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ANALYSIS OF HEAVY METAL CONTAMINATION OF Pb, Cr, Cd AND FOOD SAFETY LEVEL OF CONSUME TAWAR WATER FISH IN THE TRADITIONAL MARKETS OF PURWOKERTO CITY, BANYUMAS, CENTRAL JAVA

Analisis Kontaminasi Logam Berat Pb, Cr, Cd dan Tingkat Keamanan Pangan Ikan Air Tawar Konsumsi di Pasar Tradisional Kota Purwokerto, Banyumas, Jawa Tengah

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ABSTRACT

Fish is a favorite food source that contains amino acids, omega-3 fatty acids, vitamins, selenium and calcium that can maintain the immune system. On the other hand, fish can also absorb and accumulate heavy metals such as Pb, Cr and Cd which can cause toxic effects. Heavy metal contamination in consumed fish has become a global issue especially in developing countries including Indonesia. In 2020, Banyumas Regency (Purwokerto) was the center and largest contributor to freshwater fish production in Central Java Province, whose production reached 3.6 tons or 31% of the total production with a total value of 181.9 billion. For this reason, it is necessary to conduct research related to Pb, Cr, Cd contamination and the level of food safety of consumed freshwater fish sold in the traditional market of Purwokerto city. This study aims to determine the food safety level of freshwater fish consumed in traditional markets in Purwokerto city from contamination by heavy metals Pb, Cd, and Cr. The methods used were a survey method, heavy metal content analysis using AAS, and safety level analysis using EDI, THQ, HI, and TR. The results showed that the concentration of Pb Cd, Cr in pomfret, tilapia and catfish in the Wage, Manis and Pon markets compared to the quality standard is still below so that these concentrations are still in the safe category for consumption. The results of the risk analysis show that the values of EDI, THQ, HI and TR in pomfret, tilapia and catfish in the Wage (PW), Manis (PM) and Pon (PP) markets are still below the threshold or standard both nationally and internationally so that it can be categorized as safe or does not pose a risk to human health.

Keywords: Contamination, Food Safety, Freshwater Fish, Heavy Metals, Traditional Market

ABSTRAK

Ikan merupakan sumber pangan favorit yang mengandung asam amino, asam lemak omega-3, vitamin, selenium dan kalsium yang dapat menjaga sistem kekebalan tubuh. Di sisi lain ikan juga dapat menyerap dan mengakumulasi logam berat seperti Pb, Cr dan Cd yang dapat menyebabkan efek toksik. Kontaminasi logam berat pada ikan konsumsi telah menjadi isu global terutama di negara berkembang termasuk di Indonesia. Pada tahun 2020 Kabupaten Banyumas (Purwokerto) merupakan sentra dan penyumbang terbesar produksi ikan air tawar di Provinsi Jawa Tengah yang produksinya mencapai 3,6 ton atau 31% dari total produksi dengan total nilai sebesar 181, 9 miliar. Dengan demikian perlu dilakukan penelitian terkait kontaminasi Pb, Cr, Cd dan tingkat keamanan pangan ikan air tawar konsumsi yang dijual dipasar tradisional kota Purwokerto. Penelitian ini bertujuan untuk mengetahui tingkat keamanan pangan ikan air tawar konsumsi di pasar tradisional kota Purwokerto dari kontaminasi logam berat Pb, Cd dan Cr. Metode yang digunakan adalah metode survey, analisis kandungan logam berat menggunakan AAS dan analisis tingkat keamanan menggunakan EDI, THQ, HI dan TR. Hasil penelitian menunjukkan bahwa konsentrasi Pb Cd, Cr pada ikan bawal, nila dan lele di pasar Wage, Manis dan Pon dibandingkan standar baku mutu masih berada dibawahnya sehingga dengan demikian konsentrasi ini masih dalam katergori aman untuk dikonsumsi. Hasil analisis resiko menunjukkan bahwa nilai EDI, THQ, HI dan TR pada ikan bawal, nila dan lele di pasar wage (PW), pasar manis (PM) dan pasar pon (PP) masih berada dibawah ambang batas atau strandar baik nasional maupun internasional sehingga dapat dikategorikan aman atau tidak menimbulkan resiko terhadap kesehatan manusia.

Kata Kunci: Ikan Air Tawar; Keamanan Pangan, Kontaminasi, Logam Berat, Pasar Tradisional

INTRODUCTION

Indonesia is a maritime nation with vast fishery resources. According to a report by the Food and Agriculture Organization (FAO), Indonesia's per capita fish consumption is 36.3 kg. This figure is still low compared to Malaysia's 55.4 kg and Singapore's 37.9 kg. According to WPI KKP data, Indonesian fish consumption over the past five years, from 2013 to 2017, was 35.2 kg/cap/year in 2013, 38.1 kg/cap/year in 2014, 41.1 kg/cap/year in 2015, 43.9 kg/cap/year in 2016, and 47.3 kg/cap/year in 2017, with an average growth rate of 6.93% (Nainggolan et al., 2018).

Fish is a popular food source containing high-value amino acids and omega-3 essential fatty acids, vitamins, selenium, and calcium, which can lower cholesterol levels and maintain a healthy heart, brain, joints, and immune system (Kalantzi et al., 2016). Despite their positive health impacts, fish can also absorb and accumulate chemical contaminants, making them good indicators of water pollution. Fish can absorb heavy metals either directly from water and sediments or indirectly (Xu et al., 2021), which then accumulate in the liver, gills, kidneys, muscles, testes, and ovaries, causing changes in reproductive rates, endocrine distribution, and reproductive function (Akila et al., 2022), toxic effects, and threats to the food chain (Akila et al., 2022).

Heavy metal contamination in consumed fish has become a global issue, particularly in developing countries (Shafi et al., 2015), including Indonesia. Heavy metals are readily found in water and are persistent, toxic, bioaccumulative, biomagnificent, and stable, and they do not degrade naturally (Xu et al., 2021). Heavy metals readily dissolve in water and are absorbed by organisms, and their distribution in aquatic food webs has clear implications for biological amplification (Xu et al., 2021). Heavy metals can be divided into two categories based on their biological actions: essential and non-essential elements. Essential elements such as Cu, Zn, Cr, and Co are functionally required by organisms at low concentrations. However, at higher concentrations, these essential elements become toxic and disrupt biochemical functions. Non-essential elements, including Pb, Cd, Hg, and As, are highly toxic and can cause severe damage to aquatic organisms (Xu et al., 2021).

Heavy metals accumulated in fish can negatively impact human health if consumed continuously, such as damaging the liver, kidneys, nervous system, and blood vessels, and increasing the risk of cancer (Miri et al., 2017). For example, previous research has shown that arsenic (As), cadmium (Cd), lead (Pb), and chromium (VI) (Cr6+) have harmful effects on human health even at low concentrations (Makedonski et al., 2017). They cause damage to the central and peripheral nervous systems, cardiovascular disease, birth defects, impaired placental development, and other reproductive problems (Jomova et al., 2011). Cadmium is associated with disorders of the liver, bones, kidneys, and reproduction (Bosch et al., 2016). Lead can affect the nervous system, disrupt bone hematopoietic function, digestion, and the male reproductive system (Levin & Goldberg, 2000). Cr6+ is carcinogenic in humans (Varol & Sünbül, 2018).

Therefore, research is needed to determine the content and food safety levels of heavy metals Pb, Cr, and Cd in freshwater fish consumed, especially in Purwokerto City. Purwokerto (Banyumas) is one of the centers of freshwater fish production in Central Java Province and is the largest contributor to national gourami production. In 2020, gourami production reached 3.6 tons, or 31% of Central Java Province's total production, with a value of 181.9 billion rupiah (BPS Indonesia, 2021).

METHODS

Tools and Materials

The tools used in this study included: a 250 ml Winkler bottle, a 250 ml Erlenmeyer flask, a syringe, a dropper, a plastic bag, a camera, label paper, duct tape, stationery, a thermometer, a beaker glass, a cool box, aluminum foil, a hand refractometer, a pH meter, a stove, a stand, a Secchi disk, Whattman No. 41 and 42 paper, a water bath, a digital scale, and an Atomic Absorption Spectrophotometer (AAS) set. The materials used in this study were pomfret (Bawal), tilapia (*Oreochromis niloticus*), and catfish (Clarias) of consumption size, one each, concentrated HNO_3, $HClO_4$, distilled water, and standard solutions of the heavy metals Pb, Cr, and Cd.

Research Time and Location

This research was conducted over an eight-month period, from March to October 2023. The research locations were three traditional markets in Purwokerto City: Wage Market, Manis Market, and Pon Market.

Sampling Method

This research employed a survey method, determining the research locations and using purposive sampling as the sampling technique. This means that the location and sampling were determined by the researcher, taking into account several considerations, including the availability of consumption-sized fish, affordability, and representativeness of the Purwokerto region.

Sample Analysis Method

The heavy metal content of Pb, Cr, and Cd in fish was measured using Flame Atomic Absorption Spectrometry using an AAS (Atomic Absorption Spectrometry) device with an accuracy of 10^{-4} ppm. Fish muscle samples were washed, dried for approximately 5 days until the moisture content was less than 2%. They were then oven-dried, ground using a mortar, and sieved to pass a 60-mesh sieve. A total of 5 grams of sample was weighed, then put into an Erlenmeyer flask and moistened with distilled water. Next, 5 ml of HNO3 and 3 ml of HClO4 were added, then heated on a hot plate until almost dry and then cooled. The solution was diluted to a volume of 50 ml, then filtered using Whatman paper No. 42 and the volume was measured. The prepared samples were measured for Pb, Cr, and Cd content with AAS at a wavelength of 357.54 nm (BSN Indonesia, 2009).

Risk Data Analysis Method

Data on the heavy metal content of Pb, Cr, and Cd in fish muscle from laboratory tests will then be analyzed using:

1. Estimated Daily Intakes

Estimated Daily Intakes (EDI) or the estimated daily intake of different metals is evaluated based on the tissue concentration of each metal in the fish and the average daily fish consumption rate (in mg/kg/day) (Hidayati et al., 2020). The following relationship was used to calculate the EDI (Jiang et al., 2018):

$$\text{EDI} = \frac{\text{EF x ED x IR x Cm}}{\text{WAB x TA}}$$

Where EF is the exposure frequency (365 days/year), ED is the exposure duration (70 years, equivalent to the average lifespan as used by (Keshavarzi et al., 2018), IR is the consumption rate (g/day), Cm is the metal concentration in fish (mg/kg dw), WAB is the average adult body weight (kg), and TA is the average lifespan (70 years × 365 days/year, i.e., 25,550). The daily consumption rate was set at 20.67 g/person/day according to reports from the BPS database for fish and shrimp consumption levels (BPS Indonesia, 2016), while the average adult body weight in Asia (including Indonesia) was assumed to be 57.7 kg (Hidayati et al., 2020). 4.54 was used as a conversion factor to convert dry weight to wet weight based on a fish moisture content of 78% (Qiu et al., 2017).

2. Target Hazard Quotients

The target hazard quotient (THQ) is defined as the maximum tolerable daily intake of a specific metal that does not result in deleterious health effects. THQ is calculated as the ratio of the average daily intake of a specific chemical over a lifetime to the oral reference dose (RfD) of the trace metal. This metric is an estimate of the daily oral exposure by humans that does not pose an appreciable risk of deleterious effects over a lifetime (EPA U.S., 2002). The following equation was used to determine the THQ (Jiang et al., 2018):

$$\text{THQ} = \frac{\text{EDI}}{\text{RfD}}$$

An oral RfD (mg/kg/day) of 0.001 was used for Cd (this value is based on U.S. EPA guidelines) and 0.004 was used for Pb (Pb). A THQ of 0.0003 is used for Hg (Yabanli & Alparslan, 2015); these values are used to assess the hazard of exposure from fish consumption. A THQ value <1 indicates that adverse health effects are unlikely, and a THQ value >1 indicates that the consumer population is at potential health risk.

3. Hazard Index

The hazard index (HI) is developed from THQs and expressed as the sum of the hazard quotients (EPA U.S., 2018). The derived hazard index for shrimp is determined using the following equation:

$$HI = \sum_{i=1}^{n} THQi$$

Where THQi is the target hazard quotient for an individual metal and HI is the total hazard index for all metals. In this study, HI is the total hazard index for three metals (Pb, Cd, and Cr). HI >1 indicates potential adverse effects on human health.

4. Carcinogenic Risk

Carcinogenic risk is estimated as the incremental probability of an individual developing cancer during a lifetime of exposure to a potential carcinogen using the target cancer risk value (EPA U.S., 2018). The carcinogenic health risk associated with seafood consumption is measured based on the target cancer risk (TR), which is calculated as follows:

$$TR = EDI \times CSFo \times 10^{-3}$$

Where CSFo is the oral carcinogenicity slope factor from the Integrated Risk Information System database. For Pb, the slope values are 0.5 mg/kg/day and 0.0085 mg/kg/day, respectively. According to the New York State Department of Health (NYSDOH, 2007), the TR threshold values for categorizing risk are as follows: TR 10^{-6}, low risk; 10^{-4} to 10^{-3}, moderate risk; 10^{-3} to 10^{-1}, high risk; and 10^{-1}, very high risk.

RESULTS

The content values of heavy metals Pb, Cd, and Cr in three types of freshwater fish for consumption (Pomfret, Tilapia and Catfish) at three research stations (Wage Market, Manis Market and Pon Market) in Purwokerto City, Banyumas, Central Java.

Table 1. Pb, Cd and Cr Content in Pomfret, Tilapia and Catfish

Fish/Heavy Metals	Station			Quality Standards
	Wage Market (PW)	Manis Market (PM)	Pon Market (PP)	
Pomfret				
Pb	0.2165	0.2042	0.2194	0.3* 0.2***
Cr	<0.019	<0.019	<0.019	2.5**
Cd	<0.008	<0.008	<0.008	0.3* 0.1***
Tilapia				
Pb	0.2045	0.2015	0.1921	
Cr	<0.019	<0.019	<0.019	
Cd	<0.008	<0.008	<0.008	
Catfish				
Pb	0.2045	0.2015	0.1921	
Cr	<0.019	<0.019	<0.019	
Cd	<0.008	<0.008	<0.008	

*Minister of Maritime Affairs and Fisheries Decree No. 37 of 2019 and BPOM Regulation No. 9 of 2022
**SNI 7387: 2009
***BPOM Regulation No. 23 of 2017.

DISCUSSION

The concentrations of Cd and Cr at each station were <0.008 mg/kg and <0.005 mg/kg, respectively. The concentrations for Cd and Cr at each station were similar. This is because the concentrations of each metal in the gourami samples were low, making them undetectable by the measuring instrument or beyond the detection limit. The average Pb concentration was 0.1399 mg/kg, with the lowest value at station 4 in Tamansari II Village, Karanglewas, at 0.115 mg/kg, and the highest at station 6 in Kalikidang I Village, Sokaraja, at 0.1641 mg/kg.

The concentrations of heavy metals Cd and Cr in the pomfret and catfish samples were below the quality standard and even below the detection limit. This could be due to various possibilities, including: 1) low concentrations of Cd and Cr in pond water; 2) heavy metals accumulated in the gills, liver, and kidneys; and 3) Many factors influence the absorption of heavy metals by fish, including sex, age, size, reproductive cycle, swimming patterns, feeding behavior, and the living environment (e.g., geographic location). Furthermore, bioaccumulation is influenced by the uptake and elimination kinetics of metals entering the body (Sriyono, 2019). Variations in the rate of heavy metal bioaccumulation in fish depend on organ function, physiological status, feeding behavior, age, size, habitat, and the nature of the metal (Linnik & Zubenko, 2000).

The concentrations of Pb, Cd, Cr, and Pb in all gourami samples were below the maximum threshold for heavy metal contamination according to Ministerial Decree No. 37 of 2019, BPOM Regulation No. 9 of 2022, and SNI No. 7387 of 2009 and BPOM Regulation No. 23 of 2017. Therefore, fish products are still safe for consumption, but the quantity consumed must be properly controlled. These results are in accordance with Chi et al. (2007) who reported that the bioaccumulation of heavy metals Cr, Cu, Pb and Cd in four fish species (*Cyprinus carpio* Linnaeus, *Carassius auratus* Linnaeus, *Hypophthalmichthys molitrix* and *Aristichthys nobilisdari*) from Lake Taihu, China was lower than the Chinese Healthy Food Criteria. Wang et al. (2020) who reported that Pb, Cd, Hg, As, and Cr were found in six fish species studied in rice-fish systems in 7 provinces of southern China but the concentrations were still lower when compared to the concentrations in fish from traditional farming. Rajeshkumar & Li (2018) reported that the bioaccumulation of heavy metals Cr, Cu, Cd, and Pb in freshwater fish species (*Cyprinus carpio* Linnaeus and *Pelteobagrus fluvidraco*) from Meiliang Bay, Taihu Lake, China, was much lower than the Chinese Food Health Criteria (1994). Therefore, fish products are still safe for consumption, but the levels must be properly controlled. Batvari & Sarvanan (2020) reported that the concentrations of heavy metals Pb, Zn, Fe, Cu, Cd, and Cr in Pristipoma furcatus and Acanthurus strigosus from Pulicat Lake, Chennai, were below the maximum limits.

Different results were reported by Cahnpiwat et al. (2016) that significant heavy metal accumulation in several farmed fish species was caused by the use of chemical allometric growth promoters. Dutta et al. (2022) reported that the bioaccumulation pattern of toxic heavy metals in fish showed a trend of Pb > Cd > Cr > Hg across seasons and years. This is consistent with this study, which found that Pb levels in gourami were above the detection limit, compared to Cd and Cr, which were below the detection limit.

CONCLUSION

The results of the study showed that the concentration of Pb, Cd, and Cr in pomfret, tilapia, and catfish in the Wage, Manis, and Pon markets was still below the threshold of the quality standard so that it could be categorized as safe for consumption. The results of the risk analysis showed that the EDI, THQ, HI, and TR values in pomfret, tilapia, and catfish in the Wage, Manis, and Pon markets were still below the threshold or standards both nationally and internationally so that it could be categorized as safe or did not pose a risk to human health.

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