Introduction to Food Science and Engineering

Food Constituents: Water

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CONSTITUENTS OF FOOD

Food Nutrients: Foods when eaten and absorbed by the body maintain life and growth, i.e. supply energy, build, repair and protect tissues of the body. The chemical components that perform these functions are called food nutrients.

Types of food nutrients: Six types of nutrients have been identified in foods.

- 1. Carbohydrates,
- 2. lipids (fats & oils)
- 3. Proteins,
- 4. Vitamins,
- 5. Minerals and
- 6. water

Classification of nutrients: Based on biological functions, food nutrients can be classified into **3 groups**:

1. The nutrient required for energy, e.g. **carbohydrates, lipids and proteins.**
2. The nutrients required for growth of tissues and their maintenance,
   e.g. **proteins, minerals and water.**
3. The nutrients required for control and protection of body process,
   e.g. **vitamins, minerals, proteins and water.**

Table. Amounts of nutrients in Different foods (g/100g)

Food	Water	Carbohydrates	Fats	Proteins	Minerals and Vitamins
Milk	88	4.8	3.8	3.3	0.1
Cheese	37	0	34	25	1.0
Egg	74	0.9	11	12	0.1
Beef	59	0	18	16	1.0
Bread	38	52	2	7	1.0
Apple	84	12	0	0.3	0.1
Cabbage	90	4	0	3	0.1
Jam	30	69	0	0.6	0.2
Chocolate	0	53	38	8	0.8

Water

(H_2O)

Water: Role and Function

- Water is essential to sustain life in every living organism.
- Living species contain water as much as 60 to 95% of their body weights.
- In case of human beings, about two-thirds of the body is water. Only a few parts like teeth, bones and hair contain very little water.

Function: Water does not undergo any chemical change in the body. It functions mainly-

- as a carrier of nutrients and waste products,
- as a solvent to dissolve solutes,
- as a liquid medium for biochemical reactions and to form colloidal suspension,
- as a stabilizer of biopolymer conformation and
- as a determinant of protein activity,

Water: Dietary Requirements

Dietary requirement of water:

- Water is continuously lost from the body in the form of sweat, urine and faeces. Hence replacement of water is necessary continuously.
- The main sources of water are food and drink. Some nutrients on oxidation in the body produce water, e.g. 1 kg of glucose gives about 0.5 liter of water.

Table: Water intake and loss in human body (adult).

Source	Intake (l/d)	Source	Loss (l/d)
Food	1.12	Urine	1.30
Drink	1.18	Lungs	0.30
Oxidation of nutrients	0.28	Skin	0.92
-	-	Faeces	0.06
Total	2.58		2.58

Water: Dietary Source

Dietary Sources:

- Water is the main constituent of most foods.
- For biological process within the food and for preservation there should be optimum amount of water.

Table. Water content of various foods.

Animal foods	Water (%)	Plant foods	Water(%)
Beef	50-70	Apples, peaches, oranges and grapefruits	85-90
Chicken	70-75	Strawberries and tomatoes	90-95
Fish	65-80	Carrots and potatoes	80-90
Milk	85-90	Peas (green), bananas	75-80
Milk powder	4-5	Cabbage, cauliflower	90-95
Honey	20-25	White bread	35-40
Butter	16-20		

Water: Water Activity

Water Activity:

- The free or ready availability of water in food is important for the growth and activity of microorganism. The free availability of water is quantitatively expressed by the use of the concept of activity (a_w).

Water activity: The water activity of a solution (or even a food stuff) is defined as the ratio of the vapor pressure (P) of the solution or the water in the food to the vapor pressure of pure water (P_O) at the same temperature

$$a_w = \frac{P}{P_o}$$

- The activity of pure water is 1.0 and that of a 1.0 M solution of the ideal solute it would be 0.9823.

- Water activity of a food would be in equilibrium with relative humidity (RH) of the atmosphere surrounding the food.
- Water activity is directly related to RH as given below.

$$a_W = \frac{RH}{100}$$

Water: Water Activity

Relationship Between a_w and RH

1. A relative humidity (RH) about a food corresponding to a water activity (a_w) lower than that of food would tend to dry the surface of the food.
2. Conversely, if the relative humidity is higher than the water activity, the latter would be increased on the surface of the food due to condensation of moisture.
3. When the relative humidity and the water activity is the same, there would be no movement of water and the state is called equilibrium state.
4. The relationship between water activity (and relative humidity at equilibrium) and the moisture content of a food can be precisely described by its moisture sorption isotherm as shown in Figure 1(a).

Hysteresis of moisture sorption isotherm: Water adsorption and desorption isotherms do not coincide. They exhibit hysteresis as shown in Fig 1(b). At any given moisture content, the water activity during desorption is less than that during adsorption and at any given water activity the water content during desorption is greater than that during adsorption

Water Adsorption Isotherm

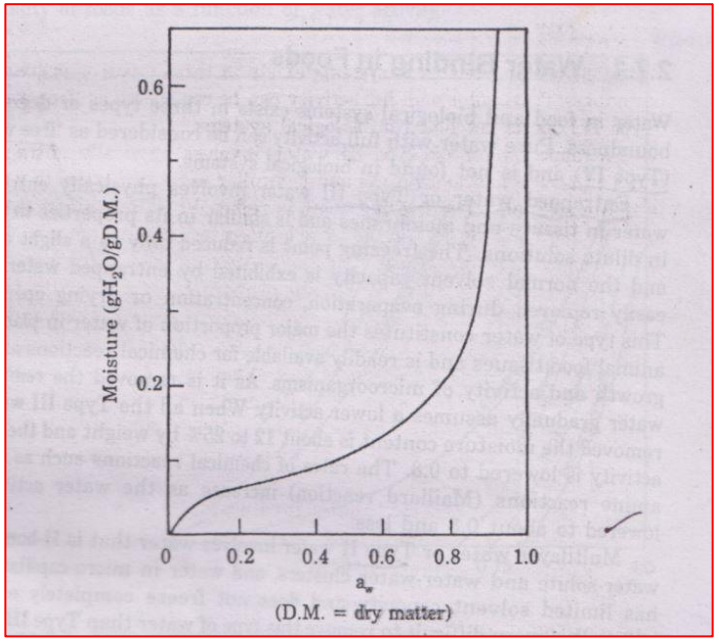

Fig 1(a). Water sorption isotherm

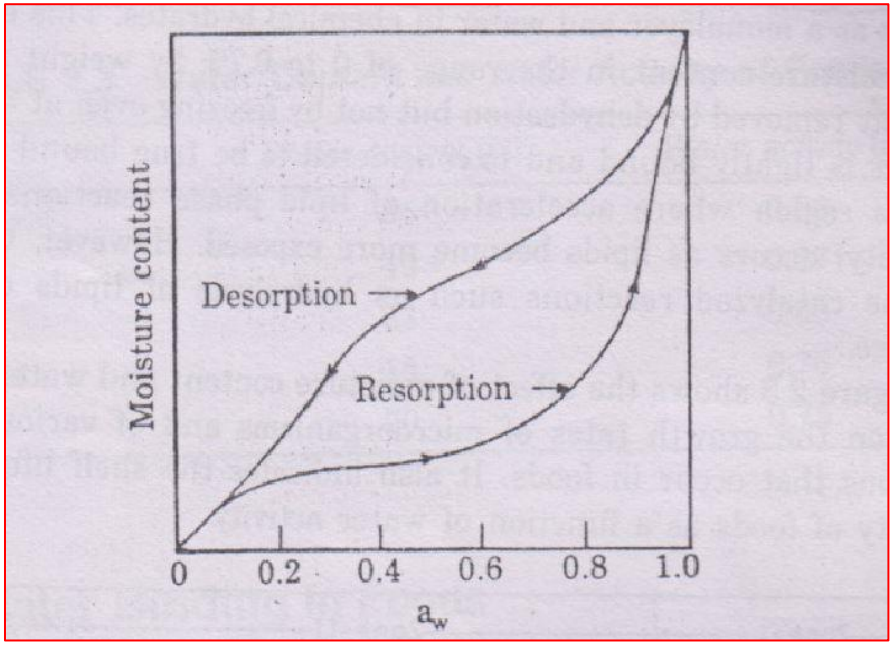

Fig 1(b). Hysteresis of moisture sorption isotherm

Water: Water Activity

Importance of Water activity:

- The practical **importance** of controlling water activity in food is primarily related to the minimization of microbial deterioration of foods.
- By lowering the water activity by dehydration, salting or sugaring, microbial deterioration of the food can be reduced and even eliminated.
- Water activity also influences the rate of chemical and enzymatic reactions in food.
- Most fresh food have water activity of 0.99. The water content and the water activity of a few typical foods are listed in table below.

Food	Water content (%)	Water activity (a_w)
Fresh meat	65	0.98
Cheese	40	0.97
Jam	33	0.88
Dried fruits	18	0.76
Honey	20	0.75

Water: Water Bonding in Foods

Type of water in food:

- **Type IV water:** It is the free water. That is, pure water with full activity. It is not found in biological systems.
- **Type III water.** It is the entrapped water in tissue and membranes and is similar in its properties to water in dilute solutions. The freezing point is reduced only to a slight extent. It is easily removed during evaporation, concentration or drying operation. It is the major portion of water in plant and animal food tissues and is readily available for chemical reactions and the growth and activity of microorganism. When all Type III moisture is removed the moisture content is 12 to 25% and a_w is lowered to about 0.8.
- **Type II water.** It is called multilayer water and it involves water that is H-bonded in water-solute and water-water cluster, and water in micro-capillaries. It has limited solvent capacity and does not freeze completely even at - 40^0C. It is more difficult to remove this type of water then type II water. Partial removal of Type II water eliminates the last possibility of microbial growth and greatly reduces most kind of chemical reaction. Complete removal of it leaves 3-7% moisture level in food (a_w is about 0.25)

Water: Water Bonding in Foods

- **Type I water:** Monolayer or type I water involves water adsorbed to solute as a monolayer and water in chemical hydrates. Moisture content ranges of 0-0.7% by weight and can be partially removed by dehydration but not by freezing even art -40^{0}C.Type I water is tightly bound and is considered to be true bound water.

Water Activity and Activity of Microorganisms

- Water activity plays an important role in the growth of microorganisms that causes food spoilage. The minimum water activity requirements for the growth of microorganisms are listed in Table below:

Table. Water activity requirements of microorganism

Microorganism	Minimum a_w required for growth
General:	:
Normal bacteria	0.91
Normal yeasts	0.88
Normal moulds	0.80
Halophilic bacteria (salt loving)	0.75
Xerophilic mould (prefer dry condition)	0.65
Osmophilic yeast (prefer high osmotic pressure)	0.60

Water Activity and Activity of Microorganisms

Factors affecting Water Requirement of Microorganism:

- Each microorganism has a maximal, optimal and minimal water requirement for its growth. This range depends on variety of factors such as:

1. Type of solute employed to reduce the water activity
2. Nutritive value of culture medium
3. Temperature
4. Oxygen supply
5. P^H value
6. Inhibitors

Controlling Water Activity in Food

Water can be made unavailable for microorganisms in food by using the following procedures:

1. Addition of solutes: Addition of ionic solutes ties-up water in solution. Thus dries the food tying-up water molecules. Water inside the microbial cell tends to leave by osmosis causing death of microorganisms.

2. Formation of gels: Formation of hydrophilic gels (e.g. 3-4% sugar) makes water unavailable in the medium, preventing bacterial growth.

3. Lowering of temperature: Lowering the temperature tends to crystallize water into ice which is not useful for the growth of the microorganisms. and

4. Dehydration: Dehydration of foods effected by drying decreases the moisture content and thereby lowers water activity.

Determination of Water Activity

There are 4 methods:

1. The Gravimetric method: For determination of Moisture content
2. The Volumetric method
3. The Relative humidity method
4. Using Instrument

The End