CHEMICAL ELEMENTS IN EGG SHELL OF A COMMERCIAL STRAIN OF DOMESTIC FOWL MANAGED IN A TROPICAL ENVIRONMENT

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ABSTRACT

A study was conducted to determine the chemical elements of the egg shell of exotic commercial pullets (Lohmann) in their first laying year. A total of 160 eggs from eighty pullets were randomly selected at three-monthly intervals during the production year for the determination of chemical elements of the eggshell. The average concentrations of calcium, magnesium, phosphorus, nitrogen, potassium, sodium, zinc, and iron were 90.36%, 0.87%, 0.90%, 3.85%, 0.51%, 0.10%, 0.002%, and 0.005% respectively. Most of the paired variates of the mineral elements showed significant ($P < 0.01$) inter-relationship as depicted by measures of correlation coefficients. There were no significant relationships between Ca and most mineral elements and on the other hand mg was signficantly correlated with phosphorus, N, K, and Zn. Correlation coefficients between P and Fe, N and Na, Zn or Fe and between Na and Zn were not significant.

Key Words: Egg shell, chemical elements, Tropical environment.

INTRODUCTION

There have been numerous investigations suggesting that eggshell consists mainly of calcium carbonate (Bradfield, 1951; Card, 1961; Gilbert, 1971; Simkiss and Taylor, 1971; Stadelman and Cotterill, 1977 and Solomon, 1994). However, mineral elements such as magnesium and phosphorus occur in avian eggshell as carbonates and phosphates respectively. Board and Scott (1980) reported that magnesium carbonate and tricalcium phosphate occur in eggshell of most avian species in the ranges of 0.84 - 1. 88% and 0.55 - 0.75% respectively. They also noted that calcium carbonate in the eggshell ranges from 97.37 - 98.84%. Traces of sodium, iron and sulphur were reported by Romanoff and Romanoff (1949), while Baker (1960) reported traces of citrate in the eggshell.

Calcification may not start without large amounts of calcium in the hen's blood stream since calcium is quantitatively the most critical element during shell formation, other minerals are equally essential. Magnesium ions (Mg^{2+}) are involved in the ultimate architecture of the eggshell. Board and Love (1980) reported that Mg^{2+} ensures that cones of the eggshell retain their identity and geometry until their bases fuse to form the foundation for the palisade layer. They also found that phosphate ions are essential for the formation of the shell accessory materials (cuticle). The trace elements of the shell are also important since they are utilized by the developing embryo.

Although the thickness and strength of the eggshell measure the amount of calcium, shell calcium is not readily available to the developing embryo in the absence of Mg^{2+}. Brooks and Hale (1955) discovered that Mg^{2+} lowers the solubility of calcium, thereby promoting the mechanism through which the embryo obtains Ca^{2+} from the eggshell for bone formation. However, all the mineral elements together with the shell physical characteristics contribute to the maintenance of the intergrity and stability of the shell as well as the functions performed by the shell. Board and Scott (1980) reported that strong and weak eggshell have 0.44% and 0.38% levels of magnesium respectively.

Environmental conditions of the laying birds affect their productivity. Sharp changes in temperature adversely affect shell quality and invariably the proportions of their mineral contents. Increase in ambient temperature is known to decrease shell thickness and average egg weight depending on age and individuality of the bird, (Ahvar *et al*, 1983) as well as the degree of acclimatization of the hen. Besides, the birds used in commercial egg production in most tropical environments are hybrids from the temperates and there may be variations in their shell minerals compared with their temperate counterparts.

It is justifiable then to investigate the shell minerals of these hybrid layers commonly used in the tropics. The objective of this study, therefore aimed at determining the eggshell mineral concentrations of the egg of domestic fowl in the first laying year and the relationship between them.

MATERIALS AND METHODS

A total of one hundred and sixty brown eggs laid by eighty hybrid Lohmann pullets were used for the study. Egg collection was commenced when the birds were three months in lay, to ensure that all the birds in the flock were laying. Thereafter, forty eggs were randomly selected at three-monthly intervals and collection stopped at exactly one year from the point of lay.

The laying birds were housed singly in battery cages. Samples of feed fed to the layers throughout the production period were analysed and contained 16.90% CP, 6.20% crude fibre, 4.58% ether extract, 14.55% ash, 10.45% moisture, 47.23% nitrogen free extract, 3.20% Ca, 0.56% P, 0.30% Mg, 0.40% Na, 0.20% K, and 0.00% Fe, Zn, and Cu. Water and feed were given *ad libitum*.

Shell samples were chemically analysed within 48 hours of egg collection. Prior to mineral analyses, the shell was separated from the yolk and albumen. The shell membrane was removed using dilute Hydrochloric acid (.0.5M) after which the shell is washed and air dried. Nitrogen component of the shell was determined with the improved Kjeldahl equipment (Gerharatvapdest 3) which automatically reads off the nitrogen content; Na, Zn, Fe and Cu contents of the eggshell were determined after wet digestion of the shell samples using atomic absorption spectrometer to read off these chemical elements, in accordance with the methods of A.O.A.C. (1975). Phosphorus was determined using Cecil spectrophotometer also according to the methods of A.O.A.C. (1975). Means and standard errors of measurements were computed for each period of egg collection. Regression, ANOVA and correlation analyses were also calculated.

TABLE 1: MINERAL ELEMENTS OF THE EGG SHELL IN THE DIFFERENT COLLECTION INTERVALS.

Mineral Elements(%)	Collection Intervals			
	1	2	3	4
Calcium	90.95 ± 0.64c	$90.45+0.82$b	89.47 ± 0.33^{a}	90.88 ± 0.54^{c}
	74.43 ± 99.13	70.99-97.39	68.32-98.75	68.00-99.02
Magnesium	0.80 ± 0.06^{a}	0.87 ± 0.07^{c}	0.95 ± 0.08^{d}	0.84 ± 0.06^{a}
	0.22 ± 2.41	0.22-2.39	0.34-2.42	0.24-2.34
Phosphorus	0.08 ± 0.1^{a}	0.09 ± 0.03^{b}	0.10 ± 0.02^{c}	0.09 ± 0.01^{b}
	0.00-0.23	0.00-0.25	0.00-0.27	0.00-0.30
Nitrogen	4.02 ± 0.17^{c}	3.98 ± 0.14^{b}	3.95 ± 0.17^{b}	3.62 ± 0.16^{a}
	1.37-4.09	1.14-4.29	1.37-4.01	1.14-4.00
Potassium	0.50 ± 0.02^{a}	0.51 ± 0.01^{b}	0.50 ± 0.03^{a}	0.53 ± 0.01^{c}
	0.30-0.62	0.31-0.62	0.30-0.61	0.28-0.89
Sodium	0.11 ± 0.02	0.10 ± 0.01	00.10 ± 0.02	0.09 ± 0.03
	0.00-0.32	0.00-0.33	0.01-0.29	0.00-0.31
Zinc	0.002 ± 0.001	0.002 ± 0.002	$0.002\pm.0003$	0.002 ± 0.003
	0.001-0.004	0.001-0.009	0.001-0.007	0.00-0.005
Iron	0.007 ± 0.002	0.005 ± 0.003	0.006 ± 0.003	0.004-0.001
	0.00-0.008	0.00-0.006	0.00-0.007	0.00.0.005
Copper	0.00	0.00	0.00	0.00

TABLE 2: CORRELATION COEFFICIENTS BETWEEN MINERAL ELEMENTS OF THE EGG SHELL

	Ca^{2+}	Mg^{2+}	P^{5-}	N^{2-}	K^{+}	Na^{+}	Zn^{2+}	Fe^{3+}
Ca^{2+}		-0.05	0.11	-0.02	0.05	-0.22**	-0.10	-0.35**
Mg^{2+}			-0.30**	0.23**	0.79**	0.45**	0.25**	0.43**
P^{5-}				-0.20**	-0.36**	-0.46**	-0.37**	0.06
N^{2-}					0.36**	0.01	0.01	0.01
K^{+}						0.42**	0.26**	0.35**
Na^{+}							0.13	0.55**
Zn^{2+}								0.36**
Fe^{3+}								

(N = 160); Significant ($P<0.05$); **highly significant ($P<0.01$)

TABLE 3: THE REGRESSION OF SOME OF THE CHEMICAL ELEMENTS

Dependent Variable	Independent Variable	a	b	r^2	p
Mg	k	-0.59	2.83	64.41	0.01
Mg	Fe	0.72	22.96	18.49	0.01
Na	Ca	0.40	-0.003	4.84	0.01
Na	K	-0.06	0.31	17.64	0.01
Na	Fe	0.06	5.88	30.25	0.01
K	N	0.35	0.04	12.96	0.01
K	Zn	0.47	17.62	6.76	0.01
K	Fe	-0.48	5.18	12.25	0.01

RESULTS AND DISCUSSION

The mineral composition of eggshell at the different intervals of egg collection is shown in Table 1. Calcium which occurs in the largest amount in the eggshell was significantly lower ($P<0.01$) in the third interval of egg collection while nitrogen was significantly lower in the fourth interval as shown in Table 1. No significant variations in zinc and also no trace of copper were obtained (Table 1). The correlation coefficients between pairs of the chemical elements are shown in Table 2. There was no significant correlation between calcium and most of the minerals. However, calcium was significantly correlated with sodium (-0.22) and iron (0.35). Potassium was found to be positively correlated with Na, Zn, Mg, Fe and N_2 (0.42, 0.26, 0.79, 0.35 and 0.36 respectively) but negatively and significantly correlated ($P<0.01$) with phosphorus (-0.36). On the other hand, sodium was found to show no significant relationship with Zn and N_2. Fe showed significant relationship with all the elements ($P<0.01$) except phosphorus and nitrogen.

The concept that eggshell consists mainly of calcium and smalll quantities of other mineral elements is true of the findings of this investigation. The calcium content of the eggshell in this study was lower than that in available literature reports. This could be due to the techniques of determining calcium or the effect of environment as suggested by Solomon (1994), that the process of shell formation may be genetically determined but environmentally modified. It has been suggested that higher values are obtained when the calcium element is not separated from other elements with which it is combined, (Jull, 1951; Gilbert, 1971; Stadelman and Cotterill, 1977, and Board and Scott, 1980). There could also be influences of such factors as age, breed, season, time of lay, nutrition, environment and disease or other unknown factors accounting for the differences. Andrade *et al* (1977) observed that environment and feed may not have any significant effect on shell calcium. However, this report of Andrade *et al* (1977) is not in agreement with the recent submissions of Solomon (1994) who observed that shell formation is environmentally modified. The negative correlation of magnesium and phosphorus implies an inverse relationship between them. It was obesrved in this study that eggs with higher proportions of phosphorus in their shells appear larger in size and have lower shell thickness than others. This could be explained by the fact that the amount of calcium in the shell is a measure of the thickness and strength of the shell.

In Table 1, the first interval of egg collection indicates higher amounts of calcium and the third interval shows lower amount of calcium implying higher and lower shell thickness respectively. On the other hand, it was found that the respective phosphorus of these intervals of collection was in the reverse order. It was also observed that eggs whose shells have larger amounts of potassium have higher proportions of magnessium as indicated in Table 1. The mean nitrogen value of 3.85% obtained in this was higher than 2% reported by Gilbert (1971). This higher shell nitrogen in this investigation agrees with the finding of Andrade *et al* (1977) who reported that hens exposed to high temperature range 0f 21-31^{o}C lay eggs with increased nitrogen contents. However, the relationship between high temperature and nitrogen needs further investigation.

The regression of magnesium separately on potassium and iron show that the relationship between magnesium and iron is stronger than that of magnesium and potassium as shown in their coefficients of variation (r^2) in Table 3. Although they occur in different amounts in the avian eggshell, they are directly porportional to amount of magnesium in the shell. Iron and sodium are strongly related than iron and potassium as indicated by their coefficients of variation (30.25% and 12.25%) respectively.

From available literature, there are reports that K, Na, Zn and Fe occur in trace amount and this is also true of this study. Shell with greater proportions of Mg^{2+} exhibited lower shell thickness than others and also have more phosphorus. Eggs whose shells have relatively small amounts to phosphorus, moderate amount of Mg and Ca and, of course, trace elements stored longer.

However, the findings of this investigation did not deviate much from that of the temperature zone. The slight variations compared with the eggshells of layers in the temperature environment may be explained in accordance with the findings of Solomon (1994) who postulated that patterns of shell mineralization were species specific and variations from the norm were now the order of the day and also in terms of survival, diet assumes secondary importance to environmental perturbance. Environment may have contributed a lot to the chemical composition of eggshell of these hybrid layers, among other factors.

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REFERENCES

AHVAR, F.: PETERSON, J., HORST, P. AND THEIN, G. (1983) Effect of high ambient temperatures on egg qualities in the first laying period. Anim Res. Dev. 17:94 - 015

ANDRADE, A.N., ROGLER, J.C., FEATHERSON, W.R. AND ALLISTON, C.W., (1977). Interrelationship between diet and elevated temperature (cyclic and constant) on egg production and shell quality. Poult Sci, 56:1178 -1188.

A.O.A.C, (1975) Official Methods of Analysis Association of Official Analytical Chemists, Washington, D.C. 12th edn.

BAKER, C.M.A. (1960). The genetic basis of egg quality. Br. Poult. Sci. 1:3-15.

BOARD, R.G. AND LOVE, G., (1980); Magnesium distribution in avian egg shell. Comp. Biochem. Physiol 66:667-672.

BOARD, R.G. AND SCOTT, N.D. (1980); Porosity of the avian egg. Ame. Zool. 20:339-349.

BRADFIELD, J.R.G., (1951). Radiographic Studies on the formation of the hen's egg shell J. Expt. Biol. 28: 125-140.

BROOKS, J. AND HALE, H.P. (1955). Strength of the shell of hen's egg. Nature 175:848-849.

CARD, L.E., (1961). **Poultry production**, 9th edn. Lea and Febiger, Philadelphia.

GILBERT, A.B. (1971). The egg: Its physical and chemical aspects. In: **Physiology and Biochemistry of the domestic fowl.** Vol. 3 by Bell, D.J., and FREEMAN, B.M. (eds). Academic Press, London, New York.

JULL, M.A. (1951). **Poultry husbandry** Mc Graw-Hill Book Co. Inc., New York, Toronto, London.

ROMANOFF, A.L. AND ROMANOFF, A.J., (1949). **The avian egg.** John Willey and Sons Inc., New York, Chapman and Hall Ltd. London.

SIMKISS, K. AND TAYLOR, T.C., (1971), Shell formation. In: **Physiology and Biochemistry of the domestic fowl.** Vol. 3. by BELL, D.J. AND FREEMAN, B.M. (eds). Academic Press, London, New York.

SOLOMON, S.E. (1994). Egg shells: Patterns of Mineralization. **Poultry International Magazine.** 33:50-53.

STADELAMAN, W.J. AND COTTERILL, O.J. (1977). **Egg Science and Technology**, AVI. Publishing Coy. Inc. Westport Connecticut.