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BIOGENIC AMINES AND FERMENTED FOODS: A REVIEW OF OCCURRENCE

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Abstract:

Biogenic amines (BAs) are de-carboxylation outcomes of amino-acids that occur during fermentation. They are produced when microbial enzymes decarboxylate amino acids. Although BAs contribute to the flavour of fermented foods, due to toxicity, excessive amounts of them can be harmful to one's health. BAs like phenylethylamine, tyramine, and histamine present in a number of fermented foods at concentrations higher than known dangerous thresholds. Depending on variables including the raw ingredients, fermentation circumstances, and microbial composition, the content of BAs in different fermented foods, even among the same food types can vary significantly. High blood pressure, tachycardia, and migraines are just a few of the negative health impacts linked to dietary intake of foods high in BAs. Toxicity caused due to BA may take place at levels many times lower than regulated and indicated dangerous doses, individual's susceptibility and other circumstances such as alcohol use and specific drugs. BAs can be found in different range in fermented foods, the safety of food including health of different professionals are often unaware of the possible health hazards and control techniques for these items. In this review, I discussed quantity of BA discovered in various fermented foods, regulation and proposed dangerous doses, and risk reduction techniques to help the food sector and public health experts practise.

Keywords: Biogenic amine, toxicity, fermented food, Histamine .

1. Introduction:

Low-molecular organic bases known as BAs are produced during fermentation when microbial species transamination of aldehydes and ketones or decarboxylate amino acids to produce the appropriate amine and CO2 (Sivamaruthi et al.). Since BAs are linked to a number of biological processes and are generally tolerated in food, little levels of them rarely have a negative impact on human health (Doeun et al.). Furthermore, small amounts of BAs are quickly metabolised and detoxified by gastrointestinal amine oxidase enzymes (Doeun et al.). High levels of BA, however, might overpower amine oxidases' detoxifying capabilities, resulting in mild allergic reactions and potentially more severe health issues (Sivamaruthi et al.; Doeun et al.; Erdag et al.). Elevated amounts of BAs have been found in a number of food categories, including fish and fish products, fermented foods, meats, vegetables, dairy products, and soy product (Spano et al.; Ruiz-Capillas and Herrero). Heat treatments, which are frequently utilised to process and make food, do not destroy BAs. Although the condition of raw food items and natural microorganism also play important factors, the accessibility of amino acids that are free is typically the primary factor driving the BA formation in foods (Sivamaruthi et al.). The enzymes known as amino acid decarboxylase, which produce BA, are found in a wide variety of food microorganisms, such as those that ferment food (Alvarez and Moreno-Arribas). Therefore, a variety of techniques can be used to stop BA from forming, such as better microbial starting culture selection and control, the use of high-quality food ingredients, stringent sanitation, and adherence to appropriate food handling procedures throughout the fermentation process. Lactobacillus, Lactococcus, Salmonella, Escherichia, Pseudomonas, Streptococcus, Pediococcus, and Bacillus species are among the prevalent microorganisms that decarboxylate amino acids to create BAs (Suzzi and Gardini; Barbieri et al.). While Lactobacillus species are called to be primarily responsible for the production of histamine and tyramine in foods (Sivamaruthi et al.). Many of the bacterial families mentioned above also promote spontaneous fermentation, even though using of fresh and high-quality of ingredients reduce particular kinds of spoilage microorganism. Depending on the food's quantitative and qualitative characteristics, the individual's susceptibility, and their current health, dietary intake of high quantity of BAs via food may be harmful (Ruiz-Capillas and Herrero). Numerous physiological symptoms, including sweating, headache, heart palpitations, nausea, respiratory distress, and hyper or hypotension, are linked to high exposure to BAs (Feddern et al.). Concerns are also raised by a number of findings in the literature about other BAs, as tyramine and phenylethylamine, even though histamine has received a lot more attention because of its higher toxicity (EFSA Panel on Biological Hazards (BIOHAZ)). This research aims to characterise the quantities of BA present in several fermented food categories and determine the health hazards and symptoms associated with BA generation. Additionally, the review will go over regulatory criteria, pinpoint risk-reduction tactics, and convey best practices to public health experts and the food business.

2. Methodology:

Three different searches were carried out. We started by finding reviews and studies on the impact of BA exposure from eating fermented foods on human health. Third, we determined the highest amounts of BA reported in various fermented foods. Secondly, we determined recommended hazardous doses limits for various BAs. Finding report pertinent to the effects of BAs on health of human was the main goal of our inclusion criteria in every search. We looked through both grey and scientific literature to find material on this subject. To find further in-depth information, the bibliographies of the publications that were retrieved were scanned. Articles written in English and published between 2012 and 2024 were included. The PubMed and Google Scholar databases were explored by the phrases "biogenic amines" in conjunction along "review," "different fermented food," "poisonousness," to find BAs related to the effects on human health. I searched the Google Scholar and PubMed databases for impurity levels in various fermented foods using "biogenic amines" in conjunction with the terms "fermented fish, "biogenic amine formation", "fermented soy food," and "fermented vegetables" as the keywords.

3. Results and discussion

3.1 : Factors effecting BA formation:

Animals, plants, and microbes can all naturally create BA through their regular metabolic processes (EFSA Panel on Biological Hazards (BIOHAZ)). Some of the critical conditions for the formation of excess BA include the presence of amino acids, the existence of de-carboxylase-positive microbes, the composition of raw materials, pH, ion power, and water activity, as well as favourable circumstances for bacterial growth during the preparation and storage of food (Ruiz-Capillas and Herrero). Among the numerous factors influencing the production of the needed substrates, their activity, and amount of BAs present in the diet (Ruiz-Capillas and Herrero). Bacteria really exploit the production of BA in their cells as a defence mechanism against stress or acidic conditions (EFSA Panel on Biological Hazards (BIOHAZ)). By generating amines, it also aids in pH restoration and serves as a source of extra energy when required. Microorganisms typically proliferate in large quantities in fermented foods, which can lead to a substantial build-up of BA, particularly in natural ferments without the addition of starter culture (Suzzi and Gardini). Different types of bacteria are capable of forming BAs. BAs in fermented foods are thought to be produced and accumulated mostly by lactic acid gram-positive bacteria in natural fermentations (Alvarez and Moreno-Arribas; Barbieri et al.; Capozzi et al.). Because BAs are thermostable, they won't be destroyed if they already exist in food before it is pasteurised, cooked, etc. (Ruiz-Capillas and Herrero).Since fermentation typically promotes the production of BA, it is vital to optimise processing conditions, including raw material quality, starter culture growth-friendly temperatures, microorganism control, and the right amounts of additives, such as sugar, salt, and antimicrobial agents, in order to limit the accumulation of BA (Ruiz-Capillas and Herrero; Gardini et al.; Turna et al.). In one instance, the production of excess BAs in meat was connected to poor raw material quality and preservation circumstances, including freezing or thawing time and temperature, as well as administering in the presence of bacteria that exhibit decarboxylase activity (Ruiz-Capillas and Herrero; Maijala et al.; Durlu-Özkaya et al.). The make-up and amounts of BAs generated are influenced by the quality of the raw materials, according to the study (Bover-Cid et al.).

3.2 : Toxicological effects of BAs:

BAs have a major impact on many natural biological processes, including cell formation and differentiation, gastric acid secretion, blood pressure and body temperature regulation, synaptic transmission, and allergy response (Tofalo et al.). Nevertheless, high quantity of BA is linked with many unfavorable health impacts, such as respiratory distress, nausea, hot flushing, sweating, headache,

bright red rash, blood pressure changes, diarrhoea, burning sensations in the mouth, and
18 hypertension (Tofalo et al.; Gardini et al.). As the hazardous dose is highly dependent on the effectiveness of the detoxifying systems, which might differ from person to person, it is tough to pinpoint the toxicity thresholds for BAs. Histamine, tyramine, and phenylethylamine are examples of BAs that can result in food poisoning when the capability of amine-metabolizing enzymes is oversaturated and certain inhibitors interfere with metabolism (Park et al.). Thus, the concentration of a single BA should not be the
2 only emphasis; other factors that should be considered the quantity of food consumed, the presence along with concentration of additional amines in the meal (Ten brink et al.). Because of the intensity of the symptoms they cause, histamines and tyramines are recognized as the most poisonous of all the BAs. The current threshold limits for histamine are derived from a small number of human investigations that include both sensitive and healthy subjects. With a histamine level 25–50 mg per individual each meal, negative effects are not anticipated in healthy individuals. However, even a modest portion of histamine intake (5–10 mg) from food might have serious negative health effects in people with histamine sensitivity (Santos). Since tyramine intoxication was first noticed following the intake of cheese tainted with elevated tyramine levels, it is often indicated to as the "cheese effect" or "cheese influence" (Barbieri et al.; Wójcik et al.). It has been proposed
3 that food containing 90-100 mg/kg of histamine, 105–800 mg/kg of tyramine, and 25-30 mg/kg of phenylethylamine is harmful (Ten Brink et al.). Table 1 provides a summary, recommended toxicological citing values for the health threats associated with BA in foodstuffs.

Table 1: Data reported and recommended levels of BAs found in food is provided.

Name of the amine	Dose suggested (mg/kg)	Toxic dose (mg)
Tyramine	100-700	>600
Histamine	100	>50
β-phenylethylamine	30	Not recorded
Reference	[24,30]	[8]

3.3: BAs' presence in several fermented foods:

Soybeans, fish, and fruits and vegetables had the highest amount of BAs among the three classes of fermented foods, as represented in Table 2. According to the approved risk assessment for histamine, tyramine, as well as phenylethylamine values in food proposed for human consumption, observations regarding fermented foodstuffs which surpassed the toxic doses of tested BA's were discovered.

3.3.1 : Fermented soybean foods:

Bacteria that produce BAs and dietary amino acid BAs are abundant in fermented soybean products. Common microorganisms that can produce BAs in fermented soy meals include Clostridium, Bacillus, Lactobacillus, Enterobacteriaceae, and Pseudomonas (Park et al.). Soy sauces, natto, Korean (doenjang), Japanese (miso), Indonesian (tempeh) and Chinese (doubanjiang, douchi) fermented soybean pastes are a few common fermentation-produced soybean foods (Mah et al.). These foods are consumed in particular families, particularly in cultures of Asia, and are often utilised in a different range of processed items (Mah et al.; Turna et al.). According to the literature, the majority of fermented soybean foods have BA levels that are within safe limits. However, certain research have indicated that soy sauces as well as fermented soybean pastes may have levels of BA that are higher than what is considered safe for human consumption. Fermented soybean products vary widely in the amount of various BAs. Given the highest levels of BA that have been documented, it appears highly probable that eating fermented soybean products could occasionally result in food intoxication. Maximum soybean products have maximum histamine levels that are greater than the recommended hazardous dose. Phenylethylamine and Tyramine have been uncovered in substantial amounts in soy food products. BA with highest concentration of all the soybean foods examined here is shown in Table 2. Bacillus starter cultures and Pediococcus pentosaceus strains have been used in numerous studies to reduce the growth of BA in fermented soy bean products (Mah et al.; Park et al.; Su-Yeon et al.).

3.3.2 : Fermented fish products:

Prior exposure evidence suggests that fermented fish items involve all eight of the BAs addressed here, including histamine, tyramine, phenylethylamine, and tryptamine, even though histamine is well-studied in fish products (Sivamaruthi et al.). Examples of fish products after fermentation as salty fish, Malaysian fish (ikan pekasam), fish sauces, and Korean fermented fish items (sand lance and anchovy sauces, prawn, clam, and squid pastes) (Sivamaruthi et al.). Escherichia coli, Streptococcus, Lactobacillus, and Clostridium perfringens are mostly found bacteria have been demonstrated for the production of BA in fish. According to several exposure reports, the amounts of histamine, tyramine, and phenylethylamine were higher than the advised hazardous threshold in some fermented fish products. This was particularly true for some fermented fish products (Table 2). Anchovy and sand lance sauces also have high levels of histamine and tyramine (Moon et al.; Koral et al.). More histamine are seen as signs of spoiling in fish products (Biji et al.). Fish sauces have more amounts of histamine and other BAs, but because of the low average consumption quantity, they may not pose serious health problems (Prester; Turna et al.; Jiang et al.). However, excess eating of fish sauces containing high amounts of BA is not recommended since it may have adverse health effects, especially when mixed with different fermented foods and drinks (Prester; Hua et al.). Fish and fish sauces might have raised BA quantity, yet fish sauces are claimed for having greater BA amount compared to other fermented fish products (Sivamaruthi et al.). However, the components that lead to the production of BA in fermented fish have been clearly identified in the literature (Sivamaruthi et al.; Ezzat et al.).

3.3.3 : Fermented fruits and vegetables:

In most of the cultures storing fruits and vegetables in Fermenting them is an ancient method. Classic fruits and vegetables are often fermented such as cucumber, Brussel sprout, and broccoli, among others, white cabbage, cauliflower, olives, beetroot and radish, pepper, carrot, pumpkin, also celery, garlic, kimchi, and mustard (Świder et al.; Paramithiotis et al.). According to reports, the main BAs are in fermented vegetables include tyramine, cadaverine, and histamine (Świder et al.)(Table 2). High levels of BA were found in kimchi in multiple tests; the maximal histamine levels were 9.5 times higher than the recommended lethal dose. The species that has been found to produce large quantities of tyramine in kimchi is Lactobacillus brevis (Jin et al.).

Table 2: Highest amount of BAs found inside fermented food items

Name of the fermented foods	Maximum exposure of BA reported (mg/kg)			Reference
	Tyramine	Histamine	β-phenylethylamine	
Soybean based foods				
Soy sauce	794.3	398.8	121.6	[17,32]
Natto	300.2	457	51.5	[17,32,21]
Miso	95.3	221	42	[21,32]
Doenjang	6616	2795	8704	[17,32]
Gochujang	126.8	59	24.8	[17,32]
Fish fermented product				
Fermented salted fish	62.6	421.7	9.2	[16,32]
Fish sauce	469	783.9	7.7	[14,32]
Ikan pekasam	110	73.9	37.2	[10,32]
Fermented fish paste	1002.9	368.6	152	[13,32]
Fermented vegetables				
Fermented vegetables	177.7	138.1	31.5	[8,32]
Kimchi	357.9	947.3	23.9	[20,32]

Fermented fruits	86.8	72	6.3	[20,32]

4. Conclusion:

Various adverse health impacts, such as neurological, digestive, cardiovascular, and respiratory diseases, are linked to exposure to elevated BA levels. Various quantities of BAs found in fermented foodstuffs. However, histamine as well as tyramine are regarded as more toxic food due to the intensity of their harmful effects. Research suggests that certain fermented foods, like kimchi, fish sauce, and soy sauce, can build up high amounts of BA, some of which are higher than the recommended harmful limits. But my main goal of the literature review was to draw attention to the possible amounts of the BAs in fermented food. To highlight the significance of the occurrence of BAs in fermented food products and also attempted to compare highest amounts recorded with recommended hazardous thresholds. Although there have been reports of many fermented foods having high concentrations of these BAs, it is unknown what possible health risks these levels may provide. As some individuals may be more vulnerable to its toxicity, Consumers, food manufacturers, and medical professionals would all benefit from knowing the intensity of BA in fermented foods.

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