The effect of water-borne fluoride on the egg production of laying hens

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Abstract

One thousand Silver Grey Hyline hens were given drinking water containing 6, 10, 14 and 20 mg/ℓ sodium fluoride during their laying period. The control group received municipal water (containing 0.29 mg/ℓ fluoride) with no added sodium fluoride (0 mg/ℓ).

Fluoride addition to the water had a significant effect (P = 0.0001) on egg production, but eggshell breaking strength was not significantly influenced.

At the termination of the study (74 weeks of age) the carcass mass and the fluoride content of the *os femur* showed a significant increase (P = 0.0001) which correlated with the increase in fluoride concentration in the water.

No important microscopic changes in the livers and kidneys were noticed, and liver mass and breaking strength of the *os femur* were unaffected by the amount of fluoride consumed.

The data showed a significant drop in egg production at 6 and 20 mg/ℓ sodium fluoride.

Introduction

A literature and water-source survey in South Africa by Casey et al. (1994), indicated that exposure time, production system, ingestion rates and species tolerance are important factors which need to be taken into account when formulating water quality guidelines for livestock. Fluoride was found to be the constituent with the highest potential to produce toxic effects in animals in South Africa. The highest fluoride concentration in the water-sources surveyed was approximately 20 mg/ℓ (Meyer et al., 1997), a concentration 10 times higher than that considered acceptable (Kempster et al., 1985). The toxicities of different forms of fluoride have been shown to be in the following descending order of severity: fluorosilicates, sodium fluoride, rock phosphate and calcium fluoride (Haman et al., 1936).

It is known that various physiological aberrations occur in poultry following the ingestion of fluorides over an extended period of time. As reported by Halpin and Lamb (1932), egg production was not affected by dietary concentrations of rock phosphate containing fluoride at 10 or 20 g/kg. However, at concentrations of 30 g/kg egg production decreased. At these concentrations the rock phosphate supplied the diets with approximately 0.35, 0.70 and 1.05 g/kg of fluoride respectively.

The occurrence of bone fragility in caged layers is a major problem in the modern poultry industry. Merkley (1981) found that fluoride treatment increased the breaking strength of humeri from 6.86 to 13.35 kg and that of tibiae from 6.61 to 13.10 kg and recommended fluoride supplementation of the water of up to 100 mg/ℓ. Egg quality and rate of production were not reduced by fluoride treatment. Huyghebaert and De Groote (1988), however, disputed Merkley's findings and recommended the discontinuation of dietary fluoride supplementation to improve bone strength. These contradictions together with the need for water-quality guidelines for livestock in Southern Africa, were the main reasons for establishing the fluoride tolerance of laying hens over their production cycle.

Previous studies on the effect of sodium fluoride on egg production and bone strength of caged laying hens (Van Toledo and Combs, 1984), were done by dietary means and used much higher concentrations of dietary sodium fluoride (0; 0.3; 0.6; 0.9 and 1.2 g/kg). In this experiment fluoride additions much closer to the natural fluoride content of South Africa's groundwater sources were used. The objective of this study was to determine the long-term effects of 5 different concentrations of sodium fluoride, in the drinking water, on the egg production of caged laying hens.

Materials and methods

Treatments

Sodium fluoride was provided in the drinking water to 1 000 day-old Silver Grey Hyline laying hens over their production period. The trial comprised 5 inclusion rates of sodium fluoride (0, 6, 10, 14 and 20 mg/ℓ) with 4 replicates of 50 birds per group. The water was obtained from Pretoria's municipal source and the negative control (0 mg/ℓ added sodium fluoride) contained 0.29 mg/ℓ fluoride. Sodium fluoride was dissolved in the water to attain the treatment concentrations.

Laying phase (18 - 74 weeks of age)

The flock was kept in a convection battery with laying cages where they were caged individually. A system measuring the precise water intakes of the birds was designed and installed. The system comprised calibrated perspex cylinders attached to the main water line, drainage taps at the bottom of each cylinder and removable lids for easy administration of chemicals. Water intake (water intake/replicate·d) and egg production (eggs/hen·d) was determined daily; production figures were later recalculated in terms of eggs/group·week. From peak production, the shell breaking strengths of a randomly selected sample of eggs (n = 20) were determined over a 20-week period (from Week 50 to Week 70).

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The trial was terminated when the birds reached 74 weeks of age. The birds were slaughtered according to the prescribed regulations (The Slaughter of Poultry (Humane Conditions) Regulations (Amendment) 1990) and the carcass and liver mass was determined. A representative sample (n = 5/replicate) of livers and kidneys was examined histopathologically by the Department of Pathology, Onderstepoort. Mid-shaft samples of the *os femur* from randomly selected carcasses were excised for fluoride analysis. Analyses were done on oven-dried bones (24 h at 100°C) using a method which entails isolating and concentrating the fluoride in the bone and determining it potentiometrically (Van Staden and Janse van Rensburg, 1991).

The *os femora* from randomly selected birds (n = 5/replicate) were subjected to a breaking strength test (Rowland et al., 1967), making use of the Allo-Kreamer shear press. The attachment for the shear press was designed whereby pressure could be placed on the midpoint of the *os femur* which was supported near the end. Making use of a milling machine, the bottom area of the attachment (3 mm x 21 mm) had been machined from a steel rod (21 mm in diameter). An adjustable support (vice) was designed to fit the Instron platform and permitted an unlimited selection of support widths. In this study each femur was supported near the ends approximately 20 mm from the midpoint at which the force was applied. The press descended at a rate of 120 mm/min. The maximum force required to break each femur was read from the chart of the shear press recorder.

TABLE 1
MEANS FOR FLUORIDE INGESTION RATE AND WATER INTAKE (ℓ/bird·d) DURING PRODUCTION (18 - 74 WEEKS OF AGE)

Sodium fluoride addition (mg/ℓ)	Fluoride ingestion rate mgF/bird·d	Treatment means for water intake (ℓ) P = 0.0001	
0	0.059	0.236[b]	SD ± 0.038
6	1.361	0.264[a]	SD ± 0.051
10	1.979	0.230[b]	SD ± 0.032
14	2.661	0.220[c]	SD ± 0.026
20	4.453	0.260[a]	SD ± 0.054

SD ± Standard deviation
Means with different superscripts within treatments, differed significantly according to Tukey's Multiple Range Test at a P< 0.05 significance level.

TABLE 2
MEANS FOR EGG PRODUCTION (eggs/bird·week) AND BREAKING STRENGTH OF EGGS (kg) DURING PRODUCTION (18 - 74 WEEKS OF AGE)

Sodium fluoride addition (mg/ℓ)	Treatment means for breaking strength of eggs P = 0.7418		Treatment means for egg production P = 0.0001	
0	0.373[a]	SD ± 0.0034	6.135[a]	SD ± 1.056
6	0.375[a]	SD ± 0.0037	6.056[b]	SD ± 1.019
10	0.372[a]	SD ± 0.0038	6.135[a]	SD ± 1.069
14	0.378[a]	SD ± 0.0035	6.083[a]	SD ± 1.108
20	0.375[a]	SD ± 0.0033	6.052[b]	SD ± 1.058

SD ± Standard deviation
Means with different superscripts within treatments, differed significantly according to Tukey's Multiple Range Test at a P< 0.05 significance level.

Statistical evaluation

Statistical analyses were conducted using the PC-SAS Version 6.08 commercial software. Analyses of variance and Tukey's Multiple Range Test were used to determine significant differences between treatment means (P < 0.05). A split-plot ANOVA was used to test for week x treatment interactions.

Results

Laying phase (18 to 74 weeks of age)

Although the sodium fluoride additions were 0, 6, 10, 14 and 20 mg/ℓ, the ingestion rates of fluoride/hen·d, were 0.059, 1.361, 1.979, 2.661 and 4.453 mg respectively (Table 1). Water intakes (Table 1) differed significantly between treatments (P < 0.0001). Although no significant differences in the breaking strengths of the eggshells were detected between treatments. the egg production decreased significantly (P = 0.0001) in hens receiving the 6 and 20 mg/ℓ fluoride treatment (Table 2). This decrease was, however, not evident in the 10 and 14 mg/ℓ fluoride treatments. Carcass mass (Table 3) differed significantly between treatments (P = 0.0332) and the groups receiving the 14 and 20 mg sodium fluoride/ℓ were heavier than controls. The treatments incrementally affected the fluoride contents of the *os femur* (P < 0.0001) (Table 3). The fluoride concentration in those from the control group was 573.69 mg/kg in contrast to the 1 671.39 mg/kg found in those receiving 20 mg/ℓ. Fluoride treatment had no significant influence on liver mass (P = 0.0902) nor on the breaking strength of the *os femur* (P = 0.5005) (Table 4).

Three histopathological changes, which could not be linked to fluoride, occurred in the livers and kidneys. They were fatty change in the livers, plasma "lakes" in the livers and kidney round-cell infiltration. Mortalities during the production period were not linked to fluoride and survival rate ranged between 95.1 and 93.8 % (Table 5); the major cause of death was peritonitis.

Discussion

When water with a potentially toxic constituent like fluoride is encountered, ingestion rates need to be calculated. This is important as it is the actual amount of the toxic constituent consumed that is relevant, and not its concentration in the water alone. The results of the trials conducted on layers with fluoride-treated water, show that egg production can be managed successfully in an area with a high concentration of fluoride in the drinking water.

The probable carry-over of potentially toxic substances to the consumer of the animal product was drawn attention to by Raica et al. (1957), who found that at a dietary fluoride content of 50 mg/kg, bone fluoride was increased about 14-fold and soft tissue fluoride by a factor 2.5. Phillips et al. (1935) showed that egg yolk increased in fluoride content about 3 times when the dietary fluoride content

TABLE 3
MEAN CARCASS MASS (kg) AND FLUORIDE CONTENT OF FEMURS (mg/kg)

Sodium fluoride addition (mg/ℓ)	Carcass mass (P = 0.0332)		Fluoride content of the *os femur* (P = 0.0001)	
0	2.153^{c}	SD ± 0.569	573.69^{d}	SD ± 154.3
6	2.233b^{c}	SD ± 0.425	947.28^{c}	SD ± 216.1
10	2.383^{abc}	SD ± 0.481	1139.91^{b}	SD ± 154.1
14	2.469^{ab}	SD ± 0.667	1329.00^{b}	SD ± 174.5
20	2.552^{a}	SD ± 0.920	1671.39^{a}	SD ± 336.9

SD ± Standard deviation
Means with different superscripts within treatments, differed significantly according to Tukey's Multiple Range Test at a P< 0.05 significance level.

TABLE 4
MEAN LIVER MASS (kg) AND BREAKING STRENGTHS OF FEMURS (kg)

Sodium fluoride addition (mg/ℓ)	Liver mass (P = 0.0902)		Breaking strength of *os femur* (P = 0.5005)	
0	0.056^{a}	SD ± 14.32	24.794^{a}	SD ± 5.312
6	0.052^{a}	SD ± 14.26	24.693^{a}	SD ± 4.048
10	0.049^{a}	SD ± 8.86	24.574^{a}	SD ± 4.572
14	0.052^{a}	SD ± 11.10	22.776^{a}	SD ± 3.299
20	0.050^{a}	SD ± 11.56	23.370^{a}	SD ± 4.702

SD ± Standard deviation
Means with different superscripts within treatments, differed significantly according to Tukey's Multiple Range Test at a P< 0.05 significance level.

TABLE 5
SURVIVAL RATE (%) OF FLUORIDE TREATED HENS

Treatment mg/ℓ				
0.29	6	10	14	20
Survival rate (18 - 74 weeks)				
95.1	94.7	91.5	91.2	93.8

was 1 050 mg/kg. From the results obtained in this experiment it is evident that the fluoride content of the *os femur* increases greatly when fluoride is added to the drinking water. Supporting the findings of Merkley (1981) it was found that the rate of egg production was influenced by fluoride treatment, this was however only observed in the 6 and 20 mg/ℓ treatments. The breaking strength of the eggshells was unaffected by high fluoride concentrations.

Because fluoride appears to stimulate new bone formation, Merkley (1976) proposed that fluoridation of the water will mitigate the development of osteoporosis in layers. He later reported (Merkley, 1981) that the addition of fluoride to the drinking water of coop-reared broilers and caged layers during their growing periods resulted in an increase in bone-breaking strength. However, Huyghebaert and De Groote (1988) recommended that dietary supplementation with fluoride should be discontinued as a means of improving bone-breaking strength. The results of this trial support this view and the findings of Chan et al. (1973) who showed that fluoride treatment at a high concentration had little effect on bone integrity or strength.

There were no significant differences between treatments regarding liver mass or in the histopathology of the livers and kidneys. Fatty changes in the livers, protein lakes in the livers and the amount of round-cell infiltration in the kidneys were not linked to fluoride intake. Mortalities were also not fluoride-related. In this trial, sodium fluoride additions of up to 20 mg/ℓ yielded significantly increased carcass mass. This increase may be due to the increase in bone mass.

Halpin and Lamb (1932) and Merkley (1981) found that egg production was not affected by fluoride treatment. This experiment showed that hens receiving 6 and 20 mg/ℓ of added fluoride had a significantly lower egg production rate. Fluoride significantly influenced the water intake of the hens, the hens receiving 6 and 20 mg/ℓ of added fluoride drank significantly more water.

In conclusion, the results obtained in this study indicate that the current guidelines on the fluoride content of drinking water may be too restrictive and that there is a need to take production criteria, exposure time and ingestion rates into account when formulating water quality guidelines.

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