Effect of high dietary intake of nickel in the West African dwarf goat

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ABSTRACT

The effect of dietary intake of nickel above nutritional requirement was studied in the West African dwarf (WAD) goat. Eight WAD goats with average initial live weight of 8.10 ± 1.46 kg were divided into two groups of four animals per group, by their body weights. Each group was fed a sole corn-based diet that was supplemented at 0 or 500 ppm level with elemental nickel as nickel sulphate hexahydrate ($NiSO_4.6H_20$). Serum total protein (g/100 ml) was significantly (P<0.05) reduced from 8.93 ± 0.28 in the control group to 5.63 ± 0.33 in the goats fed 500 ppm nickel. Effects of nickel treatment on haematological values were significant (P>0.05). Relative weights, expressed in g per 100 g weight of left side carcass (g/100 g LSC) for heart, kidney and lung were only slightly (P>0.05) reduced by the effect of high dietary nickel supplement. Tissue nickel concentration (ng/g) was in the order, 0.01, 1.55 and 5.42 for the liver, kidney and lung, respectively, in goats consuming nickel-supplemented diet. No significant (P>0.05) treatment effect was observed on the level of zinc in the heart, liver, lung or kidney. Results from the study suggested that supplemental nickel was fairly tolerated by the WAD goat at the 500 ppm level, as no drastic changes in tissue biochemical or haematological parameters were caused by the nickel treatment. However, there is need for the study to be carried out on a larger number of goats and for a longer period of feeding.

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RÉSUMÉ

YOUSUF, M. B.: *Effet de la consommation diététique élevée de nickel dans le chévre West African dwarf.* Effet de la consommation diététique de nickel au-dessus d'exigence alimentaire était étudié dans le chèvre de West African dwarf (WAD). Huit chévres de WAD avec un poids vif initial moyen de 8.10 ± 1.46 kg étaient divisés en deux groupes de quatre animaux par groupe, en se basant sur leurs poids corporels chaque groupe était nourri d'un seul régime basé sur le maïs qui était supplémenté au niveau de 0 ou 500 ppm avec nickel élémentaire comme sulfate de nickel hexahydraté ($NiSO_4.6H_2O$), Protéine totale de sérum (g/100 ml) était considérablement (P< 0.05) réduite de 8.93 ± 0.28 dans le groupe de contrôle à 5.63 ± 0.33 dans les chèvres nourri de 500 ppm de nickel. Effets de traitement de nickel sur les valeurs hématologiques étaient considérables (P<0.05). Les poids relatifs, exprimés en g par 100 g de poids de carcasse de côté gauche (CCG), (g/100 g CCG) pour le cœur, le rein et le poumon étaient seulement légèrement (P> 0.05) réduits par l'effet de supplément de nickel diététique élevé. La concentration de nickel du tissu (ng/g) était dans l'ordre 0.01, 1.55 et 5.42 respectivement pour le foie, le rein et le poumon dans les chèvres consommant le régime supplémenté avec le nickel. Aucun effet considérable (P> 0.05) de traitement n'était observé sur le niveau de zinc dans le cœur, le foie, le poumon ou le rein. Les résultats de l'étude suggéraient que nickel supplémentaire était équitablement toléré par le chèvre de WAD au niveau 500 ppm, comme aucun changement radical dans les paramètres biochimiques et hématologiques du tissu n'était provoqué par le traitement de nickel. Toutefois, il est nécessaire d'effectuer l'étude sur un grand nombre d'animaux et pour une période d'alimentation plus longue.

Introduction

Nickel is one of the few new trace minerals being considered for their essentiality in animal nutrition (Nielsen, 1991). The other trace minerals are boron, silicon, vanadium, and arsenic. Essentiality of nickel has been examined in several animal species including chicks (Nielsen & Sauberlich, 1970), rats (Nielsen *et al.*, 1975; Spears, Hartfield & Forbes, 1978a), and lamb (Spears *et al.*, 1978b). Deficiency symptoms associated with nickel in rats include

an alteration in the distribution of zinc and vitamin B_{12} (Poellot *et al.*, 1990). The white blood cell was suggested (Allison, Lancaster & Crostwaite, 1963) as the possible site of interaction between nickel and zinc. The two elements were found to increase the adhesiveness of polymorphornuclear leucocytes in rabbits. The specific biochemical function attributed to nickel was as a co-factor required for the action of biotin and vitamin B_{12} during metabolism of propionic acid (Nielsen, 1991).

Over supplementation of diets with trace minerals such as nickel could pose serious danger, not only to the livestock, but also to man consuming different animal products. The levels at which nickel is being used as dietary supplement vary considerably. Spears *et al.* (1978b) fed elemental nickel as nickel chloride at 5 ppm dietary level to sheep while a 500-ppm level was used (Spears *et al.*, 1978a) to study the interrelationship between nickel and zinc in the rat. Nielsen (1971) had earlier assessed the effects of 3-5 ppm supplemental nickel on chicks. In a study on the effect of ingestion of large amounts of nickel in the bovine, O'Dell *et al.* (1971) fed graded levels (0, 62.5, 250 and 1000 ppm) of elemental nickel to calves.

The objective of this study was to examine changes in biochemical, haematological, and carcass parameters that could result from over supplementation of diets with nickel in the West African dwarf goat. Underwood (1977) noted that the ultimate criterion of mineral imbalance, resulting from either under- or over-supplementation, is the impairment of animal performance with characteristic changes in biochemical and clinical parameters.

Materials and methods

Treatment

Eight WAD goats, varying in live weights between 7.2 and 10.4 kg, were divided into two groups. The treatment group was fed a corn-based, complete diet (Table 1) which was supplemented at 500 ppm with elemental nickel in the form of nickel sulphate hexahydrate ($N_iS0_4.6H_20$). The control group received the corn-based diet without nickel supplement. The goats were fed individually at 0800 and 1400 h daily. Clean drinking water was provided free-choice.

TABLE 1

Composition of Experimental diet

	Control	*Supplemented*
Ingredients (%)		
Ground maize	50	50
Maize offal	25	25
Cotton seed cake	14	14
Rice bran	10	10
Salt + bone meal (1:1)	1	1
Nickel sulphate hexahydrate	-	500 (ppm)
Analysed components	*g/100 gDM*	
Dry matter	94.6	
Crude protein	14.7	
Crude fibre	24.8	
Ether extract	4.6	
Ash	8.3	
Energy (Kcal/gDM)	5.4	

Collection of samples and measurement

Blood samples were drawn from the jugular vein of each goat on the last day of the 56-day trial. Two representative goats from each dietary group were then sacrificed for carcass measurements and tissue analyses. Two blood samples were collected from each goat and put into two plastic bottles, one of which contained 2 % (v/v) potassium oxalate. Records of average daily feed intake were kept for the individual goat. The weights of the left side carcass, kidney, heart, lung, spleen, and liver were determined and recorded for each goat. Tissue samples were collected from the kidney, heart, lung, spleen, and liver to determine nickel and zinc contents.

Chemical analyses

Haemoglobin concentration of the whole blood sample was estimated by using the

cyanmethaemoglobin reagent (Hycel Inc.; Huston, Texas), with reading being made at 540 nm in an atomic absorption spectrophotometer (Perkin-Elmer, 306). Serum total protein was estimated from the other blood sample by the Biuret method (Weichselbaum, 1946). Serum urea nitrogen and glucose contents were measured by the Urease and Benedict methods (Sigma Chemical Co., 1974), respectively. Nickel and zinc contents of heart, spleen, liver, lung, and kidney were determined in an atomic absorption spectrophotometer (Perkin-Elmer, 306).

Statistical analysis

The data were analysed according to Steel & Torrie (1980). Means were compared by using the paired t-test.

Results

No physical ailment that could be attributed to a high dietary nickel intake was observed in the goats during the 56-day feeding trial. The average intake (mg/d) of supplemental nickel were 0 and 110 for the control and nickel-supplemented groups, respectively.

Table 2 shows the data on serum and haematological measurements. Serum total protein was significantly ($P<0.05$) reduced by the effects of high dietary nickel intake (8.93 vs 5.63 g/100 ml). Serum glucose and urea concentrations as well as blood haemoglobin, erythrocyte and leucocyte levels tended to be higher in goats fed the control, unsupplemented diet. However, the differences were not significant ($P>0.05$). The slaughter weight response of goats to high dietary nickel intake was not significant ($P > 0.05$) (Table 3). Relative weights (g/100 g LSC) of heart, kidney and liver were slightly ($P>0.05$) reduced, while relative weight of lung increased slightly in the nickel-treated goats. Table 4 shows data on nickel and zinc contents of tissue samples of liver, lung, and kidney. Supplemental nickel was retained to a greater extent in the lung, followed by the kidney and liver in that order. Only traces of nickel were found in the internal organs of goats fed the control diet. The high dietary nickel treatment caused no significant ($P>0.05$) differences in the distribution of zinc in the heart, spleen, liver, lung or kidney.

Discussion

Supplemental nickel intake for the experimental group was estimated from an average daily feed

TABLE 2

*Influence of High Dietary Nickel on Serum Parameters and Haematological Values in the Goats**

Serum parameters	*Supplemental Ni (ppm)*	
	0	500
Av Ni intake mg/kg B.W	0	13.39
Urea nitrogen, mg/100 ml	7.40 ± 0.24	7.30 ± 0.24
Total protein, g/100 ml	8.93 ± 0.33[a]	5.63 ± 0.28[b]
Glucose, g/100 ml	66.23 ± 0.13	65.03 ± 0.44
Haematological values		
Haemoglobin, g/100 ml	10.63 ± 0.33	10.37 ± 0.32
Erythrocytes, × 10^6/ ml	7.23 ± 0.36	6.83 ± 0.34
Leucocytes × 10^6/ ml	7.80 ± 0.35	7.33 ± 0.26

* Mean of four goats ± standard error of mean.
Means followed by the same superscript letter in the same horizontal column were not significantly different ($P>0.05$).

TABLE 3

*Effect of High Dietary Nickel on Carcass Characteristics and Relative Weight of Some Internal Organs in the Goats**

	Supplemental Ni (ppm)	
	0	500
Carcass characteristics		
Left side carcass, LSC	1.95	1.90
Gut contents	1.04	0.95
Empty live weight	9.65	9.75
Organ (g/100 g LSC)		
Heart	0.48	0.46
Kidney	0.51	0.49
Liver	1.84	1.83
Lung	0.81	0.83
Spleen	0.20	0.19

* Mean of two goats

TABLE 4

*Effect of High Dietary Nickel on Tissue Distribution of Nickel and Zinc in the Goats**

	Supplemental Ni (ppm)	
	0	500
Tissue mineral level (mg/g)		
Heart	Traces (12.8)+	Traces (12.5)
Spleen	Traces (28.6)	Traces (28.8)
Liver	Traces (22.5)	0.1 (21.8)
Lung	Traces (18.5)	5.4 (18.7)
Kidney	Traces (36.2)	1.6 (34.6)

* Mean of two goats
\+ Values in bracket indicate concentration of zinc in the organs.

intake of 220.53 ± 1.83 g which showed a slight reduction from 247.20 ± 2.29 g for the control group. Average nickel intake expressed as a unit of body weight was 13.37 mg/kg for goats receiving nickel supplement. O'Dell *et al.* (1971) had an average daily supplemental nickel intake of 13.90 mg/kg body weight for calves fed at 1000 ppm dietary level.

Serum total protein appeared to be the only metabolic parameter affected by the high dietary nickel treatment in this study. Spears *et al.* (1979) reported an increase in serum urea nitrogen, total protein, and glucose concentrations in lambs fed a 5-ppm dietary nickel supplement. The heart and spleen appeared not to be good storage sites for nickel as both contained only traces of the mineral. Underwood (1977) had noted low concentrations of trace minerals in the heart even at high levels of intake. The higher concentration of nickel in the lung agreed with the findings of Wase, Goss & Boyd (1954) who suggested the formation of a complex between nickel and 'lung protein' in mice. In contrast, Spears *et al.* (1978b) reported a high concentration of ^{63}Ni in kidney, lung and liver, with the kidney retaining a substantial amount of the isotope. In the same study, they reported no significant effect of a 5-ppm dietary nickel treatment on zinc contents of lamb tissues. However, Anke *et al.* (1974) reported that swine fed low nickel diets had lower zinc concentrations in certain tissues.

This study suggests that the WAD goat has some tolerance for a high dietary nickel intake, as no adverse effect of the 500-ppm dietary intake level was observed. A homeostatic control mechanism for nickel in the calves had been suggested (O'Dell *et al.*, 1971). That notwithstanding, a study on the long term effects of nickel using a larger number of the WAD goats could provide additional information.

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