REPORT OF THE SCIENTIFIC COMMITTEE FOR ANIMAL NUTRITION ON THE USE OF COPPER COMPOUNDS IN FEEDINGSTUFFS

Opinion expressed 15 April 1982

TERMS OF REFERENCE (December 1977)

The Scientific Committee for Animal Nutrition is requested to give an opinion on the following questions :

1. Does the addition of copper compounds to feedingstuffs result in significant effects on growth and/or on the conversion rate of the feed? In this respect, are the maximum contents of copper authorized (see Background) justified?

2. What is the relationship between the copper content of the animal ration and the residual amount in animal tissue and organs? Are the residues resulting from the authorized conditions of use free from risks to the consumer?

3. What is the relationship between the copper content of the ration of the animal and the amount excreted? Can the amount of copper excreted, resulting from the authorized conditions of use, be prejudicial to the environment, and if so what is the nature of the risks?

4. In the light of the answers to the above questions, should the conditions of use authorized for the addition of copper compounds to feedingstuffs be maintained or should they be modified?

BACKGROUND

In accordance with the provisions of Council Directive 70/524/EEC of 23 November 1970 concerning additives in feedingstuffs (1), as last amended by the twentieth Commission Directive of 7 December 1977 (2), the addition of copper compounds is authorized at Community level under the following conditions set out in Annex I, Section (i), of the Directive :

Additive	Species of animal	Maximum content (ppm (mg/kg) feedingstuff)
Copper acetate Basic copper carbonate monohydrate, Copper chloride Copper oxide Copper sulphate	Swine Other species	125 (total Cu) 50 (total Cu)

Furthermore, Member States are authorized to use, by way of derogation up to 31 December 1978, complete feedingstuffs for swine with a maximum copper content (total Cu) of 200 mg/kg (Annex II, Section D (a) of the Directive).

OPINION OF THE COMMITTEE

1. Copper is a trace element essential for physiolocigal equilibrum. The physiological copper requirements of animals vary according to the species; generally speaking, they seem to be adequately covered by the copper content of vegetable and animal origin which make up their

(1) OJ No L 270, 14.12.1970, p. 1
(2) OJ No L 18, 24.01.1978, p. 7

daily rations (Maletto 1959, Jacquot et al. 1964, Boccard 1980)*.

1.1 The addition of copper compounds to feedingstuffs in quantities exceeding physiological requirements has favourable effects, similar to those of growth promoters, on weight gain and feed conversion in certain animal species. The effects have only been thouroughly studied in pigs. The results of numerous feeding trials involving large numbers of pigs, designed to investigate the effects of copper in relation to feed composition, feeding systems and other variables, have been published and discussed in comprehensive reviews of the literature (Braude 1967 and 1975, Meyer and Kröger 1973, CLO 1978, UKASTA 1978, Brajon et al. 1980, Proc. EEC Workshop 1981).

1.1.1 According to data reported by Meyer and Kröger (1973), the addition of 125 and 250 mg of copper (in sulphate form) per kg feed for early-weaned piglets between 3 and 12 kg liveweight produces average increases in weight gain of 22.2% and 28% respectively, and average improvements of 14.3% and 15% respectively in the feed conversion ratio. These values fall to 10.2% and 14.2% (weight gain) and 2.6% and 3.9% (feed conversion) in piglets between 5 and 25 kg liveweight.

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* The copper contents of daily rations given below, in mg/kg dry matter, are regarded as sufficient for physiological requirements: piglets: 6-10; adult pigs: 6; calves: 9; adult cattle: 10-14; sheep: 5; chickens (up to 8 weeks): 2; adult chickens: 3,2; turkeys: 4; rabbits: 3-5 (Jacquot et al. 1964, Neathery and Miller 1977, Brajon et al. 1980, Boccard 1980).

But the investigators stress that no conclusion may be drawn as regards the optimum copper content of the feed because of the range of variation of the individual values. Aumaître (1981) and Braude (1981) find that, up to a weight of 20 kg the effects of the addition of 250 mg copper per kg of feed are variable and sometimes nil.

1.1.2 The addition of 100-150 mg of copper (in sulphate form) per kg of feed for fattening pigs produces, according to data reported by Meyer and Kröger (1973), an average increase of 4.7% in weight gain and an average improvement of 2.3% in feed conversion in the period between 15-30 kg and 90-110 kg liveweight. The addition of 250 mg copper per kg feed procures an average increase of 7.4% in weight gain and an average improvement of 4.6% on the feed conversion ratio. The corresponding values for 250 mg copper per kg feed reported by Braude (1967 and 1975) are as follows: 8.1 and 5.4% (trials between 1955 and 1965); 9.1 and 7.4% (trials between 1965 and 1975). According to trials carried out in the Netherlands (CLO 1978), the dose/effect ratio is linear at least up to 270 mg of copper/kg feed for the weight range between 20 and 110 kg liveweight. The results of a statistical analysis of data in 129 publications (period between 1953 and 1975) carried out by UKASTA (1979) indicate that the optimum copper level is 224 mg/kg feed and that this achieves an average improvement of 6.5% on weight gain for the growth/fattening period.

1.1.3 The range of variation underlying these average values is attributable to a number of factors; in particular, the type and quantity of protein in the ration, and the quantities of iron, zinc, molybdenum and sulphur in the feed play a significant role. The effects of these factors are more variable when the copper content of the ration is low; variability tends to become insignificant at the level of 250 mg copper/kg feed (Maletto et al. 1980).

According to the data reported by Meyer and Kröger (1973), the improved growth performance observed in piglets (see Section 1.1.1 above) was not obtained when the feed contained a high proportion of skimmed milk powder. The improvements in weight gain recorded in fattening pigs at the end of the first rearing period (up to 60 kg liveweight) were distinctly better in pigs receiving feed containing fish or meat meal than in those receiving soya cakes, irrespective of the quantity of copper added (100-150 mg/kg and 250 mg/kg). On the other hand, the phenomenon was observed in reverse in the final fattening stage.

1.1.4 In cattle, the addition of copper salts exceeding physiological requirements to feed seems to have little effect; in sheep it is harmful. (See Section 3.2.2 below.)

1.1.5 In poultry and rabbits the addition of copper to feed has produced variable improvements in growth, depending on the composition of the ration (Beede and Sullivan 1975; Omole 1977 and 1980). A drop in mortality due to dissecting aneurysm has been observed in turkeys after the administration of a high protein ration supplemented with 120 mg of copper/kg feed (Hill 1969, Guenther and Carlson 1975).

1.2 According to these data, the maximum copper contents authorized in the Community in animal feed appear to be justified, economically, only in pig management. It has been established that there is no significant difference between the effectiveness of copper sulphate, carbonate, chloride or oxide (Braude 1965).

For sheep, the authorized maximum copper content is unacceptable for toxicological reasons; it should be reduced to 15-20 mg/kg complete feed. For other species, the maximum content of 50 mg/kg complete feed seems acceptable but it is not substantiated by sufficient data.

2. Copper levels in the animal organism vary according to species and according to the tissues or organ concerned. The highest levels are found in the liver. Copper ingested with feed is absorbed only partially. It circulates in the blood in the form of complexes bound to albumins and amino acids (Ludvigsen 1981). It is stored, as cuproprotein, in the liver and, to a small extent, in the kidneys, the spleen, the lungs and the muscles. The liver regulates the homoeostasis of the copper firstly by synthesis of the coeruloplasmin in the blood and by excreting excess copper as complexes through the bile. Only a small proportion is eliminated via the urine. The rate of copper retention in pigs is very low and varies between 2-10% (Bowland et al. 1961).

2.1 The data available on the ratio between the copper content of the feed and the quantity of residual copper in the organs and animal tissues relate only to pigs.

2.1.1 In fattening pigs receiving a diet supplemented with copper, the copper level in the liver rises with the copper content in the feed and the duration of the copper-supplemented diet. According to data collected by Meyer and Kröger (1973), this process of accumulation is not linear (see table below).

Relation between dietary copper and liver copper in pigs (90-110 kg) (Meyer and Kröger, 1973)

Quantity of Cu added to the diet (mg/kg)	Cu concentration in the liver (mg/kg of wet tissue)	
	Average	Range of values
0	12	1,6 - 57
60	17	12,6 - 29
125	57	7,3 - 273
250	256	8,0 - 890
500	817	- 1556

The ratio between the average quantity of copper accumulated in the liver and the quantity ingested increases appreciably when the ingested quantity exceeds 125 mg of copper/kg feed. The copper level in the liver drops when copper supplementation is stopped (Meyer and Kröger 1973, Castell et al. 1975, Lillie et al. 1977, Braude 1978). In pigs receiving copper (in the form of sulphate) at a concentration of 250 mg/kg feed, the copper level in the liver falls to less than half when supplementation is discontinued either 14 days before slaughter or as soon as the middle of the fattening period is reached (Braude 1978).

The average values quoted by Meyer and Kröger (see table) are distinctly higher than those collected by other authors. According to Braude and Ryder (1973) the average copper level in the liver is 286 mg/kg dry matter (=95 mg/kg wet tissue) in pigs receiving a feed ration supplemented with 250 mg Cu/kg. According to Nadazin et al. (1977), in pigs receiving 50 and 250 mg of copper/kg feed, the copper content in the liver was 8.9 and 88.1 mg/kg of wet tissue. According to trials carried out in the Netherlands (CLO 1978) the copper level in the liver is 150 mg/kg dry matter (=50 mg/kg wet tissue) in the case of a feed ration supplemented with 200 mg/kg.

2.1.2 The wide range of variation of the values is explained to a large extent by the variability of the composition of feed rations on different livestock units. The type and quantity of proteins in the feed ration and the quantity of trace elements (zinc, iron and molybdenum) and sulphur seem to be decisive. It has been established that copper retention by the liver is two to four times higher in the case of animal-protein-based rations than in the case of vegetable-protein-based rations (Combs et al. 1966, Parris and McDonald 1969, Drouliscos et al. 1970). On the other hand, copper retention is inhibited by the addition of zinc and iron to the feed ration (De Goye et al. 1971). The low levels of copper in the liver recorded in the Dutch trials (CLO 1978) were attributed to appropriate supplementation with zinc and iron and the lack of animal proteins in feed rations. This type of feed for pigs is now commonly used.

The chemical and/or physical form in which copper is ingested can also influence the degree of retention (Bekaert et al. 1967, Kirchgessner and Grassmann 1970).

2.2 Copper requirements and copper metabolism and toxicity in man are well known (Mason 1979, Bories 1981). According to a WHO report (1971), daily intake of 0.5 mg Cu/kg body weight may be regarded as a maximum acceptable dose provided that the diet contains appropriate quantities of zinc, iron and molybdenum. According to various surveys in Western countries, the average copper content of the human diet rarely exceeds 1-2 mg/kg food. There is therefore a large margin of safety between the quantity of copper ingested each day and the maximum acceptable daily intake (30 mg for a subject weighing 60 kg). Occasional consumption of pig's liver possibly containing a large quantity of copper resulting from the authorized maximum level of copper in pig feed (200 mg total Cu/kg complete feed) is therefore not likely to be hazardous for the consumer. However, it seems inadvisable to use liver with a high copper content for feeding young children in view of the fact that large quantities of liver are often incorporated in dietary preparations for daily consumption (Bories 1981).

Changes in the quality of pork fat (particularly a drop in melting point and an increase in the unsaturated fatty acid content) attributable to an increase in the activity of the hepatic enzyme stearyl CoA desaturase induced by excess copper, have been observed only in certain circumstances and where feed rations have contained more than 200 mg Cu/kg (Brajon et al. 1980).

3. When copper supplements are fed continuously over a long period, there is a direct relationship between the amount of copper ingested and the amount excreted (Brajon et al. 1980, CLO 1978).

3.1 According to calculation by Feenstra et al. 1979, if pigs are administered copper supplements in their feed at the rate of 200 mg/kg, about 68 g of copper/animal will have been excreted by the time market weight is reached. A total of 144 g copper per fattening place will thus be excreted each year. According to a report published by the E.C. Commission (1978), if weaned piglets are fed on a diet supplemented with 200 mg Cu/kg from the first to the seventh week and then 125 mg Cu/kg until the nineteenth week, then 86 g will be excreted per fattening place per year.

3.2 Copper administered to pigs reappears in the environment as a result of the use of slurry and manure as fertilizer and of waste water purification plants. It accumulates mainly in the surface layers of soil (Jones et al. 1967, Dalgarno and Mills 1975, Reith et al. 1979, Univin 1980, McGrath et al. 1980).

3.2.1 Although knowledge as to its different forms in pig faeces and slurry is incomplete (Braude 1980), copper is supposed to be present partly as sulphide which, under aerobic conditions in the soil, could be partially converted into copper sulphate. It could then be absorbed in ionized form by plants (CLO 1978). Given the complex nature of the subject and the fact that the data at present available are insufficient and often contradictory (Kiekens and Cottenie 1981), it is difficult to know in what forms copper is bound by the different types of soil and what factors govern the bioavailability of copper for plants and, subsequently animals.

In the soil, the bioavailability of trace elements in general and of copper in particular depends on their interaction with the various soil components such as organic matter, colloidal mineral particles (clay) and amorphous Fe, Al and Mn carbonates. The interaction features several parameters, in particular the concentration of ions in solution in the soil, the type and frequency of adsorption sites (solid phase), the concentration of ligands capable of forming organomineral complexes (fulvic and humic acids), the pH and the redox potential, etc.

The extraction solutions which are used to simulate the absorption of copper by plants vary, making comparison difficult. Using 0.43 N nitric acid, between 60% and 80% of the copper from swine excreta would appear to be available in the soil to plants (Batey et al. 1972). With 0.05 M NH_4-EDTA, 30-45% would appear to be bioavailable (Unwin 1981). With aqueous 0.5 M EDTA, 100% would be extractible (McGrath 1981).

The amount of copper taken up by plants depends on their genotype, the nature and physico-chemical properties of the soil, on micro-organism activity and the type of compound concerned (Meyer and Kröger 1973, CLO 1978, Feenstra et al. 1979, El Bassam 1979, Davis 1981). According to Feenstra et al. (1979), the amount removed annually by crops varies between 15 g and 80 g Cu/ha. The amount removed by an average harvest on sandy oil can be put at 50 g Cu/ha.

Little is known about soil leaching. According to data reported by Meyer and Kröger (1973) it would account for something in the order of 30 g Cu/ha. In Denmark, it is estimated that in practice 8-19 g/ha are removed by leaching (Kofoed 1981). Köhnlein (1972) used lysimetric readings to analyse the leaching of copper resulting from a rainfall of 270 mm in a heathland podzol and found a lixiviation of 85 g Cu/ha (topsoil 30 cm). In two brown earths with different basic saturation he found lixivations of 86-270 g Cu/ha, soils with a low basic saturation having a higher lixivation. On grassland, only the loss through leaching must be taken into account since the copper present in crops is recycled through excreta of grazing animals. The estimated overall removal through cropping and leaching would thus be 30 g Cu/ha on grassland and 80 g/ha on arable land (Feenstra et al. 1979).

Leaching of copper by rain and run-off could, in the long run, lead to undesirable concentrations of copper in ground water and bodies of surface running water, but too few data are at present available to permit a definitive conclusion concerning the possible environmental hazards of the leaching of copper.

3.2.2 Copper is an element essential to plants. Plants sometimes show signs of deficiency if there is a shortage of copper in the soil (Jacquot et al. 1964, Boccard 1980, Brajon et al. 1980, Unwin 1981). In soils with a high copper content, plant association may be disturbed, with an increase in the frequency of the more resistant species. Excess copper may be toxic (Scurti 1957).

Field data on the phytotoxicity of copper in the soil are scarce, and caution is required when interpreting the results of pot trials, especially where copper salts are added directly (Unwin 1981, Davis and Beckett 1980). The phytotoxicity of copper depends on the type of crop, the physico-chemical properties of the soil and its pH, the quantity of soluble copper in the soil and the possible interaction between copper and other minerals, such as Mo, SO_4, Zn, Cd, Fe (Williams 1975, Kofoed 1981). The fact that there are so many variables and that so many different extraction solutions are used for determining phytotoxicity thresholds accounts for the inconsistency of the results published (Adas 1971, Commission of the EC 1978, CLO 1978, Feenstra et al. 1979, Coppenet 1980). It is preferable to use plant tissue as a reference. The copper content in the leaves is a sensitive indicator of phytotoxicity in most plants.

The phytotoxicity threshold is generally of the order of 20 mg Cu/kg foliar dry matter (Davis and Beckett 1980). Above that level there is a risk of falling yields for certain species (Finck 1976, Beckett and Davis 1977 and 1978, Kofoed 1981).

However, some plants or parts of plants are capable of tolerating high quantities of copper (20-30 mg/kg dry matter). Examples are potato tops, clover and swede tops (Reith et al. 1979), carrots and buckwheat (El Bassam 1979), chenopodiaceous plants (sugarbeet roots and leaves) and ceral leaves (Davis 1981). There is a gradual rise in the copper content of plants as the accumulation of copper in the form of slurry increases (Bachtaler et al. 1974, McGrath et al. 1980, R.J. Unwin 1981). The rise in plant copper content varies considerably according to species and may even be insignificant (Martens et al. 1979, Poole 1981).

3.2.3 As regards the toxicity of copper for the higher animals, resulting from the spreading of pig slurry containing copper on grazing land, there is a risk only in the case of sheep. Small quantities of copper (12-20 mg/kg dry matter) in the forage material of sheep (Texel lambs are particularly sensitive) can induce signs of intoxication, in particular hemolytic disease (Hill 1977, Vink 1978, Hadenfeldt 1978). But the presence of molybdenum, iron or zinc in the feed counteracts the toxic effects of copper (Ferguson 1943, Dick and Bull 1945, CLO 1978, Lamand 1981). Ingestion of copper as a result of eating soil should not be overlooked, especially in the case of sheep (Field and Purves 1964, Healy 1967, Suttle et al. 1975, Poole 1981). According to Feenstra et al. (1979) the presence of 15-20 mg of 0.43N nitric-acid-soluble copper/kg of soil already constitutes a risk for grazing ovine animals.

3.2.4 Available data on the effects of copper on soil fauna and flora are very incomplete. With regard to earthworms, the data are conflicting. According to Van Rhee (1975), earthworm populations in sandy soils are depleted after 10 years of application of pig slurry with a high copper content. The minimum copper level affecting reproduction is 80 mg/kg soil (soluble in 0.43N nitric acid). According to Unwin (1981), the earthworm population in plots treated with pig slurry containing 212 kg Cu/ha doubled in the space of four years. El Bassam (1979) observed that an increase in the soluble copper content brought a gradual decrease in the activity of micro-organisms in the soil, thus jeopardizing the complete breakdown of organic matter. The action of copper on nitrogen-fixing bacteria and on methane formation in manure and slurry is not known.

3.2.5 Studies of the selection of bacteria resistant to certain antibiotics have shown that the feeding of pigs with a diet containing quantities of copper exceeding essential requirements encourages the selection of strains of *E. Coli* resistant to chloramphenicol (Gedek 1981).

3.2.6 The toxicity of copper for aquatic organisms depends on many factors, in particular temperature, pH and water hardness and the quantity of dissolved salts and oxygen (Brajon et al. 1980). For algae and plankton (*Gammarus pulex*, *Tibiflex rivolorum*, *Heptagenia lateralis*, *Chironomus thummi*), the lethal concentrations of copper range from 0.25 to 0.5 mg/l (Liepolt and Weber 1958, FAO 1968). For freshwater fish, the lethal concentrations range from 0.02 to 1.0 mg/l (Erichsen Jones 1964, FAO 1968). An increase in the copper content of water has an inhibiting effect on aquatic micro-organisms and thus slows down tne breakdown of organic substances (Maletto 1981).

Measures to protect surface water and fresh water against pollution have been taken at Community level under Council Directive 75/440/EEC of 16 June 1975 concerning the quality required for surface water intended for the abstraction of drinking water in the Member States (1) and Council Directive 78/659/EEC of 18 June 1978 on the quality of fresh waters needing protection or improvement in order to support fish life (2). Under these directives, the copper contents of surface waters must lie between 0.02 and 1 mg/l, while those of fresh water must not exceed 0.04 mg/l.

3.2.7 In intensive farming, the copper present in the feeds and excreted in the faeces may show an unfavourable interference in the functioning of the waste water purification plant. This negative effect would begin to appear at a concentration of 10 mg/l and would be magnified with the increasing concentration of copper in the sludge (Assozeni, unpublished research).

3.3 Although, under the present authorized conditions of use, the quantities of copper excreted and spread on arable land and grazing land do not seem to have had any prejudicial effect on grazing animals (except sheep), plants or fauna and flora in the soil and water there is a potential risk that the copper toxicity thresholds for susceptible animal and plant species will sooner or later be attained as a result of copper build-up in the soil. In this connection, animal excreta are not the only determining factor. Other sources of copper such as sewage sludge, household refuse compost and certain pesticides may make a significant contribution.

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(1) OJ No L 194, 25.7.1975, p. 26
(2) OJ No L 222, 14.8.1978, p. 1

4. In the light of the foregoing, the conditions under which the copper may be used in animal feed in the Community are economically justified in pig production and acceptable for other animal species except sheep.

Under these conditions of use, the use of copper has no hazardous effect on consumer health, although it is not recommended that liver with a high copper content be used as an everyday food for young children.

However, the application of animal excreta and slurry containing high quantities of copper cannot be considered as free from long-term risks for the environment. Excess levels of copper in the soil will inevitably have deleterious effects on the flora and fauna and on the yield of certain crops.

On the grounds of prudence, the Committee is of the opinion that the addition of copper compounds to animal feed should be limited to ensure that maximum levels of total copper do not exceed the following values :

125 mg/kg in complete feed for piglets and pigs;
20 mg/kg in complete feed for sheep;
50 mg/kg in complete feed other animal species.

Furthermore, the Committee recommends that no copper should be added to feedingstuffs for sheep except in cases of nutritional deficiency. The maximum level of 20 mg Cu/kg complete feed should never be exceeded; in certain circumstances and for some strains this level may already be harmful.

The proposed values should be reviewed at a later date in the light of additional data on the effectiveness of copper for animal species other than pigs and the effects of copper build-up and the leaching that may ensue.

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