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REVIEW ARTICLE

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Diversity of sambals, traditional Indonesian chili pastes

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Abstract

Indonesia, a multicultural country, exhibits high diversity of cultural heritage. Sambal, for example, a traditional chili paste or sauce usually consumed as condiment, has been an integral part of Indonesian food culture for centuries. Initially, sambal was prepared using native ingredients such as pepper and ginger. Cayenne pepper (*Capsicum annuum*), a native American plant, was incorporated in sambal recipes in the sixteenth century and since then, it has been the major ingredient of Indonesian sambal. Each region of Indonesia has its own traditional versions of sambal, distinguishable by its ingredients or production methods. The aim of this review is to identify and establish a profile regarding the diversity and geographical distribution of 110 different varieties of sambal in Indonesia reviewed from various cookbooks. The island of Java exhibits the highest amount of sambal variants (64.5% of sambal variants found in Indonesia) among other islands. More than 80% of the identified Indonesian sambals are prepared by crushing and cooking the ingredients. Some also are served as raw sambals in all islands in Indonesia, except Java and Sumatra. Besides chili pepper, sambal production often involves the use of diverse secondary ingredients that gives a unique identity for every sambal recipe (e.g., fruit, local food, aromatic herbs, etc.). Nowadays, sambal is produced both traditionally for direct consumption and modernly in food industries, thus resulting in commercially packaged sambals with long shelf life. Sambal also has potential to contribute to the nation's economic conditions, mainly by supporting the development of small and medium enterprises. With regard to novelty, this is the first international review discussing the diversity of sambals in Indonesia in a thorough and comprehensive manner.

Keywords: Chili, Indonesia, Sambal, Traditional food

Introduction

Indonesia is the world's largest archipelagic nation consisting of over 17,000 islands inhabited by more than 270 million people from 1,300 different recognized ethnic groups [1]. Such multicultural background has contributed to the country's cultural diversity, including the food culture. Indonesian food culture is strongly influenced by several factors, such as nature, history, and established local/indigenous culture. Until today, Indonesian gastronomy has been shaped through different phases throughout generations, by incorporating and assimilating different cultural exposure during trading periods, colonization, and globalization era [2].

In general, Indonesian cuisine varies greatly by region and can be classified based on its major islands. Each cuisine has different food culture characteristics that are shaped by the natural conditions, history, and culture of the region [3]. Despite such a variation, Indonesian cuisine exhibits a common characteristic which includes rich and complex flavor due to the use of different spices mixture and the notable combination of basic tastes (sweet, sour, salty, bitter, and umami) [4]. Indeed, most Indonesians favor hot and spicy food, and for this reason, chili pepper or *cabai* and its derivatives are often added during the cooking process or as condiment on final dishes. *Cabai* is a general term in Indonesian referring

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to the fruit of *Capsicum* sp. that harbors heat and spiciness. Cayenne pepper or *cabai merah* is a specific cultivar of *Capsicum annuum* widely cultivated in almost all regions in Indonesia, both in lowlands and in highlands [5, 6]. Java and Sumatra produce the most chili peppers in Indonesia, in terms of both varieties and quantities [6, 7]. Other cultivars of *C. annuum* are not commonly present in Indonesian cuisine, including bell pepper, poblano pepper, and jalapeño pepper [8]. Different cultivars of *C. chinense* and *C. frutescens* are also known in Indonesia as *cabai* [9, 10].

Sambal (or *sambel* in Javanese and Sundanese) is a sauce, paste, or relish made from chili pepper with secondary ingredients such as garlic, shallot, ginger, and shrimp paste [11]. The most common variant of chili pepper used in sambal recipes is cayenne pepper (*cabai merah*) and bird's eye chili pepper (*cabai rawit*) with a higher intensity of spiciness, both of which are the well-known varieties of *C. annuum*. Originally stemming from the culinary traditions of Indonesia, sambal is now considered as a staple condiment on all Indonesian tables and has spread to other neighboring countries including Malaysia, Singapore, Brunei Darussalam, and even Sri Lanka [12]. The highly pungent or piquant taste of sambal is correlated with the presence of natural bioactive compounds in the chili pepper known as capsaicin and capsaicinoids [13].

For centuries, sambal has been an integral part of Indonesian food culture. Interestingly, different regions in Indonesia possess their own traditional versions of sambal that differ from one another by their production methods (crushing or chopping, cooked or left raw) or types of chili peppers and secondary ingredients used. This review aims to identify and establish a profile regarding the diversity and geographical distribution of 110 different varieties of sambal in Indonesia. Sambal recipes were collected from 23 cookbooks containing various recipes of Indonesian cuisine. The data regarding the province of sambal origin, ingredients, and preparation methods used in each sambal recipe were carefully collected for further identification and analysis.

History of sambal in Indonesian gastronomy

Chili pepper, a native plant of Central and Southern America, was first introduced to Indonesia by Portuguese and Spanish sailors during the Columbian exchange in the sixteenth century [14]. However, prior to chili's arrival in Indonesian lands, sambal had already been regularly consumed in Indonesian traditional cuisine [15]. At that time, sambal in Java was reported to be made from Javanese/Balinese long pepper (*Piper retrofractum*), pepper (*Piper nigrum*), and ginger (*Zingiber officinale*) [15].

The oldest literature mentioning sambal in Indonesia was found to be *Serat Centhini*, an ancient manuscript written in Sanskrit compiling knowledge of traditional Javanese religion, arts, tales, and teachings [16]. Such artwork, published circa the tenth century, recorded as many as 16 sambal variants in Java. In the 1920s during the Dutch colonial era, the popularity of sambal increased among the upper-class Dutch communities in Indonesia [17]. Sambal became part of the *rijsttafel* (literally translates to "rice table" in Dutch), a complete Indonesian elaborate meal set containing rice, side dishes, and Indonesian specialties that were known to be expensive and enjoyed by Dutch elites [18]. In a big recipe book entitled *Mustika Rasa* composed and written in 1967 under the direction of Soekarno (the first president of Indonesia), 63 sambal recipes appeared among 1,600 recipes of Indonesian traditional dishes [19]. Over the years, sambal recipes underwent adaptations and branched off into an assorted array of varieties, localized mainly according to regional taste and the availability of the ingredients [20].

Nowadays, sambal is widely used in many regions of Indonesia as condiment. In many households and restaurants, sambals are made traditionally using fresh ingredients and supposed to be consumed directly. However, along with the development of technology, sambal has been produced commercially through sterilization with a view to fulfill high market demand and prolong its shelf life [21]. Well-known classic and traditional sambals have been consumed widely by Indonesians, but new sambal recipes are also constantly invented by food industries to meet consumers' expectations regarding novelties.

Types of Indonesian sambal

Sambals can be found almost in all regions of Indonesia spread throughout the current 34 different provinces (Fig. 1), although their names and compositions may be different according to the local cultures. Table 1 recapitulates the characteristics of sambals in different regions of Indonesia based on their ingredients and methods of preparation. Sumatra and Java Islands possess the most diverse types of sambals (64.5%), followed by Borneo Island (10.9%), Sulawesi Island (9.1%), and other islands such as Bali, Nusa Tenggara, Maluku, and Papua (15.5%). Overall, despite the existence of different sambal in the provinces in Indonesia, the distribution of sambal varieties tends to be centralized mostly in Java and Sumatra Islands where chili pepper is ubiquitous and widely cultivated [6, 7].

Sambal from different regions in Indonesia may differ in the type of chili pepper used as a main ingredient (Table 1). A majority (70.9%) of our identified sambal varieties use the ubiquitous cayenne pepper as the main ingredient. Other types of chili peppers, such as bird's

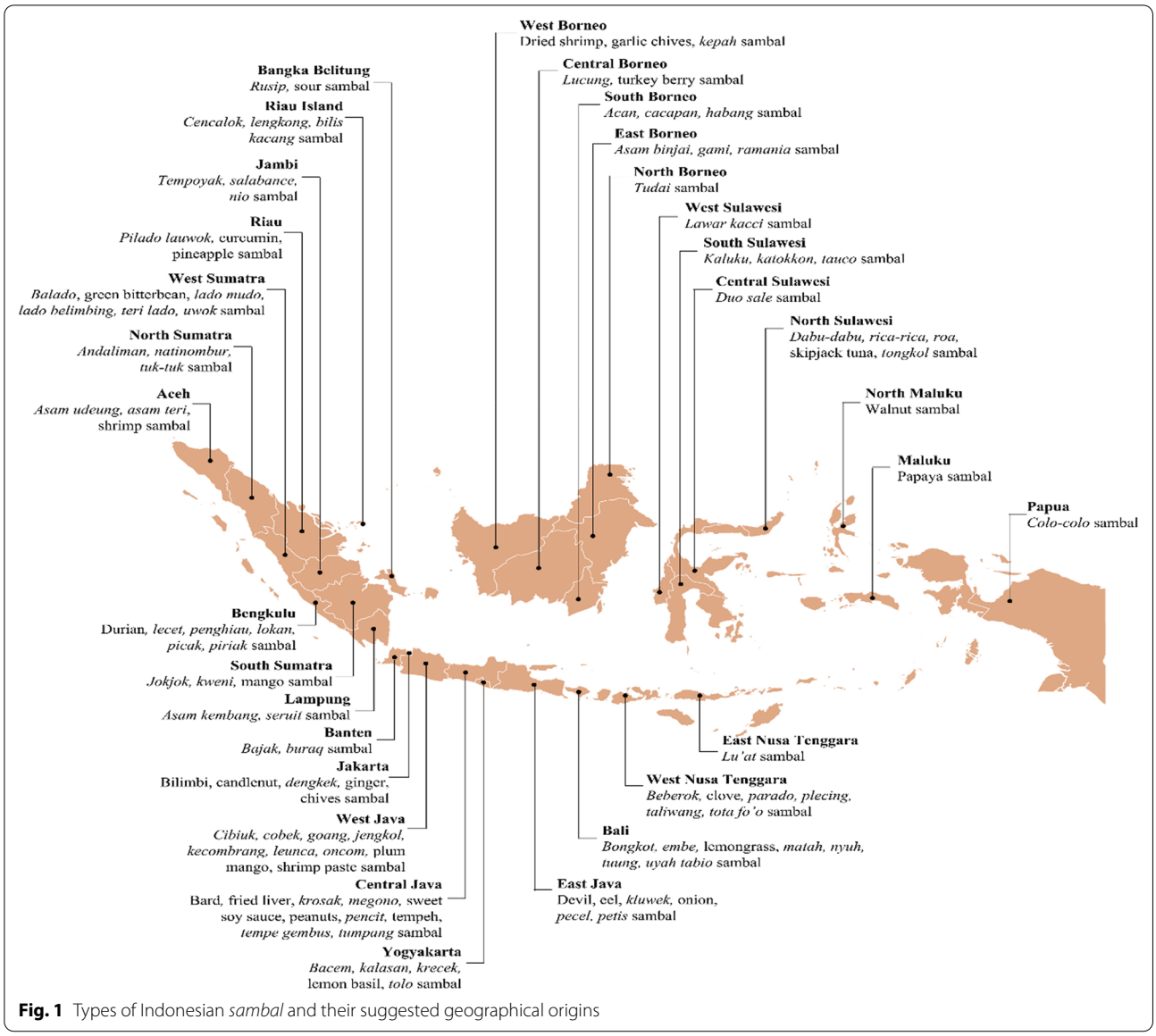

Fig. 1 Types of Indonesian *sambal* and their suggested geographical origins

eye chili pepper (56.4%) and green chili pepper or *cabai hijau* (10.9%), are also present as main ingredients. Different types of chili pepper commonly used in Indonesian sambal recipes are presented in Fig. 2. Some sambal recipes may include specific variant or cultivar of chili peppers, such as *sambal katokkon* from Sulawesi that uses Habanero pepper (*Capsicum chinense*) [22]. Indeed, the choice of chili pepper used in a sambal recipe directly influences the spiciness level or "heat" scientifically expressed in Scoville Heat Units (SHU) [23]. The spiciness level of common cayenne pepper is 30,000–50,000 SHU, while the spiciness level of bird's eye chili pepper can reach up to 175,000 SHU [24]. Such levels are much higher than the bell pepper (0–100 SHU) or Jalapeno pepper (2500–8000 SHU) that are more commonly used in western cuisine [24]. Some sambal recipes also suggest mixing several types of chili pepper to enrich the flavor and reveal some unique characteristics of the sambal. The extremely hot sambal *setan* (*setan* means devil in Indonesian) from East Java was given such a daunting name since it is made from Madame Jeanette pepper, a cultivar of *Capsicum chinense* rated at 125,000–325,000 SHU [25].

Apart from the utilization of chili pepper as a main ingredient of Indonesian sambal, secondary ingredients also play a pivotal role in determining the flavor of a sambal. While chili pepper determines mainly the spiciness level of a sambal, the secondary ingredients

Table 1 Types of sambal in Indonesia based on region of origin, ingredients, and processing method

No.	Sambal	Equivalent in English	Region of origin	Primary ingredients			Secondary ingredients						Processing				Reference
				Red chili pepper	Bird's eye chili pepper	Green chili pepper	Shallot	Garlic	Lime	Shrimp paste	Tomato	Others	Crushing	Chopping	Raw	Cooked	
1	*Asam udeung*	–	Aceh		✓		✓					Shrimp	✓			✓	[54]
2	*Asam teri*	–	Aceh		✓		✓	✓				Salted anchovy	✓		✓		[55]
3	*Udang*	Shrimp	Aceh	✓			✓	✓	✓			Shrimp	✓			✓	[56]
4	*Andaliman*	–	North Sumatra	✓			✓	✓				*Andaliman* pepper (*Zanthoxylum acanthopodium*)	✓			✓	[57]
5	*Natinombur*	–	North Sumatra	✓			✓		✓			Curcumin, ginger, candlenut	✓			✓	[30]
6	*Tuktuk*	–	North Sumatra	✓			✓		✓			Salted anchovy	✓			✓	[30]
7	*Balado*	–	West Sumatra	✓			✓	✓			✓	–	✓			✓	[58]
8	*Lado mudo*	–	West Sumatra			✓	✓	✓	✓			–	✓			✓	[48]
9	*Teri lado*	–	West Sumatra	✓			✓	✓			✓	Salted anchovy	✓			✓	[30]
10	*Uwok*	–	West Sumatra		✓		✓		✓		✓	–	✓			✓	[30]
11	*Lado Belimbing*	–	West Sumatra	✓	✓		✓			✓		Carambola (*Averrhoa carambola*)	✓			✓	[56]
12	*Hijau Petai*	Green bitter bean	West Sumatra			✓	✓	✓			✓	Bitter bean (*Parkia speciosa*)	✓			✓	[57]
13	*Pilado Lauwok*	–	Riau	✓			✓					Salted anchovies	✓		✓		[59]
14	*Kunyit*	Turmeric	Riau			✓	✓					Turmeric, coconut milk	✓			✓	[60]
15	*Nanas*	Pineapple	Riau	✓	✓							Pineapple	✓		✓		[60]
16	*Cencalok*	–	Riau Island		✓		✓	✓				Dried shrimp	✓			✓	[61]

Table 1 (continued)

No.	Sambal	Equivalent in English	Region of origin	Primary ingredients			Secondary ingredients						Processing				Reference
				Red chili pepper	Bird's eye chili pepper	Green chili pepper	Shallot	Garlic	Lime	Shrimp paste	Tomato	Others	Crushing	Chopping	Raw	Cooked	
17	*Lengkong*	–	Riau Island	✓			✓		✓	✓		Marine fish, coconut milk	✓			✓	[62]
18	*Bilis Kacang*	–	Riau Island	✓			✓	✓				Salted anchovy, peanuts	✓			✓	[63]
19	*Tempoyak*	–	Jambi	✓			✓	✓				*Tempoyak* (fermented durian paste)	✓			✓	[20]
20	*Salabance*	–	Jambi	✓	✓		✓				✓	Catfish	✓			✓	[20]
21	*Nio*	–	Jambi	✓			✓	✓				Grated coconut	✓			✓	[20]
22	*Durian*	Durian	Bengkulu	✓			✓	✓				Durian *(Durio zibenthinus)*	✓			✓	[30]
23	*Lecet*	–	Bengkulu	✓	✓		✓	✓		✓	✓	–	✓			✓	[58]
24	*Peghiau*	–	Bengkulu	✓			✓	✓			✓	Bitter melon (*Momordica charantia*)	✓			✓	[64]
25	*Lokan*	–	Bengkulu	✓			✓	✓				Shellfish	✓			✓	[57]
26	*Picak*	–	Bengkulu	✓			✓	✓		✓	✓	–	✓			✓	[64]
27	*Piriak*	–	Bengkulu		✓			✓			✓	Smoked fish	✓			✓	[64]
28	*Jokjok*	–	South Sumatra	✓			✓	✓			✓	Tamarind	✓			✓	[57]
29	*Kweni*	–	South Sumatra	✓	✓							*Kweni* mango (*Mangifera odorata*)	✓		✓		[65]
30	*Mangga*	Mango	South Sumatra	✓	✓		✓					Unripe mango, palm sugar	✓			✓	[30]
31	*Asam*	Sour	Bangka Belitung	✓			✓	✓				Tamarind	✓			✓	[57]

Table 1 (continued)

No.	Sambal	Equivalent in English	Region of origin	Primary ingredients			Secondary ingredients						Processing				Reference
				Red chili pepper	Bird's eye chili pepper	Green chili pepper	Shallot	Garlic	Lime	Shrimp paste	Tomato	Others	Crushing	Chopping	Raw	Cooked	
32	*Rusip*	–	Bangka Belitung		✓		✓	✓			✓	Salted anchovy		✓		✓	[57]
33	*Seruit*	–	Lampung	✓	✓		✓	✓	✓		✓	Kweni mango (*Mangifera odorata*)	✓			✓	[66]
34	*Asam kembang*	–	Lampung	✓	✓		✓	✓	✓	✓		White mango (*Mangifera kemanga*)		✓		✓	[57]
35	*Kemiri*	Candlenut	Jakarta	✓	✓							Candlenut (*Aleurites moluccanus*)	✓			✓	[30]
36	*Jahe*	Ginger	Jakarta	✓	✓		✓	✓				Ginger	✓			✓	[67]
37	*Dengkek*	–	Jakarta		✓	✓	✓	✓	✓	✓		–	✓			✓	[67]
38	*Belimbing wuluh*	Bilimbi	Jakarta	✓	✓		✓	✓		✓		Bilimbi (*Averrhoa bilimbi*)	✓			✓	[68]
39	*Lokio*	Chives	Jakarta	✓	✓		✓			✓	✓	Chive	✓			✓	[30]
40	*Bajak*	–	Banten	✓			✓	✓		✓		Lemongrass, palm sugar	✓			✓	[57]
41	*Buraq*	–	Banten	✓		✓	✓	✓		✓		*Melinjo* (*Gnetum gnemon*) skin	✓			✓	[67]
42	*Cibiuk*	–	West Java			✓		✓	✓	✓		Lemon basil		✓	✓		[67]
43	*Cobek*	–	West Java	✓	✓		✓	✓		✓		Ginger, aromatic ginger	✓			✓	[68]
44	*Gandaria*	Plum mango	West Java	✓	✓			✓				Plum mango (*Bouea macrophylla* Griff.)	✓			✓	[30]

Table 1 (continued)

No.	Sambal	Equivalent in English	Region of origin	Primary ingredients			Secondary ingredients						Processing				Reference
				Red chili pepper	Bird's eye chili pepper	Green chili pepper	Shallot	Garlic	Lime	Shrimp paste	Tomato	Others	Crushing	Chopping	Raw	Cooked	
45	*Goang*	–	West Java	✓				✓				Aromatic ginger	✓		✓		[67]
46	*Oncom*	–	West Java	✓	✓			✓		✓		*Oncom* (fermented tofu by-products)	✓			✓	[48]
47	*Jengkol*	–	West Java	✓			✓	✓				Jengkol (*Archidendron pauciflorum*)	✓			✓	[30]
48	*Kecombrang*	–	West Java		✓		✓	✓				Ginger flower (*Etlingera elatior*)	✓			✓	[30]
49	*Terasi*	Shrimp paste	West Java	✓			✓	✓	✓	✓		–	✓			✓	[30]
50	*Leunca*	–	West Java	✓			✓	✓				Black nightshade (*Solanum nigrum*)	✓			✓	[30]
51	*Krosak*	–	Central Java		✓			✓				–	✓			✓	[69]
52	*Jenggot*	Beard	Central Java	✓			✓	✓				Grated coconut	✓			✓	[69]
53	*Kacang*	Peanuts	Central Java	✓			✓	✓				Peanuts	✓			✓	[69]
54	*Kecap*	Sweet soy sauce	Central Java		✓		✓	✓				Sweet soy sauce		✓	✓		[69]
55	*Pencit*	–	Central Java	✓	✓		✓	✓				Unripe mango	✓			✓	[48]
56	*Tempe*	Tempeh	Central Java	✓	✓		✓	✓		✓		Tempeh	✓			✓	[30]
57	*Tumpang*	–	Central Java	✓	✓		✓	✓		✓		Overripe tempeh	✓			✓	[68]

Table 1 (continued)

No.	Sambal	Equivalent in English	Region of origin	Primary ingredients			Secondary ingredients						Processing				Reference
				Red chili pepper	Bird's eye chili pepper	Green chili pepper	Shallot	Garlic	Lime	Shrimp paste	Tomato	Others	Crushing	Chopping	Raw	Cooked	
58	*Tempe gembus*	–	Central Java	✓	✓		✓	✓		✓		Tempe gembus (tempeh made from tofu by-products)	✓			✓	[30]
59	*Goreng hati*	Fried liver	Central Java	✓			✓	✓				Chicken liver, chicken gizzard, potatoes		✓		✓	[57]
60	*Megono*	–	Central Java	✓			✓	✓		✓		Unripe jackfruit	✓			✓	[30]
61	*Krecek*	–	Yogyakarta	✓			✓	✓				*Krecek* (deep-fried beef skin)	✓			✓	[70]
62	*Bacem*	–	Yogyakarta	✓	✓		✓	✓		✓	✓	Kaffir lime leaves	✓			✓	[70]
63	*Tolo*	–	Yogyakarta		✓		✓	✓				Adzuki beans (*Vigna angularis*)	✓			✓	[70]
64	*Kalasan*	–	Yogyakarta	✓	✓		✓	✓			✓	Tamarind, lemongrass	✓			✓	[60]
65	*Kemangi*	Lemon basil	Yogyakarta	✓			✓	✓		✓		Lemon basil	✓			✓	[71]
66	*Belut*	Eel	East Java	✓	✓			✓				Eel	✓			✓	[66]
67	*Kluwak*	–	East Java	✓				✓				*Kluwak* (*Pangium edule*)	✓			✓	[57]
68	*Bawang*	Onion	East Java	✓		✓	✓			✓		Onion, palm sugar	✓			✓	[68]
69	*Petis*	–	East Java	✓				✓				*Petis*, peanuts	✓			✓	[30]
70	*Pecel*	–	East Java		✓			✓	✓			Peanuts, palm sugar	✓			✓	[71]

Table 1 (continued)

No.	Sambal	Equivalent in English	Region of origin	Primary ingredients			Secondary ingredients						Processing				Reference
				Red chili pepper	Bird's eye chili pepper	Green chili pepper	Shallot	Garlic	Lime	Shrimp paste	Tomato	Others	Crushing	Chopping	Raw	Cooked	
71	*Setan*	Devil	East Java	✓	✓		✓	✓				Madame Jeanette pepper (*Capsicum chinense*)	✓			✓	[30]
72	*Bongkot*	–	Bali	✓			✓	✓		✓		Ginger flower (*Etlingera elatior*)		✓		✓	[57]
73	*Embe*	–	Bali	✓		✓	✓	✓				–		✓		✓	[30]
74	*Matah*	–	Bali	✓			✓	✓	✓	✓		Lemongrass		✓	✓		[48]
75	*Tuung*	–	Bali		✓			✓	✓			Eggplant	✓			✓	[71]
76	*Nyuh*	–	Bali	✓	✓		✓	✓		✓		Grated coconut	✓			✓	[72]
77	*Serai*	–	Bali		✓	✓			✓	✓		Lemongrass		✓		✓	[72]
78	*Uyah tabio*	–	Bali	✓	✓	✓						Salt, coconut oil		✓	✓		[68]
79	*Cengkeh*	Clove	West Nusa Tenggara	✓	✓	✓	✓	✓				Clove (*Syzygium aromaticum*)	✓			✓	[66]
80	*Plecing*	–	West Nusa Tenggara	✓						✓	✓	–	✓			✓	[73]
81	*Taliwang*	–	West Nusa Tenggara	✓				✓		✓		–	✓			✓	[73]
82	*Tota Fo'o*	–	West Nusa Tenggara	✓	✓		✓				✓	Coconut milk, unripe mango		✓	✓		[68]
83	*Parado*	–	West Nusa Tenggara		✓							Kaffir lime	✓		✓		[30]
84	*Beberok*	–	West Nusa Tenggara	✓	✓		✓	✓				Tamarillo, cucumber, asparagus bean		✓	✓		[74]
85	*Luat*	–	East Nusa Tenggara	✓			✓		✓	✓	✓	Lemon basil	✓			✓	[20]

Table 1 (continued)

No.	Sambal	Equivalent in English	Region of origin	Primary ingredients			Secondary ingredients						Processing				Reference
				Red chili pepper	Bird's eye chili pepper	Green chili pepper	Shallot	Garlic	Lime	Shrimp paste	Tomato	Others	Crushing	Chopping	Raw	Cooked	
86	*Ebi*	Dried shrimp	West Borneo	✓			✓	✓		✓		Dried shrimp	✓			✓	[66]
87	*Suna*	Garlic chives	West Borneo		✓				✓	✓		Garlic chives (*Allium tuberosum*)	✓		✓		[59]
88	*Kepah*	–	West Borneo	✓	✓		✓	✓	✓			Shellfish (*Asaphis sp.*)	✓			✓	[60]
89	*Rimbang*	Turkey berry	Central Borneo		✓		✓	✓		✓		Turkey berry (*Solanum torvum*)	✓			✓	[60]
90	*Lucung*	–	Central Borneo	✓	✓		✓			✓		Ginger flower (*Etlingera elatior*)	✓			✓	[60]
91	*Cacapan*	–	South Borneo		✓		✓					Tamarind		✓	✓		[57]
92	*Habang*	–	South Borneo		✓		✓	✓		✓		Tamarind, ginger, cinnamon	✓			✓	[20]
93	*Acan*	–	South Borneo		✓		✓	✓	✓	✓	✓	Unripe mango	✓			✓	[67]
94	*Ramania*	–	East Borneo		✓		✓			✓		Plum mango (*Bouea macrophylla* Griff.)	✓		✓		[57]
95	*Asam Binjai*	–	East Borneo	✓	✓		✓			✓		*Binjai* (*Mangifera caesia*)	✓			✓	[67]
96	*Gami*	–	East Borneo	✓	✓		✓	✓		✓	✓	White-spotted spinefoot (*Siganus canaliculatus*)	✓			✓	[60]

Table 1 (continued)

No.	Sambal	Equivalent in English	Region of origin	Primary ingredients			Secondary ingredients						Processing				Reference
				Red chili pepper	Bird's eye chili pepper	Green chili pepper	Shallot	Garlic	Lime	Shrimp paste	Tomato	Others	Crushing	Chopping	Raw	Cooked	
97	*Tudai*	–	North Kalimantan	✓			✓	✓			✓	Blood clam (*Tegillarca granosa*)		✓		✓	[67]
98	*Cakalang*	Skipjack tuna	North Sulawesi		✓		✓	✓	✓	✓		Smoked skipjack tuna (*Katsuwonus pelamis*)	✓			✓	[68]
99	*Dabu-dabu*	–	North Sulawesi		✓	✓	✓		✓		✓	–		✓	✓		[67]
100	*Rica-rica*	–	North Sulawesi	✓	✓		✓		✓			Lemongrass	✓			✓	[57]
101	*Roa*	–	North Sulawesi	✓			✓				✓	Ballyhoo halfbeak (*Hemiramphus brasiliensis*)	✓			✓	[60]
102	*Tongkol*	–	North Sulawesi		✓		✓	✓		✓	✓	Red-tailed rock goby (*Sicyopterus lagocephalus*)	✓			✓	[30]
103	*Duo sale*	–	Central Sulawesi		✓		✓				✓	Unripe mango, coconut milk	✓		✓		[30]
104	*Lawar kacci*	–	West Sulawesi	✓	✓		✓	✓		✓	✓	Unripe mango, coconut milk	✓		✓		[30]
105	*Kaluku*	–	South Sulawesi		✓		✓	✓				Grated coconut, striped snakehead (*Channa striata*)	✓			✓	[30]

Table 1 (continued)

No.	Sambal	Equivalent in English	Region of origin	Primary ingredients			Secondary ingredients						Processing				Reference
				Red chili pepper	Bird's eye chili pepper	Green chili pepper	Shallot	Garlic	Lime	Shrimp paste	Tomato	Others	Crushing	Chopping	Raw	Cooked	
106	*Tauco*	–	South Sulawesi	✓				✓			✓	Tauco (fermented soybean paste)	✓			✓	[48]
107	*Katokkon*	–	South Sulawesi	✓			✓	✓				Habanero pepper (*Capsicum chinense*)	✓			✓	[30]
108	*Kenari*	Walnut	North Maluku	✓				✓	✓	✓		Walnut	✓		✓		[75]
109	*Pepaya*	Papaya	Maluku		✓		✓	✓	✓	✓	✓	Papaya		✓		✓	[75]
110	*Colo-colo*	–	Papua		✓		✓		✓		✓	–		✓	✓		[75]

Fig. 2 Different types of chili pepper commonly used in Indonesian sambal recipes: **A** cayenne pepper or *cabai merah*, **B** bird's eye chili pepper or *cabai rawit*, and **C** green chili pepper or *cabai hijau*

often give unique characteristics and a distinctive identity that would differentiate a sambal from other variants of sambals. Indeed, the name attributed to a sambal is often taken from the secondary ingredients added to it. According to Table 1, the most widely used secondary ingredients in Indonesian sambal recipes are shallot (80.0%), garlic (71.8%), fermented shrimp paste (38.2%), tomato (26.4%), and lime (22.7%). Garlic and shallot are commonly used in cooked sambal to strengthen and enrich its flavor. Fermented shrimp paste (traditionally known as *terasi* or *belacan*) is made from planktonic shrimp or *udang rebon,* previously and spontaneously fermented by lactic acid bacteria [26]. Such a paste is usually added to enrich the flavor of sambal by giving a strong smell and fishy flavor [27]. Originally, fermented shrimp paste was used in the recipe of sambal *terasi* from West Java (Fig. 3A, see Appendix for recipe). Now, *terasi* is also commonly found in sambal recipes originated from other areas in Java, Sumatra, and Borneo. Lime juice and tomatoes are often added to provide acidic taste, while palm sugar is used to bring sweetness, mainly in Javanese sambal recipes [28].

Besides sambal *terasi* from West Java, sambal *tempoyak* (Fig. 3B) from Bengkulu is a famous example of strongly flavored sambal due to its fermented content as its secondary ingredients. *Tempoyak* is a traditional condiment made from fermented overripe durian (*Durio zibethinus*) flesh that is widely consumed in Sumatra and West Borneo [29]. The processing of sambal *tempoyak* often includes coconut milk, galangal, lemongrass, anchovies, and turmeric leaves [30].

Some sambal varieties are made using local fresh fruits in their recipes, *e.g.,* sambal *lado belimbing* (carambola sambal) from West Sumatra (Fig. 3C), sambal *nanas* (pineapple sambal) from Riau, sambal durian (durian sambal) from Bengkulu, sambal *mangga* (mango sambal) from South Sumatra, and sambal *pepaya* (papaya sambal) from Maluku Islands [31]. In several cases, different regions may use the same fruit as a secondary ingredient in their sambal and give the sambal different names according to the local culture. *Kweni* mango (*Mangifera odorata*) appears in the recipe of both sambal *kweni* from South Sumatra and sambal *seruit* from Lampung [32]. Plum mango (*Bouea macrophylla* Griff.) is used in the recipe of sambal *gandaria* from West Java and sambal *ramania* from East Borneo. Both *gandaria* and *ramania* are two different local names for plum mango [33].

Most ingredients used in Indonesian sambal recipes are plant-based. In many cases, fermented shrimp paste (*terasi*) is the only animal-derived ingredient added in sambal recipes. Without taking into account the use of *terasi*, only 20% of the recipes presented in Table 1 contain animal-derived secondary ingredients, mostly fish and seafood, such as sambal *udang* (shrimp sambal) from Aceh, sambal *teri lado* (salted anchovy sambal) from West Sumatra, sambal *ebi* (dried shrimp sambal) from West Borneo, and sambal *tongkol* (mackerel tuna sambal) from North Sulawesi. Sambal *goreng hati* from Central Java (Fig. 3D) contains chicken liver and chicken gizzard, while sambal *krecek* from Yogyakarta is made with deep-fried beef skin that gives crunchy texture. In some areas where fisheries play a significant role in the society and culture such as Sulawesi Island, different sambal recipes were developed using specific marine ingredients ubiquitous in the areas. For instance, sambal *cakalang* from North Sulawesi is made from smoked skipjack tuna fish

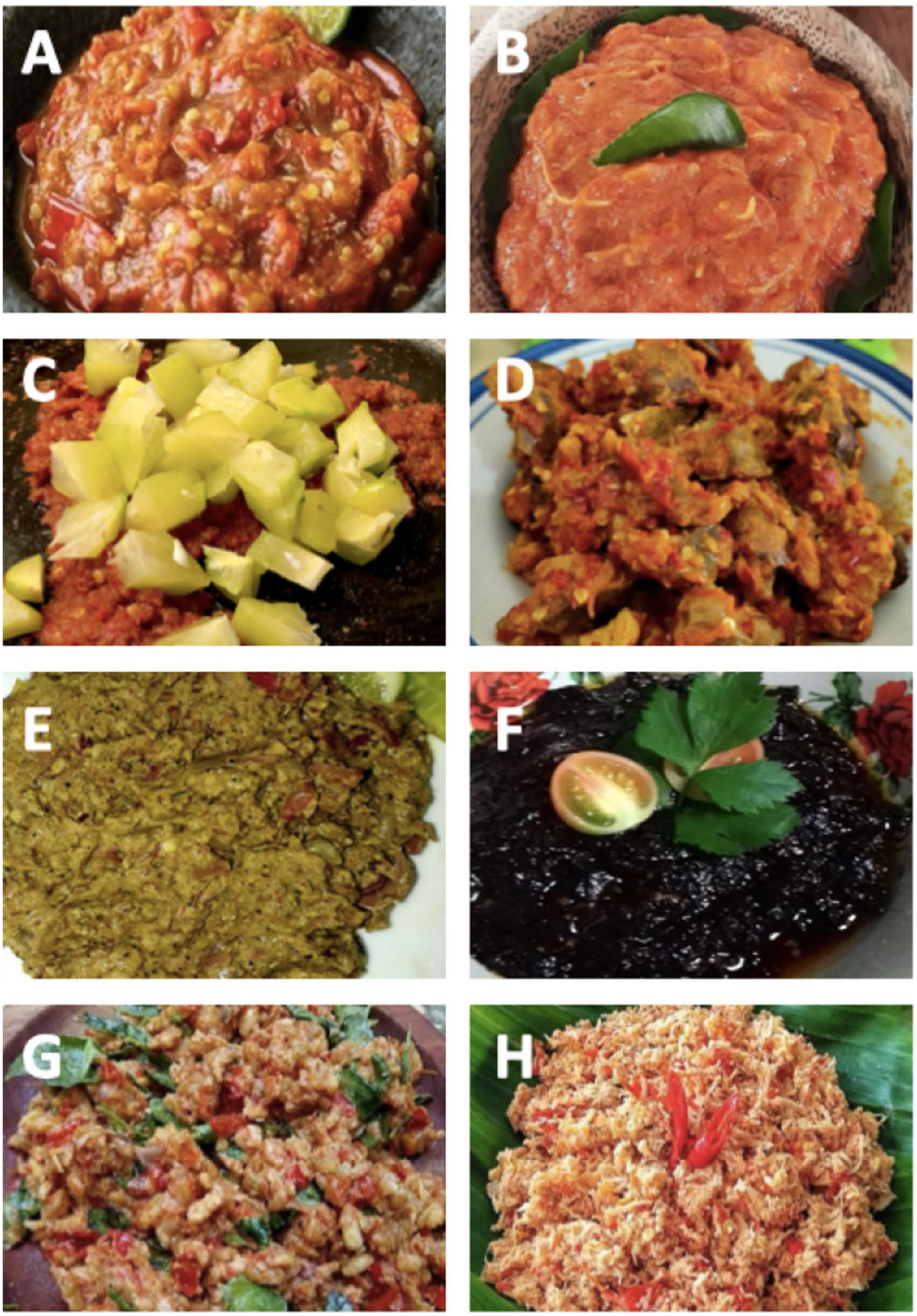

Fig. 3 Several types of sambal from different regions in Indonesia: **A** Sambal *terasi* from West Java, **B** sambal *tempoyak* from Bengkulu, **C** sambal *lado belimbing* (carambola) from West Sumatra, **D** sambal *goreng hati* (fried liver) from Central Java, **E** sambal *andaliman* (*Zanthoxylum acanthopodium*) from North Sumatra, **F** sambal *kluwak* (*Pangium edule*) from East Java, **G** sambal *tempe* (tempeh) from Central Java, and **H** sambal *jenggot* (beard) from Central Java

(*Katsuwonus pelamis*), sambal *duo sale* from Central Sulawesi is made from red-tailed rock goby fish (*Sicyopterus lagocephalus*), and sambal *kaluku* from South Sulawesi is made from striped snakehead fish (*Channa striata*) [34].

Some aromatic herbs may give a unique flavor to local sambal recipes, including sambal *leunca* (*Solanum nigrum*) from West Java, sambal *kemangi* (*Ocimum citriodorum*) from Yogyakarta, sambal *kecombrang* (*Etlingera elatior*) from West Java, sambal *serai* (*Cymbopogon schoenanthus*) from Bali, sambal *cengkeh* (*Syzygium aromaticum*) from West Nusa Tenggara, and the famous sambal *andaliman* (*Zanthoxylum acanthopodium*) from North Sumatra (Fig. 3E) that uses the seed pericarps of *Z. acanthopodium* in its recipe [35]. Such spice is closely related to Sichuan pepper with similar tongue-numbing characteristics. *Andaliman* is often difficult or even impossible to find in islands of Indonesia, except in North Sumatra as this plant can only grow in the highlands [35]. The use of *andaliman,* in sambal recipes of North Sumatran sambal, gives specific flavor that distinguishes such sambal with those found in other regions of Indonesia [36]. Sambal *kluwak* in East Java has a highly recognizable appearance since the use of *Pangium edule* gives black color to it (Fig. 3F) [37].

Some local foods are often added to sambal recipes, thus providing a distinctive identity that would tie the very recipes to the specific regions where the foods are known to be born. Some well-known examples of sambal varieties using local foods as secondary ingredients are sambal *tempe* (tempeh sambal) from Central Java (Fig. 3G), sambal *oncom* from West Java, and sambal *petis* from East Java. Tempeh is a traditional Indonesian food made from soybeans using fungi *Rhizopus oligosporus* and/or *Rhizopus oryzae* [38]. Overripe tempeh or *tempe semangit* with strongly particular flavor is also used in the production of sambal *tumpang* in Central Java [39]. *Tempe gembus* is a type of tempeh made from fresh by-products of tofu processing (soy pulp or tofu dregs) known as okara [40] that is used as ingredient in sambal *tempe gembus* from Central Java. *Oncom* is made from okara fermented with fungi *Neurospora* sp. [41]. *Petis*, native to East Java, is a dark brown to black thick and sticky paste produced from shrimp or fish extract with an addition of salt and brown sugar caramel [42]. In some cases, a variety of sambals are named on the basis of their appearance. Sambal jenggot (*jenggot* means beard in Indonesian) is named so due to its beard-like appearance and texture since grated coconut is used in the recipe (Fig. 3H) [43].

Depending on the processing methods used, sambal may exist in the form of paste (Fig. 4A, B) and pickle- or relish-like (Fig. 4C, D). The paste form is made by crushing and mixing all the ingredients using a blender or, in a more traditional way, mortar, and pestle. The production of pickle-like sambal consists in chopping different ingredients and mixing them with some vegetable oil, sugar, and salt. Furthermore, the preparation process of sambal may or may not involve cooking, and therefore, sambal can be either raw or cooked. Cooked sambals are produced by cooking process resulting in distinct flavor and aroma, while raw sambal is mixed with additional ingredients and consumed immediately. Cooked sambal is more common in western Indonesia, while raw sambal is more common in eastern Indonesia [44]. Based on the data presented in Table 1, most types of sambal in Indonesia are cooked (82.7%) and have a paste-like physical appearance due to the crushing process (84.6%).

Cooked paste-like sambal varieties dominate the diversity of sambal in Indonesia. Sambal *bajak* from Banten (Fig. 4A), sambal *balado* from West Sumatra (Fig. 4B), and sambal *rica-rica* from North Sulawesi are examples of such varieties of sambal. Sambal *bajak* (*bajak* means plowing in Indonesian) is made from crushed red chili peppers and *terasi* that undergo sautéing. It is named so since the recipe is believed to be developed in the past by farmers' wives who prepared packed meals for their working husbands plowing the field [45]. Sambal *balado* and sambal *rica-rica* are types of spice mixture made by stir-frying ground chili peppers with other spices [46]. Unlike sambal that is often used as a separate dipping condiment, sambal balado and sambal rica-rica are usually mixed and stir-fried with its main ingredients and treated as a dish.

Sambal *matah* from Bali (Fig. 4C) and sambal *dabu-dabu* from North Sulawesi (Fig. 4D) are two famous examples of raw or uncooked sambals made by mixing different chopped ingredients. Sambal *matah* (*matah* means raw in Balinese traditional language, see Appendix for recipe) is made from chopped shallots, lemongrass, and kaffir lime leaves besides red chili peppers. Sambal *dabu-dabu* is made from red and green chili peppers, tomatoes, and lime juice. The processing of the so-called raw sambal usually consists in pouring some boiling vegetable oil into the chopped raw ingredients [47]. It is noteworthy that uncooked sambal made from chopped ingredients is mostly originated from the Indonesian islands outside Java and Sumatra.

Preparation and commercialization of sambal

Sambal is usually served as condiment for almost all dishes such as *lalapan* (raw vegetables mix), fried chicken, tofu, and tempeh. Sambal has a variety of flavors that match the side dishes to be consumed. Sambal which is dominantly sour and spicy is more suitable to be consumed with fish, while sweet and spicy sambal is

Fig. 4 Examples of cooked sambal made from crushed ingredients: **A** sambal *bajak* from Banten and **B** sambal *balado* (presented with eggs) from West Sumatra; and raw sambal made from chopped ingredients: **C** sambal *matah* from Bali and **D** sambal *dabu-dabu* from North Sulawesi

suitable for tofu and tempeh [48]. Traditionally, sambal can be made using traditional tools such as mortar and stone pestle. The chili pepper, shallot, garlic, and tomato are often ground using a mortar, while the *terasi* is fried or burnt first to release its aroma as well as to kill its pungent smell. In most Indonesian restaurants and traditional eateries (*warung*), sambal is prepared daily in bulk as 'freshly made sambal'.

Today, some big food brands have commercialized ready-to-eat sambal that can be easily found in traditional markets, supermarkets, and convenience stores. The majority of commercial sambal products are bottled, with a few brands available in plastic or aluminum sachet packaging (Fig. 5). The generic production process of commercial sambal is demonstrated in Fig. 6. Briefly, chili peppers are prepared through cleaning and sorting, followed by blanching (soaking in boiled water) for 3–5 min to soften the tissues and reduce microorganism density. The blanched chili peppers are then ground, mixed with other ingredients, cooked, and hot filled into sterile bottles. The sterilization process is done at the standard sterilization temperature of 250°F (121 °C) for

Fig. 5 Commercial ready-to-eat sambal products in different packaging widely sold in the Indonesian market

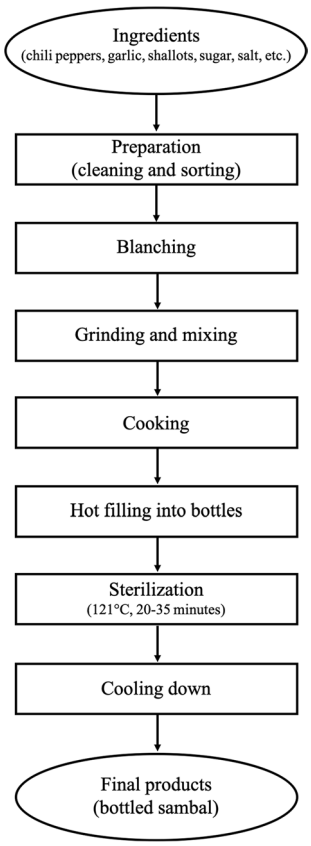

Fig. 6 Flowchart of generic production processes of commercial sambal in food industries

20–35 min to kill all putrefactive and pathogenic microorganisms, particularly *Clostridium botulinum* [49]. The sterilized sambal is then cooled down and processed for further distribution and sales.

To our knowledge, there have been no studies establishing the comparison between traditionally and commercially produced sambal in terms of production parameters, such as cooking time, temperatures, and acidity levels. However, from the perspectives of food science and technology, the production of commercial sambal implies sterilization at a higher temperature (121 °C), instead of at 100 °C commonly found in traditional sambal making. To ensure the absence of microorganisms, commercial sambal usually requires a longer cooking time than that of traditional sambal. One should also expect that commercial sambal exhibits a higher degree of acidity than traditional sambals. Acidic environment (pH < 4.6) is important to inhibit the growth of pathogens, including *C. botulinum* with ability to produce toxin during storage [50]. With regard to taste, it is quite difficult to compare the consumer acceptance regarding traditional and commercial sambal in general since each sambal maker has their own sambal recipes. Nevertheless, the sterilization process applied to *andaliman* sambal at 121 °C for 20–35 min has been demonstrated to not significantly affect its sensory properties [49]. In general, most commercial sambal is made by application of machine-driven manufacturing process, thus making it exhibit a smoother texture and more homogeneous content compared to traditionally made sambals. Commercial sambals also have a relatively long shelf life at room temperature, usually ranging from 6 months to 2 years, owing to the sterilization process [51].

It is undeniable that commercial sambal has contributed to Indonesia's economic growth through the enhancement of micro small and middle enterprises (MSMEs). According to GlobalData, the consumption of seasonings, dressing, and sauces per capita in Indonesia was reported to be higher in 2020 compared to the global averages [52]. It stood at 7.1 kg per capita in 2019 and is predicted to reach 8.5 kg per capita by 2024. The seasonings, dressing, and sauces sector in Indonesia is predicted to grow from USD 3.4 billions in 2019 to USD 4.8 billions by 2024, at an annual growth rate of 7.9%. Even though the market of commercial sambal in Indonesia is still dominated by big industries, MSMEs have thrived and expanded their marketing globally [53].

Conclusion

Sambal is undoubtedly an integral part in Indonesian cuisine and gastronomy. The development of sambal recipes is strongly associated with local culture and natural resources that vary greatly in different provinces in Indonesia. Indeed, different sambal recipes have been developed in many areas across the archipelagic nation, thus resulting in a rich diversity in Indonesian sambal. Based on our review on 110 different varieties of sambal, we identified that Sumatra and Java are the islands with the most diverse types of sambals (64.5%), followed by Borneo (10.9%), Sulawesi (9.1%), and other islands such as Bali, Nusa Tenggara, Maluku, and Papua (15.5%). About 70% of sambal varieties use cayenne pepper as the main ingredient besides other types of chili peppers, such as bird's eye chili pepper (56.4%) and green chili pepper (10.9%). Some common secondary ingredients often added in Indonesian sambal recipes are shallot (80.0%), garlic (71.8%), fermented shrimp paste (38.2%), tomato (26.4%), and lime (22.7%). Most types of sambal varieties are cooked (82.7%) and have a paste-like consistency (84.6%). It is noteworthy that uncooked sambals made from chopped ingredients (17.3%) are found mostly in islands outside Java and Sumatra. We hope this review would help and support further research related to sambal.

Appendix: Examples of Indonesian sambal recipes

This section introduces two common recipes of Indonesian sambal: sambal *terasi* from West Java (Fig. 3A) and sambal *matah* from Bali (Fig. 4C).

Sambal *terasi* (shrimp paste sambal)

The ingredients of sambal *terasi* include: 8 fresh red chili peppers (cayenne peppers), 8 bird's eye chili peppers, 5 garlic, 5 shallots, 1 small block (approximately 20 g) of *terasi* (fermented shrimp paste), ¼ tbsp. salt, ½ tbsp. sugar, and 5 tbsp. cooking oil. To make sambal *terasi*, the *terasi* (shrimp paste) is firstly heated for 1 min in a dry pan until it becomes slightly charred and fragrant. It is then cooled and set aside. All the ingredients (except shrimp paste, salt, and sugar) are sautéed together in a heated and oiled pan until they become tender. The sautéed mixture, cooked shrimp paste, salt, and sugar are then ground using a pestle and mortar or a small food processor until a smooth paste is formed. The paste is usually further cooked until it boils prior to serving. The sambal can be used immediately or kept in a refrigerator at 4 °C for 4–5 days.

Sambal *matah* (raw shallot sambal)

The ingredients of sambal *matah* include: 5 bird's eye chili peppers, 5 shallots, 1 lemongrass bottom half, 5 kaffir lime leaves, ¼ tbsp. salt, ½ tbsp. sugar, 2 tbsp. cooking oil, and 1 tbsp. lime juice. The chili peppers and garlic are chopped finely while the lemongrass and kaffir lime leaves are cut and sliced thinly. All the ingredients (except cooking oil and lime juice) are mixed together in a small bowl. The cooking oil is heated in a pan until it boils and poured directly to the mixed ingredients. Lime juice is subsequently added to give acidic flavor. The sambal can be used immediately or kept in a refrigerator at 4 °C for 1–2 days.

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Author contributions
RS designed the study and was in charge of the manuscript writing. FT collected the data, performed data analysis, and also contributed to the manuscript production. All authors read and approved the final manuscript.

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Availability of data and materials
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Declarations

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Not applicable.

Consent for publication
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