Understanding Spoilage in Canned Fish Products

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ABSTRACT

In the seafood sector, canning is a significant preservation technique that successfully causes extended the shelf life of fish while maintaining its nutritional content and flavour. But canned fish spoiling is still a major problem that compromises both consumer acceptance and product safety. Microbial spoilage in canned fish is mainly caused by pathogens like *Salmonella*, *Clostridium botulinum*, *Listeria monocytogenes*, and spoilage organisms such as *Pseudomonas*, *Shewanella*, and lactic acid bacteria. Enzymatic spoilage, particularly autolysis, breaks down proteins and lipids, affecting texture and flavour. Chemical spoilage, driven by lipid oxidation, leads to rancidity and off-flavours, worsened by oxygen and poor storage. Physical spoilage results from faulty retort processing, overfilling, under-exhausting, or contamination, compromising can integrity. Product quality is lowered by flaws including struvite crystals, blue discoloration, honeycombing, and sulphide blackening. In order to ensure safe, superior canned fish, it is essential to comprehend these characteristics.

INTRODUCTION

Canned fish products play a crucial role in global food security, offering a convenient, nutritious, and long-lasting source of protein. However, despite the protective barrier provided by canning, spoilage remains a significant concern for manufacturers, retailers, and consumers alike. In order to attain commercial sterility, fish is prepared, sealed in airtight containers (such as cans), and then heated to a particular temperature for a predetermined amount of time. This process is known as fish canning. Finding the right fish, pre-cooking, filling cans, exhausting (generating a vacuum), sealing, heat processing, cooling, and labelling are some of the most significant steps in this process. Understanding the mechanisms and causes of spoilage in canned fish is essential for ensuring product safety, maintaining quality, and minimizing economic losses. Spoilage in canned fish can be broadly categorized into three main types: microbial, chemical, and physical. Microbial spoilage is primarily caused by the survival and growth of heat-resistant bacteria, yeasts, and moulds that may persist despite thermal processing or enter through post-process contamination, such as leakage through seams or defective seals. Notably, spore-forming thermophilic bacteria like bacillus stearothermophilus and Clostridium species can survive inadequate heat treatment and subsequently multiply, leading to gas production, acidification, and characteristic defects such as can swelling or off-odours. Non-spore-forming bacteria, yeasts, and moulds may also contribute to spoilage, especially if the canning process is insufficient or if recontamination occurs after processing (Morka *et al*., 2025). Chemical spoilage in canned fish arises from reactions between the food, the can's material, and environmental factors. Oxidation, for example, can lead to rancidity, discoloration, and off-flavours, while acidic foods may react with metal cans, causing leaching of metals and further quality deterioration. Additionally, enzymatic activity within the fish itself can persist if the canning process is not properly controlled, resulting in textural changes and the formation of undesirable flavours and odours (Yi-Li *et al*., 2025). Physical spoilage, though less common, is typically a result of mechanical failures such as improper sealing, overfilling, or the use of defective containers. These issues can compromise the integrity of the can, allowing microorganisms to enter and proliferate or causing changes in the product's physical appearance and safety.

When food deteriorates or changes, or when the container's state deviates from normal, canned fish is deemed spoilt. Sometimes a completely good-looking object can conceal spoilt food inside. Fish quality is affected by spoilage, which changes the food's colour, flavour, texture, and nutritional content. A process or alteration that makes a product unfit for human eating is known as food spoiling. Both the can's shape and the food within must be in good condition for the canned food to be deemed unspoiled. Cans can spoil for a variety of reasons, which fall into the following categories: 1. Damage to the body 2. Spoilage of Chemicals 3. Microbial deterioration.

The main causes of canned fish spoiling are microbiological, chemical, and physical issues. The safety and quality of fish products in cans can be greatly impacted by these spoiling processes. Although it works well to prolong shelf life, the canning method is not impervious to spoiling concerns, which might jeopardise the quality and safety of food. A can is said to have swelled or blown when its end bulges from positive internal pressure caused by gases created by microbiological or chemical activity. The appearance of both normal and anomalous containers may aid in determining the type of deterioration.

Depending on the amount of internal pressure (figure 1), these anomalies or bulging are divided into four stages (Tang *et al.*, 2024), which are:

1. ***Flipper:*** When pressed up against a solid object, one end of a can with a regular look flips out (convex). When very little pressure is applied, the end snaps back to its original place (fig. 1a).

2. ***Springer**:* A can with a persistent protrusion at one end. The opposing end will spring out when pressure is applied to one end. may eventually turn into a mild or hard swell (fig. 1b).

3. ***Soft Swell:*** In this instance, thumb pressure can move the bulged ends, but they cannot be brought back into their original position. The metal end of the can moves in when pressure is applied to the top or bottom. may eventually turn into a hard swell (fig. 1c).

4. ***Hard Swell:*** In this case, the can's ends are securely and permanently distended. The top and bottom cannot move when pressure is applied to them (fig. 1d).

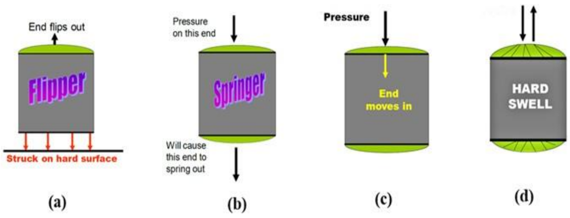

Fig. 1. Various forms of can bulging in thermal processing (source: Google)

Different types of spoilage in canned products

Physical Spoilage

Faulty Retort Procedures: When steam pressure is reduced too quickly during processing, high pressure builds up inside the cans, causing them to become severely strained and distorted and to seem swollen (Jimenez *et al*., 2024). However, because these cans lack positive internal pressure, the ends may be driven back to normal. Although these cans are not spoilt, leaker spoiling may result from this strain. When ends are formed from extremely thin tin plate, which is unable to sustain the pressure during processing, straining may also occur.

Overcapacity Filling: When the substance expands during retorting, straining happens in cans that are overfilled. The ends of these cans flip or spring because there is no hoover inside of them. With effectively heat-exhausted packs, it is unlikely that cans will be overfilled because any extra contents will expand and spill out of the can.

Under Exhausting: During heat processing, improperly exhausted can may suffer severe strain due to excessive internal pressure set up by the expansion of entrapped gases. Highly under exhausted cans may result in slight flipping to swells depending upon the size of head space and amount of gas (Nawaz *et al*., 2025). Because oxygen is a depolarising agent and speeds up internal corrosion, it is important to use appropriate exhaustion techniques and fill to lower the amount of oxygen in the head region. Less than 2% of oxygen is present in canned foods, which is significantly less than the amount in the air. Additionally, since they encourage corrosion and other harmful reactions, higher storage temperatures should be avoided.

Panelling: This state typically occurs in bigger cans with extremely high vacuums, where atmospheric pressure forces the can bodies inward (fig. 2a). If the seam is of low quality, panelling may cause it to leak. caused by an inability to regulate the retort's cooling pressure (Mohan *et al*., 2015).

Microbial Spoilage

Under Processing: Bacteria may thrive and produce gas in under processed canned food, which could lead to "swell" and spoiling. "Flat-sour" spoiling is a significant sign of under processing (Manning, 2019). It is a state in which the contents may liquefy or acidify without producing gas; this kind of spoiling may only be identified when the can is opened. When *Bacillus* species, which are thermophilic spore formers, survive heat processing, they produce "flat-sour." Proteins are broken down by mesophilic thermophiles such as *Clostridium* species, which also produce foul-smelling substances such ammonia, skatole, indole, and hydrogen sulphide. Foods that have disintegrated and containers that have swollen are signs of this type of spoiling.

Inadequate cooling: Thermophiles are controlled by quick cooling and storage at comparatively low temperatures. It is advised to chill cans to 35°C after processing since "flat-sour thermophiles" proliferate quickly in the temperature range of 48°C to 70°C. Failure to do so causes this type of spoiling. Thermophile spores have enough time to germinate because of the gradual cooling, and once activated, they proliferate and exhibit spoiling at comparatively normal storage temperatures. If *C. nigricans* is present, the inside may appear normal but will appear black due to the flat-sour pH becoming low and the suction being slightly diminished.

Post-process Spoilage: Different kinds of microorganisms, cocci, non-spore forming, and spore forming rods enter because of post-process leakage of contents. Moulds and yeast can also grow in cooling water. Since they may survive in chlorinated water, only heat-resistant spore formers may occasionally be found. Significant strain or leaking in cans is caused by poor seaming, insufficient seam overlap, and abrupt increases and decreases in steam pressure during retorting. Leakage can also cause by physical damage, abrupt temperature changes, and pressure changes during cooling.

Pre-process Spoilage: Any spoiling that occurs during the canning process prior to heat processing is referred to as pre-process spoilage. The main strategies to avoid this type of spoiling include low temperature storage, prompt handling, proper cleanliness, and personal hygiene. High temperatures allow the organisms to live and proliferate quickly. They may be killed during subsequent processing, but the gas released during the growth lag phase before to processing may result in swelling or flipping. Poor quality and poorly digested material might release an unpleasant odour, and the release of NH_3 raises the pH. Delays in preparation before or after dressing can also lead to the growth of various microorganisms that can cause spoiling, such as:

1. ***Staphylococcal food poisoning:*** If fish had *Staphylococcus aureus* before processing and was kept in an environment that was conducive to growth, like room temperature, for more than three hours, the organism could grow to high enough concentrations to produce enterotoxins in the fish product. Because it is sensitive to heat and chemicals, the organism itself might not survive processing, but the enterotoxins it produces are extremely heat stable and may survive heat processing and the preservation of canned fish.

2. ***Histamine poisoning:*** In fish, histidine is decarboxylated to create histamine. The enzyme histidine decarboxylase, which is found in many bacteria, amplifies this process. Large levels of free histidine are found in many fish species, especially scombroid kinds like tuna and mackerel. When this histidine is decarboxylated, histamine is subsequently found in canned fish. This can be reduced by using high-quality ingredients, treating fish hygienically, and storing it in a cold environment before canning (Tsai *et al*., 2005).

Chemical Spoilage

Internal corrosion: "Hydrogen swell" is the term for the hydrogen gas that may form because of internal can corrosion. The swelling could be "hard swell" or "flipping." A tiny patch of iron and tin may show through due to a lacquer coating flaw. Tin may sacrificially corrode steel plates and iron-tin alloys when it meets the product (Chandrasena, 2006). The amount of exposed steel grows as the tin coating gradually fades. Hydrogen has developed because of the exposed area being attacked quickly, leading to "hydrogen swell." Tin sulphide, iron sulphide, and staining by natural or synthetic colourants are examples of the types of stains that result from the product's contents converting the metal surface.

External corrosion: When aggressive alkaline substances meet one another, external corrosion causes either localised staining and detinning or the formation of rust. Excessive cooling after canning can cause exterior rusting, and using too much chlorine in cooling water can also induce tin plate corrosion. Effective management of the packer's plant and distribution can reduce these consequences.

Pitting corrosion*:* It is a localised electrochemical attack in which different unbalanced anode and cathode regions are connected to balanced electrode currents. Perforation is the result of this severe ailment. An illustration of this type of scenario is when the anodic end's surface area is relatively small due to defective lacquered aluminium, while the unlacquered tinplate surface is big and cathodic. In this instance, pitting will result from a very high anodic current density on the exposed aluminium and a very low cathodic current density on the tin plate.

Some commonly associated problems with Canned fishery products

Struvite Formation: Significant glass-like crystal (fig.2b) formation occurs, especially in canned marine items packed with brine at low temperatures. This is caused by the creation of the chemical compound known as "Struvite," which is $MgNH_4PO_4.6H_2O$. Phosphate comes from fish, the chemical crystallises at low temperatures, ammonium comes from fish muscle during heat processing, and magnesium comes from salt or seawater. The highest growth occurs in the temperature range of 40–50°C. Slow cooling might cause the crystal size to gradually develop to huge ones that are visible to the naked eye. Although these crystals are transparent, colourless, odourless, and nontoxic compounds, their presence is disagreeable because they resemble glass and could be confused for glass shards. Since magnesium is a necessary component to produce struvite, struvite formation can be avoided by employing chelating agents such as EDTA and hexametaphosphate (Ninawe and Rathnakumar, 2017).

Sulphide Blackening: Associated with canned crab, lobster, shrimp, etc. (fig.2c). It is brought on by the production of black iron sulphide. A lacquer that is resistant to sulphur is applied to fish cans. Tin can be revealed by any handling scratches or flaws in the lacquer finish (Tanikawa *et al*., 1967). Marine fish contain trimethylamine, which dissolves tin from the thin layer of the container that exposes iron. Fish emit sulphur-containing chemicals during heat processing, which combine with the exposed iron to generate iron sulphide, which is black in colour. This reaction occurs easily in an alkaline environment that develops because of spoiling. Careful processing handling is required to avoid this homogeneous lacquering. In addition to minimising any potential source of iron exposure, using parchment lining and keeping the right pH can also help control its incidence (Ninawe and Rathnakumar, 2017).

Curd and Adhesion: The precipitated protein known as "curd" is frequently found in canned salmon and mackerel. With salmon, which is typically canned without being cooked beforehand, this is more typical (Dolan et at., 2010). When the can is opened, the heat-coagulated meat sticks to the inside of the can ends and looks bad. When removing the curd from the can ends, the lacquer could peel off. A protein that dissolves in brine, curd exudes and coagulates when heated. Some of the causes of curd development include the use of raw fish, which is not particularly fresh, as well as insufficient brining and pre-cooking. Before stuffing, thoroughly wash the raw fish after 20 to 30 minutes of cold blanching in a 10-15% brine to avoid curd formation (Ninawe and Rathnakumar, 2017).

Blue Discolouration: Canned crabmeat is typically linked to blue discolouration. Blueing is more common in meat from areas of the body with weak blood circulation, like the legs, claws, etc. Blue copper sulphide is created when the copper in the hemocyanin of the crab haemolymphs combines with the sulphur compounds released during thermal processing. When the meat's copper content exceeds 2 milligrams per cent (wet weight), this behaviour becomes apparent. cutting the meat's copper content below the crucial threshold by bleeding it. Fractional heating at low temperatures is another technique. This is predicated on the finding that flesh proteins coagulate at 59–60°C, but blood proteins in crabs coagulate at 69–70°C. Therefore, heating the crab carcasses to 59–60°C causes the meat protein to coagulate, but the uncoagulated blood may stream out, lowering the copper content. The issue can also be managed by maintaining acidity, using a chelating agent, and lining the can with parchment.

Fig. 2. Typical spoilage and defects in canned fish products (Source: Google)

***Honeycombing*:** Tuna meat in cans that is prepared from stale raw materials has honeycombing. Because water is removed during steaming, the volume of the meat decreases because of the muscle protein coagulating at the surface. When the water inside the flesh evaporates and leaves as gas bubbles through the still-gelatinous interior, the soft, still-gelatinous interior swells like soap bubbles. The inflated gelatinous components solidify and take on the appearance of honeycomb when cooled. Perhaps the sole defence against honeycombing is the use of only fresh raw materials.

Softening of shrimp meat: The protein in raw fish breaks down into soluble non-protein components as its freshness decreases, making canned shrimp extremely tender. Softening can be avoided by using only fresh raw materials, maintaining a high standard of hygiene in the cannery, and finishing processing quickly without allowing lengthy breaks between steps.

***Mush*:** Types of pilchards captured at the conclusion of their spawning season have a flabby state known as "mush." This results in a very mushy feel in cans because the parasite protozoan *Chloromyxum* invades and breaks down the fish meat while it is being stored.

***Retort-Burn*:** Generally speaking, canned shellfish such as clams, mussels, and oysters are linked to this condition. This can occur when there is insufficient filling medium to cover the solid meal, leaving the top dry. By using enough filling media to cover the solids in the container, it can be avoided.

CONCLUSION

Canned fish is an important, nutritious, and long-lasting protein source. However, spoilage caused by microbial, chemical, and physical factors can affect product safety and quality. Proper control during raw material selection, processing, sealing, and heat treatment is essential to prevent contamination, corrosion, and can damage. Heat-resistant bacteria, oxidation, and mechanical faults are common spoilage causes leading to bulging, discoloration, and texture changes. Understanding these spoilage mechanisms and maintaining strict hygiene and processing standards help ensure product stability, extend shelf life, and reduce economic losses, thereby supporting canned fish's vital role in global food security.

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