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Food Safety Monitoring: Formaldehyde Health Risk Assessment on Imported Fruits in Indonesia 2014-2022

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ABSTRACT

Food safety monitoring is one of keys achieving SDGs in 2030 and it can be done by environmental health risk assessment. Imported fruits have high risk for health from chemical contaminants to preserve during distribution and one of them often found is formaldehyde. Formaldehyde is harmful compound for human health and it may cause carcinogenic effects. This study aimed to estimate formaldehyde health risk on imported fruits. It was determined by hazard identification, dose-response assessment, exposure assessment and risk characterization. Data used were primary data (2019) and secondary data (2014-2022) with same topic in 15 cities in Indonesia. Food intake referred to average fruit consumption person per day from national economy social survey (2016), recommendation intake from WHO, projections and realization of fruit consumption of Indonesian people from Indonesian Ministry of Agriculture's Food Security Agency (2018). The monitoring of chemical contaminant has to be priority in distribution chain and variation of fruit daily intake may decrease health risk from chemical contaminant. The consumption of fruit has to be variation.

I. Introduction

Ending hunger, achieving food security, improving nutrition and promoting sustainable agriculture are the second vision of the Sustainable Development Goals (SDGs) (UN, 2015). Food safety is the first objective of the 5 Food and Agriculture strategic objectives (FAO) to achieve SDGs in 2030 (FAO, 2019). Fruit is one of the imported commodities in Indonesia that continues to increase from 2010 to 2021. In 2021 imports in Indonesia reached 775.422,4 kg (BPS, 2022). The biggest fruit importing countries are China, Thailand and the United States with the dominance of imported fruits namely apples 235.02 million USD, pears 164.12 million USD, grapes 120.80 million USD, lemons 10.98 million USD and oranges 6.83 million USD (BPS, 2018).

Fruit is one of the foods that contain micronutrients needed by the body for everyone in the world and is an export commodity that has a risk of damage during the shipping process. One of the compounds that can preserve fruit during the shipping process is formaldehyde. Formaldehyde is a gas-shaped compound that is colorless, soluble in water and flammable at room temperature. Formaldehyde can be found in the form of liquid formalin with water and methanol (NIEHS, 2020). At high temperatures formaldehyde will decompose into methanol (wood alcohol) and carbon monoxide and are reactive to other chemicals. Formaldehyde has a pungent odor and causes a burning sensation in the eyes, nose and lungs at high concentrations (Services, 2016).

Formaldehyde is produced naturally in the body as part of the body's normal metabolism with very small amounts. Formaldehyde can be found in the air at home or work and food. The main sources of formaldehyde in the air we breathe are lower amounts of atmospheric mist, car exhausts, cigarettes or other tobacco products, gas stoves and open fireplaces(Services, 2016). In everyday life formaldehyde is used to make resins in building materials, paper coatings, clothing fabrics, synthetic fibers and includes certain insulation materials, glues and wood products. Formaldehyde is also used for making other chemicals. In the medical world, formaldehyde is used for preserving corpses, antimicrobial agents and disinfectants in industry and some household needs (NIEHS, 2020).

Formaldehyde occurs naturally in food. Food contamination may be possible through fumigation (for example grains), cooking (as a combustion product) and apart from formaldehyde resin based tableware. Formaldehyde has been used as a bacteriostatic agent in some foods, such as cheese. Formaldehyde is irritating to tissue when in direct contact. Formaldehyde can cause nasopharyngeal cancer and leukemia, respiratory irritation such as asthma, pulmonary edema and irritation of the eyes, nose, throat and skin. Formaldehyde can enter the body through breathing, ingestion and skin (NIEHS, 2020).

In this study, data on formaldehyde concentration and fruit intake rate are used to estimate health risks through maximum body weight by getting a value of RQ = 1 (Risk Quotient). In addition, this study conducts a health risk analysis which include hazard identification, dose-response assessment, exposure assessment and risk characterization.

II. Methods

This research was descriptive analytic study. We were looking for research related to the measurement of formaldehyde levels on imported fruit in Indonesia from 2014-2022. While the 2019 data were obtained from primary data. Daily intake rate is obtained from the 2016 National Socio-Economic Survey (SUSENAS), fruit intake recommendations based on WHO and the results of projections and realization of Indonesian people's fruit consumption based on the Ministry of Agriculture's Food Security Agency in 2018 (Kemenkes, 2016)(Agency, 2018). Estimates of safe weight were determined based on the calculation of health risk assessments (EHRA, 2012).

$$RQ = \frac{\mathrm{Ink}}{\mathrm{R}f\mathrm{D}}$$

$$\mathrm{Ink} = \frac{\mathrm{CxRxfExDt}}{\mathrm{Wbxtavg}}$$

One evaluation of the risk of chemical exposure through inhalation and ingestion was through a risk assessment. Risk assessment was a scientific evaluation of known or potential health effects resulting from human exposure to foodborne hazards. Health Risk Assessment was assessed from the components of hazard identification, dose-response assessment, exposure assessment and risk characterization. The following were the stages of data analysis for health risk assessment of the content of formaldehyde on imported fruit in Indonesia in 2014-2019. The ethical consideration was not needed in this research.

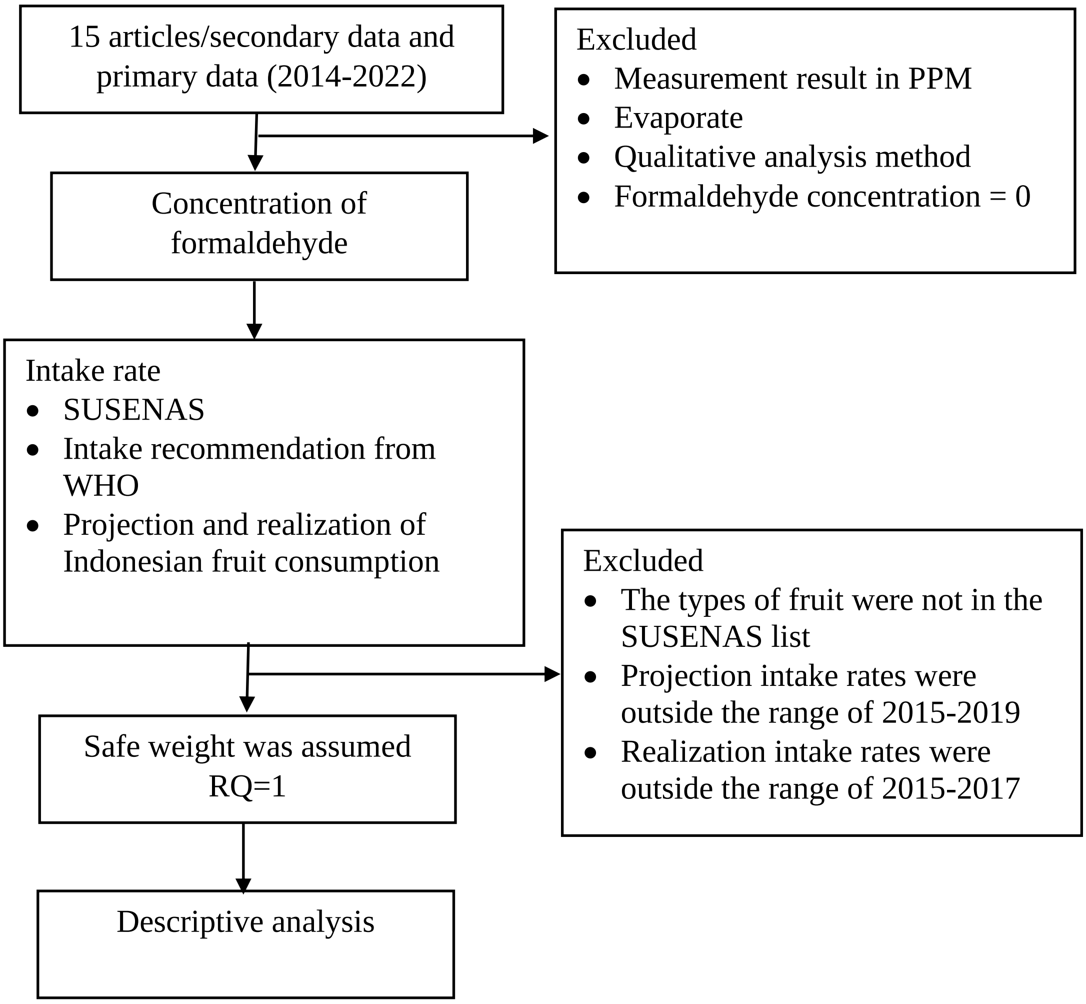

Figure 1. Data Analysis Flow

III. Results and Discussion

Table 2. Summary of Formaldehyde Study on Imported Fruits in Indonesia 2014-2022.

Study Author Date of Publication	City	Study Location	Fruits	Number of Sample	Measurement Methods	Units of Measurement	Measrument Results
Manoppo, G; Abidjulu, J; Wehantouw, Frenly (2014) (Manoppo & Abidjulu, 2014)	Manado	Large supermarkets (supermarkets A, B and C)	Apples, pears, grapes	9	Qualitative analysis (color test of Schiff reagents) and quantitative analysis (Schiff reagents measured by UV-VIS spectrophotometer)	µg/mL	a. Qualitative analysis All samples are yellow b. Quantitative analysis Supermarket A Apple = 0.195 Pear = 0.156 Grape = 0.075 Supermarket B Apple = 0.136

Study Author **Date of Publication**	**City**	**Study Location**	**Fruits**	**Number of Sample**	**Measurement Methods**	**Units of Measurement**	**Measrument Results**
							Pear = 0.095 Grape = 0.085 Supermarket C Apple = 0.095 Pear = 0.095 Grape = 0.080
Lasaiba, I & Kotala, S (2015) (Lasaiba & Kotala, 2015)	Ambo n	Modern market (supermarkets)	Apples , grapes, orange s	6	Qualitative (Schiff reagent test dyes) and quantitative (Schiff reagents and measured with UV-VIS spectrophotometer)	Mg/kg	Negative
Suparto; Prawiras, R (2015) (Suprapto & Prawiras, 2015)	Jakart a	Level of local retailers and distributors in the Keramat Jati market	Fuji apples and Washin gton apples	4	Quantitative (quantitative faormaldehyde content analysis, Pharmacopoeia III edition 1979)	ppm	a. Retailers Fuji apple 3.4 ± 0.47 Washington apple 2 ± 0.37 b. Local distributor Fuji apple 2 ± 0.2 Washington apple 7.7 ± 1.6
Zalukhu, M.E.R; Nuraini, D; Chahaya, I (2015) (Zalukhu et al., 2015)	Meda n	Berastagi Supermarkets , Carrefour supermarkets, Hypermart supermarkets	Apples , grapes and orange s	15	Quantitative analysis (iodine titration) with calculations: $= \frac{ml\ Na2S2O3xNx14.00}{100}$ ml $Na_2S_2O_3$ = amount of penetration N = $Na_2S_2O_3$ concentration 14.008 = Coefficient	mg/mL	Apple Fuji Wang Shan Apples (1.779), Blue Cheland Apples (2.451), Granny Smith Apples (1.863), Honey NZ Apples (1.863), Fuji PRC Apples (3.152), Red Delicious Apples (4.412), Japanese Fuji Apples (4.552) Grape Autum Royal Wine (3.165), Red Globe wine (3.572), Calmeria wine (4.692) Orange
							c. Imperial Seed oranges (1.610), Navel oranges (2.311), Nova Daisy oranges (2.451), Valencia oranges (1.863), Ponkam oranges (3.082)
Indrayati, W; Lin, Y.J; Holik, H.A (2015) (Inriyati,	Jatina gor	Modern market	A = green grapes B = red grapes	10	Qualitative and quantitative with Nash reagents measured using UV-VIS spectrophotometry (Specord 205)	ppm	a. Qualitative A = colorless B = slightly reddish C = yellowish

Wiwiek., Lin, Jia Yap., Holik, 2015)			C = Fuji apple D = Washington apple E = Granny Smith's apple F = golden pear G = Lie Lie pear H = Sinkao pear I = Packham pear J = Italian 10 green kiwi				D = yellowish E = colorless F = slightly reddish G = slightly yellowish H = slightly yellowish I = curvature J = colorless b. Quantitative A= 1.4214 E= 0.9149 J= 1.0194
Syahrizal (2016) (Syahrizal, 2016)	Banda Aceh	SM Supermarkets (city center), IM supermarkets (2 km from city center)	Apples, grapes and oranges	6	Quantitative analysis (spectophotometri method)	mg/L	Semua sampel yang diuji memiliki kadar >8.0 mg/L
Hasriamin, Ansharullah, Gusnawaty, H.S (2017) (Hasriamin et al., 2017)	Kendari	Andonuhu Market, Fruit Market, Mandonga Wet Market, Lipo Plaza and Central Market	Apples (21 samples) and grapes from America and China (7 samples)	28	Qualitative analysis (Fanil Hidrazin method)	-	Negative
Aprillia, A.Y; Tuslinah, L (2018) (Aprilia, 2018)	Tasikmalaya	Supermarket	Grapes, oranges, kiwi, pears and apples	14	Qualitative analysis (Schiff method) and quantitative analysis (Dinitrophenilhidrazin method)	ppm	Qualitative analysis Positive results = green grapes, red grapes, orange 1, orange 2, orange 3, orange 4, apple 1 Quantitative Analysis green grapes (69.78), red grapes (784.22), orange 1 (74.22), orange 2 (444.22), orange 3 (356.44), orange 4 (68.67), apple 1 (315.33)

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Study Author **Date of Publication**	**City**	**Study Location**	**Fruits**	**Number of Sample**	**Measurement Methods**	**Units of Measurement**	**Measrument Results**
Lestari, M; Umar, B; Hasin, A (2018) (Lestari et al., 2018)	Makassar	-	Fuji apple, Grand Smith apple, Red Delicious apple	3	Qualitative analysis (chromatophytic acid reagents and potassium permangate)	-	Negative
Rahmi, M; Dira; Herman, H. (2018) (Rahmi, 2018)	Padang	Supermarkets dan market	Red apples, green apples, pears, oranges and grapes	5	Qualitative analysis (Nash reagents, KMnO4 and fehling solution) and quantitative analysis (UV-VIS spectrophotometry)	µg/g	Qualitative analysis Positive results = red apple, green apple and orange Quantitative Analysis Red apple = 113.558 Green apple = - Orange = 251.978
Khoirunisa, S (2018) (Khoirunisa et al., 2018)	Semarang	Supermarkets	Grapes (5 samples) and apples (7 samples)	12	Qualitative and quantitative analysis	ppm	Positive results (qualitative and quantitative analysis) Peruvian Red Globe Wine (30.560) Fuji Apple RRT (37.584) Washington Apple (30.360)
Putri, D.R; Kumalasari, E.; Musiam, E (2018) (Putri et al., 2018)	Banjarmasin	Supermarket	Apple (6 samples), Grape (4 samples), Pear (4 samples)	14	Qualitative analysis	-	6 samples positive before washed and 3 samples positive after washed
Najhah, N.L (2018) (Najhah, 2018)	Medan	Transmart Plaza Medan Fair	Purple grape from America, Kiwi from Newzealand, Sunkist orange from China, delicio	5	Quantitative analysis	Mg/l	Parple grape (1.5 mg/l), Kiwi (1.5 mg/l), delicious red apple (1.0 mg/l) and pear (0.6 mg/l)

			us red apple from America and pear from North Africa				
Agustina, U (2019) Primary data	Depok	Supermarket	Apple from Newzealand, apple from USA, fuji apple, pear and grape from China	5	Quantitative analysis (PP.16.7-BTP / 17025 / LABKESDA	mg/kg	Negative
Mudaffar, R.A (2021) (Mudaffar, 2021)	Palopo	Fruit store	Apel Fuji dan red grapes	4	Qualitative and quantitative analysis	ppm	Positive results (qualitative and quantitative analysis) apple fuji A 5.93 ppm, apple fuji B 6.31 ppm, red grape A 5.69 ppm and reg grape B 10.56 ppm
Syahputra, E.R; Muzafri, A; Bahar, E (2022) (Afriani, Muzafri, 2022)	Rokan Hulu	Traditional market	Red grape	16	Qualitative analysis	-	Positive (all samples)

Table 3. Minimum Safety Body Weight According to Fruit Intake References and Fruit Intakes

Variables	N	Mean ± sd (kg)	Maximum body weight (Kg)*
Fruit intake references			
National economy social survey	34	2.07 ± 5.07	21.77
WHO's intake Recommendation	44	49.28 ± 114.79	588.16
Projections of Indonesian Ministry of Agriculture's Food Security Agency	35	39.47 ± 80.17	374.07
Realization of Indonesian Ministry of Agriculture's Food Security Agency	29	31.13 ± 73.50	323.49
Fruit intake			
Apple	70	16.07 ± 45.06	236.50
Grape	23	63.48 ± 151.25	588.16
Pear	3	0.09 ± 0.03	0.12
Orange	39	49.64 ± 85.31	333.16
Kiwi	3	0.56 ± 0.18	0.76

*Maximum body weight is more risk to health

Hazard Identification

Formaldehyde was a toxin compound that was classified as a carcinogen compound (group 1) in humans and animals (WHO, 2012). In Indonesia the use of formaldehyde in food was prohibited (Pengawasan Bahan Berbahaya Yang Disalahgunakan Dalam Pangan, 2013)(Pengawasan Bahan Berbahaya Yang Disalahgunakan Dalam Pangan, 2013). The target organs of formaldehyde were the eyes and the respiratory system (NIOSH, 2019). Formaldehyde is also known as methanal, methylene oxide, oxymethylene, methylaldehyde and oxomethane. Formaldehyde could enter the body through inhalation, drinking or eating it, or when in contact with skin. Formaldehyde was quickly absorbed from the nose and breathing over the lungs. Formaldehyde ingestion was very quickly absorbed and in very small amounts absorbed through the skin. When formaldehyde was absorbed, it was very easily broken down and almost all body tissues could break down formaldehyde compounds. When formaldehyde was absorbed in the body, it would split into formate compounds (converted into non-toxic compounds) which would be excreted into the urine. Formaldehyde could also be converted to carbon dioxide and exhaled from the body. Formaldehyde could stick to deoxyribonucleic acid (DNA) or protein in the body and is not stored in fat (Services, 2016).

Dose-Response Assessment

Reference Dose (RfD) formaldehyde was 0.2 mg / kg / day where the dose could be dangerous to the gastrointestinal. Whereas formaldehyde reference concentration (RfC) was absent (Services, 2016). Estimated daily exposure dose of formaldehyde through inhalation, assuming a respiratory volume of 20 m^3/day for an average adult with people spending 60-70% of the time at home, 25% at work and 10% outdoors at around 1 mg/day, with some exposure> 2 mg/day and a maximum of around 8 mg/day. Formaldehyde could also be in drinking water with an estimated content of less than 0.1 mg/L. In fruits and vegetables usually contained 3-60 mg/g, milk and milk products around 1 mg/g, meat and fish 6-20 mg/kg and shellfish 1-100 mg/kg. Daily intake was difficult to evaluate, but rough estimates of available data were in the range of 1.5-14 mg / day for the average adult (EPA, 2022).

Exposure Assessment

Based on the results of formaldehyde measurements on imported fruit in 15 cities in Indonesia, obtained varying levels of formaldehyde. In quantitative examinations, researchers used different methods so that different levels of levels were also obtained. The following was a reference to the rate of intake used to calculate the formaldehyde health risk assessment of imported fruit. Exposure analysis was the process of calculating the intake or intake of risk agents through the following calculation methods (EHRA, 2012).

$$I = \frac{CxRxfExDt}{Wbxtavg}$$

I was the number of risk agents that enter the body with a certain weight every day (mg / kg / day); C was the concentration of the risk agent (mg / L or mg / Kg); R was the rate of intake or consumption (L / day or kg / day); fE was the length or number of days of exposure (exposure to settlement 350 days / year); Dt was the duration of exposure with a projected 30 years for residential defaults; Wb was weight (kg); tavg was the average daily period (Dt x 365 days / year for non carcinogenic substances and 70 years x 365 days / year for carcinogenic substances).

Risk Characterization

Risk characteristics were determined based on calculations through the following formula.

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

In this case, this study was conducted to determine the estimated safe body weight with the assumption of consuming imported fruits with concentrations according to table 1 with RfD = 0.2 mg / kg / day and the assumption of RQ = 1 through the following formula (EHRA, 2012).

$$\text{Wb} = \frac{CxRxfExDt}{RQxtavgxRfD}$$

IV. Conclusion

The results from 82 samples (apple, grape, pear, orange, kiwi) showed varying levels of formaldehyde. The highest level (784.22 ppm) was found in red grape and the most frequently (90.90%) was found in orange. The highest risk from minimum body weight was got according to the intake of the national economic social survey of 21.77 kg (sd = 5.07), 333.16 kg (sd = 81.03) recommendation for intake, 374.07 kg (sd = 80.17) and 323.49 kg (sd = 73.50) projections and realization. Estimating body weight was gotten while RQ = 1 and daily intake per fruit for 30 years. The higher risk was from consumption projections for red grapes in Tasikmalaya (2017). If the body weight was under 374.07 kg, it could get a health risk because of RQ> 1. The conclusion is the monitoring of chemical contaminants has a priority in the distribution chain and the variation of fruit daily intake may decrease the health risk from chemical contaminants. The consumption of fruit has to be variation.

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