Chapter 16

Advanced fish drying techniques

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Introduction

Fish is a highly nutritious food than meat and egg and it is highly perishable because of its high moisture content which is about 80%. Fish preservation is essential immediately after the catch to increase the shelf life of fish. Preservation methods help to maintain the quality of fish for a longer period of time, prevent spoilage and decomposition, retain its original nutritional contents, and make transportation and storage of fish easier. Fish preservation techniques vary with the type, nature, size, and condition of fish. Improper handling and processing of fish lead to immediate spoilage of fish resulting in poor quality.

Conventional preservation techniques such as chilling, freezing, drying, and chemical preservation are widely used for fish preservation throughout the world. Among the various preservation techniques drying of fish is the oldest preservation technique and drying means the preservation of fish by removing water from it through heating. Drying removes the moisture content up to a certain level to prevent microbial growth thereby providing greater shelf life, and reduction in weight, volume, transportation, and storage space. Two commonly used drying methods are natural and artificial drying. Natural drying includes sun drying, and solar drying, whereas artificial drying includes a microwave, fluidized bed, spouted bed, infrared, convective drying, desiccant drying, freeze drying, osmotic, vacuum drying, pulsed electric field, high hydrostatic pressure, superheated steam drying, heat pump and spray drying *etc*.

Natural drying methods are associated with disadvantages like contamination and damage by dirt, insects, rodents, birds, and animals. Sun drying of fish often results in low-quality products since drying is slow normally it takes five to seven days. Therefore, it is necessary to choose an advanced method of drying to obtain good quality products (Curran and Trim, 1985). Artificial drying methods have advantages like less drying time, good quality drying, better process control, operational safety, and higher capacity.

1.1 Advanced drying methods

1.1.1. Solar drying

Solar energy has been used all around the world to dry food products. Solar drying is the use of equipment to collect the sun’s radiation in order to harness the radioactive energy for drying applications. Good product quality can be retained with the control of radioactive heat. It is mainly used to dry products like grains, fruits, vegetables, meat, and fish. A solar food dryer improves the open air sun drying in the following ways:

1. Solar dryers enhance the drying time because it directly traps heat inside the dryer using translucent, glazing over the collection area and raising the temperature of the air.
2. It is a more efficient method of drying than open sun drying. Food materials can be dried more quickly so less will be lost to spoilage.
3. Drying is being done in a hygienic environment and is less likely to be contaminated.
4. Drying foods at optimum temperatures and in less time enables solar dryers to retain more nutritional values such as vitamin C.
5. Using freely available solar energy instead of conventional fuels to dry products or using a cheap supplementary supply of solar heat, so reducing conventional fuel demand can result in significant cost savings.

1.1.2. Fluidized bed drying

In fluidized bed drying (FBD) system, the air is allowed to pass through the bed of solid material in the upward direction with a velocity greater than the settling rate of solid particles. It is mainly working on the fluidization of solid materials. Since hot air is introduced from the bottom of the system at high pressure the solid particles which have to be dried will be in a suspended state in a stream of air. Heat transfer is accomplished by direct contact between the solid material and hot air. Vaporized liquid is carried away by the hot air.

For most of food applications, a batch-type fluid bed dryer is a better choice since small quantity of wet material to be processed. Recent developments in FBD include mechanically agitated FBD, use of pulsating flow, and use of immersed tubes for efficient heat transfer *etc*. The advantages of FBD systems are as follows: 1. Drying temperature is low thus minimizing the quality degradation by thermal effects. 2. Uniform drying results in particles having even dryness. 3. The effectiveness of heat and mass transfer is high since there is direct contact between wet material and hot air.

1.1.3. Infrared drying

In recent years, infrared drying has gained popularity as an alternative drying method for foods. IR is electromagnetic radiation that is in the region of 0.78 – 1000μm. It is transmitted and absorbed by the food surface and gets changed into heat. Generally, the far-IR region (3 – 1000μm) is used for food processing since most of the food materials are having the ability to absorb IR in this region. IR radiation impinges on the surface of the material which has to be dried and penetrated into it. Absorption of radiation increases the molecular vibration inside the material and resulted in heat generation on both the inside and surface of the material concurrently (Sakai and Hanzawa, 1994). Faster heat generation inside the material increases the movement of moisture towards the outer surface. External hot air movement over the surface of the material can remove the moisture from the surface and influence the further mass transfer from the material. IR drying provides less drying time, is highly energy efficient, uniform in drying, and has good quality dried products. Infrared offers faster drying of products with minimum energy consumption and nutrient losses than conventional dryers. Also, IR heating provides high heat transfer with less drying time and energy cost. Drying using IR radiation will result in better quality products than another drying process since the heating is fast and uniform. It can be used for various food materials like grains, flour, vegetables, pasta, meat, and fish.

1.1.4. Vacuum drying

Vacuum drying is a process in which materials are dried in a reduced-pressure environment, which lowers the temperature required for rapid drying. Major advantages of vacuum drying are as follows: less energy is needed for drying, it is highly suitable for heat-sensitive food materials, faster method than other drying methods, it retains the integrity of materials *etc*. In general, vacuum drying is performed in combination with other drying techniques.

1.1.5. Superheated steam drying

In superheated steam drying, the drying gas in a convective dryer is replaced with superheated steam. Superheated steam at certain pressure enters in drying chamber and removes the moisture from wet foods and the exhaust from the dryer is also superheated steam with a lower specific enthalpy. A part of the steam can be recycled back after compression and the excess can be either used directly or removed from the system. Any conventional convection and conduction dryer can be easily adapted to a superheated steam dryer. It is an attractive drying medium for some products which gives better quality products in absence of oxygen.

1.1.6. Freeze drying

Freeze drying or lyophilization is a dehydration process used to preserve material and make it into more convenient for transport. It is a method of water removal from material by sublimation. This drying process is divided into three stages: pre-freezing of wet material, primary drying (sublimation of frozen water under vacuum), and secondary drying stage (desorption of residual bound water from the material). Freeze drying is initially freezing the material and then reducing the surrounding pressure to allow the frozen water in the material to sublimate directly from the solid phase to the gas phase. It is one of the best methods of water removal and results in a final product of much higher quality compared to any other drying technique. A comparative review of drying technologies showed that freeze drying, vacuum drying, and osmotic dehydration are considered too costly for large-scale production of dried products (Khin *et al.*, 2005).

1.1.7. Heat pump drying

A heat pump is a device that transports energy from a low-temperature source to a higher-temperature sink. This transfer requires an input of work which may be supplied mechanically as in a vapor-compression cycle. The most common type of heat pump operates on the vapor-compression cycle and a basic unit consists of the evaporator, compressor, condenser, and expansion valve. Heat transport is achieved through phase change of the working fluid (refrigerant). The refrigerant in the evaporator absorbs heat and vaporizes at low pressure and temperature. As the vapor condenses at a higher pressure in the condenser, it rejects heat at a higher temperature. When used in a drying system, the heat pump dryer cools the process air first to saturation, and then further for condensation of water (dehumidification), thus increasing the drying potential of air. In the process, it also recovers low-grade heat (sensible and latent) from the air, which is made available at the condenser as sensible heat of higher quality. A heat pump dryer consists of a heat pump system and a dryer, the performance of the dryer is greatly affected by the performance of the heat pump system. Heat pump drying is a technology by which materials can be dried at low temperatures and in an oxygen-free atmosphere using less energy than common drying methods. This drying recorded less drying time than other drying methods and it is simple to design.

1.1.8. Dielectric drying:

Electromagnetic energy of microwave and radio frequency (RF) can directly interact with foods to quickly raise center temperature since most food materials are dielectric materials and can store electric energy and convert it into heat. It is volumetric heating and quick raise of temperature is possible.

In microwave drying, microwaves can penetrate materials and heat resulting in water removal during drying. Microwave energy at 915 and 2450 MHz can be absorbed by water-containing materials and can be converted into heat. Food materials are dried by the interactions between the electromagnetic energy and polar molecules within the material. Polar molecules rotate in response to the applied oscillating electromagnetic waves. The reorientation of molecules in a high-frequency electric field occurs frequently and rapidly, resulting in molecular friction that generates heat. It is an energy-efficient technology and can maintain the quality of food materials upon drying. Some disadvantages of microwave drying are non-uniformity in drying, limited penetration depth, lack of equipment for large-scale production *etc*.

Radiofrequency energy generates heat volumetrically within wet material based on combined mechanisms of dipole rotation and conduction effects. The free space wavelength in the RF range is 20-360 times longer than that of commonly used microwave frequencies, allowing RF energy to penetrate foods more deeply and provide better heating uniformity in food materials than microwave energy. Therefore, radio frequency (13.56, 27.12, and 40.68 MHz for industrial applications) thermal processes have the potential to reduce thermal quality degradation in the drying of foods. Major challenges for using RF heating in the food industry are non-uniform heating which leads to overheating in corners, edges, and center parts of intermediate and high moisture food.

1.1.9 Hybrid drying/Combined drying

Hybrid drying techniques are becoming common because the combined technology receives the benefits of individual processes. Combined drying is considered as the best technique to reduce energy consumption and improve quality (Raghavan *et al.*, 2005). Combined drying technologies involve the implementation of different modes of heat transfer and two or more stages of the same or different types of dryer. Currently, some new techniques such as microwave, infrared, and radio frequency assisted drying have been used to reduce drying time and improve the final quality of dried products. Many various combinations of drying methods can be used to avoid the disadvantages of a single drying method such as long drying time, high power consumption, and low product quality. Combined drying methods include parallel and tandem drying. Parallel drying uses two or more drying methods simultaneously. Tandem drying involves the use of one drying method followed by one or more other drying methods.

Conclusion

Drying is an important process to preserve food materials and to extend the shelf life. Different drying methods are available for drying of foods and each has its own advantages and disadvantages. Traditional drying methods (sun, solar, hot air oven drying) are simple to use but have low energy efficiency and longer drying time. Thus it negatively affects the colour, flavor and nutrient content of dried products. Some advanced drying methods (freeze drying, microwave, heat pump, and vacuum drying) offer a wide scope for the production of best quality dried products. But usage of these methods for drying is restricted due to its high cost. Therefore, cost-effective alternative systems such as combined/hybrid drying can be used for the drying of products with minimum cost and simple technologies. Combination drying with an initial conventional drying process followed by microwave/vacuum or simultaneously two methods hot air with infrared/microwave/vacuum has proven to reduce drying time with improved product quality and minimizing energy requirements.

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