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The Indonesian Fermented Food Product *Terasi*: History and Potential Bioactivities

***Asep A. Prihanto [1,2,3,4], and Hidayatun Muyasyaroh [2,3]**

[1]Department Fishery Product Technology, Faculty of Fisheries and Marine Science, Brawijaya University, Jl. Veteran, Malang, 65145, East Java, Indonesia
[2]BIO-SEAFOOD Research Unit, Brawijaya University, Jl. Veteran, Malang, 65145, East Java, Indonesia
[3]Halal Thoyib Science Center, Brawijaya University, Jl. Veteran, Malang, 65145, East Java, Indonesia
[4]Coastal and Marine Science Center, Brawijaya University, Jl. Veteran, Malang, 65145, East Java, Indonesia

***Corresponding Author**: Asep A. Prihanto **Email**: asep_awa@ub.ac.id

ABSTRACT

Terasi is a fish/shrimp fermentation product native to Indonesia and is produced using bacteria generated from fish or shrimp. Also known as shrimp paste, it has a long history on the island of Java, as well as other regions that employ slightly varied processes and ascribe various names to this edible compound. The emergence, history, processing, and characterization of *terasi* are explained in this manuscript, following its extensive applications as a main seasoning in various dishes. Furthermore, potential bioactivity of this product and its derived microorganisms are discussed along with the possibility of their usage as bioactive remedies for human health.

Keywords: Bioactivity; fermentation; Indonesia; *terasi*.

Correspondence:
Asep A. Prihanto
Department Fishery Product Technology, Faculty of Fisheries and Marine Science, Brawijaya University, Jl. Veteran, Malang, 65145, East Java, Indonesia
Email: asep_awa@ub.ac.id

INTRODUCTION

Fermented seafood is a common condiment for foods in Indonesia. *Terasi* is fish and/or shrimp fermented product primarily available in paste form. *Terasi* is a condiment-like product rich in glutamate. Hence, this product usually uses as a flavor enhancer. Based on the Indonesian National Standard (SNI, 1992), *terasi* is classified as a flavor enhancing product with specific odor formed via addition of sodium chloride. Processing for *terasi* involves washing of raw materials (fish and shrimp), drying, milling, and forming [1]. The drying and milling are performed repeatedly. The *terasi* fermentation process occurs spontaneously during the entire process [2].

Terasi is fermented with or without the addition of salt. Based on the raw material, *terasi* is divided into two types, namely shrimp and/or fish paste. *Terasi* is reddish-brown to black depending on the raw material used and existing natural microbes present during fermentation. Shrimp-based *terasi* is mainly red, while fish-based *terasi* is typically dull gray. Consumers often prefer shrimp- versus fish-based *terasi* due to appearance [3], as fish paste is less attractive to consumers due to its color. Hence, coloring agents are often added during processing [4, 5].

The freshness of raw material affects the characteristics of *terasi*. Fresh shrimp paste has a strong and preferably characteristic odor, due to the released volatile compounds. *Terasi* flavoring has been shown to increase consumer satisfaction and appetite [6, 7]. Fresher and more uniform raw materials result in higher quality shrimp paste being obtained.

As fermentation results in a unique flavor and aroma, it is a critical factor during *terasi* production [8]. Fermentation involves decomposition of complex biomolecules under controlled conditions. Typical characteristics of shrimp paste include shrimp paste specific aromas caused by the degradation of proteins and fats that produce carbonyl compounds, fatty acids, ammonia, amines, and simple sulfur compounds such as sulfides, mercaptans, and disulfides [9]. Besides the high amino acid content, glutamate causes shrimp paste to be perceived as a seasoning [10]. In addition to the aforementioned characteristics, the quality of shrimp paste is determined by the presence or absence of contaminants, such as insects and other foreign materials [1]. *Terasi* has been used for centuries as a flavor enhancer in various types of Indonesia cuisines, and has played an essential role in the gastronomy originating (primarily) from mainly Java Island.

SHRIMP FERMENTATION INTERNATIONALLY

Shrimp fermented paste is widely used as a condiment in various Asian countries, as evidenced by the multitude of various designations for shrimp paste. Fermented shrimp paste is also recognized as a culinary staple in countries such as in Bangladesh (termed *Nappi*), Thailand and Cambodia (*Kapi* or *Belacan*, respectively), Malaysia and Brunei, (*Mamrouc* or *Mamtom,* respectively), Vietnam, Myanmar (*Ngapi*), China (*Shajiang*), and Korea (*Saewoojeot*) [11-13].

Each country has a specific method of generating fermented shrimp/fish. *Kapi* in Thailand is a fermented product made from shrimp mixed with salt, typically at a ratio of 20% and 30% (w/w), then dried in the sun for 1–2 days. Furthermore, it is homogenized to form a paste and fermented for 7–10 days at room temperature. The final steps include fermentation followed by packaging. It is then stored at room temperature for six months until its distinctive taste and aroma have appeared. There are two types of *Kapi*: *Kapi Ta Dam* (black), and *Kapi Ta Deang* (red), both are grouped according to the raw material of the shrimp species [13].

In Japan, fermented shrimp or other small marine animals are called *shiokara*. In Bangladesh, Myanmar, Indonesia, and the Philippines, shrimp fermented paste is classified as semisolid. In Malaysia and Brunei, *belacan* is processed by mixing shrimp with salt up to 15%–20% and then stored in a plastic bag called *guni*. The dough is then fermented at 30°C–32°C overnight and packed using mostly bamboo. The mixture is sun-dried for reducing water content, then milled.

In Korea, *saewoojeot* is available in two forms, shrimp sauce and shrimp paste. The production process involves salting, fermentation, and storing for an extended period. The addition of salt in *saewoojeot* preparations is approximately 30%–40%. *Saewoojeot* requires fermentation for 4–5 months [14]. *Bagoong* in the Philippines is made by frying a mixture of shrimp or fish with salt then fermented for 3–12 months at room temperature. The final product is a paste that is usually added to foods for flavor enhancement [15].

HISTORY OF *TERASI* IN INDONESIA

Terasi existed in Indonesia even before the country was established and was used before the rise and fall of Cirebon and Sunda kingdoms located on Java Island.

Terasi is believed to be derived from the word "*asih,*" which was then given the affix "*ter*." In Sundanese, the word "*asih*" means admiration, and "*ter*" means most, thus their combination results in a word meaning the most admired. This seasoning which was created by Prince Walangsungsang Cakrabuana (The Founders of Cirebon Sultanate, 1430–1479) [16, 17]. *Terasi* experienced popularity because of the king of the Galuh Kingdom (Kingdom of East Sunda); *terasi* stock in the Galuh Royal Palace was supplied from Cirebon [17]. The *Carita Purwaka* manuscript indicated that the Cirebon kingdom had stopped paying tax in the form of salt and shrimp paste to the Sundanese kingdom. As a result, the King of Galuh launched a threat to the kingdom of Cirebon, and this account was strengthened by the *Mertasinga* manuscript, which stated that King of Galuh's anger toward Cirebon peaked after Cirebon deliberately stopped delivering salt and *terasi*. As a consequence, the King of Galuh stormed Cirebon kingdom.

In Sundanese culture, the culinary trade was the most significant contributor to the country's foreign exchange. *Terasi* payment disobedience by Cirebon caused the destruction of culinary business in the Sunda Kingdom. Hence, salt and shrimp paste were the key to the delicacy of processed foods, especially staples. At that time, there was no widely available flavoring other than shrimp paste. The *terasi* embargo incurred a significant influence on the survival of the Sunda Kingdom, and it is speculated that the shrimp paste embargo activity that Cirebon launched against King Galuh was one of the main causes of the fall of this kingdom.

TERASI TYPE IN INDONESIA

The centers of shrimp paste production in Indonesia are primarily located in Purworejo, Pasir Sakti District, East Lampung Regency, South Bangka Regency, Lombok, Madura, Puger, Tuban, and Cirebon. *Terasi* is produced in almost all areas of the Northern coast of Java Island, and some of the types are described below.

Belitung-style Terasi

The Belitung Regency boasts one of the superior regional *terasi* products, commonly called *belacan* in the local language. *Belacan* is one of the traditional products produced by the coastal inhabitants in the Belitung coastal villages. Small shrimp or *calok* (*Atya* sp.), are used as raw material for this product. *Atya* sp. is fermented with the addition of crystalline salt to produce a product with a specific aroma and flavor. The centers for *belacan* production are located in villages within the Sijuk and Tanjungpandan districts of Belitung Regency. The important procedure for making shrimp paste in the Sungai Padang Village of the Sijuk Belitung District is sorting prime small shrimp (*Atya* sp.) into packaging and fermentation, as can be seen in figure. A unique process for *terasi* production in Belitung entails burying *Atya* sp. in beach sand for two days. This method is carried out to help speed up the process of softening and destroying the shrimp as a result of fermentation of spontaneous anaerobes in the sand. Belitung-style *terasi* is packed in woven pandanus leaves measuring 10 cm in diameter and ~5 cm in height. The weight of each package is approximately 250 grams [18].

Toboali Terasi

Toboali *terasi* is a Bangka *terasi* produced in the Toboali area in South Bangka. It is already famous for its delicious and distinctive taste without preservatives or coloring agents. The raw material used for making shrimp paste is small white shrimp ranging from 1–2 cm in length, and salt. In making shrimp paste, salt has the dual function of adding flavor to shrimp paste and is a preservative (with a size of 200g / kg). Toboali *terasi* has a reddish color, distinctive shrimp taste, and is not bitter.

Lombok Terasi

There are three variations of Lombok *terasi*: shrimp, fish, and mixed. Each type entails their peculiarities. For the people of Lombok, shrimp paste is usually used to make *plecing kale* and chicken *Taliwang* and *sumbawa*, two variations common in West Nusa Tenggara, which are special foods that inspire many travelers to visit to this area. In addition to *plecing*, here they often use shrimp paste to make sambal. The ingredients used for making shrimp paste in Lombok are the same as those in some areas such as Bangka Island.

Puger Terasi

Puger Kulon Village is an area where most of the people produce *terasi*, i.e., Puger shrimp paste, which is known for its distinctive aroma, good taste, and lack of preservatives. Shrimp paste processing is performed via the traditional method for maintaining its special flavor. The main ingredients include small shrimp—such as *Acetes* sp.—and salt with high purity. The length of full production is only about three days.

Tuban Terasi

Making Tuban-style paste employs the same ingredients as other Indonesian regions: shrimp and salt. Shrimp are first boiled in a pan, then cleaned of impurities. Salt is added at a ratio of approximately 15% of the total mixture. Then, the shrimp are dried in the sun for one day, followed by pulverization using wood mortars. The dough is dried in the sun while being protected from dust and dirt. An additional 5% salt for every kg of the mixture is added after the dough is dried, which is then grinded again in a wooden mortar until smooth, then formed and packed into a cylindrical or cubic shape. This preparation is stored for an extended period until the fermentation process occurs to emit a characteristic odor (approximately two weeks).

Cirebon Terasi

Cirebon shrimp paste is a superior shrimp paste in the market sector, as this shrimp paste has a peculiarity delicious taste and attractive reddish color. Its method of preparation is generally the same as that of other regions. However, what distinguishes this shrimp paste is the length of drying and the number of ingredients (shrimp or fish) and supporting materials (salt) that are used. The drying time for this paste is one day, after which it is fermented immediately [19].

IMPORTANCE OF SHRIMP/FISH PASTE WITHIN INDONESIAN CUISINE

Many Indonesian dishes use *terasi* as a food additive, such as: chili sauce, spinach soup, fried rice, etc. *Terasi* is a solid form seasoning condiment with or without high salt content. Even though *terasi* is typically only present in dishes in small amounts, its distinctive taste and odor serve vital functions as they are heavily favored in Indonesian cuisine.

The flavoring effects of *terasi* rely on its glutamate content and scent, the latter of which comes from volatile fatty acids causing an acidic odor, of note, the presence of ammonia and amine can cause a rancid odor. Simple sulfur compounds—such as sulfides, mercaptans, and disulphides—cause odors that stimulate shrimp paste. Carbonyl compounds are likely to result in unique smells found in aquatic animal products that are preserved by drying, salting, or fermentation. The volatile compounds contained in shrimp paste are derived from fat via oxidation and microbial activity; carbonyl is the most abundant volatile compound, among others, which affect the taste of shrimp paste [10, 20].

Shrimp paste is usually in the form of a solid, with slightly coarse texture, and has a distinctive sharp aroma (South Sulawesi Health Office, 2012). According to a previous report, a savory flavor can be obtained from the addition of amino acid compounds, such as glutamic acid and nucleic acids [21]. Glutamic acid is the most dominant source of the savory taste known as *umami* and has an impact on the authenticity of the taste [22].

PRODUCTION PROCESS

As outlined above, the process of making *terasi* typically depends on the area of production, in part because the process of making shrimp paste and its related recipes are passed down from locals' ancestors. In general, its production consists of drying, flouring, stirring, and fermentation (Figure 1).

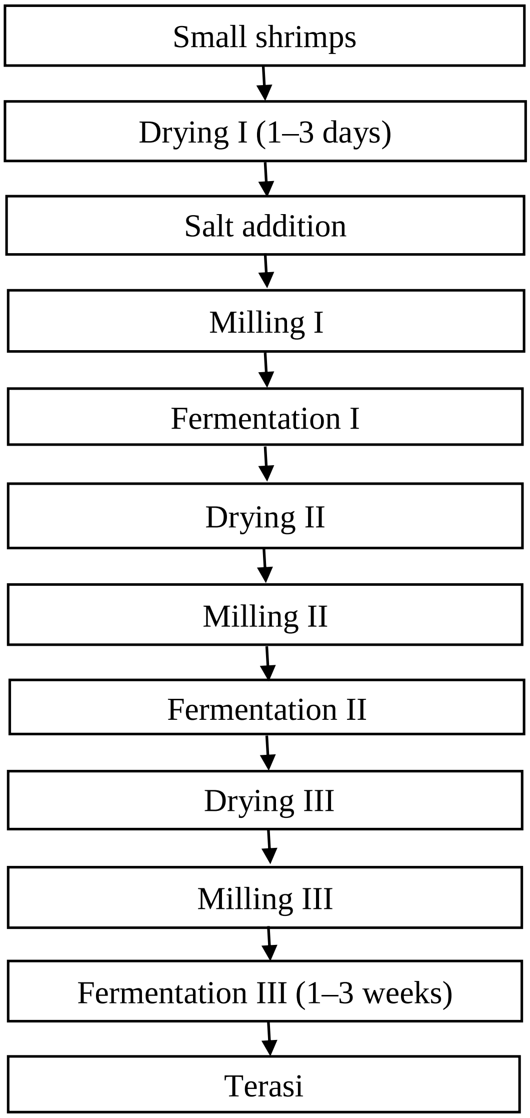

Figure 1: Typical terasi processing

Traditional shrimp paste production consists of four main stages: materials preparation, salt addition, sun drying, and fermentation. Quality of the raw materials has a significant influence on the resulting of shrimp paste. *Terasi* should consist of premium raw materials (fresh, milky white color salt, and bright red shrimp). The sorting process aims to eliminate other small fish, shellfish, and impurities. Shrimp are sun-dried for 5–6 hours; salt (1%–2%) is added, mixed, and milled. The addition of salt is a crucial step to produce *terasi* of high quality [23, 24]. The dough is then stored overnight (±18 hours). The second drying is carried out for 5–6 hours; after the drying process, the dough is then milled (milling II). The formed dough is then left overnight for the final drying process the following day. On the last day of the process, the dough that has been stored overnight is then dried in the sun (drying III) for 2–3 hours. Further steps involve fermentation for 2–3 weeks [1].

The role of lactic acid bacteria is vital during the fermentation process of vegetables, grains, and fish. Lactic acid bacteria can produce amino acids that incur a distinctive taste and flavor to the product. These bacteria inhibit the growth of bacteria that contribute to spoilage due to their ability to reduce pH value.

In the process of spontaneous fermentation of fishery products, the microbes contained therein come from natural microorganisms found in shrimp or fish itself, the salt used, as well as the equipment. Lactic acid and halophilic bacteria play an essential role in the fermentation process of fermented shrimp [25]. *Leuconostoc*, *Tetragenococcus*, *Bacillus* sp., *Bacillus licheniformis*, *Bacillus sphaericus*, and *Virgibacillus halodenitrificans* have been shown to be the predominant microorganisms found in fermented shrimp [26-29].

During fermentation, the protein will be hydrolyzed into its derivatives, such as peptones, peptides, and amino acids. Shrimp paste with a moisture content of 26%–42% is sufficient because if the water content is too low, the surface of the shrimp paste will be covered with salt crystals and the texture of the paste becomes stiff. If the water content is too high, then the shrimp paste will become too soft. The mixture of salt, shrimp, and other ingredients utilized in the making of shrimp paste initially has a pH of around 7. During the start of the process (salting and drying), the pH decreases to about to 6.8 and after final processing rises to around 7.53 [30].

During the fermentation process, the enzymes, protease, lipase, and amylase produced by microbes are essential during fermentation. Several enzymes, such as trypsin and cathepsin that are already present in fish tissue support the fermentation process. Macromolecules such as proteins, fats, and carbohydrates will be degraded to produce other molecules with lower molecular weight. Protein decomposition is a combination process of deamination and carboxylation that results in peptides and amino acids. Both of these can occur through the following stages: 1) oxidative and reductive processes of the formation of ketone acids; 2) denaturation and the formation of unsaturated organic acids; and 3) the dehydration process, namely, the formation of ketone acids.

NUTRITION

Terasi has high nutritional value (Table 1). The bioactive content contained in shrimp paste also has potential for further development.

Table 1: Nutrition values of *terasi.*

No.	Parameter	(%)*	(%)**	SNI (%)
1.	Water	25.77	3.86	Max 35
2.	Ash	1.40	8.95	Max 1.5
3.	Fat	3.45	1.94	-
4.	Protein	64.8	39.30	Min 15

*Primer Primary data, 2019
**[31]

Along with proximate value, bioactive compounds influence the quality and storability of shrimp paste. The percentage of water in of shrimp paste averages 25.77%. Water content is an indicator of the quality of fermented shrimp paste. The longer the fermentation process, the lower the water content. Low water content indicates that the fermentation process worked adequately. The longer the fermentation process, the more water that comes out from the dough. Salt penetration and water release from tissue alters shrimp weight due to the decrease in water content.

The addition of salt results in removal of water from food, thus the water activity of that food material will decrease, and microorganism growth is inhibited [32]. *Terasi* contains 1%–1.4% ash; ash content increases with the length of storage time during fermentation, and reduction of water content will increase the ash concentration. The fat content in shrimp paste averages 3.45%, and salt will also affect fat content. According to a previous study [33], increased the amount of salt added to the product will reduce the fat content. This decrease is due to the salt acting as a catalyst within the oxidation process. Fat reduction occurs during the fermentation process through fat hydrolysis by microbial and enzymatic activity, which is affected by moisture [34].

The protein content in shrimp paste totals approximately 64.8% and is an essential nutrient in shrimp paste. Fermentation time affects the protein content in shrimp paste. During the fermentation process, the breakdown of complex protein compounds into simpler peptides impacts the total amount of nitrogen, and the protein content decreases. The release of other compounds will follow the breakdown of complex protein compounds. With higher the concentrations of added salt, and longer the durations of fermentation, the concentration of dissolved protein increases. Adding salt to shrimp paste will result in selection of microbes that can grow in halophilic (high salt) environments. Such microbes will produce proteolytic enzymes that can break down proteins, these enzymes are extracellular so that even after the microbes are eliminated, the enzyme(s) remain active and break down the remaining protein, thus pastes with higher salt concentration and longer fermentation times consist of more protein that is broken down into simpler compounds that dissolve quickly. It has been shown that the fermentation process occurring in fish is a complex decomposition process, in particular one that degrades proteins into simpler compounds that will be hydrolyzed into amino acids and peptides [32].

The texture of shrimp paste is also affected by salt concentration and fermentation time. The higher the concentration of salt and the longer the fermentation, the firmer the resulting *terasi* texture will be. Since salt can pull water outside of cells, if the water content of shrimp paste is too high, the product will become too soft. Salt has the effect of hardening and forming the preferred flavor of shrimp paste [32, 35].

AMINO ACID PROFILE

Glutamic acid and aspartic acid are the primary components of the amino acid profile of *terasi*. Glutamic acid serves a vital role in the forming of *terasi* savory taste. Thus, the higher the levels of glutamic acid in shrimp paste, the better the organoleptic profile. The amino acid profile of fermented shrimp is shown in Table 2.

Table 2: Amino acid profiles of shrimp fermented paste in several countries.

No.	Parameter	Unit	A	B	C	D
1	Serine	mg / kg	11139.3	951.2	606.5	578
2	Glutamic acid	mg / kg	41552.99	5284.6	3133.7	3061
3	Phenylalanine	mg / kg	17161.22	1300.3	912.3	1021
4	Isoleucine	mg / kg	12144.67	1259.5	854.7	1178
5	Valine	mg / kg	12811.87	1417.1	962.7	1091
6	Alanine	mg / kg	18021.66	1703.3	992.8	1201
7	Arginine	mg / kg	23364.11	1042.6	1382.8	530
8	Glycine	mg / kg	18011.83	1565.2	1239.5	1041
9	Lysine	mg / kg	18726.64	2468.1	1385	1591
10	Aspartic acid	mg / kg	25312.98	2841.8	2142.9	1880
11	Leucine	mg / kg	21938.12	2450.4	1457.6	1570
12	Tyrosine	mg / kg	11884.36	1011.5	641.1	708
13	Proline	mg / kg	11240.33	1173	918.7	810
14	Threonine	mg / kg	12982.96	1290.3	864.8	955
15	Histidine	mg / kg	5106.28	491.2	320.8	442

A: Indonesian *terasi* (Primary Data, 2019), B: Brunei *belacan* [14], C: Korean *saewoojeot* [14], D: Thailand kapi [36].

Fermented shrimp from various countries primarily consists of high glutamic acid content (Table 2). *Belacan* from Brunei contains the most elevated glutamic acid levels as compared to shrimp paste from Indonesia, Korea, and Thailand. Amino acid profiles rely on several factors, including raw materials, additional materials, and the fermentation process. Glutamic acid can be produced during fermentation. Glutamic acid functions in the *umami* taste of the product [37-39]. During fermentation, several enzymes convert amino acids into flavoring compounds due to alcohol, aldehydes, and acids [40].

POTENTIAL BIOACTIVITIES

Fermented shrimp is a potential source for antibacterial compounds. Kobayashi *et al*. reported the presence of bacteriocin from the gram-positive bacteria, *Virgibacillus salexigens*, isolated from shrimp paste [41]. This bacteriocin showed a broad spectrum of inhibition against gram-positive bacteria, including the foodborne bacteria *Listeria monocytogenes*. The *Bacillus amyloliquefacien* strain SP-1-13-LM isolated from shrimp paste produced a bacteriocin that inhibited *L. monocytogenes*, *Salmonella* sp. and *Shigella* sp. The antibacterial agent is stable at temperatures above 100°C for 60 minutes and from pH 3–9 [42]. BAL from *terasi* has been confirmed to exert the ability to inhibit *Eschericia coli, Vibrio parahaemiliticus,* and *Staphylococcus aureus* [43]. The study by Kleekayai *et al*. indicated that traditional Thai fermented shrimp paste (*kapi*) is a product with potent antioxidant activity and ACE inhibitory compounds [22]. Extracts from fermented shrimp showed antioxidant activity against ABTS + radicals and ACE inhibitory activity but did not exhibit antimicrobial activity against *Staphylococcus aureus, Bacillus cereus*, *Escherichia coli*, or *Salmonella typhimurium*. Two bacteria isolated from Burmese shrimp paste exhibited high radical scavenging and antibacterial activities [44]. *Bacillus coagulans*, which was isolated from *terasi,* showed fibrinolytic activity [45]. These data suggest that fermented shrimp is not only a good food source for bacteria, but also a reservoir for their bioactivities.

Several marine protein derivative products are currently commercially available. Peptides derived from the sea organisms have promising applications as natural functional food ingredients or nutraceuticals. Seafood, waste, fish, mollusks, and crustaceans are a natural source for bioactive peptides, protein, and amino acids [46]. Issues such as problems with large-scale production, compatibility with different food matrices, gastrointestinal stability, bioavailability, and long-term stability are the main concerns for the exploration of bioactive peptides isolated from *terasi.*

CONCLUSIONS

Fermented shrimp paste is widespread throughout Asian countries, with several methods of production. *Terasi* in Indonesia has a long history that was first reported in the Cirebon kingdom. *Terasi* is an essential flavor component for many Indonesian dishes. Although it is known to consist of high nutritional value and bioactive potential, additional possibilities for the use of shrimp paste still needs to be developed and explored.

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