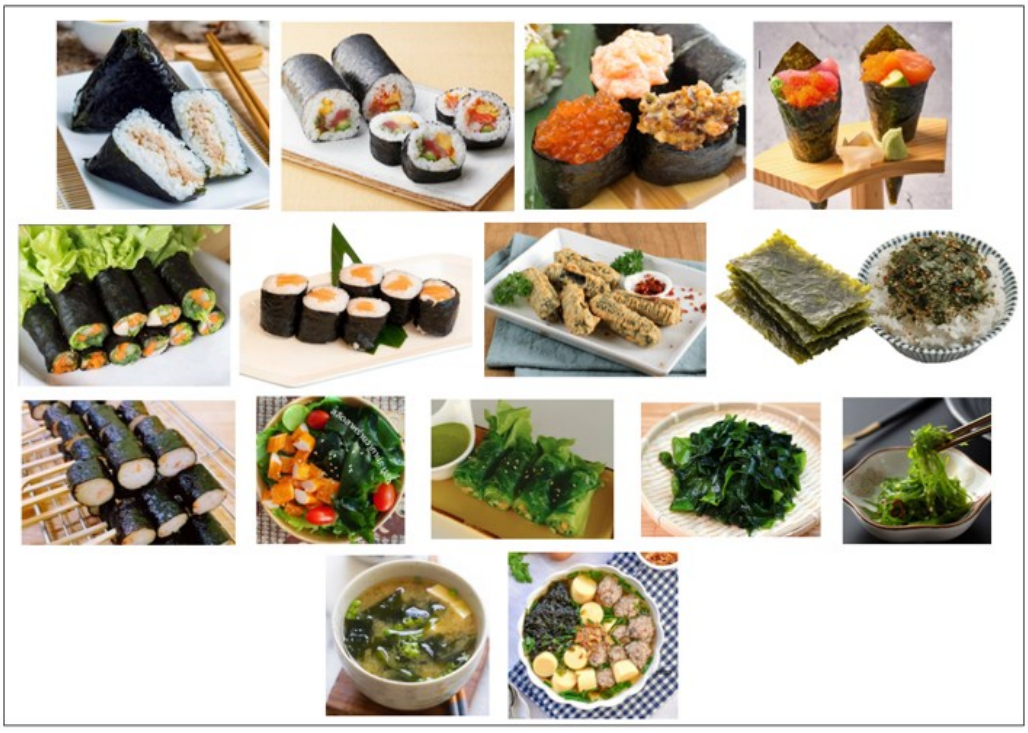

Figure 5. The popular 16 menus (including nori, zi-cai and wakame)

Validity and reliability

The content validity of the SQ-FFQ was evaluated by five experts who reviewed the relevance of each item to the study objectives. In the initial round, IOC values for all 114 items ranged from -0.2 to 1.0, were summarized in Table 3 (part 1), Table 4 (part 2), and Table 5 (part 3). According to established criteria, items with IOC values below 0.5 were considered

unacceptable and subsequently revised. A second round of evaluation was conducted with the same group of experts, resulting in IOC values ranging from 0.6 to 1.0 across 129 items. These findings confirm that the finalized SQ-FFQ items were appropriately aligned with the objectives of the seaweed consumption survey. Several methods exist to test the validity of a questionnaire, such as the content validity index (CVI) or the IOC value; both values are suitable for assessing the SQ-FFQ[18]. In addition, a content validity assessment was conducted using the IOC, a widely applied method for evaluating newly developed measurement tools[19].

The IOC values of the inclusion screening questions for participant selection was shown in Table 3, the question about living in Bangkok with -0.2 (showing in IOC round 1) was considered to be removed due to participants might be confused while answering the question, and it was changed to “Which province do you currently live in?”, with a 1.0 score of IOC.

Table 3. IOC scores of the inclusion screening questions for participant selection (1st part of the SQ-FFQ) were compared with two rounds of validation testing.

Question	IOC (round 1)	IOC (round 2)	Remarks (If IOC below 0.5 or any comments)
Do you give your consent to participate in this questionnaire?	0.6 (Q1)	1.0 (Q1)	-
Do you hold Thai nationality?	0.6 (Q2)	1.0 (Q2)	-
Are you aged 18 or above?	0.8 (Q3)	1.0 (Q3)	-
Do you live in Thailand?	0.6 (Q4)	1.0 (Q4)	-
Are you currently living in Bangkok?	-0.2 (Q5)	1.0 (Q5)	Changing this question on round 2
Have you ever consumed any dishes that contain seaweed?	0.8 (Q6)	1.0 (Q6)	-

Note: “Q” represented a question number for each question item, where is questions 1 to 6 are in screening inclusion screening questions for the participant.

As shown in Table 4, the questions on educational background, marital status, occupation, and average monthly income were removed, as they were not essential to the study objectives, despite some IOC scores falling within the acceptable range. As shown in Table 5, only the question on consumption amount estimation and the open-ended item on additional menus were revised to improve wording and formatting.

The remaining questions received acceptable scores, as they had already been modified in alignment with the study objectives based on expert recommend-dations.

To assess the stability of the content validity process, IOC scores from five experts across two validation rounds were compared using the Wilcoxon signed-rank test. As summarized in Table 6, the comparison between rounds reflects that, following expert feedback in the first round, the questionnaire items were revised accordingly, leading to improved IOC scores in the second round that met the acceptance criteria.

Table 4. IOC value of the questions regarding general participant information (2nd of the SQ-FFQ)

Question (Q7-Q11)	**IOC** (round 1)	**IOC** (round 2)	**Remarks** (If IOC below 0.5 or any comments)
Gender	1.0 (Q7)	1.0 (Q7)	-
Age	1.0 (Q8)	1.0 (Q8)	-
Body weight	0.4 (Q9)	0.8 (Q9)	Adding examples of answering
Height	0.4 (Q10)	0.8 (Q10)	
Reason for consuming seaweed	1.0 (Q11)	1.0 (Q11)	-

Note: "Q" represented a question number for each question item, where is questions 7 to 11 are in general participant information part.

A pilot study was conducted to test the internal consistency of the question-naire. A total of thirty participants completed the questionnaire, which included 188 variables related to consumption behavior. The analysis revealed that most variables yielded acceptable α-coefficient, demonstrating a high level of internal consistency. As summarized in Table 7, these findings support the questionnaire's suitability for assessing consumption behavior in large-scale applications[20]. According to Brown (1997), there are three methods to assess reliability, including, test-retest reliability, equivalent (or parallel) forms reliability, and internal consistency reliability. An internal consistency reliability requires only a single administration of the tool without the need for repeated interviews or alternative versions. It is considered the most straightforward approach from a methodological standpoint. Various methods are available for estimating internal consistency reliability. In this study, α-coefficient was selected for an internal consistency test[21].

Table 5. IOC values of seaweed consumption behavior (3rd part of the SQ-FFQ)

Question	Average IOC (round 1): From Q17 to Q113	Average IOC (round 2): From Q15 to Q111	Remarks (If IOC below 0.5 or any comments)
Eat or not eat (16 menus)	0.7	1.0	-
Consumption format	1.0	0.8	-
Source of the menu items	0.6	0.8	-
Size of sample (for nori snacks)	0.6	1.0	-
Consumption amount estimation	0.2	1.0	Changing unit of one portion
Food frequency	0.8	1.0	-
Additional question, in case of consuming very often/every day	1.0	1.0	-
The additional questions related to other menus, which contained nori, zi-cai, and wakame	0.3	0.9	Changing the question format to be appropriate.

Note: "Q" represented a question number for each question item. The average IOC in round 1 was from question 17 to 113, while the average IOC in round 2 was from question 15 to 111.

Table 6. Comparison of IOC values of two rounds tested by five experts using Wilcoxon signed rank test.

Section of SQ-FFQ	Question No.	IOC (round 1)	IOC (round 2)	*P*-value
The inclusion screening questions for participant selection (section 1)	1 – 6	-0.2 – 0.8[a]	0.6 – 1.0[b]	< 0.001
General participant information (section 2)	7 – 11	0.4 – 1.0[a]	0.8 – 1.0[b]	< 0.001
Seaweed consumption behavior, excepted additional questions (section 3)	12– 108	0.2 – 1.0[a]	0.8 – 1.0[b]	< 0.001

Note: Difference of small letters "a" and "b" represented significant differences (*P*-value < 0.001)

In this study, the SQ-FFQ was implemented once to capture habitual dietary patterns, such as consumption amounts and frequency of consumption. Given the cross-sectional design and single-time data collection for use in dietary risk assessment, α-coefficient was deemed an appropriate and sufficient method for

evaluating the internal reliability of the survey tool[22]. In most studies involving food consumption surveys related to toxic elements, including heavy metals, content validity, and reliability testing are rarely reported. Instead, researchers tend to focus on validating the methods of analysis, especially the determination of the limit of detection (LOD) and limit of quantification (LOQ)[23,24,25].

Table 7. Reliability test with Cronbach's Alpha coefficient

Reliability statistics		
Cronbach's alpha	**Cronbach's alpha based on standardized variables**	**N of variables**
0.954	0.957	188

Conclusion

This study serves as a practical example in food chemical risk assessment, emphasizing the critical role of tool development, and validation in generating reliable data for exposure-related research in food safety, particularly through the use of the SQ-FFQ. While food consumption data are fundamental to estimating dietary exposure to chemical contaminants, previous studies rarely provide detailed descriptions of the procedures used to test the validity and reliability of their data collection tools. Furthermore, available references often showed inconsistencies in questionnaire formats, such as variations in recall periods (e.g., per week versus per month), and a lack of standardized criteria for tool construction. These methodological inconsistencies weaken the reliability of exposure assessment results. The present study emphasizes a systematic approach to SQ-FFQ development, including the use of established validation techniques, such as content validity assessment, and reliability testing using α-coefficient. The findings support the importance of using well-constructed and tested tools to ensure that dietary intake data are accurate, consistent, and fit for purpose in quantitative risk assessment.

Acknowledgements

I am deeply grateful for the opportunity to have studied at the Institute of Nutrition for the generous support and provision of essential academic facilities to develop in this study.

Conflict of interest

The authors declare that there is no conflict of interest.

References

1. Wu JY, Tso R, Teo HS, *et al*. The utility of algae as sources of high value nutritional ingredients, particularly for alternative/ complementary proteins to improve human health. *Front Nutr* 2023; 10: 1277343.
2. Chen Q, Pan XD, Huang BF, *et al*. Distribution of metals and metalloids in dried seaweeds and health risk to population in southeastern China. *Sci Rep* 2018; 8(1): 3578.
3. Filippini M, Baldisserotto A, Menotta S, *et al*. Heavy metals and potential risks in edible seaweed on the market in Italy. *Chemosphere* 2021; 263: 127983.
4. FAO/WHO. Report of the expert meeting on food safety for seaweed–current status and future perspectives, 2021. Available at https://openknowledge.fao.org/server/api/core/bitstrems/43575678-4f1c-4e24-a452-3fc3c07fa4e7/content, accessed on Jun 13, 2025.
5. Kumar A, Dey PK, Singla PN, *et al*. Blood lead levels in children with neurological disorders. *J Trop Pediatr* 1998; 44(6): 320-2.
6. FAO/WHO. Safety evaluation of certain food additives and contaminants: prepared by the seventy-third meeting of the joint FAO/WHO expert committee on Food Additives (JECFA), 2011. Available at https://www.who.int/publications/i/item/9789241660648, accessed on Jun 13, 2025.
7. Tanaviyutpakdee P, Karnpanit W. Exposure assessment of heavy metals and microplastic-like particles from consumption of bivalves. *Foods* 2023; 12(16): 3018.
8. FAO/WHO. Principles and methods for the risk assessment of chemicals in food. Environmental Health Criteria 240, 2009. Available at https://www.who.int/publications/i/item/9789241572408, accessed on Jun 14, 2025.
9. ACFS. Database of food consumption of Thai people, 2010. Available at http://consumption.acfs.go.th/main;jsessionid=44F0F45858CFB3F0602939D1FFEA0568, accessed on Jun 10, 2025.
10. Nirdnoy N, Sranacharoenpong K, Mayurasakorn K, *et al*. Development of the Thai semiquantitative food frequency questionnaire (semi-FFQ) for people at risk for metabolic syndrome. *J Health Popul Nutr* 2021; 31(1): 1-8.
11. Martin-Moreno JM, Boyle P, Gorgojo L, *et al*. Development and validation of a food frequency questionnaire in Spain. *Int J Epidemiol* 1993; 22(3): 512-9.
12. Sierra-Ruelas É, Bernal-Orozco MF, Macedo-Ojeda G, *et al*. Validation of semiquantitative FFQ administered to adults: a systematic review. *Public Health Nutr* 2021; 24(11): 3399-418.
13. Cade JE, Burley VJ, Warm DL, *et al*. Food-frequency questionnaires: a review of their design, validation and utilisation. *Nutr Res Rev* 2004; 17(1): 5-22.
14. Chatprem T, Puntumetakul R, Yodchaisarn W, *et al*. A screening tool for patients with lumbar instability: a content validity and rater reliability of Thai version. *J Manipulative Physiol Ther* 2020; 43(5): 515-20.
15. Moore CG, Carter RE, Nietert PJ, *et al*. Recommendations for planning pilot studies in clinical and translational research. *Clin Transl Sci* 2011; 4(5): 332-7
16. Bujang MA, Omar ED, Foo DHP, *et al*. Sample size determination for conducting a pilot study to assess reliability of a questionnaire. *Restor Dent Endod* 2024; 49(1): e3.

17. Ab Rahman Z, Hashim A, Mohamed M, *et al*. Translation, validity, and reliability of the Malay version of the adolescent healthy lifestyle questionnaire. *J Popul Soc Stud* 2022; 31: 132-51.
18. Trangcasanchai P, Thiyajai P, Sridonpai P, *et al*. Development and validation of a semi-quantitative food frequency questionnaire for assessing prebiotic and probiotic intake among Thai adults. *J Nutr Assoc Thailand* 2024; 59(2): 67-80.
19. Turner RC, Carlson L. Indexes of item-objective congruence for multidimensional items. *Int J Test* 2023; 3(2): 163-71.
20. Dunn TJ, Baguley T, Brunsden, V. From alpha to omega: a practical solution to the pervasive problem of internal consistency estimation. *Br J Psychol* 1953; 105(3): 399-412.
21. Brown JD. Statistics Corner: questions and answers about language testing statistics: reliability of surveys. *Shiken* 1997; 1(2): 17-9. Available at http://jalt.org/test/bro_2.htm, accessed on Jun 22, 2025.
22. Alarsan SF, Mohd Saat NZ, Abd Talib R, *et al*. Validity and reliability of a questionnaire assessing changes in dietary behaviors among school children amid the covid-19 pandemic in Jordan. *Cureus* 2024; 16(8): e66980.
23. Kordas K, Cantoral A, Desai G, *et al*. Dietary exposure to toxic elements and the health of young children: methodological considerations and data needs. *J Nutr* 2022; 152(11): 2572-81.
24. Miclean M, Cadar O. Dietary metals (Pb, Cu, Cd, Zn) exposure and associated health risks in Baia Mare area, Northwestern Romania. *J Biomed Res Environ Sci* 2021; 2(7): 580-92.
25. MacIntosh DL, Williams PL, Hunter DJ, *et al*. Evaluation of a food frequency questionnaire-food composition approach for estimating dietary intake of inorganic arsenic and methyl-mercury. *Cancer Epidemiol Biomarkers Prev* 1997; 6(12): 1043-50.