Module 02 - lecture 04b

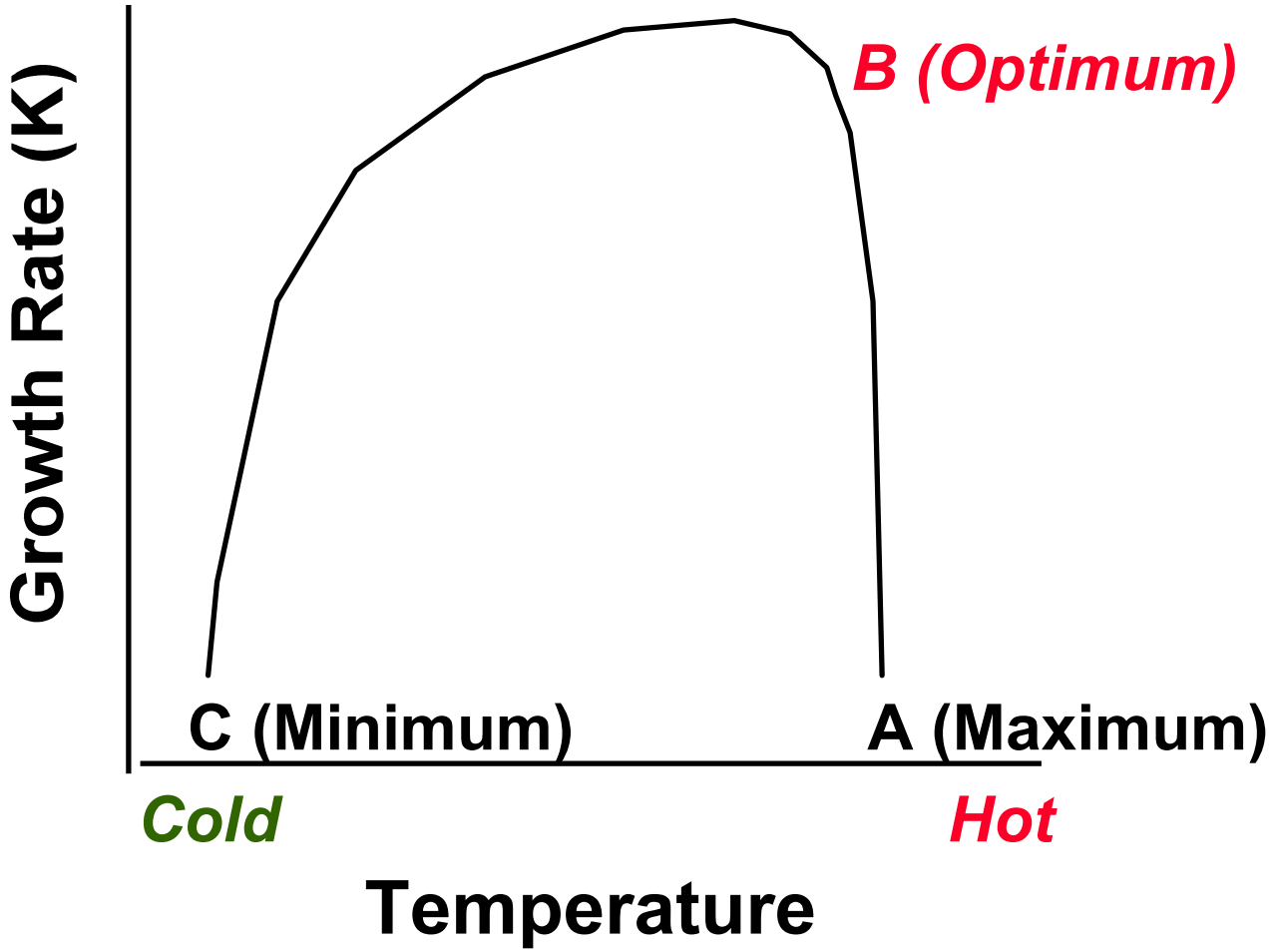
Food technologies to control the development of microbiological hazards

Technologies

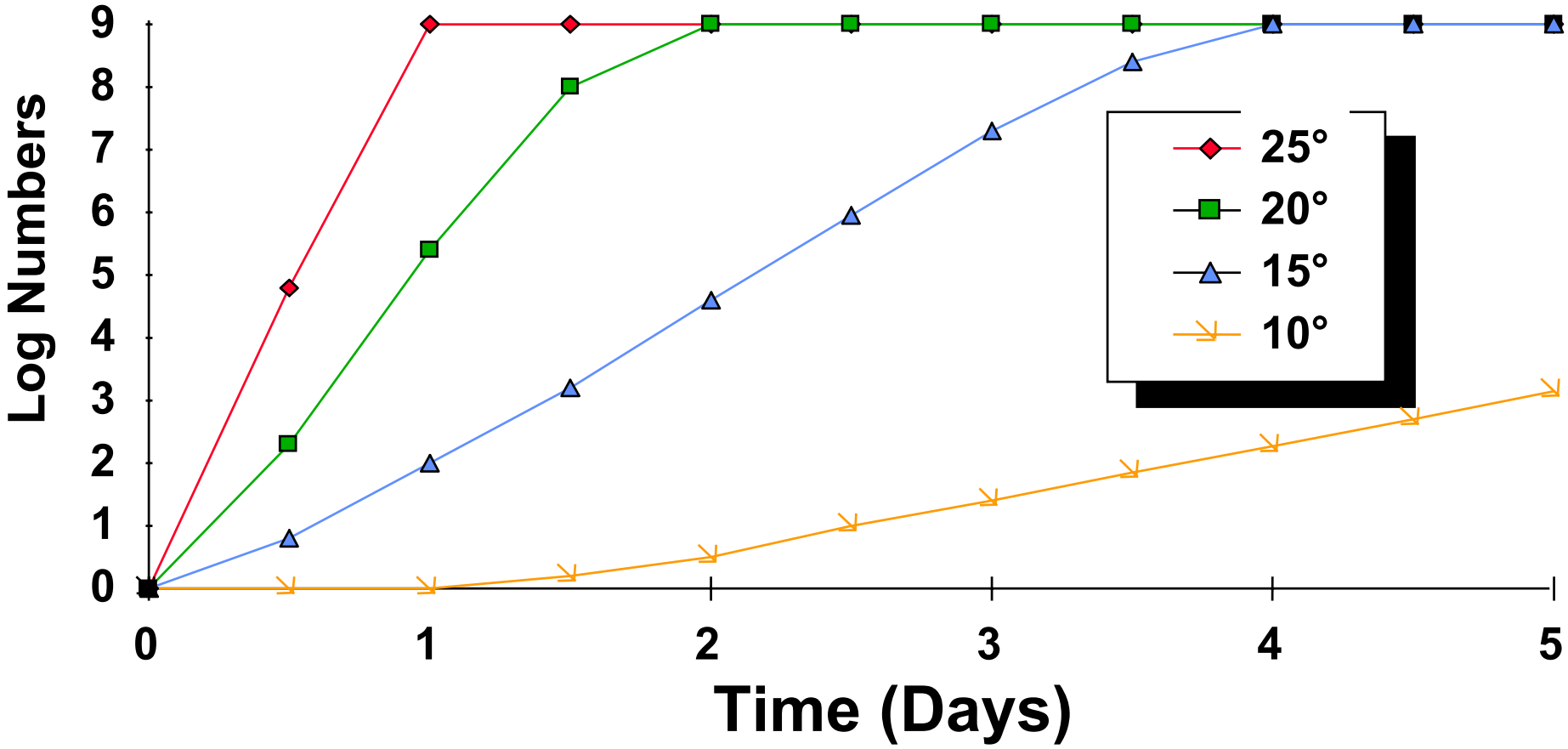
Technologies based on:

- temperature control
- control of water activity
- control of pH
- control of redox potential
- antimicrobial agents

How temperature affects growth rate of a bacterial population



Growth of *S. typhimurium* at different temperatures



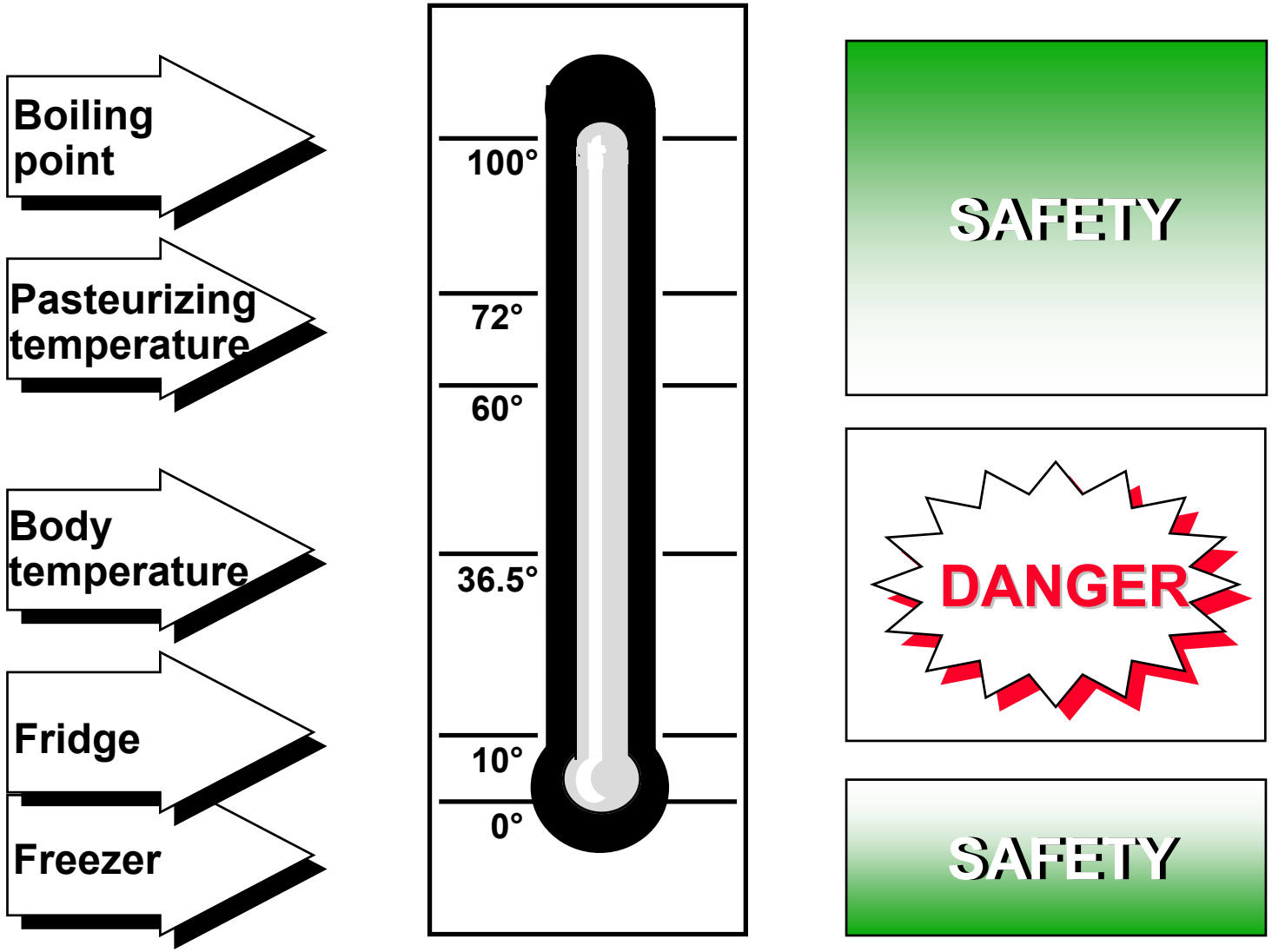
Temperature range for growth of pathogens

	Temperature °C		
	Min.	Opt.	Max.
Salmonella	5	35 - 37	47
Campylobacter	30	42	47
E. coli	10	37	48
S. aureus	6.5	37 - 40	48
C. botulinum (proteolytic)	10		50
C. botulinum (non - proteolytic)	3.3		25 - 37
B. cereus	4	30 - 35	48 - 50

Temperature range for growth of toxigenic moulds

	Temperature °C		
	Min.	*Opt.*	*Max.*
Penicillium verrucosum	0	20	31
Aspergillus ochraceus	8	28	37
Aspergillus flavus	10	32	42
Fusarium moniliforme	3	25	37

Temperature zones



Psychrotrophic pathogens

- *L . monocytogenes*
- *Y . enterocolitica*
- *C . botulinum type*

Water activity

- Water is required for the growth and metabolism of microorganisms
- All the water in foods is not available for microorganisms
- The degree of availability of water is measured by water activity (a_w)
- Chemical and enzymatic reactions are also affected by availability of water

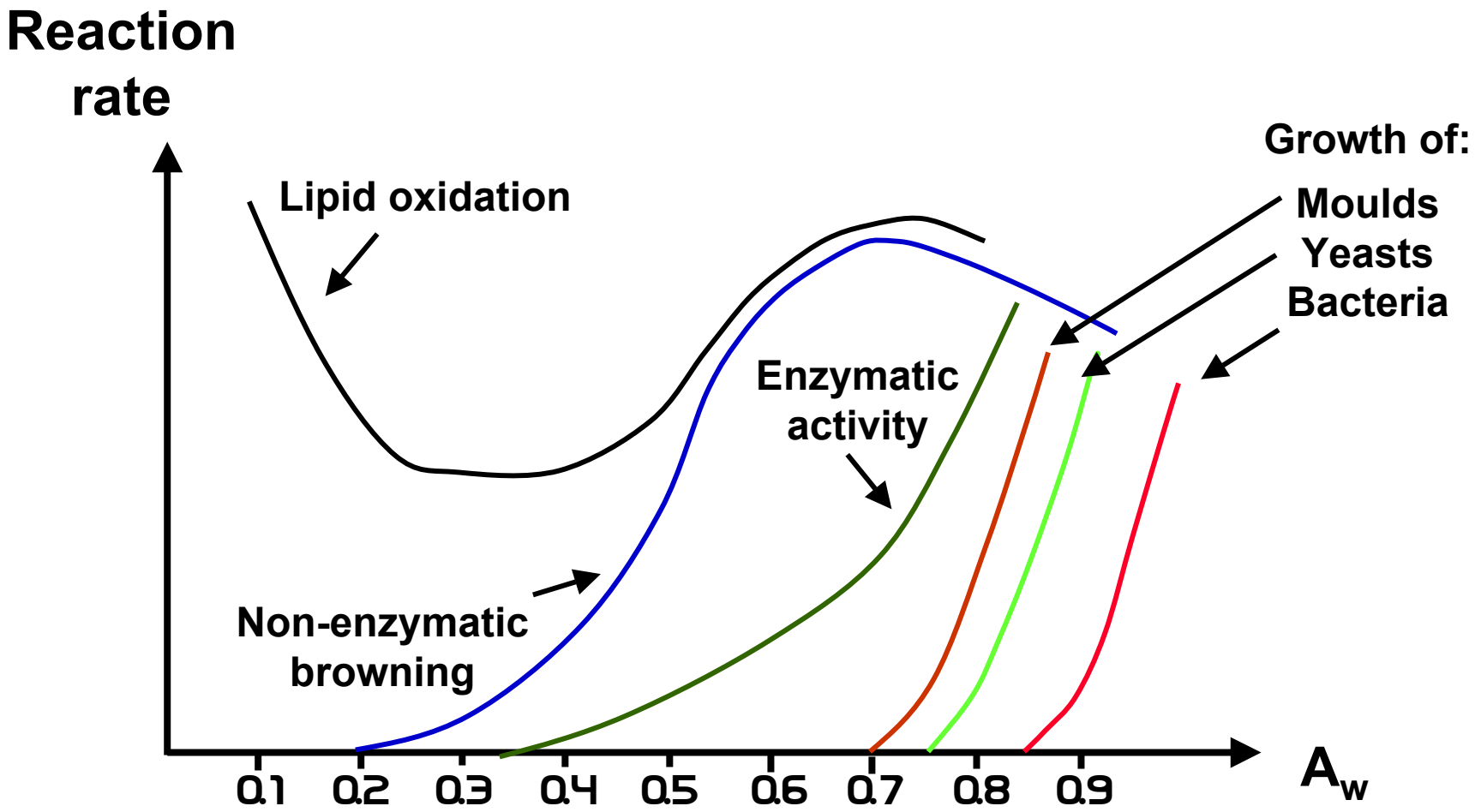
Water activity (definition)

a_w is the ratio of water vapour pressure of food (p) to that of pure water (p_o) at the same temperature.

$$a_w = p / p_o$$

$$0 < a_w < 1$$

Water activity



Minimum levels of a_W permitting growth
(at near optimum temperatures)

Moulds	*Aspergillus chevalieri*	0.71
	Aspergillus ochraceus	0.78
	Aspergillus flavus	0.80
	Penicillium verrucosum	0.79
	Fusarium moniliforme	0.87
Yeasts	*Saccharomyces rouxii*	0.62
	Saccharomyces cerevisiae	0.90
Bacteria	*Bacillus cereus*	0.92
	Clostridium botulinum (proteolytic)	0.93
	Clostridium botulinum (non-proteolytic)	0.97
	Escherichia coli	0.93
	Salmonella	0.95
	Staphylococcus aureus	0.83

Range of a_W in foods and their microbial flora

a_W range	*Foods*	*Microbial flora*
> 0.98	Fresh meats Fresh fish Fresh fruits Fresh vegetables Canned vegetables in brine Canned fruit in light syrup (<3.5 % salt, 26% sugar)	*(C. perfringens, Salmonella)* *(Pseudomonas)*
0.93 - 0.98	Fermented sausages Processed cheese Bread Evaporated milk Tomato paste (10% salt, 50% sugar)	*(B. cereus, C. botulinum, Salmonella)* lactobacilli, bacilli and micrococci

Range of a_w in foods and their microbial flora

a_w range	*Foods*	*Microbial flora*
0.85 - 0.93	Dry fermented sausages Raw ham (17% salt, saturated sucrose)	*S. aureus* Mycotoxin producing moulds Spoilage yeasts and moulds
0.6 - 0.85	Dried fruit Flour Cereals Salted fish Nuts	Xerophilic fungi Halophiles Osmophilic yeasts
< 0.6	Confectionery Honey Noodles Dried egg, milk	No growth but may remain viable

Water activity

a_w can be reduced by :

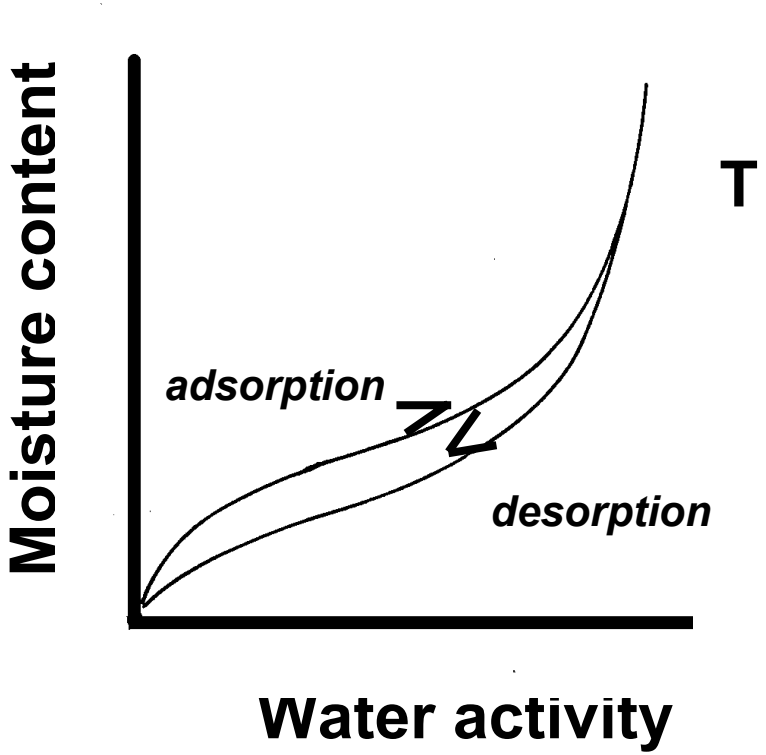
- **Removing water (drying)**
- **Decreasing availability of water by crystalization (freezing)**
- **Decreasing availability by binding water with water binding agents e.g. salt, sugar**

Concentration of NaCl and glucose at various a_w values (at 25°C)

a_w	% w / w NaCl	% w / w Glucose
1.00	0.00	0.00
0.99	1.74	8.90
0.98	3.43	15.74
0.96	6.57	28.51
0.94	9.38	37.83
0.92	11.90	43.72
0.90	14.18	48.54
0.88	16.28	53.05
0.86	18.18	58.45

Sorption isotherm (1)

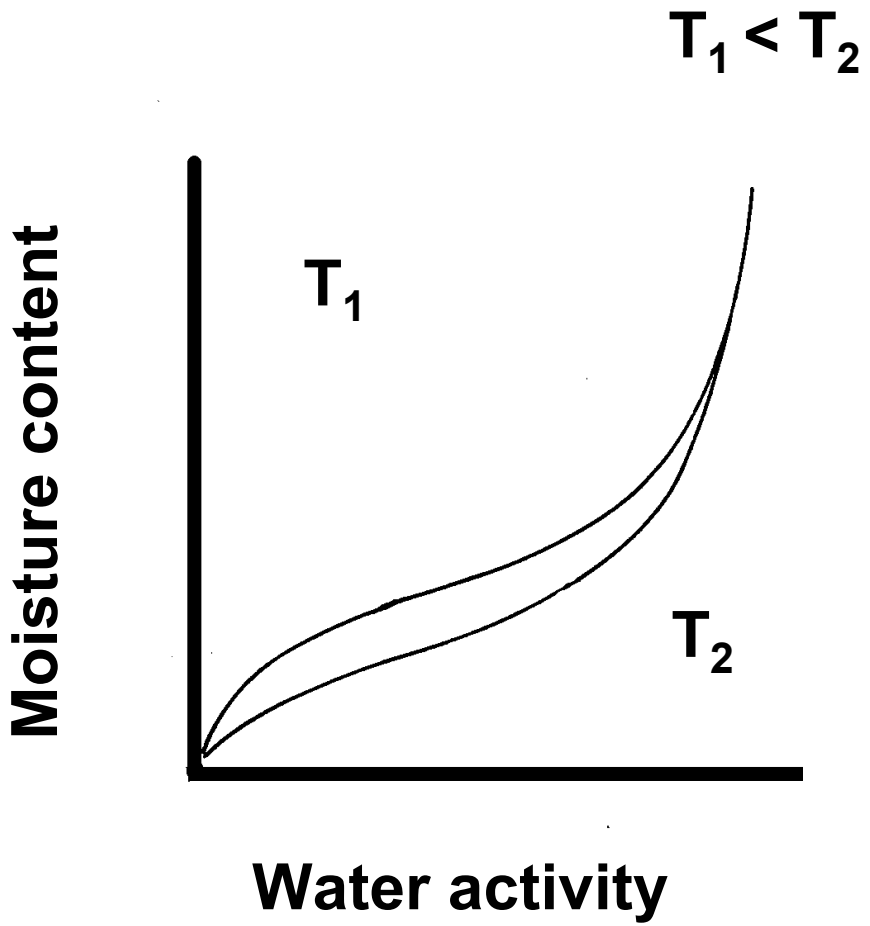
Sorption isotherm is a curve that demonstrates the relationship between water contents and a_w



Sorption isotherm (2)

The a_w and the sorption isotherm vary with temperature

This is of importance for the safety of low a_w foods which are packed in sealed packs or containers



Drying methods

Examples of drying methods are :

- **sun drying**
- **air drying**
- **spray drying**
- **freeze drying**

Drying rate (1)

Drying rate depends on :

- **air velocity**
- **surface area**
- **air temperature**
- **humidity of the air**

Drying rate (2)

In air drying, the rate of drying can be calculated according to the following equation:

$$dw / dt = k_g \, . \, a \, (P_{ws} - P_{wa})$$

dw / dt: drying rate

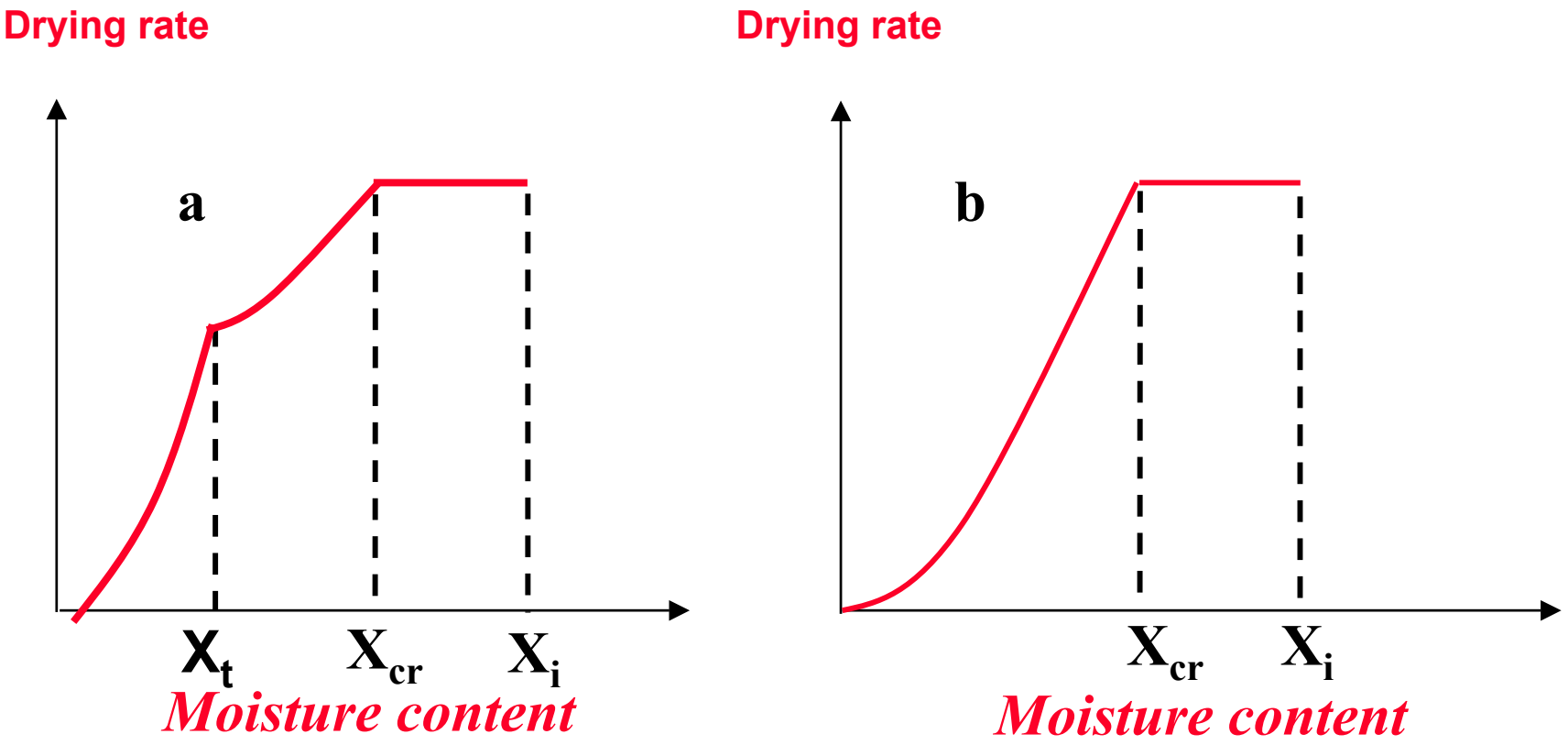
k_g : mass transfer coefficient

a : surface area

P_{ws}: water vapour pressure on the surface

P_{wa}: water vapour pressure in the air

Drying



Schematic presentation of drying curves

a. hygroscopic material **b. porous material**

pH values limiting the growth of pathogens

	pH	
	Min.	Max.
Escherichia coli	4.4	8.5
Salmonella typhi	4 - 4.5	8 - 9.6
Bacillus cereus	4.9	9.3
Clostridium botulinum	4.6	8.5
Staphylococcus aureus	4	9.8
Saccharomyces cerevisiae	2.3	8.6
Aspergillus flavus	*2.0*	*11.2*
Fusarium moniliforme	*2.5*	*10.7*
Penicillium verrucosum	*2.0*	*10.0*

pH and other factors

Microorganisms can grow in lab media at a wider range of pH than would occur in foods

Here, other factors come into effect e.g. microbial competition:

- ***oxygen tension***
- ***storage temperature***
- ***reduced a_w***
- ***heat damage to cells during processing***

pH

Acidification

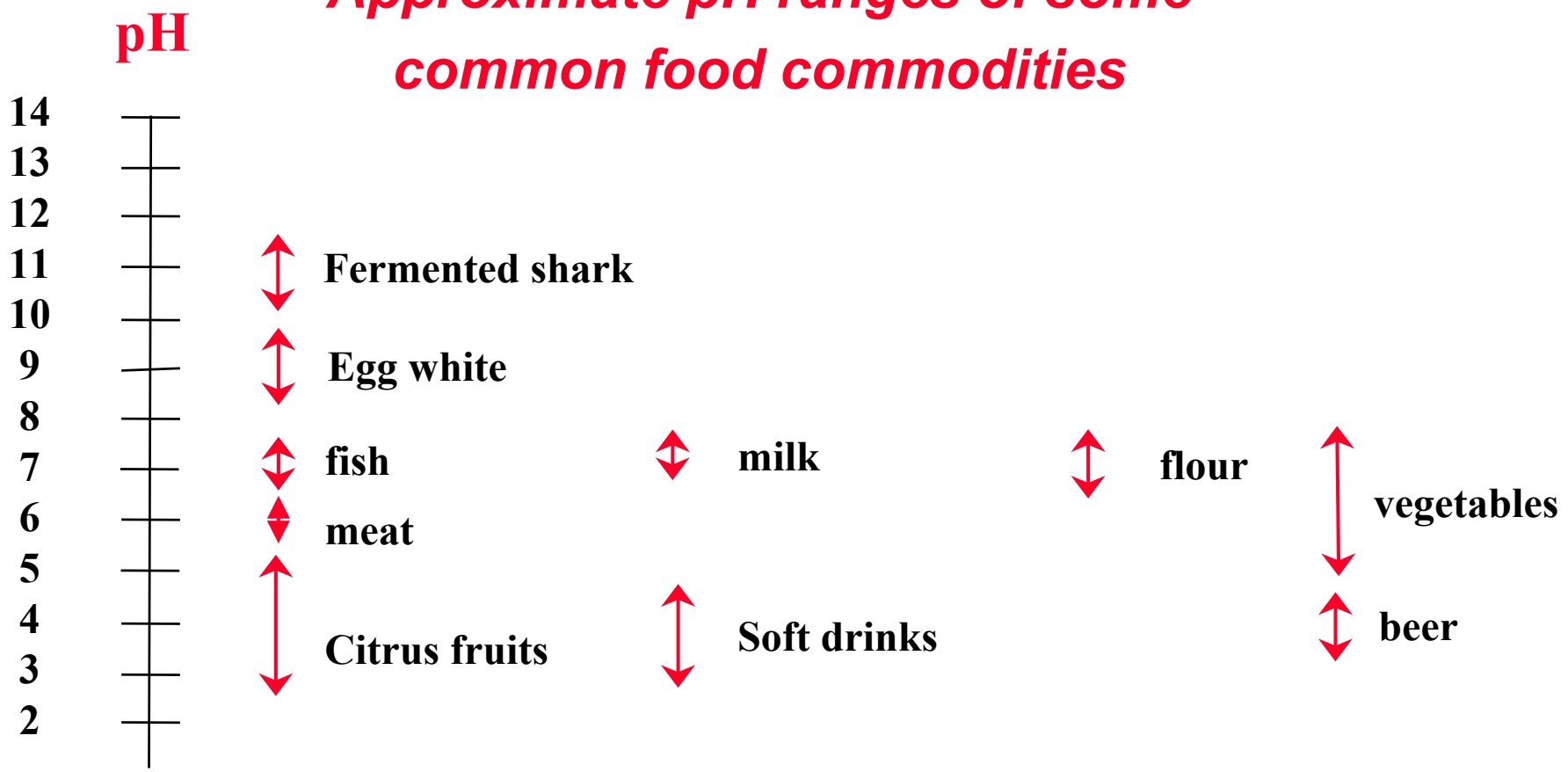
- *addition of vinegar*

Fermentation

- *organic acid*
- *competitive exclusion*
- *antimicrobial agents*

pH of different foods

Approximate pH ranges of some common food commodities



Redox (E_h)

$E_h (mV)$

low / negative: reducing medium

high / positive: oxidizing medium

$$E_h = E_o + RT / nF \,.\, (\text{oxidant}) \,.\, H+ / (\text{reductant})$$

Redox

E_h depends on :

- availability of oxygen
- ratio of oxidant and reductant
- pH
- poising capacity
- microbial activity

Redox and bacterial growth

Obligate or strict aerobes:

positive E_h

Obligate anaerobes:

negative or low E_h

E_h & pH values of foods

	E (mV)	*pH*
Raw meat	-200	5.7
Raw minced meat	+225	5.9
Cooked sausages and canned meats	-20 to -150	6.5
Wheat (whole grain)	-320 to -360	6
Barley (ground grain)	-225	7.0
Potato tuber	-150	6.0
Spinach	+74	6.2
Pear	+436	4.2

Control of E_h

- Vacuum packaging
- Modified atmosphere packaging by gas flushing: CO_2 , N_2

Antimicrobial agents

- Curing salts e.g. nitrites
- Bacteriocins e.g. nisin
- Gas: e.g. CO_2
- Organic acids / salts e.g. benzoic, sorbic and propionic acid

Antimicrobial activity

Depends on :

- **pH**
- **lipid**
- **microorganism**

Smoking

Combination of several factors :

- **heat treatment**
- **drying**
- **antimicrobial agent in the smoke**

Combinations of food technologies

Combined technologies

- **Milk pasteurization and aseptic packaging**
- **Hurdle technologies**
  - **fermentation, smoking**
  - **Refrigerated processed food of extended durability (REPFED)**