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TECHNOLOGICAL ASPECTS OF COPPER IN MILK PRODUCTS AND HEALTH IMPLICATIONS OF COPPER

Questions about copper in milk products frequently arise and are discussed. Milk itself is a food low in copper. However, when cheese is made in copper vats, copper can lead to quality problems in the by-products (1). The subject of this review is the state of knowledge regarding the technological and health implications of copper.

Copper was probably the first metal to be worked by man over 9000 years ago. The extraction of copper from ores ushered in the Copper Age and brought the Stone Age to an end. The copper deposits of the ancient world were found on Cyprus, hence the name "aes cyprium" (ore from Cyprus). Pure copper is a bright red, hard and easily forgeable heavy metal. It can be shaped into paper-thin sheets and into wire. It has the best electrical and thermal conductivity after silver. Copper alloys contain zinc, tin, silver, nickel, iron, aluminium, manganese, silicon and platinum, among others. Bronze, for example, contains ca. 80-90% of copper and 10-20% of tin. With a percent by volume of 0.01%, copper stands in 25th place in the frequency of elements found in the earth's crust. As a precious metal, it rarely occurs pure or in larger lumps (2).

The amount of copper contained in the human body is 100-150 mg. The required daily intake of copper of 1-2 mg is generally provided by a normal diet. Copper is an component of a number of oxidoreductases. From the point of view of food technology, copper has an unfavourable effect in many ways because it acts as a catalyst for unwanted reactions.

Analysis of the Situation

Raw milk contains only a low copper concentration. Therefore only a little copper is generally present in milk products. Technologically, an increased copper input can occur in the making of hard and semi-hard cheese, which leads to higher copper values in these cheese products and in the whey cream from this cheese production.

Copper from milk products has a twofold importance for nutrition. Directly it helps to provide the daily requirement of this important trace element, yet to avoid a health risk, the safety margin must be complied with. Indirectly the presence of copper can cause the formation of radicals, peroxides and other degradation products in milk fat, giving rise to quality defects in milk fat products due to increased oxidation.

Technological Aspects

Occurrence of Copper in Milk products

There is a variety of data on the copper content of milk and milk products. Older data give an average value in milk of 0.26 (0.05-0.3) (3) and 0.12 (0.01-0.7) (4) mg/L. A detailed study of the composition of milk and milk products of Swiss origin (5) also included determination of the copper content. These data are summarised in Table 1 and show that the copper content of milk is between 0.02 and 0.03 mg/kg. However, raw milk on the Canary Islands showed a level of 0.076 (0.03-0.16) mg/l and sterilised milk of 0.11 mg/l (6). The copper content of other foods is considered in the next chapter.

Table 1. Copper content of milk and milk products of Swiss origin (5) (data in mg/kg)

Products	Copper		Products	Copper	
	$\bar{x}$	s_x		$\bar{x}$	s_x
Full-cream milk past.	0.024	0.005	Emmental	15.3	3.7
Full-cream milk UHT	0.023	0.007	Gruyere	13.3	3.3
Milk drink past.	0.034	0.009	Sbrinz	16.6	4.4
Milk drink UHT	0.028	0.008	Appenzell	12.5	3.3
Skimmed milk UHT	0.032	0.011	Appenzell ¼-fat	19.8	8.1
Yoghurt, natural	0.044	0.017	Tilsit from raw milk	13.7	2.9
Sour milk Bifidus	0.038	0.008	Tilsit from past. milk	< 0.5	
Yoghurt, strawberry	0.091	0.04	Brie	0.6	0.1
Yoghurt, hazel nut	0.44	0.11	Camembert	0.8	0.6
Yoghurt, chocolate	0.64	0.16	Limburg	0.6	0.1
Yoghurt, Mocha	0.037	0.016	Raclette past.	0.7	0.1
Yoghurt, Mocha organic	0.054	0.022	Reblochon	0.5	0.2
Yoghurt, vanilla	0.047	0.022	Tête de Moine	5.6	2.4
Cream past.	0.038	0.013	Tomme	0.6	0.1
Cream UHT	0.035	0.017	Vacherin fribourgeois	4.9	1.7
Half cream past.	0.039	0.01	Vacherin Mont d'Or	8.7	3.5
Half cream UHT	0.036	0.014	Goats	5.0	3.11
Coffee cream (15% fat)	0.026	0.01	Glarner Schabziger		
Grade A butter	0.018	0.002	Stöckli	15.4	4.9
Cooking butter	0.038	0.026	Powder	39.6	5.7
Butter (Swiss product)*	0.108	0.05			
Light butter	0.077	0.022			
Butter for frying	<0.01				

* Butter obtained from a mixture of milk cream amd whey cream

Addition of Copper and Copper Contamination

During the making of raw milk cheese, copper regulates on important part of the ripening process by influencing the proteolytic enzymes and the activity of the participating microorganisms (7, 8, 9, 10, 11). Traditionally, in Switzerland hard cheese is made in copper vats. These products and its production are adapted to the effect of copper and copper is an integrated part of this manufacturing process. Usual copper levels in these cheeses lie between 7.6 and 16.5 mg/kg. The copper leached from the cheese vat walls is mostly bound by proteins and is therefore transferred into the cheese. In spite of this, the contamination of the whey is still great enough to cause quality problems in by-products such as whey cream.

Both, under- or overdosing of copper in cheese lead to quality defects. Excessively high levels inhibit propionic acid fermentation in Emmental or lead to brown or green discolouration of the texture of the cheese, as well as to brown, red or violet spots and to flavour defects. Nearly 50 years ago, Hänni and colleagues (12) established that a high copper content in conjunction with a high iron content can result in colour and flavour defects in cheese. Too low copper levels produce a poor flavour, in part due to ripening processes being too fast, but mainly they pose a risk of secondary fermentation. The copper content of cheese is actively controlled via surface treatment of the vessel walls in the cleaning procedure (13).

In the processing of all other milk products, it is a question of preventing contamination or of contaminated products such as the aforementioned whey cream from cheese-making. Such product should be treated separately and as special product. The larger portion of cream for butter-making is obtained during cheese-making. A distinction is made between sweet cream and whey cream. Some of the raw milk for cheese-making is separated. The sweet cream obtained from this is either turned into butter in the cheese factory or delivered to a butter factory. Some of the commercial milk is also separated, mainly to adjust the milk fat content and to use the surplus, in order to make cream for butter-making. The whey obtained during cheese making is also separated. It contains 2-6 g fat per litre, still. Several times, higher levels of copper were determined in sweet cream and whey cream. The following circumstances can cause a rise in the copper content:

- As mentioned cheese made in vats containing copper increases the copper content of all products made in them. Whey cream from this cheese production therefore also shows a higher copper content.
- Mixing of milk cream with whey cream.
- Brass parts are often chrome-plated. If the chrome coating is faulty, the risk of copper contamination is increased.
- Under certain circumstances, steam or water preparation can contribute to copper contamination.
- Ingredients and additives (sugar, hydrolysates) can occur as unexpected copper sources, also[1] (14).
- In the past, equipment parts containing copper (e.g. brass in old centrifuges or pumps) or collectors, which came into contact with the milk or milk cream, were sources of contamination, too.

Maximum Values for Butter in the Codex alimentarius

The Codex alimentarius used to lay down a maximum of 0.1 mg/kg for copper in butter. The current applicable standard (15) gives no data for copper.

Copper catalyzes Autoxidation of the Milk Fat

An increased copper level in sweet cream samples may have an unfavourable impact on its quality. Under the catalytic effect of the copper, the unsaturated fatty acids are oxidized more strongly. Radicals attack the double bond of these fatty acids. Volatile degradation products are formed via peroxides as interim stages, and these have a detrimental sensory effect. The cream or butter is considered to be oxidized, metallic, tallowy or in serious cases even fishy. Peroxides with dubious effects on health are also formed. The peroxide count in the fat rises. This is also classified as a quality defect in butter. Apart from sensory effects, the shelf life is also affected adversely. Therefore the copper content can be used as an indicator for correct processing of butter and cream.

Step-Control for Copper Contamination in Butter-making

If copper values in milk and milk products are above the accepted average values, the cause must be sought. It is recommended to carry out a step control. Possible causes which lead to copper contamination of milk, cream and butter have been discussed prior in 'Addition of copper and copper contamination'. The situation with regard to copper in butter production was further investigated by means of a step control in a traditional and an industrial creamery. These controls are shown as examples in figures 1 and 2. It was discovered that the copper level in butter from the traditional production plant was higher than in butter from the industrial creamery.

[1] According to a more recent publication, white sugar can contain up to 0.36 mg copper/kg (14)

Fig. 1: Copper level in the butter making of a traditional creamery (H.Eyer, unpublished results)
Key: M1 =mixed milk intake; M2 + M3 = storage tank; M4 + M5 = preliminary vessel Pasteur;
R1 = cream centrifuge; R2 + R3 = cream cooler; R4 = cream Pasteur; R5 = cream for butter-making;
B1 + B2 = butter 1 + 2

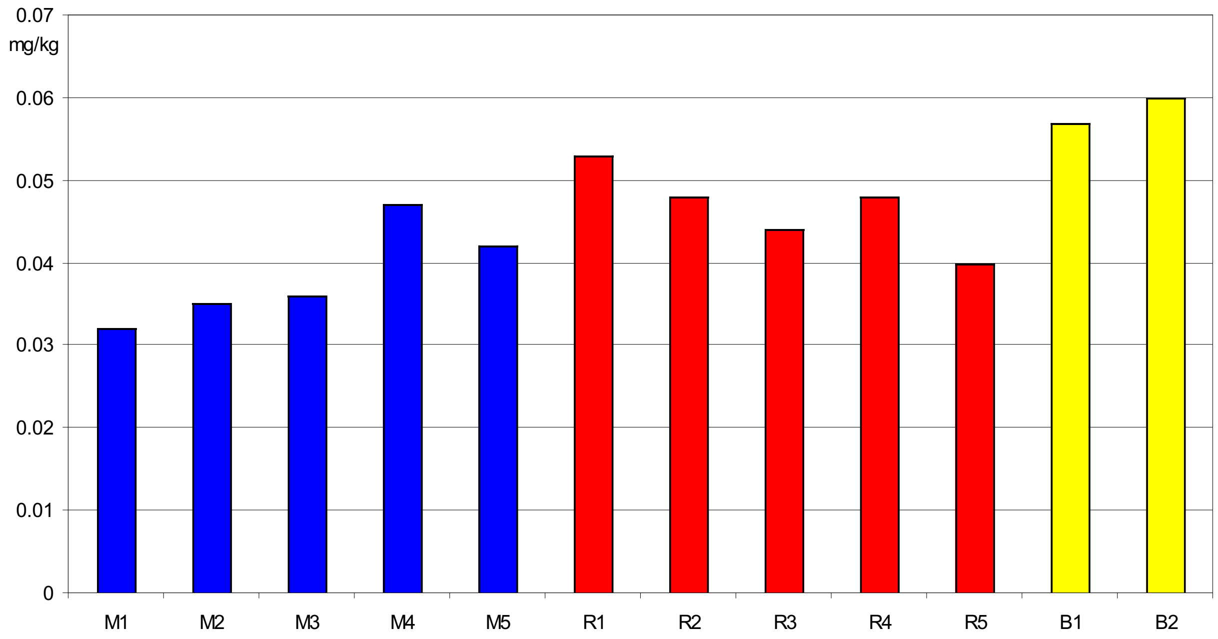
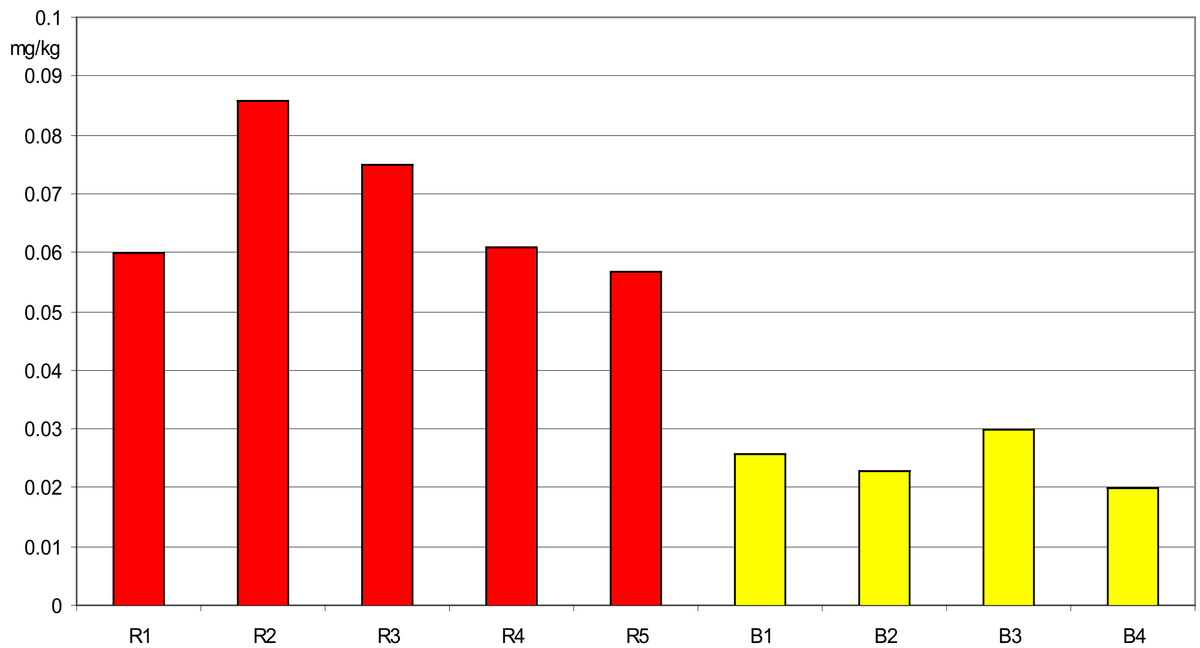


Fig. 2: Copper level in the butter making of an industrial creamery (H.Eyer, unpublished results)
Key: R1 = mature industrial cream; R2 = mature traditional cream; R3 = cream silo soured;
R4 + R5 = preliminary vessel butter-making machine;
B1 = butter-making machine; B2 = butter silo; B3 = shaping - modelling; B4 = shaping - stock



Detection of Copper

Copper is determined in cream by means of graphite-AAS [atomic absorption spectrometry] (in cheese by means of flame-AAS). Double determination is a standard procedure. Samples which oiled out hinder or prevent good mixing in the laboratory and can lead to a wider spread of the readings. Samples (at least 50 ml) must be cooled well immediately after taking and should reach the laboratory cooled. Trace components are not always uniformly distributed in spite of intensive homogenisation of the samples. This applies to the element of copper in particular. Large variations between the double determinations are therefore frequent with copper.

Physiological and Health Implications

Requirement

It is difficult to determine the copper requirement for human beings because the traditional indexes for the copper status are not sufficiently sensitive. According to studies by Turnlund et al. (16, 17) on 11 young men, who received 1.68 or 0.66 mg copper per day respectively for 24 days, then 0.79 or 0.38 mg for 42 days and finally 7.53 or 2.49 mg for a further 24 days, the minimum copper requirement should lie between 0.4 and 0.8 mg. Endogenous excretion was low when the copper intake in food was reduced. Hence the human organism shows an efficient adaptation mechanism in absorption and endogenous excretion, which prevents the development of a deficiency in case of low copper intake or toxic effects in case of increased intake.

The nutritional recommendations for copper intake over the last ten years of various countries differ considerably (Table 2). In the 1991 edition of its recommendations on nutrient intake, the "Deutsche Gesellschaft für Ernährung" (DGE) [German Society for Nutrition] (18) gave 1.5 to 2.5 mg copper per day as an estimated value for a suitable intake for children over 10 years of age and 1.5 to 3.0 mg copper/day for adolescents and adults. These were in line with the 1989 American recommendations (19) for children over 11 years of age and for adolescents. However, noticeably lower reference values were laid down in recommendations for England (20) at that time. The DACH[2] Recommendations (21) are also lower than the DGE Recommendations (18). In the most recent American recommendations (22), a distinction is made between Estimated Average Requirement (EAR)[3] and the Recommended Dietary Allowances (RDA)[4].

Tab. 2: Recommendations for copper intake (data in mg per day)

Age	DACH (21)	USA (22) EAR[a]/RDA[b]	DGE (18)	England[c] (20)	USA[d] (19)
Year	2000	2002	1991	1991	1989
1 to under 4 y.	0.5-1.0	0.26/0.34[e]	0.7-1.0	0.4	0.7-1.0
4 to under 7 y.	0.5-1.0	0.34/0.44[f]	1.0-1.5	0.6	1.0-1.5
7 to under 10 y.	1.0-1.5	0.54/0.7[g]	1.0-2.0	0.7	1.0-2.0
10 to under 15 y.	1.0-1.5	0.685/0.89[h]	1.5-2.5	0.8[i]/1.0[k]	1.5-2.5
Adolescents + adults	1.0-1.5	0.7/0.9	2.0-5.0	1.2	1.5-3.0

[a] Estimated Average Requirement
[b] Recommended Dietary Allowances
[c] Dietary Reference Value
[d] Estimated Safe and Adequate Daily Dietary Intake
[e] 1 to 3 years
[f] 4 to 8 years
[g] 9 to 13 years
[h] 14 to 18 years
[i] 11 to 14 years
[k] 15 to 16 years

2 DACH stands for recommendations on nutrient intake which are valid in Germany (D), Austria (A) and Switzerland (CH).

3 The Estimated Average Requirement is the nutrient intake value that is estimated to meet the requirement defined by a specific indicator of adequacy in 50 percent of the individuals in a life stage and gender group (22).

4 The Recommended Dietary Allowances is the average daily intake level that is sufficient to meet the nutrient requirements of nearly all (97 to 98 percent) individuals in a life stage and gender group (22).

Occurrence in Foods

Copper in foods occurs predominantly in offal, shellfish, certain cereal products as well as in nuts, cocoa and in many green vegetables (Table 3). Also some herbs and spices, for example basil, majoram, nutmeg and pepper, contain relatively large amounts of copper. On the other hand, tuber and root vegetables, confectionery, bakery good and pasta are low in copper (23). The occurrence of copper in milk and milk products of Swiss origin is shown in Table 1 (5). It demonstrates that with the exception of hard and semi-hard cheeses, which are produced in a copper vat, these foods are also low in copper. Breast-milk of the last 50 years shows a distinctly higher copper level than cow's milk with a median of 0.32 mg/l (24).

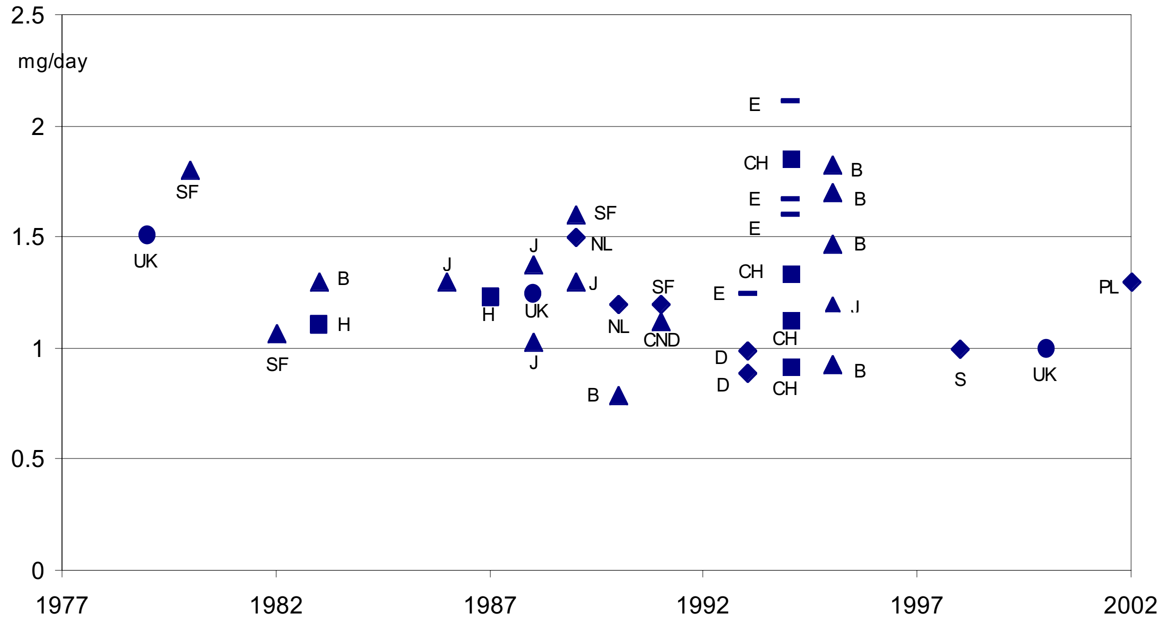
Tab. 3: Copper content of foodstuffs (23)

Food	Copper content (mg/kg)	Food	Copper content (mg/kg)
Cereals		**Nuts**	
Oat flakes	7.3 to 10.3	Hazel nuts	13.5
Rye flour, dark	6.56	Brazil nuts	10.9
Wheat bran	4.6 to 19.9	Walnuts	3.1
Whole wheat flour	4.35	Peanuts	2.7
White wheat flour	1.47	Almonds	1.4
Coarse wholemeal bread	0.6 to 14.5	**Meat/fish**	
Rye bread	0.4 to 6.8	Calf liver	40.0
Vegetables		Beef liver	20.8 to 34.5
Peas (fresh)	2.3	Poultry	2.0 to 4.1
Spinach	2.0	Pork	1.0 to 3.1
Potatoes	1.6 to 2.8	Beef	0.6 to 1.6
Cauliflower	1.4 to 2.3	Fish	0.1 to 3.4
Carrots	1.1	**Other**	
Tomatoes	1.0 to 2.5	Eggs	0.3 to 2.3
Cucumbers	0.6	Butter	0.06 to 0.4
Red cabbage	0.15 to 2.5	Milk	0.05 to 0.7
Cabbage lettuce	0.1 to 3.8	Honey	2.0
Fruit		Sugar	0.4 to 2.4
Bananas	1.35 to 2.0		
Strawberries	1.3		
Pears	1.1 to 1.34		
Grapes	1.0		
Oranges	0.76		
Apples	0.62 to 3.0		

Intake

Copper intake through food was investigated in various duplicate studies (25, 26, 27, 28). Worldwide, copper intake varies for the most part between 0.6 mg and 3.3 mg per day and person, with two exceptions (not integrated in the figure): 4.8 mg in China and 8.6 mg in Madrid (Figure 3). The intake amounts for copper measured in these two cases are above the DACH recommendations.

Fig. 3: Copper intake in duplicate studies from different countries (listed according to year of publication, compiled according to 25, 26, 27, 28)



For Switzerland there is a duplicate study by Zimmerli et al. (29) published in 1994, which was carried out as early as 1983. The results (average value in mg/day and person) were:

Restaurant staff	1.31 (0.8-2.37)
Hospital staff	0.92 (0.65-1.57)
Vegan (ovolactovegetarians)	1.34 (0.8-1.99)
Recruit Training Camp	1.86 (1.16-2.5).

The average values of the first two institutions (staff restaurant, hospital) differed very significantly from the last one (recruit training camp) ($p < 0.01$). The lowest and highest average values differed by a factor of 2. The single values fluctuated overall between 0.65 and 2.50 mg/day. The intake amounts calculated in the Third (30) and the Fourth (31) Swiss Report on Nutrition each amounted to 2.5 mg per day and person and are therefore clearly above the actual value of around 1.4 mg per person obtained from all daily rations. The contribution of milk and milk products to the copper supply of the Swiss population is approximately 5% according to the calculations for the Fourth Swiss Report on Nutrition (31).

Copper Absorption, Transport and Excretion in the Organism

Copper is an essential trace element and is necessary for adequate growth, integrity of the cardiovascular system, elasticity of the lungs, neuroendocrine function and iron metabolism (32).

Various factors in nutrition can affect the bioavailability of copper (Table 4) (33, 34). It is known that children absorb more copper from breast-milk than from cow's milk. Increased concentrations of complexing agents such as phytate, dietary fibre and also increased levels of zinc or vitamin C reduce absorption. Taking zinc supplements can lead to a reduction in copper-zinc-superoxide dismutase activity in the erythrocytes. Thus a daily zinc intake of 50 mg, which corresponds to an amount around four times the recommended requirement, reduced superoxide dismutase activity by 20%. Other minerals such as iron, tin, calcium, phosphorus, cadmium and molybdenum can interact with copper, but their effect in humans is less than with zinc. The interaction between copper and ascorbic acid is not clearly known. It is possible that Cu^{2+} ions are reduced by ascorbic acid to Cu^{+} ions, which lowers absorption of copper in the body. On the other hand, bioavailability is increased by certain essential amino acids as well as by oxalate and fumarate.

Tab. 4:. Influencing the bioavailability of copper (34)

	human	laboratory animals
Dietary fibre		
phytate	—	±
hemicellulose	↓	nd
Carbohydrates		
fructose	↓	↓
glucose polymers	nd	↑
Fat		
triglycerides	—	—
long-chain fatty acids	nd	↓
medium-chain fatty acids	nd	—
Protein		
protein rich diet	↑	↑
excess amino acids	±	↓
Organic acids		
ascorbic acid	±	↓
natural polybasic amino acids	↑	nd
Divalent cations		
zinc, iron, tin, molybdenum	↓	↓

— = no effect; **±** = uncertain; ↑ = increased; ↓ = reduced; **nd** = no data

The amount of copper which is absorbed can vary. In general, approximately 30 to 40% of dietary copper is absorbed. The absorption rate depends on the amount of copper available. In the aforementioned study of the 11 young men by Turnlund et al. (16), a percentage absorption of 56% was established with a daily intake of 0.79 mg, of 36% with 1.68 mg and of 12% with 7.53 mg. After absorption, which takes place in the small intestine via the mucosa through energy-neutral diffusion and then through divalent transport systems (an energy-requiring mechanism) into the blood, copper is bound to albumin and transcuprein for transport to the liver. There, in coeruloplasmin synthesis, copper is bound to the latter which transports it to the tissues. Distribution of copper in the blood is around 18% to albumin, around 65% to coeruloplasmin and around 12% to transcuprein. In addition, copper can also be bound to small peptides and amino acids. Approximately 2/3 of the absorbed copper is excreted again with the bile, so that around 80-90% of dietary copper is found in the stool. Less than 0.1 mg copper/day is excreted via the kidneys. Its biological half-life in the adult body is around 20 days on average.

Role of Copper in Metabolism

Approximately 100 mg of copper is present in the human body, on average 1 to 2 mg/kg body weight. It is mainly found bound to proteins. Copper is distributed in the adult human body as follows: blood 1.1; plasma 1.05; kidneys 12; liver 6.2; brain 5.2; heart 4.8; hair 20 and nails 8 to 20 μg/g (35).

Copper forms part of a large number of enzymes (35) such as cytochrome-c oxidase (1.9.3.1; widespread), superoxide dismutase (1.15.1.1; cytosol of liver, erythrocytes, brain), dopamine-b-monooxygenase (1.14.17.1; adrenal glands, formation of catecholamines), tyrosinase (1.14.18.1; cytoplasm of melanocytes), coeruloplasmin or ferroxidase I (1.16.3.1; plasma), ferroxidase II (1.16.3.2; plasma). It is necessary for the functioning of various enzymes in anaerobic metabolism (energy production, many oxidoreductases with high redox percentage) such as cytochrome-c oxidase in the mitochondria, lysyloxidase in the connective tissues, dopamine-monooxygenase in the brain and coeruloplasmin. As cofactor for apo-copper-zinc-superoxide dismutase, copper can protect against damage by free radicals to proteins, membrane lipids and nucleic acids in a variety of cells and organs. This enzyme is therefore an important antioxidant. The activity of superoxide dismutase in the erythrocytes can be used to assess the copper status in humans.

In addition to participating in the metabolism of iron, copper is also involved in the formation of erythrocytes (red blood cells), that is in haemapoiesis, specifically in the creation of haemoglobin (red blood pigment). Copper is part of the coeruloplasmin, that catalyzes the oxidation of divalent to trivalent iron, which is described as ferroxidase activity of this enzyme. Therefore in a distinct copper deficiency (microcytic) anaemia may occur. Moreover, copper participates in the formation of collagen and elastin in the connective tissues. It also contributes to the synthesis of epinephrine and norepinephrine in the adrenal- and nervous system. Copper is also necessary for the formation of melanin in the skin. Furthermore, this element has the effect of stimulating the immune system and of inhibiting inflammation.

Copper Deficiency

An acquired copper deficiency is characterized by bone abnormalities, severe anaemia, reduced immune function, skin loss and retarded growth. Under normal circumstances actual diseases of copper deficiency have not yet or only rarely been observed compared with iron. Risk groups include premature babies, people taking zinc supplements, the elderly, people with diabetes and high blood pressure and those with a genetic disposition.

Toxicology

The amount of copper which leads to nausea is given as around 65 mg for adults. Data on acute toxicity of copper ions indicate that, depending on individual sensitivity, type and composition of the diet, amounts from as low as about 10 mg can lead to symptoms (particularly nausea and vomiting) (29). Little is known about the possible chronic toxicity of copper in humans. Human beings seem to be protected against chronic poisoning due to the nauseous effect of high amounts of copper. However, some cases of copper poisoning have been described. According to a compilation in a report by the US Committee on Copper in Drinking Water (2), 30 cases of poisoning with a total of 364 people are described in the literature. Of these 33 resulted in death. Most of these were suicides, and the amount of copper used was known only in a few cases. In one case an amount of 20 g of copper is reported, in eight other cases the copper intake was estimated to be between 1 and 30 g. Recently a case was published of a 25-year old woman, who attempted suicide by taking 25 Diazepam tablets. As a result she was given 2.5 g cupric sulphate in 1.7 l water as an emetic, but the woman died 3 days later of acute haemolysis and acute kidney failure due to copper poisoning (36).

In the American recommendations, a No-Observed-Adverse-Effect-Level (NOAEL) of 10 mg/day was deduced and determined as the upper limit of the daily copper intake for adults. This level is 1 mg/day for children from 1 to 3 years, 3 mg/day from 4 to 8 years, 5 mg/day from 9 to 13 years and 8 mg/day for adolescents (22). An increased copper intake can present a health problem only in the case of infants whose copper metabolism is normally not fully formed, yet, and in that of congenital metabolism disorders (Wilson disease).

Role of Copper as Antioxidant and Prooxidant

There are two sides to copper. As an ingredient of superoxide dismutase it can contribute to antioxidant activity. On the other hand, free copper has the potential to have a prooxidant effect.

As early as the 70s, Klevay (37) hypothesized, that a relative or absolute copper deficiency, characterized by a high ratio of zinc to copper in the diet, leads to hypercholesterolemia, and this was confirmed in various tests on animals. This can be explained by two mechanisms: firstly by reduced superoxide dismutase activity and secondly by a too high copper status. Increased formation of lipid peroxides and reduced formation of prostaglandins are caused by a copper deficiency in the aorta via reduced copper-dependent superoxide dismutase activity. Rats fed a copper deficient and fructose-enriched diet died prematurely due to heart abnormalities. However, with simultaneous reduced iron intake, no heart abnormalities could be detected. As a second mechanism, a high copper status in the form of an increased serum copper concentration should be considered to be an independent risk factor for coronary heart disease. Free copper leads in vivo to the formation of free radicals, which result in the formation of oxidized LDL via lipid peroxidation or via cholesterol oxidation, thereby increasing atherogenesis. Other factors such as low serum concentrations of selenium or of antioxidants also come into play in this whole event. Thus the "French Paradox" (apparent compatibility between a high fat diet with a low incidence of coronary atherosclerosis) is explained by the effect of phenolic compounds contained in red wine on the copper-catalyzed oxidation of LDL.

On the other hand, as a component of superoxide dismutase, copper can also be effective as an antioxidant, by dismutating two superoxides (O_2^-) to oxygen (O_2) and peroxide (H_2O_2). The latter is then used by other enzymes (catalase, glutathione peroxidase).

Diseases

In India, occasional cases of early childhood cirrhosis of the liver (Indian childhood cirrhosis [ICC]) with excessive accumulation of copper in the liver have been described, particularly in non breast-fed infants. It is suspected that a high copper intake from milk stored or prepared in brass and copper vessels besides other possible circumstances can lead to cirrhotic changes. Between 1900 and 1980, 138 children in Tyrol died of cirrhosis, which was also attributed to an excessive intake of copper (2). A similar pattern of illness with a number of deaths was also described in non breast-fed babies in Germany (German childhood cirrhosis [GCC]), where it was plausibly assumed that high levels of copper contamination of the drinking water of domestic wells (copper pipes, high acidity in water) was the root cause (38, 39). However, according to a prospective study, a health risk cannot be concluded for copper pipes which are connected to the public drinking water network (40).

Menkes syndrome (progressive brain disease) is a congenital copper deficiency disease due to reduced absorption from the digestive tract. Boys are predominantly affected by this syndrome. Copper cannot be transported through the membrane of the intestinal mucosa and accumulates in these cells. This leads to a deficiency of various copper-containing enzymes. Early treatment with intravenous or oral copper supplements can be of benefit. However, the prognosis for individuals with this disease must be considered poor and most die in their first ten years (2).

Wilson disease is a disease of autosomal recessive inherited copper accumulation. Copper is stored in the liver, the central nervous system, in the eyes and kidneys due to defective excretion capacity. The first symptoms appear between the ages of 6 and 20, but can also arise as late as 40. This disease, which has an incidence of approximately 3 per 100,000 inhabitants, finally leads to cirrhosis of the liver and neurological effects, mainly during the early decades of life. Treatment lies in lifelong administration of drugs such as D-penicillamine or trientine hydrochloride, which remove the copper from the tissues. A high zinc intake and a low-copper diet can also be helpful (2).

Conclusion

Although milk is a low-copper food, an increased level of copper can occur in milk products due to the production process. From the nutritional point of view, the copper intake due to this does not have a major effect on the organism, because milk and milk products are low in copper. From the technological viewpoint, however, an excessive level of copper in cream and butter is undesirable. An increased copper content can lead to sensory defects and also to storage problems. Copper contamination of milk, cream and butter must therefore be avoided.

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