FDE 303
FOOD CHEMISTRY
WEEK-2

Water, Water activity, Water sorption isoterms

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Water

- ✓ Water (moisture) is the predominant constituent in many foods
  - ✓ supports chemical reactions
  - ✓ it is a direct reactant in hydrolytic processes

- ✓ What happens when removal of water from food or binding it by increasing the concentration of common salt or sugar
  - ✓ retards many reactions and
  - ✓ inhibits the growth of microorganisms
  - ✓ thus, improving the shelf lives of a number of foods

- ✓ Contribution of water to the texture of food: through physical interaction with proteins, polysaccharides, lipids and salts

Moisture content of some foods

Food / Food ingredient	Moisture content (weight-%)
Meat	65–75
Milk	87
Fruits, vegetables	70–90
Bread	35
Honey	20
Butter, margarine	16–18
Cereal flour	12–14
Coffee beans, roasted	5
Milk powder	4

Belitz et al. (2009)

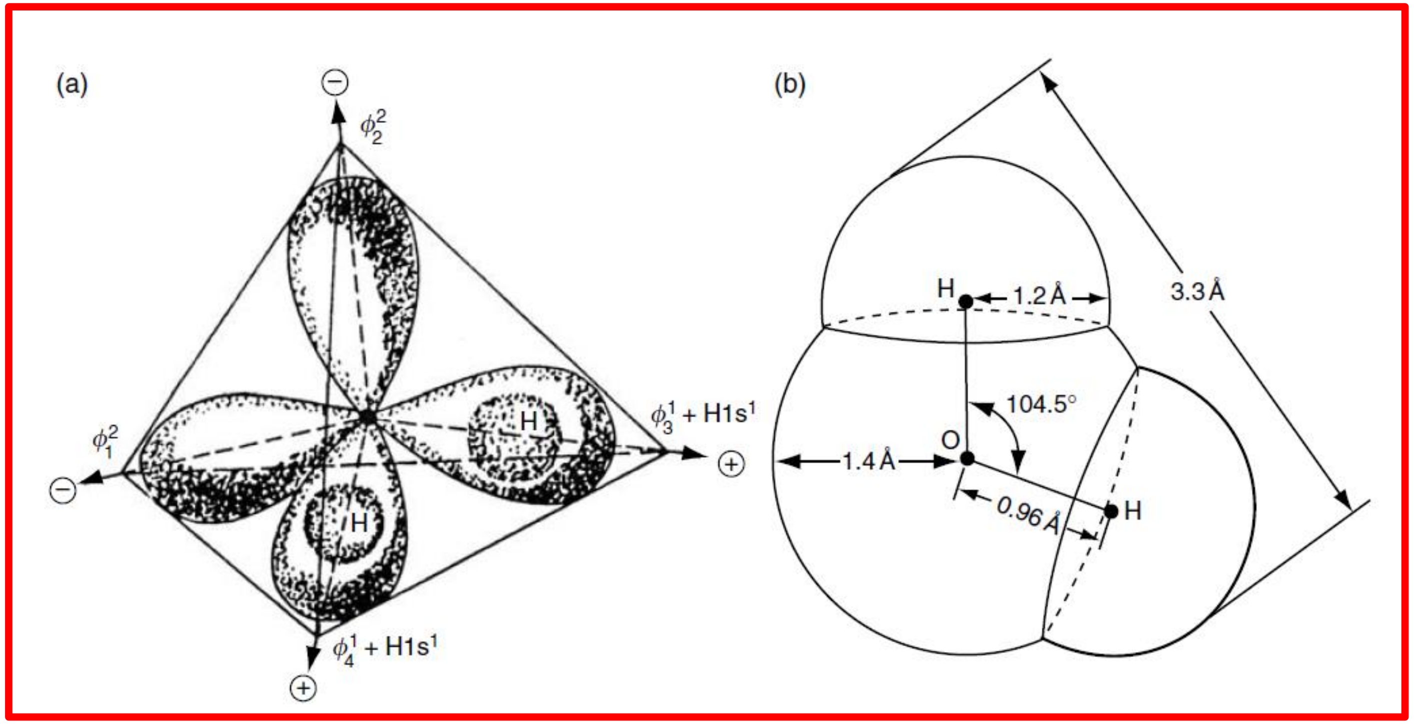
Water structure

- ✓ The function of water is better understood when its structure and its state in a food system are clarified

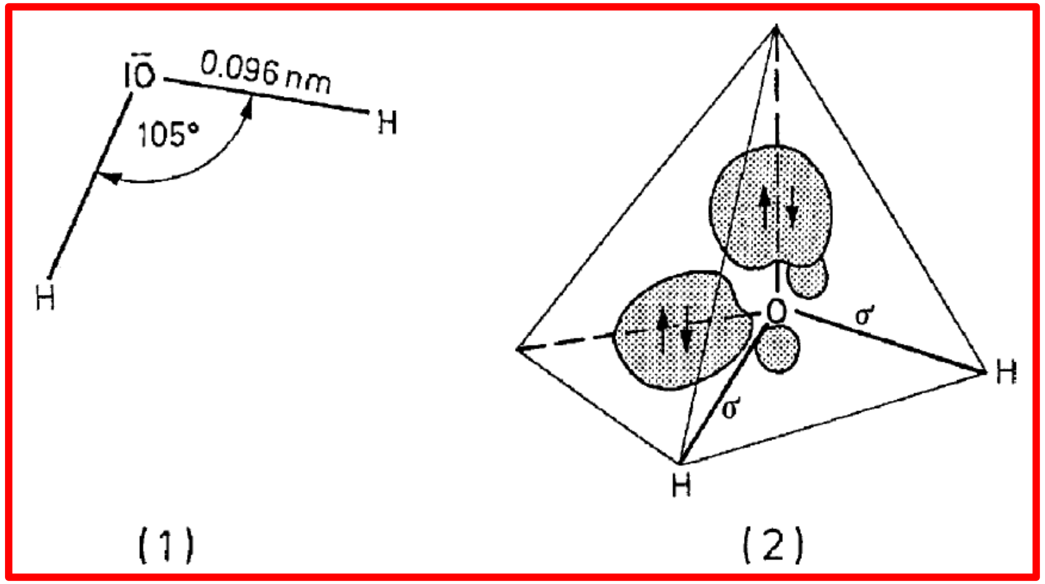
- ✓ The water molecule:
  - ❖ two hydrogen atoms interacting with the two sp^3
    - ➢ bonding orbitals of oxygen,
    - ➢ forming two covalent sigma (σ) bonds of 40% ionic character,
    - ➢ each of which has a dissociation energy of 4.6×102 kJ/mol

Water structure

➢ In the vapor state, the bond angle of an isolated water molecule is 104.5◦ close to the perfect tetrahedral angle of 109.5◦ and the van der Waals radii for oxygen and hydrogen are, respectively, 1.40 and 1.2 Å

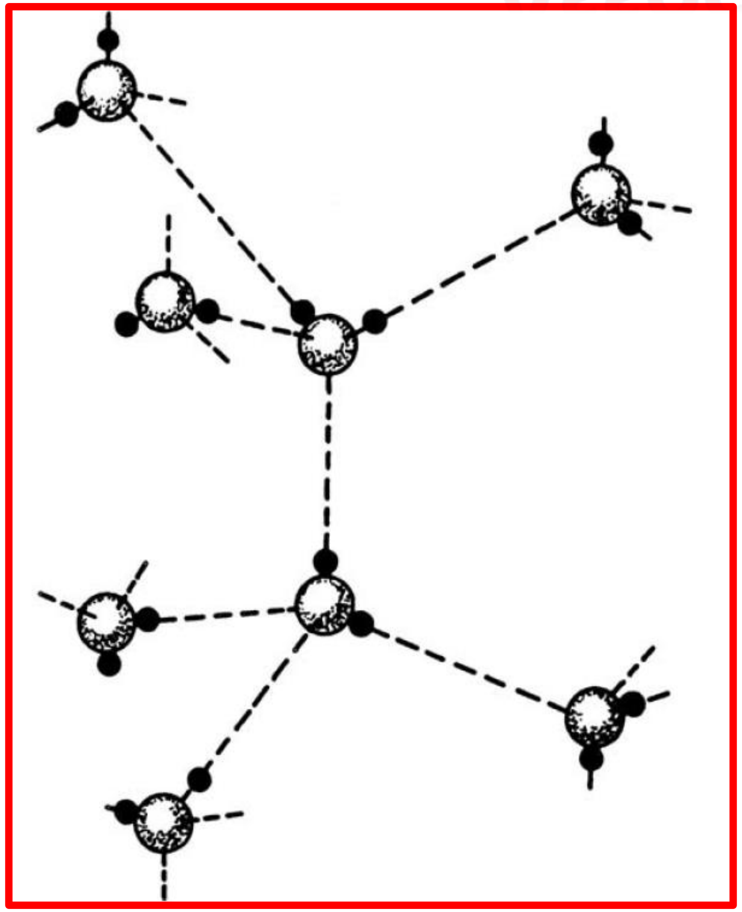


✓ **Schematic model of a single HOH molecule (a) Possible sp3 configuration; (b) van der Waals radii for a HOH molecule in vapor state (Reid and Fennema, 2008)**

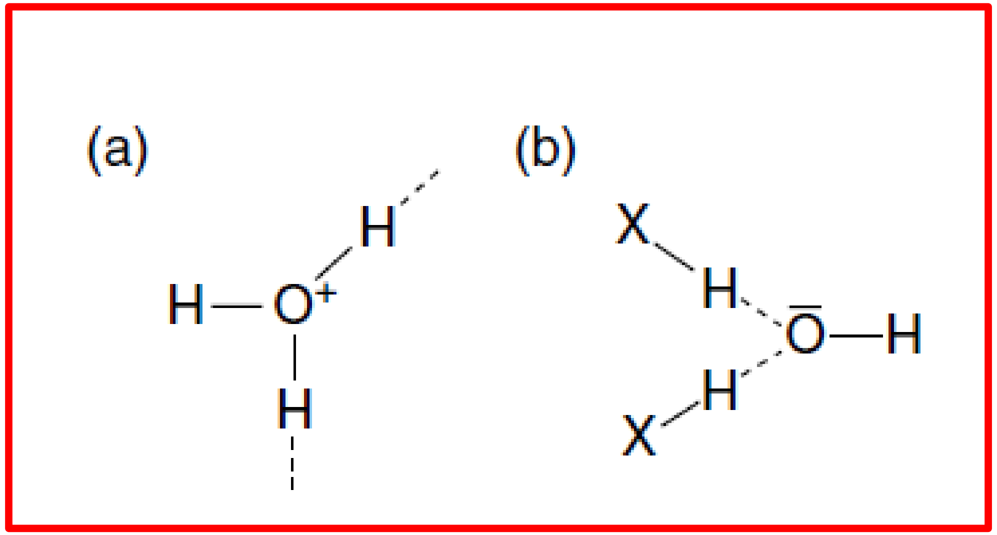


✓ **(1) Molecular geometry (2) Orbital model (Belitz et al. 2009)**

Association of Water Molecules



✓ Hydrogen bonding of water molecules in a tetrahedral configuration. Open circles are oxygen atoms, closed circles are hydrogen atoms. Hydrogen bonds are represented by dashed lines.



✓ Structure and hydrogen bond possibilities:
(a) for a hydronium ion
(b) for a hydroxyl ion
Dashed lines represent hydrogen bonds,
X––H represents a solute or another water molecule

Water-Effect on Storage Life

- ✓ Drying and/or storage at low temperatures are among the oldest methods for the preservation of food with high water contents
- ✓ A product should be dried and/or frozen only long enough to ensure wholesome quality for a certain period of time
- ✓ We need to know the effect of water on storage life to select suitable conditions to optimize drying and/or freezing for individual food products

Water Activity

- The storage quality of food does not depend on the water content, but on water activity (aw), which is defined as follows:

$$a_W = P/P_0 = ERH/100$$

P = partial vapor pressure of food moisture at temperature T

P_0 = saturation vapor pressure of pure water at T

ERH = equilibrium relative humidity at T

- In food science, because p/po is a readily measured term, which sometimes does not equate to aw
- Relative vapor pressure (RVP) is the name for (p/po)T and these terms can be used interchangeably
- The term aw is in widespread use

Moisture content of some food or food ingredients at a water activity of 0.8

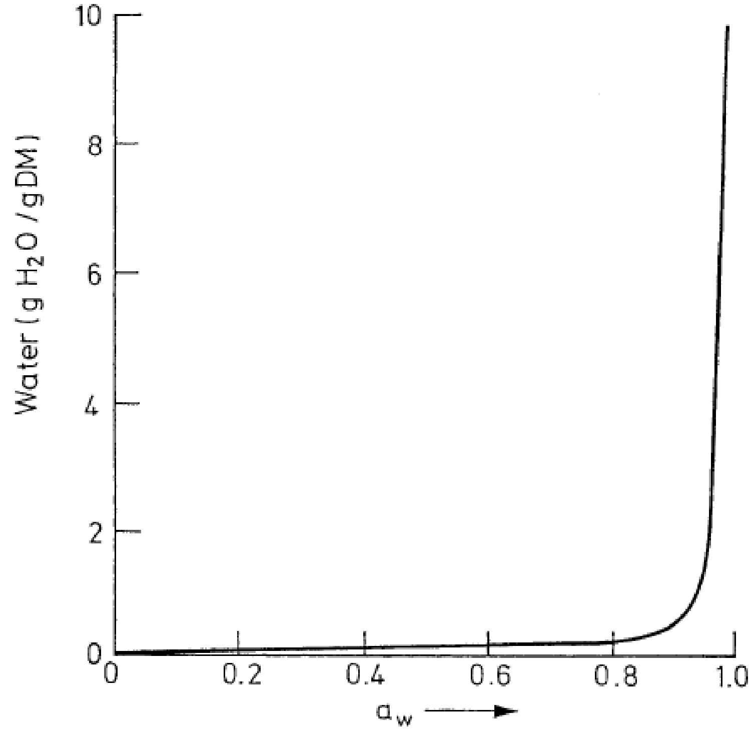
Food / Food ingredient	Moisture content (%)
Peas	16
Casein	19
Starch (potato)	20
Saccharose	56
Glycerol	108
Sorbitol	67
Sodium chloride	332

- ✓ One of the options for decreasing water activity and thus improving the shelf life of food is to use additives with high water binding capacities (humectants).
- ✓ In addition to common salt, glycerol, sorbitol and sucrose have potential as humectants. However, they are also sweeteners and would be objectionable from a consumer standpoint in many foods in the concentrations required to regulate water activity.

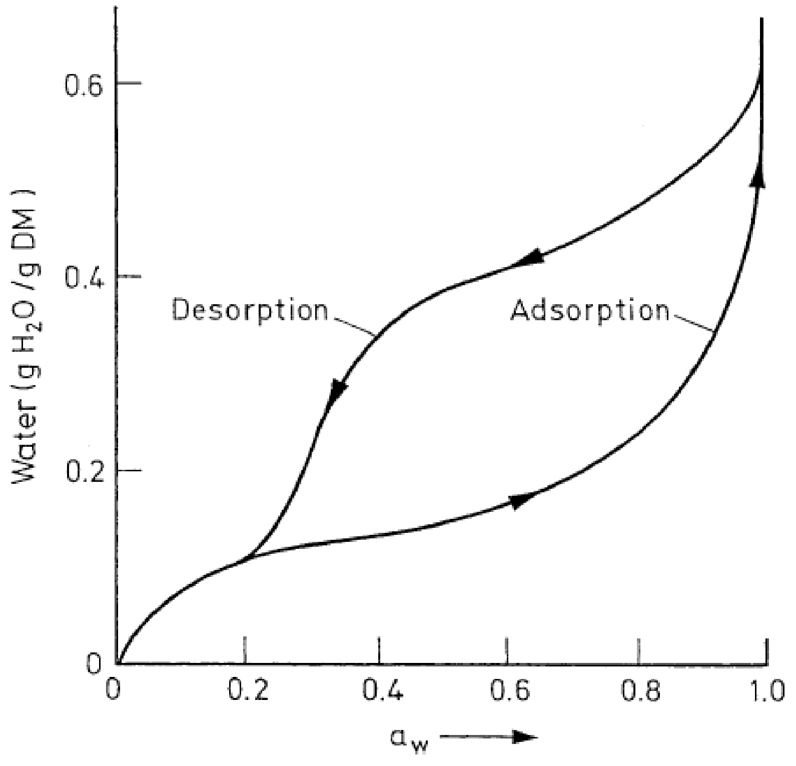
Moisture sorption isotherms

✓The relationship between water content and water activity is indicated by the sorption isotherm of a food.

✓At a low water content (<50%), even minor changes in this parameter lead to major changes in water activity.

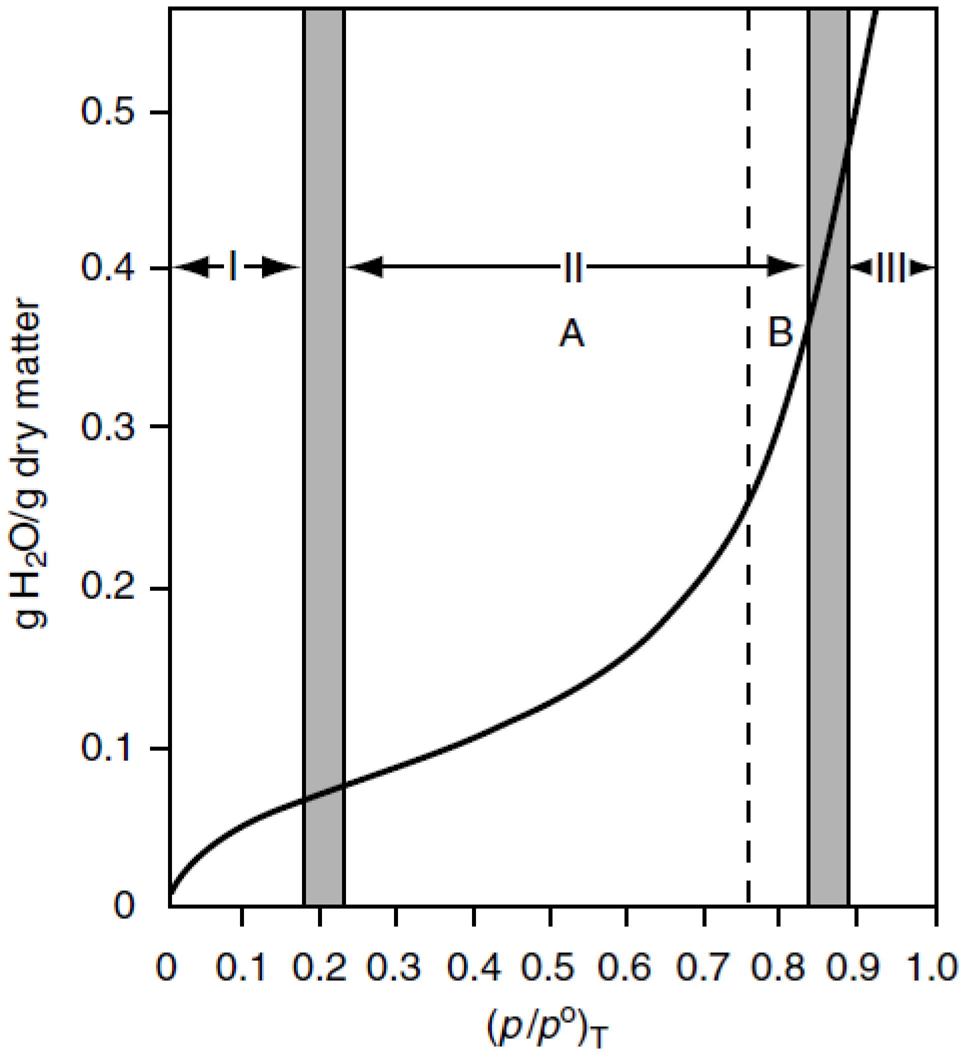


Food with high moisture content



Food with low moisture content (DM: Dry matter)

Generalized Moisture Sorption Isoterms for the low moisture segment of a food (20◦C)



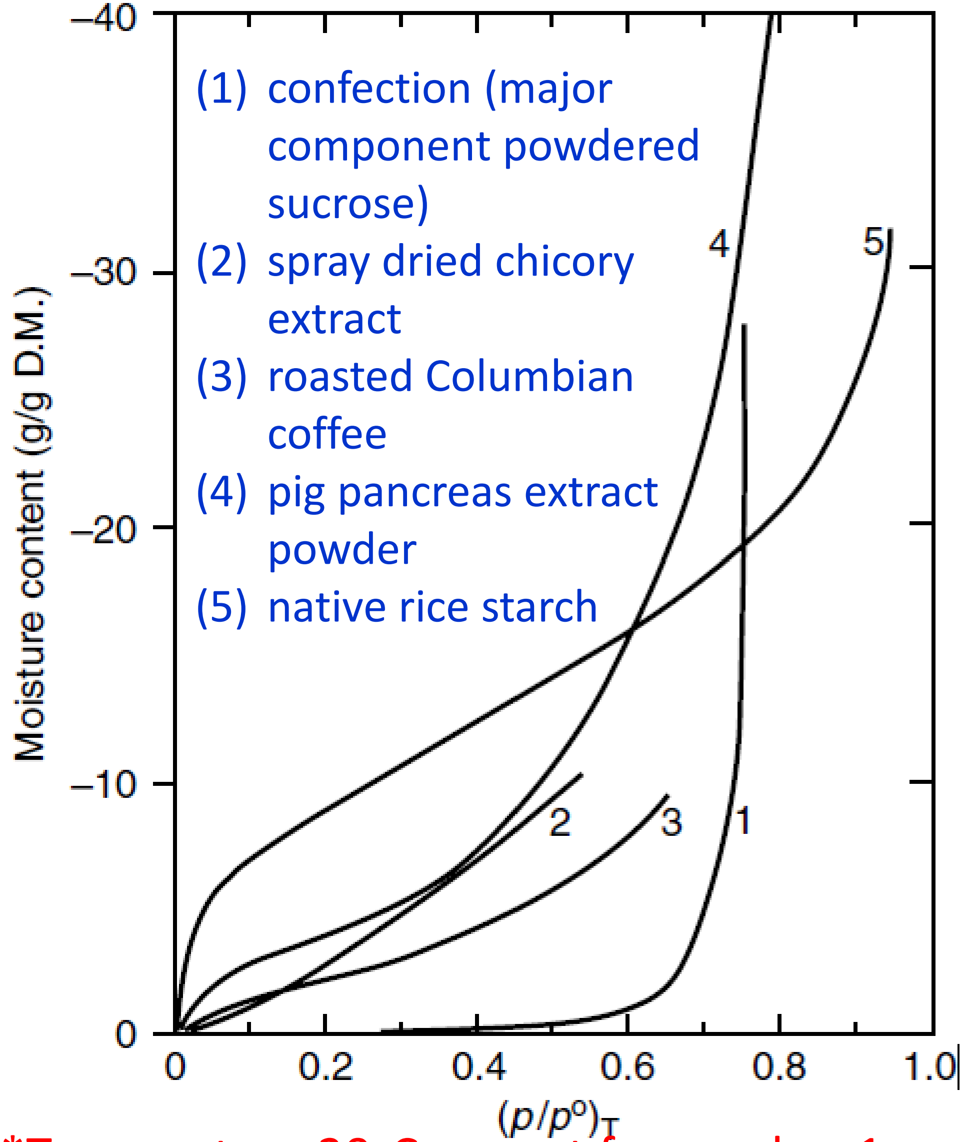
Use of Moisture Sorption Isotherms

- For studying and controlling concentration and dehydration processes
  - because the ease or difficulty of removing water is related to aw
- For formulating food mixtures so as to avoid moisture transfer among the ingredients
- To determine the moisture barrier properties needed in a packaging material required to protect any particular system
- To determine what moisture content will curtail growth of microorganisms of interest within a system
- To predict the chemical and physical stability of foods as a function of changes in their water content

Moisture sorption isotherms

- Moisture sorption isotherms exhibit a variety of shapes, many of which are amenable to at least qualitative interpretation
- The sorption isotherms associated with several substances that have MSIs of markedly different shapes are shown in the Figure on the right
- These are resorption (or adsorption) isotherms prepared by adding water to previously dried samples
- Desorption isotherms are also common.

Resorption isotherms for various foods and biological substances*

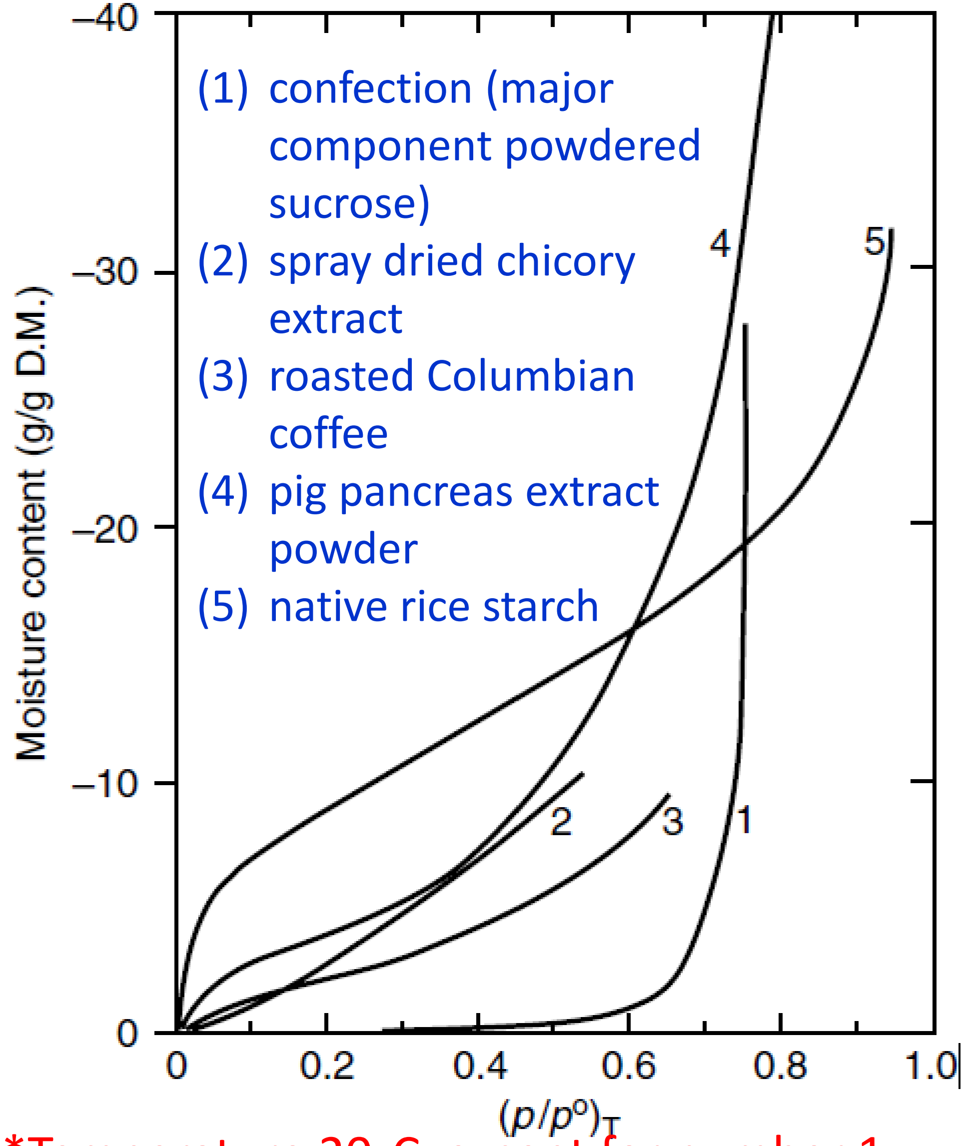


(*Temperature 20◦C, except for number 1, which is 40◦C)

Moisture sorption isotherms

- ✓ Isotherms with a sigmoidal shape are characteristic o most foods
- ✓ However, foods (such as fruits, confections, and coffee extract) that contain large amounts of sugar and other small soluble molecules, and are not rich ir sparingly soluble hydrophilic polymeric materials, may exhibit a J-type isotherm (curve 1)
- ✓ The shapes and positions of the isotherms are determined by several factors including:
  - ✓ sample composition (including molecular weight distribution and hydrophilic/hydrophobic characteristics of solutes)
  - ✓ physical structure of the sample (e.g., crystalline or amorphous),
  - ✓ sample pretreatments
  - ✓ temperature
  - ✓ methodology

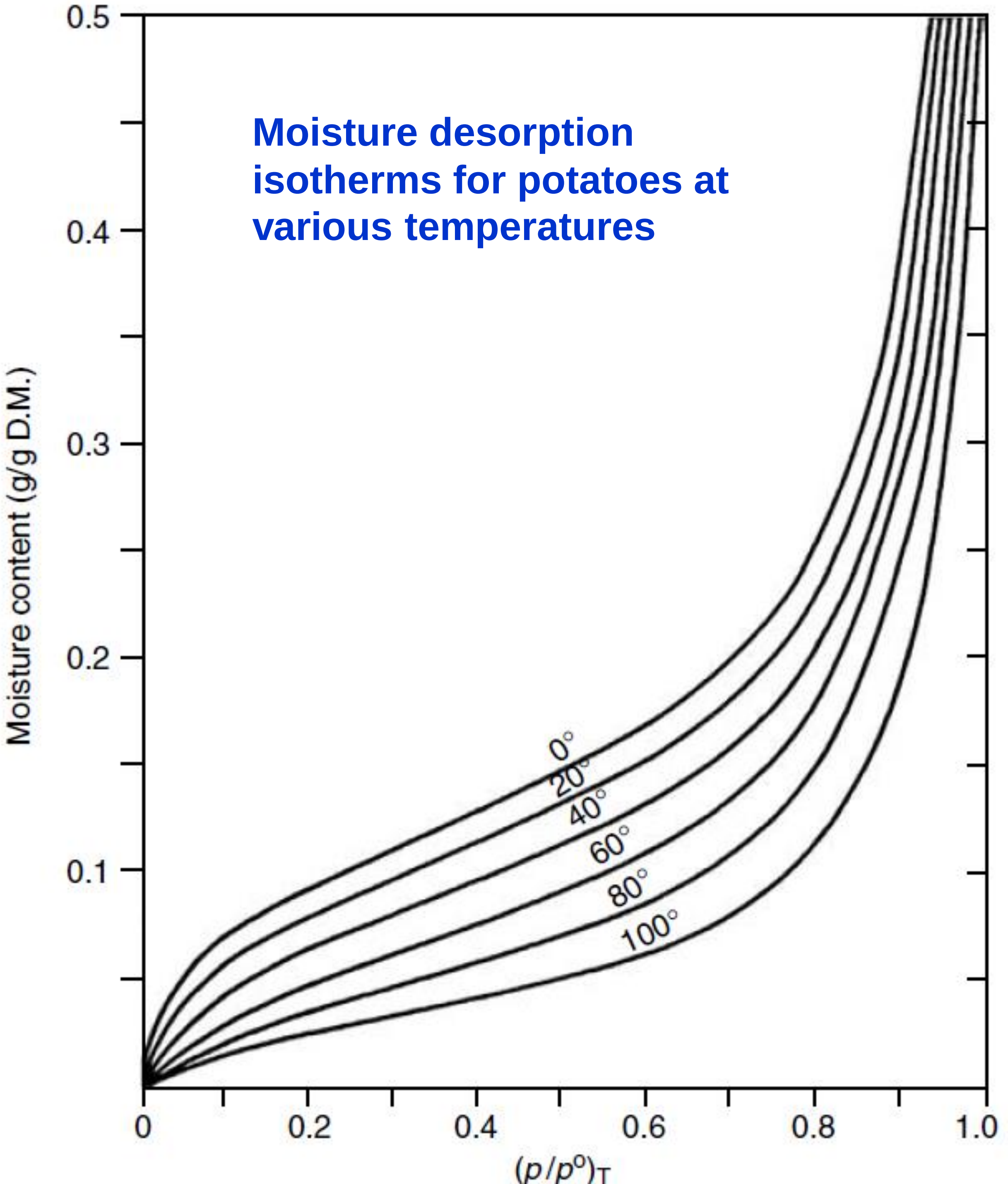
Resorption isotherms for various foods and biological substances*



(*Temperature 20◦C, except for number 1, which is 40◦C)

Moisture sorption isotherms- Temperature Dependence

- RVP is temperature dependent, thus MSIs must also exhibit temperature dependence
- An example of such temperature dependence involving potato slices is shown in Figure on the right
- At any given moisture content, food (*p/po)*T increases with increasing temperature



HYSTERESIS

- ✓ Lack of superimposability is referred to as "hysteresis" and a schematic example is shown in the Figure on the right.

- ✓ Typically, at any given (*p/po)*T, the water content of the sample will be greater during desorption than during resorption.

- ✓ It has been found that MSIs of polymers, glasses of low molecular weight compounds, and many foods exhibit such sorption hysteresis

Hysteresis of a MSI