
بسم الله الرحمن الرحيم
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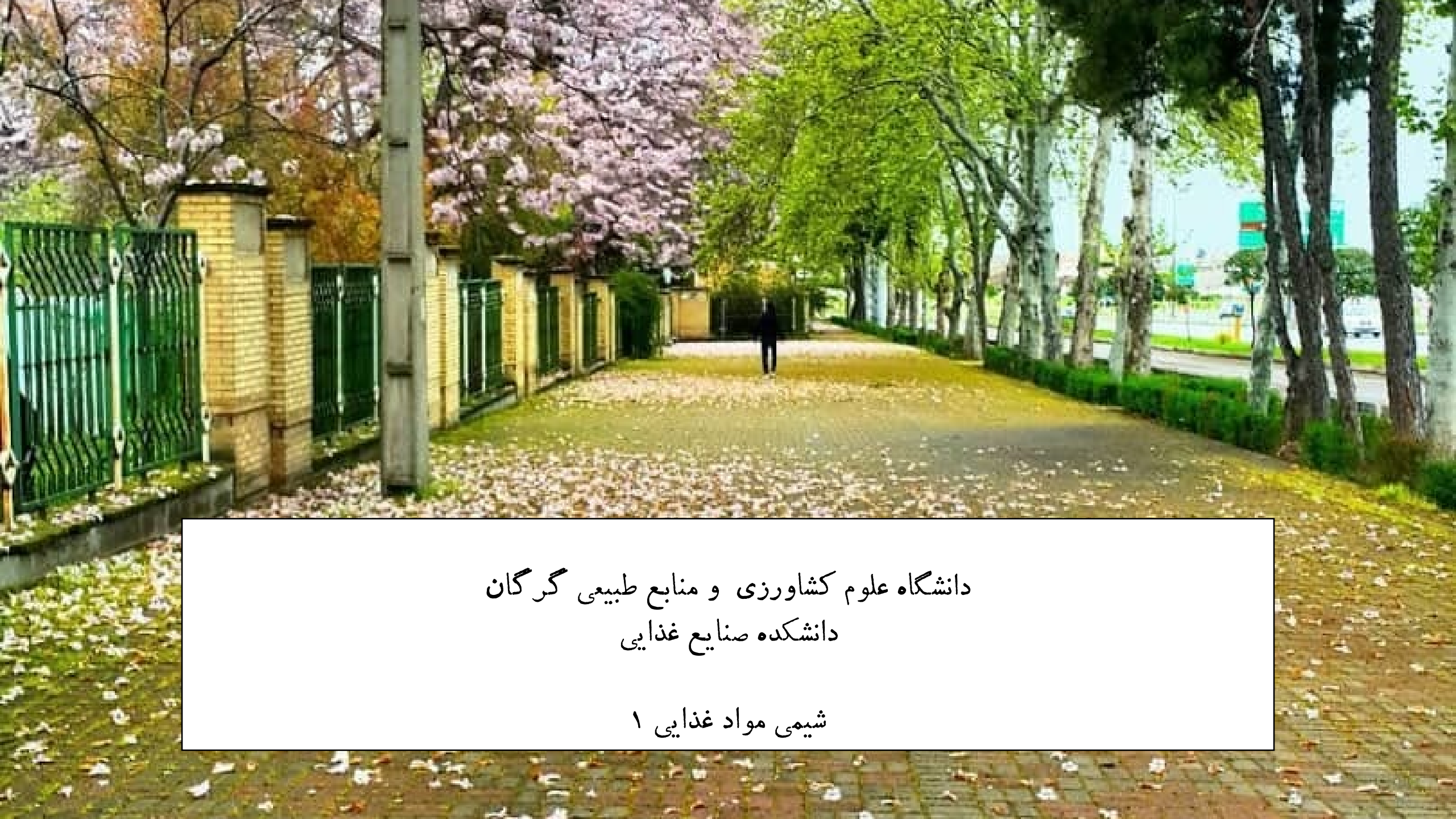
Bismillah al rahman al rahim



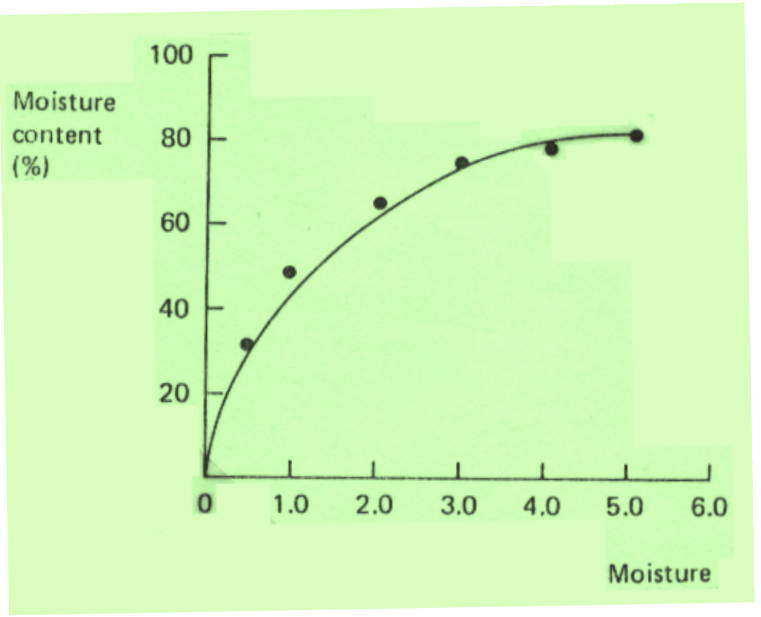
دانشگاه علوم کشاورزی و منابع طبیعی گرگان

دانشکده صنایع غذایی

شیمی مواد غذایی ۱

WATER ACTIVITY (a_W)

- Water quantity report :
  - Wet – weight basis, Moisture content, M
  - Dry – weight basis, Moisture value, m



$$M = \frac{\text{water mass}}{\text{sample mass}} \times 100 = \frac{\text{water mass}}{\text{water mass} + \text{solid mass}} \times 100$$

$$m = \frac{\text{water mass}}{\text{solid mass}}$$

"bone dry" or "oven dry" mass

$$M = \frac{100\,m}{1+m}$$

WATER ACTIVITY (a_W)

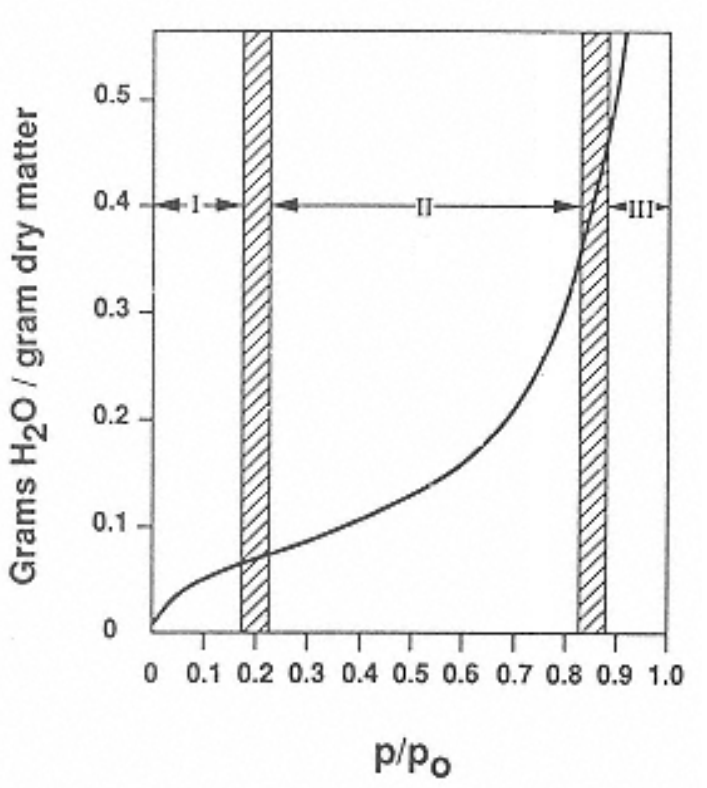
- **Practice :**

  - 250 kg tomato, M = 94%
  - Freeze drying → 25 kg
  - M = ?
  - m = ?

- 0.94 × 250 = 235 kg water (15 kg dry matter)
- M = [(25-15)/25] × 100 = 40%
- m = (25-15)/15 = 0.67

MOISTURE SORPTION ISOTHERM (MSI)

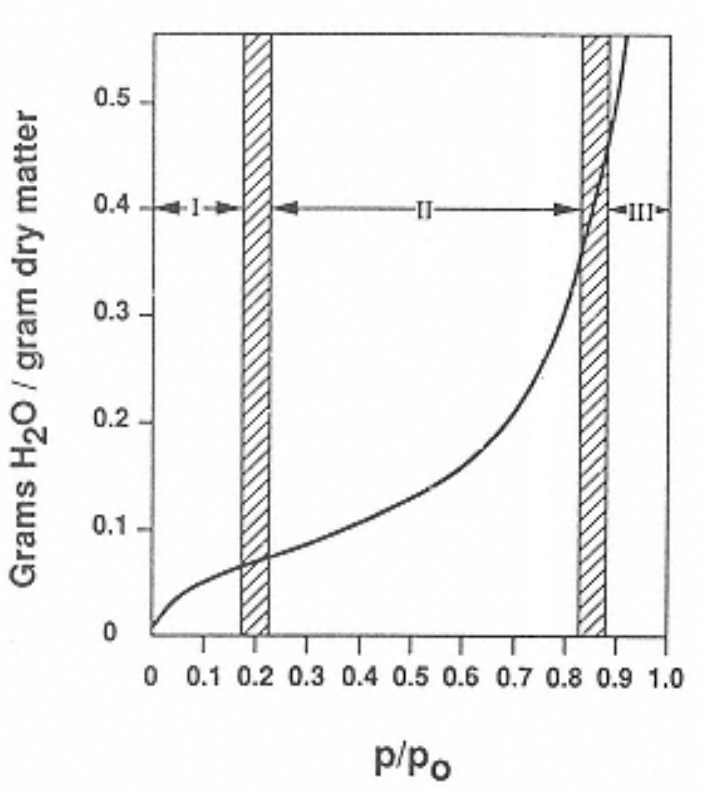
- **Zone I**
  - Most strongly sorbed and least mobile
  - Accessible polar sites by water-ion or water-dipole interactions
  - Unfreezable at -40°C
  - has no ability to dissolve solutes
  - No Plastisizing effect
  - Boundary of zones I and II : BET monolayer water (Brunauer, Emmett, Teller)
  - < 1% in high moisture food



MOISTURE SORPTION ISOTHERM (MSI)

- **Zone II**
  - Slightly less mobile than bulk water
  - Incipient swelling of the solid matrix
  - significant plasticizing action on solutes
  - Slowers their glass transition temperatures
  - < 5% in high moisture food
  - Boundary of zones II and III : full hydration (a true monolayer hydration shell)

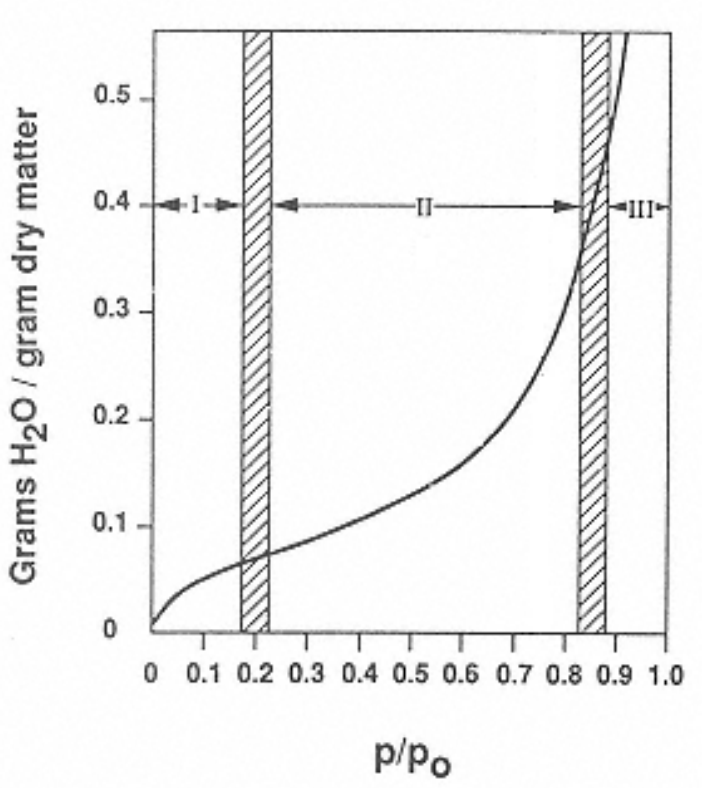
- **Zone III**
  - Bulk-phase water
  - Physically entrapped in gels and cells
  - > 95% in high moisture foods



MOISTURE SORPTION ISOTHERM (MSI)

- **The types of water in food**

  - BET monolayer water
    - Constitutional water (<0.03%)
    - Vicinal water (0.5±0.4%)
      - A monolayer coverage
  - True monolayer water (3±2%)
    - A multilayer coverage
  - Bulk-phase water (~95%)
    - Entrapped water
    - Free water



Types of water in food: some properties

All foods contain at least some water

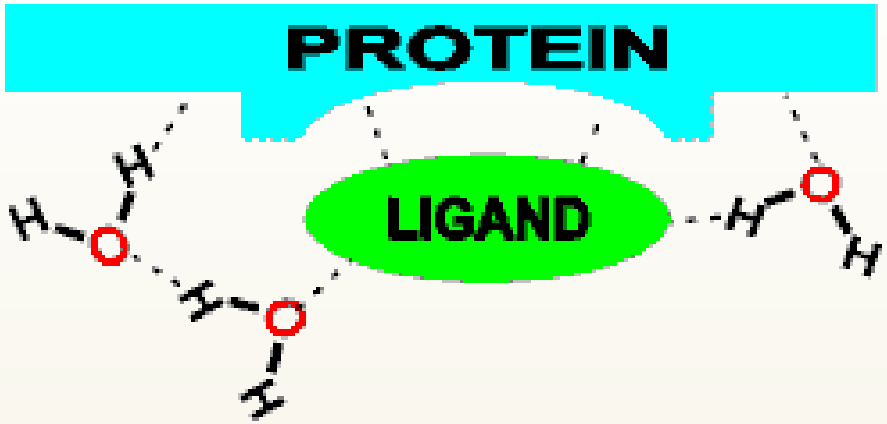
- *Free water:* can be extracted easily from foods by squeezing, cutting or pressing.
  - -free flowing
  - -great solvent for food components
  - -can be removed by pressure

- *Bound water*: cannot be extracted easily.
  - -It is not free to act as a solvent for salts and sugars
  - -It can be frozen only at very low temperatures (below the freezing point of water).
  - -It exhibits essentially no vapor pressure
  - -Its density is greater than that of free water

An example: water present in cacti

Types of bound water:

All water found in tissue is bound water



Structural water:

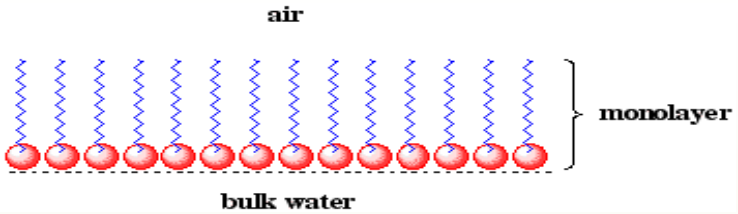
- Small portion of total bound water
- Found inside protein macromolecule
- Not available for chemical reactions.
- Bound directly to protein molecule by hydrogen bonding
- Stabilize the native conformation of the protein molecule; determine the three-dimensional conformation of the protein.
- Structural water molecules may act as prosthetic groups indispensable for proper protein function

prosthetic group is a tightly bound, specific non-polypeptide unit required for the biological function of some proteins..

- Participate in the formation of enzyme active site

(http://www1.lsbu.ac.uk/water/protein_hydration.html)

Monolayer water:



- Bound to the surface of the protein molecules by hydrogen bonding or dipole interactions.
- It represents 4-9% of the water associated with the protein.
- It has kinetic and thermodynamic properties which are different from that of the pure water.
- Not available as solvent.
- May be available for certain reactions.
- Hard to remove from food.

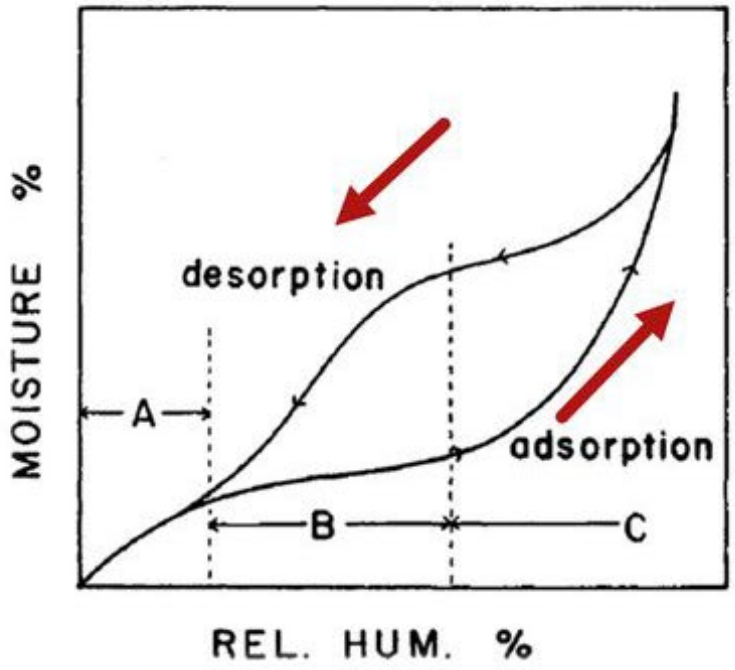
Multilayer Water:

- Additional layer of water around food particle.
- Not as hard to remove as the monolayer.

Sorption Isotherm of Water

- **Hysteresis**

- Resorption or adsorption
- Desorption
- Superimposability
- Hysteresis loop

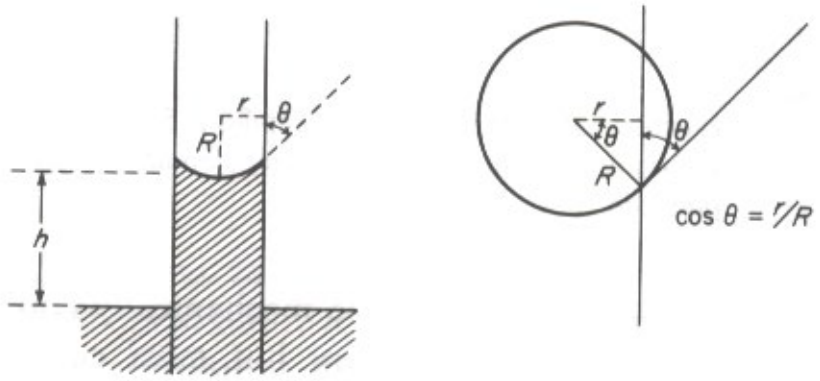


- **Relative humidity** can be simply defined as the ratio of the actual amount of water in the air compared to how much the air can hold at a specific temperature
- When the water content of food and relative humidity of the enviroment are not equal, the food gains or loses water.
- **Desorption:** Lowering water content of moist foods to reach equilibrium with its surroundings
- **Adsorption:** Increasing water content of dry foods to reach equilibrium with its surroundings
- The water content of food and enviroment are same at equilibrium stage. After the equilibrium is reached, the water content of food does not change.

MOISTURE SORPTION ISOTHERM (MSI)

- **Hysteresis**

- Ink bottle theory



Capillary rise of a liquid that wets the walls of a tube.

r (µm)	a_W
0.0005	0.116
0.001	0.34
0.002	0.583
0.005	0.806
0.01	0.898
0.02	0.948
0.05	0.979
0.1	0.989
1.0	0.999
10	0.9999
100	0.99999

$$\Delta P = -\frac{2\gamma}{r}\,\mathrm{Cos}\,\theta$$ Laplace equation

$$\Delta P = \Delta\rho.g.h$$

$$\ln a_W = \ln\frac{P}{P_0} = -\frac{2\gamma}{r}\,\mathrm{Cos}\,\theta\,.\,\frac{V_m}{RT}$$ Kelvin equation

MOISTURE SORPTION ISOTHERM (MSI)

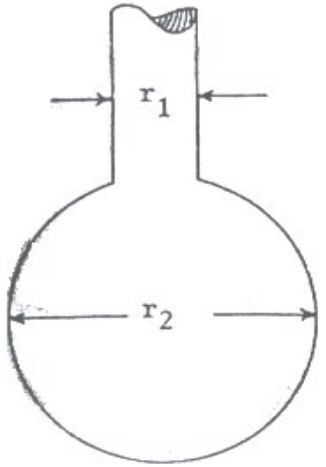
- **Hysteresis**

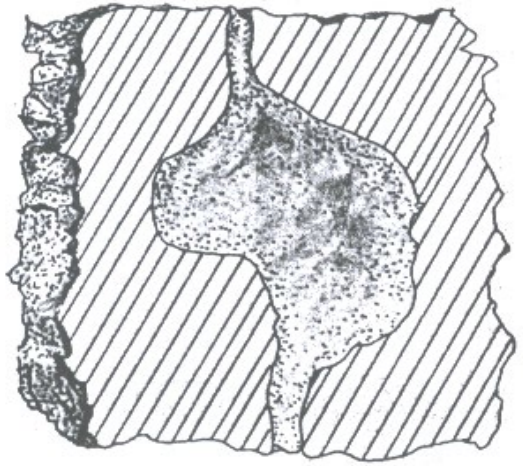
- Ink bottle theory
  - Resorption or adsorption

$$\ln a_W = -\frac{2\gamma}{r_2} \mathrm{Cos}\,\theta \,.\, \frac{V_m}{RT}$$

  - Desorption

$$\ln a_W = -\frac{2\gamma}{r_1} \mathrm{Cos}\,\theta \,.\, \frac{V_m}{RT}$$





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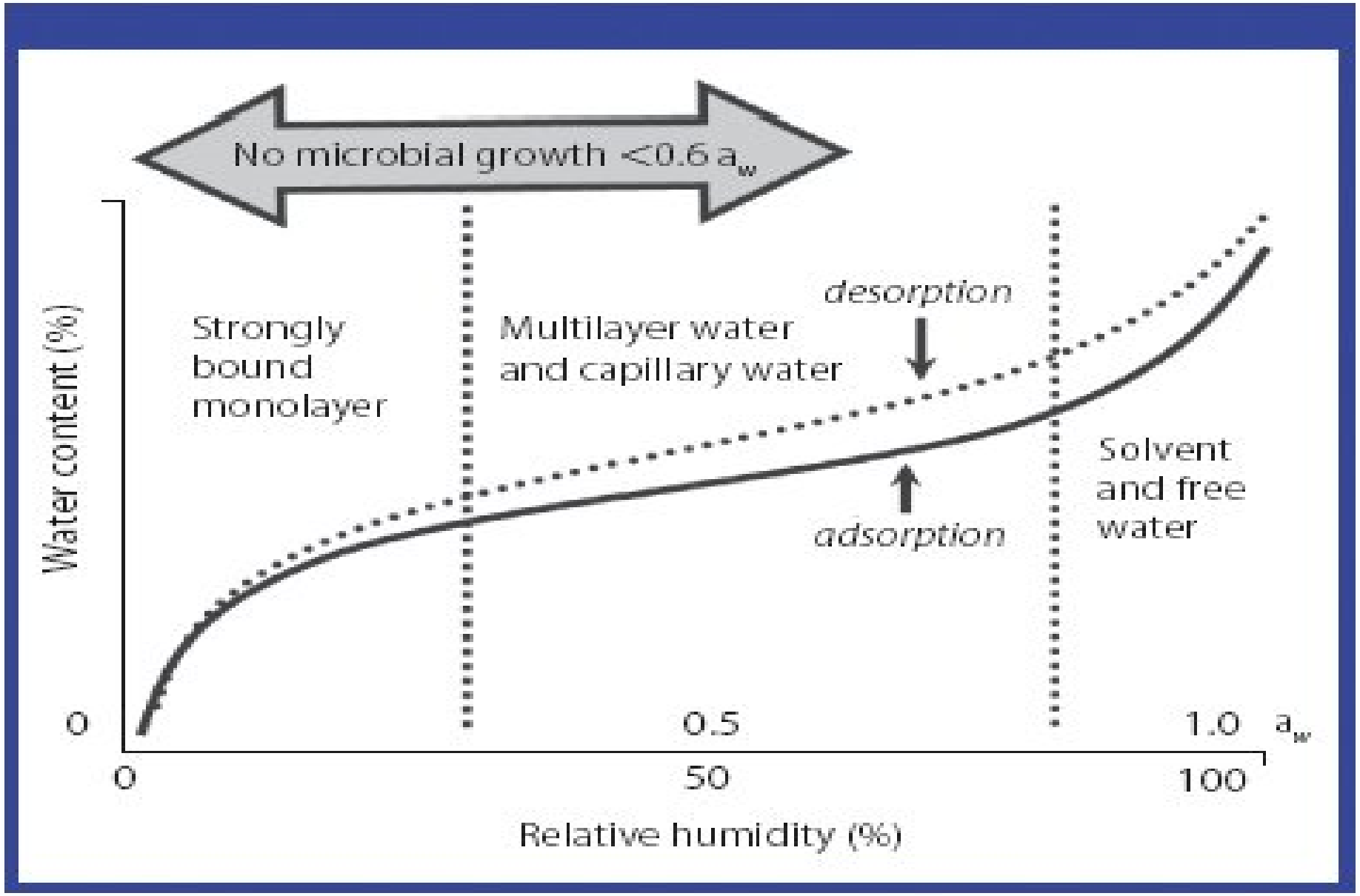
No microbial growth <0.6 a_w
Water content (%)
Strongly bound monolayer
Multilayer water and capillary water
desorption
adsorption
Solvent and free water
0
0.5
1.0
a_w
0
50
100
Relative humidity (%)

WATER ACTIVITY AND FOOD STABILITY

- Microbial growth
- Chemical reactions
- Food texture
- Food flavor

- IMF : intermediate moisture foods

Relative Vapor Pressure and Growth of Microorganisms in Food

Range of p/p_o	Microorganisms generally inhibited by lowest p/p_o in this range	Foods generally within this range
1.00–0.95	*Pseudomonas, Escherichia, Proteus, Shigella, Klebsiella, Bacillus, Clostridium perfringens,* some yeasts	Highly perishable (fresh) foods and canned fruits, vegetables, meat, fish, and milk; cooked sausages and breads; foods containing up to approximately 40% (w/w) sucrose or 7% sodium chloride
0.95–0.91	*Salmonella, Vibrio parahaemolyticus, C. botulinum, Serratia, Lactobacillus, Pediococcus,* some molds, yeasts (*Rhodotorula, Pichia*)	Some cheeses (Cheddar, Swiss, Muenster, Provolone), cured meat (ham), some fruit juice concentrates; foods containing up to 55% (w/w) sucrose or 12% sodium chloride
0.91–0.87	Many yeasts (*Candida, Torulopsis, Hansenula*), *Micrococcus*	Fermented sausage (salami), sponge cakes, dry cheeses, margarine; foods containing up to 65% (w/w) sucrose (saturated) or 15% sodium chloride
0.87–0.80	Most molds (mycotoxigenic penicillia), *Staphylococcus aureus,* most *Saccharomyces (bailii)* spp., *Debaryomyces*	Most fruit juice concentrates, sweetened condensed milk, chocolate syrup, maple and fruit syrups; flour, rice, pulses containing 15–17% moisture; fruit cake; country-style ham, fondants, high-ratio cakes
0.80–0.75	Most halophilic bacteria, mycotoxigenic aspergilli	Jam, marmalade, marzipan, glacé fruits, some marshmallows
0.75–0.65	Xerophilic molds (*Aspergillus chevalieri, A. candidus, Wallemia sebi*), *Saccharomyces bisporus*	Rolled oats containing approximately 10% moisture; grained nougats, fudge, marshmallows, jelly, molasses, raw cane sugar, some dried fruits, nuts
0.65–0.60	Osmophilic yeasts (*Saccharomyces rouxii*), few molds (*Aspergillus echinulatus, Monascus bisporus*)	Dried fruits containing 15–20% moisture; some toffees and caramels; honey
0.50	No microbial proliferation	Pasta containing approximately 12% moisture; spices containing approximately 10% moisture
0.40	No microbial proliferation	Whole egg powder containing approximately 5% moisture
0.30	No microbial proliferation	Cookies, crackers, bread crusts, etc. containing 3–5% moisture
0.20	No microbial proliferation	Whole milk powder containing 2–3% moisture; dried vegetables containing approximately 5% moisture; corn flakes containing approximately 5% moisture; country style cookies, crackers

Table 2 Water Activity and Growth of Microorganisms in Food*

Range of a_w	Microoranisms Generally Inhibited by Lowest a_w in This Range	Foods Generally within This Range
1.00 – 0.95	*Pseudomonas, Escherichia, Proteus, Shigells, Klebsiella, Bacillus, Clostridium perfringens,* some yeasts	Highly perishable (fresh) foods and canned fruits, vegetables, meat, fish, and milk
0.95 – 0.91	*Salmonella, Vibrio parahaemolyticus, C. botulinum, Serratia, Lactobacillus, Pediococcus,* some molds, yeasts (*Rhodotorula, Pichia*)	Some cheeses (Cheddar, Swiss, Muenster, Provolone), cured meat (ham)
0.91 – 0.87	Many yeasts (*Candida, Torulopsis, Hansenula), Micrococcus*	Fermented sausage (salami), sponge cakes, dry cheeses, margarine
0.87 – 0.80	Most molds (mycotoxigenic penicillia), *Staphyloccocus aureus,* most *Saccharomyces* (bailii) spp., *Debaryomyces*	Most fruit juice concentrates, sweetened condensed milk, syrups
0.80 – 0.75	Most halophilic bacteria, mycotoxigenic aspergilli	Jam, marmalade, marzipan, glacé fruits
0.75 – 0.65	Xerophilic molds (*Aspergillus chevalieri, A. candidus, Wallemia sebi*), *Saccharomyces bisporus*	Jelly, molasses, raw cane sugar, some dried fruits, nuts
0.65 – 0.60	Osmophilic yeasts (*Saccharomyces rouxii*), few molds (*Aspergillus echinulatus, Monascus bisporus*)	Dried fruits containing 15-20% moisture; some toffees and caramels; honey
0.60 – 0.50	No microbial proliferation	Dry pasta, spices
0.50 - 0.40	No microbial proliferation	Whole egg powder
0.40 - 0.30	No microbial proliferation	Cookies, crackers, bread crusts
0.30 - 0.20	No microbial proliferation	Whole milk powder; dried vegetables

* Adapted from Beuchat (1981).

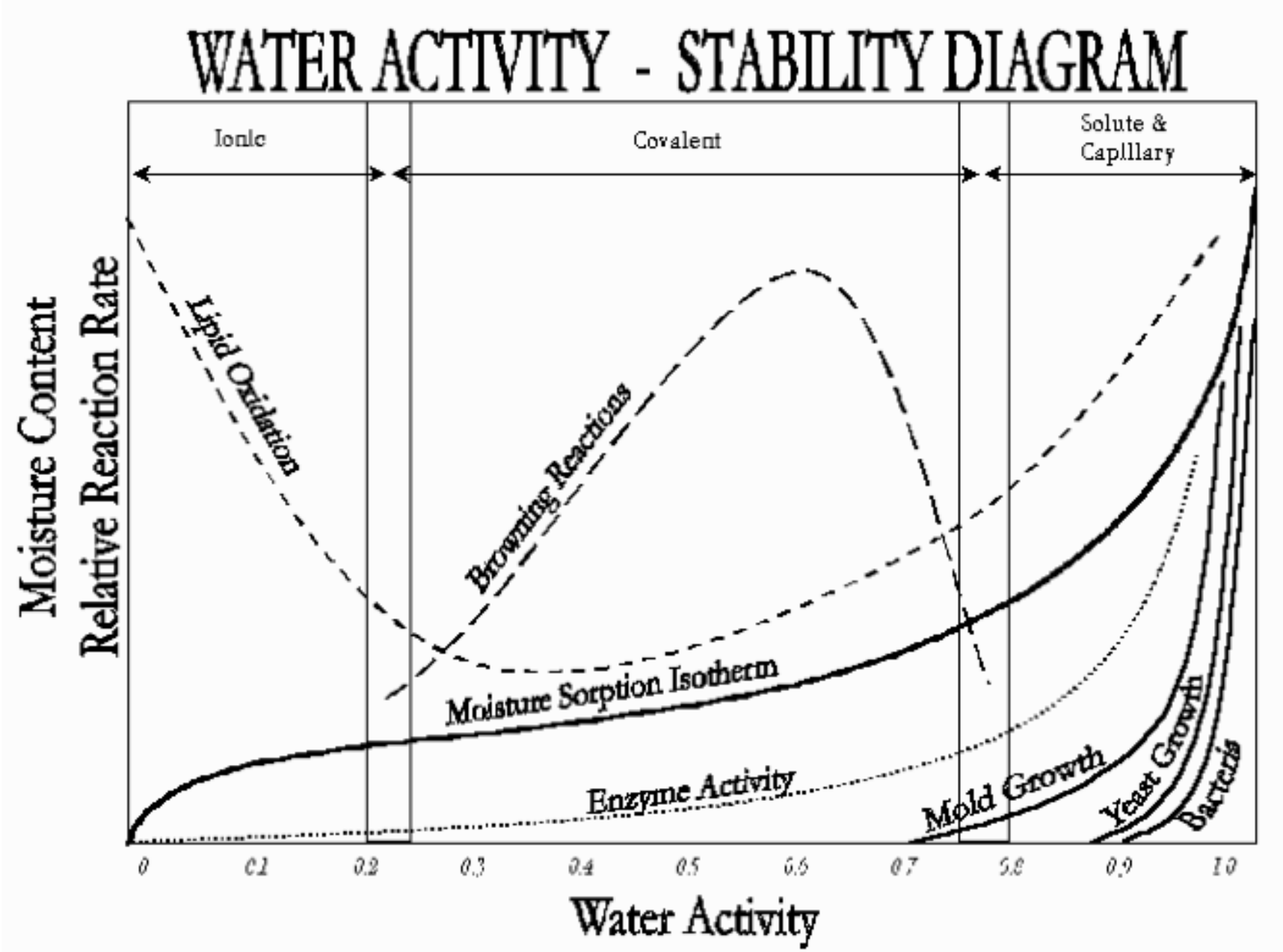

Figure 1. Water Activity – Stability Map (adapted from Labuza, (1970))