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Review Article

Formaldehyde Content in Indonesian Food and the Analysis Method: A Review

Anggita Rosiana Putri[1*], Kevin Awidarta[2], Bachtiar Rifai Pratita Ihsan[1], Intan Khaerunisa[1], Muhammad Bachrul Ulum[1], Laili Fadhotun Huda[1]

[1]Department of Pharmacy, Faculty of Medicine, Universitas Brawijaya, Malang, Indonesia
[2]Master in Pharmaceutical Sciences, Faculty of Pharmacy, Universitas Gadjah Mada, Yogyakarta, Indonesia;
*Corresponding author: Anggita Rosiana Putri | Email: anggita.rosiana@ub.ac.id

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Abstract: Apart from being rich in culture, Indonesia is also rich in food culture. However, in some cases, there are illegal additions of formalin (37% formaldehyde) to food to extend shelf life. If humans consume food containing formaldehyde, it will have a harmful impact. Formaldehyde has the potential to cause cancer. In recent years, formaldehyde has still been found in several Indonesian foods. There are several analytical methods developed to detect formaldehyde levels in food. This review overview of the formaldehyde effect to human health, formaldehyde content in fish and Indonesian food, and the detection methods.

Keywords: formaldehyde; Indonesia; food; analysis

1. INTRODUCTION

Indonesia is a diverse country that has various cultures. In line with its diverse culture, food in Indonesia is also diverse. However, there are illegal acts of deliberately adding formaldehyde to food to extend its shelf life. Formaldehyde (FA) (CH_2O) is a type of colorless gas at ambient temperature. In liquid form, FA commonly known as "formalin" (37 up to 40 % w/w formaldehyde), is a low-cost chemical [1, 2]. FA is normally used in embalming to disinfect and preserve human corpses [3, 4]. In the food industry, FA is used to inhibit bacterial growth during juice production of sugar and as a bacteriostatic agent in some varieties of Italian cheese and fresh white cheese in El Salvador [1,5-6]. FA is a useful and important chemical to the global economy and is used in many industries i.e., construction (wood processing, furniture, textile, carpeting), consumable household product industries (antiseptics, medicines, cosmetics, dish-washing liquids, glues, lacquer), etc [7].

FA is a carcinogenic and hazardous substance for human health [2, 6], therefore FA is prohibited for use as food preservatives. But FA content is still found in some foods such as noodles [9], fish and seafood [10], fruits and vegetables [9, 10], fruit juice [13], mushrooms [14], and milk [15] because it has low-cost and effective as food preservatives.

The addition of formaldehyde to food poses a significant threat to Indonesia's diverse food culture in several ways:

1. Health Risks: The consumption of food contaminated with formaldehyde poses serious health risks to consumers. Given its toxic nature, prolonged exposure to formaldehyde-laced foods can lead to various health complications, undermining the well-being of the population [16-18].

2. Cultural Degradation: Indonesian cuisine is characterized by its vibrant flavors, fresh ingredients, and traditional cooking methods. The use of formaldehyde compromises the authenticity and integrity of traditional dishes, distorting their original taste and quality. This threatens to erode the cultural significance of Indonesian cuisine over time.
3. Economic Impact: Indonesia's culinary heritage is not only a source of cultural pride but also a significant driver of the economy, supporting local farmers, food producers, and businesses. The tarnished reputation resulting from the presence of formaldehyde in food products can lead to decreased consumer trust and demand, negatively impacting the livelihoods of those involved in the food industry.
4. Environmental Concerns: The illegal use of formaldehyde in food production may also have adverse environmental effects, such as contamination of water sources and soil degradation, further exacerbating ecological challenges faced by the country.

This review overview of the formaldehyde effect on human health, formaldehyde content in fish and Indonesian food, and the detection methods of formaldehyde content in Indonesian food.

2. METHODS

The articles related to the formaldehyde content in Indonesian food were identified and selected from databases. The databases used in this review were ScienceDirect, PubMed, and Google Scholar with keywords of formaldehyde+ Indonesian food. Inclusion criteria for the articles were open access and published in the last 20 years.

3. RESULTS AND DISCUSSION

3.1. Formaldehyde effect to human health

FA is highly toxic and carcinogenic [14, 15]. FA has been reported as one of the chemical mediators that caused programmed cell death (apoptosis). Since FA can generate crosslinking with proteins and DNA, this action may alter the mitochondrial membrane, open the mitochondrial transition pore, release cytochrome c into the cytosol, activate caspases and induce apoptosis [16, 17].

FA can cause respiratory symptoms, irritation of eyes, nose, and throat when inhaled by humans [23-26]. Increasing exposure can increase the risk of cancers in pharynx, nasopharynx, and brain, as well as dermatitis and allergic reactions [27-29]. Acute effects of airborne formaldehyde exposure: Odor detection, 0.05-1.0 ppm; Eye irritation, 0.01-2 ppm; Upper respiratory tract irritation (e.g., irritation of the nose or throat), 0.10-11 ppm; Lower airway irritation (e.g., cough, chest tightness, and wheezing), 5-30 ppm; Pulmonary edema, inflammation, pneumonia, 50-100 ppm; Death >100 ppm [20, 21].

In the case of food additives, the effects of CH_2O on the human body depend mainly on the volume and concentration in which the formaldehyde is present. For example, given a large quantity of CH_2O, the formic acid produced during the metabolism process can cause local corrosive action on the gastrointestinal tract; resulting in both oral and gastrointestinal mucosa. Moreover, the ingestion of 90 ml or more of 37% formaldehyde solution leads almost inevitably to death (more than 100 ppm) [20, 21].

3.2. Formaldehyde content in Indonesian food

Table 1 was shown the formaldehyde content in Indonesian food. The imported fruit (apple, pear, and grape) that was sold in Manado was analysed [9]. The research was found that the washing

fruits contain 0.060-0.136 ug/mL and unwashed fruits contained 0.080-0.195 ug/mL of formaldehyde. It was proven that imported fruit still contain formaldehyde. Noodles that were sold in Ambon contained 9.07-10.01 mg/kg of formaldehyde [7]. While in West Java, wet noodle was found containing formaldehyde in range 801-1684 mg/kg [32]. Kembung and Cucut salted fish from Bandung were found containing formaldehyde at level 0.252 and 0.482 ppm, respectively [33]. From the literature studies conducted, formalin was mostly found in wet fish samples.

Table 1. FA content in fish and Indonesian food

Place	Sample	Instrument Analysis	FA Levels	Reference
Manado	Apple, pear, and grape (Imported fruit)	UV-Vis spectrophotometry	Washed fruits: 0.060-0.136 ug/mL	[9]
Ambon	Noodle	UV-Vis spectrophotometry	9.07-10.01 mg/kg	[7]
Bandung	Kembung salted fish and Cucut salted fish	UV-Vis spectrophotometry	0.252 ppm and 0.482 ppm	[33]
Bali	Moonfish (Lampris guttatus)	UV-Vis spectrophotometry	133 mg/kg	[34]
West Java	Wet noodles	UV-Vis spectrophotometry	801-1684 mg/kg	[32]
Jakarta	Saurida tumbil fish	NMR	14 mg/kg	[35]
Hindia Ocean	Opah fish (Lampris guttatus)	UV-Vis spectrophotometry	27.82 ± 1.66 mg/kg to 133.12 ± 1.56 mg/kg	[36]
Banten	Short mackerel (Rastrelliger brachysoma	UV-Vis spectrophotometry	1.4-1.7 ppm	[37]
Jakarta	Moonfish (Lampris guttatus), hardtail scad (Megalaspis cordyla), rank goby (Saurida tumbill), and mackerel scad (Decapterus spp).	UV-Vis spectrophotometry	0 to 6.51 mg/kg	[38]
North Sumatera	Bawal, Kerapu, Kakap, Tuna, Tongkol	Formaldehyde test kit	Tongkol: 1.73 mg/L; Tuna: 1.40 mg/L; Bawal: 0.528 mg/L; Kakap: 3.42 mg/L; Kerapu: 2.47 mg/L	[39]
West Java	Rebon, Teri Medan, Teri Cue, Pakang	UV-Vis spectrophotometry	Rebon: 0.389 ppm Teri Medan: 0.156 ppm Udang Rebon: 0.389 ppm Teri Cue: 0.182 ppm	[40]
South Sulawesi	Anchovy	UV-Vis spectrophotometry	0.196-0.270 ppm	[41]
West Kalimantan	Snakehead dried salted fish	UV-Vis spectrophotometry	0.64-0.83 ppm	[42]

3.3 Analysis method to determine formaldehyde content

Some analysis method was developed to analyse formaldehyde content in fish and food. For qualitative analysis, formaldehyde can be determined using a formaldehyde test kit and TLC (thin layer chromatography) [33,34]. While quantification of formaldehyde can use UV-VIS spectrophotometry [11]; TLC-densitometry [32]; HPLC (High-performance Liquid Chromatography) [45]; NMR (nuclear magnetic resonance) [35]; and gas chromatography-mass spectrometric (GC-MS) [35]. Bianchi et al., [46] evaluated formaldehyde content in different frozen fish products using a Solid Phase Micro Extraction Gas Chromatography Ion Trap Tandem Mass Spectrometry (SPMEGC-MS) method based on fiber derivatisation with pentafluorobenzyl hydroxylamine hydrochloride. Table 1 shows the analysis of formaldehyde in Indonesian food and the analysis methods.

In the Spectrophotometric method, formaldehyde cannot be directly analysed using UV-VIS spectrophotometry because it does not have a chromophore. Formaldehyde must react with Nash reagent (acetylacetone, ammonia) to form 3,5-diacetyl-1,4-dihydrotoludine. This reaction is called the Hantzch reaction, the mechanism was shown in Figure 1[22]. This form has maximum absorption at 550 nm [9]. Another way to analyse formaldehyde can react with 4-Amino-3-hydrazino-5-mercapto-1,2,4-triazol (AHMT), pararosaniline, 3-methyl-2- benzothiazolonehydrazone (MBTH) and chromotropic acid etc., but the colorimetric methods in general are relatively slow and less sensitive [17,37].

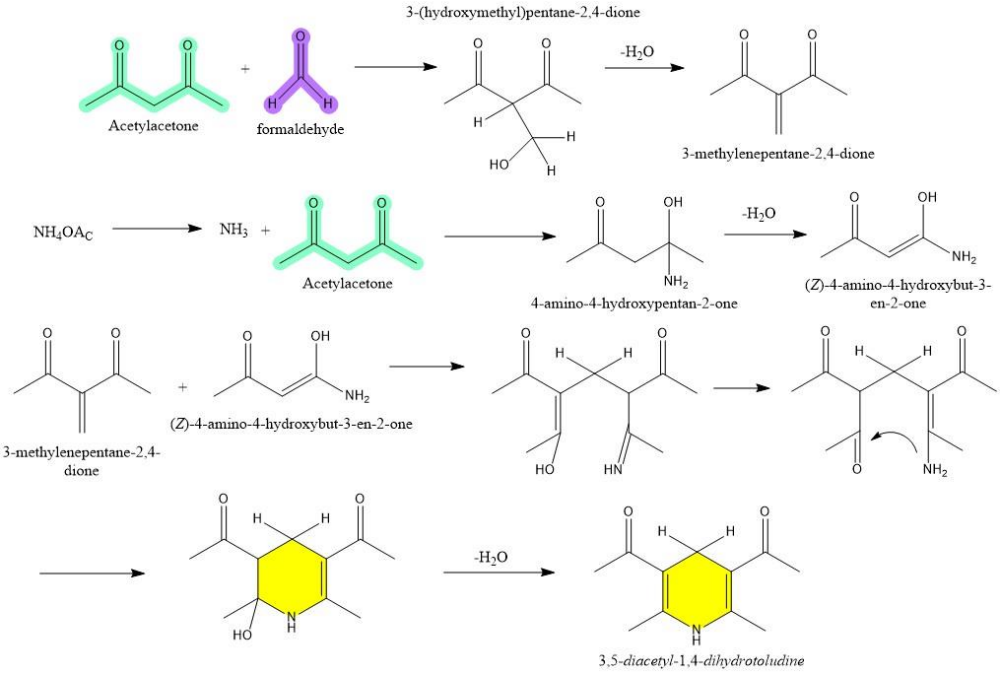

Figure 1. The mechanism in Hantzch reaction[48]

High-Performance Liquid Chromatography (HPLC) method having better selectivity, precision, and accuracy were proposed to analyse formaldehyde in squid product [49]. In the determination of formaldehyde using HPLC, the most often used derivative reagent before analysis is DNPH (2,4-dinitrophenylhydrazine), which reacted with formaldehyde to form the corresponding hydrazone [50]. The reaction between formaldehyde and DNPH was shown in Figure 2. Wang et al, [51] analyse the formaldehyde content in fruit juice samples using magnetic strong cation-exchange resin modified with DNPH. The procedures of extraction and derivatization were carried out in a single step by stirring the resins and diluted fruit juice with water. When the procedures were

completed, the resins adsorbing the HCHO–DNPH derivative were easily separated from the sample matrix by an adscititious magnet. The HCHO–DNPH derivative eluted from the resins was directly determined by high-performance liquid chromatography with UV detector at 360 nm [42].

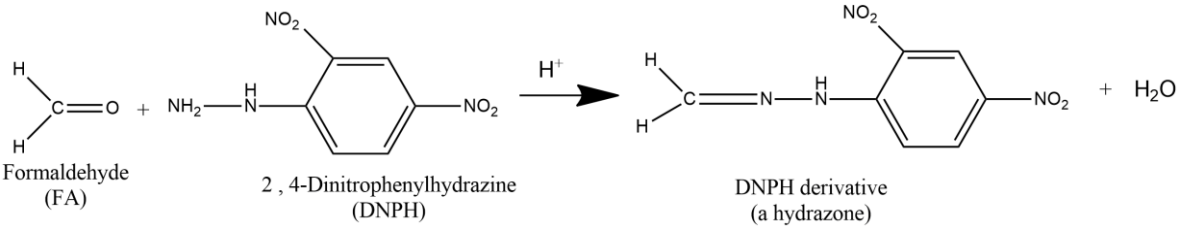

Figure 2. Reaction between formaldehyde and DNPH

3.4 Preventing the use formaldehyde in Indonesian foods

Protecting Indonesia's culinary heritage is crucial for preserving its cultural identity, promoting public health, and sustaining the country's economic development. These measures include:

a. Legislation and Enforcement: Indonesia has regulations in place that prohibit the use of formaldehyde as a food additive. The Food and Drug Supervisory Agency (BPOM) is responsible for enforcing these regulations and ensuring compliance with food safety standards. BPOM conducts inspections of food production facilities, tests food samples for chemical contaminants, and imposes penalties on violators found using formaldehyde or other harmful additives.
b. Public Awareness Campaigns: The government has also launched public awareness campaigns to educate consumers about the dangers of consuming food products contaminated with formaldehyde. These campaigns aim to raise awareness about food safety practices, encourage vigilant consumption habits, and empower consumers to report suspected cases of food adulteration to authorities.
c. Collaboration with Stakeholders: The Indonesian government collaborates with various stakeholders, including food producers, retailers, and industry associations, to promote compliance with food safety regulations and encourage responsible practices along the food supply chain. This collaboration involves providing guidance on proper food handling and storage techniques, as well as supporting initiatives to develop alternative preservative methods that are safe and effective.

Despite these regulatory efforts, challenges remain in effectively combating the illegal use of formaldehyde in food products in Indonesia. Some of these challenges include: inadequate regulatory oversight, and the presence of informal or unregistered food producers operating outside the purview of regulatory authorities. These factors can enable the continued illegal use of formaldehyde in food production despite existing regulations.

4. CONCLUSION

The illegal addition of carcinogenic formaldehyde to food is a serious concern to public health. Several analytical methods can be used to analyze the formaldehyde content in food, either for qualitative or quantitative analysis.

Foods containing formaldehyde are still found in Indonesian foods until now. So, consumers must be careful in choosing the food that they consume. Here are some recommendations and preventive actions consumers can take to avoid foods containing formaldehyde:

a. Choose Fresh Foods: Option for fresh foods over processed or packaged ones whenever possible. Fresh produce, meats, and seafood are less likely to contain added preservatives like formaldehyde.
b. Buy Organic products: Organic products are less likely to contain synthetic preservatives like formaldehyde. Look for certified organic labels when shopping for fruits, vegetables, meats, and other food items.
c. Avoid Highly Processed Foods: Processed foods, such as canned goods and ready-to-eat meals, often contain preservatives, including formaldehyde. Minimize consumption of these items.
d. Inspect Seafood: Formaldehyde is sometimes used to preserve seafood. When buying fish or shellfish, ensure they are fresh and have no off-putting odors. Avoid seafood that appears unnaturally firm or glossy.
e. Proper Storage: Properly store perishable foods in the refrigerator or freezer to prevent spoilage and the need for preservatives. Use airtight containers or wraps to maintain freshness.
f. Rinse Fruits and Vegetables: Wash fruits and vegetables thoroughly under running water to remove any surface residues, including potential traces of formaldehyde. Scrub firm produce with a brush to remove dirt and contaminants effectively.
g. Peel and Trim: Peeling and trimming fruits and vegetables can help remove surface contaminants, including any residual preservatives. However, keep in mind that some nutrients are located just under the skin, so balance this consideration.
h. Choose Trusted Suppliers: Purchase foods from reputable sources and suppliers known for their adherence to food safety regulations. Farmers' markets, local farms, and trusted grocery stores may offer fresher and less preserved options.
i. Stay Informed: Keep yourself updated on food safety guidelines and any recalls related to formaldehyde contamination. Government health agencies often provide information on food safety and recalls through websites, newsletters, and social media platforms.

By following these recommendations, consumers can reduce their exposure to formaldehyde in foods and make healthier choices for themselves and their families.

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References

[1] B. K. K. K. Jinadasa, C. Elliott, and G. D. T. M. Jayasinghe, "A review of the presence of formaldehyde in fish and seafood," *Food Control*, vol. 136, no. July 2021, p. 108882, 2022, doi: 10.1016/j.foodcont.2022.108882.

[2] K. Kaewnu *et al.*, "A portable colorimetric device based on PVDF indicator gel for formaldehyde detection in food and wood products," *Microchemical Journal*, vol. 184, no. PB, p. 108162, 2022, doi: 10.1016/j.microc.2022.108162.

[3] O. Bunkoed, F. Davis, P. Kanatharana, P. Thavarungkul, and S. P. J. Higson, "Sol–gel based sensor for selective formaldehyde determination," *Anal Chim Acta*, vol. 659, no. 1–2, pp. 251–257, Feb. 2010, doi: 10.1016/j.aca.2009.11.034.

[4] S. Kongkaew, P. Kanatharana, P. Thavarungkul, and W. Limbut, "A preparation of homogeneous distribution of palladium nanoparticle on poly (acrylic acid)-functionalized graphene oxide modified electrode for formalin oxidation," *Electrochim Acta*, vol. 247, pp. 229–240, Sep. 2017, doi: 10.1016/j.electacta.2017.06.131.

[5] M. Bononi, F. Tateo, M. Mozzarelli, and A. Vicari, "On the endogenous content of formaldehyde in typical Italian cheeses," *IRIS Institutional Research Information System*, p. 1, 2017.

[6] O. Peña-Rodas, M. Pineda-Rivas, M. Guzman-Rodriguez, R. Martinez-Lopez, and R. Hernandez-Rauda, "Residual formaldehyde contents in fresh white cheese in El Salvador: Seasonal changes associated with temperature," *Toxicol Rep*, vol. 9, pp. 1647–1654, 2022, doi: 10.1016/j.toxrep.2022.08.005.

[7] K.-H. Kim, S. A. Jahan, and J.-T. Lee, "Exposure to Formaldehyde and Its Potential Human Health Hazards," *Journal of Environmental Science and Health, Part C*, vol. 29, no. 4, pp. 277–299, Oct. 2011, doi: 10.1080/10590501.2011.629972.

[8] J. Rovira, N. Roig, M. Nadal, M. Schuhmacher, and J. L. Domingo, "Human health risks of formaldehyde indoor levels: An issue of concern," *Journal of Environmental Science and Health, Part A*, vol. 51, no. 4, pp. 357–363, Mar. 2016, doi: 10.1080/10934529.2015.1109411.

[9] Y. T. Male, L. I. Letsoin, and N. A. Siahaya, "Analisis Kandungan Formalin Pada Mie Basah Pada Beberapa Lokasi Di Kota Ambon," *Majalah BIAM*, vol. 13, no. 2, p. 5, 2017, doi: 10.29360/mb.v13i2.3530.

[10] B. P. Mohanty, A. Mahanty, P. Parida, and S. Parija, "Formaldehyde adulteration in fish as a public health concern and need for mass awareness , Journal of the inland Fisheries Society of India ISSN 0379 Formaldehyde adulteration in fish as a public health concern and need for mass awarness," vol. 50, no. June, pp. 71–74, 2018.

[11] G. Manoppo and J. Abidjulu, "Analisis formalin pada buah impor di kota manado," vol. 3, no. 3, pp. 148–155, 2014.

[12] P. Wahed, Md. A. Razzaq, S. Dharmapuri, and M. Corrales, "Determination of formaldehyde in food and feed by an in-house validated HPLC method," *Food Chem*, vol. 202, pp. 476–483, Jul. 2016, doi: 10.1016/j.foodchem.2016.01.136.

[13] A. Kundu *et al.*, "Adverse health risk from prolonged consumption of formaldehyde-preserved carps in eastern region of Indian population," *Environmental Science and Pollution Research*, vol. 27, no. 14, pp. 16415–16425, May 2020, doi: 10.1007/s11356-020-07993-0.

[14] D. J. Mason, M. D. Sykes *, S. W. Panton, and E. H. Rippon, "Determination of naturally-occurring formaldehyde in raw and cooked Shiitake mushrooms by spectrophotometry and liquid chromatography-mass spectrometry," *Food Addit Contam*, vol. 21, no. 11, pp. 1071–1082, Nov. 2004, doi: 10.1080/02652030400013326.

[15] M. I. S. Veríssimo, J. A. F. Gamelas, A. J. S. Fernandes, D. V. Evtuguin, and M. T. S. R. Gomes, "A new formaldehyde optical sensor: Detecting milk adulteration," *Food Chem*, vol. 318, p. 126461, Jul. 2020, doi: 10.1016/j.foodchem.2020.126461.

[16] A. Kundu *et al.*, "Adverse health risk from prolonged consumption of formaldehyde-preserved carps in eastern region of Indian population," *Environmental Science and Pollution Research*, vol. 27, no. 14, pp. 16415–16425, May 2020, doi: 10.1007/s11356-020-07993-0.

[17] Md. B. Rahman *et al.*, "An update on formaldehyde adulteration in food: sources, detection, mechanisms, and risk assessment," *Food Chem*, vol. 427, p. 136761, Nov. 2023, doi: 10.1016/j.foodchem.2023.136761.

[18] H. Reingruber and L. B. Pontel, "Formaldehyde metabolism and its impact on human health," *Curr Opin Toxicol*, vol. 9, pp. 28–34, Jun. 2018, doi: 10.1016/j.cotox.2018.07.001.

[19] S.-H. Park *et al.*, "Health risk assessment for multimedia exposure of formaldehyde emitted by chemical accident," *Environmental Science and Pollution Research*, vol. 28, no. 8, pp. 9712–9722, Feb. 2021, doi: 10.1007/s11356-020-11403-w.

[20] F. Villanueva, S. Lara, M. Amo-Salas, B. Cabañas, P. Martín, and S. Salgado, "Investigation of formaldehyde and other carbonyls in a small urban atmosphere using passive samplers. A comprehensive data analysis," *Microchemical Journal*, vol. 167, p. 106270, Aug. 2021, doi: 10.1016/j.microc.2021.106270.

[21] L. Zhang, C. Steinmaus, D. A. Eastmond, X. K. Xin, and M. T. Smith, "Formaldehyde exposure and leukemia: A new meta-analysis and potential mechanisms," *Mutation Research/Reviews in Mutation Research*, vol. 681, no. 2–3, pp. 150–168, Mar. 2009, doi: 10.1016/j.mrrev.2008.07.002.

[22] S. Laly, E. Priya, S. Panda, and A. Zynudheen, "Formaldehyde in Seafood: A review," *Fishery Technology*, vol. 55, no. 2, pp. 87–93, 2018.

[23] S. Zhang, C. Xie, Z. Bai, M. Hu, H. Li, and D. Zeng, "Spoiling and formaldehyde-containing detections in octopus with an E-nose," *Food Chem*, vol. 113, no. 4, pp. 1346–1350, Apr. 2009, doi: 10.1016/j.foodchem.2008.08.090.

[24] J. H. E. Arts, M. A. J. Rennen, and C. de Heer, "Inhaled formaldehyde: Evaluation of sensory irritation in relation to carcinogenicity," *Regulatory Toxicology and Pharmacology*, vol. 44, no. 2, pp. 144–160, Mar. 2006, doi: 10.1016/j.yrtph.2005.11.006.

[25] D. Norbäck, J. H. Hashim, Z. Hashim, and F. Ali, "Volatile organic compounds (VOC), formaldehyde and nitrogen dioxide (NO 2) in schools in Johor Bahru, Malaysia: Associations with rhinitis, ocular, throat and dermal symptoms, headache and fatigue," *Science of The Total Environment*, vol. 592, pp. 153–160, Aug. 2017, doi: 10.1016/j.scitotenv.2017.02.215.

[26] R. Farhadi and Z. Bayrami, "Formaldehyde," in *Encyclopedia of Toxicology*, Elsevier, 2024, pp. 821–829. doi: 10.1016/B978-0-12-824315-2.00838-1.

[27] C. Bosetti, J. K. McLaughlin, R. E. Tarone, E. Pira, and C. La Vecchia, "Formaldehyde and cancer risk: a quantitative review of cohort studies through 2006," *Annals of Oncology*, vol. 19, no. 1, pp. 29–43, Jan. 2008, doi: 10.1093/annonc/mdm202.

[28] G. M. Marsh, A. O. Youk, J. M. Buchanich, S. Erdal, and N. A. Esmen, "Work in the metal industry and nasopharyngeal cancer mortality among formaldehyde-exposed workers," *Regulatory Toxicology and Pharmacology*, vol. 48, no. 3, pp. 308–319, Aug. 2007, doi: 10.1016/j.yrtph.2007.04.006.

[29] G. Wooster, C. Martinez, P. Bowser, and D. O'Hara, "Human Health Risks Associated with Formalin Treatments Used in Aquaculture: Initial Study," *N Am J Aquac*, vol. 67, no. 2, pp. 111–113, Apr. 2005, doi: 10.1577/A04-026.1.

[30] R. Golden, "Identifying an indoor air exposure limit for formaldehyde considering both irritation and cancer hazards," *Crit Rev Toxicol*, vol. 41, no. 8, pp. 672–721, Sep. 2011, doi: 10.3109/10408444.2011.573467.

[31] I. Lang, T. Bruckner, and G. Triebig, "Formaldehyde and chemosensory irritation in humans: A controlled human exposure study," *Regulatory Toxicology and Pharmacology*, vol. 50, no. 1, pp. 23–36, Feb. 2008, doi: 10.1016/j.yrtph.2007.08.012.

[32] H. Hayun, K. Harmita, and T. B. Pramudita, "Determination of formaldehyde content in wet noodles by thin layer chromatography-densitometry after derivatization with Nash reagent," *Oriental Journal of Chemistry*, vol. 33, no. 3, pp. 1400–1405, 2017, doi: 10.13005/ojc/330341.

[33] C. Utama, N. Nurwidiyanto, F. Baehaki, and S. Ekawati, "Analysis of formaldehyde content in salted fish at Ciroyom market, Bandung City, Indonesia," *Journal of Sustainability Science and Technology*, vol. 1, no. 1, pp. 35–43, 2021, doi: 10.23960/josst.v1i1.6.

[34] U. Anissah, A. K. Putri, and G. R. Barokah, "An estimation of endogenous formaldehyde exposure due to consumption of Indonesian opah fish (Lampris guttatus) in three major export destination countries," *Squalen Bulletin of Marine and Fisheries Postharvest and Biotechnology*, vol. 14, no. 1, pp. 1–8, May 2019, doi: 10.15578/squalen.v14i1.369.

[35] U. Anissah, F. Ariyani, G. Barokah, and H. I. Januar, "NMR Metabolomics of *Saurida tumbil* Fish Treated with Formaldehyde Solution as Misconduct Food Preservation Method," *Journal of Aquatic Food Product Technology*, vol. 30, no. 3, pp. 263–270, Mar. 2021, doi: 10.1080/10498850.2021.1880510.

[36] U. Anissah, A. K. Putri, and G. R. Barokah, "An estimation of endogenous formaldehyde exposure due to consumption of Indonesian opah fish (Lampris guttatus) in three major export destination countries," *Squalen Bulletin of Marine and Fisheries Postharvest and Biotechnology*, vol. 14, no. 1, pp. 1–8, 2019, doi: 10.15578/squalen.v14i1.369.

[37] A. Poernomo, I. Widyastutik, H. B. Purnamasari, and F. Ariyani, "Effect of salting time on formaldehyde content of dried salted Indo-Pacific mackerel," *IOP Conf Ser Earth Environ Sci*, vol. 919, no. 1, p. 012042, Nov. 2021, doi: 10.1088/1755-1315/919/1/012042.

[38] Meida, S. Warno Utomo, and M. Petala Patria, "Analysis of natural formaldehyde formation on several types of marine fish circulating in Jakarta," *E3S Web of Conferences*, vol. 211, pp. 1–11, 2020, doi: 10.1051/e3sconf/202021102020.

[39] H. Simanjuntak and M. V. Silalahi, "Kandungan Formalin Pada Beberapa Ikan Segar di Pasar Tradisional Parluasan Kota Pematangsiantar," *Jurnal Sains dan Teknologi*, vol. 11, no. 1, pp. 223–228, 2022, [Online]. Available: https://dx.doi.org/10.23887/jst-undiksha.v11i1

[40] D. Suseno, "Validasi Metode Analisis Formalin dan Aplikasinya Pada Ikan Asin," *Jurnal Agroindustri Halal*, vol. 7, no. 1, pp. 173–182, 2021.

[41] A. Adriani, A. Karim, and S. Dali, "Analysis Of Formaldehyde Preservatives In Wet Anchovy (Stolephorus Sp.) From Traditional Markets In Makassar City, South Sulawesi," *Jurnal Akta Kimia Indonesia (Indonesia Chimica Acta)*, vol. 11, no. 1, p. 1, 2019, doi: 10.20956/ica.v11i1.6399.

[42] E. Mayasari, M. Azlan, and T. Rahayuni, "International Journal of Advance Tropical Food Detection of Formalin Content And Quality Properties of Snakehead (Channa striata) Dried Salted Fish From The Traditional Markets In Pontianak City In Indonesia."

[43] M. Silalahi, "Crassocephalum crepidioides (Bioactivity and Utilization)," European Alliance for Innovation n.o., Jul. 2022. doi: 10.4108/eai.17-11-2021.2318673.

[44] I. Permana and I. Irmasyanti, "Identification of Formalin in Food Sold in Ciamis by Thin Layer Chromatography," *Ad-Dawaa : Journal of Pharmacy*, vol. 1, no. 1, pp. 62–69, May 2023, doi: 10.52221/dwj.v1i1.226.

[45] A. Nageswari, K. V. S. R. Krishna Reddy, and K. Mukkanti, "Low-level quantitation of formaldehyde in drug substance by HPLC-UV," *Chromatographia*, vol. 75, no. 5–6, pp. 275–280, Mar. 2012, doi: 10.1007/s10337-012-2186-8.

[46] F. Bianchi, M. Careri, C. Corradini, M. Musci, and A. Mangia, "Innovative Method for Ultratrace Determination of Formaldehyde in Frozen Fish: SPME Extraction and GC-

ITMS/MS Analysis," *Curr Anal Chem*, vol. 1, no. 2, pp. 129–134, Jun. 2005, doi: 10.2174/1573411054021600.

[47] M. N. Indang, A. S. Abdulamir, A. Abu Bakar, A. B. Salleh, Y. H. Lee, and Y. Nor Azah, "A Review: Methods of Determination of Health-Endangering Formaldehyde in Diet," *Research Journal of Pharmacology*, vol. 3, no. 2, pp. 31–47, 2009, Accessed: Sep. 29, 2023. [Online]. Available: https://medwelljournals.com/abstract/?doi=rjpharm.2009.31.47

[48] M. Nassiri, M. Kaykhaii, S. Hashemi, and M. Sepahi, "Spectrophotometric determination of formaldehyde in seawater samples after in-situ derivatization and dispersive liquid-liquid microextraction," *Iranian Journal of Chemistry and Chemical Engineering*, vol. 37, no. 1, pp. 89–97, 2018.

[49] J. Li, J. Zhu, and L. Ye, "Determination of formaldehyde in squid by high-performance liquid chromatography," 2007.

[50] T. Wang, X. Gao, J. Tong, and L. Chen, "Determination of formaldehyde in beer based on cloud point extraction using 2,4-dinitrophenylhydrazine as derivative reagent," *Food Chem*, vol. 131, no. 4, pp. 1577–1582, Apr. 2012, doi: 10.1016/j.foodchem.2011.10.021.

[51] H. Wang *et al.*, "Determination of formaldehyde in fruit juice based on magnetic strong cation-exchange resin modified with 2,4-dinitrophenylhydrazine," *Food Chem*, vol. 131, no. 1, pp. 380–385, Mar. 2012, doi: 10.1016/j.foodchem.2011.08.056.