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INTRODUCTION TO PRINCIPLE OF DRYING

Introduction

The purpose of drying food products is to allow longer periods of storage with minimized packaging requirements and reduced shipping weights. The quality of the product and its cost are greatly influenced by the drying operation. The quality of a food product is judged by the amount of physical and biochemical degradation occurring during the dehydration process. The drying time, temperature, and water activity influence the final product quality. Low temperatures generally have a positive influence on the quality but require longer processing times. Low water activity retards or eliminates the growth of microorganisms, but results in higher lipid oxidation rates. Maillard (nonenzymatic) browning reactions peak at intermediate water activities (0.6 to 0.7), indicating the need for a rapid transition from medium to high water activities. Many dried foods are rehydrated before consumption. The structure, density and particle size of the food plays an important role in reconstitution. Ease of rehydration is increased with decreasing particle size, and the addition of emulsifiers such as lecithin or surfactants. Processing factors which affect structure, density, and rehydration include puffing, vacuum, foaming, surface temperature, low temperature processing, agglomeration, and surface coating. Storage stability of a food product increases as the water activity decreases, and the products that have been dried at lower temperatures exhibit good storage stability. Since lipid-containing foods are susceptible to lipid oxidation at low water activities, these foods must be stored in oxygen impermeable packages. Poor color retention has been a problem in the freeze-drying of coffee because the number of light-reflecting surfaces is decreased during rapid drying. This problem has been improved by slow freezing, partial melting, and refreezing to insure large ice crystal formation. Other food materials have different drying problems and specific solutions must be developed.

Drying should fulfill the following goals

(i) Minimal chemical and biochemical degradation reactions
(ii) Selective removal of water over other salts and volatile flavor and aroma substances
(iii) Maintenance of product structure (for a structured food)
(iv) Control of density
(v) Rapid and simple rehydration or redispersion
(vi) Storage stability: less refrigeration and packaging requirements
(vii) Desired color
(viii) Lack of contamination or adulteration
(ix) Minimal product loss
(x) Rapid rate of water removal (high capacity per unit amount of drying equipment)
(xi) Inexpensive energy source (if phase change is involved)
(xii) Inexpensive regeneration of mass separating agents
(xiii) Minimal solids handling problems
(xiv) Facility of continuous operation
(xv) Noncomplex apparatus (reliable and minimal labor requirement)
(xvi) Minimal environmental impact

Drying Fundamentals

Drying is defined as a process of moisture removal due to simultaneous heat and mass transfer. Heat transfer from the surrounding environment evaporates the surface moisture. The moisture can be either transported to the surface of the product and then evaporated or evaporated internally at a liquid vapor interface and then transported as vapor to the surface. The mechanisms of water transfer in the product during the drying process can be summarized as follows-: water movement due to capillary forces, diffusion of liquid due to concentration gradients, surface diffusion, water vapor diffusion in pores filled with air, flow due to pressure gradients, and flow due to water vaporization–condensation. In the pores of solids with rigid structure, capillary forces are responsible for the retention of water, whereas in solids formed by aggregates of fine powders, the osmotic pressure is responsible for water retention within the solids as well as in the surface. The type of material to be dried is an important factor to consider in all drying processes, since its physical and chemical properties play a significant role during drying due to possible changes that may occur and because of the effect that such changes may have in the removal of water from the product.

The transfer of energy (heat) depends on the air temperature, air humidity, air flow rate, exposed area of food material, and pressure. The physical nature of the food, including temperature, composition, and in particular moisture content, governs the rate of moisture transfer. The dehydration equipment generally utilizes conduction, convection, or radiation to transfer energy from a heat source to the food material. The heat is transferred directly from a hot gas or indirectly through a metal surface. The model equations for dryers cannot be discussed without a thorough understanding of the basic heat and mass transfer concepts. The typical drying cycle consists of three stages: heating the food to the drying temperature, evaporation of moisture from the product surface occurring at a rate proportional to the moisture content, and once the critical moisture point is reached, the falling of the drying rate. The critical moisture point depends greatly on the drying rate since high drying rates will raise the critical point and low drying rates will decrease them.

Principle of Drying

Dehydration involves the simultaneous application of heat and removal of moisture from foods. Factors that control throughout the food processing are many and it varies for thermal drying. Some involve the removal of moisture or volatiles from various food ingredients or products that differ in both chemical and physical characteristics. Others involve the drying of solutions or liquid suspensions and different approaches to the problem.

Three basic methods of heat transfer are used in industrial dryers in varying degrees of prominence and combinations, specifically, convection, conduction, and radiation. In the food processing industry and dairy industry, the majority of dryers employ forced convection with continuous operation. With the exception of the indirectly heated rotary dryer and the film drum dryer, units in which heat is transferred by conduction are suitable only for batch use. This limitation effectively restricts them to applications involving somewhat modest production runs. Radiant, or "infrared," heating is rarely used in drying materials. Direct heating is used extensively in industrial drying equipment where much higher thermal efficiencies are exhibitedthan with indirectly heated dryers. This is because there are no heat exchanger losses and the maximum heat release from the fuel is available for the process. However, this method is not always acceptable, especially where product contamination cannot be tolerated, particularly in dairy industry. In such cases, indirect heating must be used. With forced-convection equipment, indirect heating employs a condensing vapor such as steam in an extended surface tubular heat exchanger or in a steam jacket where conduction is the method of heat transfer. Alternative systems that employ proprietary heat-transfer fluids also can be used. These enjoy the advantage of obtaining elevated temperatures without the need for high-pressure operation as may be required with conventional steam heating. This may be reflected in the design and manufacturing cost of the dryer. Furthermore, in addition to the methods listed above, oil- or gas-fired indirect heat exchangers also can be used. In general, dryers are either suitable for batch or continuous operation.

Dehydration or drying of food is a complex phenomenon involving momentum, heat and mass transfer, physical properties of the food, air and water mixtures, and macro and microstructure of the food. There are many possible drying mechanisms, but those that control the drying of a particle product depend on its structure and the drying parameters, like drying conditions, moisture content, dimensions, surface transfer rates, and equilibrium moisture content. These mechanisms falls in to three classes: (i) evaporation from a free surface, (ii) flow as a liquid in capillaries, and (iii) diffusion as a liquid or vapour. The first mechanism follows the laws for heat and mass transfer for a moist product. The second mechanism becomes difficult to distinguish from diffusion when one sets the surface tension potential to be proportional to the logarithm of the moisture potential (or water activity). The third set of mechanisms follows Fick’s second law of diffusion, which is analogous to Fourier’s law of heat transfer when the appropriate driving force is used.

In convectional drying the heating medium, generally air, comes into direct contact with the solid. Various oven, rotary, fluidized bed, spray, and flash dryers are typical examples. In conduction drying, the heating medium is separated from the solid by a hot conduction surface. Examples are drum, cone and through dryers. In radiation dryers, the heat is transmitted as radiant energy. Some dryers also use microwave energy to dry food materials at atmospheric pressure or at vacuum.