

## Review: Medicinal and pharmaceutical uses of skipjack tuna (*Katsuwonus pelamis* Linnaeus, 1758)

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**Abstract.** Safira RN, Hafiffah AS, Allobua BSN, Mukarrumah AN, Aulia AD, Naim DM, Setyawan AD. 2024. Review: Medicinal and pharmaceutical uses of skipjack tuna (*Katsuwonus pelamis* Linnaeus, 1758). *Cell Biol Dev* 8: 75-89. Skipjack tuna or skipjack fish or cakalang (*Katsuwonus pelamis* Linnaeus, 1758) belongs to the Scombridae family. The skipjack tuna has a fusiform, round, elongated body, gill segments, small conical teeth, dark purplish-blue with a silvery underside and abdomen, and an elongated dark line. The body length of the skipjack tuna can reach 1 meter, with the weight reaching more than 18 kg. Skipjack tuna is widely spread from the western and central Pacific to the Indian Oceans, including Indonesia. Skipjack tuna can only live in salt water and live off the continental shelf in the open sea. Ecologically, this fish is an indicator of the environmental conditions in the habitat of skipjack tuna. Seasonal variations in productivity and temperature are critical in influencing reproductive factors. They underscore the significance of spatial and temporal compatibility among ecosystems regarding egg hatching, which is crucial for the survival of new fish progeny. Skipjack tuna is widely processed and is a protein source for the community. The use of tuna fish can be done in traditional and modern ways. Besides being used as processed food, skipjack tuna is also used as a natural medicine that is beneficial for the health of the human body. Skipjack tuna has various pharmacological properties, such as antioxidant, anticancer, anti-inflammatory, and antidiabetic.

**Keywords:** Medicine, pharmaceuticals, skipjack tuna, utilization

### INTRODUCTION

Skipjack tuna or skipjack fish or *cakalang* (*Katsuwonus pelamis* Linnaeus, 1758) belongs to the genus *Katsuwonus*, Scombridae family (Artetxe-Arrate et al. 2021a). Scombridae has a high natural mortality rate but can travel long distances (Cunha-Neto et al. 2022). The skipjack tuna has an elongated body that is somewhat round and fat. The pectoral and dorsal fins are black and have a short and stocky tail; the upper body is dark blue and has a gray parallel line behind the ventral fin, the tip of the pectoral fin, and the caudal stalk (Aly et al. 2022).

Skipjack tuna is a cosmopolitan species widespread in tropical and subtropical oceans. Skipjack tuna is widespread in the western and central Pacific oceans (Ashida 2020). Skipjack tuna is also distributed in the Atlantic and Indian Ocean regions and is spread almost throughout the waters of Indonesia (Ridwan et al. 2020). Its geographical boundaries are 55°-60° N and 45°-50° S, and are abundant in the equatorial region throughout the year (Grande et al. 2014). Skipjack tuna is the most dominant tuna species in the Indian Ocean. However, tuna fishermen in the Indian Ocean still have difficulty determining the

potential of skipjack fishing areas due to limited geographical information (Semedi et al. 2023).

Skipjack tuna can only live in salt water and off the continental shelf in the open sea, with the water temperature ranging from 18-31°C (Mulyadi et al. 2017). The spatial boundary of the habitat is determined from the stratification of the upper ocean based on mixed layers and dissolved oxygen (Zhou et al. 2022). Skipjack tuna are limited to water with very high dissolved oxygen concentrations, at least 3.0-3.5 mL/L (4-5 ppm), for long-term survival. Skipjack larvae emerge from the bottom of the mixed layer to the top of the thermocline in the 20-25°C temperature range and the salinity range of 33.6-35.5 ppt (Collette et al. 2021). The habitat of skipjack tuna based on fishery data includes warm waters with sea surface temperatures above 24°C between the coasts of Africa and the Asian continent, as well as around the northern boundary of the South Indian Ocean Gyre. Trawlers rarely catch skipjack tuna in the Indian Ocean, but incidental catches show extensive habitat potential for adult skipjacks (Fonteneau 2014). The 1982 United Nations Convention on the Law of the Sea required semi-closed coastal states to coordinate and comply with regulations on

fisheries issues. Asian scientists overcame this obstacle by developing the Common Fisheries Resource Analysis (CFRA) for skipjack tuna (Prince et al. 2023).

Skipjack tuna are sensitive to environmental changes because they can move on a large scale to find suitable habitats and meet their physiological needs (Yen et al. 2016). Climate change significantly influences the adaptation processes of skipjack tuna, with these adaptations closely tied to population dynamics. As a result, the vulnerability of skipjack tuna species may increase under changing environmental conditions; (Kifani et al. 2019). Skipjack tuna act as an opportunistic predator of medium trophic level that consumes prey of about 1.2-5.5% of body weight per day to support their high energy needs (Fuller et al. 2021). In the spawning process, the influence of water temperature affects the assessment of spawning habitat in the wild and the development of skipjack tuna eggs. A high hatching rate of >50% occurred at 23-31°C. Since the spawning period is vulnerable to predators, a shorter hatching time in warm water provides an ecological advantage for skipjack tuna, as its main spawning grounds are in tropical areas (Fujioka et al. 2024).

Skipjack tuna is currently vulnerable; therefore, its conditions, including its ecosystem, must be considered (Wakamatsu and Managi 2019), such as the Atlantic bluefin tuna, *Thunnus thynnus*, which has been categorized as an almost endangered species according to the IUCN red list criteria (Soares et al. 2019). It threatens skipjack tuna and tuna-like species because the threats endanger the population of these species (Aranda et al. 2017).

Skipjack tuna is widely used in food processing and as a food source (Setyowati and Rahayu 2018), so its fishery products have good economic value locally and as an export commodity. Furthermore, the current utilization of tuna fish waste has not been maximized. By repurposing skipjack tuna's skin and bone waste to produce gelatin, we can significantly enhance its economic value, owing to the substantial collagen content in these materials (Panjaitan 2017). Skipjack tuna waste, such as fish heads, meat, and bones, can produce powdered broth (Indrastuti et al. 2022).

## SPECIES DESCRIPTION

### Taxonomy

Kingdom : Animal  
 Phylum : Chordata  
 Class : Actinopterygii  
 Order : Perciformes  
 Suborder : Scombroidea  
 Family : Scombridae  
 Genus : *Katsuwonus*  
 Species : *Katsuwonus pelamis* (Linnaeus, 1758)

(GBIF 2024)

The skipjack tuna is a pelagic fish (Luhur and Yusuf 2017), the only species in the genus *Katsuwonus* and is classified as a medium-sized fish (Suara et al. 2014).

### Morphological character

The skipjack tuna has a body with a very distinctive shape. They generally have a fusiform body, which is ideal for quick movement in the water. The body of this fish also tends to be round and elongated, with a pointed head and a body shape that extends back to the tail. This slightly rounded (fusiform) elongated body shape helps skipjack tuna to adapt to the dynamic marine environment and move nimbly in the water. There are two separate dorsal fins in skipjack tuna. The first dorsal fin has 14-16 sharp fingers, followed by the second dorsal fin, which has 7-9 finlets (additional small fins) (Figure 1). Skipjack tuna generally have a purplish-blue to dark back color, with a silvery belly. The body of skipjack tuna is not scaly except for the body butt (corselet) and sidelines. In general, skipjack tuna is between 40-200 cm long and weighs between 3-130. The combination of its long body shape makes it an efficient predator in chasing prey and avoiding predators in the ocean. Moreover, this distinctive body shape also helps in their extensive migration processes and long-distance travel in the ocean. With a body designed for movement efficiency and adaptation to the marine environment, skipjack tuna are an interesting example of evolution adapted to life in the open sea. It has 53-63 gill segments on the first gill arch. It has small conical teeth with a single series and small conical gill spines with a single series. The skipjack tuna is dark purplish-blue with a silvery underside and belly and has 4-6 prominent, elongated dark stripes (Rukshana et al. 2021). The size of skipjack tuna varies, with lengths that can reach 1 meter and weigh up to more than 18 kg. Skipjack tuna have scales only found on lateral lines and scars (Purwiningsih and Sakriani 2021).

### Reproductive cycle

Skipjack spawns year-round in warm-water tropics, but the area is difficult to forage. It makes skipjack tuna move to colder subtropical regions to find food. However, not all skipjack tuna make these movements; some remain around the spawning area. Skipjack tuna is a fast-growing, early-maturing species with high reproductive potential, which makes this species more resistant to fishing pressure than other tuna species (Artetxe-Arrate et al. 2021b). Skipjack tuna can lay eggs many times throughout the year. Skipjack tuna's spawning or spawning process usually occurs in waters with a sea surface temperature of at least 24°C. These warm temperatures support the development of fish eggs and larvae (Mawarida et al. 2022). The reproductive strategy of laying eggs in large numbers is common in skipjack tuna that have a short life cycle and a high mortality rate in the early stages. The main goal of producing large quantities of eggs is to increase the likelihood that some eggs will successfully hatch into strong larvae and survive in harsh marine environments. A female skipjack can produce between 80,000 and 2 million eggs in a single reproductive period (Yetisen 2021). Due to the importance of skipjack tuna as a food and economic source, sustainable fisheries management is critical. Several countries have implemented regulations to manage skipjack fishing, including catch quotas, no-catch zones, and spawning habitat protection (Adam 2016). The

summary of skipjack tuna (*Katsuwonus pelamis*) distribution, chemical constituents, pharmacological properties, and medical utilization can be seen in Table 1.

## HABITAT DISTRIBUTION

### Environmental factors

The existence and movement of skipjack tuna are greatly influenced by various environmental factors that can determine favorable places of feed. Some ecological factors related to the movement of skipjack tuna are ocean currents, sea surface temperature, depth, chlorophyll-a, and other environmental factors, such as salinity, oxygen availability, and predators and competitors (Hidayat et al. 2020). Sea surface temperature and chlorophyll-a are two key factors that significantly affect the behavior and distribution of skipjack tuna. Sea surface temperature is important for thermoregulation; the optimal temperature ensures skipjack tuna maintain efficient metabolic activity. In addition, physiological adaptations allow skipjack tuna to live in a wide range. Sea surface temperature changes trigger skipjack tuna to move to areas more suitable for their biological needs. Chlorophyll-a concentrations are an important indicator of primary productivity in the ocean, indicating food-rich areas for skipjack tuna, and skipjack tuna often follow migration routes based on food distribution (Abudarda and Zainuddin 2021). Additionally, oceanographic parameters play an important role in the life and growth of skipjack tuna, which can affect their various physiological and behavioral aspects. Some oceanographic parameters affecting skipjack tuna are metabolism, spawning, fish feeding speed, and other activities (Nurani et al. 2022).

The distribution and abundance of skipjack tuna in coastal and offshore areas is not static but fluctuates following complex patterns. Various interrelated oceanographic factors control these dynamics and create a network of interactions (Hasyim et al. 2022). Tropical species such as skipjack tuna are distributed in waters with temperatures up to 30-32°C, preferably at temperatures around 16°C, with relatively high oxygen content, relatively strong currents in corals, reefs, and shallow waters. This skipjack tuna is very sensitive to temperature changes. They can also be found in waters with abundant food sources, such as plankton and crustaceans (Muhling et al. 2015). Climate is one of the factors affecting the life of skipjack tuna. Climate change that results in global warming may affect the productivity of medium and high trophic levels, which can potentially impact marine resources such as tropical skipjack tuna (Kim et al. 2015). Oceanographic parameters such as Sea Surface Temperature (SST) and variability of climatic factors become limiting factors for fish distribution and even their survival. At the same time, while climatic phenomena such as El Niño and La Niña can also have negative or positive impacts on fish (Putri and Zainuddin 2019). In response to changes in temperature, food availability, or other environmental factors, skipjack tuna can travel

considerable distances and even across oceans. Their ability to move widely helps them survive and reproduce in various environmental conditions, making them one of the most adaptive marine predators (Yen et al. 2016).

### Distribution

The distribution and migration pattern of skipjack tuna is very wide because skipjack tuna are fast swimmers that travel a long distance from the waters of the archipelago to sea waters but not too far from the coastline; the temperature ranges from 17-23°C, with a swimming layer between 0-40 meters. Skipjack tuna migrate in groups to find spawning grounds, waters with plenty of food, and variations in environmental factors. Skipjack tuna can be found in shallow waters and warmer temperatures than other tuna (Putri et al. 2021). The more suitable habitat influences skipjack tuna's distribution, movement, and vulnerability. The survival of skipjack tuna was affected by the presence of prey, appropriate temperature, and sufficient oxygen. As a result, the distribution of skipjack tuna is annual and seasonal (Restiangsih et al. 2020). Skipjack tuna is found in the tropical and subtropical regions of the Pacific, Indian, and Atlantic Oceans, particularly in the equatorial areas of the western and central Pacific, known for their significant fishing activities (Matsumoto et al. 2014). The annual production of skipjack tuna in the southwestern Atlantic has consistently averaged approximately 25,000 tons from 1979 until 2018. However, a notable decrease in catch volumes was recorded in 2018 (Cardoso et al. 2020). The current distribution areas for skipjack include the Maluku Sea, Halmahera Sea, Banda Sea, Flores Sea, Indian Sea, Aceh Sea, Northern Aceh Waters, South Java, North Sulawesi, West Sumatra, Cendrawasih Bay, Tomini Bay, and Arafura Sea.

Despite their wide geographical distribution, uncontrolled exploitation can lead to regional population declines, ultimately affecting global populations. Furthermore, large stocks do not guarantee availability if fishing technology continues to develop. Fishing activities can change community structure and reduce the biodiversity and resilience of marine ecosystems. Although fish species have a wide distribution, they are still vulnerable to the negative impacts of intensive fishing (Ortuño Crespo and Dunn 2017).



**Figure 1.** Morphology of skipjack tuna (Fishbase 2025)

**Table 1.** Summary on skipjack tuna (*Katsuwonus pelamis*) distribution, chemical constituents, pharmacological properties, and medical utilization

Name	Distribution	Chemical constituents	Pharmacological properties	Medical utilization	
				Traditional	Modern
<b>English &amp; Scientific Names</b> <b>Scientific name:</b> <i>Katsuwonus pelamis</i> (syn.: <i>Euthynnus pelamis</i> ) <b>Primary name:</b> Skipjack tuna <b>Alternate names:</b> Striped tuna, Oceanic bonito, Arctic bonito (rare)	<b>Tropical, subtropical, and warm-temperate waters</b>  <b>Pacific Ocean</b> <b>Western Pacific:</b> Abundant near Japan, the Philippines, Indonesia, and Australia. <b>Eastern Pacific:</b> Found from California to Peru, including the Galápagos Islands. <b>Central Pacific:</b> Common around Hawaii, French Polynesia, and other Pacific island nations. <b>Atlantic Ocean</b> <b>Western Atlantic:</b> From the Gulf of Mexico to Brazil, including the Caribbean. <b>Eastern Atlantic:</b> From Spain and Portugal down to South Africa, including the Canary and Cape Verde Islands.	<b>Macronutrients</b> Water content: 68-75% of fresh weight High-quality protein: 23-28 g/100 g (contains all essential amino acids) Fat content: 0.5-2.5 g/100 g (varies seasonally) Minimal carbohydrates: <0.5 g/100 g Ash (minerals): 1.2-1.8 g/100 g <b>Essential amino acids</b> Lysine: 85-95 mg/ g protein Leucine: 75-85 mg/ g protein Valine: 50-55 mg/ g protein Histidine: 45-55 mg/ g protein (histamine precursor) Taurine (free amino acid): 100-300 mg/ 100 g <b>Fatty acid profile</b> EPA (omega-3): 5-12% of total lipids DHA (omega-3): 15-25% of total lipids Palmitic acid: 15-20% of total lipids Oleic acid: 10-15% of total lipids Excellent omega-3 to omega-6 ratio: 5:1 to 10:1 <b>Vitamin content</b> Vitamin B12: 8-12 µg/100 g (300-500% DV) Niacin (B3): 10-18 mg/100 g Vitamin B6: 0.5-0.9 mg/100 g Vitamin D: 2-5 µg/100 g Vitamin E: 0.5-1.2 mg/100 g <b>Mineral composition</b> Selenium: 40-70 µg/100 g Potassium: 350-450 mg/100 g	<b>Antioxidant properties</b> Selenium helps neutralize free radicals. Vitamin E protects cell membranes from oxidative damage. Bioactive peptides (e.g., anserine and carnosine) exhibit radical scavenging activity. Omega-3 fatty acids (EPA & DHA) reduce lipid peroxidation. <b>Anti-inflammatory effects</b> EPA & DHA modulate NF-κB and COX-2 pathways, reducing pro-inflammatory cytokines (TNF-α, IL-6). Anserine and carnosine suppress neuroinflammation. <b>Cardiovascular protection</b> Reduces triglycerides and increases HDL cholesterol (via omega-3s). Lowers blood pressure (ACE-inhibitory peptides from tuna protein). Anti-atherogenic effects (reduces plaque formation in arteries). Anti-thrombotic (reduces platelet aggregation). <b>Neuroprotective &amp; cognitive benefits</b> DHA supports neuronal membrane integrity and synaptic function. Anserine enhances brain-derived neurotrophic factor (BDNF) levels. <b>Anticancer potential</b> Selenium induces apoptosis in cancer cells (e.g., prostate, colon). Omega-3s inhibit tumor angiogenesis and metastasis. Bioactive peptides (e.g., KPH-41 from tuna hydrolysate) show cytotoxic effects on cancer cell lines. <b>Antimicrobial &amp; antiviral activity</b> Antibacterial peptides (e.g., defensin) active against <i>E. coli</i> , <i>S. aureus</i> ,	<b>Japanese kampō medicine</b> <i>Katsuo</i> (fermented skipjack) used to: Improve digestion Treat fatigue and weakness Boost energy (as invigorating tonic) <b>Pacific Island remedies</b> Raw liver applied topically for: Skin infections Wound healing Fish oil used for: Joint pain relief Ear infections (as ear drops) <b>Southeast Asian folk medicine</b> Broths/soups prescribed for: Post-illness recovery Lactation support in nursing mothers Fever reduction <b>Coastal African traditions</b> Smoked flesh used as: Protein supplement for malnutrition Anemia treatment (iron source) Eyes consumed for: Improving night vision <b>Mediterranean traditional use</b> Preserved in olive oil for: Heart health tonic Respiratory ailments	<b>Cardiovascular health</b> Source of omega-3 for: Hypertension management Triglyceride reduction Prevention of atherosclerotic plaque <b>Neurological support</b> DHA-fortified foods for: Cognitive development in infants Alzheimer's disease prevention Depression/anxiety <b>Sports nutrition</b> Protein isolates for: Muscle recovery supplements Athletic performance Creatine source for strength training <b>Metabolic health</b> Bioactive peptides used in: Anti-diabetic functional foods Obesity management products Omega-3 formulations for metabolic syndrome <b>Geriatric nutrition</b> High-quality protein for: Sarcopenia prevention Age-related muscle loss Combined EPA/DHA supplements for joint health <b>Clinical nutrition</b> Elemental diets for: Post-surgical recovery Cancer patient nutrition Low-purine protein sources for controlled diets <b>Ophthalmic health</b> DHA extracts for: Dry eye syndrome treatments Macular degeneration
<b>Asia-Pacific</b> <b>East &amp; Southeast Asia:</b> <b>Japan:</b> カツオ ( <i>Katsuo</i> ) - standard, スジキ ( <i>Sujiki</i> ) - less common <b>Korea:</b> 참치 ( <i>Chamchi</i> ) - general term, sometimes refers to skipjack <b>China:</b> 鲣鱼 ( <i>Jiān yú</i> ) - standard, 正鲣 ( <i>Zhèng jiān</i> ) - in Taiwan <b>Philippines:</b> <i>Gulyasan</i> (Tagalog), <i>Bariles</i> (Visayan) - may also refer to yellowfin tuna <b>Indonesia/Malaysia:</b> <i>Cakalang</i> (Indonesia), <i>Kayu</i> (Malaysia), <i>Debuk</i> (Aceh), <i>Fufu</i> (North Maluku) <b>Thailand:</b> ทุ่นกะตึก ( <i>Thoo gati</i> ), ทุ่นลาฮู ( <i>Thoo lai</i> ) - "striped tuna" <b>Vietnam:</b> Cá ngừ vằn <b>Myanmar:</b> <i>Ngā myīn htwet</i> (ငါးမြင်းထွတ်)					
<b>Pacific &amp; Oceania:</b> <b>Hawaii:</b> <i>Aku</i> <b>Tahiti:</b> 'Ahi pa'i'i <b>Fiji:</b> <i>Walu</i> <b>Samoa/Tonga:</b> <i>Atu</i> <b>New Zealand:</b> Skipjack or Striped tuna					

<p><b>Indian Ocean</b>  <b>Maldives:</b> ދިވެހި (Fiyala)  <b>Sri Lanka:</b> බලාය (Balaya)  <b>Seychelles:</b> Katwal (Creole)  <b>India:</b> Bangdo (Gujarati); Kuppa (Telugu/Andhra Pradesh)</p>	<p><b>Indian Ocean</b>  Found throughout, especially near the Maldives, Seychelles, Sri Lanka, and western Australia.</p>	<p>Phosphorus: 200-280 mg/100 g  Magnesium: 30-50 mg/100 g  Iron: 1-2 mg/100 g (heme iron)  Zinc: 0.5-1.5 mg/100 g</p>	<p>and <i>Vibrio</i> spp.  Antiviral potential (omega-3s may enhance immune).</p>	<p>(mixed with honey)  <b>Polynesian healing practices</b>  Fermented preparations used for:</p>	<p>prevention  <b>Immunonutrition</b>  Selenium-rich supplements for:</p>
<p><b>Atlantic Ocean &amp; Africa</b>  <b>West Africa:</b>  <b>Senegal:</b> Yaboy (Wolof)  <b>Ghana:</b> Ammoon (Fante)  <b>Nigeria:</b> Eja ori (Yoruba), Kifi (Hausa)</p>	<p><b>Seasonal migrations</b>  Skipjack tuna prefer <b>surface waters (0-260 m deep)</b> with temperatures between <b>15-30°C (59-86°F)</b>.</p>	<p><b>Bioactive compounds</b>  Anserine: 150-300 mg/100 g (antioxidant)  Creatine: 300-500 mg/100 g  Antihypertensive peptides (Val-Tyr, Lys-Tyr)  Inosinic acid (IMP): increases during fermentation</p>	<p><b>Antidiabetic &amp; metabolic benefits</b>  Improves insulin sensitivity (via omega-3-mediated reduction of inflammation).  Low glycemic impact (high protein, low carbohydrate content).  Taurine may protect against diabetic complications.</p>	<p>Digestive disorders  Internal parasites  <b>General traditional applications</b>  Whole fish consumption for:</p>	<p>Immune system modulation  Antioxidant enhancement  <b>Functional food development</b>  Fortification of:  Baby foods (brain development)  Elderly nutritional products  Heart-healthy food lines</p>
<p><b>East &amp; Southern Africa:</b>  <b>Swahili:</b> Jodari or Sangara  <b>Madagascar:</b> Antsiva (Malagasy)  <b>South Africa:</b> Skipjack (English)</p>	<p><b>Aggregating Devices</b> and floating debris.</p>	<p><b>Potential contaminants</b>  Mercury: 0.1-0.3 ppm  Cadmium: 0.01-0.05 ppm  Lead: &lt;0.02 ppm  PCBs: 0.05-0.3 ng/g  Dioxins: &lt;0.1pg TEQ/g  Histamine: may exceed 50 mg/100 g in spoiled fish</p>	<p><b>Hepatoprotective effects</b>  Reduces liver fat accumulation (non-alcoholic fatty liver disease, NAFLD).  Taurine and selenium support detoxification pathways.</p>	<p>Muscle development (athletes/workers)  Sexual vitality (aphrodisiac)  Fish skin applied for:  Burn treatment  Eczema relief</p>	<p><b>Pharmaceutical applications</b>  Marine-derived compounds for:  ACE-inhibitor drug development  Anti-inflammatory agents  Neuroprotective formulations</p>
<p><b>Caribbean &amp; Latin America:</b>  <b>Brazil:</b> Bonito-listrado or Gaiado  <b>Mexico:</b> Barrilete  <b>Cuba:</b> Bonito  <b>Haiti:</b> Bonit (Haitian Creole)</p>	<p><b>Processing effects</b>  Drying increases umami compounds (IMP)  Canning improves protein digestibility  Fermentation generates bioactive peptides  Heat processing reduces omega-3 content by 10-20%</p>	<p><b>Bone health support</b>  Calcium, phosphorus, vitamin D aid in bone mineralization.  Omega-3s reduce osteoporosis risk.</p>	<p><b>Wound healing &amp; skin health</b>  Collagen peptides promote tissue regeneration.  Zinc and omega-3s reduce skin inflammation (e.g., psoriasis, eczema).</p>	<p><b>Key traditional beliefs:</b>  Considered "warming" food in Asian medicine  Believed to strengthen qi/vital energy  Used ceremonially for healing rituals in some cultures</p>	<p><b>Nutraceutical industry</b>  Collagen peptides for:  Skin health products  Wound healing accelerants  Taurine extracts for energy</p>
<p><b>Europe &amp; Mediterranean</b>  <b>Spain:</b> Bonito del norte (caution: refers to a different species)  <b>Portugal:</b> Gaiado  <b>Italy:</b> Tonnetto striato  <b>Greece:</b> Παλαμίδα (Palamída) - also used for other small tunas  <b>Turkey:</b> Yazılı orkinos  <b>France:</b> Bonite à ventre rayé</p>	<p><b>Anti-aging properties</b>  Carnosine and anserine prevent glycation and protein cross-linking.  Omega-3s maintain telomere length</p>	<p><b>Muscle growth &amp; performance</b>  Protein (complete amino acid profile).  Creatine (naturally occurring) improves muscle strength and recovery.</p>	<p><b>Muscle growth &amp; performance</b>  Protein (complete amino acid profile).  Creatine (naturally occurring) improves muscle strength and recovery.</p>	<p>healing rituals in some cultures  <b>Note:</b> Many traditional uses now have scientific support (e.g., omega-3 content validating cardiovascular benefits), while others remain part of cultural heritage without clinical verification.</p>	<p><b>Preventive medicine</b>  Regular consumption recommended for:  Cardiovascular disease prevention  Cognitive decline reduction  Inflammatory condition management  <b>Note:</b> Modern applications often derive from traditional knowledge.</p>
<p><b>Middle East</b>  <b>Arabic:</b> تونة مخططة (Tuna mukhattat) - "striped tuna", جَنّ (Jinn) - in some dialects  <b>Iran:</b> تن مخطط (Tuna khatdar)</p>					

Note: Names: Johannes (1981), Collette and Nauen (1983), Sainsbury et al. (1985), Lehodey et al. (2008), Dueri et al. (2014), Eveson et al. (2015). Distribution: Collette and Nauen (1983), Lehodey et al. (2008), Fonteneau et al. (2013), Eveson et al. (2015), Dueri et al. (2014). **Chemical constituents:** Balogun and Talabi (1985), Sala (2009), Intarasirisawat et al. (2013), Nurjanah et al. (2015), Klomklao and Benjakul (2016), Chakraborty et al. (2017), Yoon et al. (2018), Shin et al. (2024). **Pharmacological properties:** Dyall (2017), Ouellet et al. (2017), Chen et al. (2018), Hossain et al. (2019), Mozaffarian and Wu (2018), Najafian and Babji (2018), Guo et al. (2019), Kohen et al. (2019), Tapiero et al. (2019), Holick (2020), Zainal et al. (2020), Yan et al. (2021). **Traditional medical utilization:** Johannes (1981), Nakamura (1985), Dyer and McGoodwin (1994), Ruddle (1994), Hviding (1996), Hamilton and Walter (1999), Zann (1999), Johannes and Yeeting (2001), Miyake et al. (2004). **Modern medical utilization:** Hsu et al. (2007), Burri et al. (2012), Ding et al. (2019), Zhang et al. (2019), Pateiro et al. (2020), Cai et al. (2022), Rungruang et al. (2024)

One of the distribution areas of skipjack tuna in Indonesia is the waters of Sadeng, in which the fish can be found all year around if the fishing season is right, namely from February to March or September to October (Noegroho and Chodrijah 2015). The Sadeng Coastal Fisheries Port is the center of economic activities. It plays a role in developing fishing technology, capturing fisheries business, and other activities related to the fisheries and marine sectors. Capture fisheries business is a commercial activity that involves catching fish and other aquatic organisms (Suharyanto et al. 2024).

### **Invasiveness and environmental impact**

Annual cycles in productivity and temperature are critical in determining reproductive time, and the spatial and temporal compatibility between their ecosystems and egg hatching for the survival of new fish offspring are important (Reglero et al. 2018). The movement of skipjack tuna on a large scale may be caused by the convergence of the ocean, a foraging area. Ocean convergence can draw large amounts of plankton and fish to the surface, creating highly productive conditions for marine predators such as skipjack tuna. The accumulation of abundant food resources, such as plankton and small fish, attracts predatory fish species to move to the area. This phenomenon often occurs offshore, where continental ocean currents meet open ocean currents or near the confluence of different ocean currents. The movement of skipjack tuna on a large scale could also aim to gather in large numbers, increasing their chances of reproduction and survival. In addition, rich food resources in the ocean convergence area make this movement an efficient strategy for meeting skipjack's nutritional and energy needs (Wang et al. 2014). Understanding the reproductive biology of tuna, including skipjack tuna, is essential for managing and conserving this species. However, knowledge about reproductive biology is still relatively limited. Many aspects of life cycle and reproduction are still limited, especially in the wild (Carnevali et al. 2019). The tuna population has increased, and the number of global catches has tripled in the last 20 years, based on estimates of the population from the Indian Ocean. However, the catch of long-tailed tuna that exceeds the target tuna species (*Thunnus obesus* and *Thunnus albacares*) has resulted in the conclusion that the species has been overfishing for several years (Griffiths et al. 2019).

The exploitation of fishery resources often harms the environment. The exploitation process that does not pay attention to environmental carrying capacity is detrimental to the country and the marine and fisheries community. It can be the beginning of habitat loss due to environmental damage (Nugroho and Budianto 2021). The decline in biodiversity and biodiversity of fish resources in the wild can be associated with several factors, including uncontrolled overfishing and irresponsible and environmentally harmful fishing gear (Pratama et al. 2023). According to Indra et al. (2019), one of the efforts to reduce the negative impacts of fish exploitation is to develop environmentally friendly fishing gear. The Food Agriculture Organization (FAO 1995) issued a procedure

for responsible fishing activities (Code of Conduct for Responsible Fisheries - CCRF). In this CCRF, FAO sets a series of criteria for environmentally friendly fishing technology that are (i) fishing gear must have high selectivity; (ii) the fishing gear used does not damage the habitat; (iii) the fishing gear does not endanger fishermen; (iv) produces good quality fish; (v) the fish products produced do not endanger consumer health; (vi) the bycatch and discard results are as minimal as possible; (vii) the fishing gear used must have a minimum impact on the diversity of biological resources (biodiversity); (viii) does not catch species that are protected by law or are threatened with extinction; and (ix) the fishing gear is socially acceptable.

Mortality causes a decreasing number in a population. According to the results of Mawarida's research (2022), the total mortality value of skipjack tuna is 1.13 per year, natural mortality is 0.47 per year, and fishing mortality is 0.66 per year, with an exploitation rate of 0.59 per year. This exploitation rate indicates significant fishing pressure on the skipjack tuna population in the area. Differences in mortality values, especially fishing mortality, are caused by the number of different fishing activities in each region and at other times. Sari and Nurainun's research (2022) emphasizes that fish stocks are influenced by the population's ability to recover through reproduction and fishing pressure. Uncontrolled exploitation can decrease skipjack tuna stocks, so sustainable management is needed to maintain ecosystem balance and the sustainability of fish resources.

## **TRADITIONAL USE OF SKIPJACK TUNA**

### **Ethnozoological of skipjack tuna**

Skipjack tuna is one of the ingredients in processed cuisine in Spain. There is a celebration in May/June when fattier and tastier fish enter the Mediterranean to lay eggs. The activities include the best bluefin tuna tapa competition made from traditional recipes and the most innovative presentation by many local chefs (Pérez-Lloréns 2019). In Japan, processed skipjack tuna is a specialty food, such as smoked and dried *katsuobushi*, the main ingredient in fish soup and other Japanese specialties (Adolf 2019). Japan is the leading importer of bluefin tuna, the most preferred species to be processed into Japanese specialties, such as sushi/sashimi (Esteves and Aníbal 2019). In Sri Lanka, skipjack tuna is cooked as a curry with coconut milk or fried in palm oil, which is considered a delicacy and has become a tradition (Devadawson 2021).

Creating many facilities for processing and marketing marine products is necessary in communities with economic limitations. Developing seafood processing and marketing facilities is an important step to improving the economy of coastal communities. Through an integrated approach, including infrastructure development, marketing, government support, community empowerment, and sustainability, coastal communities can improve their living standards and create a more stable and sustainable economy (Antriyandarti et al. 2023). The calcium content

in skipjack tuna bones reaching 60-70% means that tuna fish has a high calcium content. The calcium in the bones of skipjack tuna can replace the role of fluoride, which functions to strengthen teeth. Calcium hydroxide (Ca(OH)<sub>2</sub>) is used in herbal toothpaste. These antibacterial compounds (Calcium hydroxide) can prevent the growth of dental plaque (Hariyanto and Antasionasti 2023).

In India, tuna soup powder is prepared from three traditional recipes, selected based on taste tests by the panels. The ingredients include dried tuna powder, wheat flour, milk powder, salt, black pepper, tomatoes, onions, garlic, ginger, coriander, fennel, carrots, sweet corn, and oil. During a 50-day cold storage, the soup powder contained 13.48% moisture, 38.43% protein, 0.0518% dry fat, and 12.65% ash content (Patel et al. 2023). Tuna broth supports cell growth and repair due to its richness in protein, adds umami flavor to soups and sauces, and serves as a healthier alternative to artificial flavors.

Pindang is a fishery processing product that plays an important role in post-harvest activities. Its products have a relatively short shelf life, less than two days at room temperature. Smoking is a drying technique that maintains the shelf life of fish by using wood fuel as a smoke producer. Pindang tuna that has gone through the smoking process is named *Sei-Pindang Ikan Tongkol* (Pandit et al. 2023).

### The use of body parts of tuna

Several body parts of the fish have been commonly used. The meat in skipjack tuna is the most common part to be consumed. Skipjack meat has a dense texture and is rich in protein; therefore, it is the main ingredient in various types of seafood. The fish fin is used in making soup or fish broth, where collagen content can make the dishes delicious. The tails are used in various processed dishes, such as fried or stir-fried, and are often used in making processed fish soup. Fish gills are rarely consumed directly, but they can be used as a basic ingredient in making processed fish sauces and as an additional taste in processed dishes. Skipjack tuna bones are used to make broth and processed into fishbone chips. Fish oil is extracted from offal or specific body parts and is often used as a source of omega-3, which is good for health. Skipjack tuna can be made into *arabushi* (a semi-finished product of katsuobushi) by a gradual smoking process using varying temperatures. The manufacturing process involves removing the fish entrails, boiling them at 60°C, removing the bones, and smoking them 7 times at different temperatures (Doe et al. 2020). Skipjack tuna account for 60% of the worldwide commercial tuna catch and are mainly used for canning because skipjack tuna can be stored longer and transported to various markets. This process involves processing, distilling, and pressing the fish in containers that maintain the integrity and freshness of the fish and protect it from contamination. Canning also allows skipjack tuna to be a raw material for various food products such as canned tuna, tuna in sauce, and other canned tuna. These products have become popular in the global market due to the ease of use, availability, and high nutritional value of skipjack tuna (Küçükakin et al. 2016).

In addition, skipjack tuna head bones contain gelatin extracted using the acid hydrolysis. Good quality gelatin produced from skipjack head bones can be a potential food source for pharmaceutical applications (Jalili et al. 2022). Gelatin is usually made from collagen, a protein in animals' skin, bones, and tissues. Gelatin is often used to give texture and consistency to foods such as candy, marshmallows, jellies, yogurt, ice cream, and other dishes. In addition, gelatin is also used to manufacture medicinal capsules, wound dressing materials, hair and skin care products, and photographic films (Minah et al. 2016). Gelatin contains amino acids essential for joint health, such as proline and hydroxyprolin (Suryanti et al. 2017). Gelatin consumption can help maintain cartilage structure and strength, vital for preventing joint diseases such as osteoarthritis. Gelatin contains nutrients supporting bone health, such as calcium and phosphorus (Raeatya and Rosida 2024).

Regular consumption of gelatin can help maintain bone density and prevent the risk of osteoporosis. Although often considered a part of the less desirable, skipjack head contains many vital nutrients with health benefits, such as high protein, which is essential for the growth and repair of body tissues and muscle building. Skipjack head also contains omega-3 fatty acids, such as DHA (docosahexaenoic acid) and EPA (eicosapentaenoic acid), which are essential for the health of the heart, brain, and nervous system (Apituley et al. 2020). The head of skipjack tuna contains essential minerals such as calcium, phosphorus, and selenium. Calcium is good for bone and dental health, while phosphorus is vital for energy metabolism and bone formation. Selenium is an antioxidant that can help protect the body's cells from oxidative damage. Gelatin can be obtained from the partial hydrolysis of collagen from animal skins (Aris et al. 2020).

Skipjack tuna liver, often discarded, is a valuable source of protein for human consumption. The preparation methods influence the physical, chemical, and functional properties of the skipjack tuna liver protein powder. Grinding and drying can influence the particle size and texture of protein powder. Additionally, the heating or drying may alter the powder's color and affect its final texture (Jeerakul et al. 2024). The preparation process can affect the nutrient content due to nutrient degradation and change the amino acid profile in proteins (Pawestri and Syahbanu 2023). The cooking process of skipjack tuna is determined based on color differences, texture properties, and sensory evaluation. Its nutritional quality is evaluated by measuring reduced sugar and protein levels, pH values, etc. Next, the reduced sugar and amino nitrogen content changes in the spice solution are analyzed. Boiling had the highest concentration of gradient sugar (92.5 points), and reducing sugar and non-protein nitrogen were 6.22 and 3.63 g/100 g, respectively (Zhang et al. 2023).

## CHEMICAL CONTENT OF SKIPJACK TUNA

### Nutritional composition

Fish is one of the most common food ingredients in Indonesia. However, fish consumption in Indonesia in 2018 was still relatively low at 50.69 kg/capita (The Ministry of Maritime Affairs and Fisheries 2023). Skipjack tuna has a high protein content and low fat. The protein content of the meat is 22.6-26.2 g/100g of meat, and the fat is 0.2-2.7 f/100 g of meat (Zulistina 2019). It has a high content of EPA and DHA. Skipjack tuna has essential amino acids such as histidine (11.37%), leucine (9.25%), lysine (7.78%), valine (7.16%), isoleucine (4.85%), threonine (4.51%), phenylalanine (3.39%), methionine (2.34%), and tryptophan (1.29%) (Canti et al. 2022). In addition, skipjack tuna contains minerals (phosphorus, sodium, iron, calcium), Vitamin A (retinol), and Vitamin B (niacin, thiamin, riboflavin). The nutritional content of skipjack tuna can vary is influenced by species, age, type, metabolic rate, season, movement activity, maturity level, and the skin and meat of skipjack tuna, which, of course, have different nutritional values (Hadinoto and Idrus 2018).

Skipjack tuna is a rich source of nutrients, containing various essential chemical components such as proteins, fatty acids, enzymes, vitamins, and minerals (Josef et al. 2019). Omega-3 fatty acids, such as eicosapentaenoic acid (EPA,  $C_{20}H_{30}O_2$ ) and docosahexaenoic acid (DHA,  $C_{22}H_{32}O_2$ ), are highly beneficial for heart and brain health (Pandiangan 2016). Enzymes such as pepsin and lipase play an essential role in the body's digestive and metabolic processes; skipjack tuna also contains vitamins D ( $C_{27}H_{44}O$ ) and B12 ( $C_{63}H_{88}CoN_{14}O_{14}P$ ), as well as minerals such as selenium (Se), all of which support optimal body function (Damongilala 2021). Combining these various nutrients makes skipjack tuna an excellent food choice for a healthy and balanced diet.

The nutritional profile of skipjack tuna includes high protein (20% of the meat weight), omega-3 fatty acids whose fat content varies depending on age, type, and season, rich in vitamin B12 and vitamin B6, as well as several minerals such as selenium, phosphorus, iron, magnesium, and potassium. This content is important for the growth and repair of body tissues, maintains brain health and heart function, reduces the risk of cardiovascular disease, and has a significant antioxidant effect (Ali et al. 2016). The fatty acid profile found in tuna fish includes Omega-3s such as EPA (eicosapentaenoic acid) and DHA (docosahexaenoic acid); omega-6 plays a role in helping the immune system and cell function. Unsaturated fatty acids in tuna fish are good for health. Omega-6 is a type of polyunsaturated fatty acid that is essential for the health of the human body and essential for the body's normal functioning, including cell growth, brain function, inflammation regulation, and hormone formation. Hence, omega-6 fatty acids are recommended for body health (Fitriyani et al. 2020).

Skipjack tuna also has the potential to contain heavy metals such as cadmium (Cd), lead (Pb), and Polonium-210 ( $^{210}Po$ ). However, the levels of heavy metals in skipjack tuna are usually low, especially under normal conditions.

Nonetheless, consumption of fish contaminated with high amounts of heavy metals can lead to exposures harmful to human health, such as heavy metal poisoning, and long-term exposure to heavy metals can lead to a variety of health problems (Ruelas-Inzunza et al. 2014).

Skipjack tuna is also the best choice among other tuna options to reduce the risk of mercury exposure. It is due to several factors, such as a relatively small body size, a short life cycle, and different eating habits. In contrast to other large tuna species, skipjack tuna tend to have a smaller body and live a shorter life cycle. Therefore, the period of their mercury exposure tends to be lower. In addition, skipjack tuna prefer smaller prey and are at lower trophic levels in the seafood chain, contributing to lower mercury accumulation levels in their bodies (Gunathilaka 2016). Vitamins and minerals are essential nutrients needed in small amounts to maintain health and support various vital body functions, from maintaining healthy bones and muscles to supporting the immune system and energy metabolism (Damongilala 2021). Skipjack tuna is high in omega 3, essential fat for supporting brain memory (Muchtart 2022). Omega-3s are a group of polyunsaturated fatty acids that have the benefit of reducing the risk of heart disease by lowering triglyceride levels, blood pressure, and the risk of blood clotting and supporting brain development in fetuses and children as well as cognitive function and mental health in adults (Famimah et al. 2017).

The dominant fatty acid content in skipjack tuna meat and muscle is docosahexaenoic acid (DHA), and palmitic acid is a saturated fatty acid generally associated with increased cholesterol in the blood. This fish's palmitic acid is balanced with healthier unsaturated fatty acids, such as DHA and EPA. Stearic acid ( $C_{18:0}$ ), also a saturated fatty acid, is found in smaller amounts than DHA and palmitic acid but still contributes to the lipid profile of these fish. Generally, fish have a high protein content of up to 20%. The protein content of fresh skipjack tuna is 21.45-25.29%; this content is greater than other species (*Thunnus tonggol*), which contains a protein of 21.8%; fresh skipjack tuna contains 0.60% fat (wet base), which is classified as low-fat fish which has a fat content of <5%, Carbohydrate content (db) of fresh skipjack tuna ( $3.067 \pm 0.953\%$ ) and ( $3 \pm 0.991.19\%$ ) (Nurjanah et al. 2015). The boiling process can indeed affect the nutritional content of fish, including the protein in skipjack tuna. A decrease in protein levels of about 2% after boiling for 0 to 30 minutes is a relatively small reduction. Some factors that can affect the decrease in protein levels in skipjack tuna after the boiling process are the duration of boiling, the boiling temperature, the size of the fish pieces, and the type of boiling (Pundoko et al. 2014). Skipjack tuna is known to be safe to consume because it generally has a low level of toxic metal. Factors affecting metals' low toxicity in skipjack tuna include short-lived animals, fast metabolism, feeding habits, and habitat distribution (Jinadasa et al. 2015).

Tuna bones contain about 30% collagen and 60-70% minerals in dry matter. Therefore, collagen extraction from tuna bones can be a promising way to obtain value-added products and lower environmental pollution (Yu et al. 2014). Collagen is a protein abundant in animal tissues

with a proportion of 30% of all body proteins. Collagen plays a role as the main component of connective tissue, muscles, gums and also skin. Collagen is the main connective tissue of animal proteins that has been widely used as a biomedical material. Skipjack tuna is one type of fish that is rich in collagen (Arfiani et al. 2023). Collagen is a very abundant protein in the human body, playing an important role in providing structure and strength to various tissues. Specifically, collagen is found in the skin, bones, tendons, ligaments, and other connective tissues. Collagen production decreases with age, leading to signs of aging, such as sagging and wrinkled skin and joint problems. Therefore, many supplement and skincare products contain collagen or ingredients that stimulate collagen production. One can consume collagen-rich foods such as bone broth, fish, and seafood to get the benefits of collagen.

### Physico-chemical characteristics

#### *Organoleptic characteristics*

Skipjack tuna generally have white muscles. However, some tuna species have dark muscles that are red or brown. These dark muscles contain more myoglobin, a protein that binds oxygen, than white muscles. This myoglobin turns the tuna meat red or brown (Kannaiyan et al. 2019). The organoleptic value of skipjack tuna follows the SNI standard 01-4110.1-2006. The quality of raw materials is influenced by several factors, such as cold temperatures handling throughout the supply chain, which can maintain the quality of fresh skipjacks for up to 10 days of storage. Fish texture greatly influences consumers' choice of fresh fish products rather than aroma (Sumandiarsa et al. 2020).

#### *Bacteria and parasites are potential contaminants in tuna*

In China, around 200,000 tons of tuna are processed annually. In the production of tuna fillets and cans, 25-30% of the weight of the fish is fish bones (spines and skull). Currently, some of the bones are processed into fishmeal or used as a component of animal hair feed, and the rest is disposed of as hazardous waste, increasing environmental pollution. Skipjack tuna stored at cold temperatures is still suitable for consumption for up to 4 days compared to storage at room temperature. Temperatures not correctly controlled during storage can accelerate the growth of microorganisms, leading to spoilage and deterioration of fish quality. Growth of bacteria such as *Pseudomonas* spp. and *Shewanella* spp. can cause decay by producing a foul odor and mucus on the surface of the fish. In addition, some bacteria, such as *Morganella morganii*, *Proteus* spp., and *Klebsiella* spp., can produce histamine from the amino acid histidine in fish meat, causing scombroid (histamine) poisoning (Wally et al. 2015). *Salmonella* sp. is a pathogenic bacteria in fresh and frozen fishery products. The source of the *Salmonella* sp. contamination could have originated from the equipment, poor sanitation, and poor hygiene. Provisions of SNI 2729:2013 concern about quality standards for tuna, cob, and skipjack tuna for *Salmonella* sp. suggesting minimal levels of *Salmonella* sp. to maintain the quality of fishery products (Ratnaningtyas et al. 2023). *Anisakis* sp. is an endoparasite found in fish

that can cause zoonotic or anisakiasis diseases in humans. Endoparasites infest the body of fish in the form of third-stage larvae. Infection begins with the ingestion of crustaceans contaminated with *Anisakis* sp. larvae. *Anisakis* sp. larvae were found in the fish's body in the digestive tract, muscles, and fish eggs. A previous Takubak et al. (2022) study showed that 27 fish from 120 samples were positive for *Anisakis* sp.

#### *Secondary metabolite compound contents*

Secondary metabolites in skipjack tuna include steroids and triterpenoids, with a cycloalkane basic structure and diverse substituents. These compounds are vital in regulating various biological functions and demonstrate significant anti-inflammatory and antibacterial properties (Hutajulu 2022). In the test of the content of secondary metabolite compounds in tuna, it was shown that the presence of saponins was able to damage bacterial cell membranes, and glycosides consisting of sugars bound to non-carbohydrates, had various biological activities, including antibacterial activity (Kaunsui et al. 2023). The combination of these secondary metabolite compounds contributes to the ability of skipjack tuna to fight bacterial infections, making it a potential source for developing natural antibacterial agents.

#### Chemical structure formulas

An antioxidant collagen peptide was obtained from skipjack tuna bone by combining trypsin and chymotrypsin as the catalyst. Based on the liquid chromatography-electrospray ionization quadrupole time-of-flight mass spectrometry (LC-ESI-QTOF-MS) analysis, the amino acid sequence of the peptide was identified as Ser-Ser-Gly-Pro-Pro-Val-Pro-Gly-Pro-Met-Gly-Pro-Met-Gly-Pro-Arg (SSGPPVPGPMGPMGPR). We found that the as-prepared collagen peptide can efficiently scavenge DPPH radical (IC<sub>50</sub> value was 3.149 mM), superoxide anion radical (IC<sub>50</sub> value was 3.803 mM), and ABTS radical (IC<sub>50</sub> was 9.489 mM). In addition, it has been found that the methionine (Met) residue in the collagen peptide could provide a precise active site during the scavenging of DPPH radicals by Fourier transform infrared spectroscopy (FTIR) analysis and matrix-assisted laser desorption/ionization time-of-flight (MALDI-TOF) mass spectrometry analysis. Ding et al. (2019) suggest that the peptide can be used in the food, cosmetic and pharmaceutical industries.

### MODERN USE OF SKIPJACK TUNA

Skipjack tuna is vital in maintaining fishery resources essential for global food security. As a member of the tuna family, skipjack represents one of several commercially important species that contribute significantly to the fishing industry. Nearly 7.7 million tonnes of tuna have been caught worldwide, accounting for 4.6% of all catches and aquaculture production (Sculley 2016). The highest output of skipjack tuna was in Bitung, North Sulawesi, in 2009, with around 6,132 tons, with a 398 billion rupiah (Asia et al. 2015).

Dried skipjack tuna or *katsuobushi* is a processed product of dried fish or smoked fish produced by boiling and drying. The production process of dried skipjack uses a fish drying oven with a drying time of 1.5 hours to reduce the water content by 50% and evenly cooked. The evenly cooked fish produces a texture of fish meat that is not too hard or mushy, and the color of the fish meat becomes reddish-brown, creating a savory taste. Dried skipjack tuna can be packaged using plastic packaging (Pamungkas and Irawan 2023).

Skipjack tuna is widely used as smoked fish. The organoleptic tests required for smoked fish include the acceptability of an ingredient, product quality, physical properties of the product, and moisture content contained because it can affect the texture and determine the durability (Ibrahim et al. 2014). Monitoring the quality of smoked skipjack tuna is very important to ensure that the products are safe and high-quality, following the Indonesia National Standard (SNI) 2725.1:2009 concerning smoked fish. This quality monitoring aims to protect consumers, build consumer trust, and increase product competitiveness (Hadinoto et al. 2016). Product competitiveness refers to the ability of a product to compete effectively with similar products from its competitors. It includes several factors, such as product quality, price, innovation, marketing, and customer service. Products with high competitiveness tend to have an advantage in one or several of these factors, making them more attractive to consumers than similar products from their competitors. A product with strong competitiveness tends to maintain or increase its market share and create sustainable profits.

In fish processing, salting and drying is the type of preservation most often used by the community for fishery products. It aims to remove some of the water in the fish body to inhibit the growth of microorganisms and bacteria that can damage fishery products (Nurhandayani et al. 2023). Currently, traditional fish processing still has prospects for development. Salted fish is an extensive, conventional fishery product in Indonesia due to its easiness, cheapness, and fast processing methods. It has the advantage of not requiring ice and storage at low temperatures, but the disadvantage is the lack of innovation for fishermen who process dry salted fish. However, synthetic chemical preservatives such as formalin, bleach, and borax affect the salted fish produced.

The other preservative ingredient is *atung* (*Parinarium glaberrimum*) seeds, which have broad-spectrum antibacterial and antioxidant properties. The seeds of the *atung* fruit are removed from the fruit, grated, and dried in the sun. Then, it is mashed by blending and put into plastic. An innovation breakthrough is low salt content technology in salted fish using a combination of salt and *atung*. The preservation process is done by soaking in a solution containing a salt concentration of 5 and 10%, followed by soaking in *atung* with the same concentration.

To make a 3% *atung* solution, mix 30 grams of *atung* with 1,000 mL of water. The *atung* solution can also be made at 4 and 5%. Combine 50 grams of salt with 1,000 mL of water. It can be adjusted to a 10% salt solution for use with the *atung* solutions on skipjack tuna. Clean and

cut the fish (2.5-10 kg) into long fillets. Soak the fillets in a 5% salt solution for 30 minutes, then in a 10% salt solution for another 30 minutes. Next, soak the fillets in 3, 4, and 5% *atung* solutions for 30 minutes each. After soaking, dry the fillets in the sun for 7-8 hours daily over 2-3 days. Finally, the dried fillets are weighed, and their moisture, protein, salt content, and total plate count (TPC) are tested according to Moniharapon et al. (2022). It can be used as a dietary supplement derived from unsaturated fatty acids, offering various health benefits. It is an anti-inflammatory and antiarrhythmic agent essential for heart health (Yulianto et al. 2022). Another processed fish is tuna nuggets from fresh tuna fish of high nutritional quality. With the development of current technology, skipjack tuna can make a variety of delicious processed food ingredients and contain many nutrients. Skipjack tuna nuggets combine flour, spices, and other ingredients such as flour, herbs and others mixed with fish meat (Prabowo et al. 2023).

## PHARMACOLOGICAL PROPERTIES

Skipjack tuna is a very healthy food and has many health benefits. Consuming skipjack tuna can help maintain heart health, lower high blood pressure, increase immunity, prevent cancer and kidney function, and improve blood circulation (Huang et al. 2023). Skipjack tuna contains high levels of the amino acid histidine, which microorganisms can convert into histamine during deterioration. Excessive consumption of histamine may lead to allergic reactions or poisoning. Following the fish's death, proteins break down into amino acids, including histidine. This histidine can react with the enzyme histidine decarboxylase produced by certain bacteria, resulting in the formation of histamine (Ismail 2024). The sodium content in various types of salted fish, including skipjack tuna, tude, roa, deho, and oci fish, ranges from 200 to 400 mg per 50 grams. Research indicates that individuals consuming more than 6 grams of salt per day have a significantly higher risk—approximately 5 to 6 times greater—of developing hypertension compared to those who maintain a lower salt intake. The World Health Organization (WHO) recommends limiting salt consumption to a maximum of 6 grams daily, equivalent to 2,400 mg of sodium. In light of this information, it is prudent to limit the consumption of salt-preserved foods, including salted fish varieties such as skipjack tuna, tude, roa, deho, and oci fish (Manikome et al. 2016). However, consuming skipjack tuna in reasonable quantities is still important to avoid the potential risk of heavy metal contamination (Anggraini et al. 2022). Skipjack tuna has many health benefits due to its rich nutrient content, including omega-3 fatty acids, selenium, and high-quality protein. These benefits include the prevention of arteriosclerosis, anticancer properties, anti-inflammatory effects, and the ability to lower blood cholesterol levels (Zheng et al. 2022). Consuming skipjack tuna regularly can have health benefits, including prevention of cholesterol disease, prevention of heart disease, and improved cardiovascular system health. In addition, skipjack tuna is an excellent food choice to support a diet program because

it is low in calories, high in protein, and rich in nutrients (Jemri and Jannah 2022).

Pickled skipjack tuna skin extract had strong antibacterial activity against Gram-positive bacteria (*Staphylococcus aureus*, *Bacillus subtilis*, and *Streptococcus*) and Gram-negative (*Escherichia coli*, *Salmonella typhimurium*, and *Pseudomonas aeruginosa*). The antibacterial activity is due to the extract's antimicrobial peptides and proteins. It could treat bacterial infections, food conservation, and health products.

Antioxidant properties are very important for the body because they help fight the adverse effects of free radicals. Free radicals are unstable molecules and can damage the body's cells, causing oxidative stress, which is linked to various health problems, including premature aging, cancer, heart disease, and neurodegenerative disorders (Arifin and Ibrahim 2018).

In addition, bioactive peptides in skipjack tuna also show antihypertensive, antioxidant, and immunomodulatory potential, which can be used to treat hypertension, inflammation, and degenerative diseases (Aluko 2015). Research is ongoing to explore the benefits of bioactive compounds from skipjack tuna, including omega-3 extraction, bioactive peptides for the treatment of hypertension, and the potential of antioxidant compounds to support the immune system and fight free radicals.

Skipjack tuna can prevent arteriosclerosis, anticancer, anti-inflammatory, and lower blood cholesterol levels, where the content of skipjack tuna includes omega-3 fatty acids, high-quality protein, and essential vitamins and minerals. They can help lower triglyceride levels in the blood, reduce inflammation, and slow down plaque formation in the arteries. They can also increase HDL cholesterol (good cholesterol) levels, which helps clear the arteries (Zheng et al. 2022). These nutrients work together to maintain human health, prevent diseases, and support optimal body function (Balami et al. 2019). Bogati (2018) explained that consuming skipjack tuna can help lose weight while maintaining appetite and muscle mass. It is known that DNA damage is hazardous and can give rise to various deadly diseases such as cancer, coronary heart, diabetes, etc. However, the antioxidant ability of skipjack tuna protein hydrolysate is shown by the ability to prevent DNA damage caused by hydroxyl radicals.

Skipjack tuna also contains anti-inflammatory compounds derived from eyeball oil (TEO). Eye oil (TEO) is a natural source of anti-inflammatory components, especially omega-3 fatty acids that effectively reduce nitric oxide (NO) levels and pro-inflammatory cytokines by up to 50% in a dose-dependent manner. Taking TEO may provide various health benefits, including reduced inflammation, support for autoimmune diseases, improved heart health, and protection against neurodegenerative diseases (Jeong et al. 2016). Extracting bioactive compounds from skipjack tuna must be considered efficient without wasting resources. Inefficient practices can lead to huge waste. Developing methods for synthesizing bioactive compounds or using other materials that do not rely on fish can reduce pressure on fish stocks.

## CONCLUDING REMARK

Skipjack tuna is an important fisheries resource that impacts global food security. Its wide distribution pattern, spawning throughout the year, and being found in many parts of the world make skipjack tuna the main commodity in world fisheries. The body parts of skipjack tuna have various benefits for humans. Skipjack tuna is prized for its flesh, while the fins are used for soups and stocks, adding flavor. The tail can be fried or used in fish soups. Gills are key for fish sauce, and bones are utilized for stock or fish bone chips. Tuna skipjack tuna can be processed in various ways and offers numerous health benefits, such as supporting heart health, lowering blood pressure, boosting immunity, preventing cancer, and improving blood circulation. All parts of the skipjack tuna—meat, fins, tail, gills, liver, skin, and bones—are edible and possess health advantages, making it valuable for diet and pharmaceuticals. This utilization is due to a large amount of protein, fatty acids, enzymes, vitamins, and minerals owned by skipjack tuna more than other fish, which makes skipjack tuna fish one of the types of fish that has many benefits and is widely used until now, this shows that there is a maximum level of utilization of skipjack tuna.

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