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Effects of total dissolved solids on the accumulation of Br, As and Pb from drinking water in tissues of selected organs in broilers

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Abstract

Water quality constituents ingested through drinking water can affect the animal's physiology negatively and, through bioaccumulation in tissues, pose a biohazard to consumers. The study evaluated the effectiveness of a total dissolved solid (TDS) treatment as a possible alleviator of the accumulation of potentially hazardous chemical constituents (PHCC) in drinking water in broiler tissues. The trial design was 4 treatments x 7 replicates x 12 mixed Ross broilers per replicate. Treatments were T1 = TDS (NaCl) <500 mg/L + Br, As, Pb < 0.005 mg/L, T2 = TDS <500 mg/L + Br, As, Pb 0.1 mg/L, T3 = TDS 1500 mg/L + Br, As, Pb < 0.005 mg/L, T4 = TDS 1500 mg/L + Br, As, Pb 0.1 mg/L, administered through the drinking water from Days 1 to 42. Water intake and growth performance were recorded. Broilers were slaughtered, samples taken of liver, kidney, heart, thigh and breast tissue and analysed for accumulation of elements. TDS significantly ($P < 0.05$) effected the accumulation of elements in some tissues. This confirmed the risk of ingesting PHCC through drinking water, and showed the potential of reducing the risk of accumulating PHCC in selected tissues by the controlled application of TDS in drinking water. However, the concentration attained within a short production period did not exceed the maximum allowable concentration for these elements in broiler tissue destined for human consumption.

Keywords: Water quality, poultry, bromine, arsenic, lead, heavy metals
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Introduction

Water quality constituents (WQC) determine the quality of water. The effects that these may have on an animal's physiology are determined by the WQC concentration, the ingestion rates and the agonistic or antagonistic interactions between the WQC. Total dissolved solids (TDS) may have an alleviatory effect on potentially hazardous WQC according to livestock type and site specific circumstances (Casey & Meyer, 2001; Elsenbroek *et al*., 2003). The effect of WQC on the production parameters of broilers was shown by Coetzee *et al*. (2000a), Coetzee *et al*. (2000b) and Casey *et al*. (2001).

The TDS of borehole water over a wide area in South Africa exceed 6000 mg/L, as shown in research for the Water Research Commission, the Klein Karoo Korporasie, National Department of Agriculture and the South African National Parks (Casey & Meyer, 2001). The same results revealed the presence of Br, As and Pb in concentrations that exceed the recommended guidelines, placing these WQC in the category of potentially hazardous chemical constituents (PHCC). Br, As and Pb in the drinking water of livestock are potentially hazardous to consumers for the reason that these WQC can accumulate in the tissue and become a route by which consumers are exposed to Br, As and Pb. High concentrations of heavy metals may significantly decrease water intake (WI) as there is a clear indication of a linear relationship between increased concentration of the chemical mixture in the drinking water and decreased body weight of broiler breeder hens (Vodela *et al*., 1997). Sodium chloride (NaCl) is a potential alleviator based on the positive results obtained in mitigating chronic fluorosis and selenosis in cattle and sheep (Casey *et al*., 2001; Elsenbroek *et al*., 2003), and the observations of high TDS concentrations in many rural communities.

The paper assesses the potential to alleviate the accumulation of Br, As and Pb in broiler tissues through TDS in drinking water.

Materials and Methods

The trial design was 4 treatments x 7 replicates x 12 Ross broilers of mixed sex per replicate. Treatments were T1 = TDS (NaCl) <500 mg/L + Br, As, Pb < 0.005 mg/L, T2 = TDS <500 mg/L + Br, As, Pb 0.1 mg/L, T3 = TDS 1500 mg/L + Br, As, Pb < 0.005 mg/L, T4 = TDS 1500 mg/L + Br, As, Pb 0.1

mg/L, administered through the drinking water from Days 1 to 42. The broilers were reared from Day 1 on a litter floor in an environmentally controlled house. Water was delivered from graduated cylinders via nipple drinkers for an accurate measuring of WI. The feed was the same standard broiler feed *ad libitum* throughout the trial in two feeding phases, a starter phase from Days 1 to 16 and a finisher phase from Days 17 to 49. The final concentrations of the chemical mixture were confirmed by testing the samples at the point of use. The treatments delivered final concentrations of 0.1 mg As/L as arsenic-trioxide (As_2O_3), 0.1 mg Pb/L as lead nitrate ($Pb(NO_3)_2$), and 1 mg Br/L as sodium bromide (NaBr). The lowered As level was selected as an attempt to identify an acceptable hazardous margin in excess of the recommended guideline limit (0.01 mg/L) (Casey & Meyer, 1996; Casey & Meyer, 1998). WI was recorded by week. The birds were slaughtered on Day 42 by conventional method. Samples of thigh, breast, liver, heart and kidney were collected from each broiler at slaughtering. Pooled samples were frozen and milled and analyzed using standard inductively coupled mass spectrometry (ICP-MS) techniques to determine trace element concentrations.

Statistical analysis was by the SAS (Statistical Analyses System®). General linear estimate and hypothesis tests were used for regression analysis. Significance was at P <0.05 by means of the Bonveroni test.

Results

Water intake (mL/bird/d) increased in all treatments over the period (Table 1). The TDS (NaCl) treatments (T3 and T4) significantly increased WI from Week 2 (P <0.05). No significant differences occurred between the TDS treatment groups (T3 and T4) or between the non-TDS treatment groups (T1 and T2). The mean ingestion of As was 0.0236 mg/bird/d for T2, and Pb 0.0262 mg/d/bird for T3. Br ingestion was 0.236 mg/bird/d for T2 and 0.262 mg/d/bird for T3. Total ingestion of As from T2 was 1.325 mg and Pb from T3 1.469 mg. T1 and T2 resulted in a total Br ingestion of 13.257 and 14.697 mg, respectively.

Table 1 Water intake (mL/bird/d) by broilers exposed to Br, As and Pb and total dissolved solids (TDS) in drinking water over a six week growth period

	Treatments			
	T1 (mg/L)	T2 (mg/L)	T3 (mg/L)	T4 (mg/L)
	TDS <500	TDS <500	TDS 1500	TDS 1500
	Br, As, Pb <0.005	Br, As, Pb = 0.1	Br, As, Pb <0.005	Br, As, Pb = 0.1
Period	Means (standard deviation) (mL/bird/day)* by treatment			
Week 1	93 ^{ab} (0.009)	92 ^{a} (0.002)	99 ^{ab} (0.012)	103 ^{a} (0.001)
Week 2	153 ^{a} (0.012)	150 ^{a} (0.005)	173 ^{b} (0.011)	174 ^{b} (0.008)
Week 3	180 ^{a} (0.005)	176 ^{a} (0.007)	203 ^{b} (0.009)	197 ^{b} (0.009)
Week 4	238 ^{a} (0.006)	232 ^{a} (0.007)	260 ^{b} (0.013)	272 ^{b} (0.013)
Week 5	298 ^{a} (0.013)	288 ^{a} (0.012)	326 ^{b} (0.013)	320 ^{b} (0.016)
Week 6	310 ^{a} (0.012)	301 ^{a} (0.012)	340 ^{b} (0.035)	338 ^{b} (0.021)

*Means for water intake calculated from observations of 7 replicates per group with 12 birds per replicate.
^{a,b}Means within rows for replicates bearing the same superscript did not differ (P < 0.05).

The accumulation of elements in the tissues of selected organs is shown in Table 2. In liver, Br in T2 was higher than T1 (P <0.05), whereas the levels of As and Pb did not differ, indicating that the level of Br in the water may have a direct effect on the accumulation of Br in liver tissue. In the presence of a high TDS (1500 mg/L) the Br accumulation in liver was lower, but not significantly. The level of both As and Pb in kidney tissue was higher in T2 than T1 (P <0.05), and the high TDS alleviated the accumulation of both As and Pb (P <0.05). In heart tissue the level of As was higher by T2 than T1 (P <0.05), Pb did not differ, and the Br was higher in T2 than T1 (P <0.05). The accumulation of As and Pb were lower (P <0.05) due to the high TDS, but the TDS had no apparent effect on Br. In thigh tissue, Br, As and Pb were higher in T2 (P

<0.05), while the higher TDS had no significant effect on the accumulation of these elements. Neither dosage nor TDS affected the accumulation of Br and As in breast muscle. There was no clear pattern for Pb.

Table 2 Accumulation of arsenic (As), lead (Pb) and bromide (Br) in liver, kidney, heart, thigh and breast tissue (mg/kg DM) from broilers exposed to As, Pb, Br and TDS in drinking water under intensive production conditions

		Treatments			
		T1 (mg/L)	T2 (mg/L)	T3 (mg/L)	T4 (mg/L)
		TDS <500	TDS <500	TDS 1500	TDS 1500
		Br, As, Pb <0.005	Br, As, Pb = 0.1	Br, As, Pb <0.005	Br, As, Pb = 0.1
Organ	Elements	Means (standard deviation) (mg/kg DM basis) by treatment			
Liver	As	0.3710^{a} (0.052)	0.3980^{a} (0.088)	0.3860^{a} (0.056)	0.3560^{a} (0.048)
	Pb	0.2450^{ab} (0.104)	0.3120^{a} (0.035)	0.2720^{b} (0.022)	0.2620^{ab} (0.077)
	Br	10.610^{a} (3.449)	14.890^{b} (4.542)	11.920^{ab} (3.890)	12.030^{ab} (4.120)
Kidneys	As	0.3465^{b} (0.022)	0.4515^{a} (0.054)	0.3538^{b} (0.028)	0.3573^{b} (0.03)
	Pb	0.0914^{a} (0.024)	0.0652^{b} (0.009)	0.0880^{a} (0.02)	0.0388^{c} (0.01)
	Br	6.6110^{b} (0.622)	11.2188^{a} (1.523)	6.9408^{b} (0.769)	6.0407^{b} (1.264)
Heart	As	0.2395^{b} (0.039)	0.2990^{a} (0.022)	0.2123^{c} (0.023)	0.2403^{b} (0.024)
	Pb	0.1295^{a} (0.059)	0.1327^{a} (0.047)	0.0781^{b} (0.015)	0.0675^{b} (0.017)
	Br	6.0163^{c} (1.387)	20.5238^{a} (1.007)	13.0090^{b} (2.529)	6.0027^{c} (1.514)
Thigh	As	0.2400^{ab} (0.055)	0.2740^{a} (0.067)	0.2490^{ab} (0.064)	0.2320^{a} (0.053)
	Pb	0.1320^{a} (0.069)	0.2370^{b} (0.140)	0.1160^{a} (0.042)	0.1380^{a} (0.127)
	Br	7.7370^{a} (3.695)	13.9640^{b} (5.810)	7.2630^{a} (4.387)	7.8270^{a} (3.713)
Breast	As	0.1510^{a} (0.057)	0.1670^{a} (0.072)	0.1650^{a} (0.069)	0.1460^{a} (0.067)
	Pb	0.1230^{ab} (0.068)	0.1930^{a} (0.174)	0.1300^{ab} (0.171)	0.1040^{ab} (0.087)
	Br	5.0660^{a} (4.455)	7.7030^{a} (4.998)	7.2040^{a} (4.684)	5.2540^{a} (4.173)

^{a,b}Means within rows for each element bearing the same superscript did not differ ($P< 0.05$).

Discussion

All classes of livestock can tolerate saline water with <300 mg NaCl/L comfortably. Further increases in salinity require the application of guidelines together with an observation of the reactions of livestock to that saline water source (Ahmed, 1989).

Palatability factors play a significant role in satiety for salt appetite animals (Jalowiec *et al*., 1966; Schulkin, 1982) as they select saltier tasting solutions to less salty tasting solution. The TDS treatments had significantly higher WI ($P <0.05$) than the non-TDS treatments, which concurs with the physiological situation of salt inducing thirst that leads to increased WI. The fact that the WI was higher in TDS treatments and their tissue PHCC accumulation was lower suggest that higher WI may result in lower accumulation of PHCC in chickens.

The alleviatory and physiologically beneficial effect of a high TDS was demonstrated when a TDS (NaCl) of 3000 mg/L improved the health and the reproductive status of Bonsmara cows exposed to potentially hazardous water (Elsenbroek *et al*., 2003).

The significantly lower PHCC values for the saline treatment T3 compared to T2 suggest that the alleviator potential of a volume loaded hypertensive chemical may be significant, but must not be applied in the absence of key constituents of concern (COC), as the dynamics of the alleviator treatment may precipitate a marginal deficiency of specifically those elements with a narrow range between essentiality and toxicity. An additional perspective, by implication, is that TDS must be considered in the site-specific formulation of water quality guidelines for poultry when present at concentrations exceeding 100 mg/L in terms of potential increases in tolerable ranges of other trace elements. The role of Br in alleviating accumulation of PHCC requires further investigation.

It is more appropriate not only to assess WQC ranges with regard to water quality norms, but also production systems. Based on the results obtained it would appear that the treatment levels applied for this trial would be acceptable if observed in the rural communal environment in terms of health, production and product quality norms, with the notable prerequisite being similar environmentally controlled housing facilities and quality rations. These findings support the need for rural communities to be provided with adequate facilities with which to implement poultry production especially under circumstances that see them reliant on groundwater to provide water for livestock. Rural production differs from intensive production systems in that in intensive systems the accumulation of constituents such as Pb in renal cortex tissues does not present a significant consumer hazard, as concentration and dilution within the urban diet, effectively provide for sufficient safety. However, the risk of ingesting PHCC through food increases in rural populations that have limited opportunities to vary their dietary sources.

Conclusions

The experiment confirmed the risk of ingesting PHCC through drinking water, and showed the potential of reducing the risk of accumulating PHCC in selected tissues by the controlled application of TDS in drinking water. A significant observation was not that the treatments that received elevated PHCC in drinking water accumulated PHCC at significantly higher concentrations than their counterparts, but that the concentration attained within a short production period did not exceed the maximum allowable concentration (MAC) for these elements in broilers destined for human consumption.

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