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Heavy metal content in duck eggs and meat that consumes feed containing *Sapu-sapu* fish (*Hypostomus plecostomus*)

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Abstract. *Asnawi. 2023. Heavy metal content in duck eggs and meat that consumes feed containing* Sapu-sapu *fish (*Hypostomus plecostomus*). Biodiversitas 24: 3201-3206.* This study aimed to evaluate heavy metals in the eggs and meat of ducks feeding on the *Sapu-sapu* fish (*Hypostomus plecostomus* Linnaeus, 1758) on Lombok Island, West Nusa Tenggara, Indonesia. The observation of collected *Sapu-sapu* fish samples from three major Mataram rivers. Duck eggs and meat were collected from a livestock group that fed *Sapu-sapu* fish. The observed variables include; macronutrients (moisture content, crude protein, crude fat, crude fiber, and ash) and heavy metal content (Cu and Pb) in the *Sapu-sapu* fish, duck meat and eggs fed by *Sapu-sapu* fish. The study found that the *Sapu-sapu* fish possesses complete macronutrients, making it a possible duck feed. The heavy metal content of copper (Cu) in the *Sapu-sapu* fish ranges from 189.314±0.0238 ppm, while the lead (Pb) content ranges from 4.25±0.18 ppm. The average heavy metal content of Cu in the eggs and meat of ducks consuming *Sapu-sapu* fish was 7.692±2.158 ppm and 14.523±6.481 ppm, while the levels of lead in eggs and meat of cesarean fish were 0.936±1.557 ppm 0.373±0.211 ppm. The study concluded that the *Sapu-sapu* fish in the Mataram city stream has a complete nutritional content (protein, fat, amino acids, minerals) but contains high heavy metals. Therefore, if consumed, ducks dispose of it into the eggs and duck meat. As a result, the eggs and meat of ducks that consume *sapu-sapu* fish contain heavy metals Cu and Pb that exceed the threshold, so they are unsafe for human consumption.

Keywords: Ducks, heavy metals, human consumption, macronutrients, *Sapu-sapu* fish

INTRODUCTION

Salted egg, a processed product from duck eggs, is one of the superior products of West Nusa Tenggara Province, which is widely known throughout Indonesia (Sativa 2022). Therefore, the demand for salted eggs from NTB is considerably high. However, the supply of raw materials in the form of eggs is short since traditional duck breeders have a restricted number of duck breeders (25-50 heads/person), and the product is low at 50-60% (Asnawi et al. 2011).

The duck management system on the island of Lombok is generally an intensive and semi-intensive system. Each of these maintenance systems has advantages and disadvantages. Maintenance with a semi-intensive system can save feed costs. The quality of egg yolk is quite good because livestock can choose forage as a source of β-carotene during grazing. However, this system cannot be developed on a larger scale due to limited grazing capacity and land. Maintenance with a caged system can be produced on a large scale, but this system is less profitable because egg production cannot offset production costs, mainly feed costs. To maintain the continuity of the farmer's business, they try to modify the feed formula according to the potential of local feed ingredients around the breeder's location so that the feed formulation for each group of ducks appears different from one another (Asnawi et al. 2011). One of the livestock groups in Mataram that use *Sapu-sapu* fish as the main feed ingredient besides bran and corn is the Mong Glemong livestock group in the Dasan Cermen village, Cakranegara.

Breeders have traditionally fed ducks containing *Sapu-sapu* fish (*Hypostomus plecostomus* Linnaeus, 1758). For example, feeding *Sapu-sapu* fish to Mojosari ducks by 20% and 30% resulted in an average body weight gain for three months of 136.6±41.78 g/duck/day and 101.7±92.78 g/duck/day with egg production of 47.2±7.33%, 45±9.0%, respectively (Asnawi et al. 2020). Asnawi et al. (2011) also found that ducks fed *Sapu-sapu* fish in the "Mong Glemong" livestock group in Dasan Cermen Mataram city and produced 60-70% eggs. This egg production is relatively high, so until now, farmers still maintain the use of *Sapu-sapu* fish as the main feed ingredient for ducks.

Freshwater *Sapu-sapu* fish adapt well to contaminated waterways (Elfidasari et al. 2020; Medellin-Castillo et al. 2022). According to Jumawan et al. (2016), *Sapu-sapu* fish can live in polluted waters, and these fish can even become the dominant fish in these waters. That is because this fish possesses not one but two respiratory organs. The gills and the labyrinth lends credence to this assertion (Soliman et al. 2020). The main organs of the gills are used when breathing in clear water, and the labyrinth is used by biota that lives in muddy or murky water.

The *Sapu-sapu* fish is a freshwater biota that generally consumes polluted river sediments, especially heavy metals such as copper (Cu), cadmium (Cd), and lead (Pb), which are very dangerous for the creatures that consume them. The heavy metal-contaminated precipitate will enter the fish's body and be collected in large concentrations within the fish's body (Hasnidar et al. 2021). Furthermore, it was

stated that if the body of a living thing has been contaminated with large amounts of heavy metals, it will have a detrimental impact on health. For example, the effect caused by copper (Cu) is liver damage, while cadmium (Cd) causes kidney disease, stomach disorders, and bone fragility.

This study evaluated the nutritional value of the *Sapu-sapu* fish, the heavy metal content of the *Sapu-sapu* fish, and the likelihood that the heavy metals in the *Sapu-sapu* fish will be deposited in the meat and eggs of the ducks produced.

MATERIALS AND METHODS

Experimental site

The research was conducted using the observation method at two locations, the first in three rivers crossing Mataram and the second in the livestock group "Mong Glemong" Dasan Cermen, Mataram city, Indonesia. The location selected was based on the results of a previous survey that the three streams were the habitat of the *Sapu-sapu* fish alive. At the same time, the "Mong Glemong" is a duck livestock group whose members use the *Sapu-sapu* fish as duck feed.

Research procedure

This research was conducted in two steps. Step 1: Assessing the nutritional value of the *Sapu-sapu* fish, including the presence of amino acids, macro and micro minerals, and heavy metals (Hwang et al. 2013). *Sapu-sapu* fish samples were taken from three rivers crossing Mataram: the Jangkok, Ancar, and Songoran Rivers. Three sampling points were taken for each river flow: the upstream, middle, and downstream areas. Each sample point contains five *Sapu-sapu* fish. The collected samples were analyzed at the Animal Feed and Nutrition Laboratory, Faculty of Animal Science, Mataram University.

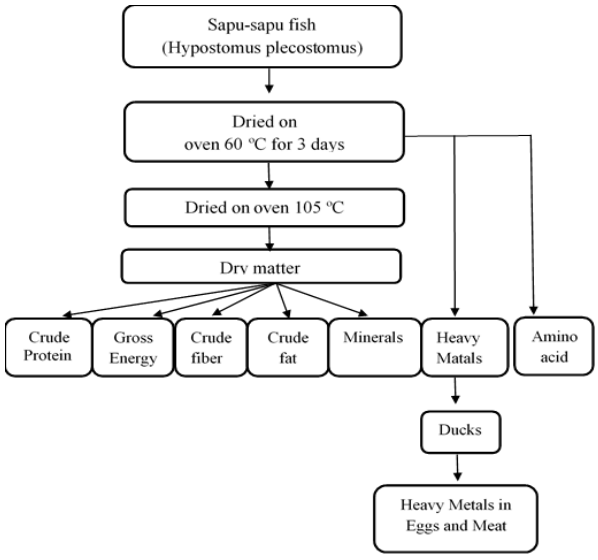

Figure 1. Sample preparation process

Step 2: Tracing the content of heavy metals (Cu and Pb) in the meat and eggs of ducks fed *Sapu-sapu* fish. The research at this stage used a sample of ten Mojosari ducks and ten eggs. Each sample was weighed, dried in an oven at 60°C, and then mashed into powder. The samples were analyzed for heavy metal content (Cu and Pb) using the AAS (Atomic Absorption Spectrophotometer) method (Butcher 2005) at the Analytical Chemistry Laboratory, FMIPA, University of Brawijaya, Malang, Indonesia. Fish meat tested chemically included protein Kjeldahl method, fat Soxhlet method, ash, dry ash method, and dry matter method; each according to SNI 01-2891-1992 standards. In addition, the essential amino acids analysis is based on the instructions of Abdullah et al. (2013). The preparation process can be seen in Figure 1.

Data collection

Gross energy was analyzed with an adiabatic Bomb Calorimeter (Basu 2018). The crude protein, fat, fiber, and ash content were examined using the Kjeldahl method for approximate analysis (Sáez-Plaza et al. 2013). Amino acids in *Sapu-sapu* fish were analyzed by High-Performance Liquid Chromatography (HPLC) (Malviya et al. 2010) conducted at the Central Laboratory of Life Sciences, University of Brawijaya (LSIH-UB) Indonesia. Minerals and heavy metals (Cu and Pb) in *Sapu-sapu* fish as determined by AAS (Atomic Absorption Spectrophotometer) at the Laboratory of Analytical Chemistry, FMIPA, University of Brawijaya in Malang, Indonesia. The heavy metal content of duck eggs and meat using the AAS (Atomic Absorption Spectrophotometer) method at the Laboratory of Analytical Chemistry, FMIPA, University of Brawijaya, Malang, Indonesia.

Data analysis

The data obtained from the study's results were tabulated with MS Excel 2019 and presented descriptively.

RESULTS AND DISCUSSION

Evaluation of nutrient content of *Sapu-sapu* fish

The proximate analysis results for the *Sapu-sapu* fish are provided in Table 1, comprising the *Sapu-sapu* fish consisting of dry matter, crude protein content, crude fat, crude fiber, ash, and gross energy. The results showed that the crude protein content of *Sapu-sapu* fish was 37.07%. The crude protein of *Sapu-sapu* fish is higher than the crude protein content of snakehead fish (*Channidae*) extract: 16.2%, catfish (*Siluriformes*): 17%, carp (*Cyprinus carpio* Linnaeus, 1758): 16%, anchovies (*Engraulidae*): 10%, and tuna (*Thunnini*): 13.07% (Khasani and Astuti 2019; Mustafa et al. 2022), shrimp waste: 35.5% (Abu-Alya et al. 2021), but less than fish meal at 48.5% (Abu-Alya et al. 2021), and 60% (Komlósi 2022), local fishmeal 40-45% (Fouad et al. 2018; Biesek et al. 2022). Furthermore, the low protein content of *Sapu-sapu* fish compared with other fish varieties is because its body is covered in mineral-rich, mineral-hard scales. Therefore, the high protein content in this fish can be used as a protein source for duck feed formulations.

Sapu-sapu fish contains 16.85±4.35% crude fat, higher than the fish meal of 10% (Applegate and Angel 2014), catfish 2.1-3.8% (Gökoğlu and Yerlikaya 2015), catfish Africa (*Clarias gariepinus* Burchell, 1822) of 9.3±0.3% (Effiong and Yaro 2019). The amount of variation in the nutritional content of these fish is influenced by species, individual, age, sex, environment, and season (Gökoğlu and Yerlikaya 2015; Merdzhanova et al. 2021; Koca et al. 2023). Koca et al. (2023) added that the fishing season affects fish species composition, which is related to environmental conditions such as the breeding season and the availability of abundant feed. Maybe that's the reason why fish contains high protein and fat.

The crude fiber content of *Sapu-sapu* fish was obtained at 1.92±1.09%. This value is similar to the crude fiber of fish meal of 1.00% (Applegate and Angel 2014), also the head and entrails of skipjack tuna, bones (fillets), and sorted skipjack tuna (Arachon), respectively of 1.02%, 1.02%, and 0.67 % (Doe et al. 2020).

The ash content of *Sapu-sapu* fish reached 33.25±3.99%. This value is higher than the ash content of the heads and entrails of skipjack tuna (*Katsuwonus pelamis* Linnaeus, 1758), bones (fillets) (*Thunnus obesus* Lowe, 1839), and sorted skipjack (Arachon), as reported by Doe et al. (2020) that the ash content of the heads and entrails of skipjack tuna was 26.06%, the bones (fillet) of 29.77%, and skipjack tuna sort of 17.27%. The high ash content in the *Sapu-sapu* fish is because the whole body is covered with hard skin and contains lots of minerals.

The *Sapu-sapu* fish's gross energy analysis is shown in Table 1. The gross energy of the *Sapu-sapu* fish is relatively high at 4,559.10 kcal/Kg. This value is within the gross energy range of meat meals, around 3,493 kcal/kg to 4,732 kcal/kg (Adedokun and Adeola 2005). This value is almost similar to the gross energy of fish meals of 4,500 kcal/kg (Applegate and Angel 2014). In addition, fish with more fat have more energy (Merdzhanova et al. 2021; Koca et al. 2023).

The Apparent Metabolizable Energy (AME) of the *Sapu-sapu* fish was obtained at 2,890.52±34.01 kcal/kg. This value is higher than a fish meal (2,753.1 kcal/kg) which was tested on male Rhode Island Red chickens (Zarei 2013; Gunawan et al. 2018), fish meal soluble dehydrated (2,530 kcal/kg), which was tested on chickens (Applegate and Angel 2014), Fish meal meat (12.5 MJ/kg) tested on cross ducks (Abu-Alya et al. 2021), lower than the AME of fresh and dry earthworms (3,679.55 kcal/kg and 3,390.66 kcal/kg) tested on broilers (Zang et al. 2018), dry meat soluble (3,266 kcal/g) tested on white Pekin ducks (Pangeran et al. 2021; Georganas et al. 2023), meat and bone meal (3,916 kcal/kg and 1,781 kcal/kg) tested on ducks Pekin (Adedokun and Adeola 2005).

Essential and non-essential amino acid content

The results indicated that the amino acid content of *Sapu-sapu* fish was rather high, although neither histidine nor cysteine was detected in the samples studied. Table 2 displays the findings of a study analyzing the amino acids of *Sapu-sapu* fish.

Table 2 shows that the *Sapu-sapu* fish has a total amino acid content of 24.027±1.796%, higher than the amino acid catfish of 16.39% (Santoso 2009), chicken egg white of 9.89% (Pratama et al. 2020; Mustafa et al. 2022) and fish meal of 12.9% (Applegate and Angel 2014). The amino acid content of lysine was obtained at 2.496±0.157%, methionine 0.79±0.151% higher than that in catfish of 0.081 and 1.702%, respectively (Santoso 2009), in local chicken egg-whites of 0.42% and 0.65% (Pratama et al. 2020; Mustafa et al. 2022) and fish meal of 0.50% and 1.73% (Applegate and Angel 2014). These results are above the standards SNI (Indonesian National Standard) set for duck diet during the egg-laying season, namely 0.8% lysine, 0.35% methionine, and 0.6% methionine+cystine (SNI 2006). These data indicate that the *Sapu-sapu* fish has the potential as a protein source for ducks. In addition, the high content of methionine and lysine will affect egg production and the growth of ducks.

Mineral content of *Sapu-sapu* fish

The contents of various critical minerals in the body of the *Sapu-sapu* fish are evaluated and shown in Table 3.

Table 1. Results of proximate analysis of *Sapu-sapu* fish

Nutrients	Average	Standard deviation
Dry matter (%)	27.85	1.18
Ash (%)	33.25	3.99
Crude protein (%)	37.07	3.50
Crude fat (%)	16.85	4.35
Crude fibre (%)	1.92	1.09
Gross energy (kcal/kg)	4,559.10	244.37
AME (kcal/kg)*)	2,890.52	34.01

Note: *)Asnawi et al. (2014)

Table 2. Composition of amino acids in *Sapu-sapu* fish (%)

Amino acid	Fish size			Average	Sd
	≤200 g	200-300 g	≥300 g		
Essential					
Histidine		Not Found			
Arginine	2.046	1.805	2.392	2.081	0.295
Threonine	1.040	0.975	1.226	1.080	0.130
Cystine		Not Found			
Tyrocine	0.637	0.565	0.776	0.659	0.107
Valine	1.250	1.188	1.408	1.282	0.113
Methionine	0.752	0.661	0.956	0.790	0.151
Lysine	2.386	2.426	2.676	2.496	0.157
Isoleucine	0.971	0.970	1.211	1.051	0.139
Leucine	1.470	1.508	1.783	1.587	0.171
Phenilalanin	0.895	0.799	1.049	0.914	0.126
Non-essential					
Alanine	1.624	1.512	1.742	1.626	0.115
Aspartic acid	2.028	1.770	1.478	1.759	0.275
Glutamic acid	3.409	3.180	2.747	3.112	0.336
Glycine	4.101	3.570	4.672	4.114	0.551
Serine	0.833	0.766	0.995	0.865	0.118
Proline	0.599	0.529	0.705	0.611	0.089
Total	24.041	22.224	25.816	24.027	1.796

The results indicated that the *Sapu-sapu* fish is rich in minerals observed from the *Sapu-sapu* fish body, which has a hard layer of skin and a large head with hard bones. The mineral content found in this fish, especially Ca and P, is excellent to be used as a source of minerals to form egg shells and bones (Lukic et al. 2009; Eleroğlu et al. 2017; Kleyn et al. 2021). The Ca and P mineral content in *Sapu-sapu* fish is relatively high at 4.26±0.0001% and 0.99±0.004%. In addition, because the *Sapu-sapu* fish has a high bone composition, it can also create high Ca and P levels, which is beneficial for laying ducks to form eggshells.

Ferrum (Fe) is essential in enzymatic processes, transporting oxygen, and oxidation processes (Galaris et al. 2019). The Fe content of *Sapu-sapu* fish has obtained at 100.131±0.025 ppm, higher than the snakehead fish at 0.2±0.09 mg/100 mL (Santoso 2009). The fish's body is composed of hard scales and bones; this content exceeds the need for ducks by 70-80 ppm (Wang et al. 2020).

Zinc (Zn) plays a critical role in metabolic processes in the body. Zn deficiency causes feather growth, decreased egg production, and hatchability (López-Alonso 2012; Güz et al. 2022). The Zn content of the *Sapu-sapu* fish was 304.633±0.0161 ppm, which was higher than the snakehead fish of 3.34±0.8 mg/100 mL (Santoso 2009) and 24 mg/kg of starch (Applegate and Angel 2014). The Zn content of *Sapu-sapu* fish is higher than the requirement for ducks of 40-75 ppm (Applegate and Angel 2014) and will become toxic if it reaches the 800-4,000 ppm limit.

Laying hens with manganese (Mg) deficiencies produce fewer eggs and weaker eggshells. Many cases of Mg deficiency result in embryos' death before being hatched. In addition, Mg deficiency results in the shrinkage of bones and the shortening of beaks and bones (Applegate and Angel 2014; Jha and Mishra 2021; Olgun et al. 2021). The Mg content of *Sapu-sapu* fish has obtained at 0.2201±0.000 ppm, lower than the NRC 1994 (Dale 1994) recommendation of 25-90 ppm, and will experience poisoning if it consumes more than 4,800 ppm.

Zinc, copper, and manganese are cofactors for hundreds of cellular enzymes and transcription factors in all animals and are engaged in many metabolic processes. In addition, these minerals also contribute to forming immunological responses, tissue and bone growth, defense against oxidative stress, and cell growth and division. Therefore, this mineral deficit might reduce the organism's metabolic processes and growth performance (Richards et al. 2010; de Arruda Roque et al. 2022).

Heavy metal content in *Sapu-sapu* fish

Table 4 shows *Sapu-sapu* fish's heavy metal contents. The fish had no Hg. Nevertheless, heavy metal Lead was 4.25±0.18 ppm, Cr was 0.28±0.000, and Cd was 0.87±0.03. The Director General of Drug and Food Control proposed a lower threshold, stating that fish meat, Hg, Pb, and Cd levels are safe at 0.5, 0.4, and 0.1 ppm, respectively (SNI 2006).

Heavy metals are harmful metal elements if they enter the body systems (Jaishankar et al. 2014; Berniyanti et al. 2020). Heavy metals have unique effects on living organisms. Balali-Mood et al. (2021) state that all heavy metals, including mercury, chromium, lead, and cadmium, can poison living organisms. Cadmium and vanadium are hazardous but less toxic than lead, arsenic, and beryllium. In addition, mercury, lead, arsenic, cadmium, and nickel poisoning the environment. When poisons accumulate, these metals can stay in the body for long periods. Calcium (Ca) and magnesium (Mg) assist fish and shrimp in building cuticles or scales, according to Habashy and Sharshar (2020).

This study revealed that *Sapu-sapu* fish from contaminated rivers have significant heavy metals presence. According to Habashy and Sharshar (2020), heavy metal toxicity depends on species, location, age (life cycle phase), resistance, and individual ability to escape pollution.

Bioaccumulation of heavy metals such as copper (Cu) and lead (Pb) in fish can occur physically or biologically. The physical process is exposing fish body parts to heavy metal compounds. In contrast, many biological processes occur through the food chain, where heavy metals contaminant levels in the water will accumulate in the fish's body.

The content of heavy metals (Cu da Pb) in the meat and eggs of ducks fed by the *Sapu-sapu* fish

The heavy metal Cu (copper) is a trace mineral that can be detrimental to individuals if its contained levels in the body are reduced. On the other hand, it will become toxic if this element is exceeded for long periods. Eggs and duck meat are human food ingredients that need to be known for their heavy metal Cu content due to the feeding of the *Sapu-sapu* fish. The heavy metal level of Cu in the eggs and meat of ducks fed *Sapu-sapu* fish feed is shown in Table 5.

Table 3. Macro and micro mineral content in *Sapu-sapu* fish

Mineral	*Sapu-sapu* fish
Ca (%)	4.26 ±0.0001
P total (%)	0.99±0.004
Na (%)	1.53±0.01
Cl (ppm)	130.174,6±993.93
Mg (%)	0.2201±0.000
K (%)	0.13±0.000
S (ppm)	275.672±0.5711
Fe (ppm)	100.131±0.0251
Zn (ppm)	304.633±0.0161

Table 4. Content of heavy metals Cu, Hg, Pb, Cr, and Cd of *Sapu-sapu* fish (%)

Heavy metals	*Sapu-sapu* fish (%)	Indonesian National Standard (SNI)
Hg (ppm)	Not detected	0.50
Pb (ppm)	4.25±0.18	0.40
Cr (ppm)	0.28±0.000	0.50
Cd (ppm)	0.87±0.03	0.10
Cu (ppm)	189.31±0.02	5.00

Table 5. The content of heavy metals Cu and Pb in the eggs and meat of the ducks that were fed the *Sapu-sapu* fish

Sample	Cu (ppm) (SNI: 0.3 ppm)		Pb (ppm) (SNI: 0.3 ppm)	
	Eggs	Meat	Eggs	Meat
1	6.606	9.151	0.577	0.284
2	6.820	9.370	0.580	0.658
3	4.205	9.590	0.523	0.267
4	8.253	9.156	1.046	0.269
5	6.100	19.085	1.160	0.278
6	6.824	20.996	1.161	0.267
7	10.385	6.106	1.447	0.289
8	11.790	21.639	0.577	0.267
9	8.062	23.520	1.158	0.864
10	7.871	16.615	1.128	0.283
	76.916	145.228	9.357	3.726
	7.692±2.158	14.5228±6.481	0.936±1.557	0.373±0.211

The average Cu content of heavy metals in duck eggs was 7.692±2.158 ppm; the lowest Cu content was 4.205 ppm, and the highest level reached 11,790 ppm. Duck meat contains an average Cu level of 14,523 ppm, of which the highest is 23.520 and the lowest is 6.106 ppm. This data has a high range because each breeder fed the ducks *Sapu-sapu* fish not uniformly. Copper toxicity values range from 0.002-100 mg/Kg, and the WHO threshold for copper in the blood is 0.8-1.2 mg/kg. Meanwhile, the standard quality for heavy metals in fish for copper is 0.02 mg/kg. Copper metal contamination in food is accepted by 0.1 mg/kg by the Director General of Drug and Food Control No. 03725/B/SK/VII/1989.

Lead (Pb) is a metal widely known to the public used in the non-food industry, but it often causes pollution, which results in the poisoning of living things. In addition, the human body does not need Pb metal, so if this metal enters the body in large quantities or exceeds a predetermined threshold, it causes poisoning.

The average Pb content in eggs was 0.936±1.557 ppm, where the lowest Pb content in duck eggs was 0.523 ppm, and the highest was 1.447 ppm. Likewise, the Pb content in meat was an average of 0.373±0.211 ppm, with the lowest level being 0.267 ppm and the highest being 0.864 ppm. The data shows that the Pb content has exceeded the quality standard of 0.3 mg/kg (SNI 2006). The mineral lead (Pb) that enters the body through the digestive tract will be deposited in the bones and kidneys (Wani et al. 2015; Collin et al. 2022). Initially, the mineral lead is deposited in the bones until a threshold is reached; this mineral will be deposited in other tissues, especially the kidneys, with a slow turnover rate.

This study concluded that the *Sapu-sapu* fish living in the Mataram city stream has a complete nutritional content (protein, fat, amino acids, minerals) but contains high heavy metals contaminations. Ducks will dispose of these contaminants in the eggs and meat; it is unsafe if consumed. In addition, the eggs and meat of ducks that consume *Sapu-sapu* fish contain heavy metals Cu and Pb that exceed the threshold (SNI 2006), so they are unsafe for human consumption.

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