

Food Safety Risks Associated with Traditional Bakasang Production

Riska Kasdi¹, Adelfia Papu¹, Beivy Jonathan Kolondam¹

¹Department of Biology, Faculty of Mathematics and Natural Sciences, Sam Ratulangi University, Manado, Indonesia

Corresponding Author: Beivy Jonathan Kolondam

DOI: <https://doi.org/10.52403/ijshr.20250309>

ABSTRACT

Bakasang, a traditional Indonesian fermented fish product, holds significant cultural value but poses considerable food safety risks due to unstandardized production methods. This review examines the key hazards associated with bakasang, including microbial contamination, biogenic amine accumulation, heavy metal exposure, and inconsistent processing conditions. The analysis highlights how traditional fermentation practices, characterized by variable salt concentrations, uncontrolled temperatures, and lack of hygiene control, contribute to these risks. Mitigation strategies are proposed, focusing on the adoption of starter cultures, improved raw material handling, basic hygiene interventions, and community-based food safety education. This review emphasizes the need for balanced approaches that integrate scientific food safety principles with traditional knowledge to preserve bakasang's cultural significance while enhancing its safety. By addressing these challenges, bakasang production can be transformed into a safer process without compromising its artisanal character, ensuring its sustainability as part of Indonesia's culinary heritage.

Keywords: Bakasang, fermented fish, food safety, traditional food processing

INTRODUCTION

Bakasang is a traditional Indonesian fermented fish product, primarily consumed in North Sulawesi and surrounding regions. (1,2) Bakasang is a fermented fish product traditionally processed using small pelagic fish such as sardines or anchovies or the entrails of skipjack tuna (*Katsuwonus pelamis*), which are by-products of the fish smoking process (cakalang fufu) as its raw material. Brownish in color with a distinctive aroma, bakasang is usually used as a flavor enhancer for sambal. (3) Made from small fish such as anchovies, it undergoes a natural fermentation process with salt, sometimes enhanced with palm sugar or rice. This condiment is prized for its rich umami flavor and is a staple in local cuisine, often used to enhance soups, sambals, and other dishes. Despite its cultural significance, the traditional methods of bakasang production raise concerns regarding food safety, primarily due to uncontrolled fermentation and variable processing conditions. (2,4) The fermentation of bakasang relies on naturally occurring microorganisms, which can lead to inconsistent product quality and potential health risks. (4,5) Unlike commercially fermented products that use standardized starter cultures, bakasang production depends on environmental bacteria, some of which may be pathogenic. (1,2,5) The lack of controlled acidity, temperature, and salt concentration

increases the likelihood of harmful microbial growth, including histamine-producing bacteria.^(6,7) These hazards pose serious health threats, ranging from allergic reactions to life-threatening foodborne illnesses.

One of the most significant risks associated with bakasang is the formation of biogenic amines, particularly histamine, which can cause scombroid poisoning.⁽⁵⁾ Histamine is produced when certain bacteria decarboxylate the amino acid histidine in fish, especially under improper storage and fermentation conditions.^(8,9) Symptoms of histamine poisoning include headaches, rashes, vomiting, and, in severe cases, respiratory distress.^(10,11) Since traditional bakasang production does not typically monitor histamine levels, consumers may unknowingly ingest unsafe amounts, particularly if the fish used were not fresh or were stored at inadequate temperatures.

In addition to microbial risks, chemical hazards such as heavy metal contamination and excessive sodium intake further complicate the safety profile of bakasang. Small fish species used in production may accumulate heavy metals like mercury and lead, especially if sourced from polluted waters.^(12,13) Furthermore, the high salt content, while necessary for preservation, may contribute to hypertension and cardiovascular diseases.⁽¹⁴⁾ among frequent consumers. Without proper regulation and quality control, these chemical risks remain unaddressed in traditional bakasang markets.

Given these concerns, there is a growing need to improve the safety of bakasang while preserving its traditional qualities. This review explores this food safety challenges in depth and discusses possible strategies to mitigate them, ensuring that bakasang remains a safe and sustainable part of Indonesia's culinary heritage.

FOOD SAFETY RISKS IN BAKASANG PRODUCTION

Microbial Hazards

The traditional production of bakasang involves a natural fermentation process that creates an environment conducive to both beneficial and harmful microbial growth. Unlike controlled industrial fermentation that uses standardized starter cultures, bakasang relies on indigenous microorganisms present in the raw fish and processing environment.^(4,5) This uncontrolled fermentation leads to significant variability in microbial populations, with certain pathogenic bacteria potentially surviving or even thriving during the process. The absence of pasteurization in traditional methods further compounds these risks, as harmful microbes are not eliminated before consumption.^(1,2,5) Among the most concerning microbial hazards are histamine-producing bacteria, including *Morganella morganii*, *Klebsiella pneumoniae*, and *Photobacterium* species.^(5,15,16) These bacteria decarboxylate the amino acid histidine in fish tissue, converting it to histamine - a heat-stable toxin responsible for scombroid poisoning.⁽¹⁷⁾ Symptoms can range from mild allergic-like reactions to severe respiratory distress, depending on the histamine concentration.⁽¹⁸⁾ The risk is particularly high when using fish that were not properly chilled before processing, as elevated temperatures accelerate bacterial growth and histamine production. Once formed, histamine remains stable even when the final product is cooked, making prevention through proper handling crucial.^(17,18)

Another critical pathogen of concern is *Clostridium botulinum*, which can grow in the anaerobic conditions typical of traditional bakasang fermentation.⁽⁷⁾ This spore-forming bacterium produces one of the most potent neurotoxins known to humans, causing botulism, a potentially fatal illness characterized by muscle paralysis and respiratory failure.⁽¹⁹⁾ The risk increases when fermentation occurs at inadequate salt concentrations or when the pH remains too high to inhibit bacterial growth. Unlike many other foodborne

pathogens, *C. botulinum* spores are highly resistant and can survive conditions that kill vegetative cells, making proper fermentation control essential for safety.^(19,20)

Additional bacterial hazards include *Salmonella* spp., *Staphylococcus aureus*, and *Vibrio* species, which may contaminate the fish either before or during processing.^(5,21) These pathogens can cause severe gastrointestinal illnesses, with symptoms ranging from mild diarrhea to life-threatening dehydration.^(7,21,22) *S. aureus* is particularly concerning as it can produce heat-stable enterotoxins that persist even if the bacteria are killed during processing.^(23,24) The risk of contamination increases with poor hygiene practices during handling, inadequate cleaning of equipment, or the use of contaminated water in processing.^(19,22)

The microbial risks in bakasang production are further exacerbated by inconsistent fermentation conditions and lack of quality control in traditional settings. Variations in salt concentration, fermentation time, and ambient temperature create unpredictable microbial environments where pathogens may survive or proliferate.⁽²⁰⁾ Without proper monitoring of critical control points such as pH, water activity, and microbial counts, hazardous batches may go undetected. These factors highlight the need for improved fermentation protocols, better hygiene practices, and potential introduction of starter cultures to ensure microbial safety while maintaining the product's traditional characteristics.

Biogenic Amines (Histamine and Others)

Biogenic amines are nitrogenous compounds that naturally form during the fermentation of protein-rich foods like bakasang, primarily through microbial decarboxylation of amino acids.^(9,17) While some biogenic amines play essential roles in physiological functions, excessive accumulation in food can pose significant health risks.^(8,9) In bakasang, the most concerning biogenic amines include

histamine, tyramine, putrescine, and cadaverine, which can reach hazardous levels due to uncontrolled fermentation conditions and variable raw material quality.⁽⁵⁾ Their presence serves as an important indicator of both food safety and quality in fermented fish products.

Histamine represents the most critical biogenic amine in bakasang due to its association with scombroid poisoning, a foodborne illness with global prevalence.^(25,26) Produced primarily by enteric bacteria

such as *M. morgani* and *K. pneumoniae*, histamine formation correlates strongly with time-temperature abuse of fish before processing. The toxin is remarkably stable, resisting degradation during cooking, smoking, or canning processes.^(16,17,23,25)

Regulatory agencies worldwide have established maximum histamine limits (typically 50-200 mg/kg) for fish product, but traditional bakasang often exceeds these thresholds due to non-standardized production methods and lack of quality monitoring.^(5,7,27,28)

Beyond histamine, other biogenic amines in bakasang contribute to both health risks and product quality deterioration.⁽⁵⁾ Tyramine, produced by decarboxylation of tyrosine, can induce hypertensive crises in individuals taking monoamine oxidase inhibitor (MAOI) medications.⁽²⁹⁻³¹⁾

Putrescine and cadaverine, while less toxic individually, can potentiate histamine's negative effects by inhibiting intestinal histamine-metabolizing enzymes.^(32,33)

These amines also contribute to undesirable off-flavors and odors when present in high concentrations, reducing product acceptability. Their formation is closely tied to specific microbial activity during fermentation, with different bacterial strains responsible for producing distinct amine profiles.

Chemical Hazards

Beyond microbial risks, bakasang production presents several significant chemical hazards that threaten consumer safety. The most prominent concerns stem

from heavy metal contamination, particularly in fish sourced from polluted waters. Small pelagic fish species commonly used in bakasang, such as anchovies and sardines, have demonstrated bioaccumulation potential for mercury, lead, and cadmium. ^(12,13) These toxic metals originate from industrial runoff, mining activities, and other anthropogenic sources, entering the marine food chain and concentrating in fish tissue. ⁽³⁴⁻³⁶⁾ Chronic exposure through regular bakasang consumption may lead to health consequences.

Addressing chemical hazards in bakasang requires comprehensive strategies throughout the production chain. Implementing source control measures for raw fish, including regular heavy metal testing of fishing grounds, could significantly reduce contamination risks. Promoting food-grade processing equipment and regulated additives would minimize processing-related hazards. Regulatory frameworks should be developed to establish maximum residue limits specific to traditional fermented fish products, accompanied by accessible testing methods for small-scale producers. Such integrated approaches would preserve bakasang's cultural significance while substantially improving its chemical safety profile.

Lack of Standardized Processing

The traditional methods of bakasang production are deeply rooted in cultural practices, often passed down through generations without formal standardization. This results in significant variability in processing techniques, including differences in fermentation duration, salt concentration, and ambient conditions. While such diversity contributes to the product's artisanal character, it also leads to inconsistent safety and quality outcomes. Without established protocols, producers may inadvertently create conditions that favor pathogen growth or chemical hazards, putting consumers at risk. The absence of standardized procedures makes it

challenging to implement widespread safety improvements or quality control measures across small-scale production sites. ⁽³⁷⁾

The lack of standardized equipment and facilities further compounds food safety risks. Many small-scale producers use non-food-grade containers, such as recycled plastic or ceramic vessels, which may harbor contaminants or leach harmful substances into the product. Open fermentation processes expose bakasang to environmental contaminants, including dust, insects, and airborne pathogens. Unlike commercial food production, traditional methods rarely incorporate basic hygiene measures like regular equipment sanitation or proper handwashing protocols. These gaps in processing standards create multiple points where microbial or chemical contamination can occur, undermining the safety of the final product.

MITIGATION STRATEGIES FOR SAFER BAKASANG PRODUCTION

To address the food safety risks associated with traditional bakasang production, a multi-faceted approach combining scientific interventions with culturally sensitive practices is essential. One of the most effective strategies involves introducing controlled fermentation using selected starter cultures, such as lactic acid bacteria (LAB) strains with proven antimicrobial properties. These cultures can outcompete pathogenic microorganisms while accelerating the acidification process, thereby inhibiting histamine-forming bacteria and other hazards. Additionally, implementing simple pH monitoring tools and standardized salt ratios (typically 20-25%) would help maintain consistent fermentation conditions. Such measures could significantly reduce microbial risks while preserving bakasang's characteristic flavor profile.

Improving raw material handling represents another critical intervention point. Establishing cold chain management for fish before processing, even though low-cost methods like community ice banks, would

minimize microbial growth and histamine formation. Training programs should emphasize the importance of using only fresh, high-quality fish and proper gutting techniques to reduce bacterial load. For chemical hazard control, partnerships with local environmental agencies could help identify and avoid fishing grounds with heavy metal contamination. Small-scale producers could also adopt simple visual quality indicators and smell tests as preliminary screening methods for raw materials, complemented by periodic laboratory testing where feasible.

Enhancing processing hygiene and infrastructure is equally vital for safer bakasang production. Basic but impactful improvements include transitioning to food-grade plastic or stainless-steel fermentation containers, implementing regular equipment sanitation protocols, and establishing dedicated processing areas protected from environmental contaminants. Solar dryers or simple fermentation chambers could provide more controlled drying conditions compared to open-air methods. These infrastructure upgrades need not be expensive; many can be adapted using locally available materials. Concurrently, community-based food safety certification programs could incentivize adherence to improved practices while maintaining traditional production values. Finally, developing context-appropriate regulatory frameworks and consumer education initiatives will ensure long-term safety improvements. Rather than imposing industrial-scale standards, regulators should collaborate with traditional producers to develop realistic, incremental safety benchmarks. Public awareness campaigns can educate consumers about proper storage, recognizing spoilage signs, and moderate consumption to address sodium intake concerns. By integrating scientific food safety principles with indigenous knowledge systems, these mitigation strategies can transform bakasang into a safer product while safeguarding its cultural importance and artisanal heritage for future generations.

CONCLUSION

Bakasang remains an important cultural and culinary product in Indonesia, yet its traditional production methods present significant food safety risks, including microbial contamination, biogenic amine formation, chemical hazards, and inconsistent processing standards. Addressing these challenges requires a balanced approach that integrates scientific food safety interventions, such as controlled fermentation with starter cultures, improved hygiene practices, and standardized processing parameters, with respect for traditional knowledge and artisanal techniques. By implementing community-based training programs, affordable technological adaptations, and context-appropriate regulations, bakasang production can be made safer without compromising its unique sensory qualities.

Declaration by Authors

Ethical Approval: Not applicable

Acknowledgement: None

Source of Funding: None

Conflict of Interest: The authors declare no conflict of interest.

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How to cite this article: Riska Kasdi, Adelfia Papu, Beivy Jonathan Kolondam. Food safety risks associated with traditional Bakasang Production. *International Journal of Science & Healthcare Research*. 2025; 10(3): 76-82. DOI: <https://doi.org/10.52403/ijshr.20250309>
