

Effects of Zinc, Iron and Copper Supplementation in Cassava-Based Diets for Broiler Chickens

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RINGKASAN

Dua percubaan yang melibatkan 216 ayam daging telah dijalankan untuk mengkaji pengaruh dari berbagai paras-paras zink (0, 25, 50 ppm) digabungkan dengan ferrum (0, 25, 50 ppm) di Percubaan 1 dan dengan kuprum (0, 5, 10 ppm) di Percubaan 2, dalam ransum mengandungi ubi kayu (40%) dan protein (20-17%). Ransum perlakuan telah disusun mengikut 3 × 3 faktorial percubaan. Penambahan mineral pada ransum asas ubi kayu tidak mempengaruhi kadar dan kecekapan kenaikan berat tubuh. Pemasukan dari zink digabungkan dengan ferrum, atau kuprum tidak mempengaruhi kandungan lemak dan protein karkas. Ayam daging yang diberikan ransum-asas ubi kayu ditambah dengan ferrum menurunkan paras zink, tetapi meninggikan kandungan zink hati dibandingkan dengan ransum-ransum yang tidak ditambah dengan ferrum. Peningkatan kandungan zink dari ransum mengurangkan retensi zink hati samada penggabungannya dengan ferrum dan kuprum.

SUMMARY

Two experiments involving 216 chicks were conducted to assess the effects of supplemental levels of zinc (0, 25, 50 ppm) in combination with iron (0, 25, 50 ppm) in Experiment 1 and with copper (0, 5, 10 ppm) in Experiment 2, in diets containing cassava (40%) and protein (20-17%). The dietary treatments were arranged in a 3 × 3 factorial experiment. Mineral supplementation in cassava-based diets had little overall effect on rate and efficiency of gain. Inclusion of increasing amounts of zinc in combination with iron or copper had inconsistent effects on fat and protein content of the carcass. Chicks fed cassava-based diets supplemented with iron showed less carcass zinc levels, but had higher liver zinc content than those fed diets unsupplemented with iron. Raising the zinc content of the diet resulted in reducing copper retention in the liver, regardless of its combination with iron and copper.

INTRODUCTION

Hutagalung *et al.* (1973) showed that pigs fed diets containing 60-75% cassava root developed disorders such as diarrhoea, skin lesions in the stomach and hind quarters, localized swelling and hind leg weakness. The diarrhoea symptom was also observed in poultry (Fraser, 1973). Maust *et al.* (1969, 1972) attributed the disorders developed in animals fed cassava-based diet to a zinc deficiency (parakeratosis). Zinc is reported to antagonize copper absorption, retention and distribution in the body (Magee and Matrone, 1960; Ritchie *et al.*, 1963; Van Campen, 1966; Van Campen and Scaife, 1967). A signi-

ficant antagonism between iron and copper is also reported (Anthony and Nix, 1965; Sourkes *et al.*, 1968, Standish *et al.*, 1969). Zinc and iron supplementation tends to reduce copper toxicity (De Goey *et al.*, 1971), as molybdenum does (Kline *et al.*, 1971).

In view of the close interrelationships among copper, iron and zinc, the following experiments were carried out to investigate the effects of these trace elements supplementation above the normal requirements on the performance, and on the carcass characteristics of broiler chicks fed diets containing a high proportion of cassava.

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MATERIALS AND METHODS

Two experiments were conducted using two-week-old broiler chicks (Red Cornish × White Plymouth Rock) fed starter (20% protein) and grower (17% protein) diets containing 40% cassava root meal. These were arranged in a 3 × 3 factorial experiment to study the effects of graded levels of supplementation of: (1) zinc (0, 25, 50 ppm) and iron (0, 25, 50 ppm) in Experiment 1; and (2) zinc (0, 25, 50 ppm) and copper (0, 5, 10 ppm) in Experiment 2. Four chicks of uniform mean weight were randomly allotted to each of the three replicates of the nine dietary treatments.

Water and feeds were provided *ad libitum*. Individual body weight and group feed consumption were recorded weekly. The diets were changed from the starter to grower diets when the chicks reached the age of six weeks. The experiments were carried out for a period of 56 days. The compositions of the diets are given in Table 1. Supplemental zinc, iron and

copper were added as zinc sulphate ($ZnSO_4 \cdot 7H_2O$), ferrous sulphate ($FeSO_4 \cdot 7H_2O$) and copper sulphate ($CuSO_4 \cdot 5H_2O$), respectively, in place of kaolin.

At the end of the trials, three birds from each treatment (one from each replicate) which had been deprived of rations for 12 hours, were killed with chloroform. The whole carcasses of the birds were frozen, cut into sections and grouped. Samples were taken for moisture, protein and fat analyses following procedures described in A.O.A.C. (1970). In addition, three more birds from each treatment were slaughtered for their livers. Samples of livers and whole carcasses were analyzed for zinc, iron and copper by acid digestion procedure (Perkin-Elmer, 1971).

The data from all experiments were statistically analyzed by the variance method as described by Steel and Torrie (1960). Significant differences between means were compared using the least significant difference (LSW) test.

TABLE 1
Composition of basal diets

	Diets	
	Starter	Grower
<i>Ingredients, %</i>		
Cassava root meal	40.00	40.00
Corn	16.25	22.25
Soybean meal	20.60	17.80
Fish meal	16.20	12.00
Palm oil	4.00	5.00
Tricalcium phosphate	1.45	1.45
Salt	0.50	0.50
Mineral mixture ¹	0.30	0.30
Vitamin premix ²	0.10	0.10
DL-Methionine	0.20	0.20
L-Lysine	0.10	0.10
Kaolin	0.30	0.30
Total	100.00	100.00
<i>Calculated constituents</i>		
Protein (N × 6.25), %	20.02	16.99
Metabolizable energy, kcal/g	3.01	3.05
Calcium, %	1.83	1.74
Phosphorus, %	1.00	0.90
Zinc, ppm	59.90	54.18
Iron, ppm	144.80	135.18
Copper, ppm	23.27	21.98

¹Contributed the following per kg diet: Fe, 59.06 mg; Cu, 13.39 mg; Mn, 82.75 mg; Zn, 33.75 mg; Co, 2.73 mg; I, 1.41 mg and Mg, 560 mg.

²Contributed the following per kg of diet: Vitamin A, 50,000 IU; Vitamin D, 10,000 IU; Vitamin E, 12.50 IU; riboflavin, 15 mg; thiamine, 5 mg; vitamin B₆, 250 mg; pantothenic acid, 25 mg; niacin, 404 mg; vitamin B₁₂, 20 mg; choline, 1008 mg.

RESULTS

Experiment 1

Performance. Incorporation of graded levels of zinc and iron in diet did not significantly affect daily gain, feed intake or feed conversion ratio; nor was there significant zinc × iron interaction for these criteria (Table 2).

Body composition. Increased dietary intake of iron significantly ($P < 0.01$) reduced the carcass protein content in a linear trend. The carcass protein, however, was not affected by an increase in zinc intake. In regard to the iron × zinc interactive effect, increased dietary zinc was found to reduce carcass protein content when birds were fed low-iron (no supplementation) diets but increased when fed the high-iron (50 ppm iron supplementation) diets.

Carcass fat content in the body was significantly ($P < 0.01$) influenced by supplementation of zinc and iron. Increasing zinc supplementation to 25 ppm in diet decreased the carcass fat content; however, a further increase to 50 ppm produced a restoring effect. The reverse was true with iron supplementation where an increase in iron supplementation to 25 ppm raised body fat content; but a further 50 ppm increase lowered the fat content. A zinc × iron interaction effect on fat deposition was also observed. An increase in iron supplement from 0 to 25 ppm in diets supplemented with up to 25 ppm zinc increased fat deposition but

SUPPLEMENTATION IN CASSAVA-BASED DIETS FOR BROILERS

TABLE 2

Effects of zinc and iron supplementation in cassava-based diets on performance and body composition of chicks (Experiment 1)

Zinc addition, ppm	Dietary variables								
	0			25			50		
Iron addition, ppm	0	25	50	0	25	50	0	25	50
Avg diet intake ¹ , g/day	56.33	52.93	58.33	51.04	49.64	56.42	51.24	48.85	47.76
Avg daily gain ¹ , g	17.22	16.74	17.53	15.71	15.67	18.37	18.37	16.18	14.83
Feed/gain ¹	3.27	3.16	3.33	3.25	3.17	3.07	3.08	3.02	3.22
Whole carcass ⁷ :									
Protein ^{2,5} , %	58.69	54.42	52.28	56.30	52.05	54.55	53.46	57.56	55.07
Fat ^{3,5} , %	33.31	36.08	38.94	33.10	35.87	31.05	37.21	37.77	33.51
Zinc ^{3,5} , ppm	163.30	168.40	167.60	193.20	167.60	186.10	238.10	173.00	172.80
Iron ^{3,5} , ppm	239.60	255.60	273.10	252.60	276.10	313.40	233.20	273.80	314.00
Copper ¹ , ppm	13.00	9.90	9.20	9.20	11.60	8.40	9.20	8.50	9.80
Liver ⁷ :									
Zinc ^{3,6} , ppm	169.52	166.67	173.30	184.23	189.47	188.57	192.54	194.34	200.44
Iron ^{3,5} , ppm	518.55	542.20	592.20	520.01	558.44	610.36	618.46	662.75	727.60
Copper ^{4,5} , ppm	34.40	32.84	36.64	24.27	28.12	26.00	19.27	17.44	17.04

¹Not significant at (P<0.05)

²Significant at (P<0.01) for iron in a linear trend but not for zinc

³Significant at (P<0.01) for both iron and zinc in quadratic trends

⁴Significant at (P<0.01) for zinc in a linear trend but not for iron

⁵Significant at (P<0.01) for iron × zinc interaction

⁶Significant at (P<0.05) for iron × zinc interaction

⁷Protein, fat, zinc, iron and copper values were based on the dry matter of samples

lowered fat deposition in diets supplemented with 50 ppm zinc.

Tissue mineral composition. The zinc deposited in tissues reflected the level of dietary zinc (Table 2). There was a significant zinc × iron interaction effect on the carcass zinc content (P<0.01). The increased zinc content in diet improved the zinc status in the liver of birds fed diets containing supplemented iron (25 and 50 ppm); the increase was more pronounced in birds fed diets containing a lower level of iron supplementation (0 and 25 ppm). Overall, the diets supplemented with 25 and 50 ppm iron appeared to reduce the zinc content of carcass but slightly improved zinc retention in liver.

The iron deposited in tissues also reflected the level of dietary iron. Carcass and liver zinc content was significantly (P<0.01) influenced by zinc × iron interaction. Increased dietary

zinc intake raised carcass iron content only up to 25 ppm zinc supplementation; above this value, the carcass iron concentration was reduced. The increase in liver iron content continued even at 50 ppm zinc supplementation. Iron in carcass was raised by increased dietary iron intake. High zinc and high iron diets enhanced iron retention in liver.

Copper content in carcass was not significantly affected by both zinc and iron supplementation. Liver copper was linearly (P<0.01) lowered by the increased dietary zinc intake, but not by iron intake. There was a marked zinc × iron interaction (P<0.01) effect on liver copper retention. Increased zinc supplementation, regardless of dietary iron, reduced liver copper content; the reduction however, was more substantial in the high-iron (50 ppm supplementation) diets.

Experiment 2

Performance. Average daily gain, feed intake or feed conversion ratios were not significantly affected by feeding graded levels of zinc and copper; nor were there significant zinc \times iron interaction for these criteria (Table 3).

Body composition. The protein and fat content of carcass were significantly ($P < 0.01$) influenced by feeding varied levels of zinc and copper; however, the response to zinc showed a quadratic trend, whereas, for copper, it was linear (Table 3). Increased zinc supplementation to 25 ppm increased the average carcass protein content from 56.23 to 61.15%, but a further addition of zinc up to 50 ppm did not increase the carcass protein. Dietary copper depressed the carcass protein content only up to 5 ppm supplementation; at 10 ppm copper supplementation there was no further depression. There was also a

zinc \times copper interaction ($P < 0.01$) effect on the protein values. Copper supplementation up to 5 ppm in diet significantly ($P < 0.01$) increased the carcass protein content at low-zinc (0 to 25 ppm supplementation) diet; however, when copper was increased to 10 ppm, a reduction in the protein content was observed. The addition of 5 ppm copper to the diet containing 50 ppm zinc reduced the carcass protein content but this was restored by increasing the copper additive to 10 ppm.

The effect of dietary zinc on fat deposition was inconsistent. Supplementation of 25 ppm zinc in the diet reduced fat content, but a further addition had a restoring effect. Increased dietary intake of copper raised the carcass fat value ($P < 0.01$). There was also a significant ($P < 0.01$) zinc \times copper interaction effect on the carcass fat content. The greater intake of copper

TABLE 3
Effects zinc and copper supplementation in cassava-based diets on performance and body composition of chicks (Experiment 2)

Zinc addition, ppm	Dietary variables								
	0			25			50		
Copper addition, ppm	0	5	10	0	5	10	0	5	10
Avg diet intake ¹ , g/day	56.12	48.35	57.14	49.26	52.07	51.01	56.80	49.30	55.96
Avg daily gain ¹ , g	17.32	16.35	18.69	17.70	18.16	17.66	19.94	17.63	19.87
Feed/gain ¹	3.25	2.96	3.08	2.78	2.88	2.90	2.84	2.80	2.82
Whole carcass ¹⁰ :									
Protein ^{2,8} , %	55.93	58.09	54.68	62.30	61.25	59.89	60.53	56.87	59.86
Fat ^{2,8} , %	29.20	21.58	27.73	21.64	27.79	22.94	23.55	27.50	28.64
Zinc ³ , ppm	194.80	211.90	225.10	228.60	228.60	187.60	231.80	212.40	164.80
Iron ^{4,8} , ppm	309.70	287.80	246.60	258.40	318.00	306.00	323.60	313.20	294.60
Copper ^{5,9} , ppm	11.80	14.80	17.70	10.40	13.60	17.90	13.10	15.90	10.70
Liver ⁹ :									
Zinc ^{6,8} , ppm	166.83	159.27	155.09	171.26	168.58	173.65	185.15	203.58	204.57
Iron ^{7,8} , ppm	585.90	547.48	582.35	516.73	585.09	557.65	559.43	600.79	551.14
Copper ^{2,8} , ppm	30.59	73.66	126.28	23.43	55.53	73.43	21.00	51.64	68.52

¹Not significant at ($P < 0.05$)

²Significant at ($P < 0.01$) for zinc in a quadratic trend but for copper in a linear trend

³Significant at ($P < 0.05$) for copper in a quadratic trend but not for zinc

⁴Significant at ($P < 0.05$) for zinc in a linear trend but not for copper

⁵Significant at ($P < 0.05$) for zinc in a quadratic trend but for copper in a linear trend

⁶Significant at ($P < 0.05$) for zinc in a quadratic trend but not for copper

⁷Significant at ($P < 0.01$) for both zinc and copper in quadratic trend

⁸Significant at ($P < 0.01$) for copper-zinc interaction

⁹Not significant at ($P < 0.05$) for copper-zinc interaction

¹⁰Protein, fat, zinc, iron and copper values were based on the dry matter of samples

appeared to reduce fat deposition in birds which had been fed on 0 and 25 ppm zinc-supplemented diets, but fat content was markedly increased by additional copper intake when the diet was supplemented with 50 ppm zinc.

Tissue mineral composition. Supplementation of copper at 5 ppm did not significantly affect the carcass zinc content. On increasing the dietary copper supplementation, however, to 10 ppm, the carcass zinc content was significantly ($P < 0.01$) reduced (Table 3). Iron content in carcass was not affected by copper supplementation but copper content in the carcass increased linearly ($P < 0.01$) as the dietary copper was raised. A zinc \times copper interactive effect on carcass zinc and iron was observed although the trend of the response was not consistent. Copper content in the carcass was not influenced by the zinc \times copper interaction.

A zinc \times copper interaction effect on liver zinc content was observed. Increased dietary copper when added to diets with no zinc supplementation reduced liver zinc but its depressing effect was reduced as a higher level of zinc was incorporated into the diets. Considering overall effects, liver zinc content was significantly ($P < 0.01$) increased by zinc supplementation.

Liver iron content was markedly ($P < 0.01$) affected by both dietary zinc and copper intake, although the effect was not linear. Dietary supplementation of 25 ppm zinc resulted in a reduction in liver iron, but when supplementation was doubled the liver iron content was restored to that found in the unfortified diet. Copper addition at 5 ppm increased iron retention in the liver (554 to 578 ppm) but the addition of a further 10 ppm copper restored the iron retention in the liver to the level obtaining in cases when copper was supplemented at 10 ppm. A significant interaction between zinc and copper on the liver iron content was also noted. Increasing copper supplementation, in the low-zinc diet increased liver iron content, but an adverse response was observed when copper was added to high-zinc diet.

Liver copper content was significantly ($P < 0.01$) reduced by supplementation of 25 and 50 ppm zinc in diets. On the other hand, copper supplementation increased the liver content linearly ($P < 0.01$). A zinc \times copper interaction ($P < 0.01$) effect on liver copper was also observed.

DISCUSSION

Supplementation of zinc, iron and copper in cassava-based diets did not show significant effects on the daily gain, food intake and feed conversion efficiency of the broiler chicken. A comparison of the requirement of zinc, iron and copper (N.R.C. 1971) with their content in the diets reveals that these elements were adequate even in the unsupplemented diets (Table 1). Since there were no cases of toxicity observed, dietary zinc, iron and copper leveled up to 104 ppm (basal + 50 ppm zinc), 185 ppm (basal + 50 ppm iron) and 32 ppm (basal + 10 ppm copper), respectively, could be safely given to the broilers.

Earlier studies on the addition of zinc to diets found that zinc additives tend to reduce feed intake and gain in poultry (Underwood, 1971) and on lambs (Ott *et al.*, 1966). These workers ascribed the depressing effects to the unpalatability of the high-zinc diet. Such observations, however, were not apparent in the present study. The reason could be that the amount of $ZnSO_4 \cdot 7H_2O$ used in the present study was not large enough to affect the taste of the rations.

With cassava-based diets, supplementation of zinc had been reported to improve growth (Hutagalung *et al.*, 1973; Maust *et al.*, 1969, 1972). Maust *et al.* (1972) postulated that factors present in the cassava-based diet decreased the biological availability of the dietary zinc. Supplementation with inorganic zinc helps to replenish the zinc that was reduced in the cassava-based diets. The extent to which the zinc is made unavailable by the cassava factors is not known. Judging from the results obtained in this study, the additional amount of zinc required to upset this factor is not great; it is estimated to be in the region of a 10 ppm zinc addition to the normal requirement.

The factors that reduced the zinc availability from a cassava-based diet could probably be related to other ingredients used in the diet. Since cassava root meal is very low in protein (about 1.5%), the amount of soybean meal and fish meal had to be proportionally raised to balance the dietary protein as a larger quantity of cassava is used in the diet. This could lead to reduced absorbability of zinc from the intestine due to the presence of phytic acid from soybean as reported by Savage *et al.* (1964). Additional fish meal introduced into the diets would raise

the dietary calcium level since fish meal is very rich in calcium (about 7.0%). Calcium aggravates zinc depletion in the intestine by raising the intestinal pH (O'Dell, 1969). Combination of these two factors would reduce the zinc availability. Hence, the addition of zinc into diet in inorganic form provides a substitute whereby zinc is made use of for normal body function.

The results obtained are in agreement with the finding that poultry response to copper supplementation in diet shows no improvement in growth (Coates and Harrison, 1959; Slinger *et al.*, 1962) or that the response is too small to be statistically significant (Smith, 1969). The relationship between copper supplementation and the nature of basal diet was studied by Jenkins *et al.* (1970). Copper supplementation at 250 ppm improved growth in diets containing wheat and tallow but depressed growth in maize diets. It appears that a similar interaction between copper supplementation and cassava diet might affect the performance of chicks. However, on the basis of this study, there is no evidence which could substantially support this speculation.

The effect of the supplementation of zinc, iron and copper on carcass fat and protein content was inconsistent. The relationship between mineral and protein or fat deposition in the body is not clear. In the present study, carcass protein content maintained an inverse relation with the carcass fat suggesting that probably zinc, iron and copper supplementation had no direct effect on the degree of protein and fat accumulation in the body.

Tissue studies show that the quantity of mineral deposited was correspondingly proportionate to that supplemented in the diet. Liver was found to be very susceptible to copper supplementation in that high dietary copper substantially increased liver copper accumulation.

The degree to which reduction of copper occurs in the liver of chicks when the diet was supplemented with dietary zinc is in agreement with earlier reports (Magee and Matrone, 1960; Ritchie *et al.*, 1963; Van Campen, 1966; Van Campen and Scaife, 1967) indicating that zinc antagonizes copper absorption and retention in the body. Starcher (1969) suggested that the depressing effect of zinc on copper absorption in chicks arises from the fact that this element binds to and displaces copper from a duodenal mucosa protein resulting in reduced absorbability of copper into the system.

From a commercial standpoint growth performance is the main criterion that determines profitability. In the present study, weight gain was not improved by mineral supplementation. It can then be concluded that with cassava root constituting meal up to 40% of the diet, the fortification of specific mineral elements is not necessary. However, this may not be true when cassava root meal constitutes a greater proportion of the broiler feed or when it is used to completely replace maize as an energy source.

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SUPPLEMENTATION IN CASSAVA-BASED DIETS FOR BROILERS

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