Fish Processing Technology

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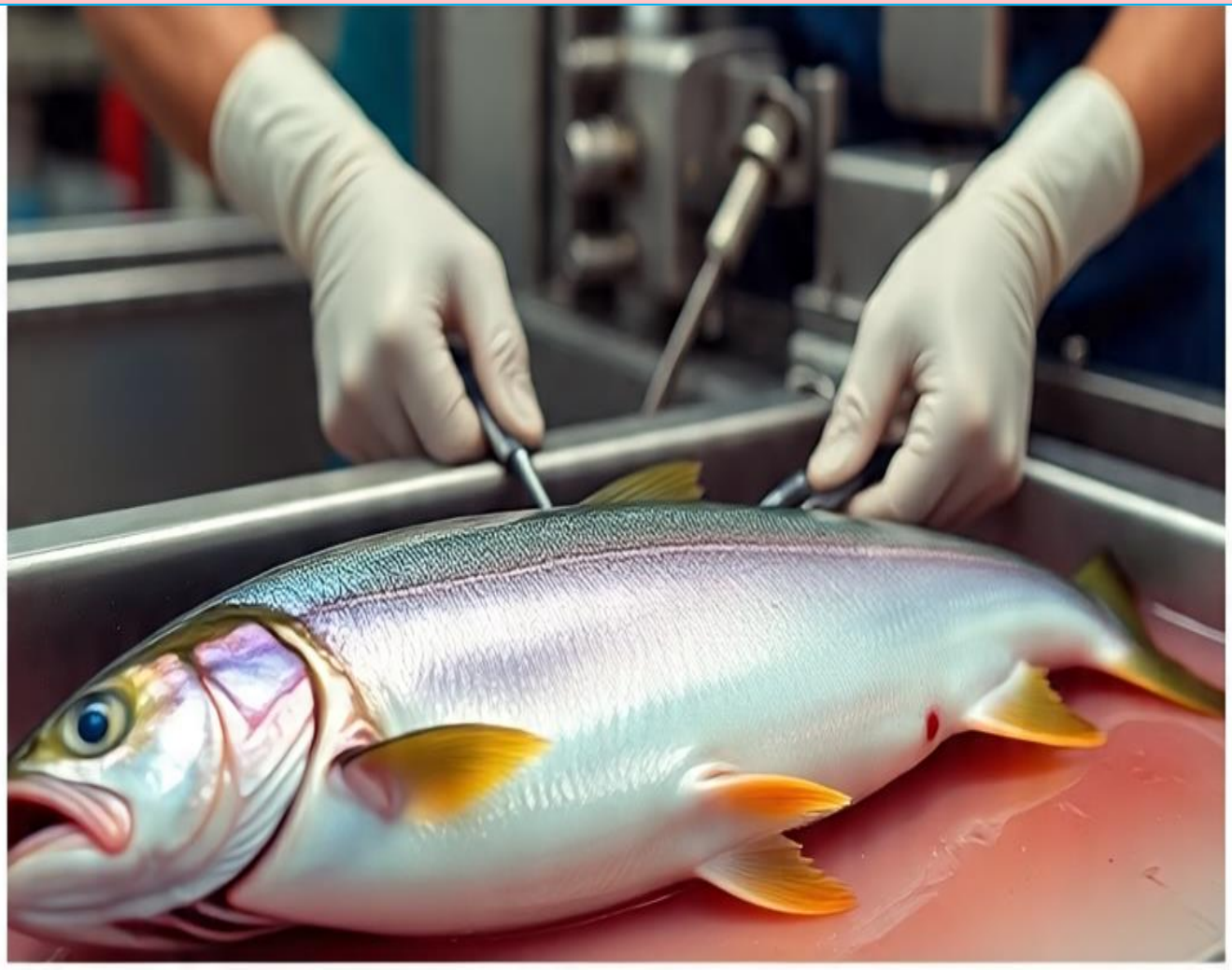

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FISH PROCESSING TECHNOLOGY

(AQUACULTURE MAJOR-COURSE-15 e-CONTENT)

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V SEMESTER

COURSE NO.: 15 - FISH PROCESSING TECHNOLOGY

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UNIT 1: INTRODUCTION

1.1 Principles of fish preservation.

Fish preservation is the process of treating fish and fishery products to prevent spoilage and extend their shelf life, ensuring they remain safe and wholesome for human consumption. This is essential because fish are highly perishable due to the rapid enzymatic, bacterial, and chemical changes that occur after capture.

Core Principles of Fish Preservation:

- **Minimizing the Growth of Microorganisms**: The primary aim of fish preservation is to prevent the growth and activity of spoilage bacteria and other microorganisms.
- **Controlling Spoilage Mechanisms**: Fish spoilage involves a series of complex enzymatic, bacterial, and chemical changes that begin soon after the fish dies.
- **Maintaining Quality and Safety:** Successful fish preservation aims to retain the fish's nutritional value, flavour, texture, and appearance while ensuring it is free from harmful microorganisms and their toxins.
- **Cleaning and Gutting**: Removing the visceral organs (gutting) and thoroughly cleaning the fish minimizes bacterial contamination and enzymatic autolysis.
- **Temperature Control:**
    - **Lowering Temperature (Chilling & Freezing):** Refrigeration and freezing slow down enzymatic activity and bacterial growth, effectively extending the fish's shelf life. Chilling (around 0°C) is effective for short-term preservation, while freezing (below 0°C, typically -18°C or lower) allows for long-term storage.
    - **Raising Temperature (Heating/Cooking):** Applying heat through cooking or processing like canning can kill spoilage and pathogenic microorganisms.
- **Dehydration:** Removing water content from the fish, either through natural drying (sun drying) or mechanical dehydration, creates an environment less favourable for bacterial growth.
- **Use of Salt (Salting):** Salt reduces the water activity in fish, making it difficult for bacteria to survive and also has a direct toxic effect on many microbes.
- **Addition of Acids (Pickling/Marinating):** Increasing the acidity of the fish muscle, often by using vinegar or other acids, inhibits bacterial growth.
- **Smoking:** Smoking combines the effects of drying and deposition of creosote compounds from the smoke, contributing to preservation and imparting a distinct flavour.
- **Exposure to low radiation of Gamma Rays:** Exposure to low levels of gamma rays is a method of fish preservation known as **food irradiation**. Gamma radiation, which is a form of ionizing radiation, is used to treat fish and other food products for various purposes, including extending shelf life, reducing spoilage, and ensuring food safety.
- **Use of fish preservatives:** Fish preservatives are substances or compounds used to extend the shelf life of fish and seafood products by inhibiting the growth of spoilage-causing microorganisms and delaying the oxidation of fats. Various preservatives, such as antioxidants and antimicrobial agents, can be used to extend the shelf life of fish products. These additives help prevent oxidation, inhibit bacterial growth, and maintain the quality of fish

- **Packaging:** Using appropriate packaging, such as vacuum packaging or modified atmosphere packaging (MAP), can reduce oxygen exposure and inhibit the growth of spoilage bacteria.

With these principles and selecting the appropriate method based on the type of fish, intended storage duration, and desired product characteristics, fish can be preserved effectively, contributing to food security, economic value.

1.2 Quality of water and ice in fish handling and processing.

Quality of water and ice play an important role in handling and processing of the fish.

1.2.1 Water Quality in Fish Handling and Processing:

Direct Impact on Fish Health and Survival:

- Fish rely on water for essential functions like breathing (extracting dissolved oxygen through gills), regulating internal salt levels (osmoregulation), and eliminating waste products.
- Poor water quality parameters such as low dissolved oxygen, high ammonia, or inappropriate pH can lead to fish becoming stressed and vulnerable to diseases.
- This stress can manifest as reduced growth, erratic behaviour, disease symptoms, or even death.
- Specific examples include low dissolved oxygen levels, which can cause respiratory distress or be fatal, and high ammonia levels, which are toxic and can cause gill damage, according to the World Aquaculture Society.

Preventing Contamination and Ensuring Food Safety:

- Water used for washing fish, cleaning processing equipment, and even for generating ice can be a source of microbial contamination if it is not of suitable quality.
- Contaminated water can introduce harmful bacteria and pathogens into the fish, posing a risk to consumer health.
- Therefore, using clean, potable water or adequately treated seawater is crucial to ensure hygienic handling and processing.

Maintaining Fish Quality:

- Water quality parameters like temperature, turbidity, and colour can affect the appearance, flavour, and overall quality of fish products.
- For example, turbidity caused by suspended soil particles can reduce light penetration and affect fish growth.

Best Practices for Water Management:

- Utilize clean water sources and monitor water quality parameters regularly.
- Employ appropriate water treatment techniques such as filtration, UV disinfection, or other suitable methods to remove contaminants and maintain optimal water conditions.
- On fishing vessels, ensure a sufficient supply of bacteriologically sound water for cleaning and handling the catch.

1.2.2. Ice Quality in Fish Handling and Processing:

Ice is widely used as a cooling agent to quickly lower the temperature of fish, which slows down bacterial growth and enzymatic spoilage, extending their shelf life. Rapid chilling is essential to maintain the quality and freshness of the fish. Ice also provides a moist environment for the fish, preventing dehydration, especially in warmer climates.

Importance of Hygienic Ice:

- Ice used for chilling fish should be made from clean, potable water to avoid introducing contaminants.

- Contaminated ice can introduce harmful bacteria and pathogens to the fish, compromising food safety and potentially causing health issues for consumers.
- Proper handling and storage of ice are also essential to prevent microbial contamination.

Considerations for Ice Type and Application:

- The type and size of ice can impact its effectiveness in chilling fish.
- Flake ice, for instance, provides a larger contact surface area for faster cooling compared to block ice.
- The use of saltwater ice (brine ice) can cause salt absorption and rancidity issues in certain fish species, making freshwater ice generally preferable for most applications.

Best Practices for Ice Management:

- Use potable water to produce ice.
- Handle ice hygienically to prevent contamination.
- Store ice in clean and appropriate containers.
- Use the correct ice-to-fish ratio to ensure sufficient cooling.
- Consider using flake ice for optimal cooling and to minimize fish damage.

Proper attention to both water and ice quality throughout the fish handling and processing stages, it is possible to significantly enhance the safety, quality, and shelf life of fish products

1.3 Preparation of ice. Different types of ice used in the seafood industry and their merits.

Ice used in the seafood industry must be produced from potable water that meets drinking water quality standards and food safety regulations, such as those set by the World Health Organization. This is essential to prevent the introduction of harmful microorganisms or taints to the fish, which could compromise food safety and quality. The ice-making process involves removing heat from the water until it freezes.

Different Types of Ice Used in the Seafood Industry and Their Merits:

1. **Block Ice:** Made by freezing water in cans, block ice is easy to store and transport due to its slow melting rate. It needs to be crushed before use, adding labour and cost.
2. **Flake Ice:** Produced by scraping thin layers of ice off a refrigerated surface. It has a large surface area for fast chilling, but melts quickly and requires more storage space. Its soft texture minimizes damage to fish.
3. **Plate Ice:** Created by freezing water on vertical plates and then chopping the resulting sheets. It shares similar advantages and disadvantages with flake ice.
4. **Tube Ice:** Forms as hollow cylinders and is then broken into pieces. It has a smoother surface that is less likely to damage fish and lasts longer in storage than flake ice. However, it needs crushing before use.
5. **Slurry Ice:** A mixture of ice microparticles suspended in a solution. It provides efficient cooling and doesn't damage fish. It can be expensive to produce.
6. **Liquid ice or Flow ice:** Liquid ice or flow ice looks like jelly. It actually consists of amorphous ice micro particles suspended in a non-corrosive, non-toxic solution. Liquid ice generator system yields a substance with ten times more cooling capacity than chilled water. Because of this it requires smaller flow rates for the same cooling capacity.
7. **Soft Ice:** Soft ice is made by freezing a weak brine or seawater in a drum provided with refrigerated walls. The crystals of fresh water ice forms slurry in the brine as

temperature falls and it is pumped into a storage tank. Ice crystals are skimmed off from the tank to be used as soft ice slurry. It has the advantage of making perfect contact with the material. Besides it does not cake, or forms air pockets as it can happen with other forms of ice.

The most suitable ice type depends on factors such as the intended use (onboard cooling, transport, etc.), available storage, cost, and the type of fish being preserved.

UNIT 2: FREEZING AND CANNING

2.1 Fundamental principles involved in chilling and freezing of fish and fishery products.

Chilling and freezing are two key methods for preserving fish and fishery products by lowering their temperature to slow down or halt spoilage mechanisms.

2.1.1. Chilling:

Chilling involves lowering the temperature of the fish to near freezing point, typically around 0°C (32°F), without actually freezing it.

Chilling is an effective way of reducing spoilage in fish if it is done quickly and if the fish are kept chilled and handled carefully and hygienically. The objective of chilling is to cool the fish as quickly as possible to as low a temperature as possible without freezing. Chilling cannot prevent the spoilage together but in general, the colder the fish, the greater the reduction in bacterial and enzyme activity.

Principles of Chilling:

- **Temperature Reduction**: Reducing the temperature significantly slows down the activity of spoilage bacteria and enzymatic degradation, extending the fish's shelf life.
- **Rapid Cooling**: Rapidly lowering the fish's temperature after capture is crucial, as spoilage rates increase significantly with higher temperatures.
- **Moisture Maintenance**: Chilling methods like icing or using chilled seawater (CSW) help keep the fish moist, preventing dehydration and maintaining its quality.
- **Hygiene:** Proper handling and hygienic practices during chilling minimize the risk of bacterial contamination.

Chilling Methods: The important chilling methods of fish and fish products at non-freezing temperature are:

1. **Iced storage:** The major advantage of using ice for chilling the fish is that it has a high latent heat of fusion so that it is capable of removing large amount of heat as it melts without changing the temperature at 0 ^{0} C. Spoilage of the fish starts immediately after the death which is largely dependent on the temperature conditions, the sooner the fish can be cooled the better will be the quality and shelf life.

2. **Chilled seawater (CSW) storage:** In this case, the fish is surrounded with a mixture of ice and water. When enough ice is added to the system it will bring the temperature of the water near to 0^{o} C. The water will remove the heat from the fish. The transfer of heat from fish to water and from water to ice will continue until the system is brought to a state of equilibrium.

   Super chilling: Super chilling has been defined as the lowering of the temperature of the flesh to within the range from -3 ° to -1°C. Brine is use as refrigerant in super chilling. The storage time of fishes should not exceed 12 days. Above this day's ice formation is increased and makes the fish unsuitable for filleting or smoking

3. Refrigerated seawater (RSW) storage.

Refrigerated Sea Water (RSW) storage is a method commonly used in the fishing industry to maintain the freshness and quality of harvested fish.

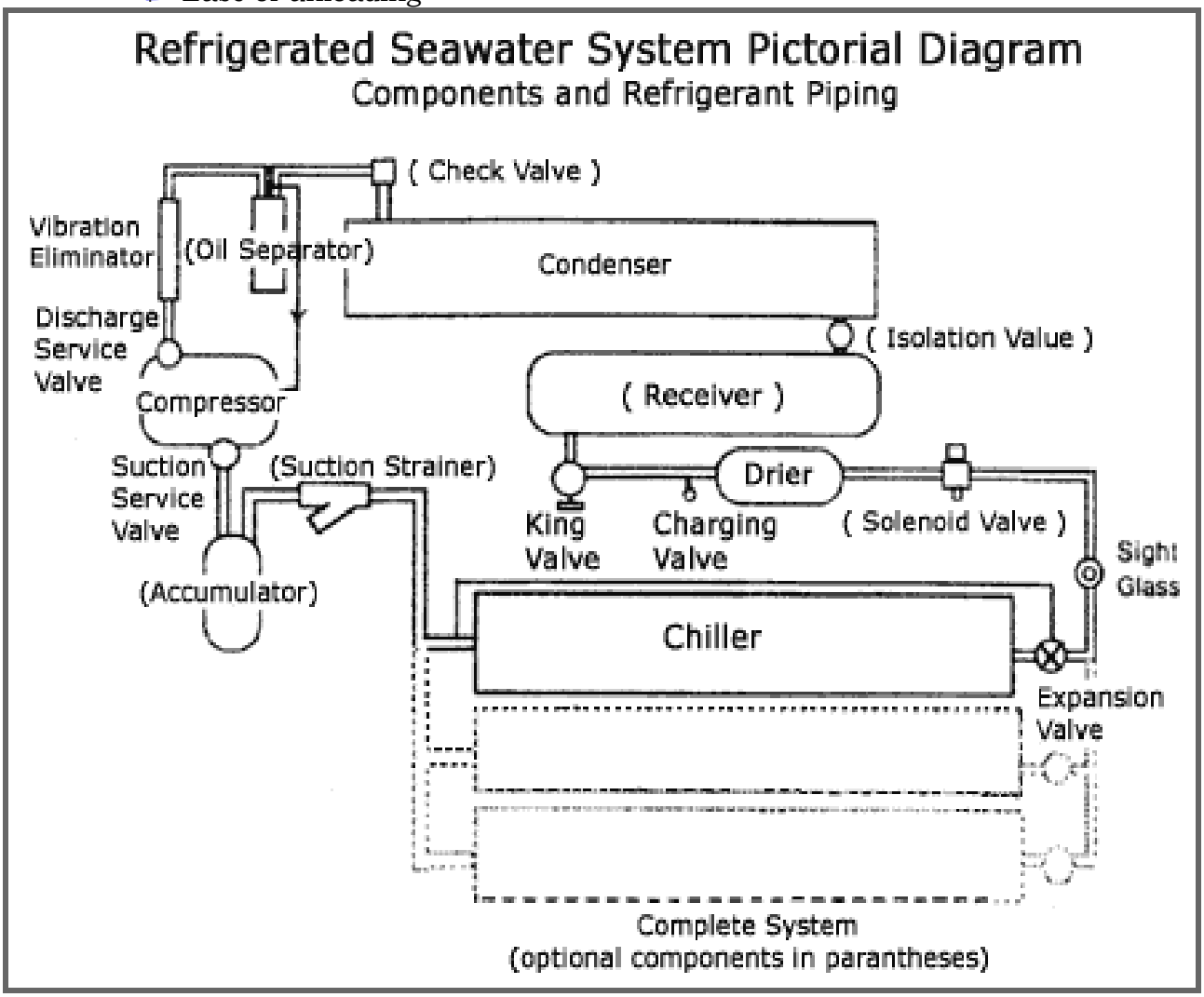
This technique involves using chilled sea water to cool and store fish immediately after they are caught. RSW storage is particularly beneficial for preserving the quality of seafood products, especially those destined for the fresh market.

In this system the seawater is cooled by mechanical refrigeration. Seawater has a salt content of around 3 to 3.5%. At 3.5% salt, seawater has a freezing point of about –2°C. Thus, if seawater is refrigerated, it is possible to reduce the temperature so that a storage temperature of –1°C can be achieved.

RSW may also be used to cool the catch by spraying over the top surface of ungutted fish or shrimp in the hold. Rapid chilling and holding of the catch in RSW is a popular practice on board large vessels which catch shrimps.

The advantages of RSW are

- Labour saving in storage
- Rapid chilling, 2 to 3 times as fast as with ice
- Elimination of crushing and ice pitting
- Lower chill temperatures
- Washing effect
- Ease of unloading



2.1.2. Freezing:

Freezing involves lowering the temperature of the fish below its freezing point (typically -1°C to -2°C) to convert most of the water in the fish into ice crystals.

In the simplest terms refrigeration means removal of heat from the body or atmosphere, which is desired to be cooled and its transfer to another medium. The refrigeration cycle involves steps to remove the heat from the evaporating refrigerant by again converting it into the liquid state in order that it may be used repeatedly in a continuous process. As more heat requires to be extracted during the second stage, in order to turn the bulk of the water to ice, the temperature changes by a few degrees and this stage is known as the period of "**thermal arrest**".

Principles of Freezing:

- **Ice Crystal Formation**: Freezing converts the water in the fish muscle to ice, making it unavailable for microbial growth and biochemical reactions.
- **Microbial Inactivity:** Freezing temperatures (ideally below -18°C) render most bacteria inactive, preventing spoilage. Even at higher temperatures like -10°C, bacteria can still grow, albeit slowly.
- **Enzyme Activity Reduction:** Freezing also slows down enzymatic activity, further extending the fish's shelf life.
- **Protein Denaturation:** Slow freezing can lead to the formation of large ice crystals, which can damage cell membranes and cause protein denaturation, affecting texture and thaw drip.
- **Rapid Freezing:** Quick freezing is crucial to minimize ice crystal damage and protein denaturation, preserving the fish's quality and texture. It ensures the fish passes through the zone of maximum ice crystal formation (-1 to -5°C) quickly.
- **Dehydration:** Dehydration during freezing and frozen storage can lead to "freezer burn," affecting quality. Packaging and glazing are used to minimize this.
- **Frozen Storage:** Maintaining a consistently low temperature during frozen storage is vital to minimize further quality degradation, such as protein denaturation and fat oxidation.

Both chilling and freezing work by reducing the fish's temperature to slow down or halt spoilage mechanisms. Rapid cooling, proper hygiene, and maintaining appropriate temperatures during storage are crucial for preserving the quality and safety of fish and fishery products

2.2 Various freezing methods. Freezing of shrimps and fishes.

Freezing methods are broadly classified into

- Freezing in air
- Indirect contact freezing
- Immersion freezing
- Cryogenic freezing

2.2.1 Freezing in air: Air is the most common freezing medium. Air freezing systems are of two types- **still air freezing** and **forced air freezing**.

a. Freezing in still air: The freezer consists of an insulated room or a cabinet maintained at -28 to - 45 ° c. Fish, packaged or otherwise, placed in aluminium trays, is kept on shelves made of pipes or coils through which the refrigerant is circulated. Time taken for freezing may be 12 hours or more. Freezing in still air is the least expensive method of freezing; however, is the slowest method as well.

b. Forced air freezing: Forced air freezing is a method of rapidly freezing products by using forced convection to circulate cold air around them. This differs from still air freezers, where heat transfer primarily relies on natural convection and is therefore slower.

Types of Forced Air Freezing Systems:

- **Air Blast Freezers**: This is a common method that utilizes fans to rapidly circulate cold air in a room or tunnel. Products can be frozen in batches or continuously on a conveyor belt.
- **Fluidized Bed Freezers**: Products are suspended in a stream of cold air, allowing for rapid and even freezing of individual pieces, as in Individual Quick Freezing (IQF).

2.2.2 Indirect contact freezing

Indirect contact freezing can be defined as freezing a product by keeping it in contact with a metal surface which is cooled by some refrigerant.

They are of two types – **Horizontal plate freezer** and **Vertical plate freezer**.

a. **Horizontal plate freezer:** These freezers in general have 15-20 plates. The product to be frozen contained in metal freezing trays are loaded between freezing plates and are maintained in close contact with top and bottom plates under slight hydraulic pressure to ensure maximum heat exchange. The freezing trays are also covered with tightly fitting lids which will help to provide contact with the freezing plates at the top.

b. **Vertical Plate Freezer:** These are most commonly used for freezing fish at the sea. They consist of number of vertical freezing plates that form partitions in a container called stations. Fish are loaded between the plates until each station is full and then the plates are closed together to form fish blocks. Temperature ranges between -30 to -40^0 c. Contact plate freezer is very economical to operate. Dehydration of the product will be minimum and it remains in uniform blocks without bulging

2.2.3. Immersion freezing:

In this method freezing is achieved by immersion in, or spraying with, a refrigerant that remains liquid throughout the process. Refrigerated aqueous solutions of propylene glycol, glycerol, sodium chloride, calcium chloride and mixtures of sugars and salt can be used as medium for freezing. Immersion freezing allows for intimate contact of every surface of the material with the freezing medium and thus ensures very efficient heat transfer. It is of two types

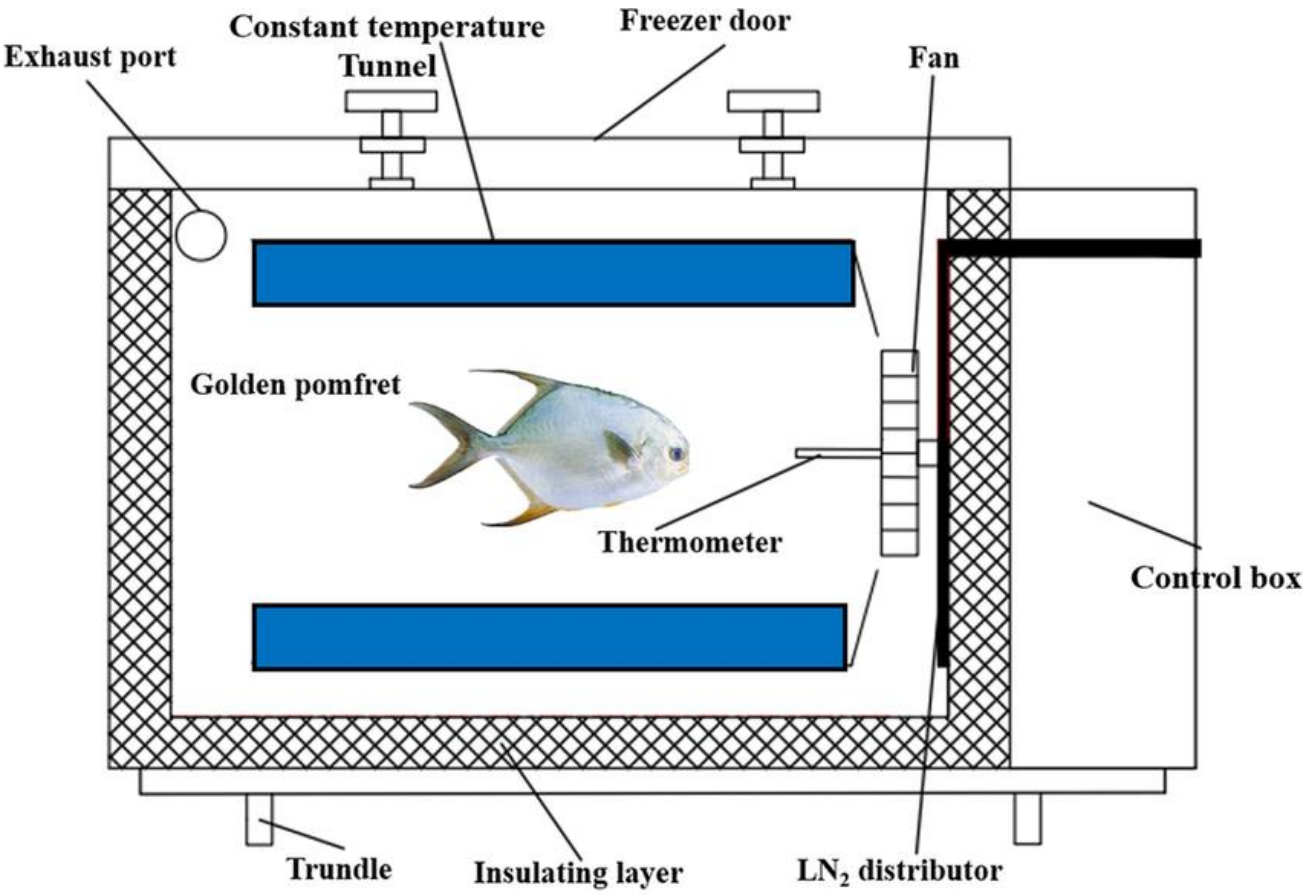
i) Freezing in brine: Brine freezing is rapid and is adaptable for continuous operation. however, the fish will absorb some salt, which will depend on several factors such as temperature of the brine, duration of immersion, fat content of the

fish and the surface area. Contamination of the medium and subsequent cross contamination of batches is a major disadvantage of this process.

ii) Brine spray freezing: Chilled brine is sprayed over the fish placed in trays. Heat is removed from the fish by the chilled brine in 1-2 hours.

2.2.4 Cryogenic freezing:

In cryogenic freezing very rapid freezing is achieved by exposing the fish, unpacked or with a very thin package, to an extremely cool freezing undergoing a change of state. The most common food grade cryogenic freezants are boiling nitrogen and boiling or subliming carbon dioxide. Cryogenic freezing is much faster than air blast or contact plate freezing; but is only moderately faster than fluidized bed or liquid immersion freezing. Types of cryogenic freezing



Cryogenic food freezer (-196 ~ 30°C)

i. Freezing using liquid nitrogen: In freezing using liquid nitrogen, liquefied nitrogen gas is sprayed over the product as it travels in a tunnel over a conveyor belt. The nitrogen gas passes counter current to the movement of the fish so that the fish gets precooled before reaching the liquid nitrogen spray. After the spray the product is allowed to temper for a while being discharged from the tunnel.

ii. Freezing using liquid / solid carbon dioxide: Liquid carbon dioxide is sprayed over the fish as it travels through a tunnel on a moving conveyor. The carbon dioxide

is sprayed through the nozzles and while spraying the pressure is quickly reduced and about 50 % of it suddenly changes to tiny particles which absorbs the heat from the surroundings and gets converted to gas resulting in rapid cooling of the fish. Freezing can be done by exposing the fish to powdered solid carbon dioxide. Freezing with carbon dioxide has most of the advantages of freezing with liquid nitrogen. However, unpacked foods may absorb or entrap carbon dioxide to the extent of causing undesirable swelling.

2.3 Changes during the cold storage of fish and fishery products.

During the cold storage of fish and fishery products, several changes occur, primarily affecting their quality and shelf life. These changes are slowed down significantly by refrigeration, but not entirely stopped**.**

1. Physicochemical and Biochemical Changes:

- **Rigor Mortis:** Following death, fish muscles become stiff due to chemical changes, primarily the depletion of adenosine triphosphate (ATP) and accumulation of lactic acid. This leads to a decrease in pH. With the resolution of rigor mortis, the flesh softens again. Handling fish pre or during rigor mortis is important for maintaining quality.
- **Protein Denaturation**: Changes in protein structure can lead to loss of functional properties, such as reduced water-holding capacity and textural changes, like toughness.
- **Lipid Oxidation:** Fats in fish, especially polyunsaturated fatty acids (PUFAs), are susceptible to oxidation, resulting in rancid flavours and odours.
- **Enzymatic Activity:** Enzymes within the fish tissue remain active even at chilling temperatures, contributing to autolysis (self-digestion) and producing unpleasant flavours and odours.
- **Changes in Non-Protein Nitrogen (NPN**): NPN content, which includes free amino acids and peptides, tends to decrease during chilled storage, reflecting a decline in flavour and potentially contributing to microbial growth.
- **Water-Holding Capacity:** The ability of fish muscle to retain water changes during storage, potentially affecting texture and leading to weight loss.

2. Microbial Spoilage:

- **Bacterial Growth**: While cold temperatures significantly slow bacterial growth, some spoilage bacteria, including psychrophilic organisms, can still proliferate at refrigeration and even freezing temperatures.
- **Formation of Volatile Compounds**: Microbial activity leads to the breakdown of proteins and other components, releasing volatile compounds such as trimethylamine (TMA) and ammonia, which are responsible for the characteristic fishy odour and off-flavours.
- **Pathogenic Bacteria**: Although bacterial growth is reduced at low temperatures, some pathogenic bacteria, such as *Listeria monocytogenes*, can still survive and pose a risk to consumers, emphasizing the importance of food safety practices.

3. Physical Changes:

- **Dehydration and Freezer Burn:** Moisture loss during cold storage can lead to dehydration and a condition known as freezer burn, affecting appearance and texture.
- **Colour Changes**: Oxidation of pigments and other reactions can cause discoloration of the fish flesh.
- **Textural Changes:** Besides protein denaturation, textural changes can occur due to ice crystal formation and changes in the muscle structure's ability to hold water.

Factors Influencing Changes:

- **Species:** Different fish species have varying compositions and enzyme systems, influencing their susceptibility to specific changes.
- **Initial Quality:** The quality of the fish before storage significantly impacts its shelf life and the rate of deterioration.
- **Handling Practices:** Proper handling during capture and processing, including rapid chilling and hygienic conditions, can minimize damage and microbial contamination.
- **Storage Temperature and Conditions:** Maintaining low and consistent temperatures is crucial for slowing down chemical, biochemical, and microbial changes.
- **Packaging:** Effective packaging materials can help reduce dehydration and oxidation.

In summary, cold storage slows down spoilage processes in fish but does not completely halt them. Various physical, chemical, and microbiological changes continue to occur at varying rates, depending on the factors mentioned above. Understanding these changes is essential for maintaining the quality and safety of fish products during cold storage.

2.4 Principles involved in canning of fish. Different types of containers.

Canning is a method of food preservation in which food is packed in metal or glass or plastic containers, sealed air tight and heated sufficiently to destroy the spoilage, pathogenic and fish food poisoning organisms making the food safe for consumption.

2.4.1. Principles involved in canning of fish

Canning of fish relies on the principle of thermal processing to achieve commercial sterility.

1. Thermal Processing:

This involves subjecting sealed containers of fish to high temperatures for a predetermined period.

The high temperatures destroy microorganisms, including bacteria, yeasts, moulds, and enzymes, preventing spoilage and ensuring the product is safe to consume.

2. Hermetic Sealing:

The fish must be sealed in airtight containers to prevent recontamination after sterilization and maintain a vacuum.

3. Commercial Sterility:

Canning aims for "commercial sterility," meaning the contents are safe (pathogenic microorganisms are destroyed) and shelf-stable at normal storage temperatures.

While absolute sterility is not achieved, the process is designed to destroy most heat-resistant pathogens and minimize spoilage organisms, ensuring a long shelf life.

4. Preventing *Clostridium botulinum* Growth:

A major concern in fish canning is the risk of *Clostridium botulinum* spores, which can survive mild heat treatments and produce a dangerous toxin in low-acid canned foods (pH > 4.5). Therefore, thermal processes are specifically designed to destroy *C. botulinum* spores, usually employing processing temperatures of 116-121°C (240-250°F).

5. Heat Penetration and "Cold Point":

The thermal process is calculated to ensure the "cold point" (the slowest heating point within the can) reaches the required temperature and duration to achieve the desired level of microbial destruction.

6. Cooling:

After heat processing, rapid cooling prevents overcooking and the growth of thermophilic microorganisms (bacteria that thrive at high temperatures).

2.4.2 Steps involved in canning:

I. Pre-processing operations: Depending on the nature of the food, different preprocessing operations are carried out. Washing, separation of edible parts, cleaning, cutting into desired size and shape, brining, precooking, blanching, frying etc. are done prior to filling of the can. The difference in canning method for various foods stuffs lies in this stage.
II. Can filling: The pre-processed food is filled in to the cans along with suitable filling medium. The quantity of food to be filled varies with the size of the can. Sufficient space has to be provided between the lid and the top layer of the food.
III. Exhausting: The exhausting is the process to remove the air and gases inside the filled cans. This is achieved either by using steam or by creation of vacuum by a pump.
IV. Can closing/seaming: Can closing or seaming is a process wherein, the lid and the body of the can are tightly sealed. This is done by can seamer. Can closing should be airtight preventing the exchange of gases between atmosphere and inside of the can.
V. Heat processing (Retorting): Retorting is a process where the closed cans are subjected to heat processing at high temperature to destroy spoilage and pathogenic microorganisms. This is the most important step in canning.
VI. Cooling of the cans: After heat processing, cans are cooled immediately either in air or more commonly in water to the ambient temperature. Cooled cans are dried, labelled and stored.

2.4.3 Different Types of Containers for Canning Fish:

Several types of containers are used for canning fish products, each with its own advantages and disadvantages:

1. Metal Cans:

a. Tinplate Cans:

- Traditional and widely used.
- Made from steel sheets coated with a thin layer of tin for corrosion resistance and structural strength.
- Offer excellent barrier properties against oxygen, moisture, and light, essential for preserving fish quality.
- Can withstand the high temperatures required for thermal processing.

b. Aluminium Cans:

- Lightweight and offer good portability.
- Have natural corrosion resistance.
- Rapid heat transfer, potentially reducing processing time.
- More susceptible to dents and may require thicker material for comparable strength to tinplate.

c.Tin-Free Steel (TFS) Cans:

- A newer option where steel is coated with chromium instead of tin.
- Offer cost-effectiveness as they don't use tin.
- Have good polish adhesion.

2. Glass Containers:

- Offer a high-quality, artisanal image.

- Inert to food, meaning they don't react with the contents.
- Resistant to temperature variations, making them suitable for sterilization.
- Transparent, allowing consumers to see the product (can be an advantage or disadvantage).
- Recyclable. Can be heavier and more fragile than metal cans.

3. Flexible Packaging (Retort Pouches):

- Multi-layered pouches made of combinations of polymers and aluminium foil.
- Lighter weight compared to metal cans and glass jars.
- Rapid heat transfer, leading to shorter processing times.
- Require careful heat treatment with counter-pressure to prevent bursting.

Selection of the appropriate container depends on various factors, including the type of fish product, processing requirements, desired shelf life, and consumer preferences.

UNIT 3: DRYING, SMOKING AND FREEZE-DRYING

3.1 Different types of drying, Factors affecting drying.

3.1.1 Different types of drying

Drying is a time-honored method of preserving fish by removing moisture to inhibit microbial growth and enzymatic reactions that lead to spoilage. This process can be achieved through various techniques, each with unique characteristics and influencing factors.

Types of fish drying

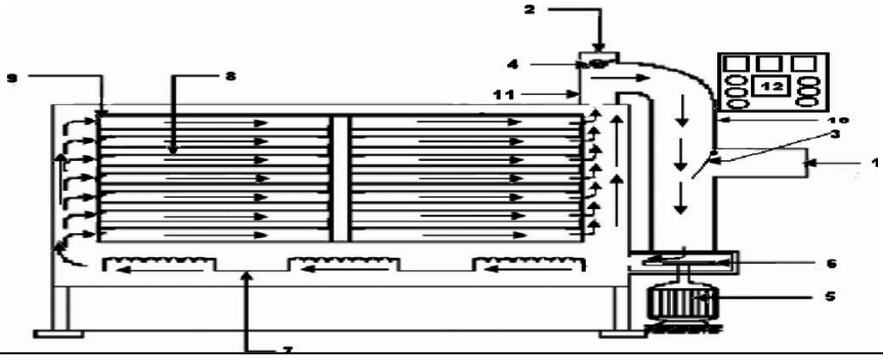
1. **Natural or Sun Drying**: This traditional method involves spreading fish in the open air, relying on natural sun and wind to evaporate moisture.
   - It is simple and cost-effective, particularly in regions with abundant sunlight.
   - However, it's susceptible to weather conditions, slower, less hygienic due to potential contamination by dust, insects, and animals, and can lead to uneven drying and quality loss if not properly managed.
   - Improvements like drying on elevated racks enhance hygiene and air circulation.

2. **Solar Drying**: This method utilizes solar energy more efficiently through enclosed structures like solar tent dryers, solar collector dryers, or solar cabinet dryers.
   - They harness solar radiation to increase air temperature and reduce relative humidity, leading to faster drying compared to open sun drying.
   - Solar dryers offer better protection against contamination and insects, resulting in improved hygiene and product quality.

- Some models use fans for forced convection, further accelerating drying,

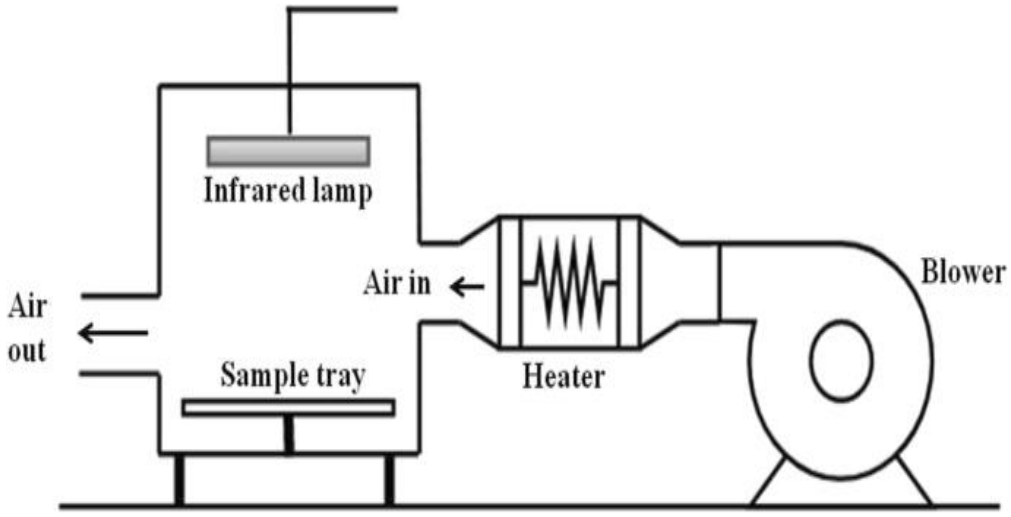
3. **Artificial or Mechanical Drying (Dehydration):** These methods involve controlled environments and external energy sources for drying fish.

- **Hot Air Drying:** Hot air is circulated over the fish, providing consistent temperature, humidity, and airflow. This method is faster and more controllable than natural methods, but high temperatures can negatively impact fish quality, such as lipid oxidation and browning.



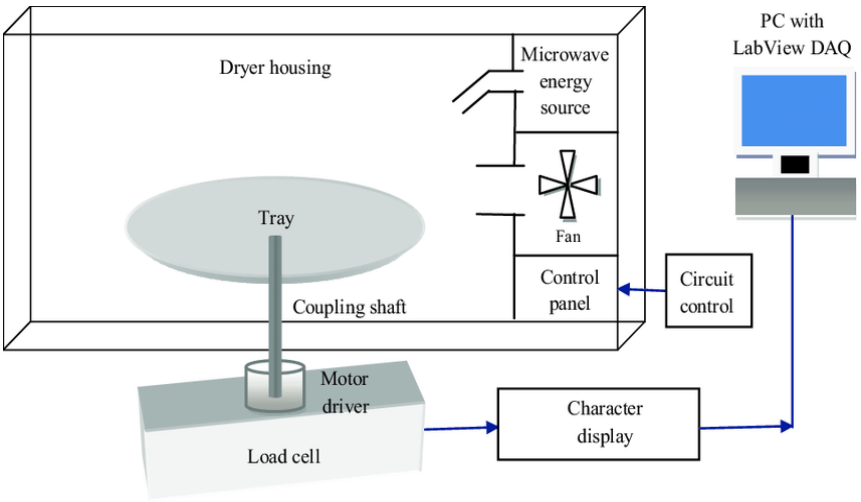
Schematic diagram of recirculatory hot-air dryer.
(1) Fresh air inlet port (2) Exhaust air outlet port (3) Inlet air flow control flap (4) Exhaust air flow control flap (5) Blower motor (6) Blower (7) Heaters

- **Cold Air Drying:** This technique uses low temperatures, low humidity, and high air velocity to dry fish. It is particularly suitable for fatty fish as it minimizes quality



deterioration associated with high temperatures. However, it can be slower than hot air drying.

- **Microwave Drying**: Microwave energy quickly heats the internal moisture, leading to rapid evaporation. This method offers fast heating and uniform drying, but uneven heating can occur, especially during the final stages.



- **Vacuum Freeze Drying (Lyophilization):** This high-quality drying technique freezes the fish and then removes ice through sublimation under vacuum. It preserves the original structure, nutritional content, and rehydration properties of the fish exceptionally well, but it is expensive and time-consuming.
- **Infrared Drying:** Infrared radiation provides efficient and uniform heating, reducing drying time. However, its limited penetration makes it suitable mainly for thin-layer drying.

- **Heat Pump Drying:** This energy-efficient method utilizes a heat pump system for drying. It provides precise control over temperature and humidity, minimizing quality degradation and energy consumption.

3.1.2. Factors affecting fish drying

The drying rate of fish is influenced by several factors:

1. **Environmental Factors:**

- **Air Temperature:** Higher temperatures generally accelerate drying by increasing water evaporation and the air's moisture-holding capacity. However, excessive temperatures can lead to "case hardening" (a dry surface layer preventing further moisture escape) and potentially cook the fish.
- **Relative Humidity (RH) of Air:** Lower relative humidity increases the air's ability to absorb moisture, thus accelerating the drying rate. High humidity, on the other hand, slows down drying considerably.
- **Air Velocity:** Faster air movement carries away evaporated moisture more efficiently, leading to a faster drying rate.

2. **Fish-related Factors:**

- **Surface Area:** Larger exposed surface areas facilitate faster drying. Splitting fish open increases its surface area, speeding up the drying process.
- **Thickness:** Thicker fish have a longer path for moisture to travel from the interior to the surface, resulting in slower drying.
- **Fat Content:** Fish with higher fat content dry slower as fat acts as a barrier to water diffusion.
- **Water Content**: The initial water content of the fish impacts drying time. As water content decreases, the rate of water movement to the surface also reduces.

3. **Processing Factors:**

- **Preprocessing (Salting, Smoking):** Salting fish before drying can reduce water activity and inhibit microbial growth, potentially shortening drying time. Smoking, in addition to drying, adds flavour and preserves the fish.
- **Drying Method**: The choice of drying method significantly impacts the drying rate and product quality. Advanced techniques like vacuum freeze drying offer faster drying and better quality but are more expensive than traditional sun drying.
- **Handling:** Proper handling, including maintaining hygiene, reducing temperature immediately after catch, and avoiding damage, is crucial to minimize spoilage and ensure a good quality final product.

Understanding the various drying techniques and the factors that influence the drying process is essential for producing high-quality and safe dried fish products. Choosing the most appropriate method depends on the type of fish, available resources, desired product quality, and cost considerations

3.2 Packing and storage of dried products. Spoilage of dried products. Preventive measures

3.2.1 Packing and storage of dried fishery products

Proper packing and storage are crucial for preserving the quality and extending the shelf life of dried fish and fishery products, protecting them from spoilage, infestation, and environmental damage.

Packaging materials

Choosing the right packaging material is vital to protect dried fish from moisture, oxygen, and pests.

- **Traditional options**: Coconut, palmyra, or bamboo leaf baskets and polythene-lined gunny bags are used traditionally, especially for bulk transport, though they offer limited protection against moisture and pests.
- **Plastic bags:** Polyethylene (PE) or polypropylene (PP) bags are commonly used for consumer packs as they are inexpensive and readily available.
- **Laminated pouches:** Polyester/polyethylene laminates offer better protection than

single-layer plastic bags against moisture and insects.
- **Vacuum-sealed bags:** These remove air from the packaging, minimizing oxidation and bacterial growth, and are highly effective for extending shelf life and preserving the fish's flavour and texture.
- **Foil bags and pouches:** Aluminium foil pouches and Mylar bags provide excellent barriers against light, moisture, and oxygen, further extending shelf life.
- **Containers:** Glass jars, plastic containers, and even tin containers offer rigid and durable protection, particularly for larger quantities or delicate products.
- **Cardboard boxes:** Often used as secondary packaging for additional protection during transportation.
- **Desiccants:** Silica gel or activated charcoal can be added to absorb any residual moisture inside the package.

Storage conditions

The storage environment significantly impacts the quality and shelf life of dried fish.

- **Cool, dry place:** Store dried fish in a cool, dry area away from direct sunlight and heat sources to prevent spoilage and maintain flavour,
- **Refrigeration/Freezing:** Storing dried fish in the refrigerator or freezer further extends its shelf life significantly, especially for longer durations. Vacuum-sealed dried fish stored at ambient temperature has a shelf life of approximately 45 days, while unsealed fish spoils in about 15 days.
- **Airtight containers:** Always store dried fish in airtight containers to prevent moisture and pests from entering the package.
- **Avoid moisture:** Ensure containers are completely dry before storing the fish, as moisture can lead to spoilage and mould growth.
- **Regular checks**: Inspect dried fish regularly for signs of spoilage, such as mould, discoloration, or unusual odours, and discard any spoiled fish immediately.

Vacuum sealing or using appropriate packaging materials helps prevent freezer burn, which can damage the quality and appearance of frozen dried fish. Appropriate packaging materials, maintaining proper storage conditions, and adhering to strict hygiene practices are crucial for preserving the quality and safety of dried fish and fishery products, ensuring they remain fit for consumption for extended periods.

3.2.2. Spoilage of dried products. Preventive measures

3.2.2.1 Spoilage of dried products

Dried fishery products, despite undergoing a preservation process, are still susceptible to various forms of spoilage if not handled and stored properly. Understanding these spoilage mechanisms and implementing effective preventive measures is crucial for ensuring the quality, safety, and shelf life of these products.

Spoilage mechanisms in dried fishery products

1. **Mould and Fungal Growth:**

Dried fish with high moisture content and stored at high humidity (above 75% RH) are particularly vulnerable to mould and fungal growth. These can appear as brownish-black or yellowish-brown spots, particularly on salted fish, often caused by halophilic moulds like *Sporendonema epizoum*, resulting in a visually unappealing product.

Causes discolouration, off-flavours, and potential health risks if mycotoxins are produced by the moulds.

2. **Rancidity (Lipid Oxidation):**

This is a major concern for fatty fishlike mackerel and sardine, where the unsaturated fats react with oxygen, creating peroxides and other compounds that cause an unpleasant flavour and odour (often described as "rust"). The colour of the fish may also change from yellowish to brown.

Leads to undesirable changes in flavour and odour, reduces nutritional value (especially of beneficial fatty acids), and leads to consumer rejection.

3. **Pink/Red Halophiles (Bacterial Spoilage):**

Certain halophilic bacteria, often introduced through salt, cause spoilage, particularly in heavily salted fish. They appear as slimy pink patches on the surface and produce an ammoniacal odour. These bacteria are generally not harmful but impact the product's quality.

Affects the appearance, texture (sliminess), and odour of the dried fish, making it unappetizing.

4. **Insect Infestation:**

Dried fish can be infested by insects, especially during the drying stage and during storage. Flies lay eggs on moist fish during drying, which develop into larvae (maggots) that feed on the flesh. During storage, beetles (e.g., *Dermestes* species) and mites (e.g., *Lardoglyphus* species) are common pests, causing damage by consuming the fish flesh.

Causes direct quantitative loss of the product, physical damage to the flesh, contamination by insect bodies, and potential quality deterioration. Heavy infestations can also create conditions for mould growth.

5. **Fragmentation:**

- Description: Excessive drying or improper handling can lead to denaturation of the fish flesh, causing it to become brittle and easily break apart.
- Impact: Reduces the product's value and consumer appeal, as fragmented fish is less desirable than intact pieces.

3.2.2.2. Preventive measures against spoilage

1. **Optimizing Drying:**

- Reduce the moisture content of the fish below the levels that support microbial and enzymatic activity.
- Controlled drying environments: Use drying methods that allow control over temperature, humidity, and airflow to ensure consistent and optimal drying, such as solar dryers or mechanical dryers.
- Use netting or covers to protect fish from insects and contaminants during sun drying.

2. **Proper Salting and Curing Practices:**
   - Ensure the salt is clean, free from contaminants, and stored hygienically to prevent the introduction of halophilic bacteria.
   - Use appropriate salt concentrations and salting times to effectively reduce water activity without causing excessive lipid oxidation or texture changes.
3. **Effective Packaging:**
   - Store dried fish in airtight containers to prevent moisture reabsorption and oxygen exposure.
   - This is a highly effective method to remove air and inhibit lipid oxidation and the growth of aerobic microorganisms.
   - Use packaging materials with good barrier properties against moisture, oxygen, and light, such as laminated pouches or foil bags.
   - Include desiccants like silica gel or activated charcoal within the packaging to absorb any residual moisture.
4. **Controlled Storage Conditions:**
   - Store dried fish in a cool, dry place, ideally at refrigeration or freezing temperatures to further slowdown spoilage reactions.
   - If cold storage is not feasible, ensure storage areas have good ventilation, low relative humidity, and consistent temperatures to prevent moisture absorption and microbial growth.
   - Maintain good hygiene, dispose of waste properly, and use physical barriers like screens to prevent insect access.
5. **Hygiene and Sanitation:**
   - Maintain strict hygiene during the handling, processing, and packaging of dried fish to minimize microbial contamination.
   - Regularly clean and sanitize all equipment, drying racks, and surfaces used for processing dried fish.
6. **Quality Control and Monitoring:**
   - Regularly inspect dried fish for signs of spoilage, including mould growth, discoloration, off-odours, or insect activity.
   - Use moisture meters to ensure optimal moisture levels and monitor storage temperatures to maintain quality.

With these preventive measures, the spoilage of dried fishery products can be significantly reduced, leading to improved product quality, extended shelf life, and greater consumer satisfaction.

3.3 Smoking of fish, Salting of fish

Smoking and salting are traditional and effective methods for preserving fish, enhancing its flavor, and extending its shelf life. Both techniques rely on specific principles and procedures to achieve their preservative and organoleptic effects.

1. Smoking of fish

Smoking involves treating fish with smoke from burning organic materials like wood or plants, adding flavor and acting as a preservative through a combination of salting, drying, heating, and exposure to smoke compounds.

Principles of smoking

- **Preservation:** Smoke contains various compounds, particularly phenols and other natural chemicals, that are antibacterial and prevent the growth of spoilage microorganisms.
- **Drying:** The heat generated during smoking (especially hot smoking) contributes to the drying effect, further reducing moisture content and inhibiting bacterial growth and enzymatic activity.
- **Flavor and Colour Development:** Smoke components impart a typical colour (often golden brown) and smoky flavor to the product, enhancing its appeal and marketability.

Types of smoking

1. Hot Smoking:

- **Temperature:** Typically carried out at temperatures between 70-80°C or higher (120-180°F).
- **Effect:** Cooks the fish flesh, making it ready for immediate consumption. It also provides a longer shelf life compared to cold smoking as the fish is fully cooked and dried.
- **Texture:** Cooked, flaky texture.
- **Flavor:** Bold, intense smoky flavor.

2. Cold Smoking:

- **Temperature**: Temperatures are kept low, below 30-35°C (below 90°F).
- **Effect:** Flavors the fish without cooking it. The fish remains essentially raw and requires further cooking or consumption within a shorter timeframe compared to hot-smoked fish.
- **Texture:** Tender and moist.
- **Flavor:** Delicate and subtle smoky flavor.

2. Salting of fish

Salting, also known as salt curing, involves using common salt (sodium chloride) to preserve fish. This method reduces the water activity (Aw) of the fish, making it unsuitable for the growth of most spoilage bacteria and inhibiting enzymatic activity.

Principles of salting

- **Dehydration:** Salt draws moisture out of the fish flesh, effectively dehydrating it and reducing the overall water content.
- **Osmosis:** The high salt concentration outside the fish tissue creates an osmotic pressure, forcing water out of the fish cells and into the salt solution, leading to the plasmolysis of bacterial cells.
- **Enzyme Inhibition:** High salt concentration inhibits the action of proteolytic enzymes in the fish, further slowing down spoilage.
- **Chloride effect:** The chloride ions produced from salt ionization are harmful to microorganisms.
- **Flavor development**: Salting can improve the taste and texture of the fish.

Methods of salting

1. Dry Salting:

- **Process:** Dry salt is directly rubbed or applied to the surface of the fish, particularly on the flesh side after dressing (removing head, guts, etc.). The fish and salt are often layered in containers, allowing the extracted moisture to drain away.
- Best for: Lean fish, as fatty fish are prone to rancidity during this process.

- Disadvantages: Uneven salt penetration is a potential issue.

2. Brine Salting (Wet Salting):

- Process: Fish is immersed in a concentrated saltwater solution (brine), typically a saturated solution with about 36% salt. This method ensures uniform salt penetration.
- Best for: Fatty fish, as the brine protects the fish from atmospheric oxygen and thus reduces rancidity.
- Advantages: Better penetration of curing ingredients into the muscle and enhanced storability and product quality.

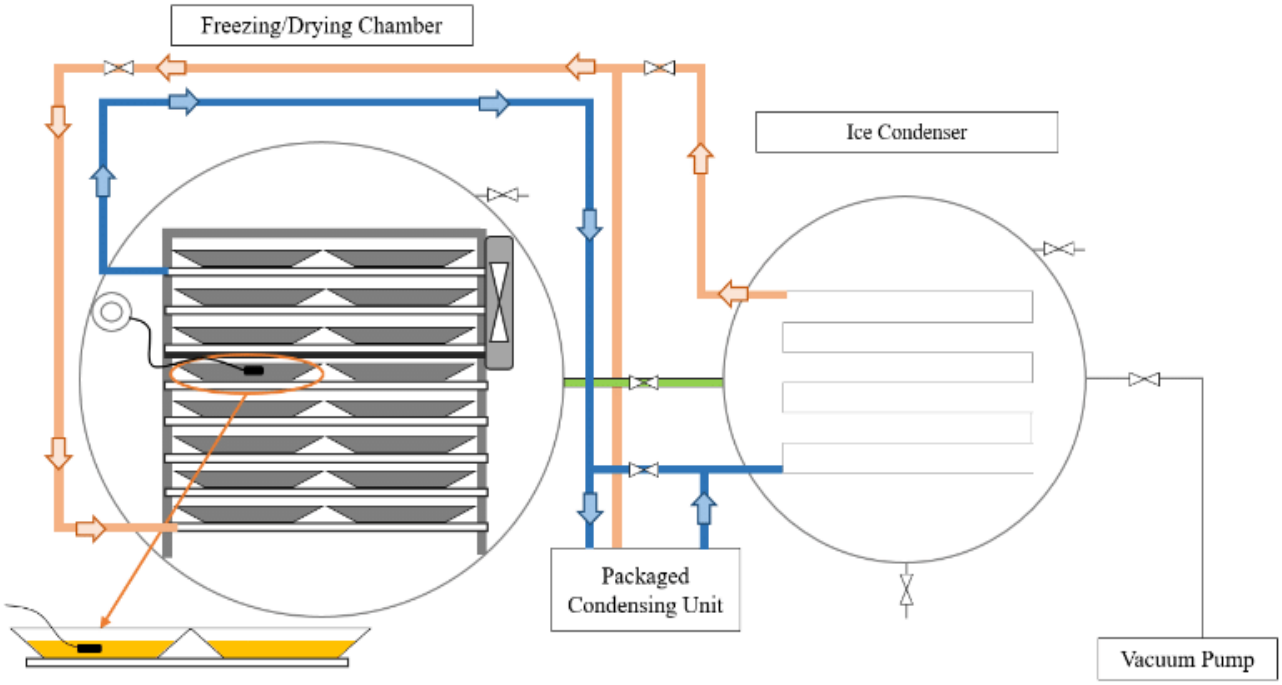
3.4 Principles of freeze drying. Accelerated freeze drying and packing of freeze dried products. Modern methods of preservation by irradiation and modified atmospheric storage

3.4.1 Freez drying

Freeze drying, also known as **lyophilization or cryodesiccation**, is a sophisticated dehydration process used for preserving food and other materials, particularly those sensitive to heat. In the context of fishery products, freeze drying is a valuable method for extending shelf life and retaining quality attributes.

Fundamental principle behind freeze drying revolves around the unique behaviour of water under specific conditions of temperature and pressure, particularly around the triple point, where solid, liquid, and gas phases coexist in equilibrium.

Freeze drying avoids the detrimental effects of high temperatures associated with traditional drying methods, which can compromise the nutritional content, taste, and texture of delicate foods like fish.



Schematic diagram of designed freeze dryer

The freeze-drying process typically involves three key stages: **freezing, primary drying (sublimation), and secondary drying (desorption).**

1. Freezing

- The process starts by freezing the fish at very low temperatures, typically between -30°C and -50°C. The freezing process is carefully controlled to form ice crystals within the fish tissue.

2. Primary drying (sublimation)

- Once the fish is frozen solid, it's placed in a vacuum chamber, and the pressure is significantly reduced, typically to a few millibars. Heat is then applied, facilitating the process of sublimation, where the frozen water (ice) directly transforms into water vapor without passing through the liquid phase. This stage removes the vast majority of the water content, about 95%.

3. Secondary drying (desorption)

- The secondary drying phase focuses on removing any remaining unfrozen or bound water molecules that cling to the dried material. In this stage, the temperature is raised further (potentially above 0°C), and the pressure might be slightly lowered again to encourage desorption of these residual water molecules. The goal is to achieve an extremely low final moisture content, typically between 1-4%, to ensure product stability during storage.

Freeze drying is a valuable technology for preserving fishery products, offering excellent quality retention and extended shelf life, especially for delicate or high-value items. However, the high costs and long processing times associated with the method limit its widespread adoption, especially for large-scale production of lower-value products.

3.4.2 Accelerated freeze drying (AFD) of fishery products

Accelerated freeze-drying (AFD) is a variation of freeze-drying specifically designed to reduce processing time, making it potentially more efficient and cost-effective, particularly for fishery products.

AFD achieves faster drying by optimizing the heat and mass transfer processes involved in sublimation. This method is still based on the principles of freeze-drying, including freezing the product and then removing water by sublimation under vacuum conditions.

Key aspects of AFD in fishery products

1. Rapid freezing

- AFD often involves rapid freezing techniques before the drying phase. This minimizes the formation of large ice crystals that can damage the cell structure and affect the texture of the fish upon rehydration. Rapid freezing methods include:
    - **Blast Freezing:** Uses high-speed, extremely cold air to freeze the product quickly.
    - **Plate Freezing:** Freezes fish by direct contact with refrigerated metal plates.
    - **Immersion Freezing:** Submerges the product in a chilled liquid like brine for rapid cooling.
    - **Cryogenic Freezing:** Utilizes very cold agents like liquid nitrogen or carbon dioxide to freeze almost instantly.

2. Enhanced heat and mass transfer during drying

- AFD implements strategies to improve the rate at which heat is transferred to the frozen product and the rate at which sublimated water vapor is removed from the drying chamber.
    - **Modified Trays and Product Layering:** Using trays with a greater surface area or fins, along with optimizing product thickness and arrangement, to facilitate better heat transfer and vapor escape.
    - **Conductive Heating:** Heating can be applied more rapidly through direct contact with heating plates, especially when fish is placed between layers of mesh or under slight pressure.
    - **Reduced Pressure Drop:** Minimizing the resistance to vapor flow from the sublimation front to the condenser, often achieved by efficient vacuum systems and optimal drying chamber design.

Benefits of AFD in fisheries

- The primary advantage is the reduction in drying time compared to conventional freeze drying, potentially enhancing processing throughput and efficiency.
- AFD can lead to lower energy consumption compared to traditional freeze-drying methods, offering cost savings and a more sustainable approach.

- AFD aims to preserve the quality attributes of freeze-dried products, including flavor, colour, texture, and nutritional value.
- AFD can be applied to a variety of fishery products, such as fish fillets, shrimp, and shellfish.
- Freeze-dried products offer convenience in terms of lightweight transport, long shelf life without refrigeration, and rapid rehydration.

Accelerated freeze-drying represents a promising technology for the preservation of fishery products. By combining the benefits of freeze-drying with optimized and accelerated processes, AFD offers a path towards efficient, high-quality, and potentially more sustainable methods for producing shelf-stable seafood products.

3.4.3. Packing of freeze-dried fishery products:

Freeze-dried fishery products, being practically devoid of moisture (generally below 2%), are highly susceptible to oxidation, moisture absorption, colour deterioration, and fragmentation. Thus, the packaging plays a critical role in preserving their quality and extending their shelf life. The primary function of the package is to provide protection against these factors, as well as against physical damage during handling and transportation.

Packaging requirements

1. **Low Water Vapor Transmission Rate (WVTR):** Freeze-dried products are highly hygroscopic, meaning they readily absorb moisture from the environment. Packaging must have a very low WVTR to prevent rehydration and maintain the product's dryness.
2. **Low Oxygen Transmission Rate (OTR):** Oxidation of fats and other sensitive components can lead to rancidity, colour deterioration, and off-Flavors. An oxygen-impermeable package is essential to prevent these chemical reactions and preserve the product's quality.
3. **Mechanical Strength:** Freeze-dried products are often fragile and brittle, making them prone to fragmentation during handling and transportation. The packaging must offer sufficient mechanical strength to protect the product from physical damage and shock.
4. **Inertness:** The packaging material should be chemically inert and not react with the product or impart any off-flavours or odours.

Suitable packaging materials and formats

1. Flexible packaging

- **Multilayer films/laminates**: These are combinations of different films that offer superior barrier properties compared to single films. Examples include:
    - Polyester/aluminium foil/polythene laminates: Aluminium foil is an excellent barrier to moisture and oxygen. Combined with polyester (for strength and heat resistance) and polythene (for heat sealing and flexibility), it forms a highly effective packaging solution. Metallized polyester polythene laminated pouches are also recommended.
    - Nylon-based co-extruded films: Nylon provides good oxygen barrier properties and puncture resistance, making it suitable for packaging products with sharp edges or high mechanical stress.
- **Vacuum-sealed bags:** These remove the air from the package, creating an oxygen-free environment that significantly extends the shelf life and prevents oxidative

spoilage and microbial growth. Vacuum packaging also helps retain moisture, flavor, and nutritional value.

- **Modified atmosphere packaging (MAP):** This technique replaces the air inside the package with a controlled gas mixture (e.g., CO2, N2, O2) that helps inhibit microbial growth and maintain product quality. MAP is often combined with vacuum packaging for enhanced shelf-life extension.

2. Rigid packaging

- **Metal cans (tinplate, aluminium):** These provide excellent protection against moisture, oxygen, light, and mechanical damage, making them suitable for longer storage or bulk packaging. They are hermetically sealable and can withstand the rigors of thermal processing (if needed for the product). However, cans can be heavy and difficult to reclose or dispose of.
- **Glass containers:** These are strong, rigid, and chemically inert, offering excellent barriers to solids, liquids, and gases. They also protect against odour and flavor and offer product visibility. However, glass is fragile and heavier than other options.

3. Other packaging types

- Paper/paperboard with liners: Paper-based cartons or boxes can be used as secondary packaging, especially when lined with materials like polythene or wax coatings to provide moisture resistance.
- Trays: Thermoformed trays made of food-grade materials like PVC, high impact polystyrene (HIPS), and high-density polyethylene (HDPE) offer mechanical protection and are suitable for packaging value-added fishery products like battered and breaded items.

Packaging of freeze-dried fishery products requires a careful selection of materials and techniques that provide high barriers against moisture and oxygen, sufficient mechanical protection, and potentially light protection. Appropriate packaging ensures the preservation of quality attributes, extends shelf life, and ensures that the product reaches the consumer in optimal condition.

3.4.4. Modern methods of preservation in fisheries: Irradiation and modified atmosphere storage

Modern methods of fish preservation play a crucial role in extending shelf life, enhancing food safety, and maintaining the quality of fish and fishery products. Among these, **irradiation** and **modified atmosphere packaging (MAP**) stand out as effective technologies in modern fisheries.

3.4.4.1. Irradiation

Irradiation is a physical process that exposes food to **ionizing radiation, like gamma rays or electron beams**, to achieve various desirable effects, such as inhibiting spoilage, delaying ripening, and eliminating harmful microorganisms. This process involves the controlled application of radiation energy to disrupt the DNA of microorganisms, insects, and parasites, preventing their replication and causing their elimination.

Principles

- **Mechanism of action:** Ionizing radiation damages the DNA of microbes, insect gametes, and plant meristems, thereby preventing reproduction and ensuring safety and quality attributes of the food.

- **Sources of radiation**: Gamma rays (from Cobalt-60 or Cesium-137), electron beams (from electron accelerators), and X-rays are the three main sources used in food irradiation.
- **Dose levels**: The amount of radiation energy absorbed by the food is measured in kilograys (kGy). Different doses are used for various purposes:
    - Low dose (up to 1 kGy): Used for delaying ripening, inhibiting sprouting, and controlling insects.
    - Medium dose (1-10 kGy): Effective in reducing pathogenic bacteria and extending shelf life.
    - High dose (>10 kGy): Used for sterilization to achieve commercial sterility, similar to thermal processing.

Benefits

- **Improved Food Safety:** Irradiation effectively eliminates pathogenic bacteria, viruses, parasites, and insects in fish and fishery products. This helps reduce the risk of foodborne illnesses from bacteria like Salmonella and Listeria.
- **Extended Shelf Life**: Low and medium doses of irradiation can reduce spoilage-causing organisms, extending the shelf life of fresh fish by several days.
- **Reduced Need for Chemical Treatments:** Irradiation can replace or reduce the need for chemical preservatives and pesticides traditionally used in food preservation.
- **Minimal Impact on Food Quality:** Irradiating food does not make it radioactive, nor does it significantly compromise the nutritional quality, taste, texture, or appearance.
- **Enhances Hygiene:** Can be applied to packaged products, preventing recontamination after processing.

Limitations

- **Consumer Acceptance:** Concerns exist regarding the safety and perceived risks of irradiated food, limiting its widespread acceptance.
- **Initial Quality:** Irradiation cannot improve the quality of spoiled or poorly handled fish; it merely preserves the initial quality.
- **Not Effective Against Toxins:** It may not inactivate all toxins produced by microorganisms.
- **Potential for Undesirable Changes:** High doses can induce off-flavours, texture changes, and discoloration in some fish.

3.4.4.2. Modified atmosphere packaging (MAP)

Modified Atmosphere Packaging (MAP) is a technique that involves replacing the air inside a food package with a specific gas or a mixture of gases different from the normal atmospheric composition. This modified atmosphere helps to slow down the rate of spoilage, extending the shelf life and maintaining the quality of fresh fish and fishery products.

Principles

- **Gas Mixtures:** The atmosphere in the package is modified using different combinations of carbon dioxide ($CO2$), nitrogen ($N2$), and oxygen ($O2$), and sometimes other gases like carbon monoxide or argon.
- **Carbon Dioxide (CO_2):** Inhibits the growth of spoilage-causing microorganisms like Pseudomonas species by affecting their cell membranes, inhibiting enzymes, and changing intracellular pH.
- **Nitrogen (N_2):** An inert and tasteless gas used as a filler to prevent package collapse and displace oxygen, thereby inhibiting aerobic microbial growth and delaying oxidative rancidity.

- **Oxygen (O_2):** Typically kept at low levels to inhibit aerobic spoilage bacteria. However, it can be used in some cases, such as for red meat or to maintain the bright red colour of fish like tuna.
  In some instances, it may be included at low levels to inhibit the growth of strictly anaerobic pathogens like *Clostridium botulinum*.

Benefits

- **Extended Shelf Life:** MAP can significantly extend the shelf life of fresh fish by inhibiting the growth of spoilage microorganisms and slowing down enzymatic and oxidative processes.
- **Preservation of Sensory Qualities:** Properly designed MAP can help preserve the natural colour, odour, flavor, and texture of fish.
- **Improved Product Presentation:** The use of transparent packaging allows consumers to see the product clearly and provides an attractive appearance.
- **Reduced Drip:** Optimal gas mixtures can help minimize the formation of unsightly drip inside the package.

Combining the methods (hurdle technology)

It is common to combine these modern methods with other preservation techniques as part of a "hurdle technology" approach.

For example, MAP can be combined with irradiation, chilling, or the addition of chemical preservatives to create multiple barriers against spoilage, ensuring product safety and quality. This synergistic approach offers a comprehensive strategy for fish preservation, addressing various spoilage factors and maximizing the benefits of each technique.

UNIT 4: PACKING, COLD STORAGE AND EXPORT OF FISHERY PRODUCTS

4.1 Functions of packing. Different types of packing materials and its quality evaluation.

4.1.1 Functions of packing, materials, and quality evaluation in fisheries

Packaging is crucial in the fisheries industry to protect, preserve, and transport highly perishable fish and seafood products.

Functions of packing in fisheries

- **Protection:** Shielding the fish from physical damage (e.g., bruising, crushing), contamination (e.g., bacteria, dirt), and environmental factors like oxygen and light.
- **Preservation:** Delaying spoilage through methods like chilling, freezing, vacuum packing, or Modified Atmosphere Packaging (MAP).
- **Temperature Control:** Maintaining optimal temperature for freshness and safety with insulated containers and refrigerants like ice or gel packs.
- **Moisture Management:** Preventing dehydration or excessive moisture absorption, which can affect texture and flavor.
- **Safety and Hygiene:** Acting as a barrier against microbial contamination and facilitating hygienic handling.
- **Convenience:** Making it easier to handle, store, and transport products like fillets, individual servings, or ready-to-cook options.
- **Information and Marketing:** Displaying product details, brand messaging, and enhancing appeal to consumers.

4.1.2: Different types of packing materials in fisheries

- **Plastics:**
  - **Polyethylene (PE) (including LDPE and HDPE):** Lightweight, flexible, resistant to moisture and chemicals, commonly used for bags, pouches, and linings in cartons.

  - **Polypropylene (PP):** Stronger and more rigid than PE, with higher heat resistance, suitable for films and some containers.
  - **Polyester (PET):** Known for strength, low gas permeability, and wide temperature range, often laminated with polyethylene for heat sealing.
  - **Polyvinyl Chloride (PVC):** Used for trays, films, and bottles, offers waterproof and gas barrier properties.
  - **Laminated Films:** Combinations of various plastic films (e.g., polyester/LDPE, nylon/polyethylene) glued together to achieve superior barrier properties and strength, suitable for vacuum packing and retort pouches.
- **Paper and Cardboard:**
  - **Corrugated fiberboard cartons:** Used for shipping containers, providing protection against crushing and impact.
  - **Waxed or Coated Cartons:** Offer improved moisture resistance for fresh or frozen fish.
  - **Duplex cartons:** Laminated with plastic film for improved functional and aesthetic properties.
- **Metal:** Tinplate and aluminium cans: Provide excellent barrier properties and are used for thermally processed fish products, offering long shelf life.
- **Glass**: Bottles and jars: Chemically inert and durable, used for products needing airtight seals or light protection, such as fish pickles.

4.1.3 Quality evaluation of packing materials in fisheries

Evaluation of packaging materials is essential to ensure they meet the specific requirements for fish and seafood products.

- **Physical and Mechanical Testing:**
  - **Tensile Strength and Elongation:** Measures how much the material can stretch before breaking.
  - **Tear and Impact Strength:** Assesses resistance to tearing and impact damage.
  - **Bursting Strength and Puncture Resistance:** Evaluates the material's ability to withstand pressure and punctures, crucial for handling sharp fish bones.
  - **Stiffness and Compression Strength:** Relevant for containers to ensure they maintain their shape during stacking and transportation.
  - **Seal Integrity:** Checks the strength and effectiveness of seals in pouches and bags to prevent leaks and maintain product integrity.
- **Barrier Properties:**
  - **Water Vapor Transmission Rate (WVTR):** Determines how well the material prevents moisture from entering or escaping, protecting against dehydration.
  - **Oxygen Transmission Rate (OTR):** Measures how easily oxygen can pass through, critical for products susceptible to oxidation and spoilage.
- **Chemical Testing:**
  - **Migration Testing:** Assessing the potential for harmful chemicals to leach from the packaging material into the fish product.
  - **Heavy Metal and Contaminant Detection:** Checking for the presence of elements like lead, cadmium, or other contaminants that may affect product safety.

Ensuring no adverse reactions occur between the packaging material and the fish product itself. Proper packaging is vital in the fisheries industry, serving multiple functions from protection and preservation to information and marketing.

A variety of materials, including different plastics, paper, cardboard, metals, and glass, are used depending on the specific product and intended use. Rigorous quality evaluation through physical, chemical, and specialized testing ensures that packaging materials are safe, effective, and meet the unique demands of this perishable and valuable food source.

4.2. Packing requirements for frozen and cured products.

Effective packaging is crucial for preserving the quality, safety, and shelf life of both frozen and cured fishery products. Packaging needs vary depending on the product type, storage conditions, and intended use (e.g., retail or bulk).

4.2.1 Packing requirements Frozen fishery products

Frozen fish and seafood require packaging that can withstand low temperatures and protect against freezer burn, dehydration, oxidation, and contamination.

1. Primary Packaging:

Vacuum-sealed bags: Commonly used for frozen fish, vacuum bags remove air to prevent freezer burn and oxidation, extending shelf life and retaining quality.

Plastic Pouches: Laminated pouches made of materials like polyethylene and nylon are suitable for frozen products and can even be used for boil-in-bag applications.

Individually wrapped portions: For convenience and prevention of freezer burn, frozen fillets or other portions may be individually wrapped in plastic films or moisture-resistant materials.

Freezer bags or Zip-top bags: Freezer-safe plastic bags are also used for packaging frozen fish, with excess air squeezed out before sealing.

LDPE liners: Low-density polyethylene (LDPE) is often used to line primary cartons for block frozen fish, surimi, and shrimp.

2. Secondary Packaging:

Cartons: Corrugated cardboard boxes are commonly used as secondary packaging to protect individually packed frozen products during shipping and storage.

Insulated containers: Styrofoam boxes or other insulated containers are used for transport to maintain the low temperatures required for frozen products.

Waxed or coated boxes: For bulk packaging, heavy duty corrugated or fiberboard cartons that are wax-saturated, wax-coated, or treated with other water-resistant processes are desirable.

Refrigerants: Gel packs, dry ice, or wet ice (when appropriate, and avoiding direct contact with the product) may be used to maintain the cold chain during transport.

Lightweight, strong, and leak-proof packaging: Essential for air transport, often consisting of heavy-duty waterproof corrugated cartons with polyethylene liners and insulating materials.

Packaging material characteristics:

- High water vapor and oxygen barriers.
- Withstand sub-zero temperatures without becoming brittle or torn.
- Retain odour within the package.
- Non-toxic and not reactive with the product.
- Food-grade and compliant with regulations such as those established by the FDA or FSSAI.

4.2.2 Packing requirements Cured fishery products

Cured fishery products like dried fish, smoked fish, and fish pickles require packaging that protects against moisture absorption, oxidation, infestation, and physical damage, while maintaining their characteristic flavour and texture.

1. Dried products

Vacuum-sealed bags: Ideal for preventing moisture gain, protecting against oxidation, and preserving freshness for a longer time.

Polyester polythene laminated pouches: Provide good barrier properties against moisture and gases, suitable for consumer packs.

High-density polyethylene (HDPE) or polypropylene (PP) woven sacks: Used for bulk packaging of dried fish.

Mylar Bags: Offers excellent protection from moisture, light, and oxygen, ideal for long-term storage of smoked fish.

Paper/Aluminium Foil/Polythene Laminates or Metallized Polyester Polythene Laminated Pouches: Recommended for accelerated freeze-dried products to protect from rancidity and moisture absorption.

Metal cans: In some cases, metal cans (tinplate, aluminum) are used for freeze-dried products that require exceptional protection from shock.

Pressure Bags: Offers two-in-one packaging and refrigeration benefits, acting as a moisture and oxygen barrier during storage and transit.

2.For Fish Pickles:

Glass Bottles: Traditionally used and offer inertness, non-toxicity, and impermeability to gases and moisture.

Plastic containers/pouches: Laminated pouches with materials like polyester/LDPE-HDPE co-extruded films or Nylon/Surlyn are also used.

3.Other Cured Products:

Fish Sausage: Stuffed in synthetic casings like Ryphan (Rubber hydrochloride) or Kurehalon (Vinylidene chloride) and wrapped in cellophane laminated with polythene.

Fish Soup Powder: Requires high barrier strength and low permeability to oxygen and water vapor. Appropriate packaging includes 12 microns plain polyester laminated with LDPE-HDPE co-extruded film or multilayer films like LD/BA/Nylon/BA/Prima core.

Fish Hydrolysate: Packed in jars or cans made of polypropylene or HDPE.

Shark Fin Rays: Moisture-resistant packaging with good puncture resistance and mechanical strength is required. Polyester/polythene laminates or Nylon-based co-extruded films are appropriate.

Choosing the right packaging for frozen and cured fishery products ensures product safety, maintains quality, extends shelf life, and meets consumer expectations and regulatory standards.

4.3. Statutory requirements for packing.

Packaging in the fisheries industry, especially when dealing with exports, is subject to stringent statutory requirements to ensure product safety, quality, and compliance with regulations in the importing countries.

A. Statutory requirements as prescribed under Food safety and standards

1. **Hygiene and sanitation:** Regulations emphasize maintaining high levels of hygiene throughout processing, handling, and packaging to prevent contamination.
2. **Material safety:** Packaging materials must be food-grade, non-toxic, and not transfer any harmful substances or undesirable tastes/odours to the fish or fishery products. According to the Food and Agriculture Organization, packaging materials must be strong enough to protect the fish and must not affect the taste or smell of the fish.
3. **Temperature control:** Specific temperature requirements must be maintained during storage and transportation (e.g., -18°C or lower for frozen products) to prevent spoilage and ensure product safety.
4. **Traceability:** Systems must be in place to trace the product from the source of origin to the final consumer, especially for aquaculture products and those requiring specific certifications.

B. Packaging and labelling requirements

1. **Proper labelling:** Mandatory information on the label includes the name of the product, list of ingredients, nutritional information, manufacturer's details, net quantity, batch/lot number, date of manufacture/packing, best before/use by date, and country of origin.
2. **Specific declarations:** Depending on the product type (e.g., fresh, frozen, canned), additional declarations might be required, such as instructions for use, storage conditions, and specific warnings for allergens.
3. **Packaging specifications:** Regulations may dictate the types of packaging materials suitable for different products and conditions, ensuring they are leak-proof, durable, and offer appropriate protection against environmental factors like moisture, oxygen, and light.

C. Export-specific requirements

1. **Importing country regulations:** When exporting, compliance with the specific regulations and standards of the importing country is crucial.
2. **Health certificates:** Consignments often require a health certificate issued by the competent authority of the exporting country, providing official guarantees required by the importing country.
3. **Pre-approval processes:** Some importing countries may require prior approval of the processing facility and residue monitoring plans for aquaculture products before imports are authorized.
4. **Inspection and checks:** Imports are subject to various checks, including documentary checks, identity checks, and physical inspections at the border inspection posts of the importing countries.

It is essential for businesses in the fisheries sector to stay updated with the latest regulations from relevant authorities like the **Food Safety and Standards Authority of India (FSSAI)** and export councils, and to consult with their export inspection agency to ensure full compliance with national and international requirements.

4.4 Labeling requirements. Different types of cold storages, Insulated and refrigerated vehicles.

4.4.1. Labelling requirements for processed fishery and fishery by products

- **Product Name and Identification:** The label must clearly state the name of the fish or fishery product, including its common and scientific names.
- **Method of production:** Whether the seafood is "wild-caught" or "farm-raised" should be stated for consumers who may have preferences.
- **Net Contents:** The net weight or quantity of the product must be declared.
- **Ingredients and Allergens:** A list of ingredients, including additives, and declarations for allergens (e.g., shellfish) is required.
- **Country of Origin:** The specific country where the seafood was harvested or processed must be stated, particularly for imported products.
- **Date Marking:** The date of manufacture, packing, best before date, or use by date must be present.
- **Storage Instructions:** Clear instructions for safe storage and handling, such as "keep frozen at -18°C," are necessary.
- **Name and Address of Manufacturer/Distributor/Importer:** Contact details for the responsible party must be provided.
- **FSSAI License Number and Logo:** In India, the FSSAI logo and license number are mandatory.
- **Non-vegetarian logo:** In India, a brown non-vegetarian logo indicates the presence of meat or seafood.
- **Nutritional Information:** A nutrition facts panel listing serving size, calories, fat, protein, and other nutrients is usually mandatory.

4.4.2. Different types of cold storages in fisheries

- **Chilled storage:** This includes methods like iced storage, chilled seawater (CSW) storage, chilled freshwater (CFW) storage, and mechanically refrigerated seawater (RSW) storage. These are used for short-term preservation and maintaining freshness.
- **Frozen storage:** Freezing preserves fish and seafood for longer durations. This includes blast freezers for rapid freezing and cold rooms or refrigerated warehouses for maintaining temperatures typically at -18°C or lower.
- **Deep Freezing Tunnels (IQF):** These use high-velocity cold air to rapidly freeze individual items like shrimp or small fish, preserving their texture and quality.
- **Controlled Atmosphere (CA)** Storages: Some cold storage facilities may utilize CA technology to regulate oxygen and carbon dioxide levels, further extending the shelf life of certain fish products.
- **Onboard cold storage:** Large fishing vessels like freezer trawlers have insulated and refrigerated holds or use systems like RSW to preserve the catch at sea.

4.4.3. Insulated and refrigerated vehicles in fisheries

- **Insulated vehicles:** These vehicles have insulated walls, floors, and ceilings to minimize heat transfer. They are suitable for shorter transport distances or when used in conjunction with ice or other refrigerants.
- **Refrigerated vehicles**: Equipped with a mechanical refrigeration unit, these vehicles can maintain specific temperatures for chilled (0-4°C) or frozen (-18°C or below) fish and seafood over long distances.
- **Refrigerated Containers (Reefers):** These are intermodal containers with integrated refrigeration machinery used for both land and sea transport. They can maintain temperatures between -25°C and +30°C and are essential for global trade in fishery products.

These measures ensure that fish and fishery products remain safe, high-quality, and comply with legal requirements throughout the supply chain, ultimately benefiting both consumers and the industry.

UNIT 5: EXPORT OF FISHERY PRODUCTS

5.1 Export of Fishery products from India - major countries, important products, export documents and procedures.

India is a major player in the global seafood market, with exports touching an all-time high in terms of volume during the financial year 2023-24, despite challenges in key markets.

Marine Products Export Development Authority (MPEDA), a statutory body under the Ministry of Commerce and Industry, is tasked with the primary role of promoting exports of marine products from India.

Major export destinations

The top export destinations for Indian seafood are the USA, which is the largest importer by value, followed by China (excluding Hong Kong and Taiwan) in terms of value. Japan is the third largest importer by both quantity and value, while Vietnam ranks fourth in both value and volume. Thailand is the fifth largest market by value and third by volume. Other important markets include the EU, Southeast Asia, the Middle East, Canada, Spain, Belgium, UAE, and Italy.

Important products

- Frozen shrimp is the primary export product in terms of both quantity and value, accounting for significant portions of the total exports.
- Frozen fish is the second largest export item by quantity and value. Other key export items include fish and shrimp-meal & feed-non-edible dried items, frozen squid, and Surimi and Surimi Analogs.
- Additional significant exports include frozen cuttlefish, chilled items, frozen octopus, fish oil, live items, dried edible items, and frozen lobster.

Export documents and procedures

Exporting fish from India requires several steps and documents to meet legal and international standards.

- **Initial steps:** These include business registration, obtaining an Importer-Exporter Code (IEC) from the DGFT, securing an FSSAI Central License, obtaining a Registration Cum Membership Certificate (RCMC) from MPEDA, registering and getting approval from MPEDA for facilities, and obtaining approval from the Export Inspection Council (EIC).
- **Documents required for each shipment:** These include the Shipping Bill, Bill of Export, Business Identification Number (BIN), Bill of Lading, Export General Manifest (EGM), Commercial Invoice, Packing List, Certificate of Origin (from MPEDA), Health Certificate (from Export Inspection Agency), Catch Certificates (from MPEDA), Certificate of Incorporation, valid ID and address proof, and passport-size photographs.
- **Compliance and other considerations:** Exporters must comply with the specific requirements of the importing country. This includes maintaining quality control, implementing HACCP, ensuring hygiene and temperature control, and proper labelling and packaging. Customs clearance can be done online through ICEGATE, or with the help of Customs House Agents.

Exporters should be aware of the specific regulations of their target markets, such as health and safety standards, packaging, labelling, and import tariffs. MPEDA's website offers resources and guidance on various aspects of seafood export.

5.2 Prospects and constraints in export including tariff and non- tariff barriers, marine insurance, export incentives, registered exporters

5.2.1 Prospects and constraints in Indian fishery exports, including tariff and non-tariff barriers

Prospects

- **Growing global demand:** Increased global consumption of fish and seafood products, driven by health consciousness and dietary shifts, presents a significant opportunity for India.
- **Abundant resources:** India's vast coastline, diverse marine resources, and growing aquaculture sector offer a strong base for production.
- **Government support:** Initiatives like the Pradhan Mantri Matsya Sampada Yojana (PMMSY) focus on developing infrastructure, promoting aquaculture, and enhancing processing capabilities, along with offering incentives like reduced import duties on feed ingredients and enhanced RoDTEP refund rates.
- **Emerging markets**: Diversification beyond traditional markets into regions like Eastern Europe, South America, and Africa holds potential for growth.

Constraints

1. **Non-tariff barriers (NTBs):** Stringent requirements in major markets like the EU, USA, and Japan regarding food safety, quality, and environmental standards pose significant challenges. These include:
   - **Sanitary and Phytosanitary (SPS) Measures:** These measures are crucial for protecting human or animal life from risks arising from food additives, contaminants, toxins, or disease-carrying organisms.
   - **Technical Barriers to Trade (TBT):** Regulations covering product standards, including labelling, packaging, and testing procedures, can be complex and difficult to comply with for Indian exporters.
   - **Antibiotic residues:** Strict limits on antibiotic residues in seafood products frequently lead to rejections of Indian consignments, especially in the EU.
   - **Lack of awareness and clarity:** Exporters may face challenges understanding and complying with evolving international standards and regulations in different countries.
   - **Discriminatory testing norms:** Sometimes, testing norms in importing countries may be perceived as unfair compared to those for competitors.
   - **Environmental standards:** Requirements concerning sustainable fishing practices and the use of Turtle Excluder Devices (TEDs) are also crucial, particularly for exports to the US.
2. **Tariff barriers**: While general tariffs on fish products have reduced globally, some high tariffs on specific products or "tariff escalation" on processed fish products in developed countries can hinder market access, impacting processed or value-added Indian seafood products.
   - **Anti-dumping and countervailing duties:** The imposition of anti-dumping duties, as seen in the US shrimp market in the past, significantly impacted Indian exports. In April 2025, a new tariff of 26% was implemented by the US on a range of Indian goods including seafood, raising concerns among Indian exporters about the impact on their competitiveness, especially against rivals like Ecuador.

- **Infrastructure gaps:** Inadequate cold chain facilities, processing plants, and fishing harbours can lead to post-harvest losses and limit efficiency.
- **Sustainability concerns:** Overfishing, illegal fishing practices, and resource depletion threaten the long-term sustainability of the industry and impact export potential.

- **Climate change impacts:** Changing Ocean conditions, including increased temperature and extreme weather events, can negatively impact fish productivity and coastal livelihoods.
- **Limited value addition:** India still heavily relies on exporting primary products like frozen shrimp, missing opportunities to capture higher value through processed and ready-to-eat products.
- **Policy fragmentation**: Disjointed governance across coastal states and weak enforcement mechanisms hinders effective management of marine fisheries, according to PMF IAS.

Addressing these constraints, particularly by strengthening quality control systems, ensuring traceability, promoting sustainable fishing practices, investing in infrastructure development, and diversifying export products, are key to realizing India's full potential in the global seafood export market.

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