Changes undergone by the food components during Evaporation, Drying

1 INTRODUCTION

The primary objectives of evaporation, as a unit operation in food processing, are to reduce the volume of the product by some significant amount with minimum loss of nutrient components, and to preconcentrate liquid foods such as fruit juice, milk, and coffee before the product enters a dehydration process, thus saving energy in subsequent operations and reducing handling (transport, storage, and distribution) costs. Evaporation increases the solids content of a food and hence preserves it by a reduction in water activity; however, the flavour and colour of a food may be changed during the process. The technical simplicity of evaporation gives it an obvious advantage compared to other methods such as reverse osmosis and freeze concentration.

Drying differs from evaporating in that the former takes the food to nearly total dryness or the equivalence of 97 or 98% solids. The oldest method of drying food is to put the food under a hot sun. This practice probably started thousands of years ago. Although sun drying is still practiced, especially in many third world countries, modern food drying has been modified to a nearly exact science. Drying has multiple objectives:

- To preserve the food from spoilage
- To reduce the weight and bulk of the food
- To make the food enjoy an availability and consumption pleasure similar to that of canned goods
- To develop “new” or “novelty” items such as snacks.

Some well-known products prepared from drying include dried milk powder, instant coffee, fish and shellfish, jerky, dried fruits and dried potato flakes.

Dehydration is the removal of water from a product. The purpose of dehydrating (drying) is usually to improve the shelf life of the product, and thus dehydration is a unit operation of great importance to the food industry. During dehydration moisture content is reduced, the water activity of the product is also reduced. Once the water activity has dropped to about 0.6, the product is generally considered to be shelf stable. Products may be dried for other reasons; for example, to control texture properties such as crispness (biscuits), to standardize composition, and to reduce weight for transport. The most important reason, however, is control of water activity. Drying is expensive, since the energy required to remove water is high. In this chapter we will discuss the effects of evaporation and drying on quality of foods.

2 EFFECT OF EVAPORATION ON FOOD QUALITY

Nutritional changes take place during evaporation processing, the extent varying with the type of food, the process, the plant in use, and the degree of control exercised. Many losses are inevitable, particularly if the process involves heating.

- **VITAMINS:** Part of the water-soluble nutrients such as the B vitamins, together with lesser and less-important amounts of mineral salts, protein, and even carbohydrate will be precipitated out. Vitamin C is oxidized in air and accelerated by heat, whereas vitamins A and D and niacin are unaffected.

- **AROMA:** Aroma compounds that are more volatile than water will be lost during evaporation. With some products such as fruit juices, the retention of taste and aroma is important, yet in other foods such as cocoa and milk, the loss of unpleasant volatiles improves the product quality.
- **COLOUR:** The colour of foods darkens, partly due to an increase in the solids content and partly because the reduction in water activity promotes chemical changes like Maillard browning.

As these changes are time and temperature dependent, short residence times and low boiling points produce concentrates with higher qualities. For instance, the Centri-therm mechanical thin-film evaporator produces a concentrate that, when diluted, has sensory and nutritional qualities that are virtually unchanged from those of the feed material.

3 EFFECT OF DRYING ON FOOD QUALITY

Dehydration changes food products in several ways, affecting the organoleptic qualities of the product. Dehydration normally requires high temperatures, which can cause chemical reactions such as nonenzymatic browning, caramelization, and denaturation of proteins in the product. Drying also affects the physical parameters of the product, as removal of water causes shrinkage. Due to these changes, rehydration after drying may not restore the original product. Table 27.1 shows the major changes taken place in food during drying.

Table 1: Changes Taken Place in Food during Drying

Basis of	Example and consequence

reaction	
Physical	**Moisture movement:** causing drying and toughening of texture, hydration and softening of texture, aggregation
Chemical	**Oxidation:** causing oxidative rancidity, loss of colour Maillard reactions, causing discolouration, change in texture
Enzymatic	**Polyphenoloxidase:** causing enzymic browning **Lipoxygenase:** causing oxidative rancidity **Lipase:** causing lipolytic rancidity **Protease:** causing gelation and flavour and texture changes
Microbial	**Growth of spoilage organisms:** causing quality deterioration **Growth of toxigenic organisms:** causing food poisoning **Presence of infectious organisms:** causing food poisoning

Many biochemical reactions can be induced by temperature increase in foods during drying: Maillard reactions, vitamin degradation, fat oxidation, denaturation of thermally unstable proteins (resulting in variation of solubility or of the

germinating power of grains), enzyme reactions (which can either be promoted or inhibited), and so on. Some of these biochemical reactions generate components suitable, for example, for their sensory properties (flavor development); others may be more or less undesirable for nutritional or potential toxicity reasons (vitamin losses, changes in color, taste or aroma, formation of toxic compounds). All the reactions are linked to the factors like product composition, temperature and water content.

3.1 PHYSICAL QUALITY

Physical properties such as colour, texture, density, porosity, and rehydration capacity are affected by the drying method. A tough and woody texture, slow and incomplete rehydration, and loss of the typical fresh food juiciness are the most common defects encountered during drying. The physicochemical basis for these changes is complex, and its understanding requires tedious lab measurements.

3.1.1 COLOUR

Colour is a major quality parameter in dehydrated food. During drying, colour may change because of chemical or biochemical reactions. Enzymatic oxidation, Maillard reactions, caramelization, and ascorbic acid browning are some of the chemical reactions that can occur during drying and storage. Discolouration and browning during air drying may be the result of various chemical reactions including pigment destruction.

3.1.2 SHRINKAGE, POROSITY, AND BULK DENSITY

One of the most important physical changes that foodstuffs undergo during drying is the reduction of their volume, often called shrinkage. Shrinkage is caused by structural collapse

attributable to the loss of water. Changes in shape and size, loss of rehydration capacity, surface cracking, and hardening of food materials are among the most important physical phenomena associated with shrinkage.

Porosity and bulk density are important physical properties in dried foods. These two properties play an important role in rehydration of dried materials and their handling and packaging aspects. The extent of shrinkage influences the resulting changes in porosity during drying. The bulk shrinkage and the porosity changes were related to moisture content of dried foods. Porosity in fruits and vegetables increases during drying, depending on the initial moisture content, composition, and size, as well as the type of drying method employed.

3.1.3 CASE HARDENING

Case hardening occurs when rapid drying causes compounds such as sugars to form a hard, fairly impermeable case around the food piece. This phenomenon can cause the rate of dehydration to decrease. Case hardening can occur in high-sugar products such as tropical fruit and many temperate fruit products. Dehydration procedures are designed to minimize the development of case hardening as much as possible.

3.2 MICROBIOLOGICAL AND CHEMICAL QUALITY

Dehydrated foods are preserved because their water activity is at a level where no microbiological activity can occur and where deteriorative chemical and biochemical reaction rates are reduced to a minimum. Reducing water activity below 0.7 prevents microbiological spoilage. Most oxidation reactions and enzyme reactions will be inhibited as water activity decreases. However, auto oxidation of lipids could take place

at very low water activity values 0.2. The maximal rate of nonenzymatic browning reactions (Maillard reaction) is achieved at intermediate water activity values (0.4 to 0.65). These reactions result in the loss of nutritive value, formation of brown pigments, as well as the formation of off-flavours, especially when the products are stored at high temperatures. Dried products are considered to be more stable at their monolayer moisture content.

3.3 NUTRITIONAL QUALITY

Nutritional quality of food can be affected by handling, processing, and packaging. Aside from physical and chemical changes, drying can also cause loss of nutritional value. The major losses of vitamins and other substances take place because of solubility in water, enzymatic oxidation, oxygen and heat sensitivity, and metal ion catalysis during processing. In addition, sugar–amine interactions (Maillard reaction) can occur during drying and storage, causing loss of nutrients. All these losses in food can be reduced by: pretreatments, proper selection of drying methods, new and innovative drying methods, and optimization of drying conditions.

3.3.1 CHANGES IN PROTEIN

The biological value of protein is dependent on the method of drying. Prolonged exposures to high temperatures can render the protein less useful in the dietary. Low temperature treatments of protein may increase the digestibility of protein over native material. Milk proteins are partially denatured during drum drying, and these results in a reduction in solubility of the milk powder, aggregation and loss of clotting ability. At high storage temperatures and at moisture contents above approximately 5%, the biological value of milk protein is decreased by Maillard reactions between lysine and lactose.

Lysine is heat sensitive and losses in whole milk range from 3-10% in spray drying and 5-40% in drum drying.

3.3.2 CHANGES IN LIPID

Rancidity is an important problem in dried foods. The oxidation of fat is greater at higher temperature than at low temperature of dehydration. Protection of fat with antioxidant is an effective control.

Lipid oxidation is responsible for rancidity, development of off flavours, and the loss of fat soluble vitamins and pigments in many foods, especially in dehydrated foods. Factors that affect oxidation rate include moisture content, type of substrate (fatty acid), extent of reaction, oxygen content, temperature, presence of metals, presence of natural antioxidants, enzyme activity, ultraviolet light, protein content, free amino acid content, other chemical reactions. Moisture plays an important part in the rate of oxidation. The elimination of oxygen from foods can reduce oxidation, but the oxygen concentration must be very low to have an effect. The effect of oxygen on lipid oxidation is also closely related to the product porosity. Freeze -dried foods are more susceptible to oxygen because of their high porosity. Air-dried foods tend to have less surface area due to shrinkage and thus are not as affected by oxygen. Minimizing the oxygen level during processing and storage, and addition of antioxidants as well as sequestering agents, has been recommended in the literature to prevent lipid oxidation.

3.3.3 CHANGES IN CARBOHYDRATE

Fruits are generally rich sources of carbohydrates, poor sources of proteins and fats. The principal deterioration in fruits is in carbohydrates. Discoloration may be due to

enzymatic browning, or to caramelization types of reactions. In the latter instances, the reaction of organic acids and reducing sugars causes discolorations noticed as browning. The addition of sulphur dioxide to tissues is a means of controlling browning. Carbohydrate deterioration is most important in fruit and vegetable tissues being dried. Slow sun drying permits extensive deterioration unless the tissues are protected with sulphates, or suitable agents.

3.3.4 CHANGES IN VITAMINS

Vitamins have different solubility in water, and, as drying proceeds, some (e.g., riboflavin) become supersaturated and precipitate from solution. Losses are therefore small. Others, (e.g., ascorbic acid) are soluble until the moisture content of the food falls to very low levels and react with solutes at higher rates as drying proceeds. Vitamin C is also sensitive to heat and oxidation. Short drying times, low temperatures, and low moisture and oxygen levels during storage are necessary to avoid large losses. Thiamin is also heat sensitive, but other water-soluble vitamins are more stable to heat and oxidation, and losses during drying rarely exceed 5—10% (excluding blanching losses).

Oil-soluble nutrients (e.g., essential fatty acids and vitamins A, D, E, and K) are mostly contained within the dry matter of the food and they are therefore concentrated during drying. However, water is a solvent for heavy-metal catalysts that promote oxidation of unsaturated nutrients. As water is removed, the catalysts become more reactive, and the rate of oxidation accelerates. Fat-soluble vitamins are lost by interaction with the peroxides produced by fat oxidation. Losses during storage are reduced by low oxygen

concentrations and storage temperatures and by exclusion of light.

4 CONCLUSION

Evaporation and drying plays an important role in food preservation despite having some desirable and undesirable changes taken place during both the processes. But these changes can be avoided by employing appropriate process handling of foods during evaporation and drying. More profound knowledge of the changes in the properties of foods that occur with processing is needed for the design of better drying methods that preserve desirable characteristics and minimize or eliminate undesirable ones.