Heavy Metal Testing in Salted Fish and Its Relationship with Economic Value: Evidence from Small and Medium Enterprises in Indonesia

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Abstract. This study is founded on the assumption that food safety must be ensured in all food products, including salted fish, particularly in terms of heavy metal levels. Salted fish, which poses considerable hazards to food safety during processing, is an attractive issue for investigation, especially when seen through the lens of economic value, which has not been well addressed in prior studies. This study used both experimental methods and literature reviews to examine the heavy metal content of raw salted fish and its link to economic value from the perspectives of both business actors and customers. This study utilized laboratory testing using the 18-13-14/MU/SMM-SIG (ICP MS) methodology. The factors examined in this study were arsenic, cadmium, mercury, lead, and tin. The analysed samples were raw salted fish from a fish salting company in Kali Baru Cilincing, North Jakarta. This study examines these findings in terms of economic value, combining methodologies from various earlier studies. The findings show that all measures of heavy metal level in raw salted fish examined were still within the required limits. This is an essential economic determinant, as is the selling value of salted fish produced by small, and medium-sized enterprises (SMEs).

1 Introduction

Food safety is one of the most serious challenges in food today, especially in the food processing business, because it protects customers from the potential health hazards associated with consuming contaminated or unsafe food items [1]. There has been an increasing concern in recent years over the safety of salted fish, namely due to the existence of specific heavy metals like arsenic, cadmium, mercury, lead, and tin. Heavy metals have the ability to build up in fish from different sources, including polluted water, contaminated feed, and environmental contamination [2–4]. The inclusion of extremely high levels of heavy metals in salted fish presents a substantial health hazard to individuals, since extended exposure can result in a range of detrimental impacts on human well-being, including

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neurological diseases, organ impairment, and potentially even cancer [5,6]. Moreover, the capacity to guarantee food safety and adhere to regulations concerning heavy metal pollution is strongly linked to the economic worth of salted fish and the operational success of small, and medium firms operating in this industry. The origin of raw materials is a potential determinant that impacts the safety of salted fish. The origin of the raw materials used in the production of salted fish is of utmost importance in defining the overall quality and safety of the end product [7].

Multiple prior studies have examined the correlation between food safety and economic worth in the salted fish industry. At Bogor's Lawan Seketen market, [8] tracked the origins, distribution, and consumption of salted fish. The rules and policies that ensure salted fish is safe and of high quality are the focus of this research. There are four distinct kinds of salted fish items at the Lawan Seketen Bogor market, according to the research, and each has its own set of problems and possibilities when it comes to food safety. Furthermore, in order to enhance the quality of salted fish processed in Burukumba District, [9] performed a study to identify methods for doing so. For salted fish processing to be more hygienic and produce better, more competitive products, as this study shows, strict hygiene regulations are necessary. Furthermore, the study emphasized the need for businesses to prioritize sanitation and hygiene to improve the longevity and general quality of salt-boiled fish products. [10] give an alternative perspective, stressing that the salted fish business includes not only processing but also market opportunities.

It is critical to establish and execute efficient supply chain monitoring and control systems to resolve the issue of heavy metal contamination in salted fish. Finding a middle ground between lowering salinity for nutritional and financial reasons and knowing the possible health concerns of microbial growth and worse product quality is crucial. The objective of this study is to examine the correlations between varying degrees of knowledge among business participants concerning the food safety of salted fish processing, its influence on the economic worth of salted fish, and the performance of the salted fish industry.

2 Methodology

Using both experimental methods and literature reviews, this study seeks to understand how food safety relates to its economic value. Laboratory testing was carried out in December 2023 using the 18-13-14/MU/SMM-SIG (ICP MS) technique. The test utilized a sample obtained from a small group located in Kali Baru Cilincing, North Jakarta, precisely at coordinates 6°05'50.7"S 106°55'53.0"E (Figure 1).

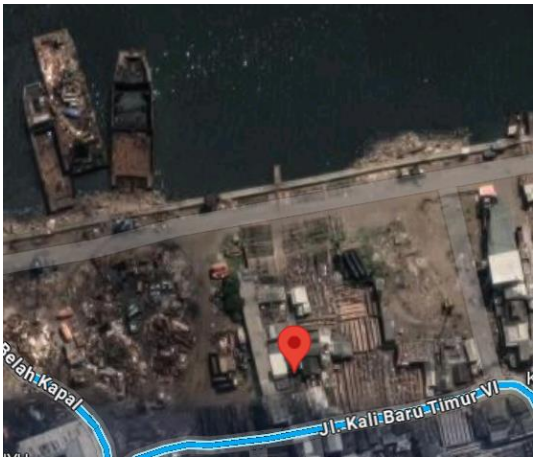

Fig. 1. Fish Salting Location

This group represents a raw salted fish center situated at the center, located in urban development and the coastal area, characterized by high population density and numerous structures. Raw salted fish can have heavy metals like arsenic, cadmium, mercury, lead, and tin detected by this test. Second, we can look into food safety by observing what's already been published on the subject; in this case, we'll be looking at heavy metals in salted fish and how they affect the perceived economic value of both businesses and consumers.

3 Results and discussion

3.1 Test on Parameters

Table 1 presents the laboratory test findings regarding the concentration of heavy metals. Subsequently, we will juxtapose these findings with the threshold constraints established by the Food and Drug Supervisory Agency of Indonesia [11] about the concentration of heavy metals. The arsenic (As) concentration in both the first and second tests of the raw salted fish sample was 0.67. Research shows that raw salted fish samples evaluated for arsenic (As) had concentrations lower than the 2 mg kg^{-1} benchmark. The detection limit for the heavy metal cadmium (Cd) in fish samples was 0.0002 mg kg^{-1}, but no results were obtained from this measurement. The findings show that the content of Cd in the raw salted fish samples is lower than the 0.3 mg kg^{-1} limit. The salted fish samples tested negative for mercury (Hg) at the 0.0008 mg kg^{-1} detection limit, according to the laboratory results. The findings indicate that the salted fish samples tested had a Hg concentration that fell under the specified threshold limit of 0.5 mg kg^{-1}. Lead (Pb) yielded findings that were below the detection limit of 0.002 mg kg^{-1}, indicating that it was not detected. These results suggest that the concentration of the heavy metal Pb is within the acceptable limit of 0.3 mg kg^{-1}. The subsequent laboratory test results indicated that the detection limit for tin (Sn) was 0.0009, suggesting that it was not present. The findings indicate that the Sn level in the tested samples of raw salted fish remained within the permissible limit of 40 mg kg^{-1}.

Table 1. Lab Test Results for Heavy Metal.

No	Parameter	Unit	*Simplo*	*Duplo*	Limit of Detection
1	Arsenic (As)	mg kg^{-1}	0.67	0.67	-
2	Cadmium (Cd)	mg kg^{-1}	Not detected	Not detected	0.0002
3	Mercury (Hg)	mg kg^{-1}	Not detected	Not detected	0.0008
4	Lead (Pb)	mg kg^{-1}	Not detected	Not detected	0.002
5	Tin (Sn)	mg kg^{-1}	Not detected	Not detected	0.0009

Arsenic is naturally present in both organic and inorganic forms in the Earth's crust. Industrial activities, mining, and the application of specific pesticides result in environmental pollution. This pollution leads to the contamination of some food products, such as fish, with inorganic arsenic, which is very harmful [12]. The studies conducted by [13] and [14] have demonstrated that certain food products, such as fish, are contaminated with inorganic arsenic, a highly dangerous substance. Arsenic in salted fish poses a risk to health when taken in excessive quantities over a prolonged period. Prolonged exposure to elevated quantities of inorganic arsenic can result in a range of health problems, such as skin lesions, cancer, cardiovascular disorders, and diabetes. Hence, it is imperative to supervise and regulate the quantities of arsenic present in salted fish to guarantee that they remain within the prescribed safety thresholds, thereby safeguarding the well-being of consumers [15]. The information is supported by studies conducted by [16] and [17]. Simultaneously, both natural phenomena and human actions, such as industrial operations, farming methods, and waste management,

release cadmium, an extremely poisonous heavy metal, into the surrounding environment. Cadmium has the ability to build up in aquatic organisms, such as fish, and subsequently transfer into the food chain [18,19]. The presence of cadmium in salted fish poses a significant risk as it has the potential to accumulate within the human body, namely in the kidneys, leading to long-term damage. Prolonged exposure to cadmium can result in renal dysfunction, bone demineralization, fractures, and an elevated susceptibility to cancer. Cadmium has been categorized by researchers as a carcinogen for humans [20,21]. Like arsenic, it is crucial for the salted fish processing sector to oversee and manage cadmium levels to guarantee they remain within acceptable thresholds, safeguard consumer well-being, and adhere to food safety requirements.

Mercury is an innate, dense metallic element that, once discharged into the surroundings, has the potential to pollute the atmosphere, bodies of water, and land. Bacteria can transform mercury into methylmercury, a profoundly poisonous form that builds up in fish and shellfish. Mercury pollution commonly arises from industrial emissions, mining activities, and poor disposal of trash [22–24]. Methylmercury, found in salted fish, can present substantial health hazards to people if consumed. Methylmercury can impact the neurological system, especially in fetuses and young children, which may result in cognitive impairments, motor skill deficits, and developmental delays. Mercury exposure in adults can result in neurological and cardiovascular complications. Pregnant women face significant concerns regarding the potential dangers to the developing baby when consuming high amounts of mercury in their diet [25–27]. To protect the health of consumers, the salted fish sector must strictly follow food safety requirements to reduce the amounts of mercury in their goods.

Lead can be released into the environment by both natural and artificial sources, including old paint, industrial emissions, polluted soil, and some types of plumbing. Lead can enter the food chain through contaminated water bodies, and fish have the ability to collect it in their bodies [28–30]. The presence of lead in salted fish poses significant health hazards for humans. Exposure to lead can result in many health complications, such as neurotoxicity, anemia, hypertension, renal impairment, immune system suppression, and reproductive disorders. Children and pregnant women are particularly susceptible to the harmful effects of lead exposure. This can result in developmental delays and learning issues in children, as well as impairment to the baby during pregnancy [31,32]. Minimizing lead contamination in salted fish is crucial for guaranteeing the safety and welfare of customers. Adhering to safety norms and regulations is crucial for the industry to ensure that their products contain minimal levels of lead. Tin is a metallic element that finds application in different fields, such as food packaging and container lining, to avoid corrosion. Although tin is generally less hazardous than other heavy metals, exposure to specific tin compounds, especially organotin compounds, can be detrimental to health [6,33,34]. The primary risk associated with tin in salted fish is potential contamination through tin cans or other packaging materials that encounter the fish. Consuming elevated amounts of tin can lead to immediate symptoms such as abdominal pain, queasiness, throwing up, and diarrhea. Prolonged contact with specific organotin has been linked to more serious consequences such as impaired immune function, damage to the nervous system, and disruption of hormone regulation [35,36]. Reducing tin contamination is an essential safety concern for the salted fish sector, especially when storing or processing food in containers lined with tin. Adhering to food safety standards can effectively mitigate the risk of tin contamination and safeguard the well-being of consumers.

The laboratory tests conducted on the raw salted fish samples indicate that the levels of heavy metals, including arsenic, cadmium, mercury, lead, and tin, are below the acceptable limits. Based on the results of the study conducted by [37], it can be concluded that the raw salted fish samples evaluated are safe to eat in relation to their heavy metal levels. In addition, the research findings indicate that the use of appropriate processing processes and compliance with food safety laws have led to raw salted fish samples that contain acceptable levels of

heavy metal contamination [38]. Ensuring the safety and quality of salted fish products is crucial, as elevated levels of heavy metals might potentially endanger the health of consumers [1].

3.2 Perspectives of Food Safety in Salted Fish Processing

The study findings indicate that employing appropriate processing processes and strict compliance with food safety rules have led to raw salted fish samples that contain permissible levels of heavy metal contamination. Ensuring the safety and quality of salted fish products is vital for the ongoing development and expansion of the sector, as it instils consumer confidence [39]. The study findings suggest that there is a presence of high levels of heavy metals in the collected samples of raw salted fish. According to [1], this indicates that the products are both safe and of high quality. Nonetheless, if correct processing processes and food safety rules are not adhered to, salted fish might still be susceptible to heavy metal contamination. This emphasizes the significance of enforcing rigorous food safety protocols and ongoing surveillance in the preparation of salted fish to mitigate any potential health hazards linked to heavy metal pollution. The economic worth of salted fish and the business performance of small and medium enterprises (SMEs) in this field are strongly influenced by the parameters of heavy metal contamination. SMEs in the salted fish processing industry must prioritize food safety and ensure that their products adhere to the required standards for heavy metal contamination [7]. This is essential not only to safeguard consumers but also to uphold the reputation and profitability of their businesses. The research findings suggest that the safety and quality of salted fish products, as well as the economic viability of SMEs in the industry, depend on using appropriate processing procedures and following food safety rules. The study emphasizes the importance of applying Hazard Analysis and Critical Control Points (HACCP) and developing Standard Operating Procedures (SOPs) in the manufacturing of salted fish to comply with food safety regulations [40]. Moreover, the study highlights the significance of suppliers in the food processing sector and the necessity for dependable and regular sources of raw materials [7]. This underscores the need for employing appropriate processing methods and adhering to food safety laws in the salted fish sector.

By applying these steps, SMEs can safeguard consumers from potential health hazards linked to the presence of heavy metals and uphold the reputation and profitability of their businesses. Overall, the research results highlight the need for employing appropriate processing methods and complying with food safety laws in the salted fish sector [40]. Neglecting to do so might not only endanger the well-being of consumers but also result in adverse outcomes for the business, such as damage to its reputation and reduced profitability [7]. Hence, it is imperative for SMEs in the salted fish processing sector to give utmost importance to food safety. This may be achieved by adopting strategies to minimize the presence of heavy metals and guaranteeing that their products adhere to the required regulations. It is crucial for SMEs in the salted fish processing industry to tackle heavy metal contamination to ensure compliance with food safety regulations, safeguard consumers, and preserve their corporate reputation and profitability. However, the rejection of the raw material source owing to social or religious reasons, as well as the necessity to address potential health issues such as bovine spongiform encephalopathy, requires the utilization of other sources. Moreover, this highlights the necessity of implementing sustainable practices in the fish processing business to minimize waste and adhere to environmental rules. Research indicates that in the salted fish processing industry, SMEs must undertake crucial measures to ensure food safety, maintain operational efficiency, and foster sustainable growth without causing harm to the environment. The procedures involve tackling heavy metal pollution, adopting HACCP and SOPs, securing reliable suppliers of raw materials, and promoting the sustainable utilization of aquatic resources. Consistent with prior studies,

it has been elucidated that achieving strong business performance is crucial for ensuring the long-term survival of a business [41,42]. The research findings highlight the need for employing appropriate processing methods and adhering to food safety rules within the salted fish business. Neglecting to do so might not only endanger the well-being of consumers but also result in detrimental outcomes for the business, including damage to its reputation, reduced profitability, and diminished reliability of suppliers.

Business stakeholders consider food safety in the processing of salted fish to be a vital determinant of the economic worth of the salted fish in the market. Additionally, the study emphasizes that the existence of high levels of heavy metals in salted fish might have a substantial effect on its economic worth and the operational success of SMEs. Hence, it is imperative for SMEs in the salted fish processing sector to give utmost importance to food safety protocols, namely by closely monitoring and regulating the presence of toxic heavy metals like arsenic, cadmium, mercury, lead, and tin. SMEs may uphold food safety regulations, safeguard consumers, and retain their business reputation and profitability in the market by ensuring that these contaminants are kept below the required thresholds. From the viewpoint of customers, food safety is a crucial consideration when it comes to salted fish. Consumers are becoming more aware of the potential health hazards linked to consuming contaminated foods, such as salted fish [1]. Consumers are more inclined to select products that have obtained certification for being safe and devoid of heavy metal contamination. Customers' food safety will be guaranteed, whether they purchase directly from this business group or through other supply channels [43,44]. Additionally, consumers have a tendency to give higher importance to items from organizations that have a well-established history of implementing effective food safety procedures [40]. This study aims to highlight the association between heavy metal contamination in salted fish and its economic worth and business performance for SMEs. The study focuses on presenting unique and novel elements in this regard. Equally significant is the sustainable exploitation of aquatic resources in the fish processing sector to minimize waste and adhere to environmental rules. A sufficient degree of understanding of food safety is crucial for preventing antimicrobial resistance and guaranteeing the safety of food for public health [45,46].

4 Conclusion

The research indicates that the levels of heavy metals, including arsenic, cadmium, mercury, lead, and tin, are below the acceptable limits. We can conclude that the raw salted fish samples evaluated are safe to eat in relation to their heavy metal levels. The research findings indicate that the use of HACCP and SOPs is essential for maintaining the safety of salted fish products. They systematically oversee and regulate the concentrations of toxic heavy metals like as arsenic, cadmium, mercury, lead, and tin in their salted fish products.

4.1 Implications

This work has ramifications that are both theoretical and practical. In theory, the findings of this study, which illustrate the influence of heavy metals on the market value of salted fish, provide evidence in favor of the notion of environmental economics [47,48]. Moreover, the notion of pressure on environmental choice objects (OEC) is complex and arises from a range of activities, predominantly in six domains: policy formulation, the magnitude and economic worth of environmental amenities, OEC as a hazard, effects on distribution, and the interaction between economic growth and natural resources. The practical ramifications of this study involve offering precise recommendations to SMEs on how to improve their food safety standards and ultimately improve their business success. Furthermore, this study emphasizes the significance of effective managerial assistance, staff engagement, an

emphasis on customer satisfaction, and the establishment of strong supplier connections in the successful execution of food safety regulations.

4.2 Recommendations

This study proposes several recommendations, including the implementation of comprehensive training and education programs, the regular monitoring and control of heavy metal levels, consistent communication with customers regarding food safety measures, and the cultivation of strong connections with suppliers. The purpose of these guidelines is to assist SMEs in guaranteeing food safety throughout the processing of salted fish, improving their business success, and upholding consumer confidence.

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