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Risk Assessment of Inhalation Exposure to Formaldehyde (FA) in Chicken Wings at Makro Cambodia and Derm Kor Market of Phnom Penh, Cambodia

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សង្ខិត្តន័យ

ការចម្លងផរម៉ាល់ដេអ៊ីត (FA) នៅក្នុងស្លាបមាន់ពីផ្សារម៉ាក្រូនិងផ្សារដើមគរក្នុងរាជធានីភ្នំពេញប្រទេសកម្ពុជាត្រូវ បានវាយតម្លៃពីបញ្ហាសុខភាព ដែលអាចកើតមានចំពោះប្រជាជនក្នុងតំបន់តាមរយៈការទទួលទានស្លាបមាន់ ។ ការសិក្សានេះប្រើវិធីសាស្ត្រស្ពេចត្រូផូតូមេទ្រិច (spectrophotometric) វាយតម្លៃការប៉ះពាល់នៃសារធាតុផរម៉ាល់ដេអ៊ីត (FA) នៅក្នុងស្លាបមាន់ទៅលើសុខភាពអ្នកទទួលទានស្លាប់មាន់នៅទីក្រុងភ្នំពេញ ។ ក្នុងស្លាបមាន់មួយ គីឡូក្រាមមានផ្ទុកផរម៉ាល់ដេអ៊ីត(FA) ចន្លោះ 0.757 ± 0.090 ទៅ 1.260 ± 0.090 មីលីក្រាម ។ រីឯតម្លៃប៉ាន់ប្រមាណការទទួលទានប្រចាំថ្ងៃ (EDI) ចាប់ពី 4.1.128 × 10^{-3} ទៅ 4.246 × 10^{-3} មីលីក្រាមក្នុងមួយគីឡូក្រាមនៃទម្ងន់ក្នុងខ្លួនដែលទាបជាងតម្លៃ RfD ប្រចាំថ្ងៃអតិបរមា 0.15 និង 0.2 មីលីក្រាមក្នុងមួយគីឡូក្រាមនៃទម្ងន់ខ្លួនចំពោះផរម៉ាល់ដេអ៊ីត(FA) ដែលអនុម័តរៀងគ្នាដោយអង្គការសុខភាពពិភពលោក (WHO) និង ទីភ្នាក់ងារការពារបរិស្ថានសហរដ្ឋអាមេរិក (EPA)។ លទ្ធផលនៃការសិក្សាបានបង្ហាញថាសន្ទស្សន៍ហានិភ័យមិនបង្កជំងឺមហារីក(THQ)និងសន្ទស្សន៍ហានិភ័យចំពោះសុខភាព(HRI) ចំពោះភាគសំណាកគ្រប់ប្រភេទ គឺទាបជាង 1 ដែលមានន័យថាកុមារជំទង់ និងមនុស្សពេញវ័យស្ថិតនៅក្នុងចន្លោះសុវត្ថិភាព។ ប៉ុន្តែការសិក្សានេះក៏បង្ហាញផងដែរថា ភាគសំណាកស្លាបមាន់ដែលប្រមូលបានពីផ្សារម៉ាក្រូនិងផ្សារដើមគរ នៅតែមានសុវត្ថិភាពសម្រាប់ការទទួលទាន។

Abstract

Formaldehyde (FA) contamination of chicken wings at the Makro Cambodia and Derm Kor markets in Phnom Penh, Cambodia, was assessed for potential health concerns to the local community through chicken wing consumption. This study evaluates the exposure of

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the Phnom Penh population of Cambodia to FA through the consumption of chicken wings by spectrophotometric method. FA content was between 0.757 ± 0.090 and 1.260 ± 0.090 mg/Kg. The estimated daily intake (EDI) values ranged from 4.1.128 × 10-3 to 4.246 × 10-3 mg/Kg BW/day, which was also lower than the maximum daily reference dose (RfD) of 0.15 and 0.2 mg/Kg BW/day for FA established by the WHO and the United States EPA, respectively. The risk assessment from the study indicated that the THQ and HRI computed for all the species were far below 1, which means children, adolescents, and adults are within the safe interval. However, it also indicates that chicken wing samples collected from Makro Cambodia and Derm Kor Market were still safe for human consumption.

Background

Formaldehyde (FA) is a highly volatile, colorless liquid that is flammable and has a strong, irritating odor. It is a well-recognized human carcinogen, on continuous exposure, poses a significant risk to the health of individuals in various forms (Alotaibi *et al*., 2022; Chaiklieng, Tongsantia, & Autrup, 2021; Protano *et al*., 2022; Xinxuan Li, Yaohua Gao, Pinghua Deng, 2023). Inhalation exposure, representing a primary mode of intake, can lead to myriad health problems like respiratory symptoms, eye, nose, and throat irritation, and even cancer. Among the various foods, FA treatment is often associated with preserving and enhancing the quality standards in the poultry industry worldwide (Chaiklieng *et al*., 2021; Mathur & Rastogi, 2007; Protano *et al*., 2022; Xinxuan Li, Yaohua Gao, Pinghua Deng, 2023; Zain, Azmi, Veloo, & Shaharudin, 2019). However, FA has long been banned as a food additive and is listed as a carcinogen by the International Agency for Research on Cancer and the World Health Organization. However, due to its antiseptic and preservative properties, FA is illegally added to food to extend its shelf life. Some sellers apply FA to aquatic products as a food preservative to maintain freshness during transport and storage, thereby compromising food safety. Hence, monitoring of FA exposure is of significant interest from both analytical and toxicological perspectives (Fappiano, Carriera, Iannone, Notardonato, & Avino, 2022).

For many decades, Cambodia, similar to many developing countries, has used formaldehyde (FA) in the poultry industry primarily for its disinfectant properties and to extend the shelf life of products. This practice has been driven by the need to ensure the safety and durability of poultry in the market. As urbanization and changes in lifestyle have increased, there has been a noticeable shift towards eating out and a higher demand for pre-cooked and processed foods. This shift has led to greater consumption of processed chicken wings, often treated with FA, as they are convenient and readily available. The rise in eating out and the growing popularity of ready-to-eat meals have exacerbated the issue, as these processed foods frequently include chicken wings that may be treated with FA to preserve freshness and enhance appearance. Consequently, this increased consumption of processed chicken wings, along with the widespread use of FA in the poultry industry, raises concerns about potential health risks associated with FA exposure from these food sources (Burgos, Hinrichs, Otte, Pfeiffer, & Roland-Holst, 2008; Ntzimani, Kalamaras, Tsironi, & Taoukis, 2023; Ravindran, 2013; Windus, Duncanson, Burrows, Collins, & Rollo, 2022; Yitayih, Geremew, Esatu, Worku, & ..., 2021).

This study focuses on Phnom Penh, the capital city of the Kingdom of Cambodia, recognized for its vibrant and dynamic environment. As the political, economic, and cultural epicenter of the nation, Phnom Penh is characterized by rapid urbanization, a diverse demographic, and a vibrant street culture. The growth of the city is inclined toward fast food which highlights the integral role of processed chicken wings in the daily diet of its inhabitants. The detection of FA in these food items presents a potential health risk, given the compound's known hazardous effects. This issue is particularly concerning in the context of Phnom Penh's urban food distribution networks, where the concentration of FA in widely consumed chicken wings necessitates comprehensive food safety evaluations and public health interventions (Sim & Laohasiriwong, 2019). The aim herein is to conduct a risk assessment of inhalation exposure to FA when dealing with chicken wings in Phnom Penh, providing much-needed insight into the health implications of such practices (Chaiklieng *et al*., 2021). Thorough risk assessments are essential to help minimize the potential health hazards from exposure to FA by inhalation. Their significance lies in providing relevant data for developing strategic interventions to protect public health, especially for high-risk populations (Wang, Feng, He, Jin, & Fu, 2023; Zain *et al*., 2019). Therefore, the research herein embarks on a journey to measure and evaluate the FA concentrations in the chicken wings market in Phnom Penh, Cambodia. Focusing on the current situation, the relevant consumer behavior patterns, processing methods, and potential security gaps related to FA usage, the risk assessment will employ advanced technologies and methodologies for data collection and assessment purposes (Environmental Protection Agency, 2020). Despite the recognized risk associated with FA inhalation exposure, studies in Cambodia, particularly on chicken wings, a significant part of the local diet, appear scanty. Thus, the research generates a timely response, endeavoring to bridge this gap and contribute to the scarce literature on the topic (Khoshakhlagh, Mohammadzadeh, Sicard, & Bamel, 2024; Thompson, Vipham, Hok, & Ebner, 2021). The objective is to analyze FA concentrations in chicken wings and evaluate the health risks posed to consumers and individuals involved in preparation. The findings from this study will inevitably provide policymakers with the necessary data to establish prudent and adequate policies and ensure proper measures to safeguard the public from the potential risks of FA exposure. To this end, the paper proceeds by elucidating a comprehensive introduction to the field, outlining the significance and gravity of the issue at hand, and laying down the foundation for the sound, data-driven risk assessment to follow. The efforts contribute to a broader understanding of health risks in daily consumable food products in Phnom Penh, Cambodia, and, further, broader learning about the harmful effects of chemicals like FA on food products in other parts of the world. The outcomes of this research would, moreover, serve as a baseline for future studies on similar topics within and beyond the Cambodian context, echo the need for tighter controls and regulatory mechanisms within the poultry industry and allied sectors, and finally, stimulate awareness and catalyzing changes concerning chemical use in food processing at the consumer level.

Materials and Methods

All the chemicals used were analytical grade. FA solution, AR, contains 5 to 8% methanol as stabilizer, 37 to 41% (w/v) (Sigald), acetic acid (Sigald), trichloroacetic acid (TCA) for analysis (Millipore), aluminum acetate (Aldrich), acetylacetone (Millipore) were obtained from the life science business of Merck KGaA, Darmstadt, Germany operates as Millipore Sigma in the US and Canada. About 6.0% (w/v) trichloroacetic acid was prepared by weighing 60.0 g and dissolved in 1000.0 mL of distilled water. Nash's reagent was prepared by weighting ammonium acetate 150.0 g, dissolved in distilled water 800.0 mL, dropping 3.0 mL of acetic acid and 2.0 mL of acetylacetone, and adjusted with distilled water to 1000 mL for hold research. Due to its light sensitivity, the reagent was stored in the dark at 0°C.

Phsar Daeum Kor (11.558301758045776, 104.90437965613171) is a prominent and highly frequented local market in Phnom Penh, Cambodia. This market provides a diverse selection of fresh vegetables, street food, clothing, home products, and more items. It is unquestionably a prime destination in the city for immersing oneself in the authentic Cambodian culture and way of life. Makro Cambodia (11.59447140650159, 104.8804872384171) is a subsidiary of Makro's global retail chain, which operates in many Asian and European countries. The company provides an extensive range of items primarily targeted towards the food service industry and associated sectors. Their establishments are characterized as warehouse clubs catering to corporations and people seeking to get products in large quantities. Makro has retail outlets in Phnom Penh and Siem Reap, which are located in Cambodia.

Chicken wing samples were collected from both markets on February 24, 2023. The collection process involved randomly purchasing samples from Phsar Daeum Kor (see the map Figure 1). To ensure the samples remained fresh, they were immediately preserved in iceboxes maintained at a temperature of 3 to 4°C. These iceboxes helped to slow down any bacterial growth and prevent spoilage. The samples, sealed in zip-lock bags for added protection, were transported back to the laboratory within 24 hours of collection to

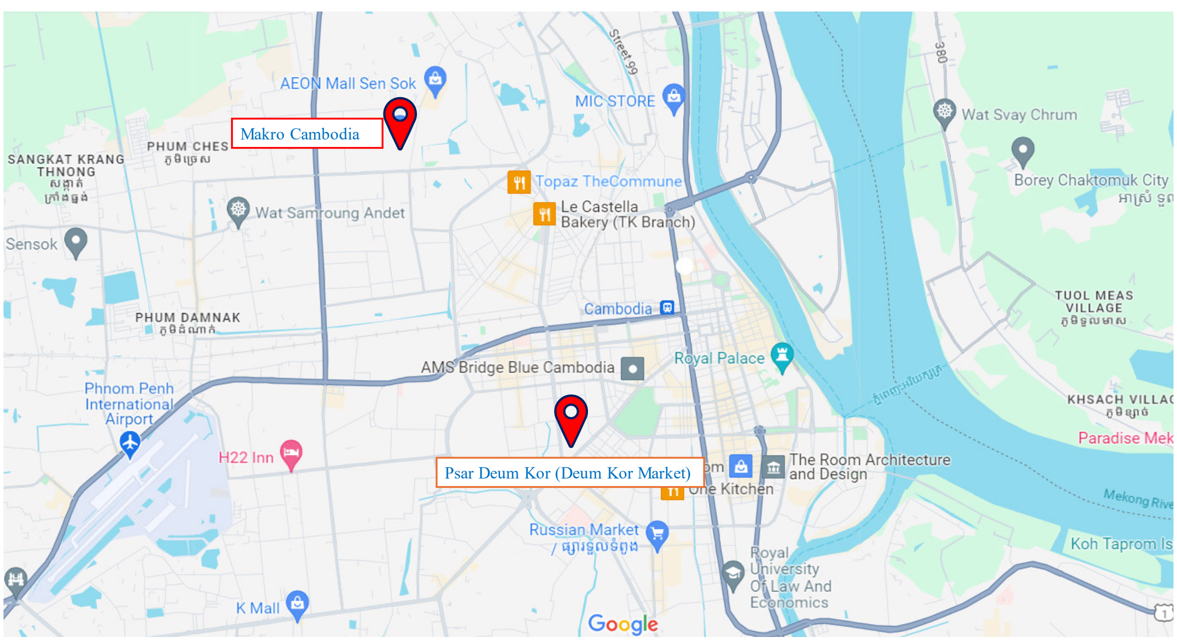

Fig. 1: Map of sampling market (Makro Cambodia and Deum Kor)

maintain sample integrity for accurate analysis. Upon arrival at the laboratory, the samples were transferred to a refrigeration unit set at -20°C. This deep-freezing step ensured that the samples were preserved in their current state, halting any biological activity and allowing for reliable and consistent testing at a later analysis (Fonvielle, Felgate, Tanentzap, & Hawkes, 2023; Siddiqui, Singh, Bahmid, & Sasidharan, 2024).

Chicken wing samples were filleted to remove the bone and blended using a blender (Bear Electric Meat Grinders 2 L). 30.0 g of blended samples were weighed in the 100.0 mL beaker, and 60.0 mL of 6% (v/v) trichloroacetic acid (TCA, ≥ 99.0% (titration)) was added; the samples were stirred and filtered through the Whatman filter paper (diameter 70 mm, grade no. 42). The solution of samples was 5.0 mL into 10.0 mL glass test tubes by adding 3.0 mL of Nash reagent and mixing well. In the next step, take samples to put in the water bath at 60℃ for 30 minutes, keep them at room temperature and analyze them using a UV-vis spectrometer (413 nm) (Kim, Jahan, & Lee, 2011). Statistical analysis was performed using Minitab 21. and Microsoft Office Excel 2017. Initially, the data were examined and described using descriptive statistics. Then, associations between categorical data for symptoms and FA concentration were evaluated using the ANOVA-one-way or Fisher's exact test. Every statistical test was run with = 0.05 and a 95% confidence range.

The calibration curve for calculating the concentration of FA was constructed. Briefly, FA stock solution (20.0 mg/kg) was prepared and then diluted to concentrations of 0.5, 1.0, 2.0, 4.0, 6.0, and 8.0 mg/kg using a 25.0 mL volumetric flask adjusted with distilled water. Next, 5.0 mL of each standard solution was mixed with 3.0 mL of Nash's reagent. These mixtures were then incubated in a water bath set at 60°C for 30 minutes to ensure the reaction proceeded to completion. In a separated flask, a blank reagent consisting of 3.0 mL of Nash's reagent and 5.0 mL of distilled water, was also prepared for baseline measurements. The absorbance of each reaction mixture was measured at 413 nm using a UV-vis spectrometer (G10S UV-Vis, Thermo Fisher Scientific, USA). The measurements were used to create a standard calibration curve by plotting the absorbance against the FA concentration. Each FA concentration was measured in triplicate to ensure accuracy and reliability, followed by the ISO 14184-1:2011 standards.

Quality control is important in chemical analysis to ensure the accuracy and reliability of the results. During subsequent chemical analysis, a UV-vis spectrometer (G10S UV-Vis, Thermo Fisher Scientific, USA) was utilized for FA detection. The following table presents the percentages of FA recovered from the chicken wing samples: 95% with R^2 = 0.9999. Triplication value analyses were performed on samples to determine the precision of the approach, known as the relative standard deviation (RSD). RSD values were found to fall anywhere between 2.903 and 4.366% of the total. The recovery was calculated using equation (1) (Mine *et al.*, 2012).

$$R = (C_{spiked\ sample} - C_{unspiked\ sample})/C_{standard\ added} \times 100 \quad (1)$$

Where the concentration used for defense is the Cstandard added, the concentration discovered in the sample before defense is the Cunspiked sample, and the concentration found in the sample after defense is the C-spiked sample. The spiked method was used for the accuracy of the sample preparation method. The standard solution of FA at 6.000 mg/Kg was added to chicken wing samples and presented as percentage recovery (%Recovery). It was calculated to determine the efficiency of the FA detection method. The spiked sample was 6.496 mg/Kg, and the unspiked sample was 0.789 mg/Kg. The recovery percentages were 95%, which was between 80 to 120%, and demonstrated the good accuracy of the method (Mine *et al.*, 2012). The limit of detection (LoD) is the smallest concentration a machine can measure in a sample. A blank solution used for infection detection with analytical elements before sample collection proved non-infectious. To be more accurate, we need to find a limit of quantification (LoQ) (Armbruster & Pry *et al.*, 2008). The values of LoD and LoQ were calculated using σ (standard deviation of response) and b (slope of the calibration curve, Fig. 2) by equations (2) and (3) (Jain, Chaudhari, Patel, Patel, & Patel, 2011). The LoD of 0.067 mg/Kg and LoQ of 0.225 mg/Kg were obtained.

$$LoD = (3.3 \times \sigma)/b \quad (2)$$

$$LoQ = (10 \times LoD)/3.3 \text{ or } LoQ = (10 \times \sigma)/b \quad (3)$$

The consumer health risk is evaluated by calculating the estimated daily intake (EDI) of formaldehyde (FA). The EDI depends on the concentration of FA in the chicken wings and the quantity of chicken consumed. To determine the EDI, the following equation is used.

$$EDI = (C_{FA} \times D_{Chicken\ wing\ intake})/B_{average\ weight} \quad (4)$$

Where C_{FA} (mg/Kg), $D_{Chicken\ wing\ intake}$ (Kg/person), and $B_{average\ weight}$ (Kg/person) are the FA concentrations in chicken wing, daily intake of Chicken wing, and

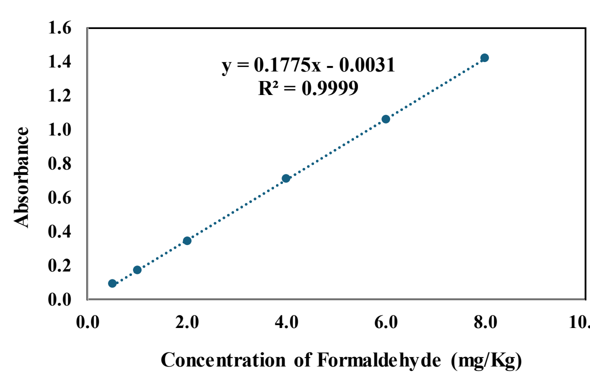

Fig. 2: The calibration curve of FA assay ranges from 0.5 to 8.0 mg/Kg

average body weight, respectively. The World Health Organization's recommended daily intakes of FA and FA consumption were compared (Bhowmik, Begum, & Alam, 2020; Bhowmik, Begum, Hossain, Rahman, & Alam, 2017; Liteplo, Beauchamp, Meek, & Chénier, 2002).

For the assessment of health risks through the consumption of chicken wings by the local inhabitants, the target hazard quotient (THQ) was calculated following the method described by USEPA (Amirah, Afiza, Faizal, Nurliyana, & Laili, 2013). THQ was determined based on the formula given by Chien *et al*. with equation (5) (Chien *et al*., 2002):

$$THQ = 10^{-3} (EF \times ED \times FIR \times C)/(RfD \times TA) \text{ or } THQ = [(Ed \times Ef \times EDI)/ (RfD \times At)] \times 10^{-3} \quad (5)$$

where EF is the exposure frequency (365 days/year); ED is the exposure duration (70 years); FIR is the chicken wing ingestion rate (Kg/person day); C is the FA concentration in Chicken wing (mg/Kg); RfD is the oral reference dose, and At is the average exposure time for noncarcinogens (365 days/year × number of exposure years, assuming 70 years in this study). The WHO and the United States EPA established an RfD of 0.15 and 0.2 mg/Kg BW/day for FA (Weng, Chon, Jiang, & Li, 2009). If the value of THQ is less than one (THQ <1), it is assumed to be safe from the risk of carcinogenic effects. If it exceeds one (THQ >1), it is believed that there is a chance of carcinogenic effects with an increasing probability as the value of THQ increases (Zheng *et al*., 2007). Using EDI and oral reference dose (RfD), we obtain the health risk index (HRI). Equation (6) calculates the HRI using the following formula.

HRI = daily intake of the chicken wing (EDI)/RfD (6)

If the HRI value is below 1, it indicates that the exposed population is considered to be at a low risk and is likely safe. (Bhowmik *et al*., 2017; Forum & Agency, 1986).

Results and Discussion

FA Content in Chicken Wing

FA content in selected chicken wing species in Makro Cambodia and Derm Kor Market was significantly different ($p < 0.05$). This variation in FA levels can be attributed to various factors, as detailed in Table 1. Each of these factors can influence the FA concentration in the chicken wings. The mean FA concentration in chicken wing samples was 0.757 ± 0.090 to 1.260 ± 0.090 mg/Kg in both market and conditions. FA is naturally formed from the postmortem enzymatic reduction of trimethylamine-N-oxide (TMAO) to equimolar amounts of FA and dimethylamine (DMA) after the death of animals (IRAC, 2012). Additionally, the presence and activity of microorganisms in the chicken and feed can contribute to increased levels of FA (Asare-Donkor, Adaagoam, Voegborlo, & Adimado, 2018; Siti Aminah, Zailina, & Fatimah, 2013). Also, the results showed a significant difference between the FA content in chicken wings with both markets and conditions from the results of the one-way ANOVA analysis; they are still lower than the standards of India, Malaysia, Italy and China (Bokthier Rahman *et al*., 2023). This indicates that while there is variability in FA content, the levels found in the sampled chicken wings remain within acceptable limits according to international standards.

Health Risks from Consuming Chicken Wing

The estimated daily intake of FA (EDI) through chicken wing ingestion for adults, adolescents and children is given in Table 2.

FA background levels in food products vary and can be as high as 200.0 mg/Kg in certain fish species and as low as 0.1 to 0.3 mg/Kg in milk. Given the significant variation in FA concentrations and the assumption that an individual consumes one kilogram of food daily, it was estimated that oral FA exposure in humans would not surpass 100 mg of FA daily, which translates to 1.7 and 1.4 mg/Kg bw daily for 60 and 70 Kg, respectively. A few small tissue deposition experiments involving cows have investigated carryover in animal tissues. The results indicated that the greatest rise in FA concentration was between 0.1 and 0.2 mg/kg of milk or meat (Food & Authority, 2014; Nowshad, Islam, & Khan, 2018; Wahed,

Table 1: Mean concentrations of FA in chicken wings with different conditions

Location/Condition	*Mean Conc. (mg/Kg)*	*SD*	*%RSD*
Derm Kor Market	0.806[b]	0.087	4.366
Markro Cambodia	1.260[a]	0.090	2.903
After 3 days	0.757[d]	0.090	4.832
Cooked	0.784[c]	0.028	1.442
Standard (food)	4.0[*], 5.0[**], 10.0[***]		

Data are presented as the mean values; SD means standard deviation, Values with similar letters refer to "not significantly different", where a, b, c, d refer to "significantly different" ($p < 0.05$) with the following order: a > b > c > d (Minitab 21 ANOVA one-way test), *India, **Malaysia, and ***Italy and China.

Table 2: Estimated daily intake of FA in chicken wings with different conditions

Location/ Condition	*Estimated daily intake of FA*		
	Adult (52 Kg)	*Adolescent (44 Kg)*	*Children (23 Kg)*
Derm Kor Market	1.201×10^{-3}	1.420×10^{-3}	2.716×10^{-3}
Markro Cambodia	1.878×10^{-3}	2.219×10^{-3}	4.246×10^{-3}
After 3 days	1.128×10^{-3}	1.333×10^{-3}	2.551×10^{-3}
Cooked	1.168×10^{-3} 1.381×10^{-3} 2.642×10^{-3}		

Table 3: Target hazard quotient of FA in chicken wing with different conditions

Location/ Condition	*Target hazard quotient*		
	Adult (52 Kg)	*Adolescent (44 Kg)*	*Children (23 Kg)*
Derm Kor Market	8.008×10^{-6}	9.464×10^{-6}	1.811×10^{-5}
Markro Cambodia	1.252×10^{-5}	1.480×10^{-5}	2.830×10^{-5}
After 3 days	7.521×10^{-6}	8.889×10^{-6}	1.701×10^{-5}
Cooked	7.790×10^{-6}	9.206×10^{-6}	1.761×10^{-5}

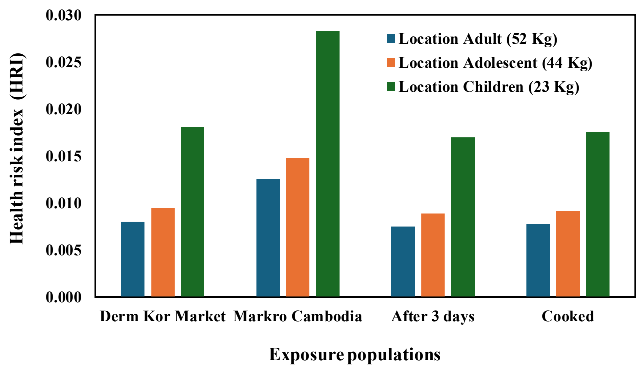

Fig. 3: Mean health risk index for FA via dietary intake of both markets and conditions

Razzaq, Dharmapuri, & Corrales, 2016). Therefore, the average FA concentrations for chicken wings were used to calculate the THQ for adults, adolescents, and children, as shown in Table 3.

All THQ values determined in this investigation were less than one, indicating that there is typically no harm to health from exposures occurring across the food chain. These outcomes aligned with the findings published by Hoque *et al.*, Asare-Donkor *et al*, and Bhowmik *et al.* (Asare-Donkor *et al.*, 2018; Bhowmik *et al.*, 2020; Hoque, Jacxsens, De Meulenaer, & Alam, 2016) which showed that human exposure to FA through food chain was at safe levels because the THQ for FA in fish was less than one (THQ < 1). The HRI was the ratio of the estimated daily intake (EDI) of FA in fish to the WHO daily RfD of 0.15 mg/Kg BW/day (Weng *et al.*, 2009). The RfDs signify an approximation of daily human chicken wing consumption, above which consumers might be constantly exposed to significant health threats. The EDI values for the FA in the different types of chicken wings from both markets and conditions analyzed ranged between 1.128×10^{-3} and 4.246×10^{-3} mg/Kg BW/day, which was all for less than 0.15 and 0.2 mg/Kg BW/day limit set by WHO and USEPA, respectively. The HRI values of cooked chicken wings for adults, adolescents and children were 7.790×10^{-3}, 9.206×10^{-3}, and 1.761×10^{-2}, respectively, in Table 4.

Generally, the average HRI of FA is less than one, which means they are within the safe interval and do not have potential adverse health effects on the consumer (Fig. 3). However, HRI values for FA for

Table 4: Health risk index of FA in chicken wing with different conditions

Location/ Condition	*Health risk index*		
	Adult (52 Kg)	*Adolescent (44 Kg)*	*Children (23 Kg)*
Derm Kor Market	8.008×10^{-3}	9.464×10^{-3}	1.811×10^{-2}
Markro Cambodia	1.252×10^{-2}	1.480×10^{-2}	2.830×10^{-2}
After 3 days	7.521×10^{-3}	8.889×10^{-3}	1.701×10^{-2}
Cooked	7.790×10^{-3}	9.206×10^{-3}	1.761×10^{-2}

adults, adolescents, and children will be greater than one because chicken wings are an important source of dietary exposure to FA for the local people, and they are a popular street food in Cambodia. As reported by many other studies, they may also suffer significantly from FA exposure through other foods such as vegetables, fruit, meat, eggs, fish, and milk. Other sources of FA exposure, such as inhalation dermal contact, have been given little attention. Multiple exposure pathways coexist in everyday life, affecting human health simultaneously. For example, a one-exposure pathway (ingestion of chicken wing) was assumed in a study. Therefore, the potential health risks of FA may be far beyond our estimation. The acceptable daily intake (0.2 mg/Kg day) is sufficient to guarantee consumer safety. However, the study showed that the consumption of marketed chicken wings could influence the risk of FA.

Conclusion

The investigation indicated that there was FA in all chicken wing samples analyzed, and this ranged between 0.757 ± 0.090 and 1.260 ± 0.090 mg/Kg, which was far lower than the maximum limit of 4.0, 5.0, and 10.0 mg/Kg set by the Indian, Malaysian, and Italian/Chines Food Act and Regulation; respectively for FA in meat products. The EDI values for FA in the chicken wings ranged from $4.1.128 \times 10^{-3}$ to 4.246×10^{-3} mg/Kg BW/day, which was also lower than the maximum daily RfD of 0.15 and 0.2 mg/Kg BW/day for FA established by the WHO and the United States EPA, respectively, and hence not of regulatory concern. The risk assessment from the study indicated that the THQ and HRI computed for all the species were far below 1. This signifies that the amount of FA in the chicken samples is not likely to cause any potential adverse health effects to the consumer. Therefore, according to the study results, fresh chicken wings in Makro Cambodia and Derm Kor Market of Phnom Penh do not contain high levels of FA. Thus, fresh chicken wings from Makro Cambodia and Derm Kor Market of Phnom Penh might not have been treated with FA as a preservative during the study period.

Author Contributions

Kao Pei conducted all experiments and methodology. Lita Chheang analyzed the data, validated the analytical methods, partly supervised the discussion section, and wrote the original manuscript draft. Thavy Chey conceptualized, planned, designed, directed the project, supervised, reviewed, and edited the final version of the manuscript.

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Data availability statement

The authors confirm that the data supporting the findings of this study are available within the article.

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Declaration of competing interests

The authors declare no conflict of interest. All authors have read and approved the final, published version of the manuscript.

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