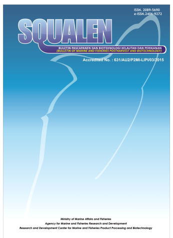

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An Estimation of Endogenous Formaldehyde Exposure due to Consumption of Indonesian Opah Fish (*Lampris guttatus*) in Three Major Export Destination Countries

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Abstract

The demand for Indonesian opah fish as an export product is increasing in the international market. Three countries (Malaysia, Mauritius, and Taiwan) recorded as the leading export destination of Indonesian opah fish. However, as the fish kept in a frozen state during export transportation, the endogenous formaldehyde may increase over time. This research presented the health risk assessment of population in the leading export destination countries that consumed opah fish from Indonesia. The study aimed to reveal the most potential export destination country that may accept an increasing volume of opah fish supply from Indonesia. The potency was determined from current export volume, the amount of endogenous formaldehyde content, and fish consumption at each country. The data were calculated with @Risk®7.0 software. The results showed opah fish consumed by Malaysian can be categorized as safe. Increasing the number of opah fish imported by Malaysian as much as six times, 12 times, 18 times, 27 and 36 times relatively does not cause health risks related to the presence of its endogenous formaldehyde. Moreover, opah fish consumed by Taiwanese is also safe, but with increasing the number of consumptions by more than 26 times is suspected to be potentially causing a health problem. However, opah fish consumed in Mauritius was categorized as unsafe and potentially caused health risks. Based on these results, Indonesia may consider to increase the opah fish export to Malaysia and Taiwan in the future.

Keywords: formaldehyde exposure, *Lampris guttatus*, Malaysia, Mauritius, Taiwan

1. Introduction

Formaldehyde is a toxic compound that can be harmful to human body. Recently, International Agency for Research on Cancer (IARC) has classified formaldehyde as a Group 1 Carcinogenic to humans and enter the human body through the mechanism of inhalation, oral and skin contact (IARC, 2012). Formaldehyde can also cause allergic reactions in humans. Systemic or local allergic reactions in humans depend on the amount of exposure to formaldehyde contained in the food that they consume (Aminah, Zailina, & Fatimah, 2013). Sufficient evidence showed that formaldehyde causes nasopharyngeal cancer, sinonasal cancer, and leukemia in human. However, formaldehyde is not considered to be a reproductive or developmental toxicant (Abdollahi & Hosseini, 2014; Aminah et al., 2013; EFSA, 2014; Tang, Bai, Duong, Smith, & Zhang, 2009; IARC, 2012; Norliana, Abdulamir, Bakar, & Salleh, 2009).

Formaldehyde occurs endogenously in fish. According to research conducted by Wang, Cui, and Fang (2007), fresh sea products had an average value of endogenous formaldehyde content of 2.177 ± 1.414 mg/kg (mackerel, squid, pomfret, tail hair, sea cucumbers, red shrimp, yellow bakers, shellfish, and octopus). The content of formaldehyde in postharvest fish showed an increase during the frozen and ice cube storage (Rachmawati et al., 2007; Murtini, Riyanto, Priyanto, & Hermana, 2014).

Formaldehyde compounds may be formed during the storage process and accumulated in fish tissue. It occurs because formaldehyde conversed into other

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chemical compounds (Tsuda, Frank, Sato, & Sugimura, 1988). Endogenous formaldehyde might be formed via the enzymatic mechanism, where the lipid oxidation occurs by the activity of microorganisms (Noordiana, Fatimah, & Farhana, 2011). The deterioration of fish quality during frozen storage depends on several factors such as the characteristics of fish meat (species) and environmental factors (storage temperature, time and enzymatic degradation) (Badii & Howell, 2002; Benjakul, Visessanguan, Thongkaew, & Tanaka, 2005; Rachmawati et al., 2007; Murtini et al., 2014). Among many fishes, opah fish was indicated to contain high endogenous formaldehyde, and its concentration was increased during frozen storage (Murtini et al., 2017a).

In Indonesia, opah fish is a valuable marine resource for export commodity. Indonesian opah fish that was caught during the period of 2015-2017 showed that there was 573.44 tons with 29.1% of it were used for domestic consumption and 70.9% as export commodities (BKIPM, 2017). Indonesian opah fish was exported to several countries such as Malaysia, Mauritius, Japan, Taiwan, etc. However, Malaysia, Mauritius and Taiwan was the major export destination countries (107.04 tons, 32.2 tons and 11.02 tons in total respectively, equivalent to 49.83%, 25.60% and 13.34%) during 2015-2017. The endogenous formaldehyde content of Indonesian opah fish for domestic consumption ranged from 4.62 ± 0.00 mg/kg to 58.10 ± 0.46 mg/kg. It potentially caused health problems for the residents of female children in Jakarta and Surabaya (Putri, Anissah, Ariyani, & Wibowo, 2018). United States Environmental Protection Agency set the daily intake (ADI) for formaldehyde which was 0.20 mg/kgBW/day (United States Environmental Protection Agency, 2000). An increase of opah fish demand in foreign countries has a consequence with the high level of formaldehyde in this species that may risk human health. This study presented an assessment of Indonesian opah fish consumption in three major exporting countries (Malaysia, Mauritius, and Taiwan), to determine the most potential export destination country that may accept an increasing volume of Indonesian opah fish export.

2. Material and Methods

2.1. Sampling Location and Sample Collection

Sample of four opah fish with average weight of 18.57 ± 3.14 kg were captured and kept in frozen condition for one week by KM Perintis Jaya 88. The coordinates of opah fish catching locations were at 17° 32' 0"S 111° 20' 0" E and 17° 33' 0" S 111° 18' 0" E in the Hindia Ocean. The samples were transported to the laboratory in Jakarta, and the meat were separated from other organs. Furthermore, the meat from each sample was divided into six groups and had been stored within one month to six month at frozen storage (temperature -18 °C). The time of storage in this study was assumed as the time of opah fish storage and distribution before it consumed by consumers in exporting destination countries (Malaysia, Mauritius and Taiwan).

2.2. Determination of Formaldehyde Concentration

The determination of formaldehyde concentration was carried out in two stages. The first stage was the extraction of fish samples using the extraction method proposed by Nash (1953). The next step was measuring the concentration of formaldehyde in the appropriate sample using Perkin Elmer Lambda 25 UV/VIS Spectrofotometer (Benjakul, Visessanguan, & Tanaka, 2004; Putri et al., 2018).

2.3. Data Collection of Malaysian, Mauritians and Taiwanese Fish Consumption

The type and source of data that used to determine opah fish consumption in the three major destination country consumption consist of data on the supply of fish and seafood, average fish consumption, and average body weight during 2015-2017. The number of opah fish exported to the three major export destination country were assumed as the number of their opah fish consumption. Table 1 shows the export values data of opah fish (BKIPM, 2018) and opah fish consumption of three major destination countries.

The population in the range of 18-59 years old were divided into three groups of adolescent (18 to 29 years), adult (30 to 49 years), and elderly (50 to 59 years) (Azmi, Junaidah, Maryam, Safiyah, Fatimah et al., 2009). These three sub-populations were referred as age grouping categories (Hoque, Jacxsens, De Meulenaer, & Alam, 2016). The body weight of population was divided into three sub-populations referred as minimum (50 kg), most likely (62,65 kg) and maximum (69,8 kg) body weight (Azmi et al., 2009; Hoque et al., 2016).

The estimated opah fish consumption for each of three major export destination country was done by three step calculation. First, the total amount of fish data for export during 2015 – 2017 collected from BKIPM (BKIPM, 2017). Furthermore, the export data was graded in to the opah fish data that exported to the three major export destination countries (A). Second, data on the supply of fish and seafood in the

Table 1. Amount of export and opah fish consumption from three major destination countries

Country	Total amount of Indonesian opah fish exports in 2015-2017 (tons)	KIPM that exported opah fish	National fish consumption (g/day)	Opah fish consumption (g/day)*	Comparison of opah fish consumption and national fish consumption (%) **	References
Malaysia	107,04	KIPM Station Class I Medan II	169	0,0035	0,0021	BKIPM, 2018, FAO, 2018a, Hajeb, Jinap, Ismail, Fatimah & Jamilah et al., 2009, Azmi et al., 2009
Mauritius	32,2	KIPM Class I Jakarta II and KIPM Class I Surabaya I	27,38	0.3742	0,2214	BKIPM, 2018, FAO, 2018b, FAO, 2013a, World Data, 2018
Taiwan	11,02	KIPM Class I Jakarta I	21,37	0.0091	0,0054	BKIPM, 2018, FAO, 2018c, FAO, 2013b, World Data, 2018

*)The data were obtained by followed several steps as mentioned in data collection section 2.3

**)Percentage of opah fish consumption compared to total amount of national whole fish consumption

three major export destination country during 2011 - 2013 was collected from FAO (FAO, 2018) (B). Then, the number of exported opah fish (A) was compared with the data on the supply of fish and seafood for consumption (B) and showed in pencentage (C) (Eq.1)

$$C = (A/B)*100\% \qquad \text{Eq 1.}$$

Third, data of average fish consumption for three major destination country (g/day) was collected from any sources as showed on Table 1 (D). Furthermore, avarage consumption of opah fish in three major destination country (E) was calculated by multiplying percentage of opah fish presence in fish and seafood consumption in the three major export destination (C) and average fish consumption for three major destination country (D).

$$E = (C/100)*D \qquad \text{Eq 2.}$$

2.4. Probabilistic Exposure Assessment and Simulation

Evaluation of health risks caused by consumption of Indonesian opah fish were carried out with the probabilistic exposure assessment. The calculation of the amount of exposure and risk analysis were done by categorizing the population of people in Malaysia, Mauritius and Taiwan into three groups of age in the range between 18-59 years (adolescents, adults and elderly). Formaldehyde dietary exposure in opah fish samples included the real consumptions and five different scenarios of formaldehyde concentration (real concentration, 6, 12, 18, 27, and 36 times of real concentration) data were analyzed. The scenarios were chosen by considering the estimation of endogenous formaldehyde formation for opah fish as mentioned in previous study (Putri, et al., 2018). Based on the study, opah fish might be deteriorated up to 26,27 mgN% for TVB in three months. Therefore, the simulation predicted the highest endogenous formaldehyde intake based on the total amount of fish consumption, which were relatively low, by multiplying the concentration. Risk exposure analysis (mg/kg body weight/day) were conducted based on the available data of formaldehyde concentration in opah fish (mg/kg) during the storage period, average opah fish consumption (g/day/person), body weight (kg), and was calculated as the following equation (Hoque et al., 2016):

Exposure = (F X G) / H .... Eq. 3

Note: F = Concentration of Contaminant (mg/kg)
G = Consumption (g/day)
H = Body weight (kg)

Estimation of health risk assessment were assesed based on Palisade (2010) using @Risk®7.0 for Microsoft Excel 2010. Best fit distributions were applied to formaldehyde contents (mg/kg) in opah fish samples and the opah fish consumption in three major export destination countries (g/day) by Chi-square statistics. The average body weight (kg) of the population in each country were grouped into three groups (minimum, most likely and maximum) then simulated by pert distribution (Hoque et al., 2016). Analysis of formaldehyde exposure were carried out using data on average consumption of each country and doubling the average consumption data (6, 12, 18, 27 and 36 times) to get a picture of health risk assessment when the consumption was increased. First-order Monte-Carlo simulations were carried out with 50,000 iterations. To ensure a stable estimation, the simulations were repeated three times. The results were average, standard deviation, maximum and minimum, which can be predicted from the output of the simulation model in the @ Risk®7.0 program (Hoque et al., 2018).

3. Results and Discussion

3.1. The Concentration of Endogenous Formaldehyde Compound in Indonesian Opah Fish

The concentration of formaldehyde in the Opah fish was in the range of 27.82 ± 1.66 mg/kg to 133.12 ± 1.56 mg/kg. In the first week of storage, the endogenous formaldehyde content already reached 9 mg/kg and in the sixth month, the concentration was detected up to 133 mg/kg. Fresh opah fish has a relatively low-fat content of about 1.76% but has a high protein content which is 21-25% (Murtini et al., 2017b). Formaldehyde formation is reported to be related to the process of denaturation and protein aggregation (Badii & Howell, 2002). During frozen storage, opah formaldehyde formed will react with proteins which subsequently caused protein denaturation of the muscle. Fish with high protein content will produce high formaldehyde during the frozen storage period (Benjakul et al., 2005).

3.2. Probabilistic of Endogenous Formaldehyde Exposure in Indonesian Opah Fish in Three Major Export Destination

The probabilistic of endogenous formaldehyde exposure due to Indonesian opah fish intake was conducted by processing the data of formaldehyde concentration and consumer's weight (Table 2). Then, this data was used to calculate the probabilistic dietary exposure concentration of formaldehyde in Indonesian opah fish with various scenarios (Table 3). The data described the formaldehyde intake from six scenarios in opah fish for consumers in each country (18-59 years old). Based on the data, the mean formaldehyde intake in Malaysia, Mauritius and Taiwan were 0.004 mg/kg BW/day, 0.37 mg/kg BW/day and 0.01 mg/kg BW/day, respectively (Table 3). When compared to the maximum limit of average daily intake (ADI) for formaldehyde(ADI 0.20 mg/kgBW/day set by United States Environmental Protection Agency), in Malaysia and Taiwan by the population range of 18-59 years old were considered as safe to consume opah fish from Indonesia, but people in Mauritius were not safe to consume Indonesian opah fish.

Based on the results, consumption of opah fish from Indonesia more than 75.54 mg/kg for Malaysian and Taiwanese of 18-59 years old, would not cause any severe problems in health due to endogenous formaldehyde intake. On the other side, the consumption with the same level might risk the consumers from Mauritius. The dietary exposure for Malaysian consumers were 0.0230, 0.0461, 0.0691, 0.1038, and 0.1455 mg/kg BW/day. The formaldehyde's dietary exposure of Mauritian consumers for five scenarios were 2.1932, 4.3862, 7.6201, 9.8693, and 13.8387 mg/kg BW/day. Five scenarios of formaldehyde's dietary exposure of Taiwanese consumers were 0.0090, 0.0544, 0.1089, 0.1633, 0.2450 and 0.3435 mg/kg BW/day. Eventually, the results could answer the potential health risk of consuming opah fish with the formaldehyde contamination of 166.92 to 3594.24 mg/kg. Data and simulations show that the increase in Indonesian opah fish consumption by Malaysian society up to 36 times did not cause health problems from its formaldehyde. The consumption of Indonesian opah fish in Taiwan with a scenario of 27 times real consumption caused health problems because they exceed the acceptable daily intake (ADI) value (0.2 mg/kg BW/day). Whereas

Table 2. Best fit distribution simulation of formaldehyde concentration (mg/kg) in opah fish (*Lampris guttatus*) along with the variation and body weight of three different populations using @Risk®7.0 for Microsoft Excel 2010 program

Parameter	The best fit distribution function	Min	Max	Mean	SD
Concentration of FA (mg/kg)					
FA	RiskLaplace(67.47,33.0716,RiskName("FA (mg/kg)"))	27,82	133,12	75,54	29,97
FA 6 times	RiskTriang(166,3;166,3;944,64;RiskName("6x FA (mg/kg)"))	166,92	798,72	453,26	179,81
FA 12 times	RiskTriang(332,6;332,6;1889,3;RiskName("12x FA (mg/kg)"))	333,84	1597,44	906,52	359,62
FA 18 times	RiskTriang(498,9;498,9;2833,9;RiskName("18x FA (mg/kg)"))	500,76	2396,16	1359,77	539,43
FA 27 times	RiskTriang(748,35;748,35;4250,9;RiskName("27x FA (mg/kg)"))	751,14	3594,24	2039,66	809,15
FA 36 times	RiskTriang(997,8;997,8;5667,8;RiskName("36x FA (mg/kg)"))	997,8	5094,97	2719,54	1067,01
Body Weight (kg)					
Malaysian consumers	RiskPert(50;62,65;69,8)	50,3	69,72	61,73	3.68
Mauritian consumers	RiskPert(64,77;69,45;71,9)	64,77	71,9	69,08	1,32
Taiwanese consumers	RiskPert(60,7;67,85;74,8)	60,7	74,8	67,85	2,67

the export of Indonesian opah fish to Mauritius based on 2015-2017 data has caused health problems as seen from the value of dietary exposure to endogenous formaldehyde of 2.1982 mg/kgBW/day.

The analysis results may become a consideration to increase the export volume of opah fish to Malaysia. It is shown that the increase of the opah fish export volume to Malaysia up to 27 times from the current amount did not potential to affect the Malaysian consumers health, but it must be wary if the export increase into 36 times. Opportunities to increase the volume of export of Indonesian opah fish are also open for Taiwan. Multiplying export volume up to 18 times would not cause health problems, but if the export reaches up to 27 times, the dietary exposure of formaldehyde has exceeded the acceptable daily intake (ADI). Based on the calculations, the volume of exported Indonesian opah fish to Mauritius has the potential to cause health problems. However the Probabilistic Exposure Risk Assessment of Formaldehyde results cannot be interpreted absolutely. Various factors need to be considered, so therefore probabilistic value is only an illustration. Errors in reporting fish consumption data, misreporting the fish consumption and estimating the fish consumption quantity (based on perception of respondents) can contribute to errors in estimating the fish consumption. The determining concentration of formaldehyde contained in opah fish also affects the assessment of exposure. The handling of opah fish before consumption such as freezing, washing, cooking, and serving may result in changes in the concentration of formaldehyde, so that the Probabilistic Exposure value will changes. For example, some cooking methods are reported to reduce formaldehyde content in average 72% (Hoque et al., 2016; Ariyani, Setyawan, & Ibrahim, 2016).

3.3. The Health Problem Implication from Increasing the Export Volume of Opah Fish to the Three Major Destination Country

The processing of dietary exposure data showed that the country that had a chance to increase the export volume of opah fish without the potential to cause health problems due to the content of endogenous formaldehyde was Malaysia, and then

Table 3. Probabilistic dietary exposure of endogenous formaldehyde from opah fish (*Lampris guttatus*) consumption (mg/kg BW/ day) with six variations of formaldehyde concentration in the three major export destination countries

Scenario	Dietary Exposure of Formaldehyde (mg/kg BW/day)							
	Min	**Max**	**Mean**	**SD**	**P50**	**P75**	**P90**	**P95**
Malaysia								
FA	-0.0097	0.0187	0.0038	0.0019	0.0038	0.0048	0.0060	0.0069
FA 6 times	-0.0671	0.1150	0.0230	0.0113	0.0231	0.0286	0.0359	0.0415
FA 12 times	-0.1309	0.2256	0.0461	0.0226	0.0461	0.0572	0.0718	0.0829
FA 18 times	-0.2152	0.3390	0.0691	0.0339	0.0692	0.0858	0.1078	0.1244
FA 27 times	-0.3657	0.5126	0.1038	0.0509	0.1038	0.1287	0.1616	0.1866
FA 36 times	0.0568	0.3222	0.1455	0.0627	0.1348	0.1899	0.2387	0.2634
Mauritius								
FA	-13.657	19.462	0.3655	0.1793	0.3655	0.4533	0.5693	0.6572
FA 6 times	-56.724	119.682	21.932	10.752	21.931	27.201	34.165	39.433
FA 12 times	-117.870	198.900	43.862	21.496	43.862	54.400	68.329	78.865
FA 18 times	16.993	339.369	76.201	34.639	69.682	94.609	122.645	142.112
FA 27 times	-256.544	503.424	98.693	48.376	98.691	122.401	153.745	177.451
FA 36 times	54.057	306.500	138.387	59.631	128.153	180.549	227.042	250.471
Taiwan								
FA	-0,0238	0.0440	0.0090	0.0044	0.0091	0.0113	0.0141	0.0163
FA 6 times	-0.1434	0.2563	0.0544	0.0267	0.0544	0.0675	0.0848	0.0979
FA 12 times	-0.3258	0.5109	0.1089	0.0533	0.1088	0.1350	0.1696	0.1958
FA 18 times	-0.4506	0.8737	0.1633	0.0801	0.1633	0.2026	0.2544	**0.2937 ***
FA 27 times	-0.7513	12.182	0.2450	0.1201	0.2450	0.3038	0.3816	0.4405
FA 36 times	0.1342	0.7596	0.3435	0.1480	0.3181	0.4482	0.5636	0.6218

Note: FA stands for Formaldehyde, P stands for Probability, *)The value has exceeded the ADI of 0,2 mg/kgBW/day.

followed by Taiwan. Opah fish export opportunities to Malaysia can be increased up to 36 times of the exports volume (approximately 1.284 tons/year), while the export of opah fish to Taiwan has an opportunity to be increased up to 27 times (approximately 99 tons/ year). Meanwhile, Mauritian people tend to consume any kind of fresh fish rather than frozen or processed fish. They consume more local fish than imported products (FAO, 2013b). Based on this habitual tendency, exceedingly fish exports to Mauritius cannot be increased. Based on the calculation of formaldehyde dietary exposure, it is known that the volume of opah fish exports to Mauritius recorded in BKIPM has the potential to cause health problems. Therefore, opah fish exports to Mauritius must be below 32.2 tons in total for 3 years, as recorded by BKIPM in 2015-2017, or in average of 10.73 tons/year. The risk assessment of Indonesian opah fish exported to Mauritius showed the average consumption of opah fish as much as 0.3742 g/day where the formaldehyde exposure value reaches 0.366 mg/kg BW/day. This value has exceeded the average threshold of daily formaldehyde input of 0.20 mg/kgBW/day. The government of Mauritius has set a regulation regarding the maximum amount of formaldehyde content in fish and fishery products by 5 mg/ kg (Subsidiary Legislation of Mauritius, 1999). Based on this regulation and compared it with the lowest formaldehyde content measured in opah fish originating from Indonesia (27.82 mg/kg), the export of opah fish should have been refused to enter Mauritius. But in fact, in the period of 2015-2017, Indonesia was recorded for exporting opah fish to Mauritius (BKIPM, 2018). The average value of formaldehyde intake according to the calculation provides an average description of formaldehyde that enters the consumer's body. In practice, the value of formaldehyde that enters the consumer's body also depends on how to cook the fish until it is ready for consumption. The improvement on fish handling and processing would decrease the potency of formaldehyde contaminations (Hoque et al., 2016).

Conclusions

Opah fish consumed by Malaysian consumers was categorized as safe or not at risk for health. Increasing the number of opah fish imports by Malaysian as much as six times, 12 times, 18 times, 27 and 36 times did not cause health risks related to the presence of endogenous formaldehyde in opah fish. Total amount of 9.1 mg/day opah fish consumed by Taiwanese consumers categorized as safe or not at risk for health, but increasing the number of consumption exceeding 27 times or 246.25 mg/day will potentially cause health problems because of its formaldehyde content.

Opah fish consumed by Mauritian consumers categorized as not safe or at risk for health 1.5 times higher from tolerable daily intake (ADI) for formaldehyde (0.2 mg/kgBW/day). Based on the results of several simulations in this study, Indonesia may consider to increase the quantity of opah fish exports to several major destination countries without worrying about causing health problems, especially Malaysia and Taiwan. Therefore, the state revenues from the foreign fish trade sector is expected to increase.

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