Advances in Freeze Drying: Lyophilisation

Joshi, Nirav D.
Associate Professor, College of Food Technology, Sardarkrushinagar Dantiwada Agricultural University, Dantiwada.
*Corresponding Author's Email: niravjoshi56@sdau.edu.in

Introduction

Freeze drying dates back to the Incas, who used it to preserve their food during the winter months by freezing it in the highlands. At the same time, the low vapour pressure of the water in the surrounding air at those high altitudes removes the frozen water. Naturally, this was a pretty slow procedure, but because the food was frozen, its quality was preserved throughout the drying process. Food items like potatoes and veggies displayed a noticeably improved quality over time after being dried. Only since World War II has this drying technique been adopted as an industrial technique for material preservation. The creation of the contemporary tray-type lyophilizer, which is still in use in many sectors today, was primarily motivated by the need to extend the shelf life of medications like penicillin and preserve blood plasma during times of war. The abundance of coffee in nations like Brazil in the late 1930s served as another impetus for the development of the freeze-drying technique. Here, too, the water from the frozen coffee granules was sublimated using a tray-type freeze drier. At that period, well-known brands like Nescafe were established. Nowadays, the most popular freeze-dried commodity is instant coffee.

Tray freeze dryers

A huge chamber is needed for freezing in tray freeze dryers, and a vacuum pump is needed to remove the moisture. Trays holding the material to be dried are set up on cooling/heating shelves in the drying chamber. The substance is first frozen by reducing the shelf's temperature. A thick covering of ice has frozen the substance. Following freezing, the drying chamber is closed and the product is placed under vacuum. This makes it possible for the product's frozen solvent to sublimate—vaporize—without going through the liquid phase. During drying, vacuum levels typically range from 1 mbar to 0.01 mbar. For instance, the vacuum will guarantee sublimation temperatures of -20°C or below when water is sublimated at such high vacuum levels. To speed up the sublimation process, heat is applied to the frozen product through the shelves. But as the process progresses, a dry coating of product will build, which will significantly impede this sublimation. Because of this, freeze drying is by far the slowest drying technique possible. The drying system also includes a low-temperature condenser that turns the vaporised solvent back into a solid, thus eliminating it from the vacuum chamber. The solvent and liquid separation procedure is now complete. The trays are taken out of the drying chamber once the drying process is finished, and the dried cake is removed from the tray. Usually, some grinding is required to turn the dried material into a fine powder. Up to hundreds of trays might be found in large-scale systems. Therefore, a significant disadvantage of this technique is heavy handling, in addition to the lengthy drying durations.

Recent Advancement

The potential to produce loose and free-flowing powder at low temperatures and low pressures in a single vessel, as well as a faster and less labour-intensive freeze drying process. Even this little introduction demonstrates how the recently created Active Freeze Drying technology may be viewed as a significant advancement in the fields of powder and freeze drying technology.

It is feasible to achieve an effective freeze drying procedure, according to early tests using a drying driven drying chamber run at low temperatures and low pressures. The end product is free-flowing and lump-free. Because the product is always moving, active freeze dryers have a higher rate of heat transmission. Because the dried product no longer obstructs the sublimation, the drying process is shortened. Ultimately, transferring product-filled trays between freezing units, drying chambers, and crushers is no longer necessary because all process steps may be completed in a single processing unit. When compared to conventional tray drier equipment, this makes handling the product easier.

A commercial dynamic freeze drying method has been developed as a result of the successful outcomes of these early studies. The material to be dried is frozen in a specially built drying chamber. The substance, which might be a liquid, paste, or solid, will become solid granules as a result of forceful motion. The machine's dynamics can regulate the granules' sizes and forms. The drying chamber is closed and suction is applied when the freezing process is finished. The sublimation process will begin after the freezing ingredient has been evacuated. At this point, the vacuum level controls the product's temperature. The jacket provides heat during sublimation, and the chamber design effectively distributes it throughout the product. The sublimation of the connecting ice structure between the frozen material will cause the originally coarse granules to progressively get smaller. A loose powder will be formed from the discharged dry particles. The product temperature will begin to increase near the conclusion of the drying process when the majority of the frozen solvent has been sublimated. When the product and wall temperatures finally match, the drying process is complete. By that point, all of the material has turned into a loose, fine powder.

After breaking the vacuum the dryer can be discharged easily as a free-flowing material from the dryer vessel, assisted by the transporting characteristics of the drying chamber.

Application

This dynamic freeze drying process is mostly used in the pharmaceutical industry to generate electrolytes and antibiotic macromolecules. Freeze-drying is also commonly used to create proteins, hormones, viruses, vaccines, bacteria, yeasts, blood serum, liposomes, and transplant materials like collagen sponge. The preservation of the product structure, particle size, and low temperature load are the key factors that determine whether to utilise freeze-drying for any of these items.

The materials industry, particularly for nanomaterials, is another rapidly expanding sector for the larger-scale application of Active Freeze Dryers. For these wet base processed materials, dynamic freeze drying offers unique benefits. Both the freezing and drying processes keep the suspended particles apart. Single particles will split as sublimation progresses, but the material's constant motion will cause weak agglomerates to develop. The finished result will be a fine, cohesive powder made up of loosely bonded single particles. In order to preserve a wide range of goods while preserving their natural taste, colour, fragrance, texture, and nutritional content, the food sector frequently uses freeze-drying.

Common Food Items Freeze-Dried:

- Fruits (e.g., strawberries, apples, bananas)
- Vegetables (e.g., peas, carrots, spinach)
- Meats (e.g., chicken, beef)
- Aquatic products (e.g., shrimp, fish fillets)

ACTIVE Freeze Drying: it awaits ahead

This novel dynamic method of freeze drying has opened the door to a new kind of industrial technology. Batch quantities for active freeze dryers can vary from a few litres for small-scale and laboratory production applications to hundreds of litres for bulk drying. The benefits are clear in all sizes: quick drying, easy handling, and distinctive product quality. Many tests in a variety of sectors have been conducted for customers throughout the last year. Regular medications, insects, nanomaterials, germs, special herbs, and other premium food items are among the elements being examined. The goal of recent advancements is to transform this special technology into a continuous manufacturing process so that capacity may be increased even more.

Conclusion

Particularly in the food and pharmaceutical industries, freeze-drying continues to be the industry standard for preserving valuable, thermally sensitive goods. For sensitive materials like fruits, vegetables, vaccines, and biologics, its special capacity to eliminate moisture at low temperatures guarantees the preservation of nutritional, structural, and functional properties. However, conventional freeze-drying has long been linked to serious disadvantages, such as excessive energy usage, protracted processing periods, and expensive operating costs. These difficulties have prevented it from being widely used, especially in large-scale and cost-sensitive production settings. These developments are increasing the speed, sustainability, and versatility of freeze-drying. Processing functional foods, snacks, and ready-to-eat meals is increasingly more practical in the food industry. All things considered, freeze-drying is evolving from a specialised preservation technique into a next-generation solution that satisfies worldwide demands for scalable production, energy efficiency, and product quality.

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