5) Solubility: Many factors affect solubility.

- processing conditions
- storage
- composition
- pH
- density
- particle size.

* Considering drying process =>

Increasing the drying T (i.e., product T) causes by protein denaturation which decreases solubility.

* The larger particles are less soluble. It is due to the longer drying time required to dry large particles.
* Denatured protein => solubility ↓.

∴ - The heat treatment } must be considered when determining solubility.
- The particle size

6) Texture: Factors affecting texture are

a) Moisture content

b) Composition of food

c) Variety

d) pH of food

e) Product history (maturity/unmaturity)

- Changes to the texture of solid foods are an important cause of quality deterioration, The loss of texture in these products is caused by gelatinization of starch, crystallization of cellulose, and localized variations in the moisture content during drying, which set up internal stresses.
- These rupture, crack, compress and permanently distort the relatively rigid cells, to give the food a shrunken shrivelled appearance. **On rehydration** the product **absorbs water more slowly and does not regain the firm texture of the fresh material.** There are substantial variations in the degree of shrinkage and rehydration with different foods.
- In general, rapid drying and high temperatures cause greater changes to the texture of foods than do moderate rates of drying and lower temperatures. As water is removed during drying, solutes move from the interior of the food to the surface. The mechanism and rate of movement are specific for each solute and depend on the type of food and the drying conditions used. The "case hardening" results in the outer surface being hard and/or rubbery.
- Evaporation of water causes concentration of solutes at the surface. High air temperatures (particularly with fruits, fish and meats), cause complex chemical and physical changes to solutes at the surface, and the formation of a hard impermeable skin. This is termed *case hardening* and it reduces the rate of drying to produce a food with a dry surface and a moist interior. It is minimised by controlling the drying conditions to prevent excessively high moisture gradients between the interior and the surface of the food.

7) Flavor And Aroma

- Volatile organic compounds responsible for aroma and flavor have boiling points at temperatures lower than water. So, they are lost during dehydration.
- However, if a thin dry layer is formed over the product during initial stage of drying, these components can be retained. This is because the thin layer of dried food material is selectively permeable to water only.
- Heat not only vaporises water during drying but also causes loss of volatile components from the food and as a result most dried foods have less flavour than the original material. The extent of volatile loss depends on the temperature and moisture content of the food and on the vapour pressure of the volatiles and their solubility in water vapour.

- Volatiles which have a high relative volatility and diffusivity are lost at an early stage in drying. Foods that have a high economic value due to their characteristic flavours (for example herbs and spices) are dried at low temperatures.
- Flavour changes, due to oxidative or hydrolytic enzymes are prevented in fruits by the use of sulphur dioxide, ascorbic acid or citric acid, by pasteurisation of milk or fruit juices and by blanching of vegetables. Other methods which are used to retain flavours in dried foods include:

➢ recovery of volatiles and their return to the product during drying

➢ mixing recovered volatiles with flavour fixing compounds, which are then granulated and added back to the dried product (for example dried meat powders)

➢ addition of enzymes, or activation of naturally occurring enzymes, to produce flavours from flavour precursors in the food (for example onion and garlic are dried under conditions that protect the enzymes that release characteristic flavours).

➢ **Freeze drying causes more in volatiles. WHY ?**

8) Vitamin Loss:

a) Ascorbic acid (Vit. C).

- It is sensitive to high T's at high MC.
- The maximum rate of ascorbic acid degradation occurs at specific (critical) moisture contents.
- losses of ascorbic acid is higher when dehydrating fruits under sunlights.
- sulfuring reduces the ascorbic acid losses.

⊛ To optimize ascorbic acid retention, the product should be dried at a low initial T when the MC is high since acid is the most heat sensitive at high MC's. The T can,

then, be increased as drying progresses and ascorbic acid is more stable, due to a decrease in moisture.

b) Thiamine: No significant change during drying.

c) Riboflavin: " " " " .

- Large differences in reported data on the nutritional value of dried foods are due to wide variations in the preparation procedures, the drying temperature and time, and the storage conditions. In fruits and vegetables, losses during preparation usually exceed those caused by the drying operation.
- In a study it has been showed that losses of vitamin C during preparation of apple flakes were 8% during slicing, 62% from blanching, 10% from pureeing and 5% from drum drying.
- Vitamins have different solubilities in water and as drying proceeds, some (for example riboflavin) become supersaturated and precipitate from solution, so losses are small. Others, for example ascorbic acid, are soluble until the moisture content of the food falls to very low levels and these react with solutes at higher rates as drying proceeds. Vitamin C is also sensitive to heat and oxidation and short drying times, low temperatures, low moisture and oxygen levels during storage are therefore necessary to avoid large losses.

Vitamin losses in selected dried foods

	Loss (%)						
Food	Vitamin A	Thiamin	Vitamin B_2	Niacin	Vitamin C	Folic acid	Biotin
Fruits[a]	6	55	0	10	56		
Fig (sun-dried)	–	48	42	37	–	–	–
Whole milk (spray dried)	–	–	–	–	15	10	10
Whole milk (drum-dried)	–	–	–	–	30	10	10
Pork		50–70					
Vegetables[b]	5	< 10	< 10				

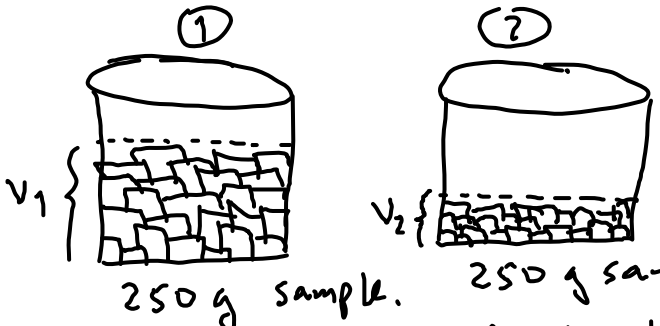
9) Protein losses: It is not a major nutritional problem during drying.

10) Microbiological Quality: Reducing a_w of a product below 0.70 inhibits growth but doesn't result in a steril product. The heat of the drying process does reduce their numbers, but the survival of food spoilage organisms may give rise to problems in the reconstituted food.

⊗ Recommendation:
The highest possible drying T's should be used to maximize thermal death rate.

11) Bulk density: The bulk density is strongly affected by the drying conditions.

- a highly shrinking material, when dried slowly => it shrinks down fully onto a solid core. So, its bulk density increases ($\rho = \frac{m\downarrow}{V\downarrow\downarrow}$) ↗.
- drying it rapidly => the faces become much drier than the center and the interior finally dries and shrinks. So, nearly the the initial/original dimensions of the piece are set. => ρ_{bulk} is low ($\rho = \frac{m\downarrow}{V\rightarrow}$) ↓.



250 g sample. 250 g sample.

Rapidly dried potato dice. Slowly dried potato dice.

$\rho_{bulk_1} < \rho_{bulk_2}$

Drying of Fruits and Vegetables

1) Pretreatments of raw product:

- To obtain a dried product of excellent, the raw produce must be harvested and handled properly.
- Sanitation, storage stability and retention of flavor and nutritive qualities require that most foods to be dried undergo some pretreatments such as washing, trimming, slicing, blanching, dipping, sulfuring etc.

Fruits & Vegetables
↓
Washing
↓
Sorting
↓
Peeling, slicing, coring, pitting
↓
Blanching
↓
Sulfuring
↓
Drying
↓
Packaging

Flow sheet for dehydration of fruits and vegetables.

2) Washing: Fruits and vegetables are washed to remove surface particles by use of heavy sprays and rotary washers.

3) Sorting: Sorting plays an important role in controlling the effectiveness of many food processes.

It is advantageous in processes in which uniformity of heat transfer is desirable (e.g., dehydration and freezing).

Kinds of sorting

- weight sorting
- size sorting (for drying)
- shape sorting (hulled and unhulled wheat)
- color " (photocells).

4) Peeling and slicing:

a) Peeling: Root vegetables, apples and sometimes peaches are peeled prior to drying. This is accomplished by different methods:

- abrasion
- lye solution (for peaches)
- hot brine peelers
- high pressure steam for root crops
- mechanical knife peelers for apples
- ammonia vapor
- enzymes.

b) Slicing, Cutting, Dicing etc.:

⊛ Root crops are cut into cubes, strips or slices for drying.

- Cabbage is shredded
- potatoes may be diced and dried into powder form
- prunes, grapes, berries and cherries are dried whole.
- apricots, nectarines, peaches are halved and pitted
- pears are halved
- apples are peeled, cored and sliced

⊛ Slicing is usually accomplished with sharp rotating knives.

- The sharper the knife blade the less cellular damage that is caused and the higher quality end produce that is obtained.

5) Dipping:

a) Alkaline dip: Dipping involves immersion of the product in an alkaline solution prior to drying. It is used primarily for fruits that are dried whole, especially prunes, grapes and apricots.

- Dipping facilitates drying by forming fine cracks in the skin.

- Hot dip solutions

A sodium carbonate or lye solution (0.5% or less) is used at a T ranging from 93 to 100°C.

- Cold dip solutions

- (Na, K) carbonate or lye with olive oil or commercial dipping solutions are used.
- The main active ingredients of commercial solutions are oleate esters (known as oil-surfactant emulsions, e.g., 2% ethyl oleate).
- These emulsions accelerate moisture loss by causing the waxy layers on the fruit skin to dissociate, thus facilitating water diffusion.
- Fruits treated with cold dip are light in color.

b) Acid dip:

- It is used before sulfuring to provide a product of better color stability.
- A 1% ascorbic acid and 0.25% malic acid dip is used to retard enzymatic browning.
- These products have to be held at low T's to keep them from darkening during storage (risk of ascorbic acid oxidation)

6) Sulfuring or Sulfiting:

Sulfuring is an old method of pretreating fruits and widely used in the food industry.

Aim of sulfuring: Sulfuring (absorption or penetration of SO_2 by fruits)

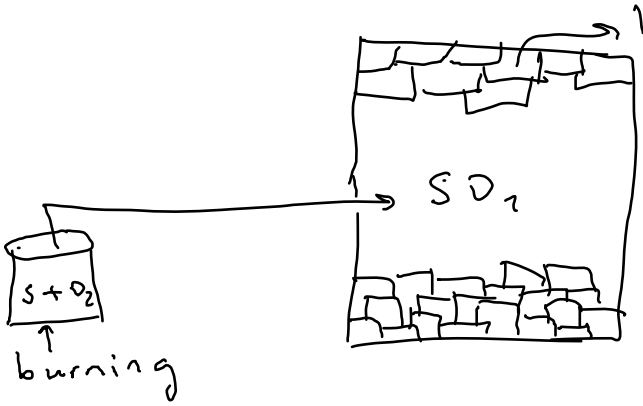
- maintains attractive color. How?
  SO_2 prevents both types of browning by inactivating irreversibly enzyme systems (enzymatic browning stops) and blocking the reducing groups of sugars (non enzymatic browning stops)
- prevent spoilage (by ↙ pH)
- sulfur fumes preserve or reduce certain nutritive attributes such as vitamins A and C.

Methods of Sulfuring

1) Burning elemental sulfur.

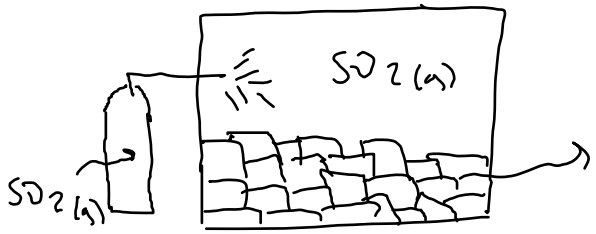
$$S_{(s)} + O_{2(g)} \longrightarrow SO_{2(g)}$$

Primitive sulfuring house (traditional)



- it takes 24 hr
- then, the room is ventilated to remove excess SO_2 in the room

2) Using $SO_{2(g)}$

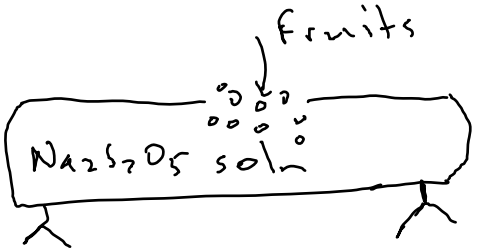


→ trays or boxes of fruits in single layer.

- gas is directly injected into the chamber containing fruits
- this method is an expensive (costly) method.

3) Sulfite dip process

Fresh fruits or vegetables are dipped in a sodiummetabisulphite ($Na_2S_2O_5$) solution of 5-8% in water for ~30 min or less.



500 lt $Na_2S_2O_5$ soln (8%) can be used for ~500 kg of apricots.

- After 30 min sulfured apricots are fished out by using a perforated plastic basket.
- Advantage of this method is simultaneous washing of the fruit in the soln.
- The tank must be re-filled to 500lt with a new soln of 8% for further use.

Sulfuring Fruits

- Cut fruits and grapes (for producing golden-bleached raisins) are exposed to SO_2 gas before drying.
- Apples may be dipped in a sulfurous acid soln prepared by dissolving sodium bisulfite or

sulfur dioxide in water.

⊛ Some optimum levels in ppm are;

	ppm SO_2
Apricots	1500 - 2000
Peaches	2500
Pears	2000
Apples	1500
Golden-bleached raisins	1000

} Max amount of SO_2 in dried fruits varies with the demands of importing country.

⊛ Sulfuring Vegetables

- SO_2 gas treatment is impractical for vegetables.
- Sulfite solns are preferred as the most practical method.

⊛ The highest levels of SO_2 for vegetables;

	ppm SO_2
Cabbage	750 - 1500
Potatoes	200 - 500
Carrots	200 - 500

⊛ Sulfites and Health Relationships

- Sulfites present in the foods have been found to cause asthmatic reactions in a small portion of the asthmatic population (2%).
  - lung or breath problems
  - headache "
  - stomach "
  - irregularity in blood pressure (↓ tension).

7) Blanching

- Blanching consists of partial cooking, usually in steam or hot water prior to drying
- Blanching in hot water (~ 95°C, 3 min) causes leaching losses. Thus, steam blanching is favored commercially by continuous blanchers which involves 2 to 10 min exposure to live steam.

* Blanching can produce one or more of the following affects:
  1) Causes softer texture
  2) Reduces drying time
  3) Retards the development of objectionable odors and flavors during the storage by enzyme inactivation.
  4) Retains carotene and ascorbic acid during storage (due to enzyme inactivation)
  5) Removes pungency, particularly in onions.
  6) Causes loss of soluble solids if blanched by hot water.
  7) Removes intercellular air from the tissues.
* The expulsion of air from the tissues has two effects:

1- In vegetables, if the tissues are collapsed, the cell beneath the surface are protected effectively from the adverse effects of

oxygen in the air. This is particularly noticeable in products high in starch such as potatoes (this is, possibly, one reason why potatoes are considered a good vegetable to dry).

2- In fruits such as apricots, peaches and pears, it imparts the desired translucent appearance to the dehydrated product.

* How the completeness (effectiveness) of blanching is tested:

- the degree of enzyme inactivation indicates the effectiveness of the blanching treatment.

In fruits, the activity of polyphenol oxidase is monitored.

In cabbage, the activity of catalase is monitored.

In the other vegetables, that of peroxidase is ".