

Milk and Dairy Products : A Unique Micronutrient Combination

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Plan of Presentation

- General Definitions
- Minerals in Milk and Dairy Products
 - Macroelements and Trace elements
 - Locations and Concentrations in Milk and Dairy Products
- Vitamins in Milk and Dairy Products
 - Hydrophilic and lipophilic vitamins
 - Locations and Concentrations in Milk and Dairy Products
- Conclusion and Perspectives

General Definitions of Micronutrients

- Not synthesized by the human organism
- Present in low quantity
- Are not energetic sources
- Contribute to the good functions of the organism

Minerals

Macroelements :

Ca, Mg, Na, K, P and Cl

Trace elements :

Fe, Zn, Cu, Se.....

Vitamins

Lipophilic vitamins :

A, D, E, K

Hydrophilic vitamins :

*B1, B2, PP, B5, B6, B8, B9, B12
and C*

Calcium in Milk : a Major Cation

Trace elements

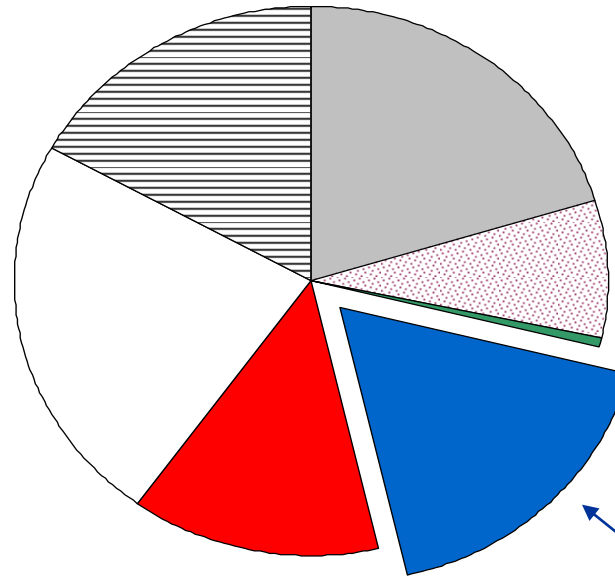
Chloride (~1200 mg/L)

Potassium (~1400 mg/L)

Citrate (~1600 mg/L)

Sodium (~500 mg/L)

Magnesium (~120 mg/L)



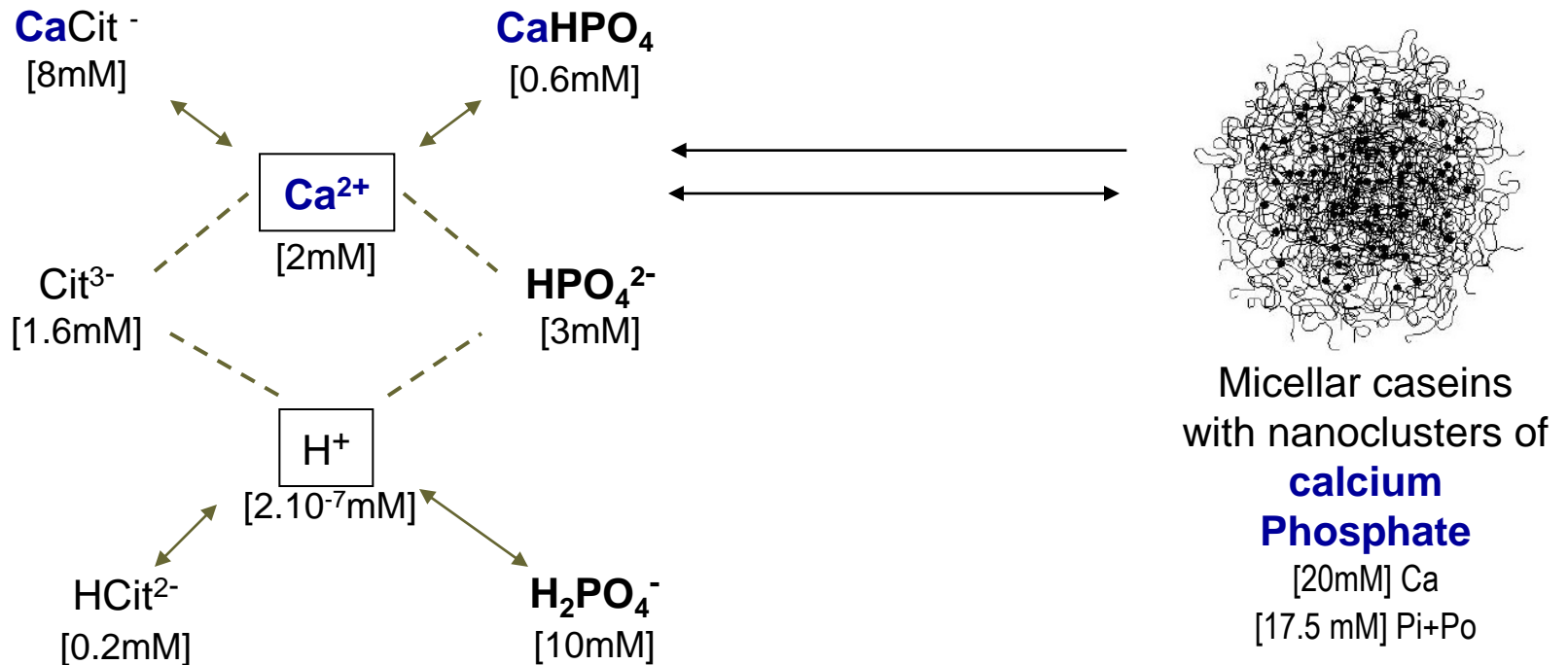
Calcium (~1200 mg/L)

Phosphorus (~ 950 mg/L)

Different Forms of Calcium in Milk

Aqueous Phase

Micellar Phase



Different Forms of Calcium in Dairy Products

- The forms and locations of calcium are multiple :
 - Free (ionic calcium \Rightarrow Ca^{2+}) (milk, fermented milks, cheeses)
 - Associated to
 - casein molecules (milk, cheeses)
 - counter-ions (inorganic phosphate, citrate) to form soluble salts
 - α -lactalbumin, osteopontin,.....
 - free fatty acids (after lipolysis) to form soap
 - phosphopeptides (after proteolysis of casein)
 - Precipitates under
 - calcium phosphate (surface of Camembert)
 - calcium lactate (Cheddar)
 - calcium carbonate (Emmental)
- Calcium concentration in the dairy products depend on the technology used to manufacture them
- Important to consider the different forms of calcium which could be differently absorbed (effect of environment – lactose, phosphopeptide, others cations, presence of chelatants – Ca/P ratio, type of matrix, ...)

Concentrations of Calcium in Some Dairy Products

(mg / 100 g)

Cheese and fermented milk foods, Vol 1, origins and principles, Kosikowski and Mistry, 3rd edition, 1997

Minerals	Ca	P	Mg	Na	K	Fe	Zn	Cu
Blue (USA)	528	387	23	1395	256	0.3	2.7	0.04
Brick	674	451	24	560	136	0.43	2.6	0.024
Brie	184	188	20	629	152	0.5	2.4	0.019
Camembert	387	346	20	842	187	0.33	2.4	0.021
Cheddar	721	512	28	620	98	0.68	3.1	0.031
Cheshire	643	464	21	700	95	0.21	2.8	0.042
Cottage	60	132	5	405	84	0.14	0.4	0.028
Cream	80	104						0.016
Edam	731	535						0.036
Feta	492	337						0.032
Gouda	700	546						0.036
Gruyere	1011	605						0.032
Limburger	498	393						0.021
Mozarella (whole milk)	517	371						0.02
Munster	717	468						0.031
Neufchatel	75	136						0.016
Parmesan (grated)	1376	807						0.037
Pasteurized Process Cheese	723	526	28	1552	284	0.6	3.5	0.03
Port Salut	650	360	24	534	136	0.43	2.6	0.022
Provolone	756	496	28	875	138	0.52	3.2	0.026
Ricotta (whole milk)	207	158	11	84	105	0.38	1.2	0.021
Roquefort	662	392	30	1809	91	0.56	2.1	0.034
Tilsit	700	500	13	753	64	0.23	3.5	0.026
Whole milk	119	93	13	49	151	0.05	0.4	0.01
Low fat milk	122	95	14	50	154	0.05	0.4	0.008
Skim milk	124	101	11	51	166	0.04	0.4	0.011
Yoghurt whole milk	121	95	12	46	155	0.05	0.6	0.009
Acid whey powder	2054	1348	199	968	2288	1.24	6.3	0.05
Sweet whey powder	796	932	176	1079	2080	0.88	2.0	0.07

Milk and dairy products



very good sources of calcium

Phosphorus in Milk

Trace elements

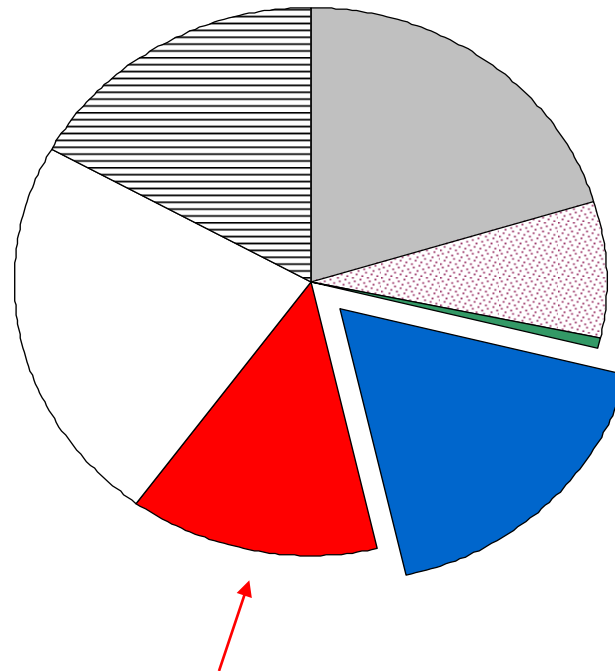
Chloride (~1200 mg/L)

Potassium (~1500 mg/L)

Citrate (~1600 mg/L)

Sodium (~500 mg/L)

Magnesium (~120 mg/L)



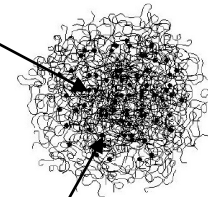
Phosphorus (~ 950 mg/L)

Calcium (~1200 mg/L)

Different Forms of Phosphorus in Milk

Organic phosphorus (Po)

- **Aqueous and lipidic phase** : Esterified with small molecules (nucleotides, sugars, phospholipides)
- **Micellar phase** : Esterified with casein (phosphoseryl residues)



Inorganic phosphorus (Pi)

- **Aqueous phase** :
 - Free ($\text{H}_2\text{PO}_4^- / \text{HPO}_4^{2-}$)
 - Associated with calcium (CaHPO_4)
- **Micellar phase** : Associated with micellar calcium

Variation of their ionisation and concentration as a function of physico-chemical conditions especially pH

Different Forms of Phosphorus in Dairy Products

Its form, location and concentration depend on the considered product :

- Free but with different ionisation state depending on the pH value
(~~H_3PO_4~~ \leftrightarrow H_2PO_4^- \leftrightarrow HPO_4^{2-} \leftrightarrow ~~PO_4^{3-}~~) (milk, fermented milks, cheeses)
- Associated to casein micelles (milk, cheeses)
- Associated to calcium to form soluble salts and precipitates (surface of Camembert)
- Associated with phosphopeptides (after proteolysis of casein)
- Associated to phospholipides, nucleic acids, sugar,
- Polyphosphates added for processed cheese

Concentrations of Phosphorus in Some Dairy Products

(mg/100 g)

Cheese and fermented milk foods, Vol 1, origins and principles, Kosikowski and Mistry, 3rd edition, 1997

	Calcium	Phosphorus	Magnesium	Sodium	Potassium	Iron	Zinc	Copper
Blue (USA)	528	387	23	1395	256	0.3	2.7	0.04
Brick	674	451	24	560	136	0.43	2.6	0.024
Brie	184	188	20	629	152	0.5	2.4	0.019
Camembert	387	346	20	842	187	0.33	2.4	0.021
Cheddar	721	512	28	620	98	0.68	3.1	0.031
Cheshire	643	464	21	700	95	0.21	2.8	0.042
Cottage	60	132	5	405	84	0.14	0.4	0.028
Cream	80	104						16
Edam	731	535						36
Feta	492	337						32
Gouda	700	546						36
Gruyere	1011	605						32
Limburger	498	393						21
Mozarella (whole milk)	517	371						2
Munster	717	468						31
Neufchatel	75	136						16
Parmesan (grated)	1376	807						37
Pasteurized Process Cheese	723	526	28	1552	284	0.6	3.5	0.03
Port Salut	650	360	24	534	136	0.43	2.6	0.022
Provolone	756	496	28	875	138	0.52	3.2	0.026
Ricotta (whole milk)	207	158	11	84	105	0.38	1.2	0.021
Roquefort	662	392	30	1809	91	0.56	2.1	0.034
Tilsit	700	500	13	753	64	0.23	3.5	0.026
Whole milk	119	93	13	49	151	0.05	0.4	0.01
Low fat milk	122	95	14	50	154	0.05	0.4	0.008
Skim milk	124	101	11	51	166	0.04	0.4	0.011
Yoghurt whole milk	121	95	12	46	155	0.05	0.6	0.009
Acid whey powder	2054	1348	199	968	2288	1.24	6.3	0.05
Sweet whey powder	796	932	176	1079	2080	0.88	2.0	0.07

Milk and dairy products



very good sources of phosphorus

Magnesium in Milk

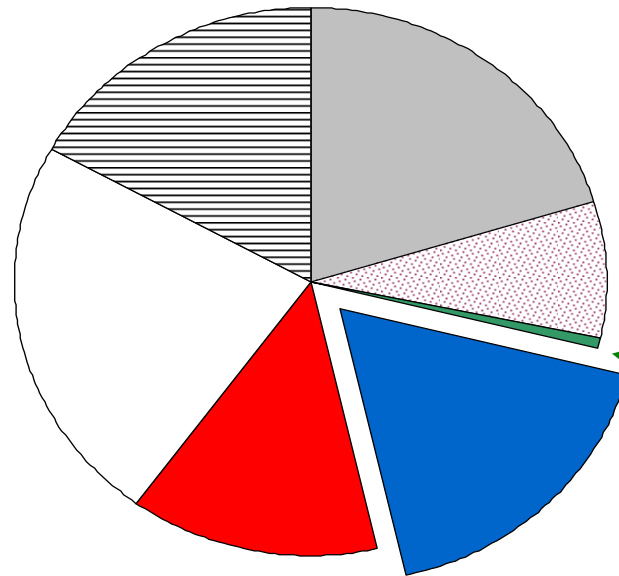
Trace elements

Chloride (~1200 mg/L)

Potassium (~1500 mg/L)

Citrate (~1600 mg/L)

Sodium (~500 mg/L)



Magnesium (~120 mg/L)

Calcium (~1200 mg/L)

Phosphorus (~950 mg/L)

Different Forms of Magnesium in Milk and Dairy Products

- In milk, magnesium is distributed between micellar (50 mg/L) and aqueous phase (70 mg/L)
- As described for calcium and phosphate, the chemical form, location and concentration of magnesium depend on the considered product :
 - Free
 - Associated to casein micelles
 - Associated to inorganic phosphate and citrate

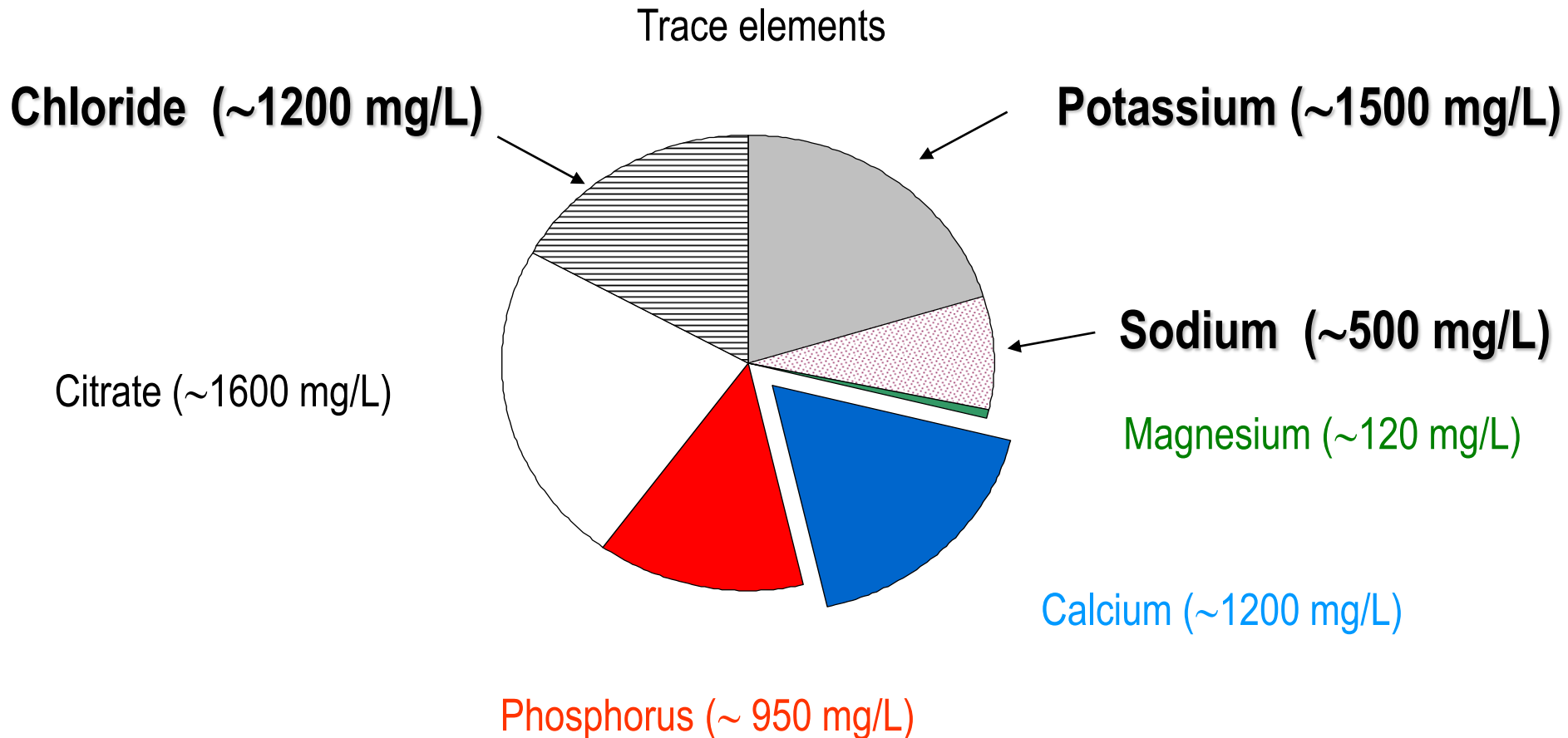
Concentrations of Magnesium in Some Dairy Products

(mg/ 100 g)

Cheese and fermented milk foods, Vol 1, origins and principles, Kosikowski and Mistry, 3rd edition, 1997

Minerals	Calcium	Phosphorus	Magnesium	Sodium	Potassium	Iron	Zinc	Copper
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Cheshire	643	464	21	700	95	0.21	2.8	0.042
Cottage	60	132	5	405	84	0.14	0.4	0.028
Cream	80	104	6	295	119	1.2	0.5	0.016
Edam	731	535	30	965	188	0.44	3.7	0.036
Feta	492	337	19	1116	62	0.65	2.9	0.032
Gouda	700	546	29	819	120	0.24	3.9	0.036
Gruyere	1011	605	36	336	81	0.17	3.9	0.032
Limburger	498	393	21	800	128	0.13	2.1	0.021
Mozarella (whole milk)	517	371	19	373	67	0.18	2.2	0.02
Munster	717	468	27	628	134	0.41	2.8	0.031
Neufchatel	75	136	7	399	114	0.28	0.5	0.016
Parmesan (grated)	1376	807	51	1861	107	0.95	3.2	0.037
Pasteurized Process Cheese	723	526	28	1552	284	0.6	3.5	0.03
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Sodium, Potassium and Chloride in Milk



Sodium, Potassium and Chloride in Milk and Dairy Products

- Monovalent ions (Na^+ , K^+ , Cl^-)
- Sodium, potassium and chloride are mainly in the aqueous phase of milk and dairy products
- Mainly free or weakly associated to ions of opposite charge
- In dairy products, the concentration of NaCl is increased by salting or brining (cheeses)
 - Contribute to :
 - Draining
 - Organoleptic properties of the cheeses
 - Selection of microorganisms and enzyme activities during ripening
 - Important variations depending on the type of the cheeses

Concentrations of Na and K in Some Dairy Products

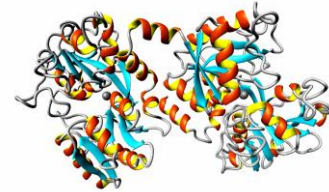
mg/100g

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Edam	731	535	30	965	188	0.44	3.7	0.036
Feta	492	337	19	1116	62	0.65	2.9	0.032
Gouda	700	546	29	819	120	0.24	3.9	0.036
Gruyere	1011	605	36	336	81	0.17	3.9	0.032
Limburger	498	393	21	800	128	0.13	2.1	0.021
Mozarella (whole milk)	517	371	19	373	67	0.18	2.2	0.02
Munster	717	468	27	628	134	0.41	2.8	0.031
Neufchatel	75	136	7	399	114	0.28	0.5	0.016
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Whole milk	119	93	13	49	151	0.05	0.4	0.01
Low fat milk	122	95	14	50	154	0.05	0.4	0.008
Skim milk	124	101	11	51	166	0.04	0.4	0.011
Yoghurt whole milk	121	95	12	46	155	0.05	0.6	0.009
Acid whey powder	2054	1348	199	968	2288	1.24	6.3	0.05
Sweet whey powder	796	932	176	1079	2080	0.88	2.0	0.07

Iron in Milk and Dairy Products

- Different states of ionisation (Fe^{2+} or Fe^{3+})
- In milk (associated to casein, citrate, lactoferrine)
- Results depend on the analytical methods used for the determination
- Milk and dairy products are considered as very poor sources of iron
 - ⇒ low contributions of dairy products to total iron intake



Iron Content of Some Dairy Products

Cheese and fermented milk foods, Vol 1, origins and principles, Kosikowski and Mistry, 3rd edition, 1997

	Calcium	Phosphorus	Magnesium	Sodium	Potassium	Iron	Zinc	Copper
Blue (USA)	528	387	23	1395	256	0.3	2.7	0.04
Brick	674	451	24	560	136	0.43	2.6	0.024
Brie	184	188	20	629	152	0.5	2.4	0.019
Camembert	387	346	20	842	187	0.33	2.4	0.021
Cheddar	721	512	28	620	98	0.68	3.1	0.031
Cheshire	643	464	21	700	95	0.21	2.8	0.042
Cottage	60	132	5	405	84	0.14	0.4	0.028
Cream	80	104	6	295	119	1.2	0.5	0.016
Edam	7	7	7	7	88	0.44	3.7	0.036
Feta	2	2	2	2	2	0.65	2.9	0.032
Gouda	7	7	7	7	20	0.24	3.9	0.036
Gruyere	1	1	1	1	1	0.17	3.9	0.032
Limburger	4	4	4	4	28	0.13	2.1	0.021
Mozarella (whole milk)	5	5	5	5	7	0.18	2.2	0.02
Munster	7	7	7	7	84	0.41	2.8	0.031
Neufchatel	7	7	7	7	4	0.28	0.5	0.016
Parmesan (grated)	1	1	1	1	07	0.95	3.2	0.037
Pasteurized Process Cheese	7	7	7	7	84	0.6	3.5	0.03
Port Salut	650	360	24	534	136	0.43	2.6	0.022
Provolone	756	496	28	875	138	0.52	3.2	0.026
Ricotta (whole milk)	207	158	11	84	105	0.38	1.2	0.021
Roquefort	662	392	30	1809	91	0.56	2.1	0.034
Tilsit	700	500	13	753	64	0.23	3.5	0.026
Whole milk	119	93	13	49	151	0.05	0.4	0.01
Low fat milk	122	95	14	50	154	0.05	0.4	0.008
Skim milk	124	101	11	51	166	0.04	0.4	0.011
Yoghurt whole milk	121	95	12	46	155	0.05	0.6	0.009
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Milk and dairy products



very poor sources of iron

Zinc and Copper in Milk

Zinc :

- Divalent cation
- Milk concentration ~ 3-4 mg/L
- Locations :
 - mainly associated (95%) to casein micelles
 - secondly associated to citrate molecules in the aqueous phase

Copper :

- Milk concentration ~ 0.1 mg/L
- Milk and dairy products : poor sources of copper \Rightarrow low contribution to the intake of copper
- Locations :
 - 8% to whey proteins
 - 44% to casein
 - 47% to low molecular weight fraction (citrate)

Zinc and Copper in Some Dairy Products

Cheese and fermented milk foods, Vol 1, origins and principles, Kosikowski and Mistry, 3rd edition, 1997

Minerals	Calcium	Phosphorus	Magnesium	Sodium	Potassium	Iron	Zinc	Copper
Dairy Products	mg/100 g	mg/100 g	mg/100 g	mg/100 g	mg/100 g	mg/100 g	mg/100 g	mg/100 g
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Cheddar	721	512	28	620	98	0.68	3.1	0.031
Cheshire	643	464	21	700	95	0.21	2.8	0.042
Cottage	60	132	5	405	84	0.14	0.4	0.028
Cream						0.2	0.5	0.016
Edam						0.44	3.7	0.036
Feta						0.65	2.9	0.032
Gouda						0.24	3.9	0.036
Gruyere						0.17	3.9	0.032
Limburger						0.13	2.1	0.021
Mozarella (whole milk)						0.18	2.2	0.02
Munster						0.41	2.8	0.031
Neufchatel						0.28	0.5	0.016
Parmesan (grated)						0.95	3.2	0.037
Pasteurized Process Cheese						0.6	3.5	0.03
Port Salut						0.43	2.6	0.022
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Sweet whey powder	796	932	176	1079	2080	0.88	2.0	0.07

Milk and dairy products
 😊 good sources of zinc
 ☹️ very poor sources of copper

Selenium in Milk and Dairy Products

- Concentration in milk : 30 µg/l
- Concentration in dairy products : poor knowledge
- Location : mainly in the skim milk
- Association with protein fraction (casein and whey protein)

General Roles of Minerals (7-9 g/l of milk)

- Structural functions (bone) (Ca, P, Mg)
- Homeostasis (Na, K, Cl, Ca, P)
- Muscular contraction (Na, K, Cl, Ca)
- Blood coagulation (Ca)
- Structure of cellular membranes
- Enzymatic systems (Cu, Fe, Zn, Se,...) and activation of enzyme (Ca, Mn, Fe, Mg, Cu, Zn,...)
- Complexes hormones/trace elements (Zn and I)

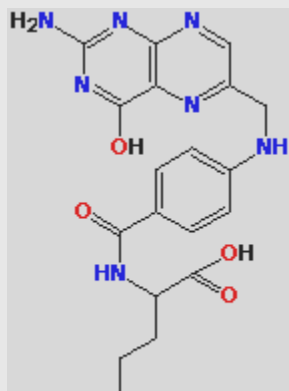
Recommended Daily Allowance (RDA) of Some Micronutrients of Milk for Human

600 ml of milk

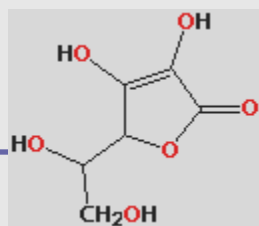


720 mg of Ca ↓ ~80 % of the RDA	65 mg of Mg ↓ ~16 % of the RDA	0.1 mg of Fe ↓ ~2.5 % of the RDA	2.4 mg of Zn ↓ ~20 % of the RDA	0.3 mg of Cu ↓ ~5 % of the RDA	20 µg of Se ↓ ~33 % of the RDA
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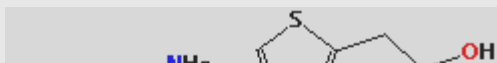
Vitamin B9 Folic acid



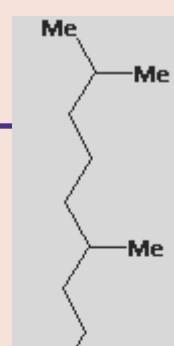
Vitamin C



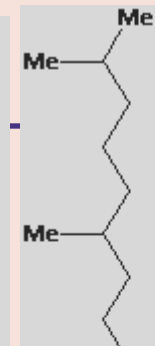
Vitamin B1



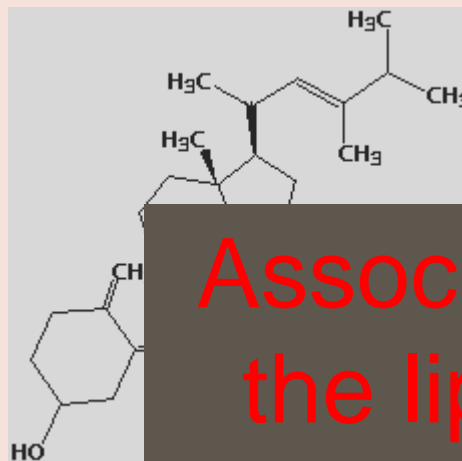
Vit E



Vit K



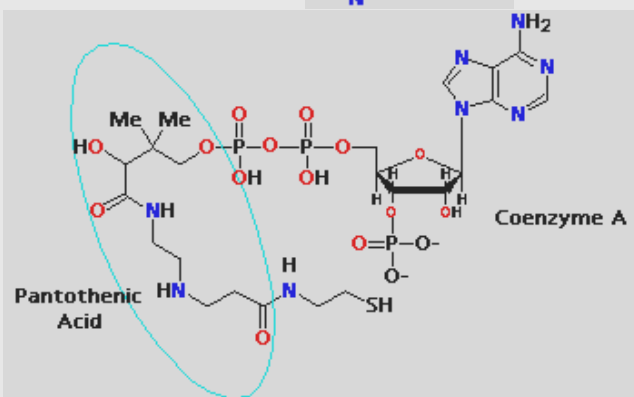
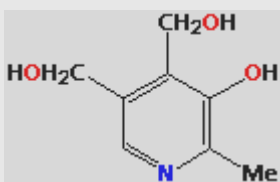
Vitamin D



Present in the aqueous phase of milk

Associated to the lipids of milk

Vitamin B6

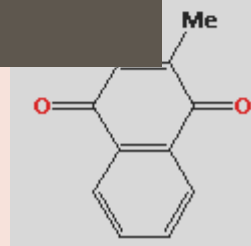
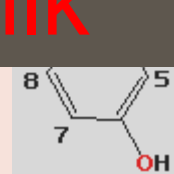
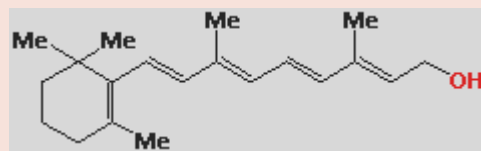


Vitamin B5 Pantothenic acid

Niacin



Vitamin A



Vitamin Contents in Some Dairy Products

Cheese and fermented milk foods, Vol 1, origins and principles, Kosikowski and Mistry, 3rd edition, 1997

	Vit B1	Vit B2	Vit B3	Vit B5	Vit B6	Vit B9	Vit B12	Vit A	Vit A	Vit E	Vit C
	Thiamin	Riboflavin	Niacin	Pantothenic acid		Folate					Ascorbate
	mg/100 g	mg/100 g	mg/100 g	mg/100 g	mg/100 g	µg/100 g	µg/100 g	IU	RE	ATE	mg/100 g
Blue (USA)	0.029	0.382	1.016	1.729	0.166	36.4	1.217	721	228	0.640	0
Brick	0.014	0.351	0.118	0.288	0.065	20.3	1.257	1083	302	0.500	0
Brie	0.070	0.520	0.280	0.600	0.225	65.0	1.650	667	182	0.655	0
Camembert	0.030	0.350	0.150	0.500	0.080	25.0	1.200	700	200	0.600	0
Cheddar	0.015	0.300	0.100	0.300	0.050	15.0	0.600	350	100	0.300	0
Comté	0.020	0.350	0.120	0.400	0.060	18.0	0.700	400	120	0.360	0
Emmentaler	0.015	0.300	0.100	0.300	0.050	15.0	0.600	350	100	0.300	0
Gruyere	0.060	0.279	0.106	0.562	0.081	10.4	1.600	1219	301	0.350	0
Limburger	0.080	0.500	0.150	1.177	0.086	57.5	1.040	1281	216	0.640	0
Mozzarella	0.015	0.300	0.100	0.300	0.050	15.0	0.600	350	100	0.300	0
Neufchatel	0.015	0.195	0.126	0.566	0.041	11.3	0.264	1134	264	ND	0
Parmesan (grated)	0.045	0.386	0.315	0.527	0.105	8.0	1.400	701	173	0.800	0
Pasteurized Process Cheese	0.014	0.400	0.104	0.500	0.035	5.8	2.300	856	243	ND	0
Port Salut	0.014	0.240	0.060	0.210	0.053	18.2	1.500	1333	372	0.500	0
Provolone	0.019	0.321	0.156	0.476	0.073	10.4	1.463	815	264	0.350	0
Ricotta (whole milk)	0.013	0.195	0.104	0.213	0.043	12.2	0.338	490	134	0.350	0
Roquefort	0.040	0.586	0.734	1.731	0.124	49.0	0.643	1047	299	ND	0
Tilsit	0.061	0.359	0.205	0.346	0.065	20.0	2.100	1045	291	0.701	0
Whole milk	0.038	0.162	0.084	0.314	0.042	5.0	0.357	126	31	0.100	0.940
Low fat milk	0.039	0.165	0.086	0.320	0.043	5.1	0.364	205	57	0.070	0.950
Skim milk	0.036	0.140	0.088	0.329	0.040	5.2	0.378	204	61	0.040	0.980
Yoghurt whole milk	0.029	0.142	0.075	0.389	0.032	7.4	0.372	123	30	0.088	0.530
Acid whey powder	0.622	2.060	1.160	5.632	0.620	33.2	2.500	58	9	0.015	0.900
Sweet whey powder	0.519	2.208	1.258	5.620	0.584	11.6	2.371	44	10	0.029	1.490

Milk and dairy are considered as essential sources for vitamins

↳ 250 ml of milk correspond to 12, 27 et 24% of human daily needs in vitamins B1, B2 and B12, respectively.

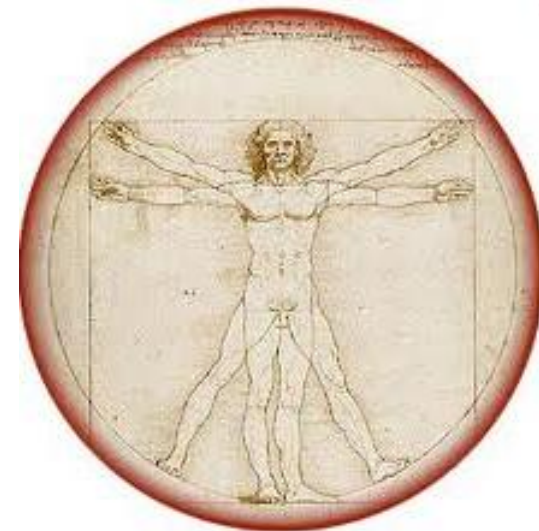
See next conference for more details

Variations in the concentrations of vitamins

- Diet
- Microbial synthesis in the gastrointestinal tract
- Endogenous synthesis by the animal tissues
- Difficulties of analytical determination

General Roles of Vitamins

- Good health of skin and eyes (**Vitamin A**)
- Participe to absorption of calcium (**Vitamin D**)
- Anti-oxidant (**Vitamin E**)
- Use energy coming from glucides (**Thiamin**)
- Protein synthesis (**Riboflavin**)
- Use energy and contributes to the nervous system (**Niacin**)
- Metabolism of proteins and development of tissues (**Pyridoxine**)
- Fabrication of red cells (**Folic acic and Vit B12**)
- Metabolism and formation of new tissues (**Pantothenic acid**)



The dairy products = unique sources of micronutrients



- ↪ Micronutrients are various in term of :
 - ↪ Concentration (milk to cheeses)
 - ↪ Forms, locations and interactions

- ↪ They contributes significantly to our state of health

- ↪ For vitamins, the data are lacking or sometimes not in accordance between them (difficulty of the quantification due to sample preparation and the use of appropriate methods)

- ↪ To understand the biological effects of these micronutrients, it is necessary to know the concentration but also to integrate the chemical form, their associations with others compounds (ions, proteins)

Perspectives : Some Actual Questions on Micronutrients



- What are the amounts of each vitamin in different dairy products?
- What are the evolutions of these micronutrients during the manufacture of dairy products?
- What are the effects of external compounds present in the food on the absorption of these micronutrients?
- Is it nutritionally interesting to enrich dairy products in micronutrients?

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- Thank you and congratulations to the scientific committee for organizing this symposium
 - Special “Thanks” to MC Bertière (CERIN) for this invitation and coordination

Thank you for your attention

