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Health Risk Analysis of Formalin Exposure from Sausage Consumption Sold at Harapan Baru Public Market, Samarinda City, East Kalimantan

Yulis Tanty[1,2*], Rahmadi, Rahmadi[1], Rico Fernando A.A[1], Blego Sedionoto[3]

[1] Postgraduate of Public Health, Faculty of Public Health, Universitas Mulawarman, East Kalimantan, Indonesia
[2] Dinas Peternakan dan Kesehatan Hewan Provinsi Kalimantan Timur, Indonesia
[3] Department of Public Health, Universitas Mulawarman, East Kalimantan, Indonesia

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A B S T R A C T

Formalin is a chemical substance prohibited for use as a food additive; however, it is still detected in certain processed food products and may cause adverse health effects following repeated consumptionChildren are more vulnerable because their lower body weight may result in a higher formaldehyde exposure dose per kilogram of body weight than that experienced by adults. This study aimed to assess the non-carcinogenic health risks of formalin exposure through sausage consumption among children and adults at Harapan Baru Public Market, Samarinda City, East Kalimantan. This study employed a quantitative descriptive approach using the Environmental Health Risk Assessment method based on secondary data. The formaldehyde concentration was derived from sausage testing results, with a maximum concentration of 256.1 mg/kg. The analysis included children aged 2.5, 5, and 7.5 years, as well as adults. The parameters included formaldehyde concentration, consumption rate, body weight, exposure frequency of 350 days per year, exposure duration, and a reference dose of 0.2 mg/kg/day. Risk was expressed as the Risk Quotient. Based on an assumed sausage consumption of 25 grams per day for children and 50 grams per day for adults, all groups had Risk Quotient values greater than one. The values were 2.56 for children aged 2.5 years, 2.05 for those aged 5 years, 1.53 for those aged 7.5 years, and 1.03 for adults. Children aged 2.5 years had the highest risk level, highlighting the need for special protection of children as the most vulnerable group. Formalin exposure through sausage consumption may pose non-carcinogenic health risks to all groups analyzed. Food surveillance, regular laboratory testing, product-source tracing, and risk communication should be strengthened. These estimates represent risk characterization and should not be interpreted as safe limits for formalin use in food.

Formalin adalah zat kimia yang dilarang penggunaannya sebagai bahan tambahan pangan. Namun, zat ini masih ditemukan pada produk pangan olahan tertentu dan dapat menimbulkan dampak kesehatan yang merugikan akibat konsumsi berulang. Anak-anak lebih rentan karena berat badan mereka yang lebih rendah dapat mengakibatkan dosis paparan formaldehida per kilogram berat badan yang lebih tinggi dibandingkan dengan orang dewasa. Penelitian ini bertujuan untuk mengkaji risiko kesehatan non-karsinogenik akibat paparan formalin melalui konsumsi sosis pada anak-anak dan orang dewasa di Pasar Rakyat Harapan Baru, Kota Samarinda, Kalimantan Timur. Penelitian menggunakan pendekatan deskriptif kuantitatif dengan metode Analisis Risiko Kesehatan Lingkungan yang didasarkan pada data sekunder. Konsentrasi formaldehida diperoleh dari hasil pengujian sosis, dengan konsentrasi maksimum sebesar 256,1 mg/kg. Analisis mencakup anak-anak berusia 2,5, 5, dan 7,5 tahun, serta orang dewasa. Parameter yang digunakan meliputi konsentrasi formaldehida, tingkat konsumsi, berat badan, frekuensi paparan sebesar 350 hari per tahun, durasi paparan, dan dosis referensi sebesar 0,2 mg/kg/hari. Risiko dinyatakan dalam Risk Quotient (RQ). Berdasarkan asumsi konsumsi sosis sebesar 25 gram per hari untuk anak-anak dan 50 gram per hari untuk orang dewasa, seluruh kelompok memiliki nilai RQ lebih besar dari satu. Nilai tersebut adalah 2,56 untuk anak berusia 2,5 tahun, 2,05 untuk usia 5 tahun, 1,53 untuk usia 7,5 tahun, dan 1,03 untuk orang dewasa. Anak-anak berusia 2,5 tahun memiliki tingkat risiko tertinggi, yang menunjukkan perlunya perlindungan khusus bagi anak-anak sebagai kelompok yang paling rentan. Paparan formalin melalui konsumsi sosis dapat menimbulkan risiko kesehatan non-karsinogenik pada semua kelompok yang dianalisis. Pengawasan pangan, pengujian laboratorium secara berkala,

penelusuran sumber produk, dan komunikasi risiko perlu diperkuat. Estimasi ini merupakan bentuk karakterisasi risiko dan tidak boleh ditafsirkan sebagai batas aman penggunaan formalin dalam pangan.

* Corresponding author: Yulis Tanty
Postgraduate of Public Health, Faculty of Public Health, Universitas Mulawarman, East Kalimantan, Indonesia
Email: smartyvet.yt@gmail.com

1. Introduction

Food safety is an essential component of public health protection because food can serve as a route through which hazardous chemicals enter the body. Food safety risks arise not only from microbiological contamination but also from chemical contamination and the misuse of prohibited substances. In dietary exposure assessment, the magnitude of risk is influenced by the chemical concentration in food, the amount and frequency of consumption, exposure duration, body weight, and the characteristics of the exposed population group (Food Standards, 2024; Medeleanu et al., 2024).

Formalin is a formaldehyde-containing solution with antimicrobial properties and may therefore be misused to extend the shelf life of food products. Formalin is not a food additive and is prohibited in processed foods under Indonesian Food and Drug Authority Regulation No. 22 of 2023. Accordingly, no permitted limit exists for formalin use in food. Its presence in food products, at any concentration, constitutes non-compliance with food safety requirements and warrants regulatory surveillance and product-source tracing (Badan Pengawas Obat dan Makanan Republik, 2023). Repeated dietary exposure to formaldehyde may cause adverse health effects, particularly in vulnerable groups such as children. Such exposure has been associated with irritation, systemic effects, and other health outcomes that depend on the dose, duration, and route of exposure (Kaur et al., 2024; Rahman et al., 2023; Sun et al., 2025).

Despite its prohibition, formalin continues to be detected in various foods sold to the public. Studies have reported formalin in tofu, meatballs, salted fish, processed foods sold in traditional markets, and processed meat products (Agustina et al., 2023; Alifia et al., 2023; Haikal et al., 2022; Jayadi et al., 2023; Khasanah et al., 2025; Patimah . & Khumairoh, 2023; Rovita & Wulandari, 2022; Sari et al., 2022; Taupik et al, 2024). These findings indicate that regulatory prohibition has not completely eliminated the potential misuse of formalin in food production and distribution chains. Most previous studies have focused on detecting formalin and measuring its concentration, whereas studies translating laboratory findings into health-risk information for different consumer groups remain limited.

Beef sausage is widely consumed because it is convenient, readily available, and suitable for various age groups, including children. Children require particular attention because, at the same consumption level and formaldehyde concentration, their lower body weight may result in a higher formaldehyde exposure dose per kilogram of body weight than in adults. Studies of processed meat products indicate that formaldehyde surveillance remains necessary to prevent the circulation of foods containing prohibited substances (Maulina & Ginting, 2022; Permadi et al., 2024). Afifah et al. (2024) reported formaldehyde concentrations ranging from undetectable to 256.1 mg/kg in sausages sold at Harapan Baru Public Market, Samarinda City. This finding indicates that formalin may still occur in processed foods despite its prohibited use. Although that study documented the presence and concentration of formaldehyde in sausages, it did not quantify potential health risks according to consumption rate, exposure frequency, body weight, and consumer age group. Further analysis is therefore required to translate laboratory results into health-risk information that can support food safety control.

Advances in detection methods, including sensors, semi-quantitative analysis, and UV–Vis spectrophotometry, have supported the identification and measurement of formaldehyde in various food products (Fappiano et al., 2022; Kaur et al., 2024; Putri et al., 2024; Rizky et al., 2026). Nevertheless, laboratory results should not merely demonstrate the presence of a prohibited substance; they should also be further analyzed to estimate health risks in exposed population groups. Such information is needed to support

market surveillance, product-source tracing, business-operator guidance, and public risk communication (Badan Pengawas Obat dan Makanan Republik, 2023)

The literature indicates that most previous studies have focused on detecting and quantifying formaldehyde in food. Studies that specifically integrate formaldehyde concentrations in beef sausages with consumption rate, exposure frequency, and body weight to compare health risks across age groups remain limited, particularly in Samarinda City. This gap highlights the need for research that not only identifies formaldehyde but also characterizes the potential health risks of repeated consumption among children and adults.

Environmental Health Risk Assessment (EHRA) can be used to estimate dietary chemical intake and characterize non-carcinogenic health risks. Risk is expressed as the Risk Quotient (RQ), the ratio of estimated exposure intake to the reference dose. An RQ greater than one indicates a potential non-carcinogenic health risk and the need for control measures. In this study, the reference dose is used solely as a toxicological benchmark for risk characterization and must not be interpreted as a safe limit, legal threshold, or justification for formalin in food. Formalin remains prohibited in processed foods under applicable regulations (Badan Pengawas Obat dan Makanan Republik, 2023). Several food-risk studies have applied estimated intake and Risk Quotient calculations to characterize non-carcinogenic risks associated with formaldehyde exposure through food consumption (Agustina et al., 2023; Lee et al., 2024).

Children require particular attention because, at the same formaldehyde concentration and consumption level, their lower body weight may result in a higher estimated formaldehyde intake per kilogram of body weight than in adults. This study therefore aimed to assess the non-carcinogenic health risks of formalin exposure through beef sausage consumption among children aged 2.5, 5, and 7.5 years and adults at Harapan Baru Public Market, Samarinda City, East Kalimantan Province. The findings were expected to identify risk levels and the most vulnerable group and to support priority setting for food surveillance, periodic laboratory testing, product-source tracing, business-operator guidance, and public risk communication.

2. Methods

This study This quantitative descriptive study applied an Environmental Health Risk Assessment (EHRA) approach using secondary data. The analysis characterized non-carcinogenic health risks from formaldehyde exposure through ingestion among children and adults. No primary data were collected from respondents. Consumer groups were simulated using body weight, consumption rate, exposure frequency, and sausage formaldehyde concentration parameters.

Secondary formaldehyde concentration data were obtained from Afifah et al. (2024), who conducted a descriptive cross-sectional study using total sampling of 10 sausage brands sold at Harapan Baru Public Market. Seven samples (70%) tested positive for formalin and three (30%) tested negative. The highest reported concentration was 256.1 ppm in sample E. In the present study, this maximum concentration was used as a conservative exposure scenario to estimate risk under the highest-concentration condition.

The study site was Harapan Baru Public Market in Harapan Baru Subdistrict, Loa Janan Ilir District, Samarinda City, East Kalimantan Province. The market is located at approximately 0°32′27″ S and 117°06′16″ E. These coordinates should be reconfirmed against the location stored in the QGIS project before manuscript submission; online mapping sources place the market near these coordinates. The study location map was prepared using the World Geodetic System 1984 (WGS 84) and Universal Transverse Mercator (UTM) Zone 50 South projection. It includes a scale bar, legend, north arrow, coordinate grid, and inset maps showing Samarinda City within East Kalimantan Province and Indonesia. The map provides geographical context and was not used for quantitative spatial analysis.

Formaldehyde concentration data were based on Afifah et al. (2024), with a maximum concentration of 256.1 mg/kg. This maximum value was used to represent a more conservative, health-protective scenario. Exposure assessment and risk characterization approaches have been used in several studies to evaluate formaldehyde exposure

through food consumption (Agustina et al., 2023; Lee et al., 2024)

The simulated groups comprised children aged 2.5, 5, and 7.5 years and adults, with respective body weights of 12, 15, 20, and 60 kg. Comparative consumption assumptions were 0.025 kg/day for children and 0.05 kg/day for adults, with an exposure frequency of 350 days/year. These parameters were used to calculate formaldehyde intake and characterize non-carcinogenic health risks in each simulated group.

The oral reference dose (RfD) for formaldehyde was 0.2 mg/kg body weight/day, based on the United States Environmental Protection Agency Integrated Risk Information System. The RfD is a toxicological benchmark for evaluating potential non-carcinogenic effects and is not a permitted limit for formalin use in food. The US EPA further emphasizes that the RfD is not a direct estimate of risk probability but a reference point for assessing potential health effects from oral exposure (Direktorat Jenderal Pengendalian Penyakit & Lingkungan., 2012; United States Environmental Protection Agency, 2024).

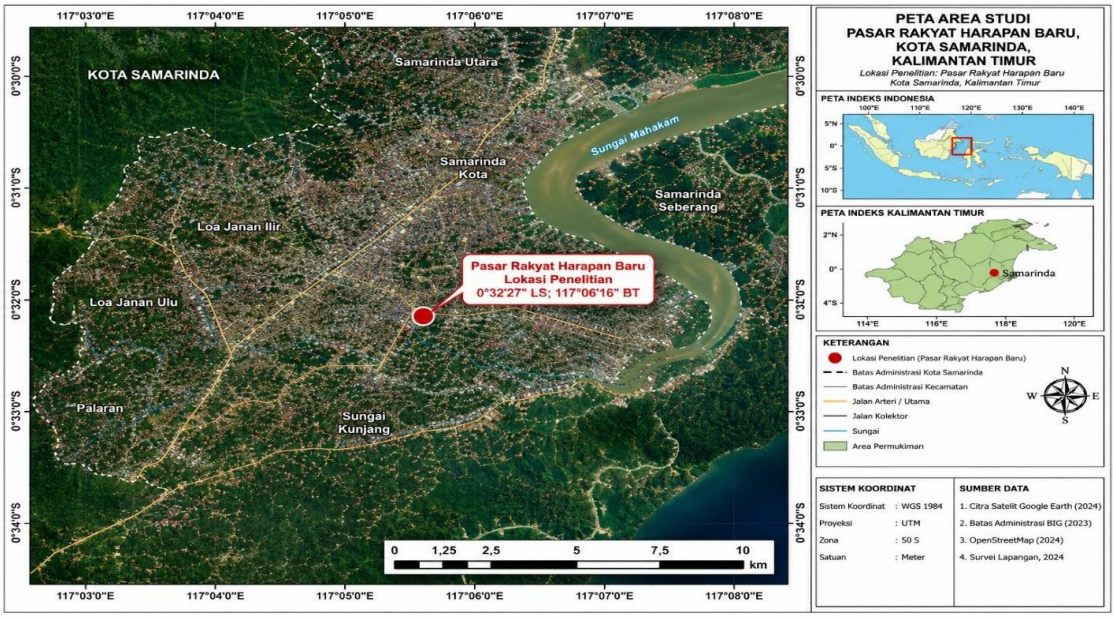

Figure 1. Study location at Harapan Baru Public Market, Samarinda City, East Kalimantan Province.

The analysis was limited to non-carcinogenic risk because the exposure route assessed was ingestion. Carcinogenic risk was not analyzed because an oral cancer slope factor or quantitative estimate of cancer risk from oral formaldehyde exposure is unavailable in the US EPA IRIS. The US EPA carcinogenic assessment of formaldehyde applies to inhalation exposure.

Non-carcinogenic exposure intake was calculated according to the Indonesian Ministry of Health Guidelines for Environmental Health Risk Assessment using the following equation:

$$I = \frac{C \times R \times f_E \times D_t}{W_b \times t_{avg}}$$

where, I= formaldehyde exposure intake (mg/kg body weight/day); C= formaldehyde concentration in sausage (mg/kg); R= sausage consumption rate (kg/day); f_E= exposure frequency (days/year); D_t= exposure duration (years); W_b= body weight (kg); and t_{avg}= averaging time for non-carcinogenic exposure (days).

Non-carcinogenic risk was characterized using the Risk Quotient, calculated as follows:

$$RQ = \frac{I}{RfD}$$

where, RQ= *Risk Quotient*; I= formaldehyde exposure intake (mg/kg body weight/day); and

RfD= oral reference dose for formaldehyde, 0.2 mg/kg body weight/day.

An RQ greater than one indicates that estimated exposure exceeds the reference dose and suggests a potential non-carcinogenic health risk requiring control measures. An RQ less than or equal to one indicates that estimated exposure does not exceed the reference dose. However, such a value must not be interpreted to mean that a formalin-containing product is safe or permissible for consumption, because formalin remains prohibited in food.

This study used published secondary data and involved no intervention, specimen collection, or direct interaction with human or animal subjects. Therefore, ethical clearance was not required under applicable institutional guidelines and research provisions.

All research procedures adhered to ethical principles, including scientific integrity, honest reporting, accurate citation, and compliance with applicable laws and regulations.

3. Results

The Formaldehyde was the chemical risk agent assessed in this study. Beef sausage was the exposure medium, and ingestion through direct consumption was the exposure route. The maximum formaldehyde concentration used in the analysis was 256.1 mg/kg. This value represented a conservative scenario for characterizing health risk at the highest concentration. The formaldehyde hazard identification is presented in Table 1.

Table 1. Hazard identification of formalin in sausage

Component	Description
Risk Agent	Formaldehyde
Hazard type	Chemical contamination of processed food
Exposure medium	Beef sausage
Exposure rute	Ingestion through direct consumption
Study location	Harapan Baru Public Market, Samarinda City
Maximum concentration	256,1 mg/kg
Oral reference dose	Formaldehyde RfD: 0.2 mg/kg body weight/day
Groups analyzed	Children aged 2.5, 5, and 7.5 years and adults
Vulnerable group	Children
Potential effect	Non-carcinogenic health risk from repeated exposure

Exposure intake and risk characterization were calculated using a maximum formaldehyde concentration of 256.1 mg/kg, an exposure frequency of 350 days/year, and an oral reference dose of 0.2 mg/kg body weight/day. The simulation parameters for each group are presented in Table 2.

Table 2. Parameters used to estimate formaldehyde exposure intake by simulated group

Group	Age	Body weight (kg)	Assumed consumption (kg/day)	Exposure frequency (days/year)	Formalin concentration (mg/kg)
Children	2.5 years	12	0.025	350	256.1
Children	5 years	15	0.025	350	256.1
Children	7.5 years	20	0.025	350	256.1
Adults	≥18 years	60	0.050	350	256.1

Based on these parameters, the highest estimated formaldehyde intake occurred among children aged 2.5 years, at 0.512 mg/kg body weight/day. Intake estimates subsequently decreased among children aged 5 years, children aged 7.5 years, and adults. These differences were primarily attributable to the body weight assigned to each simulated group.

Risk characterization showed that all simulated groups had RQ values greater than one. The highest RQ was observed among children aged 2.5 years (2.56), followed by children aged 5 years

(2.05), children aged 7.5 years (1.53), and adults (1.02). These results indicate that estimated formaldehyde intake exceeded the oral reference dose in all groups. Children aged 2.5 years were the most vulnerable because they had the highest exposure intake per kilogram of body weight and the highest RQ.

Tabel 3. Estimated formaldehyde exposure intake and Risk Quotient

Group	Age	Exposure intake (mg/kg body weight/day)	RfD (mg/kg body weight/day)	RQ	Interpretation
Children	2.5 years	0,512	0,2	2,56	Potential non-carcinogenic risk
Children	5 years	0,409	0,2	2,05	Potential non-carcinogenic risk
Children	7.5 years	0,307	0,2	1,53	Potential non-carcinogenic risk
Adults	≥18 years	0,205	0,2	1,02	Potential non-carcinogenic risk

An RQ greater than one indicates a potential non-carcinogenic health risk and the need for control measures. Although the adult RQ was close to one, estimated intake still exceeded the reference dose. The RQ does not represent the probability of disease and must not be interpreted as a permissible formalin limit in food. Formalin remains prohibited in food.

4. Discussion

All simulated groups had RQ values greater than one. The highest RQ occurred among children aged 2.5 years (2.56), followed by children aged 5 years (2.05), children aged 7.5 years (1.53), and adults (1.02). These values indicate that estimated formaldehyde intake exceeded the oral reference dose used in this study, suggesting potential non-carcinogenic health risks in every group analyzed. The findings identify children, particularly those aged 2.5 years, as the group most vulnerable to formaldehyde exposure through sausage consumption.

Differences in risk across groups were primarily influenced by body weight and consumption rate. At a given formaldehyde concentration and exposure frequency, individuals with lower body weight have a higher estimated formaldehyde intake per kilogram of body weight, even when the absolute amount consumed is lower. Consequently, estimated intake and RQ values were higher in children than in adults. This finding is consistent with dietary exposure-assessment principles, which state that risk is influenced by chemical contaminant concentration, consumption amount, exposure frequency, and individual characteristics, particularly body weight (Food Standards, 2024; Medeleanu et al., 2024).

In this study, the RQ characterized potential non-carcinogenic health risk and did not represent the direct probability of disease. An RQ greater than one must not be interpreted as a tolerable formalin limit or as a basis for recommending a safe amount of sausage consumption. Formalin remains prohibited in processed food. Thus, these calculations should be understood as a characterization of risk under the analyzed exposure scenario, not as justification for the presence of formalin in food.

Children aged 2.5 years had the highest risk because they had the lowest body weight among the groups. Although their assumed consumption was lower than that of adults, their exposure dose per kilogram of body weight remained higher. This finding demonstrates the importance of considering age-group characteristics in formaldehyde risk assessment and is consistent with Lee et al. (2024), who emphasized that differences in population characteristics, particularly body weight and consumption patterns, can produce different risk levels at the same chemical concentration.

These findings further support evidence that formalin in food remains a food-safety concern. Previous studies have reported formalin in various food products, including processed foods and products sold in traditional markets (Amaral et al., 2025; Khasanah et al., 2025; Mehta et al., 2024; Rahman et al., 2023; Sun et al., 2025). This suggests that prohibition has not completely eliminated potential misuse throughout food production and distribution. In other local food contexts, formalin has been reported in meatballs, tofu, salted fish,

and processed meat products (Haikal et al., 2022; Jayadi et al., 2023; Maulina & Ginting, 2022; Rovita & Wulandari, 2022; Sari et al., 2022; Taupik et al, 2024). Alifia et al. (2023) emphasized the importance of monitoring processed meat sold by micro, small, and medium enterprises to prevent the use of prohibited additives. Surveillance should therefore encompass not only detection but also risk assessment to identify population groups requiring the greatest protection.

A key consideration in interpreting this study is that its findings must not be used to justify consuming food containing formalin. RQ values indicated potential non-carcinogenic risk in all groups, while formalin remains prohibited in food. The findings should therefore strengthen prevention, surveillance, and control rather than establish a supposedly safe consumption limit. Consumers cannot determine formaldehyde concentrations in purchased products without laboratory testing. Responsibility for control should not be shifted to consumers through consumption restrictions; instead, control must focus on preventing formalin use from production through distribution.

The public health implication of this study is the need to strengthen surveillance of sausages and other processed foods sold in public markets. The findings can inform surveillance priorities, particularly for products frequently consumed by children. Control measures may include periodic sampling, laboratory testing, producer and distributor tracing, guidance for business operators, and enforcement against products containing prohibited substances. Risk communication should clearly state that products found to contain formalin are unfit for consumption, rather than merely recommending reduced consumption. This approach aligns with food-safety principles that prioritize contamination prevention in food-risk control (Badan Pengawas Obat dan Makanan Republik, 2023)

Food surveillance can also be strengthened by advances in formaldehyde detection methods, including sensors, semi-quantitative analysis, and UV–Vis spectrophotometry (Fappiano et al., 2022; Kaur et al., 2024; Putri et al., 2024; Rizky et al., 2026). Practical and sensitive methods may support preliminary field screening, while laboratory analysis remains necessary to confirm results and quantify formaldehyde concentrations. These developments can enable faster, routine, and better-targeted food surveillance.

Theoretically, these findings reinforce the importance of integrating chemical concentration, consumption level, exposure frequency, and characteristics of exposed groups in dietary risk assessment. The same concentration can produce different risk levels across age groups because of variations in body weight and consumption patterns. Technically, the findings can support the identification of priority groups for food surveillance, sampling plans, improved guidance for business operators, and more targeted risk communication.

This study was limited by its reliance on secondary data and simulated groups. Actual consumption data were not measured directly; consequently, the analysis depended on assumptions regarding consumption rate, exposure frequency, body weight, and the maximum formaldehyde concentration. Using the maximum concentration provided a conservative scenario but did not capture exposure variability across all products in circulation. Future studies should use primary data, larger samples, multiple concentration scenarios, actual consumption patterns, and broader age groups to produce more representative risk characterization.

5. Conclusions

The analysis showed that formaldehyde exposure through sausage consumption may pose non-carcinogenic health risks in all simulated groups. RQ values were 2.56 for children aged 2.5 years, 2.05 for children aged 5 years, 1.53 for children aged 7.5 years, and 1.02 for adults. All values exceeded one, indicating that the estimated formaldehyde intake was higher than the oral reference dose used in this study. Children aged 2.5 years had the highest risk because they had the highest estimated formaldehyde intake per kilogram of body weight.

Formalin is prohibited in food. Accordingly, the RQ values in this study must not be interpreted as safe limits for formalin use or as a basis for recommending an allowable amount of sausage consumption. The findings underscore the importance of considering body weight, consumption level, exposure frequency, and age

group when characterizing dietary chemical risks. They can support the identification of priority groups for food surveillance, periodic sampling and laboratory testing, product-source tracing, guidance for business operators, and public risk communication. Control measures should focus on preventing formalin use from production through distribution rather than limiting consumption by the public.

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