# Freeze drying of seafood: Fundamentals, opportunities and challenges

The following article is a part of FIFP webinars conducted on 7th November 2020 on the topic 'Value addition in fishery industry' (Part 2)

## Note from the Chief Editor:

Main theme of the third in the series of FIFP webinars was 'Value addition in fishery industry' (Part 2) conducted on 7th November 2020. In all, four presentations were made that covered prospects of value-added seafood from India; freeze drying of seafood; scope of shrimp value addition for India in the global context; and innovations in shrimp value addition: focus on product knowledge. Mr.Laiju Lazar

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highlighted the possibilities of value addition of seafood products through adoption of innovative freeze-drying technology. He explained the fundamentals of freeze-drying process and described the steps involved in freeze drying such as selecting the product; weighing and arranging the products in trays for freezing; freezing the product below -25$^{o}$C; freeze drying program and packing. He brought out the advantages of freeze-drying technology particularly the superior quality and preservation of flavour, colour, and appearance of seafood products. Quality parameters of freeze-dried products such as bulk density; reconstitution; and residual moisture have been discussed and possibilities of freeze drying of wide variety of seafoods explored. He identified some of the challenges in the adoption of freeze-drying technology.

## Introduction

Seafood industry provides employment opportunities to skilled, semi-skilled and unskilled labour force in India while earning valuable foreign exchange. Conventional freezing of seafood started in India in the early 60s and since then exporting of frozen seafood became a commercially viable activity. Freeze-drying, a remarkable technology is a later innovation for material preservation. Industrial freeze-drying of foods began during 1950s. It is currently used as a preservation method for foods, pharmaceuticals, and a wide range of other products. In India, seafood freeze-drying started during early 80s. Freeze-drying is the removal of ice from a material through the process of sublimation, process in which a solid (ice) changes directly to vapor without first going through a liquid (water) phase.

### Sublimation in freeze drying

The entire process of freeze drying happens in three stages: freezing; vacuum processing; and drying.

Freezing – The product is properly arranged in trays and then completely frozen.

Vacuum processing – The product is placed under a deep vacuum chamber, well below the triple point of water (Fig.1).

Drying – Drying process under vacuum happens in two phases. Primary Drying (Sublimation) and Secondary Drying (Adsorption).

Primary Drying (Sublimation) – In this phase, pressure is lowered, and heat is added to the material in order for the water to sublimate. The vacuum speeds sublimation. The cold condenser provides a surface for the water vapor to adhere and solidify. The condenser also protects the vacuum pump from the water vapor. About 95% of the water in the material is removed in this phase. Primary drying can be a slow process. Too much heat can alter the structure of the material.

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Secondary Drying (Adsorption) – In this phase, the ionically-bound water molecules are removed. By raising the temperature higher than in the primary drying phase, the bonds are broken between the material and the water molecules. Freeze dried materials retain a porous structure. Most materials can be dried to 1-5% residual moisture.

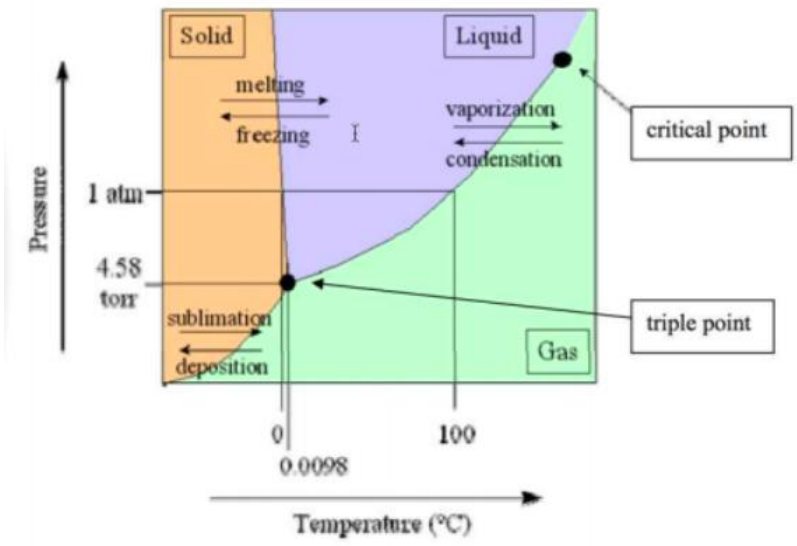


**Fig.1 Sublimation in freeze-drying (understanding Triple point of water)**

**Preservation by reducing Water Activity (aw)**

Water activity (aw) is an indication of amount of free-water available in the product. The water activity (aw) of a food item is the ratio between the vapour pressure of the food itself, when in a completely undisturbed balance with the surrounding air media, and the vapour pressure of distilled water under identical conditions. Preservation and shelf stability of the freeze-dried product is achieved by lowering the water activity below 0.85 aw. By attaining this, the enzymatic and bacterial

changes in the food product are arrested and the shelf life is enhanced. This could be measured as residual moisture level in the final product as below 3%.

**Freeze drying process - Equipment**

Freeze drying process involves two stages: freezing and freeze-drying

Freezing- Any type of freezer that can freeze the product below -25°C like blast freezer, IQF freezer can be used. Products are arranged in trays with specific weights and frozen below -25°C before transferred to Freeze Dying Unit.

Freeze drying- Freeze-drying unit consists of vacuum chamber, heating plates, trays with product for drying loaded between the plates, and refrigeration coil for trapping the moisture sublimed from the product (aka, condensation coils)as shown in fig.2.

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**Fig. 2. Freeze drying unit**

**Freeze drying process**

***Selecting the product***

It is possible to freeze-dry wide range of products as given below.

- Shrimp, Mussel, Squid, Crab meat
- Small fish as whole
- Large fish meat cut into cubes/slices

It is ideal to have the thickness of the product

Mussel meat

less than 2 cm in cross section.
Freeze-drying could be done for cooked or raw products based on end consumption/ requirement.

Salmon Cubes

Tuna Cubes

BabyShrimp

Minnows

***Weighing and arranging the products in trays for freezing***

Uniform thickness is to be ensured while arranging the products.

Baby Shrimp arranged in tray

Mussel meat arranged in tray

***Freezing the product below -25°C***

It has to be ensured that the product core temperature reaches below -25° C. It is important to freeze the products rapidly in order to avoid formation of large ice crystals which may deteriorate quality of the product.

***Sample freeze-drying program***

There are two major elements of freeze- drying program: Time and temperature also called Time-temperature profile. This varies from product to product. Total time taken for completion of a program may vary from 6-18 hours or even more based on the dried product quality and application requirements.

| Time (min) | Temperature | Vacuum Pressure |
|---|---|---|
| 30 | 70° C | 0.5-0.7 mb |
| 120 | 100° C | 0.5-0.7 mb |
| 240 | 90° C | 0.5-0.7 mb |
| 240 | 85° C | 0.5-0.7 mb |
| 120 | 70° C | 0.5-0.7 mb |

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Deleted[Laiju Lazar]: /freeze-drying program

The quality of freeze-dried product is completely dependent on the efficiency of the freeze-drying program which is developed through R&D and various trials executed at different settings of main parameters. It requires skill and expertise to develop efficient freeze-drying program. Once the freeze-drying process is successfully completed, moisture level in the product will be less than 2%. This provides the product shelf stability at ambient storage condition.

***Packing***

Final stage in freeze-drying process is packing of the products. About 98% of the moisture gets removed from the product during freeze drying process. Freeze-dried products are ideally packed in packing materials with moisture barrier to enhance the shelf life at ambient storage conditions. Relative humidity of the packing room has to be below 40 units.

**Quality parameters of freeze-dried products**

**Bulk Density**

Bulk density is the measurement of the weight of the freeze-dried product for a specific volume. Freeze-dried products are highly porous and occupy the same volume as that of the original product. Optimum bulk density in correlation with the dry matter of the product indicates efficiency of the freeze-drying process. Bulk density can be measured by weighing freeze-dried product taken in a measuring cylinder of known volume, for e.g. 500 ml.

**Reconstitution**

The high porosity of freeze-dried product makes it rapidly rehydrated. A reconstitution ratio 1:3 and above is considered good for a quality freeze-dried product. Reconstitution ratio can be measured by the weight gained by the product after immersing in lukewarm water for 2 minutes.

**Residual moisture**

This is the percentage of the moisture remaining in the product after freeze-drying process. Residual moisture level below 3% is desirable. An efficient freeze-drying process should remove 99% of the moisture and the product should have moisture below 1%.

**Quality parameters of freeze-dried products**

| Organoleptic | Chemical | Microbial |
|---|---|---|
| Appearance | Sulphite | Total Plate Count |
| | | *Staphylococcus aureus* |
| Colour | | Coliforms |
| | | *E.coli* |
| Odour | | *E.coli* HS O:157 H7 |
| | | Salmonella |
| | | *Vibrio parahaemolyticus* |
| | | *Vibrio cholera* |
| | | Yeast and mould |
| | | *Listeria minocytogenes* |

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## Advantages and opportunities

Main advantage of freeze-dried products is the convenience. It can be stored at room temperature. This makes it versatile for a wide variety of options like ready meals, instant foods, snacks and ingredients for other types of prepared meals.


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**High-end seafood pet treats**


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## Other benefits

### Superior quality

The quality of freeze-dried foods is superior to those made by other dehydrated methods. The reasons for high quality are a) absence of a liquid phase in the process and b) the low temperature at which the operation is carried out. Freeze-dried food materials preserve the flavour, colour and appearance while minimising thermal damage to heat sensitive nutrients. Another advantage is well-preserved texture as the process takes place in solid state.

Freeze-dried products are crispy and have four to six times higher rehydration ratios than conventional air-dried foods. The shape of the product is maintained in freeze-drying. Also, there is no shrinkage like in conventional drying methods. Other benefits include long shelf life of six months to one year in sealed condition and substantially reduced weight for storage, shipping and handling.

### Main Challenges

High cost of installation, operation and maintenance.

High energy consumption – freezing, vacuum and sublimation processes are high energy consuming.

Availability of high-quality raw material and meeting documentation requirements for importing countries.

Since freeze-drying process is product specific, it calls for technical expertise and extensive in-house R&D.

Freeze-dried products are expensive.

### Market scenario

The annual growth of freeze-dried food market is estimated at 7.4% as per Mordor Intelligence. US market is expected to reach USD 66.5 billion by 2021. Among freeze-dried food products, fruits occupy 32% market share. North America holds

the largest share (35%) of global freeze-dried market. South America and Asia Pacific are the fastest growing markets.

## Conclusion

Freeze drying is a remarkable technology adopted for preservation of raw/cooked material. Wide range of seafood products can be freeze-dried for convenience, enhanced quality and longer shelf life. The quality of freeze-dried product is completely dependent on the efficiency of the freeze-drying program, developed through R&D and several trials. It requires skill and expertise to develop efficient freeze-drying program. Residual moisture level below 3% is desirable. Ideally, an efficient freeze-drying process should remove 99% of the moisture and the product should have moisture below 1%. Freeze-dried products retain their flavour, colour and appearance and can be stored at room temperature. Higher cost of production, lack of availability of high-quality raw material and technical expertise are some of the challenges.

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