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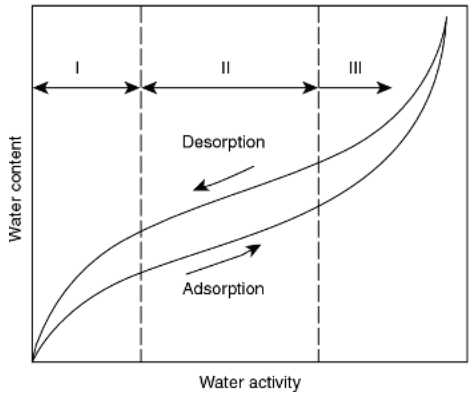
METHODS OF DRYING FOODS

Food drying is one of the oldest methods of preserving food; it was more of a discovery than an invention. Evidence shows that foods were dried by the hot sun as early as 12,000 BCE in the Middle East and oriental cultures. Dehydration removes the moisture from the food so microorganisms cannot grow or spoil the product. In addition, it slows down the action of enzymes, but it does not inactivate them. Food products dry by the evaporation of surface water as warm air is blown across and carries the water vapour away from the food. As the surface moisture is lost, additional water comes to the surface by the process of diffusion. The nature of this moisture movement defines the rate at which products will dry.

Since water removal is the defining step in dehydration, we must understand the nature of water in food. Water exists in foods in two forms, bound and unbound. The unbound (or free) water can support the growth of undesirable bacteria, yeasts and moulds. The term water activity is used to represent the degree of unbound water in food systems. Water activity (a_w) represents the ratio of the water vapour pressure of the food to the water vapour pressure of pure water under the same conditions. The relationship between the water content and a_w of food is not linear, meaning as water is removed from food, there is a decrease in a_w, but but the decrease in water activity is not proportional. This relationship is described by a graph called a Sorption Isotherm, which plots a_w on the x-axis and moisture content on the y axis (see diagram below).



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The desorption line reflects the drying step, and the adsorption line indicates the manner of rehydration. The difference between the two represents the hysteresis of a given food or the physical changes from drying that affect the ability to take up water. There are three major sections on the graph. For the desorption line - from the upper right (high moisture and high a_w), one often sees a typical steep drop down from initial moisture content with very little change in a_w. This demonstrates that there is a significant amount of unbound water in the food, and even as moisture is removed, there is still free water. At the second stage of the graph, as the line on the isotherm drops down to the point where free water becomes limiting, then with subsequent water removal, there is a significant drop in a_w getting closer to where microbial action is being suppressed. Not all microorganisms have the same lower limit of available water for growth. The table below lists types and minimum a_w values for specific groups of microorganisms.

The tables below outline minimum a_w values for various microorganisms.

Microorganism	minimum a_w values	Microorganism	minimum a_w values
Most spoilage bacteria	0.90	Halophilic bacteria	0.75
Most spoilage yeasts	0.88	Xerophilic moulds	0.61
Most spoilage moulds	0.80	Osmophilic yeasts	0.61

Microorganism	minimum a_w values
Clostridium botulinum E	0.97
Pseudomonas fluorescens	0.97
Escherichia coli	0.95
C. perfringens	0.95
C. botulinum A, B	0.94
Salmonella spp.	0.95
Vibrio parahaemoliticus	0.94
Bacillus cereus	0.93
Listeria monocytogenes	0.92
B. subtilis	0.91
Staphylococcus aureus (anaerobic)	0.90
S. aureus (aerobic)	0.86

Most pathogens require a high a_w to grow. *S. aureus* is the pathogen that can grow at the lowest minimum a_w, which is why 0.85 is used as a maximum acceptable value for the safety of dried shelf stable products.

Advantages of drying for preservation

1. Volume and weight reduction, so lower transportation and storage cost throughout the supply chain.
2. Desirable taste and texture for many types of products (chewy, sweet dried fruit).
3. Form changes and the opportunity to infuse other ingredients creating novel products (beef jerky, craisins, flavoured dry apple pieces).
4. Relatively safe and simple to perform with limited need for chemical additives.

Disadvantages of drying for preservation

1. Time commitment – drying time is directly affected by the desired final a_w and dryer temperature/air velocity.
2. Taste and appearance changes – the finished product may have a bland taste, and appearance is often shrivelled. Browning reactions may occur.
3. Rehydration is slow and the product's shape does not return to that of the original.
4. Lowers values of some nutrients but makes foods more calorie-dense.
5. Capital cost – investment in a dryer may be necessary unless a suitable co-packer is available.

TYPES OF INDUSTRIAL DRYERS:

Forced Air or Convection Drying:

This can be batch or continuous. Batch dryers such as a kiln dryer or a simple tray dryer consist of warming up intake air and blowing over the product either on the floor of the drying room for a kiln dryer or through the chamber of the simple tray dryer. This type of dryer is typically used for particulate types of foods such as apple rings or other fruits and vegetable pieces. Convection is also used for continuous systems such as the belt or tunnel dryers. The continuous nature is a benefit in the processing plant but requires a uniform particle size.

Drum or Spray Drying:

Other atmospheric dryers that are used for liquid or slurry products include drum or spray dryers. Conductive drums are heated by steam, and the product is applied to the surface of a single drum or the point of contact of a double drum. A film is created, and moisture is removed in a continuous process. Spray drying is accomplished by atomizing a liquid or paste into a chamber where it comes into contact with hot air and is rapidly dried.

Vacuum or Freeze-Drying:

More sophisticated types of drying utilize modifying pressures to facilitate the removal of water. Vacuum drying allows water to be evaporated at lower temperatures, resulting in improved quality and nutritional value of the finished product. Freeze-drying or lyophilization of food is performed by freezing the food product, and then applying a high-pressure vacuum to sublime the water in the vapour form. The vapour collects on a condenser, turns back to ice and is removed. This process retains the physical structure of the food product and provides an excellent matrix for rehydration. Freeze drying is used for high-value products such as fruits in breakfast cereals, backpacking meals and instant coffee.

PROBLEMS ASSOCIATED WITH DRYING

Case hardening is the condition where moisture is removed so rapidly from the surface that the hot air creates a hard, dry layer that prevents the diffusion of the moisture to the surface of the food. Excessive dryer temperature is usually the cause; contrary to what one might think, reducing the dryer temperature (to 60°C for fruits and vegetables) will decrease the drying time by removing the water at a more stable rate.

Uneven drying is a common problem in tray batch systems where the center of the tray is too moist, and the edges are too dry. To rectify this problem, an additional equilibration step is required where the drier areas absorb some of the moisture from the wetter areas. The humidity of the equilibration chamber must be strictly controlled.

Browning reactions are a common problem in dried foods. Since the dryer temperature is not sufficient to destroy enzymes, browning by polyphenol oxidase in fruits is often exhibited. Pre-drying blanching can prevent the browning reaction, but it is not always possible. Browning due to caramelization in high sugar products at high temperatures can also occur.

Spoilage by yeasts and moulds can be a problem if water activity is not strictly controlled. Osmophilic yeasts and moulds can create spoilage even in properly dried foods, so good manufacturing practices and the use of clean raw materials are essential to prevent contamination with these organisms.

THE FUTURE OF DRYING

Dried foods will have a place in our diet for many years to come. What started thousands of years ago with solar drying has evolved over many years; now many of the new technologies twin solar with other energy sources to reduce the environmental footprint of the process. In Nova Scotia, microwave vacuum drying is being used commercially to produce high-quality products. Even small to medium size companies can be leaders in embracing new technologies. Perennia has the capabilities to help you with development and problem solving of your drying operations. We can assist with water activity measurement, pilot-scale drying applications and technical problem-solving. To get in touch with our innovation team, please contact **innovation@perennia.ca**.

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