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Effect of copper on growth and serum constituents of immunized and non-immunized rabbits infected with *Trypanosoma brucei*

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Résumé.

Effet du Cuivre sur la croissance et les constituants sériques de lapins immunisés ou non puis infecté par *T. brucei*.

Soixante-douze lapins originaires de Nouvelle-Zélande ont été répartis en 3 groupes. Pour deux d'entre eux le régime de base a été supplémenté respectivement par 125 et 250 ppm de Cu. Quatre semaines plus tard, ces deux derniers sous-groupes ont été subdivisés en 3 lots de 8 lapins, Le premier lot a été immunisé par *Trypanosoma brucei,* puis inoculé par le même parasite ; le second lot fut inoculé sans immunisation préalable ; le troisième ne fut ni immunisé, ni inoculé.

Il a été d'abord confirmé que l'adjonction de Cu favorisait la croissance des animaux et le rendement de la nourriture ingérée. Il a été ensuite constaté que la parasitémie a des effets légèrement contraires, mais que les deux paramètres sont améliorés par l'adjonction de 125 ou 250 ppm de Cu à la diète. Si l'immunisation confère une légère protection contre la perte de poids des lapins parasités, celle-ci est complètement neutralisée par l'adjonction de 250 ppm de Cu, seule ou associée à l'immunisation.

La parasitose entraîne encore une baisse de l'hématocrite, une diminution de l'hémoglobine et du glucose sérique. En même temps, l'activité phosphatase alcaline s'élève. Avec lé régime supplémenté en Cu, ces effets sont inversés.

Le cuivre a donc pour conséquence non seulement de favoriser la croissance des lapins, mais encore de neutraliser la trypanosomose à *T. brucei* sur le développement des animaux et sur certains paramètres sanguins.

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Summary.

Seventy-two five-week-old New Zealand White rabbits were divided into three groups and fed a basal diet containing 0, 125 or 250 ppm supplemental Cu for 4 weeks before each Cu-group was further subdivided into three lots of 8 rabbits each. One subgroup was immunized with *Trypanosoma brucei* before being infected with the same parasite, another subgroup was infected without immunization while the third subgroup was neither immunized nor infected. Parasitemia slightly depressed growth and efficiency of feed utilization while supplemental Cu at 125 and 250 ppm improved both parameters in rabbits. Immunization conferred slight protection on body weight losses by the infected rabbits while supplemental Cu at 250 ppm alone or in combination with immunization completely obliterated the effects of infection on growth performance. Infection depressed haematocrit, haemoglobin, and serum glucose, while the alkaline phosphatase activity was increased. Supplemental Cu significantly increased both haemoglobin and serum glucose levels. Supplemental Cu reversed the effects of parasite infection on blood constituents. The study indicates that Cu may not only promote growth but will also suppress the effects of parasitemia on performance and serum profile of rabbits infected with trypanosomes.

Introduction

Although the effect of experimentally infecting rabbits with trypanosome parasite has been well studied, the specific consequences of such practice on the host animal is not clearly delineated. While researchers including Losos and Ikede (1970) observed that parasitemia in such rabbit is seldom very intense, Goodwin and Guy (1973) reported death due to renal failure resulting from allergic reactions stimulated by parasitemia in rabbits infected with *Trypanosoma brucei.* Where death does not occur, Pearse (1977) indicated poor growth and poor feed utilization as opposed to the findings of Lincicome *et al* (1963) and Lincicome and Lee (1971) who reported rapid rate of growth in rats infected with *Trypanosoma lewisi* and *Trypanosoma duitoni.*

However, there is need to control the incidence of parasitemia when animals are heavily afflicted with trypanosomes. The effect of immunization as a means of control is very variable. Dusanic (1968) and Garcia and Muhlpfordt (1969) have obtained significant control of parasitemia by immunizing with the same strains of trypanosome parasite while McNeillage and Herbert (1968) and Van Miervenne *et al* (1975) have reported differences in infectivity and virulence between antigenic types of a given strain of *Trypanosoma brucei.*

Investigation with dietary minerals have revealed that supplemental Cu at levels up to 250 ppm in the diet of rabbits will not only promote rapid rate of growth and efficiency of feed utilization (King 1975, Omole 1977) but may also alter intestinal microflora. Studies relating to dietary manipulation for suppression of parasitemiasis in animals is limiting.

This study is therefore designed to observe the response of rabbit when fed varying levels of supplemental Cu, immunized and infected with *Trypanosoma brucei.*

Matérials and methods

Seventy-two five-week-old New Zealand White rabbits averaging 480 g in weight were randomly alloted to nine treatment groups of eight rabbits each. A basal diet containing about 18 % protein (*Table I*) was supplemented with copper sulphate ($CuSO_4$ $5H_2O$) to supply 0, 125 or 250 parts/10^6Cu in the diet. The resulting twenty four rabbits in each group received the Cu-diets for four weeks when each Cu treatment group was further divided into three subgroups of 8 rabbits each. A sub group was immunized with *Trypanosoma brucei* before being infected with the same parasite, another subgroup was infected without immunization while the third subgroup was neither immunized nor infected.

Table I. *Composition of basal diets.*

Ingredients	Percent
Yellow corn (8.5 %)	58.0
Groundnut cake (45 %)	14.0
Brewers' dried grains (25 %)	15.0
Fishmeal (Herring)	4.0
Fat (palm oil)	1.0
Stylo (1)	3.0
Oystershell	2.0
Dicalcium phosphate	2.0
Salt	0.5
Vitamin-Mineral premix (2)	0.25
Ofurason (3)	0.25
Total	100.00
Chemical Composition (DM basis) :	
Crude protein (%)	18.31
Ether extract (%)	4.73
Crude Fibre (%)	7.85
Ash (%)	8.54
NFE (%)	60.57
Gross energy (kcal/kg)	3978
Copper (ppm)	17.3

(1) Stylo is a forage legume *(Stylosanthese gracilis)*.

(2) To supply the following per 100 kg of the diets 400 mg riboflavin, 880 mg calcium pantothenate, 2 g niacin, 2.2 g choline chloride, 15 mg folic acid, 1 mg vitamin B_{12}2, 500,000 IU vitamin A, 66,000 IU vitamin D_2, 1,000 IU vitamin E. It also supplied 50 ppm zinc, 113 ppm cobalt, 6 ppm copper, 112 ppm iron and 37 ppm manganese.

(3) A commercial coccidiostat with nitrofurazone base.

Immunization was done by intraperitoneally injecting the rabbits with 0.5 ml of a suspension of trypanosomes in physiological saline containing about 100 *T. brucei* cells prepared by the method of Lincicome and Watkins (1963). The initial dose of the antigen was followed by 1 ml booster dose after two days and another 2 ml second booster dose seven days later.

Eight days after the second booster dose, animals from the immunized group and one of the unimmunized groups were injected intraperitoneally with saline blood suspension of *Trypanosoma brucei* obtained from previously infected reservoir rats. An estimated microscopic quantity of 50,000 trypanosomes was used for each infection. Blood samples were collected from ear veins of infected rabbits into small heparinized tubes 5th, 8 th, 11 th and 14 th day following innoculation to determine parasitemia. A week after the last blood sampling, all the rabbits were sacrificed by a slitting of the throat and blood rapidly collected. For blood chemistry, plastic tubes containing heparinized saline solution (1 ml of 0.85 % NaCl containing 5 mg of heparin) were used while the tubes for blood glucose estimation contained Fluoride oxalate (FO/2.5).

Serum contents determined included haemoglobin, total protein, albumin (globulin by difference), blood urea nitrogen, glucose, amylase, alkaline phosphatase, bilirubin, calcium, sodium potassium and chloride. Total protein, haemoglobin and albumin were determined by the methods described by Wooton (1964), glucose values were measured by the techniques of Tonks (1952), Test for blood urea nitrogen were performed by the method of Sobel *et al.* (1944) while potassium and calcium levels were determined by the methods of Fawcett and Wynn (1961).

The kidney and liver were weighed while the carcass yield was computed from the sum of carcass and skin weights expressed as a proportion of final live weight.

The data were treated statistically by analysis of variance and Duncan's multiple range test after Steel and Torrie (1960).

Results

Growth and carcass performance

Effect of parasite : Daily feed intake, rate of growth and efficiency of feed utilization were not significantly influenced ($p>0.05$) by parasite treatments (*Table II*). However, the rabbits infected with trypanosomes consumed slightly less feed than those uninfected. Similarly, the infected group grew more slowly and utilized their feed less efficiently than the uninfected group while the infected but immunized group gained faster and utilized their feed more efficiently than the infected unimmunized group.

The liver of the uninfected group was slightly bigger ($P>0.05$) than those infected but immunized. Liver as percent body weight was smallest in the group infected but unimmunized. None of the differences was statistically significant ($P>0.05$). The pro-

Table II. *Effects of* Trypanosoma brucei *or supplemental copper on growth and carcass performance of rabbits.*

Treatment	Parasite				Copper levels (ppm)			
	NM, NF	NM, IF	IM, IF	SEM	0	125	250	SEM
No. of animals	24	24	24	—	24	24	24	—
Av. initial wt. g.	565.7	564.8	565.5	—	566.5	565.3	564.2	—
Av. final wt., g.	1825.7	1738.7	1779.3	—	1666.9	1747.6	1929.2	—
Daily feed, g.	62.39	61.12	61.00	1.85	61.22	60.54	63.05	2.66
Daily gain, g.	20.0	18.63	19.27	2.05	17.46a	18.77ab	21.67b	1.94
Feed/gain, g.	3.13	3.32	3.19	0.34	3.52b	3.21ab	2.91a	0.28
Liver (% body wt.)	3.90	3.16	3.72	0.53	3.49	3.53	3.75	0.17
Kidney (% body wt.)	0.51	0.53	0.53	0.02	0.51	0.53	0.53	0.02
Carcass yield (%) ...	62.1	60.1	61.8	3.50	60.8	61.8	61.3	2.79

NM = Non-immunized.
NF = Non-infected.
IM = Immunized.
IF = Infected.
a, b : Values in each row with a common letter or with no letter are not significantly different at (P > 0.05).

portions of kidney to the body were equal for the infected groups. Kidney weight was very slightly (P>0.05) depressed in the uninfected group. Carcass yield was not affected (P>0.05) by parasite treatments. Carcass yield was however lowest when rabbits were infected but not immunized and highest when they were not infected at all.

Effect of Copper : Rate of daily consumption was not consistently influenced by dietary Cu. Rabbits fed 250 ppm Cu gained significantly faster (P>0.05) than those receiving no supplemental Cu while the animals fed 125 ppm Cu grew slightly less than those fed the 250 ppm level but slightly more than those fed diets unsupplemented with Cu. None of the differences was significant (P>0.05).

Efficiency of feed conversion followed a similar pattern with daily gains. The 250 ppm Cu diet was more efficient than the diets unsupplemented with Cu (P<0.05) or the diet supplemented with 125 ppm Cu (P>0.05). The 125 ppm Cu diet was also utilized better (P>0.05) than the diet containing no supplemental Cu. Liver as percent body weight non-significantly (P>0.05) increased as the level of Cu incresad in the diet. Also, kidneys of Cu-fed rabbits were slightly bigger (P>0.05) than those fed 0 ppm supplemental Cu. Carcass yield did not seem to be consistently influenced by level of supplemental Cu.

Combined Effects of Copper and Parasites : There were no significant interactions between Cu and parasite treatments on feed intake of fryer rabbits (*Table III*). Regardless of whether rabbits were infected with parasites or not the 250 ppm Cu fed animals

Table III. *Effects of supplemental copper and* Trypanosoma brucei *on growth and carcass performance of rabbits.*

Parasites	NM, NF			NM, IF			IM, IF			
Cu, (ppm)	0	125	250	0	125	250	0	125	250	
No. of animals	8	8	8	8	8	8	8	8	8	
Av. initial wt, g	566.8	566.1	564.3	566.7	564.4	563.2	566.1	565.3	565.1	
Av. final wt, g	1757.5	1788.3	1931.4	1593.6	1704.7	1917.7	1649.7	1749.7	1938.5	
Daily feed, g	62.37	60.92	63.80	61.45	59.55	62.35	59.86	60.16	63.0	3.19
Daily gain, g	18.9ab	19.4ab	21.7b	16.3a	18.1ab	21.5b	17.2a	18.8ab	21.8b	2.20
Feed/gain, g	3.30abc	3.14ab	2.94ab	3.77c	3.29abc	2.90a	3.48bc	3.20ab	2.89a	0.27
Liver (% body wt) ..	3.82	4.10	3.78	3.01	2.95	3.51	3.64	3.55	3.97	0.65
Kidney (% body wt)	0.52	0.51	0.49	0.51	0.55	0.53	0.49	0.54	0.56	0.04
Carcass yield (%) ...	61.2	60.3	64.8	59.8	61.5	58.9	61.4	63.7	60.2	3.78

NM = Non-immunized.
NF = Non-infected.
IM = Immunized.
IF = Infected.

a, b, c : Values in each row with a common letter or with no letter are not significantly different at ($P > 0.05$)

grew more rapidly ($P<0.05$) and utilized their feed significantly ($P<0.05$) better than the ones receiving no supplemental. The 125 ppm Cu fed rabbits grew slightly faster and were more ($P>0.05$) efficient than the groups receiving no supplemental Cu. The combination of the various Cu levels and parasite treatments did not influence ($P>0.05$) liver and kidney weights and the dressing value of fryer rabbits.

Blood constituents.

Effect of Parasite : PCV Haemoglobin, Total protein albumin and blood urea nitrogen were not significantly ($P>0.05$) influenced by parasite treatment (*Table IV*). However, infection with parasite slightly depressed both PCV and Haemoglobin values as compared with the uninfected group. The infected but unimmunized group was lower than infected and immunized group. Total protein, globulin, amylase sodium and potassium and chloride values followed the same pattern, they were slightly increased

Table IV. *Effects of* Trypanosoma brucei *or supplemental copper on serum constituents of rabbits (per 100 ml blodd).*

Treatment	Parasite				Copper levels (ppm)			
	NM, NF	NM, IF	IM, IF	SEM	0	125	250	SEM
PVC (%)	41.07	40.33	38.4	2.04	38.8	40.0	41.0	2.36
Haemoglobin, g	14.0	13.8	13.2	0.75	12.9a	13.6ab	14.4b	0.43
Total protein, g	6.33	6.71	6.59	0.34	6.70	6.42	6.52	0.21
Albumin, g	3.73	3.33	3.38	0.25	3.43	3.21	3.81	0.29
Globulin, g	2.60	3.38	3.21	0.46	3.27	3.21	2.71	0.33
BUN, mg	18.76	17.04	17.64	0.94	13.47a	19.49b	20.48b	2.57
Glucose, mg	91.15b	83.97a	83.76a	3.48	76.98a	86.0ab	95.87b	7.49
Amylase (S.U.)	296.7	301.6	300.8	12.72	321.06	309.0ab	269.2a	22.82
Alkaline phosphatase (K.A.U.)	7.22a	9.62b	9.26b	0.91	9.80b	8.80ab	7.51a	0.86
Bilirubin, mg	0.19	0.18	0.21	0.02	0.21	0.19	0.17	0.02
Calcium, mg	14.76	14.34	14.77	0.27	14.80	14.89	14.19	0.38
Sodium, mg	139.8	144.4	147.7	4.95	143.9	141.0	147.0	3.02
Potassium mEq/l	5.83	5.96	6.57	0.44	5.7	6.36	6.30	0.40
Chloride mEq/l	97.1	100.6	103.4	3.50	97.5	100.8	102.8	4.21
Mean Parasitemia $\times 10^3/mm^3$	—	197.7	140.0	—	174.0	110.3	53.3	—

NM = Non-immunized.
NF = Non-infected.
IM = Immunized.
IF = Infected.

a, b : Values in each row with a common letter or with no letter are not significantly different at ($P > 0.05$).

Table V. *Effects of supplemental copper and* Trypanosome brucei *on serum constituents of rabbits (per 100 ml blood).*

Parasites	NM, NF			IM, IF			NM, IF			
Cu, (ppm)	0	125	250	0	125	250	0	125	250	
PCV (%)	39.4	41.3	42.5	39.9	40.2	40.9	37.0	38.5	39.7	3.18
Haemoglobin, g	13.3	13.9	14.8	13.1	14.0	14.3	12.4	13.0	14.1	1.7
Total protein, g	6.48	6.00	6.52	7.00	6.49	6.65	6.62	6.77	6.38	0.88
Albumin, g	3.75b	3.31ab	4.14b	3.38ab	2.96a	3.65b	3.15ab	3.37ab	3.63b	0.45
Globulin, g	2.73	2.69	2.38	3.62	3.53	3.00	3.47	3.40	2.75	0.63
BUN, mg	15.46abc	19.72c	21.10c	11.56a	18.84ab	20.72c	13.40ab	19.90c	19.63c	3.68
Glucose, mg	82.56ab	91.32ab	99.56	74.8a	79.3ab	97.8b	73.6a	87.4ab	90.3ab	11.42
Amylase (S.U.)	315.7	298.0	276.4	322.3	311.4	271.2	325.0	317.5	260.0	37.5
Alkaline phosphatase (K.A. unit)	8.00bc	7.74abc	5.93a	10.92d	8.55bc	9.38cd	10.47cd	10.10cd	7.22ab	2.00
Bilirubin, mg	0.21	0.20	0.16	0.19	0.18	0.16	0.24	0.20	0.19	0.03
Calcium, mg	15.12	14.93	14.25	14.30	14.73	14.00	14.98	15.00	14.33	0.90
Sodium, mg	137.4	139.6	142.5	145.3	140.8	147.4	149.1	142.7	151.2	10.14
Potassium mEq/l	5.8	5.6	6.1	5.3	6.6	6.0	6.0	6.9	6.8	0.84
Chloride MEq/l	92.4	97.3	101.5	98.5	99.8	103.6	101.5	105.4	103.4	7.20
Mean parasitemia $10^3/mm^3$	—	—	—	203	155	62	319	176	98	

a, b, c, d : Values in each row with a common letter or with no letter are not significantly different at ($P > 0.05$).

($P > 0.05$) in the parasite infected groups as compared with the uninfected groups. On the other hand, parasite infection decreased ($P > 0.05$) both albumin and bilirubin values. Glucose values were significantly decreased ($P < 0.05$) while the alkaline phosphatase was significantly increased ($P < 0.05$) by parasite infection. Immunization reduced parasite population by 29 % as compared with the unimmunized group.

Effect of Copper : The haematocrit levels slightly increased while the haemoglobin levels significantly ($P < 0.05$) increased as supplemental Cu increased in the diet. Total protein, albumin, globulin, and calcium were not influenced ($P > 0.05$) by dietary Cu. Supplemental Cu significantly enhanced BUN and glucose values ($P < 0.05$) while the amylase and alkaline phosphetase values decreased ($P < 0.05$) as supplemental Cu increased in the diets. Bilirubin decreased while calcium and potassium and chloride values increased as dietary Cu levels increased. However, none of the differences was statistically significant ($P > 0.05$).

Blood parasite population decreased with increasing levels of supplemental Cu (*Table IV*). The inclusion of 125 ppm Cu in the diet suppressed parasite level by 36.6 % while the 250 ppm Cu decreased parasite by 69.4 %.

Combined Effects of Copper and Parasites : There were no significant interactions between parasites and Cu levels for PCV, haemoglobin, total protein globulin and amylase (*Table V*). Albumin values were significantly increased in the non-infected group fed 250 ppm Cu. The infected but non-immunized group that received 250 ppm Cu has albumin value slightly less than the uninfected fed 0 ppm supplemental Cu. BUN followed the same general pattern, being highest in the non-infected group fed the 250 ppm Cu. Glucose level was significantly highest in the non-infected group fed the 250 ppm level and lowest ($P < 0.05$) in the infected and non-immunized group receiving no supplemental Cu while the alkaline phosphatase level was highest ($P < 0.05$) in the infected and immunized group fed no supplemental Cu and lowest ($P < 0.05$) in the non-infected group fed 250 ppm supplemental Cu. Bilirubin, calcium, sodium, potassium and chloride levels were not significantly influenced by the parasite-Cu combinations.

In both immunized and non-immunized group, the incidence of parasite was reduced as supplemental Cu increased (*Table V*). Immunization also generally reduced parasitemia. The infected but non-immunized group receiving no supplemental Cu had the highest parasite population, about 5 times the infected, immunized group fed the 250 ppm Cu level which had the lowest parasite population.

Discussion

These results suggest that rabbits will live with this level of *T. brucei* infection, but will grow slowly and utilize their feed relatively inefficiently. Similar to these are our earlier findings (Simaren and Omole 1975 and 1976 unpublished) and the findings of Pearse (1977) who observed depressed growth when rabbits were infected with a similar strain of *T. brucei*. However, these reports contradict the observations of Lincicome *et al.* (1963) and Lincicome and Lee (1971) who have reported rapid rate of growth in rats infected with *T. lewisi* and *T. duttoni* respectively. It is possible that when parasitemeasis exerts some stress on animals, rate of body gains will slow down.

When judged by body weight gains and feed conversion efficiency, immunization seemed to offer some protection to rabbits infected with the dosage of *T. brucei* used in this study. Dusanic (1968) observed that cultures of *T. lewisi* conferred some protection against infection of rats with the blood forms of *T. lewisi* while Garcia and Muhlpfordt (1969) reported partial protection against *T. cruzi* infection on mice infected with culture forms of *T. lewisi.* Kloetzel and Deane (1971), however, were unable to elicit any protection against *T. cruzi* in rats which had recovered from an infection by *T. lewisi,* also mice receiving multiple dose of *T. lewisi* blood stream forms developed practically no resistance against *T. cruzi.* Differences in host species and in strains and levels of parasites used for immunization may be responsible for the variation in responses. Much more than immunization, Cu supplementation may be an effective means of counteracting poor growth, poor feed utilization and high incidence of parasitemia in rabbits exposed to trypanosome parasites. The fact that supplemental Cu will improve growth and rate of feed conversion in rabbits as borne out by this study has been properly documented (King 1975, Omole and Adegbola 1976, Omole, 1977).

Depression of both haematocrit and haemoglobin in infected rabbits seems to indicate that high level of parasitemia may lead to anaemia in this species. A similar relationship between anaemia and density of parasites has been observed in infection with *T. lewisi* (Sherman and Ruble 1967) with *T. evansi* (Assoku, 1975) and with *T. musculi* (Jorviner and Dalmasso 1977). It seems reasonable to suggest that the presence of parasite in blood will influence blood packed cell volume. It is also possible that trypanosome may utilize some of the substrates involved in heme or globin biosynthesis thereby lowering blood haemoglobin. Lower blood glucose level in infected rats may indicate demand and consumption of glucose by the parasite. Sanchez and Dusanic (1968) observed hypoglycemia in rats infected with *T. lewisi* when parasitemia was greatest. Similarly Simaren and Awopetu (1973) reported high sugar consumption by *T. congolense* in host rats. Contrary to these findings are the observations of Grant and Fulton (1957) and Goodwin and Guy (1973) who reported that blood glucose and pyruvate levels in rats infected with either of two strains of *T. rhodesiense* or *T. brucei,* respectively, increased with peaks of parasitemia. Blood glucose may possibly serve as a source of energy for both host and parasite.

Increases in levels of total protein in the serum of infected rabbit as observed in this study are in accord with the findings of Barnes (1951) and Simaren and Awopetu (1973). Activity of alkaline phosphatase has been known to decline in animals infected with trypanosome parasites (Goebel and Puchtler 1954, Facer, *et al.* 1978). We on the contrary observed in this study that alkaline phosphatase level increased in rabbits infected with *T. brucei.* It is difficult to find any explanation for the elevation in alkaline phosphatase activity in these animals.

With regards to blood constituents, immunization offered little protection to infected rabbits, whereas, supplemental Cu at the 250 parts/10^6 level completely nullified the consequences of *T. brucei* on the blood content of host animals which had similar values with the control animals.

The main effect of supplemental Cu alone on blood profile of rabbits include increases in both haematocrit and haemoglobin levels. The effect of Cu on haemoglobin synthesis has been extensively studied. Cu aid Fe metabolism by promoting the synthesis of heme from Fe (II) and protopophyrin, the mobilization of Fe from reticuloendothelial and hepatic parenchymal cells to transferrin, and the mobilization of Fe from gastrointestinal tract (Williams *et al.* 1976). The mobilization of iron from the storage sites for incorporation into haemoglobin is largely dependent upon the oxidation of iron to the ferric form, which combines with the transport protein transferrin. This oxidation is enzymatically mediated by the Cu-containing protein, ceruloplasmin (Osaki *et al.* 1966). Supplemental Cu also enhanced blood glucose and depressed alkaline phosphatase activity. How Cu influences glucose metabolism is not clear.

In general, this study suggest that Cu may not only promote rapid rate of growth and suppress parasitemiasis in rabbits afflicted with trypanosomes, it may also influence some serum constituents of such animals.

Bibliographie

Assoku R. K. G., 1975 : Immunological studies of the mechanism of anaemia in experimental *Trypanosoma evansi* infection in rats. Intl. *J. Parasitol.*, *5*, 137-145.

Barnes E., 1951 : Effect of benzene and six selected salicylates on the development of immunity in *Trypanosoma lewisi* infection and on various aspects of the blood picture. *Iowa State Coll. J. Sci.*, *26*, 1-17.

Dusanic D. G., 1968 : Growth and immunologic studies on the culture forms of *Trypanosoma lewisi*. *J. Protoz.*, *15*, 328-333.

Facer C. A., Molland E. A., Gray A. B., Jenkins G. C., 1978, *Trypanosoma brucei :* Renal pathology in rabbits. *Exp. Parasitol.*, *44*, 244-261.

Fawcett J. K., Wynn V., 1971 : Determination of calcium by direct flame photometry in Richard J. Henry. Ed. Clinical Chemistry, Principle and Techniques. *Harper and Rowe Publ.* New York, pp. 356-374.

Garcia W., Muhlpfordt N., 1969 : Infeccion de *Trypanosoma cruzi* en ratons despues de su tratamiento con *Trypanosoma lewisi*. *Rev. Inst. Med. Trop. Sao Paulo*, *11*, 67-70.

Goebel A., Puchtler H., 1954 : Ueber das Verhalten der histochemisch nachweisbaren alkalisdien phosphatase und 5-Nucheotidase im Sauerstoffmangel und im Niereniafarkte. *Virch. Arch. Pathol. Anat.*, *326*, 119-134.

Goodwin L. G., Guy M. W., 1973 : Tissue fluid in rabbits infected with *Trypanosoma brucei*. *J. Parasitol.*, *66*, 499-513.

Grant P. T., Fulton J. D., 1957 : The catabolism of glucose by strains of *Trypanosoma rhodensiense*. *Biochem J.*, *66*, 242-250.

Jarviner J. A., Dalmasso A. P., 1077 : *Trypanosoma musculi :* Immunologic features of the anaemia infected mice. *Exp. Parasitol.*, *43*, 203-210.

King J. O. L., 1975 : The feeding of copper sulphate to growing rabbits. *Br. Vet. J.*, *131*, 70-75.

Kloetzel J., Deane M. P., 1971 : Protective cross immunity between *Trypanosoma cruzi* and *Trypanosoma lewisi*, *Rev. Inst. Med. Trop. Sao Paulo*, *13*, 31-36.

Lincicome D. R., Rosan R. N., Jones W. C., 1963 : Growth of rats infected with *Trypanosoma lewisi*. *Exp. Parasitol*, *14*, 54-65.

Lincicome D. R., Watkins R. C., 1963 : Method of preparing pure cell suspensions of *Trypanosoma lewisi. Am. Inst. Bio. Sci. Bull., 13,* 53-54.

Lincicome D. R., Lee C. M., 1971 : *Trypanosoma duttoni :* Body weight gains, food consumption and longevity of pantothenate deficientmice given living cells, cell homogenates and cell mitotic products. *Exp. Parasitol., 30,* 331-344.

Losos G. J., Ikede B. O., 1970 : Pathology of experimental trypanosomiasis in the albino rat, rabbit, goat and sheep — a preliminary report. *Can. J. Comp. Med., 34,* 209-212.

McNeillage G. J. C., Herbert W. J., 1968 : Infectivity and virulence of *Trypanosoma brucei* for mice. II. Comparison of closely related antigenic types. *J. Comp. Pathol., 78,* 825-840.

Omole T. A., Adegbola A. A., 1976 : The effects of dietary brewers' grains and supplemental copper on growth performance, carcass characreristics and organ measurements of fryer rabbits. *Niger. Agric. J., 13,* 50-59.

Omole T. A., 1977 : Influence of levels of dietary protein and supplementary copper on the performance of growing rabbits. *Br. Vet. J., 133,* 593-600.

Osaki S., Jonhson D. A., Frieden E., 1966 : The possible significance of ferrous oxidase activity of ceruloplasmin in normal human serum. *J. Biol. Chem., 241,* 2746-2751.

Pearse J. D. 1977 : A comparative biochemical study of some blood serum constituents in immunized and non-immunized rabbits infected with *Trypanosoma brucei. B. Sc. Dissertation,* Faculty of Health Sciences, Univ. of Ife, Nigeria.

Sanchez G., Dusanic D. G., 1968 : *Trypanosoma lewisi :* Creature phosphohenase, oruithine carbamgl transferase, ATP-ase, Pi and glucose levels in the rat host. *Exp. Parasitol., 23,* 371-378.

Sherman I. W., Ruble J. A., 1967 : Virulent *Trypanosoma lewisi.* Infection in cortisone treated rats. *J. Parasitol., 53,* 258-262.

Simaren J. O., Awopetu J. I., 1973 : Effects of pregnancy on *Trypanosoma congolense* infection in rats : Serum biochemistry and cellular disorders. *Ann. Parasitol. Hum. Comp., 48,* 433-446.

Sobel A. E., Mayer A. M., Gotteried P., 1944 : A convenient trimetric ultramicromethod for the estimation of urea and kjeldahl nitrogen. *J. Bio. Chem., 156,* 355-363.

Steel R. G. D., Torrie J. H., 1960 : Principles and Procedure of Statistics. *McGraw-Hill Book Co. Inc.,* Publ., New York.

Tonks D. B., 1052 : An improved technique for blood glucose by the Folin-Wu method. *Am. J. Clin. Pathol., 22,* 1009-1017.

Van Miervenne N., Janssens P. G., Magnus E., 1975 : Antigenic variation in syringe passaged populations of *Trypanosoma brucei* I. Rationalisation of the experimental approach. *Ann. Soc. Belge Med. Trop., 55,* 1-23.

Williams D. M., Loukoprulous D., Lee G. R., Cartwright G. E., 1976 : Role of copper in mitochondrial iron metabolism *Blood, 46,* 77-85.

Wooton D. P., 1964 : Microanalysis in Medical Biochemistry. *Churchill (J. A.) Ltd.* Publ., London.