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Proteolysis and Amino Acid Catabolism in The Formation of Umami Flavor in Shrimp Paste : A Narrative Review

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Abstract: *Shrimp paste (Acetes sp.) develops its characteristic umami flavor and aroma through biochemical changes during fermentation. This study reviews previously published research on proteolysis, amino acid metabolism, glutamate formation, and volatile compounds in shrimp paste. The findings indicate that proteases and peptidases break down shrimp proteins into peptides and free amino acids, including glutamate, which contributes to umami flavor. Amino acid catabolism also produces volatile compounds, such as 3-methylbutanal, 2-methylbutanal, phenylacetaldehyde, and benzaldehyde, which contribute to aroma. Previous studies reported that increasing salt concentrations from 2% to 8% and 14% reduced glutamate levels from 13.68% to 9.01% and 5.70%, respectively. These findings highlight the role of microbial activity and fermentation conditions in regulating proteolysis, glutamate accumulation, and volatile compound formation. Overall, shrimp paste flavor results from interactions between protein degradation, amino acid metabolism, and microbial activity.*

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Introduction

Shrimp paste (Acetes sp.) is a traditional Indonesian fermented condiment with a distinctive flavor and aroma. These characteristics are formed through various biochemical changes during fermentation, involving the activity of microorganisms and enzymes on the raw material components. Shrimp protein is a crucial substrate in this process and undergoes hydrolysis by protease enzymes into peptides and free amino acids, which act as flavor precursors. Fermentation with salt is known to produce a savory flavor through the breakdown of shrimp components by protease activity and affects the glutamic acid content of the shrimp paste product (Murti et al., 2021).

Free amino acids formed through proteolysis then undergo various metabolic reactions that contribute to flavor formation. Glutamate is a key component in producing the umami sensation, while further amino acid metabolism can produce various aroma-forming volatile compounds. Research on shrimp paste has shown that changes in salt concentration and fermentation time are associated with changes in the bacterial community and flavor profile, with 29 volatile compounds identified and showing correlation with the bacterial community during fermentation (Huang et al., 2024). The addition of halophilic bacteria as a starter has also been reported to affect sensory characteristics and increase several volatile compounds, such as benzaldehyde, phenylacetaldehyde, and 3-methylbutanal, which contribute to the aroma character of shrimp paste (Yu et al., 2022).

The formation of aroma and flavor in shrimp paste is thus the result of the interaction between protein degradation, amino acid metabolism, microbial activity, and fermentation conditions. Salt concentration is an important factor because it can influence the activity of microorganisms and proteolytic enzymes, thus impacting glutamic acid formation and the organoleptic characteristics of shrimp paste. Murti et al. (2021) showed that increasing salt concentration from 2% to 8% and 14% caused glutamic acid levels to decrease from 13.68% to 9.01% and 5.70%, respectively, while organoleptic characteristics also experienced changes, especially in taste and texture parameters. Understanding the relationship between proteolysis, glutamate formation, amino acid catabolism, and volatile compounds is necessary to explain the mechanism of formation of the characteristic aroma and flavor of rebon shrimp paste.

Based on this, this study aims to elucidate the mechanisms of aroma and flavor formation in rebon shrimp paste through the stages of protein degradation, amino acid and glutamate formation, amino acid catabolism, and volatile compound formation during fermentation. The study also links these biochemical changes to the organoleptic characteristics of shrimp paste as the final fermentation product. This approach is expected to provide a more systematic understanding of the relationship between microbial activity and protein component metabolism in the formation of rebon shrimp paste's flavor characteristics.

Research Methods

This study used the Narrative Literature Review (NLR) method to examine the fermentation process of rebon shrimp paste, particularly the formation of aroma and flavor. The literature was searched based on the topics of proteolysis, amino acids, glutamate, volatile compounds, and local fermentation spices. Relevant literature was then analyzed descriptively to examine the relationship

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between microbial activity and protein metabolism during fermentation. The results of the study were then linked to the organoleptic characteristics of rebon shrimp paste, including appearance, odor, taste, and texture.

Results and Discussion

Microbial Protease Enzymes

Rebon shrimp (Acetes sp.) is the main raw material for shrimp paste, containing protein that acts as a substrate in the proteolysis process during fermentation. During the shrimp paste-making process, the protein from rebon shrimp undergoes degradation into compounds with a lower molecular size through the activity of hydrolytic enzymes, especially proteases. Proteolysis is one of the main reactions during shrimp paste fermentation, which is related to the formation of components that make up the taste and aroma (Herlina & Setiarto, 2024). Rebon shrimp protein is the initial substrate that is gradually hydrolyzed during fermentation, producing peptides and subsequently free amino acids as important products of the proteolysis process in shrimp paste.

Proteases are hydrolytic enzymes that play a crucial role in the proteolysis pathway during shrimp paste fermentation. These enzymes catalyze the breakdown of peptide bonds in proteins, enabling their degradation into compounds with simpler molecular sizes. Proteases produced by microorganisms have the advantage of being produced in large quantities and are generally secreted extracellularly, allowing them to interact directly with proteins in the fermented raw materials. This protease activity is the initial step in the proteolysis pathway, providing essential precursors for flavor formation in fermented spices (Istiadi et al., 2026).

In Indonesian shrimp paste fermentation, the dominant bacterial communities include Tetragenococcus, Aloicoccus, Atopostipes, Alkalibacillus, and Alkalibacterium, whose presence is associated with various biochemical changes during fermentation (Helmi et al., 2022). These microorganisms produce extracellular enzymes, including proteases and aminopeptidases, which play a role in the degradation of fermented raw material proteins into compounds with simpler molecular sizes. This enzymatic activity supports the proteolysis pathway by gradually breaking down peptide bonds in proteins. Thus, the presence of protease-producing bacteria plays a crucial role in providing precursors needed for subsequent metabolic stages during fermentation.

Protein hydrolysis during fermentation occurs through the gradual cleavage of peptide bonds by protease enzymes. Proteases break down the bonds connecting amino acids in polypeptide chains, allowing large proteins to be converted into shorter peptides, ultimately producing free amino acids. These stages demonstrate that proteolysis gradually converts shrimp protein into simpler molecules, namely peptides and free amino acids, which are then available for further biochemical changes during fermentation.

In the fermentation of rebon shrimp paste, microbial protease activity plays an initial role in flavor formation through the proteolysis pathway. The protein hydrolysis process that occurs during fermentation produces compounds resulting from protein degradation, which then serve as substrates for various subsequent metabolic reactions (Surya et al., 2023). The availability of these proteolysis compounds contributes to the formation of the components that make up the distinctive flavor and aroma of shrimp paste. Therefore, proteolysis is a crucial link between protein breakdown and amino acid metabolism, which plays a role in flavor formation in subsequent stages.

Formation of Amino Acids and Glutamate

The formation of free amino acids is a crucial biochemical change during fermentation, as these compounds contribute not only to the nutritional value but also to the characteristic flavor of shrimp paste. In general, proteolysis during food fermentation is a key step in the production of amino acids and peptides, which contribute to flavor.

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Protease enzymes break peptide bonds in proteins, producing smaller peptides. Peptidases then continue the hydrolysis to form free amino acids. Microorganisms that develop during fermentation can contribute to this process through the production of proteolytic enzymes. Research on shrimp paste shows that fermenting microorganisms, including lactic acid bacteria and yeast, play a role in chemical changes during fermentation. Recent research indicates that spontaneous fermentation of shrimp paste involves a consortium of microorganisms that contribute to the formation of glutamate and GABA.

The formation of free amino acids in shrimp paste is also influenced by fermentation conditions, particularly salt concentration. Salt controls the growth of microorganisms during fermentation, thus determining the activity of enzymes and microbes involved in protein hydrolysis. Murti et al. (2021) explained that fermented shrimp paste produces a savory flavor because the shrimp components are broken down by protease enzyme activity. Higher proteolytic activity results in greater amino acid production, while excessively high salt concentrations can inhibit proteolytic enzyme activity.

This is evident in research by Murti et al. (2021), where the glutamate content of shrimp paste decreases with increasing salt concentration. Shrimp paste with 2%, 8%, and 14% salt added produced glutamate levels of 13.68%, 9.01%, and 5.70%, respectively. High salt concentrations can reduce the activity of proteolytic bacteria in breaking down proteins into amino acids, including glutamate. Therefore, the amount of salt not only determines the safety and shelf life of shrimp paste but also influences the formation of flavor compounds by regulating proteolytic activity during fermentation.

Among the various amino acids formed, glutamic acid (glutamate) plays a crucial role in the characteristic flavor of shrimp paste. Glutamate is one of the dominant amino acids found in protein-based fermented products. In shrimp paste, glutamate, along with aspartic acid, is an important component that contributes to the savory or umami taste. A review of shrimp paste published in the Journal of Ethnic Foods states that the four dominant amino acids in shrimp paste are glutamate, aspartate, arginine, and leucine, with glutamate and aspartate playing a key role in the characteristic flavor of fermented shrimp paste.

Glutamate formation can be understood as the end result of a series of protein degradation processes during fermentation. Shrimp protein is first hydrolyzed into peptides, which are then broken down into free amino acids. Glutamate can be derived from the breakdown of proteins containing glutamate residues or through the conversion of compounds related to glutamine metabolism by microorganisms. In general, in food fermentation, the activity of microorganisms and enzymes during fermentation can increase the amount of free glutamate due to protein hydrolysis. Therefore, the increase in glutamate in shrimp paste depends not only on the initial protein content but also on the activity of enzymes and microorganisms during the fermentation process.

Glutamate then contributes to the umami taste through its interaction with the taste receptor system. In its free form, glutamate is the main component that gives a savory sensation to various fermented foods. Research on shrimp paste shows that an increase in glutamate is associated with an increase in umami taste characteristics, while research on other fermented products also shows that glutamate and aspartate are the main amino acids that contribute to umami intensity. For example, found that glutamic acid was the amino acid with the highest concentration in over-fermented tempeh powder and associated it with the savory or umami taste character. In the study, glutamate levels reached 5.50%, 5.05%, and 5.43% at drying temperatures of 55, 60, and 65°C, respectively, and glutamate is considered an important component in the formation of umami taste.

Recent research has further strengthened the relationship between microbial activity, free amino acids, and umami taste in fermented shrimp paste. Yu et al. (2022) reported that the use of halophilic bacteria as a starter in fermented shrimp paste can increase umami-related amino acids, especially glutamate and aspartate, and improve the product's sensory characteristics. Thus,

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glutamate formation in shrimp paste can be viewed as the result of an interaction between the protein content of the raw material, proteolytic enzyme activit y, fermentation microorganisms, fermentation time, and salt concentration. The accumulation of free glutamate, along with other flavor-contributing amino acids, then becomes one of the main factors that shape the distinctive savory taste of shrimp paste.

Amino Acid Catabolism

Shrimp paste is a fermented product that undergoes various biochemical changes due to the activity of microorganisms and enzymes during the ripening process. According to Daroonpunt et al. (2016), during fermentation, the protein contained in shrimp is broken down into simpler components in the form of peptides and free amino acids. This process occurs due to the activity of protease enzymes derived from the raw materials and fermentation microorganisms.) Protein hydrolysis in shrimp paste during fermentation is influenced by the activity of endogenous proteases and microbes that produce short-chain peptides and free amino acids that play a role in flavor formation. In line with this, Ali et al. (2020) stated that shrimp paste fermentation occurs through the activity of hydrolytic enzymes and endogenous microbes that are able to degrade complex compounds from raw materials into simpler forms. The results of this protein degradation form the basis for amino acid metabolism, including transamination and deamination reactions during shrimp paste fermentation.

After shrimp protein undergoes hydrolysis into peptides and free amino acids, one of the nitrogen metabolism reactions that can occur is transamination. In shrimp paste fermentation, the transamination reaction allows for changes in the amino acid composition resulting from protein degradation into various new metabolites. According to Guo & Berglund (2017), transamination is the process of transferring an amino group (-NH_2) from a donor amino acid to an acceptor keto compound, resulting in the production of new keto acids and amino acids. Transaminase, or aminotransferase, is an enzyme that plays a role in the transfer of amino groups from an amino donor to an acceptor molecule in an amino acid metabolism reaction. The transamination mechanism involves the vitamin B6-based cofactor pyridoxal phosphate (PLP), which helps carry the amino group during the transfer process. This reaction is also associated with changes in amino acids resulting from fermentation, especially the formation of glutamate, which is an important component in flavor formation. This is in accordance with research by Ali et al. (2020) that the dominant non-essential amino acids in shrimp paste include glutamic acid, aspartic acid, and alanine.

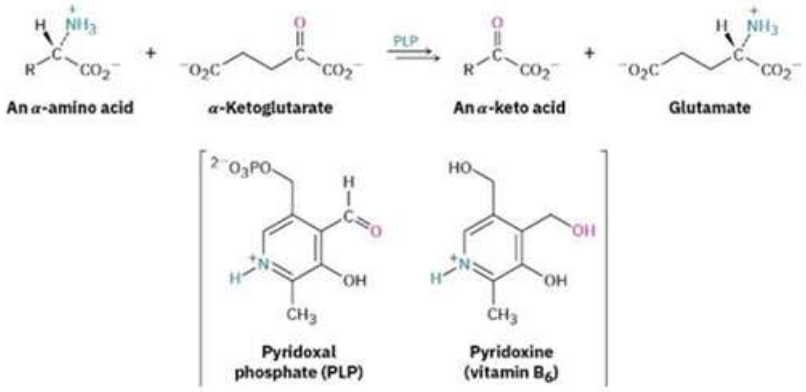


Figure 1.The mechanism of transamination reactions in amino acid metabolism. Source: Organic Chemistry LibreTexts

The figure shows that the amino group of an amino acid can be transferred to α-ketoglutarate through the help of the aminotransferase enzyme, resulting in α-keto acid and glutamate (Guo &

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Berglund, 2017). In shrimp paste products, the formation of glutamate through amino acid metabolism plays a role in increasing the umami taste. This is in line with Daroonpunt et al. (2016) that glutamic acid is one of the dominant amino acids in fermented shrimp paste products. The high glutamate content plays a role in providing the umami taste characteristics in fermented fishery-based products. Thus, transamination is an important mechanism that connects the protein degradation process with the formation of flavor components in rebon shrimp paste.

In addition to transamination, some amino acids (glutamate) formed during fermentation can undergo deamination reactions. According to Martono et al. (2016), deamination is the process of releasing amino groups into keto acids and ammonia (NH_4^+) during the fermentation process.

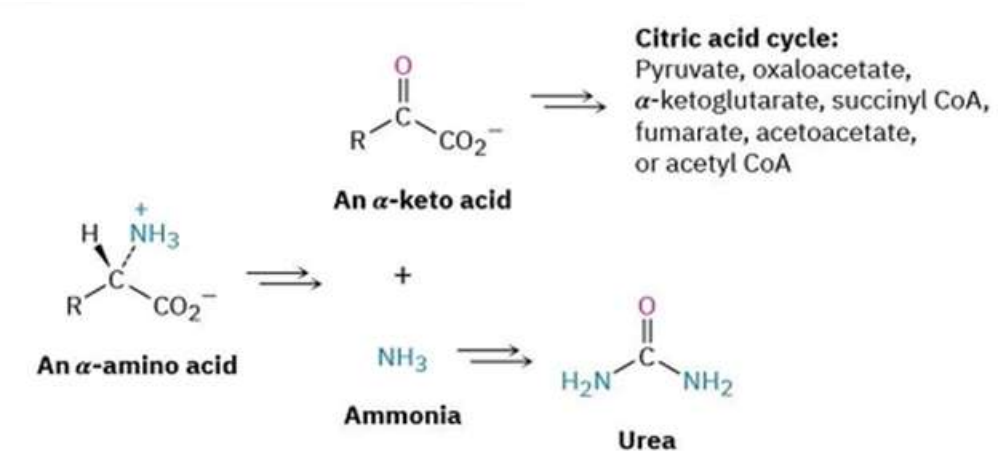


Figure 2.The mechanism of deamination reactions in amino acid metabolism. Source: Organic Chemistry LibreTexts

The image shows that the amino group of an amino acid molecule is released through the deamination process, producing keto acid compounds and ammonia (NH_4^+) (Martono et al., 2016). This process illustrates the subsequent changes in amino acids resulting from protein degradation during fermentation, where the release of nitrogen groups leads to the formation of simpler nitrogen compounds. According to Helmi et al. (2022), during the ripening process, degradation products and volatile base compounds such as ammonia are formed. Furthermore, Ali et al. (2020) explain that various volatile compounds such as ammonia formed during fermentation contribute to the distinctive aroma of shrimp paste.

Formation of Volatile Compounds and Aroma

Amino acid catabolism during fermentation can produce various compounds that play a role in shaping the aroma character of the product. One group of these compounds is aldehydes, which can be formed through the degradation of aromatic amino acids, deamination, decarboxylation, and subsequent reactions during fermentation. The activity of enzymes and microorganisms helps decompose amino acids into various volatile compounds, such as phenylacetaldehyde, 3-methylbutanal, 2-methylbutanal, and benzaldehyde. These compounds can impart bitter almond, fatty, and fruity aroma characteristics to fermented products (Pawestri et al., 2025). The formation of these compounds indicates that amino acid catabolism is one of the pathways that plays a role in producing volatile components that form aroma.

In addition to aldehydes, amino acid metabolism products can undergo further changes into other compounds that contribute to aroma character. Metabolic reactions during fermentation involve various enzyme activities that convert compounds resulting from amino acid degradation into metabolites with volatile properties. One reaction related to these compound changes is the oxidation of alcohols to aldehydes that can involve the enzyme Alcohol Dehydrogenase (ADH), while aldehydes can then be converted to carboxylic acids by Aldehyde Dehydrogenase (ALDH)

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(Situmorang et al., 2025). This pathway indicates the existence of further changes between groups of compounds during metabolism, although the source has not specifically explained the type of volatile alcohol derived from amino acid catabolism in fermented spices.

The formation of volatile compounds during fermentation is also influenced by the activity of microorganisms that play a role in the metabolism of food components. In shrimp paste fermentation, the microbial community that develops during the maturation process is associated with changes in metabolite profiles and the formation of volatile compounds. The activity of microorganisms and enzymes during fermentation can produce various compounds that contribute to the product's distinctive aroma. Fermentation conditions, such as raw materials, type of microorganism, salt content, temperature, humidity, stirring, and fermentation time, can influence the composition of the volatile compounds formed, resulting in different aroma characteristics (Pawestri et al., 2025).

Various volatile compounds formed during the fermentation process further contribute to the aroma character through their volatility properties and sensory detection thresholds. Volatile compounds have the ability to evaporate easily and some have low sensory detection thresholds, so they can influence aroma even at certain concentrations. Product aroma is the result of the interaction of various volatile compounds with different types, concentrations, and proportions. Differences in the composition of these compounds can produce a variety of aroma characters, such as sweet, floral, spicy, fruity, woody, and earthy (Nalurita et al., 2026). Thus, the formation and accumulation of volatile compounds during fermentation contribute to the resulting aroma and flavor character, while differences in raw materials, microorganisms, and fermentation conditions can cause differences in sensory characteristics in each fermented product.

Application in Local Fermented Spices

Shrimp paste is a local fermented spice whose flavor characteristics are influenced by microbial metabolic activity during the fermentation process. Volatile compounds formed during fermentation contribute to the distinctive aroma and can influence sensory perception of shrimp paste. The flavor characteristics of shrimp paste are also influenced by fermentation conditions, temperature, humidity, type of microorganism, salt content, raw materials, stirring, and fermentation duration. These differences in conditions can cause variations in the quality, taste, and aroma of shrimp paste during fermentation (Pawestri et al., 2025).

Based on research by Murti et al. (2021), the organoleptic test of rebon shrimp paste was influenced by differences in salt concentration. The results of the panelist organoleptic test of rebon shrimp paste based on differences in salt concentration included parameters of appearance, odor, taste, and texture. The results of the panelist assessment of these parameters are presented in the following figure.

Table 2 Organoleptic of Rebon Shrimp Paste

Parameter	A	B	C
Appearance	8.93±0.30^{a}	8.93±0.30^{a}	8.26±0.90^{b}
Smell	8.40±0.90a	8.20±0.90^{a}	8.00±1.00^{a}
Taste	8.60±0.80^{a}	8.00±1.00^{a}	7.40±0.80^{b}
Texture	8.93±0.30^{a}	8.60±0.80^{ab}	7.13±1.40^{b}

Information: different letter in same row indicate a significant difference

Figure 3 Organoleptic Panel Results of Rebon Shrimp Paste (Source: Murti et al. (2021)

According to research by Murti et al. (2021), the results of organoleptic tests on the appearance parameter showed that rebon shrimp paste with a salt concentration of 2% and 8% obtained the same value, namely 8.93, while the 14% concentration obtained a value of 8.26. The resulting shrimp paste has a clean appearance with a reddish brown color, while the 30-day

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fermentation process also affects the color change to a darker shrimp paste. In the odor parameter, the three salt concentrations did not show significant differences in values of 8.40; 8.20; and 8.00. The resulting aroma has the characteristics of shrimp paste because during fermentation there is activity of microorganisms that produce volatile compounds that form the aroma.

The taste parameters showed that Murti et al. (2021) obtained values of 8.60 and 8.00 at 2% and 8% salt concentrations, respectively, while the 14% concentration had a lower value of 7.40. The decrease in value is related to the increasingly salty taste due to the use of higher salt concentrations, while the distinctive taste of shrimp paste is influenced by amino acids during fermentation. The texture parameter showed the highest value of 8.93 at a 2% salt concentration with compact shrimp paste characteristics, while the 14% concentration obtained a value of 7.13 with a dense but less compact texture. The texture of shrimp paste is influenced by the drying process, pounding, water content, and the addition of salt which can bind water, thus affecting the cohesiveness of the product.

Conclusion and Recommendation

Fermentation of shrimp paste begins with proteolysis, the breakdown of protein into peptides and free amino acids. Free amino acids contribute to the formation of glutamate, which imparts an umami flavor, and then undergo transamination and deamination to produce flavor metabolites. Further metabolism produces volatile compounds that contribute to the shrimp paste's distinctive aroma. Organoleptic results showed that the shrimp paste was reddish-brown in color, had a distinctive shrimp paste odor and flavor, and had a compact texture. As the salt concentration increased, the preference for taste and texture tended to decrease, while the aroma did not significantly differ.

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