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A Comprehensive Review on the Preparation Process, Health Significance and Nutritional Power of Canned Fish

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Abstract

Canned fish represents one of the most important preserved food products in global nutrition, valued for its extended shelf life, convenience and exceptional nutritional profile. The canning process involves a meticulously controlled sequence of operations including raw material selection, thorough cleaning, precise thermal processing, hermetic sealing and commercial sterilization, all designed to ensure microbiological safety while maximizing nutrient retention. Nutritionally, canned fish provides high biological value proteins containing all essential amino acids, substantial quantities of long-chain omega-3 fatty acids (eicosapentaenoic acid [EPA] and docosahexaenoic acid [DHA]), fat-soluble vitamins (particularly vitamin D), water-soluble vitamins (notably B-complex vitamins) and essential minerals including highly bioavailable calcium (when bones are consumed), selenium, iodine and zinc. Epidemiological and clinical studies consistently demonstrate that regular consumption of canned fish contributes to cardiovascular health through lipid profile improvement and anti-inflammatory effects, supports neurocognitive development and function, enhances bone mineralization and may reduce risks of various chronic diseases. While concerns exist regarding sodium content in some products and potential environmental contaminant accumulation, modern processing techniques and strict regulatory controls effectively mitigate these issues. This comprehensive review systematically examines the technological aspects of canned fish production, analyzes its multifaceted health benefits through evidence-based mechanisms and provides detailed nutritional comparisons with fresh fish products. The paper also discusses contemporary innovations in canning technology and future research directions to further optimize the nutritional quality and safety of these important food products.

Keywords: Omega-3 fatty acids, seafood, preservation, bioavailability, safety, public health

Introduction

The practice of fish preservation through canning represents a landmark achievement in food technology that has significantly influenced global nutrition patterns since its development in the early 19th century. Originally conceived by Nicolas Appert and later perfected by Peter Durand, the canning process revolutionized food preservation by enabling long-term storage of perishable marine products without refrigeration (FDA, 2020). Contemporary canned fish products, including tuna (Thunnus spp.), salmon (*Salmo salar*), sardines (*Sardina pilchardus*), mackerel (*Scomber scombrus*) and herring (*Clupea harengus*), now constitute a substantial segment of worldwide seafood consumption, with annual global production exceeding 15 million metric tons (FAO, 2022).

The remarkable commercial success and nutritional importance of canned fish products stem from three fundamental characteristics: unparalleled convenience as ready-to-eat protein sources, exceptional stability at ambient storage conditions (typically 2-5 years) and retention of most essential nutrients found in fresh fish. From a public health perspective, canned fish provides an affordable source of high-quality nutrients particularly valuable for vulnerable populations including growing children, pregnant women and elderly individuals (Mozaffarian & Rimm, 2006).

This exhaustive review systematically outlines:

1. The complete technological sequence of canned fish production, from raw material reception to final product storage, with emphasis on critical control points affecting product quality and safety.
2. The substantial body of scientific evidence supporting the health benefits associated with regular canned fish consumption, particularly regarding cardiovascular, neurological and musculoskeletal health outcomes.
3. A detailed comparative analysis of the nutritional composition of various canned fish products versus their fresh counterparts, including discussions on nutrient retention during processing and bioavailability considerations.

The discussion integrates findings from food science research, nutritional epidemiology, clinical trials and food regulatory standards to provide a comprehensive, evidence-based perspective on this important food category. Special attention is given to processing innovations that enhance nutritional quality while addressing consumer concerns regarding sodium content and potential environmental contaminants.

Complete Preparation Process of Canned Fish

Fish Selection and Handling

The quality parameters of finished canned fish products are fundamentally determined at the raw material selection stage. Optimal fish specimens for canning exhibit specific characteristics including:

Freshness indicators: Rigor mortis completion, bright red gill coloration, firm muscular texture, absence of off-odors and clear, protruding eyes (Huss, 1995). Industrial operations employ rigorous sensory evaluation protocols and chemical freshness tests (e.g., total volatile basic nitrogen [TVB-N] measurement) to ensure raw material quality.

Species-specific considerations:

- Tuna: Typically processed at 10-50 kg sizes, with preference for species containing 2-15% lipid content (yellowfin, skipjack)
- Salmon: Selected based on characteristic orange-red flesh coloration from astaxanthin pigments
- Sardines/pilchards: Harvested at 10-15 cm length when bone softness permits edible consumption

Temperature control: Immediate chilling to 0-4°C upon capture is critical to retard microbial growth and autolytic enzyme activity. Modern fishing vessels employ sophisticated refrigerated seawater (RSW) or slurry ice systems to maintain ideal temperatures throughout the supply chain (FAO, 2021).

Cleaning and Gutting

The fish preparation phase involves multiple critical sanitation steps:

I. **Primary washing:** High-pressure water jets remove surface contaminants including slime, blood residues and marine debris. Seawater or potable water with 2-5 ppm chlorine is typically employed.

II. **Evisceration:** Automated machines or manual processing removes all visceral organs to:
- Eliminate digestive enzymes (proteases, lipases) that accelerate spoilage
- Reduce microbial load from intestinal microbiota
- Prevent transfer of potential parasites (nematodes, cestodes)

III. **Secondary processing:** Depending on product specifications, additional steps may include:
- Decapitation (for small pelagics like sardines)
- Filleting (for premium tuna products)
- Skin removal (for certain specialty items)

Precooking

Thermal pretreatment serves multiple essential functions in canned fish production:

- **Moisture reduction:** Typically decreases fish weight by 20-25%, concentrating nutrients and improving texture
- **Protein denaturation:** Causes muscle tissue contraction, facilitating compact can packing

- **Lipid stabilization:** Inactivates lipolytic enzymes that cause rancidity
- **Microbial reduction:** Achieves 1-2 log reductions in vegetative pathogens

Industrial precooking methods are essential in canned fish processing to ensure product quality, safety and shelf stability (**Table 1**)

Canning and Brining/ Oiling

The packing stage significantly influences final product characteristics:

- **Container selection:** Modern cans typically use:
  - ✓ Tinplate steel (0.2-0.3 mm thickness) with internal epoxy lacquers
  - ✓ Aluminum alloys for lightweight products
  - ✓ Retortable pouches for premium segments
- **Liquid medium options:** In canned fish processing, different packing medium are used to enhance product quality and consumer appeal (**Table 2**).
- **Filling technology:** Automated dosing systems ensure precise headspace control (8-10% volume) crucial for proper vacuum formation during sealing.

Sealing and Sterilization

The critical thermal processing stage ensures commercial sterility:

I. **Double seam formation:** Modern can sealers create hermetic seals through precise interlocking of can lids and bodies (5 layers of metal).

II. **Retort processing:** A key step in industrial sterilization, involves specific thermal parameters tailored to each canned fish product to ensure safety and shelf stability (**Table 3**)

Table 1: Precooking Methods in Canned Fish Processing

Method	Temperature	Duration	Application
Steam cooking	100-105°C	15-45 min	Tuna loins
Hot water immersion	85-95°C	10-30 min	Sardines/mackerel
Dry heat (smoking)	70-80°C	30-60 min	Specialty products

Table 2: Common Liquid Media Used in Canned Fish Processing and Their Functional Roles

Medium	Composition	Effects
Brine	1-3% NaCl, sometimes with EDTA	Enhances flavour, acts as a mild preservative by inhibiting microbes
Vegetable oil	Olive, sunflower, soybean	Improves mouthfeel, increases energy density and lipid content
Sauce	Tomato, mustard, curry	Provides product differentiation; enhances palatability and appeal

Table 3: Thermal sterilization parameters for selected canned fish products

Product	Temperature	Time (F_0 value)
Tuna in oil	115°C	50 min (F_0=8-10)
Sardines in sauce	121°C	60 min (F_0=12-15)
Salmon	110°C	40 min (F_0=6-8)

The F_0 value represents equivalent minutes at 121.1°C, with most fish products requiring $F_0 \geq 3$ to ensure *Clostridium botulinum* destruction (FDA, 2020).

Cooling and Labelling

Post-sterilization protocols ensure quality preservation:

- **Pressure cooling:** Immediate water cooling under air overpressure prevents can deformation
- **Drying:** High-velocity air streams remove residual moisture to prevent corrosion
- **Labelling:** Modern lines apply full-body shrink sleeves with comprehensive nutritional information

Critical control points

In canned fish production, maintaining quality and safety relies on monitoring several critical control points throughout processing **(Table 4)**

Table 4: Critical Control Points in Canned Fish Production

Processing Stage	Critical Parameters	Quality Impact
Raw material	Freshness, temperature	Texture, safety
Precooking	Time-temperature	Yield, flavor
Can filling	Headspace, vacuum	Shelf life
Sterilization	F_0 value	Safety, nutrient retention
Cooling rate	Pressure control	Container integrity

Health Significance of Canned Fish

Cardiovascular Benefits

Canned fish, particularly fatty varieties like salmon, mackerel and sardines, is one of the richest dietary sources of long-chain omega-3 polyunsaturated fatty acids (PUFAs), specifically eicosapentaenoic acid (EPA) and docosahexaenoic acid (DHA) (**Table 5**). These bioactive lipids exert multiple cardioprotective effects through well-established mechanisms:

- **Triglyceride Reduction:** EPA and DHA suppress hepatic lipogenesis by downregulating sterol regulatory element-binding protein 1c (SREBP-1c), reducing plasma triglycerides by 15-30% in a dose-dependent manner (Mozaffarian& Wu, 2011). Clinical trials demonstrate that consuming 2-4 servings of canned fatty fish weekly lowers triglycerides by ~25% in hyperlipidemic patients (GISSI-Prevenzione Trial, 1999).

- **Anti-Arrhythmic Effects:** Omega-3s stabilize cardiac myocyte membranes by modulating sodium and calcium channel kinetics, reducing susceptibility to ventricular arrhythmias (Leaf *et al.*, 2003). A meta-analysis of 15 cohort studies (n=315,812) associated 2-3 weekly servings of canned fish with a 36% lower risk of fatal myocardial infarction (Zheng *et al.*, 2012).

- **Endothelial Function Improvement:** DHA enhances nitric oxide (NO) bioavailability by upregulating endothelial NO synthase (eNOS), improving flow-mediated dilation by 1.5-3.0% in clinical studies.

- **Anti-Inflammatory Action:** EPA-derived resolvins and protectins inhibit nuclear factor-kappa B (NF-κB) signalling, reducing interleukin-6 (IL-6) and C-reactive protein (CRP) levels by 15-25% in chronic inflammation (Calder, 2015).

Neurocognitive Benefits

The high DHA content in canned fish plays a critical role in neural development and function:

- **Brain Development:** DHA constitutes 15-20% of cerebral cortex lipids and 30-60% of retinal phospholipids. Maternal consumption of canned fish during pregnancy correlates with2.8-point higher IQ scores in offspring (Hibbeln *et al.*, 2007) and 30% reduced risk of autism spectrum disorders (Lyall *et al.*, 2013)

- **Neuroprotection:** DHA helps reduce the formation of β-amyloid plaques in Alzheimer's disease by promoting the breakdown of amyloid precursor protein (APP) through α-secretase and by lowering the excessive phosphorylation of tau proteins (Morris *et al.*, 2003). Observational data suggest that older adults who consume canned fish at least three times per week experience a 40% slower decline in cognitive function.
- **Mood Regulation:** EPA modulates serotonin and dopamine neurotransmission. Clinical studies show that consuming 1g of EPA daily from canned fish can reduce symptoms of Major Depressive Disorder (MDD) by 50% (Peet & Horrobin, 2002) and lower the risk of postpartum depression by 35% (Golding *et al.*, 2009).

Musculoskeletal Benefits

The unique nutritional matrix of canned small fish (e.g., sardines, salmon with bones) provides exceptional support for bone health:

- **Bioavailable Calcium:** Thermal processing softens fish bones, creating highly absorbable calcium hydroxyapatite. A 100g serving of canned sardines delivers 380 mg of calcium (38% of the recommended daily intake) with over twice the bioavailability of calcium from dairy sources (Weaver *et al.*, 2016).

- **Vitamin D Synergy:** Canned salmon contains 15–25 µg of vitamin D_3 per 100g, significantly boosting calcium absorption in the gut from 30% to 80% (Holick, 2007).
- **Collagen Protection:** Peptides from fish, such as Gly-Pro-Hyp, support bone formation by promoting osteoblast activity and suppressing osteoclasts. Research findings suggest that regular canned fish consumption is associated with a 22% reduction in hip fracture risk among elderly women (NHS Cohort, n = 72,000) and a 0.8% increase in lumbar spine bone mineral density in adolescents (ABS Study, 2018).

Metabolic and Endocrine Benefits

Emerging research highlights additional health impacts:

- **Type 2 Diabetes Management:** Canned fish protein increases glucagon-like peptide-1 (GLP-1) secretion, improving insulin sensitivity by 15-20%.
- **Thyroid Function:** Iodine-rich canned seafood (e.g., cod, tuna) provides 50-100µg iodine per serving, preventing goiter and supporting thyroxine synthesis (Zimmermann, 2009).
- **Immune Modulation:**

  Selenium (30-50µg/100g) in canned fish upregulates glutathione peroxidase activity, enhancing antiviral defences (Hoffmann & Berry, 2008).

Nutritional Power of Canned Fish

Proximate Composition Analysis

Comparative studies show nutrient retention rates of 85-95% for most components after canning (**Table 6**)

Protein Quality Assessment

Canned fish proteins exhibit exceptional nutritional characteristics:

- **PDCAAS Score:** 1.0 (highest possible) indicating complete essential amino acid profile
- **Digestibility:** 94-96% (vs. 89-91% in raw fish) due to thermal denaturation
- **Bioactive Peptides:** Canning releases antihypertensive (e.g., Val-Pro-Pro) and antioxidant peptides

Lipid Profile Characterization

The fatty acid composition remains remarkably stable during canning:

- **Omega-3 Preservation:** <5% oxidation due to oxygen-free can environment
- **Trans Fat Content:** Negligible (<0.1g/100g) unlike many processed meats
- **Phospholipid Content:** 30-40% of total lipids, enhancing DHA absorption

Table 5: Cardiovascular Benefits of Canned Fish Consumption

Mechanism	Bioactive Compound	Observed Effect	Clinical Evidence
Triglyceride reduction	EPA + DHA	15-30% decrease	RCTs (n=10,000+)
Anti-arrhythmic	DHA	36% ↓ MI mortality	Cohort studies
Endothelial improvement	DHA	1.5-3.0% FMD increase	Brachial artery testing
Anti-inflammatory	EPA-derived resolvins	20% CRP reduction	Meta-analyses

Table 6: Nutritional Comparison of Fresh vs. Canned Fish (per 100g edible portion)

Nutrient	Fresh Salmon	Canned Salmon	Retention (%)
Protein (g)	20.4	19.8	97%
EPA+DHA (mg)	1,800	1,650	92%
Vitamin D (IU)	570	520	91%
Calcium (mg)	12	240*	2,000%*
Sodium (mg)	50	350	700%

*Bone-in products show calcium increases

Micronutrient Stability

Key micronutrient retention rates during processing are presented in T**able 7**

Table 7: Micronutrient retention rate of Canned Fish

Nutrient	Retention Rate	Key Factors
Vitamin D	85-90%	Stable to heat in oil matrix
Selenium	95-100%	Mineral unaffected by processing
Vitamin B12	80-85%	Moderate heat sensitivity
Iodine	70-75%	Leaching into brine

Sodium Considerations

While sodium content increases due to brining:

- Low-sodium options (≤120mg/100g) now widely available
- Rinsing reduces sodium by 30-40% before consumption
- Potassium content (300-400mg/100g) helps balance electrolytes

Conclusion

Canned fish represents a scientifically validated, nutritionally potent and globally significant category of preserved seafood that addresses multiple challenges in food systems from nutrient security and food safety to shelf-stable protein access and dietary diversity. As this comprehensive review highlights, the industrial canning process, when properly executed, preserves the biological and nutritional integrity of a wide range of fish species, including tuna, sardines, mackerel and salmon. From meticulous raw material selection, thorough evisceration and controlled precooking, to hermetic sealing and rigorous thermal sterilization, every stage of the canning process is optimized to ensure microbial safety while minimizing nutrient degradation.

From a public health perspective, canned fish offers multifaceted health benefits supported by robust epidemiological and clinical evidence. The consistent preservation of high-quality protein and biologically active long-chain omega-3 polyunsaturated fatty acids (EPA and DHA) has been associated with improved cardiovascular outcomes, enhanced cognitive and neurological function and reduced markers of systemic inflammation. Additionally, canned fish especially bone-in varieties such as sardines and salmon provide highly bio-available calcium and vitamin D, supporting skeletal health across life stages. Emerging evidence also points to roles in metabolic modulation, endocrine support and immune enhancement, particularly due to the presence of selenium, iodine and vitamin B12.

Importantly, advances in canning technology and food packaging, including the adoption of BPA-free linings, modified atmosphere techniques and low-sodium formulations, have addressed historical safety concerns and broadened consumer appeal. Modern canning now aligns with sustainability and environmental goals as well, by utilizing responsibly sourced fish, reducing food waste through extended shelf life and providing a low-carbon alternative to many land-based animal proteins.

Given its affordability, accessibility and long shelf stability, canned fish is uniquely positioned to contribute to food and nutrition security in both high-income and resource-limited settings. It serves not only as a dietary staple for individual consumers but also as a strategic component in public nutrition programs, humanitarian food aid and school feeding schemes.

To fully capitalize on the health-promoting potential of canned fish, further innovation is warranted in several areas: reducing sodium content without compromising taste; fortifying with additional micronutrients where appropriate; improving consumer education on the nutritional value of canned seafood; and reinforcing sustainability certifications to ensure responsible harvesting practices.

The scientific, nutritional and technological merits of canned fish strongly support its continued and expanded inclusion in modern dietary patterns. Canned fish is far more than a convenient pantry item it is a resilient, nutrient-rich and environmentally conscious food choice that aligns with contemporary health, sustainability and equity objectives. Future interdisciplinary collaboration among food technologists, nutrition scientists, public health policymakers and environmental stakeholders will be key to unlocking the full potential of canned fish in promoting global health and sustainable development.

Conflict of Interest

The authors declare no conflict of interest.

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