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A comparative study on the distribution of cyanide in sections of the digestive tracts and other organs in the domestic chicken (*Gallus domesticus L.*) exposed to varying levels of cyanide

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ABSTRACT

The distribution of cyanide in the domestic chicken (Gallus domesticus) given different doses (1, 2 and 3 mg kg^{-1} body weight of cyanide) directly (by gavage) and in the diet for a period of 12 weeks was investigated in this study. A total of eighty four-day old birds were used for this experiment. The chicks were divided into seven groups of twelve birds each: Group I- normal control, Group II, III and IV - received 1, 2 and 3 mg CN kg^{-1}b.w. as Sodium cyanide (NaCN) directly respectively, while Group V, VI and VII received 1, 2 and 3 mg CN kg^{-1}b.w. as NaCN in their feed respectively. The study revealed that the accumulation and distribution of CN^- in the organs and sections of the digestive tract was influenced by time and mode of exposure. Irrespective of the duration of exposure, the duodenum had the highest concentration of cyanide, in birds offered cyanide in their diet; conversely after 12weeks,while the ileum had the highest concentration in birds treated with CN^- directly also irrespective of the mode or dose of exposure the kidney had the highest CN^- level. Cyanide concentration was also found to be significantly higher in the serum, sections of the digestive tract and organs of birds given cyanide directly compared with those given cyanide contaminated feed.

Key words: Sodium cyanide, domestic chicken, digestive tract

INTRODUCTION

Cyanide is well known among the public as a very poisonous substance. However man and animals are regularly ingesting variable levels of cyanide in certain natural diets [1,2]. Indeed estimates suggest that the amount taken in some of such diets are sometimes considerable [3,4]

The major sources of cyanide in the diet are cyanogenic glycosides and an example of a cyanogenic plant is cassava (*Manihotesculentacrantz).*Others include common foods such as sorghum, linseed, maize, millet, sweet potatoes and bamboo shoots [5,6] The maximum yield of cyanide from some of these sources could be as high as 100-300mg/100g of tissue [2,7]. The high demand for cereals due to increasing human population and their use by millers for compounding livestock feeds coupled with the need for livestock products have led to the use of unconventional feeds for animal production [8]. These unconventional feed materials include sorghum, spent grains and wheat offals (by-product of sorghum and wheat malting respectively) as well as cassava [9, 10, 11]. As a result of the increasing use of cassava in animal feeding there is greater exposure to dietary toxins from cyanogenic glycosides. It is generally accepted that the toxicity of cyanogenic glycosides is due entirely to the release of free cyanide[12,13].The use of cassava in animal feed presents two major problems: the presence of cyanogenic glycosides in the tuber, and the remarkably low protein levels in fresh and dried cassava. [14,15] Many studies have reported the death of birds from cyanide poisoning through several routes, including exposure to cyanide salts or ingestion of cyanogenic plants [16,17] Although the liver has been considered to be the major source of rhodanese and is believed to be the major site of cyanide detoxification, some researchers have shown that considerable variations exist in rhodanese distribution in different parts of the digestive parts of the chicken at different ages [18,19] There have also been studies on the distribution of cyanide radical in the tissues of animals [20,21,22] However, it has also been shown that the thiocyanate formed from cyanide in the mammalian tissue is largely secreted into the stomach contents of rats and rabbits, but reabsorbed in the gut to be partly excreted in the urine and partly reabsorbed into the stomach contents[23]. However with respect to birds, there have been limited studies on the distribution of cyanide and thiocyanate in the digestive tract of the bird. The mode of metabolism of cyanide has not also been established in birds.

MATERIALS AND METHODS

Animal Procurement

A total of eighty four one-day old birds purchased from Zartech farms Sapele, Delta state, Nigeria, were used for the study. The birds used in this study were maintained in accordance with the guidelines approved by the animal ethical committee, Delta state university Abraka, Delta State Nigeria. The chicks were kept in a standard wooden cage made up of wire gauze net and solid woods. The chicks were fed with starters mash for three weeks and thereafter, they were fed with growers mash, both mash were purchased from Top feeds, PLC, Sapele, Delta state, Nigeria. The chicks were also given tap water ad libitum

Experimental Design

The chicks used for the experiment were divided into seven groups of twelve birds each, the groups were given the following treatments. The chicks were brooded on deep litter using 100 watt bulbs, flat plastic feeders and shallow drinkers for the first two (2) weeks of the experiment. The birds were fed starter mash experimental diets for four (4) weeks. Feed and water were provided *ad-libitum*. The birds were vaccinated against gumboro disease at the second and fourth weeks of age as first and second doses respectively. The experimental birds (Group II – IV) were intoxicated with cyanide every morning using gavage but they are fed with normal mash and tap water. Groups V-VII experimental birds were fed with different concentrations of cyanide in their feed every morning and normal tap water. The weights of the chicken were taken before administering the cyanide every morning. A third of the birds in each group was given this treatment for four weeks, while another third was for eight weeks. The final third in each group was treated for twelve weeks. Thus each group had four birds for each of the duration of exposure. The treatments are as shown below

Group I- normal control.
Group II - received 1 mg CN/kg body weight directly
Group III - received 2 mg CN/ kg body weight directly
Group IV – received 3 mg CN/kg body weight directly
Group V – exposed to 1 mg CN/ kg feed
Group VI – exposed 2 mg CN/kg feed
Group VII – exposed 3 mg CN/kg feed

Collection of Samples

After completing the duration specified for each sub group chicks were weighed and sacrificed under anaesthesia: The blood, sections of the digestive tracts, liver, brain, heart and kidney were collected.

Treatment of Samples

The tissues of the digestive tract of the chicken were weighed and 20% homogenates were prepared using 10% sucrose solution. The homogenates were centrifuged and the supernatants obtained were used for biochemical analysis.

Principle

Estimation of cyanide in the diet, serum and tissues was based on the procedure of Esser et al., [24]

RESULTS AND DISCUSSION

The biochemical effects of cyanide and its distribution and metabolism in the digestive tract and other organs of the domestic chicken (*Gallus domesticus*) given different doses of cyanide directly and indirectly via diet were investigated in this study. The significant increase ($p<0.05$) in serum cyanide level in most of the cyanide exposed birds indicates that the cyanide given to the birds via the two methods was absorbed into the blood stream. This is in agreement with the findings from previous studies [25, 26] involving rats.

Cyanide is a highly toxic compound that is readily absorbed and causes death by preventing the use of oxygen by tissues [27, 19] Results from this study also indicate that the weight of birds can be affected by both dose and mode of exposure to cyanide [1]. At the different doses of cyanide given to the birds, mean body weight gain was only significantly decreased at the highest dose (3mgCN^-/kg body weight) in those given cyanide directly, for 8 and 12 weeks. Conversely there was no significant change in weight gain in those given the toxicant in their diet. This is consistent with the results of previous studies that revealed a lack of significant change in body weight in chicks fed diets containing up to 30% cassava root meal for 28 days with the cassava root containing 300 mg of total cyanide/ kg. [28]

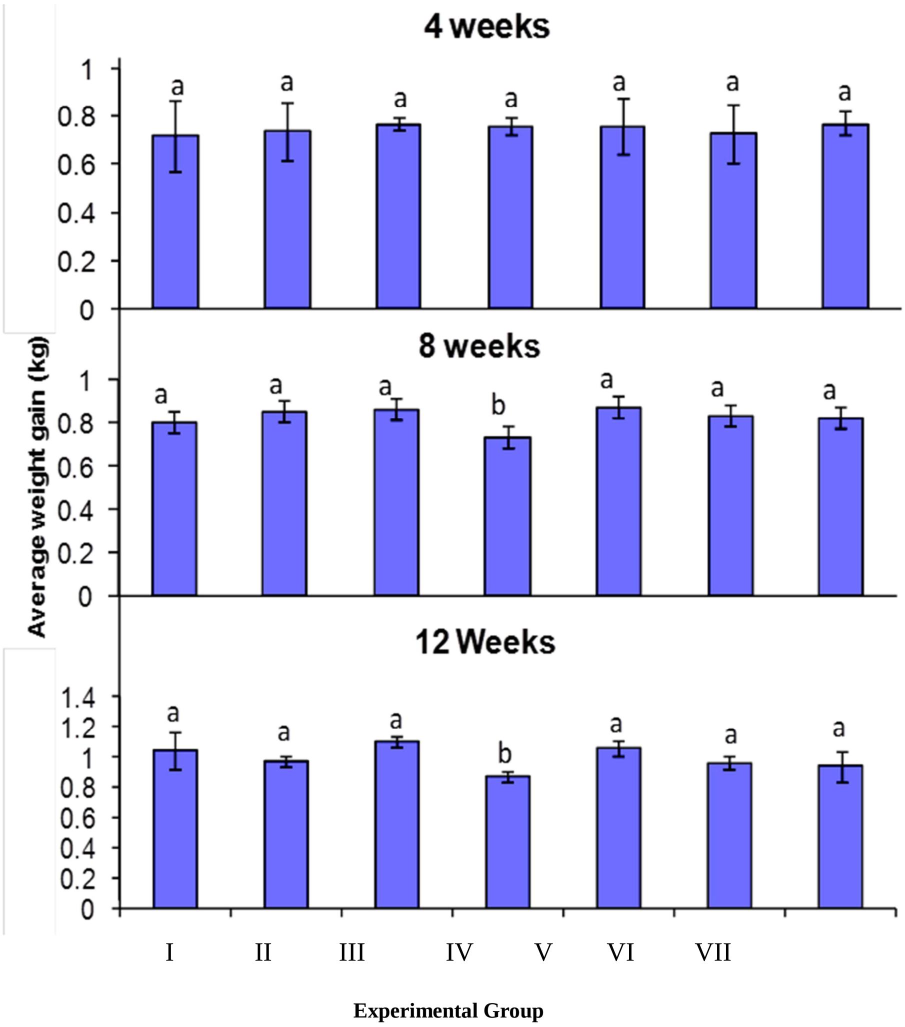

Figure 1: Average weight gain of birds exposed to cyanide directly (II-IV), via food (V- VII) and cyanide free birds
The results are expressed as mean±Standard Deviation (n=4)
Bars not sharing a common superscript differ significantly (P<0.05) from the others.

The kidney had the highest cyanide level irrespective of the mode and duration of exposure among the organs. High concentration of cyanide in the kidney may be related to the role of this organ in eliminating the metabolites through urate [29] It has also been suggested that the level of rhodanese in different tissues of animals is correlated with the level of exposure to cyanide[30,31]. Therefore the findings of this study is in agreement with that of CastellaBertran [32] and Oh *et al.*, [33] which reported that rhodanese activity in the kidney is twice that of the liver in chicken. Similarly available reports indicate that renal activity of rhodanese significantly ($p<0.05$) exceeds that of liver in pigeon [34,19] in ostrich[30] and in Japanese quail[29].Okohand Pitt [23] also showed that radioactive cyanide was widely distributed, with the highest concentrations in the gastrointestinal tract, blood, kidneys, lungs, spleen, and liver in rats fed KCN in the diet at 77 µmol/day (approximately 5.5 mg/kg-day CN) for 3 weeks and then injected intraperitoneally (i.p.) with radiolabeled NaCN. Apart from the kidney, the organ with the highest concentration of cyanide after 12 weeks of exposure *in vivo* (Table 4.1) is the liver. The liver has been known to be the major site of cyanide metabolism and detoxification, [35,36,34] The high concentration of cyanide in the liver may also be due to the first-pass metabolism in the liver, following oral dosing, and initial deposition at the portal of entry, following exposure.

Table 1: The distribution of Cyanide in the serum and organs of birds exposed to cyanide directly and in their feed for 12weeks

GROUPS	DIRECT EXPOSURE				EXPOSURE VIA FOOD		
Organ	Group I (Control)	Group II (+CN)	Group III (+CN)	Group IV (+CN)	Group V (+CN)	Group VI (+CN)	Group VII(+CN)
Serum	0.35±0.02[a]	2.22±0.04[b]	3.45±0.06[c]	4.63±0.04[d]	0.42±0.05[a]	0.66±0.04[e]	0.88±0.06[f]
Liver	0.17±0.03[a]	0.45±0.05[b]	0.79±0.04[c]	1.09±0.04[d]	0.27±0.06[a]	0.43±0.04[b]	0.60±0.04[e]
Pancreas	0.06±0.01[a]	0.19±0.04[b]	0.31±0.04[c]	0.54±0.03[d]	0.07±0.04[a]	0.09±0.04[a]	0.14±0.03[b]
Kidney	0.20±0.01[a]	0.48±0.04[b]	0.91±0.04[c]	1.56±0.04[d]	0.35±0.05[a]	0.49±0.04[b]	0.85±0.04[c]
Brain	0.15±0.04[a]	0.26±0.04[b]	0.44±0.04[c]	0.65±0.04[d]	0.20±0.04[a]	0.30±0.07[b]	0.45±0.04[c]
Heart	0.10±0.07[a]	0.42±0.03[b]	0.66±0.03[c]	0.76±0.04[d]	0.16±0.03[a]	0.25±0.03[e]	0.39±0.04[b]

The results are expressed as mean± Standard Deviation (n=4)
The cyanide concentration and it is in µg/g tissue for the organs and mg/ml for serum. Value not sharing a common superscript on the same row differ significantly (P<0.05) from each other

Table 2: The distribution of cyanide in different sections of the digestive tract of birds exposed to cyanide directly and in their feed for 12weeks

GROUPS	DIRECT EXPOSURE				EXPOSURE VIA FEED		
ORGANS	Group I Control	Group II +CN	Group III +CN	Group IV +CN	Group V +CN	Group VI +CN	Group VII +CN
Oesophagus	0.06±0.03[a]	0.35±0.03[b]	0.58±0.04[c]	0.74±0.05[d]	0.07±0.03[a]	0.10±0.04[a]	0.21.±0.05[b]
Crop	0.10±0.03[a]	0.25±0.04[b]	0.44±0.02[c]	0.65±0.03[d]	0.12±0.05[a]	0.18±0.02[a]	0.47±0.03[c]
Gizzard	0.18±0.04[a]	0.44±0.04[b]	0.67±0.06[c]	0.97±0.04[d]	0.24±0.07[a]	0.28±0.04[a]	0.62±0.04[c]
Proventriculus	0.16±0.06[a]	0.36±0.03[b]	0.61±0.04[c]	0.91±0.03[d]	0.27±0.03[ab]	0.32±0.04[b]	0.64±0.03[c]
Ileum	0.24±0.04[a]	0.57±0.05[b]	0.83±0.05[c]	1.07±0.04[d]	0.30±0.05[a]	0.36±0.05[a]	0.71±0.04[c]
Duodenum	0.18±0.02[a]	0.53±0.04[b]	0.68±0.05[c]	1.03±0.03[d]	0.33±0.06[e]	0.47±0.05[b]	0.85±0.05[f]
Large Intestine	0.06±0.06[a]	0.16±0.03[b]	0.28±0.04[c]	0.55±0.05[d]	0.08±0.03[a]	0.12±0.04[ab]	0.25±0.05[c]
Caeca	0.05±0.04[a]	0.12±0.03[b]	0.19±0.05[b]	0.49±0.07[c]	0.09±0.03[a]	0.13±0.03[b]	0.27±0.04[bd]
Cloaca	0.07±0.03[a]	0.15±0.03[a]	0.26±0.07[b]	0.53±0.04[c]	0.10±0.03[a]	0.16±0.05[a]	0.31±0.03[b]

The results are expressed as mean± Standard Deviation (n=4)
Cyanide concentration is expressed in µg/g tissue for the organs.
Values not sharing a common superscript on the same horizontal row differ significantly (P<0.05)

Cyanide was also found to be present in all the sections of the digestive tract of the birds given cyanide *in vivo* and in their diet (Table 2) which is in agreement with previous works carried out in the diet of chicks, rabbits and rats [28,37,23].The duodenum had the highest concentration of cyanide in birds offered cyanide in their diet, while the ileum had the highest concentration of cyanide in those treated with cyanide *in vivo*. It is noteworthy that there has been no previous report on the distribution of cyanide in the digestive tract of birds. However the reports of Aminlari*et al*.,[19] revealed that the level of the enzyme rhodanese involved in cyanide detoxification increases in the duodenum with age of the chicken and this might reflect the efficacy of the tissue in cyanide detoxification.

The higher cyanide in the serum, liver, pancreas, brain, heart and sections of the digestive tract of the birds given cyanide *in vivo* compared with those given cyanide in their diet may be due to the fact that food in the stomach delays absorption of cyanide [38]

CONCLUSION

The accumulation and distribution of cyanide in the serum, digestive tract and organs of the domestic chicken exposed to different concentrations of cyanide directly and in their feed was influenced by both the mode of exposure and dose. Also, cyanide concentration was found to be significantly higher in the serum, sections of the digestive tract and organs of birds given cyanide directly compared with those given cyanide contaminated feed.

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