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From tradition to table: An introduction to the culture and nutritional significance of Malaysian fermented foods products

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Abstract

Fermented food has been an integral part of many cultures and communities around the world. In Malaysia, fermented foods hold significant cultural and culinary importance, reflecting the country's multicultural heritage and unique gastronomical landscape. This exploratory paper provides an in-depth examination of traditional fermented foods in Malaysia, focusing on their historical significance, cultural context, diversity, health benefits, and production methods. Through a semi-systematic review, the paper explores the cultural importance, health advantages, and economic potential of these foods while emphasizing their role in cultural preservation and sustainable food practices. We discuss the ingredients used, preparation methods, and fermentation times of Malaysian fermented foods like *belacan*, *budu*, *cincalok*, *pekasam*, *tempoyak*, and *tapai,* emphasizing their potential health benefits and how they differ in various fermented food types available in Malaysia. This research also discusses the microbial processes involved in fermentation and highlights the importance of standardized food processing methods and stringent quality control measures to ensure the safety and quality of Malaysian fermented foods. The cultural significance and economic potential are investigated, exploring opportunities for niche market development, job creation, and livelihood improvement. To preserve these culinary traditions, the challenges and opportunities associated with revitalizing fermented food production in Malaysia are discussed, considering implications for food sustainability, cultural preservation, and community resilience.

Keywords Fermented food, Cultural diversity, Health benefits, Malaysia

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Introduction

Every region boasts its unique variation in fermented food products as a result of disparate variables such as climate, social patterns, consumption practices, and the availability of raw materials. For millennia, humans have incorporated fermented foods into their diets. Initially developed as a preservation method, the inherent qualities beyond preservation would have become apparent. With the absence of modern technology, such as electric refrigeration, the preservation of foods via fermentation has helped people in the past to store their food rations amidst the harsh climate, especially during drought and winter, when foods are scarce [1]. Fermented food exhibits distinctive flavors, textures, appearances, and functionalities distinct from their raw counterparts. Centuries preceding the emergence of nutrition science, these foods were deliberately crafted to serve as reliable sources of essential vitamins, minerals, calories, and assorted nutrients. Malaysian fermented foods like *belacan* and *budu* have gained attention for their potential health benefits, particularly due to their fermentation processes which often involve lactic acid bacteria (LAB) [2]. As such, fermented food products are also recognized to have great potential in preventing micronutrient deficiencies and non-communicable diseases like heart disease, type 2 diabetes, and obesity. As much of the world's population is still experiencing malnutrition and has limited access to nutritional interventions, there is a sense of urgency to identify locally sourced, health-promoting nutrition solutions that can not only treat malnutrition but also decrease the risk of non-communicable diseases (NCDs).

Malaysia, an upper middle-income country, produces a variety of fermented food products; however, the consumption associated with these fermented foods is usually associated with the less urbanized population, thus representing aspects of a disappearing cultural heritage as many of these fermented food products are usually produced by traditional households or small-scale food industries and sold to local markets.

Some of the common fermented food products produced are made from seafood *(belacan,*[1] *budu,*[2] *cincalok,*[3] *pekasam*[4]), vegetables (*tempeh,*[5] *chilli boh*[6]) cereals (*tapai*[7]) and fruits (*tempoyak,*[8] *toddy,*[9] rice wine[10]) [3, 4]. However, though there is a resurgence in the significance of fermented food among the population, particularly in Western societies, the majority of research on fermented food products revolves around its biological and chemical properties and the biochemical mechanisms involved in improving gut microbiota. Also, a lot of research is focused on popular fermented food products from East Asia and European countries such as kimchi, natto, miso, sauerkraut, and yogurt. There are very few research papers on locally available fermented food products as well as the market potential for commercialization of these traditional fermented food products, particularly in the Southeast Asian region, let alone Malaysia.

It is also worth noting that Malaysia has the highest overweight and obesity rates among Asian countries and the majority of the population is not consuming the recommended amounts of fruits and vegetables daily. As the double burden of malnutrition is becoming a common problem among both developing and underdeveloped countries, this can be approached through various cultural avenues, one such being the investigation of ancient and ubiquitous practices that may hold the key to impactful and locally targeted nutritional interventions that combine both tradition and science. As the nutritional quality of fruits and vegetables is significantly improved during the fermentation process, as it not only improves the texture and taste but also enhances the absorption of essential micronutrients, while enhancing food safety and preventing food spoilage quickly, especially during the monsoon months in Malaysia, thus fermented food products can be considered as an alternative approach [5]. Traditional fermentation processes not only preserve cultural legacy, but they also provide long-term answers for modern food systems. They help the environment by decreasing food waste and using natural, low-energy procedures. Furthermore, as emphasized by [6], fermented food plays an important role in sustainable food systems by providing ethically produced, nutritionally enriched products with a reduced environmental footprint. The economic benefits of revitalizing traditional techniques, ranging from improving local economies to expanding export options, highlight their significance in modern food production.

This review aims to identify fermented food products commonly found in Malaysia. It explores the preparation method for these fermented food products and their potential health benefits across different types of fermented foods in Malaysia. Additionally, the paper examines the cultural significance of fermented foods in Malaysian society, while also addressing the challenges in creating standardized food products. By highlighting the health-promoting properties of fermented foods and their cultural importance, this review not only advocates for their inclusion as a source of probiotics for overall health and well-being but also suggests their potential

[1] *Belacan*: A fermented shrimp paste, commonly used in Malaysian cuisine as a seasoning.

[2] *Budu*: A traditional fish sauce made from fermented anchovies, often used as a condiment in various dishes.

[3] *Cincalok*: A fermented shrimp product, similar to budu, that is typically used as a dipping sauce or seasoning.

[4] *Pekasam*: Fermented fish, often seasoned with spices, and used in various local dishes.

[5] *Tempeh*: A fermented soybean product originating from Indonesia; it is rich in protein and often used as a meat substitute.

[6] *Chili Boh*: A fermented chili paste made from ground chilies and spices, commonly used as a base for many dishes.

[7] *Tapai*: A fermented product made from rice or tapioca, often sweetened and enjoyed as a snack or dessert.

[8] *Tempoyak*: Fermented durian, known for its strong flavor, is used as a condiment or in dishes.

[9] *Toddy*: A fermented drink made from the sap of palm trees, often mildly alcoholic.

[10] Rice Wine: A traditional alcoholic beverage made from fermented rice, popular in many Asian cultures.

to create a niche market, bolster the local economy, and generate employment opportunities.

Additionally, Malaysian local culinary landscapes enriched by a diverse range of fermented foods will have a significant market potential other than local consumption. This was supported by the fact that more consumers are demanding natural and health-oriented foods which often can be found in the local food community [7, 8]. To sustain this practice to be on par with economic drives, there are areas such as distribution constraints due to confines in marketing efforts, regulations on food safety compliance, and demand fluctuation due to seasonality. Additional proposals such as government support through micro-financing, business-scale model, skills, and technical training will enhance, sustain, and modernize the food preservation industry without losing the cultural and traditional elements.

Methodology

A semi-systematic review was conducted to get a thorough understanding of Malaysian traditional fermented foods, with an emphasis on its cultural value, health advantages, production procedures, and economic possibilities. The review aimed to identify overarching themes while charting the historical and current development of fermented food research in Malaysia. By examining how these foods have been studied across disciplines, the review seeks to provide a comprehensive understanding of the field and propose directions for future investigations. To achieve this, the study systematically searched academic databases such as Web of Science, Scopus, PubMed, and local Malaysian repositories using keywords such as "fermented foods in Malaysia," "cultural significance of fermented foods," and "health benefits of fermented foods." Relevant studies were selected based on their alignment with themes such as cultural heritage, microbial processes, food sustainability, and economic impact. The reviewed literature covers publications ranging from 1994 to 2024. Through a thematic synthesis of the literature, the review traced the evolution of fermented food studies in Malaysia, explored various methods and ingredients used, and assessed the challenges and opportunities in preserving these culinary traditions. Ultimately, the semi-systematic approach provided valuable insights into the broader implications of Malaysian fermented foods for cultural preservation and sustainable food practices.

Evolution of fermentation

Fermentation techniques as a means to preserve and enhance the flavor of foods can be traced back thousands of years. This can be found through evidence from cheese production in the Fertile Crescent, near the Tigris and Euphrates rivers in Iraq in around 7000 BC, during the genesis of plants and animal domestication techniques. Later, in around 4000–2000 BCE, the Egyptians and Sumerians were thought to have developed a new technique of fermentation using alcohol to develop wine and beer brewing, to which they also developed the leavening of dough technique via yeast fermentation to create leavened bread around the same periods [9]. Food fermentation is a common practice across various civilizations worldwide, often stemming from the seasonality and limited availability of certain foods during specific times of the year. Each region presents its distinct array of fermented food products, influenced by factors like climate, social customs, consumption habits, and the accessibility of raw materials.

The preparation of fermented food involves several techniques. Fermentation usually involves the use of lactic acid bacteria (LAB) and other microorganisms to break down sugars and produce lactic acid, which preserves the food and enhances its flavor [10]. Some fermented foods rely on the use of microbial organisms in protein production, such as tempeh and tofu, which are made from soybeans and are rich in protein, making them a healthy alternative to meat [1]. The use of acid and alkaline products is also common, which transforms the flavor profile of the food, depending on the pH value of the ingredients used. These foods not only provide vital nutrients but also contribute to the unique identity and heritage of each culture.

In line with this, researchers emphasize the significance of maximizing local food fermentation to develop more nutrient-dense foods that can be prepared at home [9]. Fermented local foods demonstrate how communities can boost the nutritional content of regional ingredients to prevent malnutrition. This approach of including fermented foods in dietary recommendations could enhance health outcomes while preserving cultural relevance.

Malaysian fermented food and culture

Traditional food plays an important part in expressing culture, identity, and tradition. It acts as a physical link to the past, connecting today's generations to their forefathers and embodying the long-lasting practice of sustainable living [11]. Fermented foods, in particular, have a long history and global tradition, which adds to their cultural significance in Malaysia. Fermented foods' historical roots and ties to other world traditions are major elements that highlight their cultural significance in Malaysia. These dishes did not appear immediately, but rather evolved over generations, demonstrating the Malaysian people's enduring values, habits, and practices. The Malays acquired a great taste for fermented ethnic foods due to their long shelf life, which made them ideal for their long trips to work in other places. This would supply meals to individuals who had to commute a long distance to work [3]. As noted by [12], Asia is well known for its ability to preserve and balance food availability changes during the monsoonal cycle. Southeast Asian countries produce 25% of global paddy, with 95% consumed inside the region. Fermenting cereals and other plant materials to make a variety of cuisines has been standard practice since the earliest times [13].

It is crucial to note that the diversity of Malay traditional fermented dishes varies from location to region in Malaysia (Fig. 1). The Northern area (which includes Perlis, Kedah, and Perak) and the East Coast region (which includes Kelantan and Terengganu) each have their own distinct identity of traditional cuisines influenced by local preferences. Due to the high humidity levels in Southeast Asia, like Malaysia, fermentation became a required procedure for fish preservation, especially since salt was the most readily available preservative. *Budu*, a fermented fish product, has been fundamental to the cuisine traditions of Kelantan and Terengganu. These fermented foods are not only a way to preserve food, but they also contribute to the region's culinary identity. For example, fish fermented with salt is frequently offered as a side dish, complimenting and flavoring the basic diet of rice [14].

Fermented fish, a classic Malaysian delicacy, has a long and illustrious history dating back to ancient times. Fermenting fish is not a Malaysian heritage, but rather part of a global history of preserving and increasing the flavor of fish. Fermented fish products are an essential source of protein, constituting a significant portion of the staple diet in many Asian countries [11]. The use of fermented fish is not new; in ancient Rome, a sauce known as "garum" was produced which demonstrates how eating traditions may traverse geographical boundaries and evolve throughout time. The umami flavor and taste of fermented fish sauces, as well as their ability to transform everyday dishes, are well known throughout cultures [12]. Another common fermented food that can often be seen is the *tapai*. *Tapai* is a popular dish offered at special events such as Hari Raya Aidilfitri and Malay weddings[15]. This can also be seen among the Minangkabau people of West Sumatra, who offer *Tapai* during weddings and traditional ceremonies. According to [4], this delicacy represents the Minang people's oneness because it is always made together. Similarly, during weddings and festive seasons in Malaysia, the making and consumption of traditional foods like *tapai* can promote a similar sense of connection and togetherness. The act of creating and savoring traditional dishes becomes a sign of cultural unity and shared celebrations in both circumstances, enhancing the link between the people involved.

Fig. 1 Map of Malaysia

Furthermore, *tapai* has a distinct flavor that is sweet with a wonderful scent. The glutinous rice used in *tapai* is soft and moist, and some liquid is created during the fermentation process, adding to its characteristic texture and flavor. Furthermore, another traditional Malay cuisine such as "*gulai tempoyak*" is renowned in the states of Perak and Pahang. The recipe is popular for both regular meals and celebratory festivities. Additionally, *"sambal tempoyak*," which is created by mashing fresh chillies with fermented durian meat, is widely available in most markets [13]. Traditional fermented foods play a vital role in Malaysian culture. These items not only provide nourishment but also help to promote food security and the nutritional quality of the Malaysian diet. They have historical and cultural significance, providing a link to the past and reflecting Malaysian cuisine's versatility [16]. Additionally, this historical and cultural context is particularly relevant when considering the recent challenges faced by fishermen in Malaysia. Due to circumstances like the Malaysian movement control order (MCO) during COVID-19, Malaysian fishermen were obliged to throw out their extra fish supplies for less than RM1 per kilogram. Although this price remains rather high, transitioning to the production of budget-friendly fish (BFF) products may offer a viable solution for utilizing leftover or underutilized fish. Furthermore, BFF manufacture is commonly seen as a "stock solution" in which fish can be fermented and marketed allowing for product variety and possible cost savings [11].

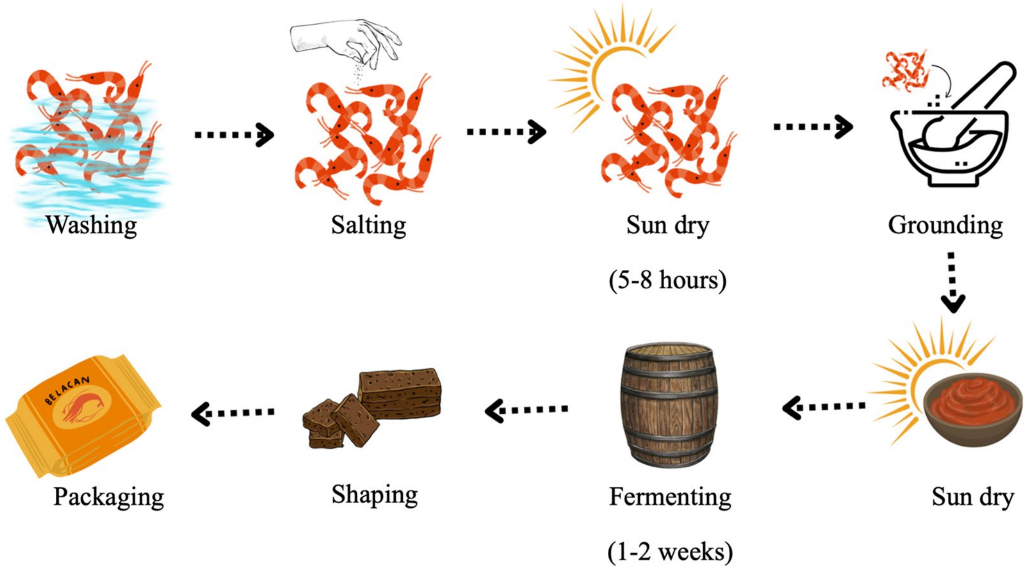

Fig. 2 Process of making *Belacan*

Diversity of traditional fermented food

Belacan

As mentioned in the previous section, Malaysia has a diverse selection of traditional fermented food from seafood and plant origin. *Belacan* is one of the most well-known fermented foods among Malaysians. *Belacan*, also known as shrimp paste, is mainly made of small shrimp and salt that has been fermented and made into paste or blocks for retail purposes [17]. According to [17], belacan is produced by first washing and draining fresh shrimps then salted to a 5:1 ratio (shrimp to salt). The salted shrimps are then dried under the sun for 5 to 8 h then pounded. This process is repeated again one more time before the *belacan* is fermented for 1 to 2 weeks as shown in Fig. 2. *Belacan* has a thick texture, salty taste and a strong and pungent smell. It is generally used as a condiment or part of the ingredients for a dish rather than being consumed on its own. Since *belacan* is strong in flavor, other ingredients are used together with it to balance out the taste and aroma which can be overwhelming by itself. Traditionally, *belacan* is fused with spicy and acidic ingredients such as chilli, lime or tamarind. Common dishes that use *belacan* are the many varieties of *sambal*, such as *sambal belacan* (Fig. 3), *sambal tumis, asam pedas,* stir-fried vegetables, stir-fried meat and poultry dishes and soup [18, 19].

Sambal belacan is a popular Malaysian chili condiment made from chilies, *belacan* (fermented shrimp), and lime juice. It is commonly used to enhance the flavor of various dishes.

Budu

Budu or fermented anchovy sauce is another type of fermented food based on seafood. *Budu* is mainly produced and consumed on the East Coast of Malaysia; Kelantan and Terengganu [20]. It is produced by mixing anchovies and salt at a certain ratio followed by fermentation for six months in closed tanks [21]. Appearance-wise, the color of *budu* can vary from murky gray to dark brown with a liquid consistency. It has a strong anchovy aroma and is very salty, normally used as a condiment and flavoring ingredient [20]. As a condiment, *budu* is normally mixed with onion, chilli, lime juice, and lemongrass (Fig. 4) and is commonly served with raw vegetables, rice, and seafood dishes, adding a rich umami flavor. It is also used to make *budu tumis* a condiment for Nasi Kerabu, a very popular dish in Kelantan [22].

Budu, is a popular fermented fish dish from Kelantan and Terengganu, Malaysia.

A visual representation of the step-by-step process involved in making *budu* is shown in Fig. 5.

This product, created from post-handling fish, has grown from local delicacies to commodities in high demand on both domestic and international markets. While conventional packing methods are meant to avoid unpleasant odors, the fermented foods' particular flavors and cultural significance have spurred their commercialization [23]. *Budu* Cap Ketereh (Fig. 6), a well-known Malaysian brand, is halal-certified and has been marketed to international sectors, particularly in Europe and Saudi Arabia.

Fig. 3 Sambal belacan

Fig. 4 *Budu* ready to eat

Cincalok

Cincalok, a type of fermented seafood in Malaysia, is made from fresh baby shrimp, coarse salt, and other ingredients and is naturally fermented for 3 to 14 days [24] (Fig. 7). It typically has a light pink color, though some producers add red coloring to achieve a darker hue [24]. Similar to other fermented seafood products, cincalok is commonly used as a condiment or flavor enhancer. The most popular way to enjoy it is by mixing it with sliced shallots, chili, and lime juice, either cooked or raw, and serving it with rice and other main dishes [25]. Made from fermented prawns, salt, and cooked rice, cincalok has a distinctive salty and sour flavor. It is often served as a dipping sauce with lime, shallots, and chilies but can also be incorporated into various dishes.

Originally from Melaka, cincalok is widely enjoyed throughout Malaysia and Southeast Asia for its unique taste and versatility in traditional cuisine.

Figure 8 shows bottles of *cincalok,* a commercially packaged Malaysian condiment widely available in supermarkets.

Pekasam

Pekasam is a delicacy traditionally produced in the Northern states of Malaysia, mainly in the states of Perak, Perlis, and Kedah. It is a type of fermented fish made by fermenting whole fresh fish with salt and covered with ground-roasted rice grains [26]. Fermentation of fish is a method that has been used traditionally since ancient times to preserve fish which are perishable [27]. The Sumerians from Ancient Mesopotamia fermented their fish in brine to make a sauce called the *siqqu* [28]. The Romans too fermented their fish to make a fish sauce called *garum* as early as the fifth-century BCE [29]. The process of making *pekasam* starts by rubbing the fish with a generous amount of salt and tamarind juice and storing it in an airtight container for 2 to 3 days [20]. Subsequently, excessive salt is washed off from the fish and is dried before mixing roasted ground rice, sugar, and tamarind slices then continues to be fermented for up to 2 to 3 weeks [30] (Fig. 9). *Pekasam* has a distinctive flavor and taste. It is salty and prominently sour due to the fermentation process. The name *pekasam* is derived from the Malay word '*asam*' which translates to sour in English [30]. Before serving, *pekasam* is normally deep-fried or cooked with other ingredients such as onion and then served together as a side dish with rice [20] (Figs. 10 and 11).

Tempoyak

Tempoyak, a traditional fermented durian paste, is commonly consumed by the Malay ethnic group in Malaysia [31]. The fermentation process occurs naturally through spontaneous and uncontrolled microbial activity present in the durian [32]. To begin, ripe durian pulp is mixed with salt and placed in a clean, airtight container, where it ferments at a temperature between 28 °C and 34 °C for 4 to 7 days [33]. The salt is crucial as it inhibits the growth of harmful bacteria while allowing natural fermentation to occur, resulting in the characteristic sour flavor of the durian. After fermentation, the *tempoyak* is transferred to the refrigerator to preserve its quality and is then ready to be used in various dishes (Fig. 12). This method not only enhances the flavor but also improves the preservation of the *tempoyak*. *Tempoyak* has a sour or tangy taste, and, unlike the intense pungent smell of fresh durian, it has a more subtle aroma. *Tempoyak* is particularly popular and readily available in the states of Pahang and Perak [31]. However, it is widely consumed throughout the country and is used in a variety of dishes. Unlike other fermented foods discussed previously, *tempoyak* can be enjoyed on its own without being processed into a different dish. Nonetheless, it also commonly used

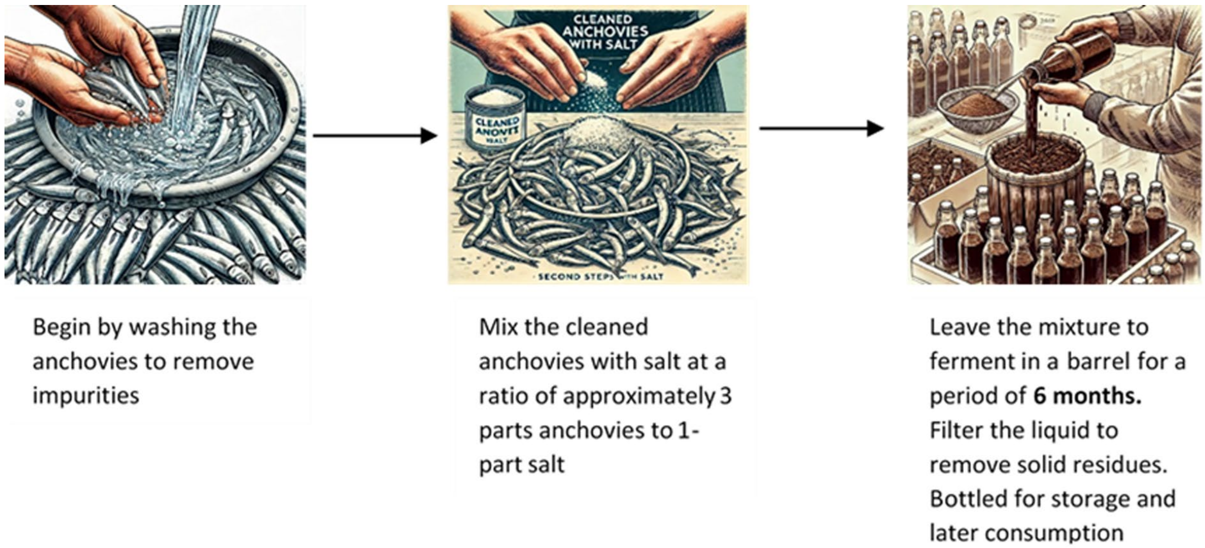

Fig. 5 Process of a traditional fermented anchovy sauce *budu*

Fig. 6 *Budu* in bottles

in cooking to create flavorful dishes like *Sambal bilis tempoyak, singgang tempoyak* (fish stew), *tempoyak daun kayu* and many others with its sour taste, complex flavor, and thick texture [33] (Fig. 13).

Tapai

Tapai is a popular fermented delicacy consumed as a dessert among the Malays in Malaysia. Originated from West Sumatra, it is use in various traditional ceremonies of Minangkabau people or also known as the Minang people [4]. The Minang people are known to be voyager and proceeded to form populations in Malaysia specifically in Negeri Sembilan, Kuala Lumpur, Melaka, and Penang [4]. The word *tapai* originated from Proto-Malay-Polynesian '*tapay*' or Proto-Austronesian '*tapaJ*' which means fermentation [4]. The two common types of *tapai* that can be found in Malaysia are *tapai pulut* (fermented glutinous rice) and *tapai ubi* (fermented tapioca) [22]. To make *tapai,* the main ingredients are steamed then added with sugar and ragi (yeast) and the mixture is fermented for at least 30 h [34]. Traditionally, *tapai pulut* is portioned and wrapped in rubber plant

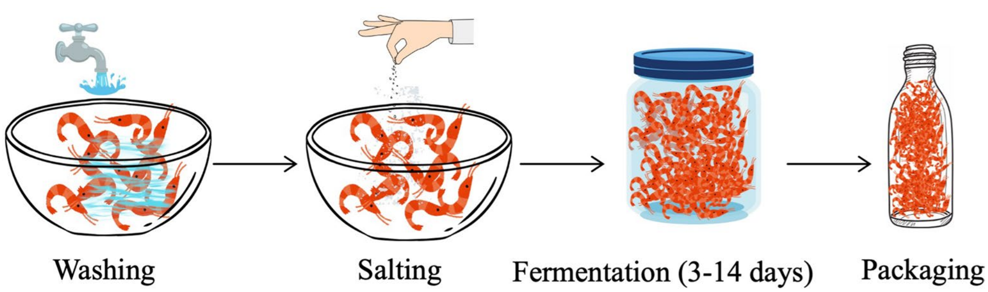

Fig. 7 Process of making Cincalok

Fig. 8 Cincalok

leaves (Fig. 14), banana leaves, ketapang leaves, baharu leaves or keladi leaves [35]. These days, however, *tapai* is mainly wrapped using plastic, paper, or fermented in small plastic containers [22]. When it reaches the optimum fermentation stage, *tapai* has a sweet taste and has the aroma of alcohol [4]. However, over-fermentation of *tapai* will result in a sour and more alcoholic taste which is not suitable for consumption [36]. To avoid over-fermentation, *tapai* can be stored for up to 2 weeks in refrigerators. The cold temperature will help to decelerate the fermentation process [36]. In Malaysia, *tapai* is traditionally served at important ceremonies such as religious activities, weddings, and the birth of newborns [37].

The main ingredients are steamed then added with sugar and ragi (yeast), wrap, and the mixture is fermented for at least 30 h.

Figure 14 illustrates *tapai,* also known as glutinous rice wrapped with rubber leaves. Rubber tree leaves are used to wrap *tapai* because they are soft, yet resistant to tearing, making them easy to work with. This method is an eco-friendly way to prepare food (Fig. 15).

Table 1 offers a concise summary of various fermented foods, detailing their type, origin, ingredients, fermentation duration, and traditions of consumption. It includes products such as *belacan, budu, cincalok, pekasam, tempoyak,* and *tapai,* each with unique ingredients and fermentation processes, often used as flavoring, condiments, or accompaniments to rice dishes. The table serves as a quick reference before diving into the more detailed descriptions of each product.

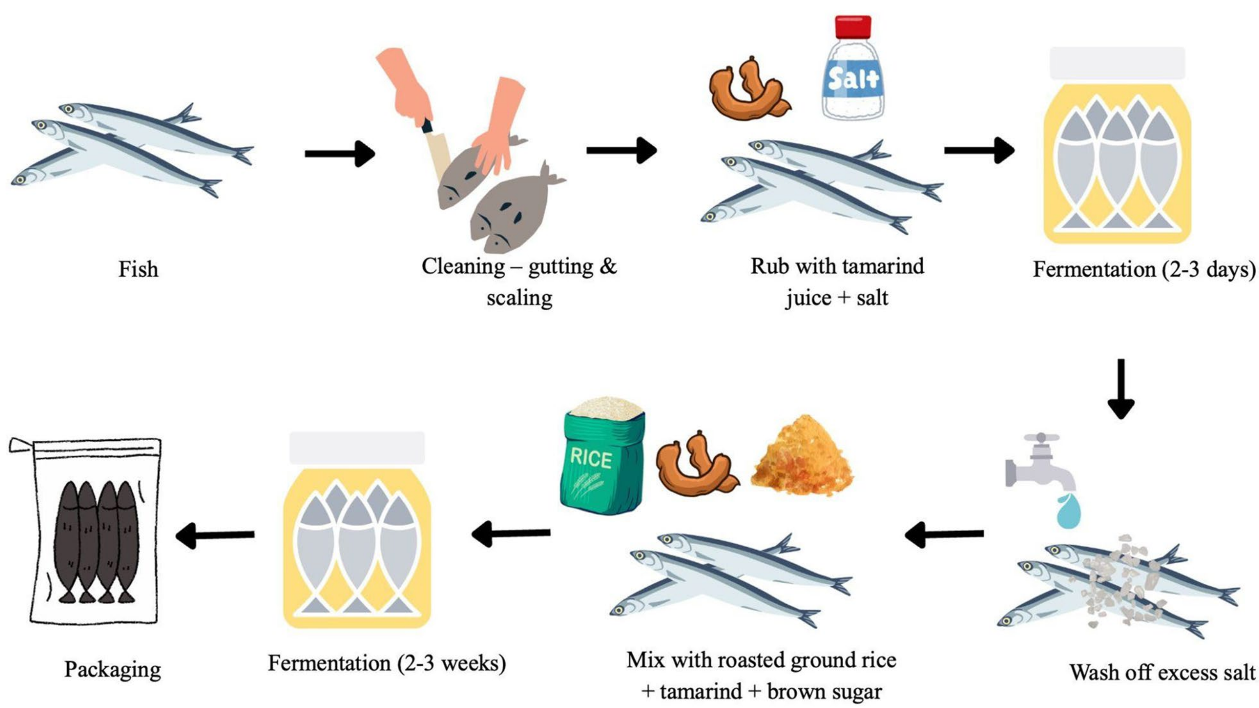

Fig. 9 Process of making *Pekasam*

Fig. 10 Variety of *Pekasam* in vacuum sealed packs

Comparative analysis of other similar fermented foods in Indonesia

While Malaysia boasts various fermented delights, its neighboring country, Indonesia offers a diverse range of its own. For instance, Indonesia's *tempoyak*, like Malaysia's, uses durian, but variations in preparation and regional preferences lead to distinct flavors [38]. *Terasi,* Indonesia's version of *belacan*, also relies on fermented shrimp; however, it is often drier and coarser in texture, while *belacan* tends to be moister and more compact. The fermentation process also varies, with *terasi* typically sun-dried for longer, giving it a stronger, smokier aroma compared to the more subtly pungent *belacan* [39]. Additionally, regional variations in shrimp species and fermentation duration contribute to differences in taste intensity and umami depth. Similarly, *budu*, a fermented anchovy sauce from Malaysia, can be compared to Indonesia's *petis udang,* which also utilizes fermented fish but has a thicker consistency. Indonesia's *petis,* a dark, thick paste made from fermented fish or shrimp, has a very different flavor profile not commonly found in Malaysian cuisine. *Tapai* is common in both countries, but the specific grains or tubers used and the starter cultures can result in variations. For example, Malaysian *tapai* is often made from glutinous rice (*tapai pulut*) or cassava (*tapai ubi kayu*) and has a sweeter, softer texture, while Indonesian *tape singkong* (cassava based) is firmer and can develop a stronger alcoholic taste. Additionally, the fermentation starter (ragi) varies slightly, influencing the microbial composition and resulting in different flavor profiles and moisture levels [4]. Both countries utilize fermentation to create unique flavors and extend food shelf life, but the specific ingredients and cultural influences lead to distinct regional specialties. Comparing these fermented foods reveals the rich culinary heritage and diverse applications of fermentation across the Malay Archipelago.

Fig. 11 *Pekasam* fish after being fried and ready to eat

Health benefits and nutritional value

The availability of raw materials significantly influences the variety and characteristics of fermented foods, contributing to food security through the selection of ingredients with natural vitamin fortification, shelf stability, enhanced flavor, and toxin-free properties. Many of the fermented food products found in Malaysia contain various microorganisms, with bacteria, particularly Lactic

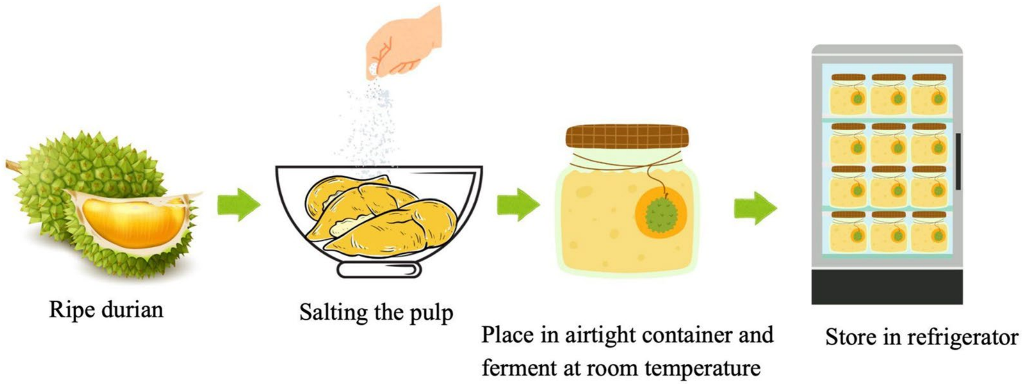

Fig. 12 Process of making *tempoyak*

acid bacteria, being the most common and constituting around 80% of probiotic starter cultures. These bacteria are defined as "live microorganisms that, when administered in adequate amounts, confer health benefits on the host" [40]. Various probiotic bacteria that can be found in some traditional fermented foods in Malaysia include *Lactobacillus brevis, Lactobacillus confusus, Pediococcus pentosaceus* and *Leuconostoc mesenteroides*, among many others [5]. Researchers have been actively isolating and identifying various lactic acid strains found in indigenous fermented fruits and vegetables in Malaysia. Their objective is to explore their potential as natural probiotic sources, further enhancing the sensory properties and overall nutritional quality of food [41]. The presence of these microbes in food can lead to either spoilage or the creation of safe and edible products, highlighting the crucial role fermentation plays in shaping our culinary heritage and dietary well-being.

Preparing food using the fermentation technique helps to extend shelf life, improves the organoleptic properties of food (although there has to be a balance between taste and flavor), and enhances the nutrition quality. It does this by improving the digestibility of proteins, and carbohydrates, the bioavailability of vitamins and minerals, and the sensory quality of food [42, 43]. The anti-nutritional compounds found in some of these fruits and vegetables can also be removed during the fermentation process. The leaves of *Manihot esculenta,* also known as *daun ubi*, can only be made edible after toxins are removed, and that is achieved through fermentation [41].

A study was conducted on the variety of Malaysian *belacan* (a type of fermented shrimp paste), potential probiotic properties were identified from the isolates

Fig. 13 *Tempoyak* ready to eat

Fig. 14 *Tapai* wrapped using rubber leaves

Fig. 15 Appearance of Tapai Pulut (fermented glutinous rice)

Table 2 Proximate analysis (protein, fat, and carbohydrate) of different types of fermented food product found

Type of fermented food	Protein (%)	Fat	Carbohydrate	References
Belacan	31.83 ± 0.66	1.01 ± 0.23%	11.01%	[59]
Budu	9.69 ± 0.19	0.30 ± 0.15%	4.80 ± 0.25%	[7]
Cincalok	34.22 ± 0.47	2.38 ± 0.95%	19.43%	[44]
Pekasam	16.15 ± 1.25	3.1 ± 0.98	% Not reported	[60]
Tempoyak	6.37	2.69%	48.79%	[8]
Tapai	3.3 ± 0.04	0.1 ± 0.004	34.3 ± 0.04%	[53]

of lactic acid bacteria, and they were able to withstand low pH conditions and exposure to bile salts [44]. It has been identified by [45] that *Cincalok* contains seven isolates which are *Staphylococcus carnosus, Corynebacterium phoceense, Vagococcus vulneris,* and *Priestia filamentosa, Tetragenococcus halophilus, Enterococcus faecalis,* and *Pisciglobus halotolerans,* with the last three being LAB. Firmicutes also is found in higher proportion in cincalok, and it plays a significant role in the relationship between gut bacteria and human health [46].

Pekasam, which is produced from freshwater fish, contained *Bacillus megaterium, Pediococcus pentosaceus, Lactobacillus plantarum, Lactobacillus pentosus*. Some of these strains showed some probiotic activity, no hemolytic activity, demonstrated tolerance to low pH and bile salts, and also displayed antimicrobial activity against pathogenic microorganisms. [26]. Various researchers have reported that the use of different fish species shows variations in the microflora profile, although the mechanism behind this is still unknown [47]. Higher protein content in the fish species used is associated with a greater *Lactobacillus* growth profile, which helps prevent the growth of putrefactive microorganisms [48]. Additionally, Lactobacillus acts as a natural preservative.

Budu contains *Lactobacillus casei, Lactobacillus plantarum, Lactobacillus paracasein (liasia).* Relatively few microorganisms are able to grow in *budu* due to reduced oxygen level, low pH, and very high salt content. When analyzing the proximate composition of *belacan* and *cincalok* (Table 2), research conducted by [44] showed that *cincalok* had a higher protein, fat, and carbohydrate content compared to *belacan.* The use of cooked rice as an ingredient in *cincalok* likely contributes to its higher carbohydrate content. It is generally observed that carbohydrate content decreases in fermented foods compared to their fresh counterparts, as microorganisms utilize these biomolecules during the fermentation process [49]. The high-fat content in both *cincalok* and *belacan* can be attributed to the polyunsaturated fatty acid content

Table 1 Ingredients and fermentation duration

Type of fermented food	Origin	Ingredients	Duration of fermentation	Traditions of eating
Belacan	Melaka	Tiny shrimps, salt	1–2 weeks	As a flavoring ingredient
Budu	Kelantan	Anchovies, salt	6 months	As a condiment and flavoring ingredient
Cincalok	Melaka	Fresh tiny shrimps, coarse salt	3- 14 days	As a condiment
Pekasam	Kedah Perak	Fresh fish with salt, and covered with ground-roasted rice grains	2–3 weeks	Normally deep-fried and eat as condiment with rice dishes
Tempoyak	Pahang Perak	Durian pulp, salt	4–7 days	As a condiment and flavoring ingredient
Tapai		Glutinous rice/tapioca, ragi (yeast), sugar	At least 30 h	Often consumed as a snack, dessert, or accompaniment to other foods

in the shrimp oil [50]. In comparison, *budu* samples exhibited lower protein and fat content than both *belacan* and *cincalok*. According to [51], the protein and fat content of *budu* can vary depending on factors such as the type of fish used, the fish-to-salt ratio, and the fermentation time.

When it comes to the production of fish-based fermented products like *belacan, budu,* and *pekasam,* the salting process helps reduce the water availability in the fish and alters the protein structure in the fish muscle. This leads to the production of essential amino acids and volatile compounds that contribute to flavor development, taste, and aroma [12]. Additionally, because they are seafood-based products, they have a higher nutritional density, particularly in protein, iodine, and omega-3 fatty acids.

In comparison with other popular fermented food such as yogurt and kimchi, while yogurt does have a high protein content, it lacks iodine and omega-3 fatty acids, which are only found in fish-based products. The same applies to kimchi.

In order to prepare *sambal belacan,* you would need approximately 18% *belacan* [17]. *Sambal belacan* contains up to 24 volatile compounds, including terpenes like limonene and butanoic acid [52]. Terpenes, such as limonene, have been researched for their potential health benefits, including antioxidant and anti-inflammatory properties (N). Butanoic acid, a short-chain fatty acid, is believed to support gut health and may also exhibit anti-inflammatory effects.

According to [53], *tapai* fermentation consists of both yeast and LAB which included yeast species from *Saccharomyces cerevisiae, Candida krusei, C. pelliculosa, C. glabrata, C. utilis, C. sphaerica, C. magnoliae, Rhodotorula mucilaginosa, R. glutini*s and *Cryptococcus laurentii*. From the LAB isolates, *Lactobacillus plantarum* and *Lactobacillus brevis* were the predominant ones found in the fermentation process of *tapai*. Yeasts and lactic acid bacteria can work together in a symbiotic relationship, in which the bacteria provide the acid environment that favors the growth of yeasts, while the yeasts supply vitamins and nutrients that benefit the bacteria [54]. The increasing demand for plant-based probiotic foods, driven by lactose intolerance and the high saturated fat and cholesterol content in dairy products, has led to the creation of nutritious lacto-fermented glutinous rice with a reliable probiotic live culture [55]. It has been found that that certain LAB strains from *tapai* can adhere to intestinal cells and inhibit harmful bacteria, with fructo-oligosaccharides enhancing their probiotic function [15].

During the fermentation of *tempoyak,* it has been reported by [41] that the dominant LAB strains in *tempoyak* are *Weissella paramesenteroides, Enterococcus faecalis, Enterococcus gallinarum, Lactobacillus plantarum, Lactobacillus brevis, Lactobacillus fermentum, Lactobacillus mali, Lactobacillus mesenteroides, Lactobacillus casei*, and *Pediococcus acidilactici*. Notably, these prevalent LAB strains in *tempoyak* fermentation are similar to those found in fermented vegetables like sauerkraut [56] and kimchi [57]. In a study conducted by [13], they found that *tempoyak,* a lactic-fermented durian product, contained elevated levels of minerals, amino acids, vitamins, and antioxidant activities, with reported immunostimulatory properties. Similarly, [58] found that *tapai* contained *Lactiplantibacillus plantarum* (an RB5) strain which can not only withstand harsh environmental conditions such as a low pH, and high temperatures, and exhibit antibiotic susceptibility but also improve immune system support by increasing white blood cell, neutrophils, and lymphocytes count in the body. Research has shown that both the bacterial cells and the cell-free supernatant (CFS) of Lactobacillus plantarum isolated from *tempoyak* can inhibit the growth of human cancer cells, specifically HT-29 cells [51]. This effect was found to increase as the concentration of the bacteria or CFS was higher and also imply potential probiotic properties. In terms of its carbohydrate content, *tempoyak* exhibited a high carbohydrate content as it is made from durian [8].

Table 2 presents the nutritional composition of various fermented foods, highlighting their protein, fat, and carbohydrate content. *Belacan* and *cincalok* are high in protein, while *tempoyak* has the highest carbohydrate content. *Pekasam, tapai,* and *budu* show varying levels of protein and fat, with some missing carbohydrate data.

Fermented food production in Malaysia encompasses various scales, ranging from households and villages to cottage industries and commercial facilities. However, this diversity in production methods creates difficulties in maintaining consistency and quality control. A study examining 20 bottles of *budu* (fermented anchovy sauce) from seven different manufacturers revealed significant inconsistencies in microbial diversity, demonstrating the absence of standardized procedures across all production scales [61]. This inconsistency was further compounded by the presence of food spoilage bacteria such as *Xanthomonas, Acinetobacter,* and *Pseudomonas* in many of these samples.

While fermented foods generally contribute to the improvement in the nutritional quality of food, there are instances where the breakdown of fish protein, particularly in the production of *budu,* may cause significant health risks such as gout due to the formation of purine as a by-product [62]. The high amounts of histamine found in these products can lead to scombroid food poisoning, the symptoms of which include breathing difficulties and irregular heartbeats [63].

As such, for Malaysia to develop its potential in developing fermented-based products, standardized food processing methods and stringent quality control measures are crucial. Key practices include monitoring fermentation duration, conducting microbial safety checks, maintaining hygienic storage conditions, pH monitoring, controlling moisture and temperature levels, ensuring precise salt ratios, and applying consistent starter cultures [30]. *Budu* could benefit from documented salt ratios, fermentation time, and microbial safety testing to prevent contamination while maintaining its distinctive umami taste [59]. *Tempoyak* could be examined through pH monitoring, controlled fermentation conditions, and storage guidelines to maintain its desired sourness and prevent harmful microbial growth. *Cincalok*, production could include standardized shrimp size, precise fermentation duration, and safe packaging practices to ensure consistent quality while retaining its characteristic pungency [24]. These measures help prevent spoilage, enhance safety, and ensure consistency in taste and quality. Implementing uniform, high-quality standards across all production scales is essential for ensuring consistent product quality and safety and would strengthen the commercialization of these traditional Malaysian fermented foods. Additionally, more research is needed to identify the microbial composition in these products. This knowledge would empower producers to harness beneficial bacteria, mitigating potential hazards, particularly in fermented seafood products, and enhancing the overall nutritional value of these foods [44].

Efforts to preserve and revitalize traditional fermentation methods and recipes

Food preservation has been practiced since the Palaeolithic era for a variety of reasons, including limited food supply due to seasonality [64—66]. Initially, fruits and plant ingredients were primarily preserved through drying and heating [67, 68]. This practice eventually spreads to meat preservation during the Mesolithic era. The primary motivation for these preservation efforts was to prevent bacterial and fungal growth and extend the shelf life of food items [14]. The practice of food preservation serves both scientific and cultural purposes. Scientifically, documentation of traditional fermentation practices teaches about fermentation processes and the role of microorganisms [68, 69]. Preservation techniques are deeply ingrained in communities, frequently linked to festival ceremonies and familial traditions [22, 68]. Dishes such as *tapai, pulut hitam,* and *terasi* in Indonesian tradition, *nam ruoc* in Vietnamese cuisine, and *kapi* in Thai cuisine are not only preserved foods, but also symbols of cultural heritage and endurance [10, 45].

Documentation efforts in Asia frequently involve collaboration with communities to standardize recipes and preserve cultural practices, as seen in initiatives such as "Menu Warisan Keluarga" [3]. Food preservation in some Asian cultures is part of health-related concerns such as the ginger fermentation often used as medication due to its antifungal properties and antioxidants, similar to using black glutinous for antimicrobial activity in strengthening weakened muscle [68, 70]. These preservation practices are deeply embedded in local food sustainability cultures and passed down through generations as family traditions [64, 67]. Furthermore, the preservation of specific foods such as fruits, rice, grains, and beans is intended to provide families with balanced nutrition [71]. Ultimately, food preservation is a diverse practice that stems from scientific necessity as well as cultural heritage [27, 30]. By documenting and carrying on these traditions, communities not only ensure food security but also preserve their identity and promote cultural sustainability for future generations.

Additionally in light of the imperative to address climate change, fermented foods not only help to lower carbon footprints but also support local farmers and sustainable agricultural practices [54, 72]. By often utilizing locally sourced ingredients, fermented foods exemplify a conscientious approach to consumption patterns that align with the goals of environmental stewardship and resilience in the face of climate change. Due to their strong cultural foundation, fermented foods have the potential to cultivate a niche market, bolster the local economy, and generate employment opportunities. This is because the production of fermented food is often rooted in local businesses run by families, village cooperatives, and social community clubs [7, 19, 33]. These enterprises thrive within village societies mainly because fermentation is relatively easy to manage, requires low-cost materials, and relies on traditional knowledge and expertise. Additionally, it serves as a vital source of household income, enabling families to support their livelihoods while preserving their culinary tradition and skills [20]. Continued government support through improved market access, regulatory flexibility, and quality training programs in food production would enhance the productivity, competitiveness, and sustainability of this industry, further contributing to national economic growth.

Moreover, fermented foods attract tourists and customers seeking authentic culinary experiences, thereby enabling local communities to thrive. The accessibility of small-scale production allows local entrepreneurs to enter the market easily, fostering employment opportunities across various sectors, including food processing and hospitality. By documenting and carrying on these traditions, communities not only ensure food security, foster resilient local food economics, and encourage economic growth but also preserve their identity and promote cultural and environmental sustainability for future generations.

Conclusion and recommendation

In conclusion, the practice of food preservation demonstrates humanity's ingenuity and resourcefulness in ensuring food security throughout history as it does not only help to overcome seasonal shortages, prevent spoilage, and preserve cultural traditions. The documentation and perpetuation of these preservation techniques serve not only as educational tools for comprehending fermentation processes and microbial involvement but also as a means of preserving cultural heritage and fostering community unity. Furthermore, the importance of food preservation goes beyond mere sustenance; it has social, economic, and environmental implications. Preserving traditional food practices helps to build local food sustainability cultures, increases community resilience, and fosters intergenerational bonds through the transmission of knowledge and skills. The increasing demand for fermented food is rising as people become more aware of their health benefits, giving regional producers a chance to stand out from the competition and appeal to health-conscious consumers. This exploratory study, based on existing research, identifies several key avenues for future investigation into Malaysian fermented foods. To fully understand their probiotic potential and health benefits, laboratory experiments and in-depth interviews with indigenous communities are crucial. A thorough analysis of fermentation's impact on the nutritional profile of these foods is also essential. Future research should prioritize a detailed characterization of the microbial composition and diversity within these traditional foods, identifying the specific microorganisms involved in fermentation as this is currently lacking. This knowledge will allow for the optimization of production techniques and ensure consistent flavor profiles during the production process. Furthermore, rigorous investigation into the health benefits of lesser-known Malaysian fermented foods is needed, particularly focusing on their influence on gut health, immune function, and potential therapeutic applications. Beyond the scientific aspects, exploring the cultural and socioeconomic significance of these foods within various communities is equally important. Examining their role in culinary traditions, social rituals, and economic livelihoods will shed light on their broader impact and contribute to preserving these valuable cultural practices for future generations. Addressing these research gaps will not only expand our scientific understanding of Malaysian fermented foods but also promote their consumption and potentially uncover novel health benefits.

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