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Original Article

Application of food description to the food classification system: Evidence of risk assessment from Taiwan as Acrylamide of grain products

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ABSTRACT

Harmonization of national consumption data for international comparison is an important but challenging work, yet to date there is a lack of comparable food classification system that incorporates food description in Taiwan. In 2015, European Food Safety Authority (EFSA) released a new standardized food classification and description system called FoodEx2, which provides a flexible combination of classifications and descriptions. Based on FoodEx2 and a unique data set of daily food consumption offered by Taiwan Food Consumption Database, this study aims to provide a harmonized, food description incorporated, food classification system (HFDFC system) that captures all the useful details of food groups in exposure assessments. The HFDFC system was built according to six risk-assessment-related facets including food sources, processed products, cooking methods, manufacturers (brand), food additives and specialty foods. The HFDFC system includes 199 foods in the core list and 131 foods in the extended list. This study also compared the Acrylamide hazard index estimated under the HFDFC system with that under the National Food Consumption Database in Taiwan (NFCDT). The findings indicated that the HFDFC system provides useful and detailed information that helps the users to quickly identify food information in a harmonized manner and to reduce estimation bias. The HFDFC system is expected to facilitate global comparisons in the food risk assessment because it is built based upon EU Foodex2.

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1. Introduction

There have been a growing number of food risk assessment research in Taiwan, for example, aluminum exposure of candies [1], dioxin exposure of food [2]. Food classification system plays an important role in the risk assessment of food safety and health worldwide. A good food classification system shall fulfill its users by providing information in a timely and efficient manner. A prominent example in Taiwan is the edible oil scandal. In September 2014, a large edible oil producer was discovered selling contaminated cooking oil. When investigators accessed the food classification system for risk assessment, they found that the database only provides total intakes of fats and oils and that there is a lack of edible oil dietary consumption data classified according to the brand name of edible oil products. Another example is Acrylamide risk assessment. Acrylamide risk assessment has gaining its importance in recent years. Acrylamide, commonly contained in fried, grilled, or baked foods containing carbohydrates, is listed by the International Cancer Research Institute (IARC) as Group 2A carcinogens [3]. However, the food classification system fails to provide dietary consumption data in terms of cooking methods, which could result in biased results in the Acrylamide risk assessment. To illustrate, a chicken thigh itself is not carcinogenic, but a roasted chicken thigh raises cancer risk. If the description of the food classification system is standardized in terms of cooking method, e.g. roast, it will help the users to focus on the dietary consumption of roasted chicken thighs in their risk assessment. This may further affect the accuracy of findings. Yet to date there is a lack of standardized food classification system that incorporates appropriate food description in Taiwan.

We fill the gap by providing a harmonized, food description incorporated, food classification system (hereafter, HFDFC system) that involves useful details of food groups in the Acrylamide risk assessments under the framework of FoodEx2. FoodEx2 is a new standardized food classification and description system released by the European Food Safety Authority (EFSA) in 2015 [4]. The system encompasses 32 facets that describe food properties and aspects from various perspectives, which helps its user conveniently to compare food consumption data from different sources. We expect the new HFDFC system provides better information for the users in the Acrylamide risk assessments.

2. Methods

2.1. Food description and classification systems

There are a variety of food description systems around the world, such as INFIC/ENFIC System, INFOODS Nomenclature System, and AGROVOC thesaurus [5–8]. The most popular standardized food description system called LanguaL™ was developed by the United States Food and Drug Administration (FDA) in the late 1970's. This system was further administered by the European LanguaL™ Technical Committee in 1996. LanguaL™ included 75,000 descriptions and 14 facets for users [9,10]. To facilitate the use of the standardized food description system in the food risk assessment, EFSA developed a food classification and description system for exposure assessment called FoodEx in 2011, which included 25 facets that describe food properties and aspects from various perspectives. In 2015, EFSA expended the system to 32 facets, called FoodEx2 [4,11,12]. In Europe, the FoodEx2 includes food consumption data coming from 22 different national dietary surveys in the 20 Member States [11]. FoodEx2 is also used by a well-known food-searching engine called the Ontology-Driven Mobile Safe Food Consumption System (FoodWiki), which provides food consumption suggestions to consumers who want to know more detail about the food product [13].

In Taiwan, there are mainly three popular food classification systems. Nutrient Composition Data Bank for Foods (NCDBF) is the food classification systems provided by Taiwan Food and Drug Administration (TFDA), which encompasses 18 level-one food groups including mixed grains, starch products, dry beans and nuts, fruit products, vegetable products, alga products, mushroom products, bean products, meat products, fish and shellfish products, egg products, milks products, oil products, sugar products, drinks, seasonings and spices, cakes and snacks, and seasoning packs [14]. Nutrition and Health Survey in Taiwan (NAHSIT) is maintained by Taiwan Health Promotion Administration, which provides 12 level-one food groups including (1) cereals, grains, tubers and roots; (2) fats and oils; (3) poultry; (4) meat; (5) seafood; (6) other protein-rich foods; (7) vegetables; (8) fruits; (9) refreshment and snakes; (10) alcoholic beverages; (11) sauces, condiments and spices; (12) miscellaneous foods, and also provides 48 level-two sub-groups [15]. National Food Consumption Database in Taiwan (NFCDT) is maintained by TFDA, which provides 17 level-one food groups including (1) wholegrain and mixed grains; (2) dry beans and nuts; (3) fats and oils; (4) poultry and poultry products; (5) livestock and livestock products; (6) fish, seafood; (7) eggs; (8) dairy; (9) fruits; (10) vegetables; (11) sugar and confections; (12) drinks; (13) wine; (14) seasonings; (15) composite food, soups and other categories; (16) infant foods; (17) health foods. It also includes 67 level-two sub-groups, 199 level-three sub-groups, and 131 level-four sub-groups [16]. The NFCDT only provides consumption data in terms of food name for risk assessment, and it does not provide detailed information such as brand name, cooking methods, etc. The use of NFCDT in the risk assessment is limited because the users cannot distinguish different cooking methods from food consumption data.

2.2. Research framework

Fig. 1 outlines how we shape the HFDFC system. We initiated building the food information by constructing food description facets in terms of the dietary consumption data retrieved from NAHSIT, following the process of food description construction in the EFSA. In 2015, our working group discussed with TFDA regarding the food messages available from the NAHSIT diet database. TFDA and our working group reached a consistency regarding three types of food information: (1) Food description for the nutritional information that is sufficient to provide basic food information. (2) Information about food additives in the food safety events. (3) Food information for risk assessment. We then built the HFDFC system by classifying the facets

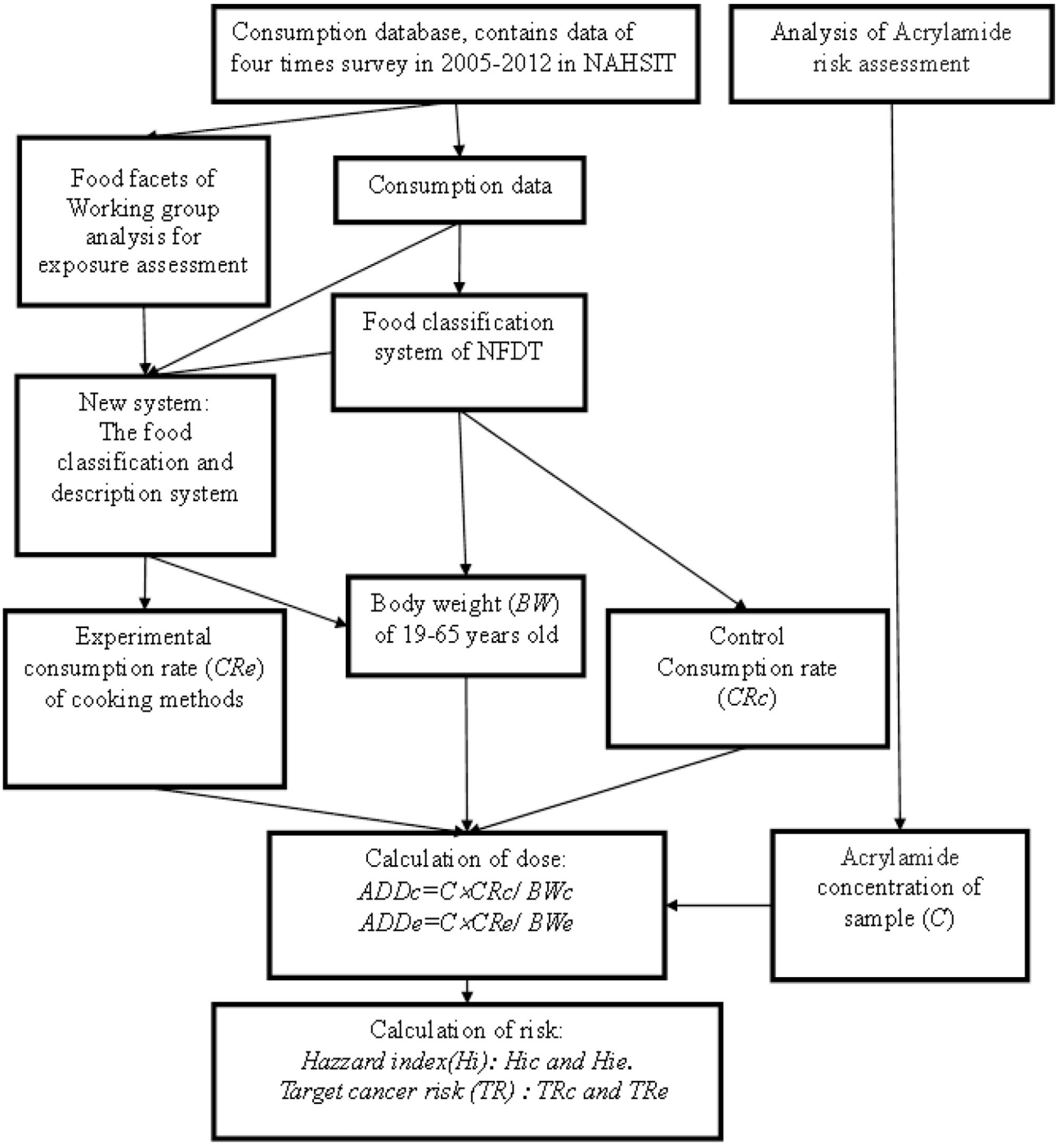

Fig. 1 – Process of Food classification and description system establishment and the analysis of Acrylamide risk assessment.

according to cooking methods [17,18]. We then used the HFDFC system to calculate the consumption rate (*CR*) according to different cooking methods as well as the average body weight (*BW*) between 19 and 65 years old citizens. The *CR*, *BW*, the Acrylamide concentration of sample (*C*), and the oral exposure (*RfD*) were then used to calculate the average daily dose (*ADDe*) as well as the Hazard index (*HIe*) under the HFDFC system. Following the same procedure, we calculated the average daily dose (*ADDc*) and the Hazard index (*HIc*) under the NFCDT. The difference between HFDFC system and NFCDT lies in that HFDFC system involves description (cooking methods) while NFCDT does not include the description.

2.3. *Calculation of Acrylamide risk assessment (non-cancer risk assessment)*

There was currently no carcinogenic data available for the assessment of Acrylamide carcinogenic risk in current

chronic ingestion studies [19]. So we study was on the non-cancer risk assessment. We conducted Acrylamide risk assessment according to World Health Organization (WHO). Following prior research [20], we used the Equations (1)–(3) to calculate the Hazard index.

I Reference Dose for Oral Exposure of acrylamide (*RfD*) and no-observed-adverse -effect level (*NOAEL*):

$$RfD_{(mg/kg-BW/day)} = \frac{NOAEL}{UF} \quad (1)$$

Both toxicological parameters are measured in mg/kg-BW/day. *RfD* is in accordance with the CASRN 79-06-1 retrieved from the United States Environmental Protection Agency (EPA). *NOAEL* of a chemical can be retrieved from the animal experiments reported in toxicology reference databases such as Joint FAO/WHO Expert Committee on Food Additives (JECFA) or EPA. *UF* represents the uncertainty factor, which refers to unit-less numbers between 100 and 1000 used to extrapolate from dose for animal to dose for human [21,22].

II The average daily dose (ADD):

$$ADD = \frac{C*CR}{BW} \quad (2)$$

C refers to the concentration of acrylamide in the food item, which is measured with mg/kg. It is obtained from the reference report [21,22]. *CR* refers to the consumption rate of the food item, which is the gram of consumption per person per day (g/person/day). *BW* refers to the body weight.

III Hazard index (*HI*) refers to the ratio of average daily dose (*ADD*) to reference dose for oral exposure of acrylamide (*RfD*). The value of Hazard index that is lower than one means no harm from dietary exposure in any consumer.

$$HI = \frac{ADD}{RfD} = \frac{C*CR}{BW} * \frac{1}{RfD} \quad (3)$$

IV Target cancer risk (*TR*) refers to the carcinogenic risk of Acrylamide. If the value of target cancer risk lower than 10^{-6}, it means within acceptable range from dietary exposure [23].

$$TR = \frac{EF*ED*C*MCS*CPS}{BW*AT} \quad (4)$$

EF: Exposure frequency, 350 days/year.
ED: Exposure duration, total, 30 years.
MCS: Concentration in edible portion of food, μg/g.
BW: Body weight, adult.
TR: Target cancer risk.
CPS: Carcinogenic potency slope, oral, risk per mg/kg/day.
AT: Averaging time about carcinogens set 70 years or 25,550 days.
C: Concentration, $\mu g/m^3$ or g/day.

2.4. Data and statistics

The dietary consumption data is retrieved from NAHSIT during the period of 2005–2012, which covers both food information and food consumption data at all ages [15]. Data for the determination of body weight and food consumption rate is retrieved from NFCDT. The statistics of data was by SAS 9.4(SAS Inc., USA). Descriptive statistics should follow the scales used in data description.

3. Results

The sample contains total 12,082 foods consumed by Taiwan citizens at all ages in our food classification database. In the database, there are 2015 citizens who are the age between 19 and 65. We divided the age into seven intervals and one interval for childbearing age: 0–3, 4–6, 6–12, 13–15, 16–18, 19–65, >65, and female between the childbearing age of 19–45. We identified the source, processed product, cooking method, brand name, food additives and cuisine as the six facets that may help the users quickly find out the food.

According to the definition of the food descriptors reported in Table 1, we then divided the facets into sub-groups food facets that are associated with risk assessment. This procedure yielded six sub-groups for processed product, five sub-groups for cooking method, five corporate brand names for food additives, and five corporate brand names for cuisine.

We then built the HFDFC system by recoding the foods listed in NFCDT, according to the food facets. Table 2 illustrates how we classified the grains according to the facets. There are four levels in the classification system. In the second level, grains are classified into rice and rice products, wheat, and other grains, according to the product categories. In the third level, the grain items in the second level are further classified into several groups including rice, rice porridge, rice milk, processed rice products, wheat and wheat products, flour and flour products, mixed grains, and processed mixed grain products, according to the types of food processing. In the fourth level, each group in the third level is further classified into several extended items. To enhance the comparability between HFDFC system and NFCDT, we create combined standardized food codes that incorporate the food facets into NFCDT. We use the symbol "#" to establish a link between food classification items and food description items. We use the symbol "$" to establish a link between two food description items. For instance, white rice is coded A010101 in the food classification system, and it is coded F01.1 by the plant origin of the food source facet. The combined code of the white rice in terms of the food source facet is A010101# F01.1. In doing so, the users are able to identify the foods in terms of the food sources.

The recoding procedure yielded 17 groups in the first level, 67 groups in the second level, 191 groups in the third level, and 131 groups in the fourth level. The 131 groups in the fourth level are further extended to approximately 12,082 food items that can be traced by the food facets. Because the HFDFC coding system is built based on the code index in Foodex2, it facilitates global comparisons of food consumption.

Table 1 – Food information in NAHSIT.

Facets	Description	Note
Food source	Plant	The source of the principal ingredient is plant origin.
	Animal	The source of the principal ingredient is animal origin.
	Mixture of Plant and animal	The source of the principal ingredient consists of both plant and animal origins, such as composition food.
	Other sources	The source of the principal ingredient is not plant and animal origins or the mixture of plant and animal origins, or is unidentifiable.
Processed product	Canned product	The food material or the processed product is canned in a can.
	Pickled product	The food material or the processed product is pickled with salt or sauces.
	Smoked product	The food material or the processed product is smoked over a long period of time.
	Fermented product	The food material or the processed product is made by microorganisms from fermentation.
	Other processed method of food product	The processed method does not belong to canned, pickled, smoked, or fermented method.
	Non-processed product	The food is unprocessed.
Cooking method	Grilled/Baked	The food material or the processed product is cooked or processed using fire or using oven with high temperature.
	Fried	The food material or the processed product is cooked in the oil with high temperature.
	Raw	The food is uncooked, such as fish, fruits, vegetables, and fresh food.
	Unknown cooking method of food	The cooking method is unidentifiable.
Brand name		The brand name of the food product is shown in the food label.
Food additives	Nitrite	Nitrite is listed in the food label.
	Benzoic acid	Benzoic acid is listed in the food label.
	Phosphate	Phosphate is listed in the food label.
	Caramel	Caramel is listed in the food label.
	Unknown Food additives	The food label does not list food additives.
Cuisine	Chinese cuisine	The food is representative in the traditional Chinese culture, such as buns, dumplings, etc..
	Japanese cuisine	The food is representative in the traditional Japanese culture, such as sushi.
	European and American cuisine	The food is representative in the traditional European and American culture, such as pizza and hamburgers.
	Southeast Asians Cuisine	The food is representative in the traditional Southeast Asian culture, such as meat and bone tea.
	Other cuisine	The food is unidentifiable in any culture.

Table 3 illustrates how HFDFC system provides more useful information on grain foods than NFCDT does, using grains as an example. Reported in Table 3, there are total 561 wholegrain and mixed grains products. NCFDT classifies the wholegrain and mixed grains products into 195 rice and rice products, 276 wheat and wheat products, and 90 other grains. In the HFDFC system, the wholegrain and mixed grains products are classified into 164 baked/grilled products, 1 fired product, 0 raw product, and 96 products with unknown cooking methods. Therefore, the users who want to search the food consumption information about Baked/Grilled products can obtain relatively precise and useful information from HFDFC system as compared to NCFDT. This is because fresh foods themselves are not carcinogenic and pathogenic to human body, but cooking methods or food additives are carcinogenic or pathogenic to human body. Hence, food consumption data classified according to food description facets provides better information for the users.

Table 4 compares the hazard index of Acrylamide for grain products consumed by citizens between the age of 19–65 under the HFDFC system and that under NFCDT. The hazard index of the processed mixed grain products for male under NFCDT is higher than one ($HI_c = 3.11$), which means the processed mixed grain products are a potential source that may cause harmful effects on human body. Because acrylamide arises in frying or roasting process, we expect potato chips and fritters, the two processed mixed grain products, to exhibit high values on hazard index. The hazard index of potato chips and of fritters under the HFDFC system is 0.67 and 0.11, respectively and the TR of AA is in the acceptable range. This means that potato chips and fritters are less likely to cause harmful effects on human body.

4. Discussion

Based on a sample of 12,082 food names, we develop a harmonized, food description incorporated, food classification system (HFDFC system) that classifies consumption data in terms of six facets including food source, processed product, cooking method, brand name, food additives, and cuisine. The HFDFC system includes 199 foods in the core list and 131 foods in the extended list. Traditional consumption classification system such as NFCDT only provides limited information for the users who are undertaking food risk assessment. When conducting food safety risk assessments, the users need food messages such as cooking methods and product brand names. Accordingly, the hazard index of

Table 2 – Example of Grains in the HFDFC coding system.

The classification system				The description system
Level 1	Level 2	Level 3 Core list	Level 4 Extend list	Facets
				Food source
A. Grain	01. Rice and Rice products	01. Rice	01. White rice	F01.1 Plant
			02. Brown rice	F01.1 Plant
			03. Glutinous rice	F01.1 Plant
			04. Wholegrain rice	F01.1 Plant
			05. Other Rice	F01.1 Plant
		02. Rice porridge	01. White rice porridge	F01.1 Plant
			02. Brown rice porridge	F01.1 Plant
			03. Glutinous rice porridge	F01.1 Plant
			04. Wholegrain rice porridge	F01.1 Plant
			05. Other Rice porridge	F01.1 Plant
		03. Rice milk	01. White rice milk	F01.1 Plant
			02. Brown rice milk	F01.1 Plant
			03. Wholegrain rice milk	F01.1 Plant
			04. Other rice milk	F01.1 Plant
		04. Processed rice products	01. Rice noodles	F01.1 Plant
			02. Flat noodles	F01.1 Plant
			03. Grain rice flour	F01.1 Plant
			04. Other processed rice products	F01.1 Plant
	02. Wheat	01. Wheat and wheat products	01. Wheat	F01.1 Plant
			02. Barley	F01.1 Plant
			03. Buckwheat	F01.1 Plant
			04. Oat	F01.1 Plant
			05. Other kinds of wheat	F01.1 Plant
		02. Flour and flour products	01. Flour	F01.1 Plant
			02. Noodles	F01.1 Plant
			03. Gluten products	F01.1 Plant
			04. Crust and dough	F01.1 Plant
			05. Other processed flour products	F01.1 Plant
	03. Other grain	01. Mixed grains	01. Corn	F01.1 Plant
			02. Other kinds of grains	F01.1 Plant
		02. Processed mixed grain products	01. Corn chips	F01.1 Plant
			02. Barley flour	F01.1 Plant
			03. Other processed mixed grain products	F01.1 Plant

Acrylamide of processed mixed grain products could be overestimated in the previous NFCDT, because the users of NFCDT are unable to identify the food products in terms of cooking methods.

The acrylamide risk assessment of food has been a considerable issue in different country or area. U.S. Food and Drug Administration (FDA) released a declaration about Guidance for Industry Acrylamide in Foods and information of the chemical contaminants of acrylamide [24,25]. It standardized the steps and conditions information for the growers, manufacturers and food service operators within decreasing the level of food acrylamide. Research showed that potential conditions may reduce acrylamide, for example, potatoes keeping in high temperatures during the transport

Table 3 – Food list of wholegrain and mixed grains products in the NCFDT and HFDFC.

HFDFC system (Experimental Group)		NCFDT system (Control Group)			
Facets	N of foods	The food list			N of foods
F03.1 Baked/Grilled	164	A01.Rice and Rice products			195
		A02.Wheat and wheat products			276
F03.2 Fired	1	A03.Other grain	Mixed grains	Corn	38
F03.3 Raw	0			Other kinds of mixed grains	6
F03.4 Unknown cooking method	**396**		Processed mixed grain products		**46**
Total wholegrain and mixed grains products	**561**	Total wholegrain and mixed grains products			**561**

Bold signifies "Unknown cooking method was that foods cooked by uncertainty cooking method", "Processed mixed grain products were that mixed grain products made by processed of other grains" and "Total wholegrain and mixed grains products were the numbers of wholegrain and mixed grains products

Table 4 – The Hazard index of Acrylamide for grain products consumed by citizens between the age of 19–65.

HFDFC								NFCDT					
Food list		C (mg/day)	CR_e (mg/kg/day)		HI_e		TRe		Food list	HI_c		TRc	
			Male	Female	Male	Female	Male	Female		Male	Female	Male	Female
Breakfast cereals	Dry type	0.056	473.61	185.38	0.13	0.06	0.191×10^{-6}	0.099×10^{-6}	Wheat and wheat products	1.26	0.50	0.808×10^{-6}	0.035×10^{-6}
	Brewing Type	0.095	108.05	103.51	0.05	0.06	0.074×10^{-6}	0.094×10^{-6}					
	Instant Food	0.019	22.23	107.43	0.00	0.01	0.003×10^{-6}	0.020×10^{-6}	Mixed grains Corn	0.14	0.13	0.009×10^{-6}	0.009×10^{-6}
									Other kinds of grains	0.05	0.05	0.003×10^{-6}	0.004×10^{-6}
Potato chips		1.104	137.08	56.22	0.67	0.33	0.998×10^{-6}	0.543×10^{-6}	Processed mixed grain products	3.11	5.03	0.200×10^{-6}	0.354×10^{-6}
Fritters		0.348	61.98	78.38	0.10	0.16	0.157×10^{-6}	0.262×10^{-6}					

Note. 1. *RfD* (mg/kg/day) = 0.003, US EPA, ORD number CASRN 79–06–1.
2. C = Concentration in food.
3. *HI* = Hazard index.
4. Male and female body weight between the age of 19–65 is 69.33 Kg and 57.27 Kg, respectively.
5. *TR* = Target cancer risk.

[24], selecting potato varieties which have low acrylamide [24], treatment of puffed shrimp chips with 0.1% calcium supplements [26]. The food classification and food information of guidance will be useful detail for us to increase the description of HFDFC system in the future, such as, variety of raw materials, condition of during harvest, transport, delivery, and storage, food additives within processing.

Taiwan Food and Drug Administration (TFDA) and FoodDrinkEurope also had guidance about the reducing acrylamide [27,28]. Compared with the information of guidance within U.S., Taiwan and Europe, all of them provided the similar detailed conditions to reduce the food acrylamide, but slightly difference in food group. In addition to grain and potato products, brown sugar and fritters which were the popular foods in Chinese food culture had higher acrylamide in Taiwan Chinese food culture and would be a considerable object of research.

Beside the guidance of reducing acrylamide, HFDFC system consistently make progress by taking research of world as reference and cooperating with the needs of users. Our HFDFC system provides useful and detailed information that helps the users to quickly identify food information in a harmonized manner, which not only reduces estimation bias and enhances the appropriateness of conclusions. Because the HFDFC system is built based upon EU Foodex2, it also facilitates global comparisons in the food risk assessment. Collectively, we expect the HFDFC system to play a key role in the global community where food safety risk assessment is gaining its importance.

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