Water

nutrient

functions

- heat managing of organism
- transport medium
- stabilizator of biopolymers
- solvent
- reaction medium
- reactant

balance

income (g/day)		outcome (g/day)	
food	900	urine	1500
drink	1300	skin	550
oxidation of nutrients	300	air	350
		excrements	100
sum	2500	sum	2500

clasification

- **endogenous water** oxidation of the main nutrients
  300-400 g/day

oxidation

nutrients → energy + CO_2 + H_2O

100 g proteins	=	37 g water
100 g lipids	=	40 g water
100 g sugars (glucose)	=	60 g water

- **exogenous water** drinks, food
  2000-2800 g/day (average 2500 g/day)

drinking water

source in Czech Rep. **surface water** (~ 80%) river, water reservoirs

- very pure water
- pure water

underground water (~ 20%) wells

- suitable for waterworks

plain water (< 1 g/l)

minerals (> 1 g/l)

quality requirements for drinking water

- microbiological
- physical
- chemical
- radiological

requirements by food industry

- water hardness, content of some cations and anions
- for baby feeding (special sort of water from underground sources)
- drinking water (a sort of drinking water)
- soda water (from table or drinking water and CO_2)
- natural, spring water

parameter	requirement	parameter	requirement
appearance	colorless transparent	mercury ($mg.dm^{-3}$)	max. 0.001
pH	6-8	selenium ($mg.dm^{-3}$)	max. 0.01
oxidizability (mg/l O_2)	max. 3	silver ($mg.dm^{-3}$)	max. 0.05
bacteria coliform. enterococcus	0	vanadium ($mg.dm^{-3}$)	max. 0.01
bacteria mesophilic	20	calcium ($mg.dm^{-3}$)	min. 20
bacteria psychrophilic	200	zinc ($mg.dm^{-3}$)	max. 5
all dissolved substances ($mg.dm^{-3}$)	max. 1000, opt. 500	iron ($mg.dm^{-3}$)	0.3
humic substances($mg.dm^{-3}$)	max. 2.5	**nitrates ($mg.dm^{-3}$)**	**max. 50**
ammonia, NH_4^+ ions ($mg.dm^{-3}$)	max. 0.5	**nitrites ($mg.dm^{-3}$)**	**max. 0.1**
arsenic ($mg.dm^{-3}$)	max. 0.05	chlorides ($mg.dm^{-3}$)	max. 100
barium ($mg.dm^{-3}$)	max. 1.0	fluorides ($mg.dm^{-3}$)	max. 1.5
aluminum ($mg.dm^{-3}$)	max. 0.2	cyanides ($mg.dm^{-3}$)	max. 0.01
magnesium ($mg.dm^{-3}$)	max. 125	sulphates ($mg.dm^{-3}$)	max. 250
chrome ($mg.dm^{-3}$)	max. 0.05	active chlorine ($mg.dm^{-3}$)	min. 0.05 max. 0.3
cadmium ($mg.dm^{-3}$)	max. 0.005	sulfan ($mg.dm^{-3}$)	max 0.01
manganese ($mg.dm^{-3}$)	0.1	phenols ($mg.dm^{-3}$)	max. 0.05
copper ($mg.dm^{-3}$)	max. 0.1	PAHs ($mg.dm^{-3}$)	max. 0.04
lead ($mg.dm^{-3}$)	max. 0.05	oil products ($mg.dm^{-3}$)	max. 0.05

requirements and reality

component	mineral	table	for baby	sparkling
NO_3^- (mg/l) *	≤ 50	≤ 25	≤ 15	
NO_2^- (mg/l) *	≤ 0.1	≤ 0.1	≤ 0.1	
CO_2 (% hm.)	-	-	-	≥ 0.4

***** highest amount (Vyhláška č. 292/1997 Sb., č. 335/1997 Sb.).

content	Dobrá voda	Aquila	Magnesia
mg/l	stolní pramenitá	stolní pramenitá	minerální přírodní
Na	5.2	15.4	5.4
Mg	8.1	9.6	234
Ca	5.6	36.2	37.7
F	0.3	-	0.2
Cl	1.4	3.0	5.3
SO_4^{2-}	2.9	48.4	29.9
NO_3^-	0.10	3.94	0.75
NO_2^-	0.00	0.01	-
sum	**130.8**		**1870**
clasification	**plain**	**plain**	**mineral**

water in foods

typical content in commodities

- organoleptic properties (texture, taste, ….)
- resistance agains microorganisms
- biochemical (enzymatic) and chemical reactions

clasification

- foods with high water content
- foods with medium water content
- foods with low water content

Food	water (%)	Food	water (%)
meat	65-75	pasta	9-12
milk	87	legumes	10-12
cheese	30-78	fruit, vegetable	70-90
butter	15-18	nuts	3-6
margarines	20-75	roasted coffee	5
egg	74	dried milk	4
bread	35-45	vegetable oil, sugar	0
cereals	11-14	beer	90-96 (%vol.)

changes during storage and processing
• spontaneous (natural)
• intentional (prolongation of storage time)

losses
• heat treatment (drying, cooking, roasting, ….)
• thaving

accumulation
• moisturing
• swelling
• boiling

meat pork	%
raw	68
roasted	55
fried	53

milk (3,5% fat)	%
raw	87
pasteurised	87
unsweetened condensed	74
sweetened condensed	27
dried	4

apples	%
after harvest	85
stored	84
juice	88
dried	24

soybeans	%
beans raw	10
- in water 1 h	35
- in water 10 h	60
-boiled	71
-tofu	85
-„milk“	92
-shoju	63
„meat“ dry	9
- in water 1 h	65
- in water 10 h	73
- boiled	79

potatoes	%
raw	80
boiled in peel	80
boiled unpeeled	83
dried powder	8
French fries prefried	74
- fried	55
chips	2

onions	%
raw	89
boiled	92
fried	42
dried	4

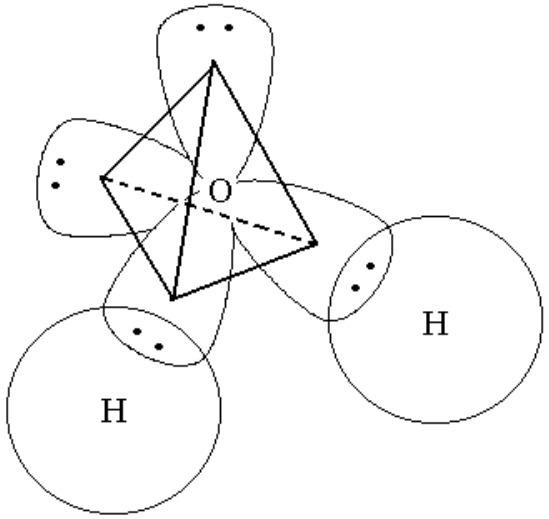
structure

water (chemical individuum) contains

- undissociated molecules H_2O
- hydrated hydronium ion (protons) H_3O^+ ($H_9O_3^+$)
- hydroxyl ions HO-
- their isotopes (^2H, ^3H, ^{17}O, ^{18}O)

pH 7/20 °C: H_3O^+ (HO^-) : H_2O = 1 : $7.14.10^8$

18 isotope variations of molecules H_2O



2 binding (molecular) orbitals

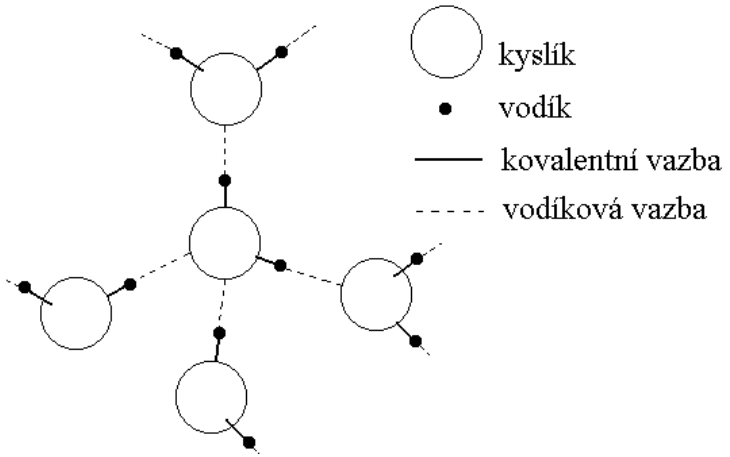
2 non-bonding orbitals

bond angle109°28´

dipole moment → **electrically stable (permanent) dipole**

interaction of water molecules

electrostatic interactions of molecules
association by hydrogen bridges

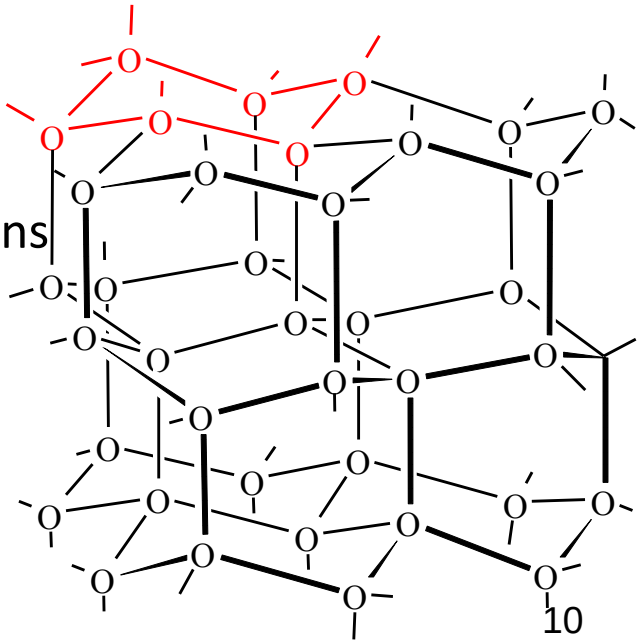


coordination number: ice=4, water by 1.5 °C = 4.4
association structure: lattice

defects of structure: nonelectrolytes, elektrolytes, ions

growth density up to 3.98°C: growth coordination numbers

decrease at higher temperature: increasing the distance between the molecules



properties

at common temperatures: 3 states (phase diagram)

unique, anomalous properties

- melting point
- boiling point
- surface tension
- dynamic viscosity
- density (dependence on temperature)

technological consequences and utilisation

freeze-drying

change the density, size: destructive effects on freezing, thawing

interactions in food

non-bonding (non-covalent) interactions

kind of interaction	example
electrostatic	
permanent dipole – ion	water–ions of salts
	water–ionized functional groups (proteins, saccharides)
hydrogen bond	water–nonionized functional groups (proteins, lipids, saccharides)
hydrofobic	hydrofobic functional groups (proteins, lipids)

interactions water – minerals

- dissolving and formation of true solution
- ion hydratation

interactions water – proteins

- native conformation
- enzyme activity
- denaturation
- formation of disperse system (gels, foams, etc.)

interactions water – lipids

- formation of biomembranes
- formation of disperse system (emulsions)

interactions water – saccharides

- dissolving of crystals
- stabilisation of anomers, conformers
- formation of disperse system (gels)

(6.6 molecules water surrounds glucose, 550 molecules water / agar, gel)

Clasification

- free water (mobilised)
- bound water (imobilized)

categories

in ordinary food with > 90% water

- monomolecular layer (vicinal water)
- multilayer water
- condensed water (bound, free)

category	content (%)	activity (a_w)	enthalpy of bond (kJ/mol)	properties
monomolecular layer (vicinal)	0-1	0.0-0.25	- 4 až - 6	chemisorption, solvent - no, solidifies at – 40°C - no
multilayer water	1-5	0.25-0.7	1-3	partial physical sorption, solvent - no, mainly H-bonds solidifies at – 40°C -partially
condensed (bound, free)	90-95	0.7-1.0	- 0.3	only physical sorption (capillary forces), solvent - yes, solidifies at – 40°C - yes

Water activity

water quantity related to:

- growth of microorganisms
- biochemical and chemical reactions
- sensory properties

accesibility

$$a_w = (f / f_0) = p_w / p_w^0 = \varphi / 100$$

p_w = the vapor pressure of water in the substance (food) p_w^0 = the vapor pressure of pure water at the same temperature, φ = the relative humidity of air in equilibrium with a sample is called the Equilibrium Relative Humidity (ERH)

Water activity or a_w was developed to account for the intensity with which water associates with various non-aqueous constituents and solids

- pure distilled water has a water activity of exactly one

microorganisms	Water activity (a_w)
bacteria	0.91
yeast	0.88
fungi (moulds)	0.80
halophilic bacteria	0.75
xerophilic fungi	0.65
osmophilic yeasts	0.60

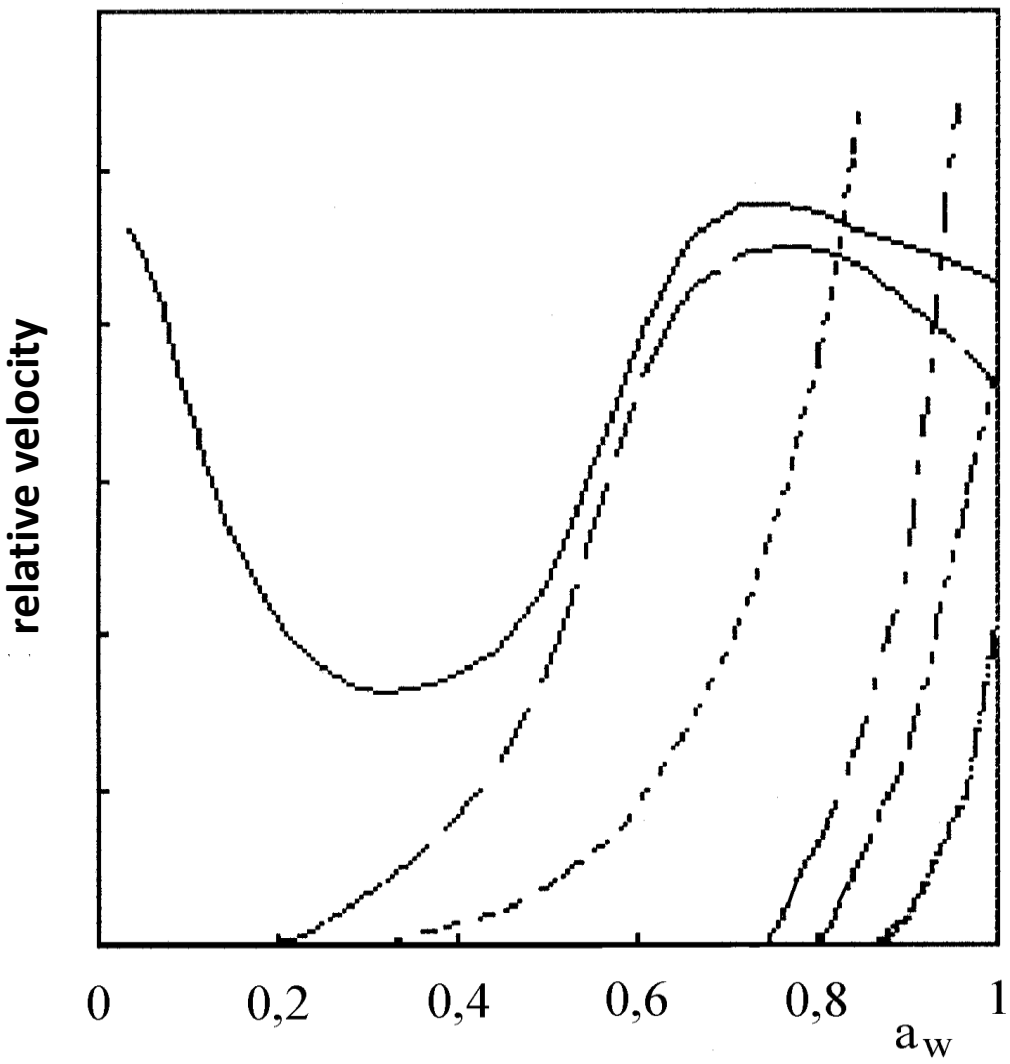
extremophilic organism - can grow and reproduce in conditions with a low availability of water

xerophile (from Greek xēros /ˈzɪroʊs/, meaning "dry", and philos, meaning "loving")

Food	Water activity (a_w)
raw meat, egg, vegetables, fruits	0.97-0.98
cheese, bread	0.97
marmalade, jams	0.82-0.94
sausages, hams	0.82-0.85
dried fruits	0.76-0.80
honey	0.75
pasta, cereals (12%), spices (10%)	0.50
cookies	0.30
dried vegetables (5%), dried milk (4%)	0.20
sugar	0.10

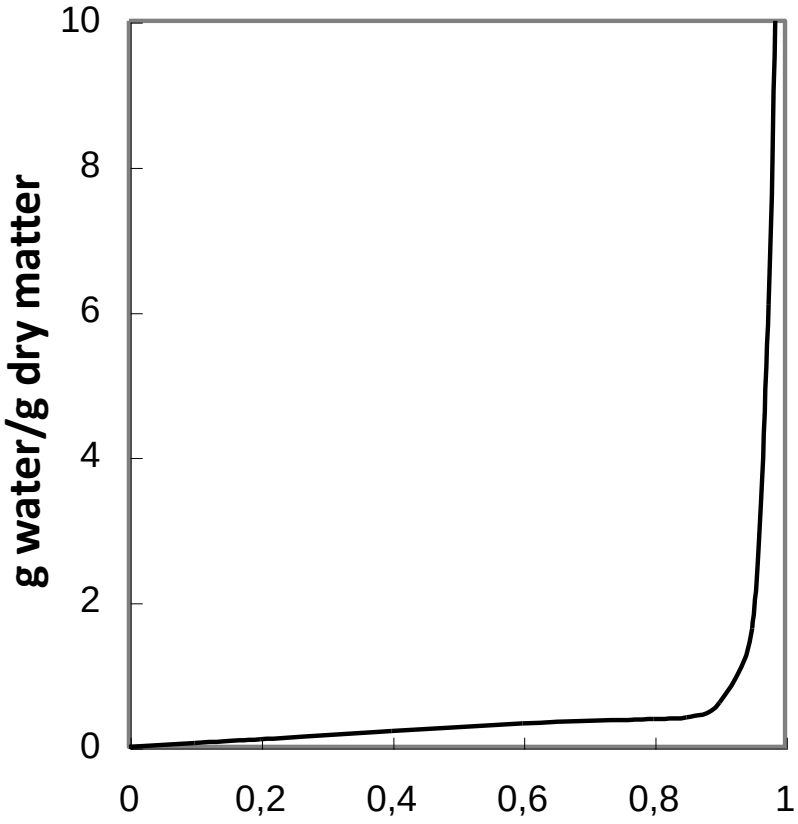
Microorganism Inhibited	a_w
Clostridium botulinum	.97
Pseudomonas fluorescens	.97
Clostridium perfringens	.95
Escherichia coli	.95
Salmonella	.95
Vibrio cholerae	.95
Bacillus cereus	.93
Listeria monocytogenes	.92
Bacillus subtilis	.91
Staphylococcus aureus	.86
Most molds	.80
No microbial proliferation	.50

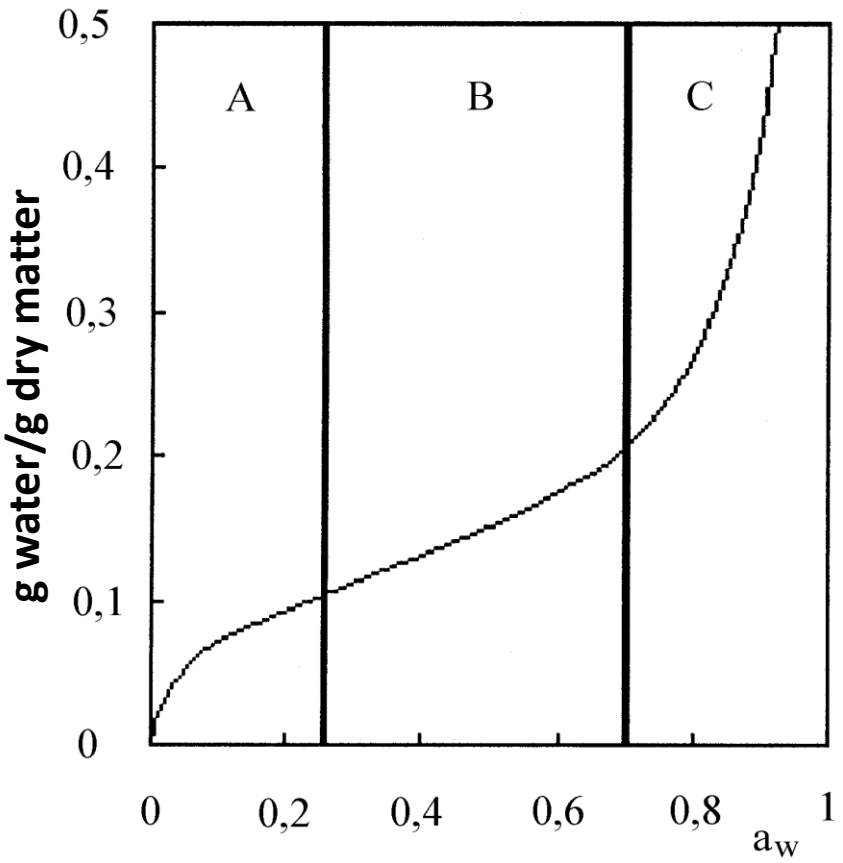
influence of a_w on microorganisms and important reactions



sorption isotherms

relation between water content in foods and their water activity
(the relative humidity of air)





A = monomolecular layer (vicinal water), B = multilayer water,
C = condensed water (bound, free)