# COMPARATIVE STUDIES ON THE UTILIZATION OF CALCIUM BETWEEN LAYING TSAIYA DUCK AND LEGHORN HEN

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## Summary

Studies were conducted to compare the utilization of dietary calcium between brown laying Tsaiya duck and Leghorn hen. Birds were fed corn-soybean diets containing 1.0, 2.0, 3.0, 4.0 and 5.0 % calcium, respectively, with five birds per treatment. The metabolizability of calcium was determined by the indicator method. Experiments were conducted three times each at the age of 27, 31 and 36 weeks.

Results appeared that duck eggs were heavier with better shell quality in comparison with hen eggs. Ducks fed 1% calcium diet resulted in severely depressed egg production (19%), but not for hens which still had 56% egg production. The metabolizability of calcium for hens was significantly higher than that for ducks ($P < 0.05$) when both were fed diets containing 1 or 2% calcium. As the dietary calcium level was increased to 3 to 5%, there was no significant difference in calcium metabolizability between ducks and hens. When the dietary calcium was between 2 to 5%, the ducks retained more calcium than did the hens. Plasma calcium content for both hens and ducks fed 1% calcium diet was about the same. When the amount of the dietary calcium was increased to 2-5%, the plasma calcium level of ducks was approximately 7-10 mg/dl higher than that of hens. The calcium content in the egg shell of duck was significantly higher than that of hens, too. As the dietary calcium level was increased, there was a decreased magnesium content in the eggshell of hens, but not for ducks. The magnesium level in the eggshell was higher in hens than that in ducks. It is concluded that ducks could retain significantly more calcium and maintain higher plasma calcium level which might be the reason for larger eggs with better shell quality by ducks.

(Key Words: Laying Tsaiya Duck, Leghorn Hen, Calcium Metabolizability, Plasma Calcium, Eggshell Quality)

## Introduction

Both Tsaiya ducks (*Anas platyrhynchos* var. *domestica*) and Leghorn hens are major laying fowls in Taiwan. The average body weight at maturity for both ducks and hens were in the similar rank which were around 1.3 and 1.5 kg, respectively. However, there are some differences in egg laying performance. In general, the rate of egg production of duck is slightly higher and the duck eggs are larger and of better egg shell quality than those of hen eggs. Furthermore, the time required for the formation of a complete eggshell in the shell gland was 18-19 hr (Ma, 1968) for ducks and 19.76 hr for Leghorn hens (Melek *et al.*, 1973). Accordingly, Tsaiya ducks might have a better utilizability of dietary calcium than Leghorn hens.

Studies have been shown that a line of hens producing thick or heavy eggshells had significantly higher levels of total blood calcium (Combs *et al.*, 1979; Grunder *et al.*, 1980; Wideman and Buss, 1985) and retained significantly higher amount of dietary calcium (Hurwitz and Bar, 1967) than a line of hens producing thin or light eggshells. Up to now, the information on the difference in calcium utilizability between ducks and Leghorn hens is quite limited. This experiment, therefore, was conducted to evaluate the utilizability of dietary calcium of laying Tsaiya ducks and Leghorn hens fed dietary calcium concentrations varying from low to high. The effect of dietary calcium on plasma calcium level and eggshell quality was also investigated.

## Materials and Methods

### Birds and Dietary Treatment

Hisex white Leghorn chicks and brown Tsaiya ducklings used in the experiment were purchased

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from commercial hatcharies. They were raised in the laboratory from day-old with the practical self-prepared growing diets, and were transferred to laying diets which were prepared in the laboratory, at the age of 14 weeks for ducks and 20 weeks for pullets, respectively. The laying diet for hen and duck contained 3.4% and 3.0% calcium, respectively. The average age of laying first egg from a group of 48 ducks was 125-day old, and from 36 hens was 148-day old. The average body weight at this time was 1.2 kg for ducks and 1.3 kg for hens.

Twenty-five ducks and 25 hens were selected for the experiment on the basis of egg production records. They were kept in individual cages, randomly divided into 5 groups of 5 birds each and fed corn-soybean diets containing 1.0, 2.0, 3.0, 4.0 and 5.0% calcium, respectively. The composition of a basal diet providing 17.1% crude protein, 0.4% available phosphorus and 2,753 kcal/kg of metabolizable energy for all groups during the experimental period is shown in table 1. The graded levels of calcium for the groups with diet 1 through 5 were made by adding different levels of ground limestone and non-nutritious cellulose as shown in table 1. Diets and water were supplied *ad libitum*. Light was given 14 hours per day (06:00 to 20:00) with artificial illumination.

Experiments were conducted in triplicates with ducks and Leghorn hens both at 27, 31 and 36 weeks of age. After each 15-day experimental period, all birds were returned to laying diet until

TABLE 1. COMPOSITION OF EXPERIMENTAL DIETS (%)

| | Diets[1] | | | | |
|---|---|---|---|---|---|
| Ingredient | 1 | 2 | 3 | 4 | 5 |
| Yellow corn | 55.8 | | | | |
| Soybean meal (44%) | 23.3 | | | | |
| Fish meal (65%) | 3.0 | | | | |
| Soybean oil | 3.25 | | as diet 1. | | |
| Dicalcium phosphate | 1.27 | | | | |
| Iodized salt | 0.30 | | | | |
| Vitamin premix[2] | 0.30 | | | | |
| Mineral premix[3] | 0.20 | | | | |
| DL-Methionine | 0.08 | | | | |
| Chromic oxide | 0.50 | | | | |
| Limestone, pulversized | 1.07 | 3.76 | 6.44 | 9.13 | 11.81 |
| Cellulose | 10.93 | 8.24 | 5.56 | 2.87 | 0.19 |
| | 100.00 | 100.00 | 100.00 | 100.00 | 100.00 |
| Calculated value: | | | | | |
| Calcium (%) | 1.0 | 2.0 | 3.0 | 4.0 | 5.0 |
| Available phosphorus (%) | 0.4 | 0.4 | 0.4 | 0.4 | 0.4 |
| Analyzed value: | | | | | |
| Dry matter (%) | 89.5 | 89.7 | 89.3 | 89.7 | 90.4 |
| Calcium (%) | 1.24 | 2.44 | 3.40 | 4.39 | 5.44 |

[1] Diets contain 17.1% crude protein and 2,752 kcal ME/kg.

[2] Vitamin premix supplied the following per kilogram of diet: vitamin A, 8,000 IU; vitamin $D_3$, 1,000 ICU; vitamin E, 10 IU; vitamin $K_3$, 1 mg; thiamin, 0.8 mg; riboflavin, 4.4 mg; vitamin $B_4$, 3 mg; Ca-pantothenate, 9.68 mg; niacin, 50 mg; d-biotin, 0.1 mg; folic acid, 0.25 mg; and vitamin $B_{12}$, 0.04 mg.

[3] Mineral premix provided the following per kilogram of diet: Cu ($CuSO_4 \cdot 5H_2O$, 25.45% Cu) 6 mg; Fe ($FeSO_4 \cdot 7H_2O$, 20.09% Fe) 50 mg; Mn ($MnSO_4 \cdot H_2O$, 32.49% Mn) 40 mg; Zn (ZnO, 80.35% Zn) 60 mg; and Se ($NaSeO_3$, 45.65% Se) 0.075 mg.

all birds returned to normal egg production. The experimental data reported in this study were the mean values of these 3 experimental periods.

### Determination of Calcium Metabolizability

Indicator method was applied to determine calcium metabolizability. Chromic oxide ($Cr_2O_3$) was added at a concentration of 0.5% as an indicator to each experimental diet. The diets containing $Cr_2O_3$ were fed for a 8-day preliminary period. Then a representative sample of excreta uncontaminated with feed, feathers and scales was collected at 24-hour intervals on 5 consecutive days. Immediately after each day's collection, the excreta were placed in a glass dish and dried in an oven at 65°C for 22 hours. The successive dried excreta were mixed together to make a total sample for each bird. Both feed and dried excreta were ground through a Wiley mill using a 20-mesh screen and stored at 4°C for subsequent analysis of dry matter(DM), calcium(Ca) and chromium (Cr) contents. Calcium metabolizability was calculated by the following equation:

$$\text{Ca metabolizability (\%)} = \left(1 - \frac{\text{excreta DM(\%)} \times \text{excreta Ca(\%)}}{\text{feed DM(\%)} \times \text{feed Ca(\%)}} \times \frac{\text{feed Cr(\%)}}{\text{excreta Cr(\%)}}\right) \times 100$$

During the collection period, feed consumption was recorded and eggs were collected daily for measuring the egg weight, eggshell breaking strength, shell thickness and shell weight. Rate of egg production was estimated from the number of eggs collected per hen for 7 days after the 8-day preliminary period.

After the 5-day excreta collection period, 5 ml of blood was taken at 6:00 pm. on 2 consecutive days from the brachial vein (V. Ulnaris) using a heparinized syringe. Plasma was separated from whole blood by centrifugation at 1000 x g for 10 minutes and kept frozen until the assay for calcium and magnesium.

### Measurement of Egg Samples

After the egg was weighed, eggshell breaking strength was determined using a Fudoh rehometer (NRM-2002J, Fudoh Kogyo Co., Tokyo, Japan) to measure the force necessary to break the shell. Shell thickness (without membrane) was measured with a Peacock dial pipe gauge, taking the average of three measurements from the equator and the two pole ends. The eggs were then broken open, the liquid content of each egg was removed, shell (plus membrane) was washed and dried together with these 3 tested pieces at 105°C for 6 hr, and subsequently weighed. The shells were ground to pass through a 20-mesh sieve for calcium and magnesium analysis.

### Quantitative Analysis of Samples

The dry matter contents of the excreta and feed samples were determined by the procedures in the Association of Official Analytical Chemists (AOAC, 1984). Analysis for mineral concentration of all samples were performed in a Perkin – Elmer 372 Atomic Absorption Spectrophotometer. The calcium and chromium contents of feeds and excreta were analyzed according to the methods described in AOAC (1984) with some modifications. Approximately 1.0 g feed or 0.5 g excreta were weighed and ashed at 600°C for 4 hr. Three ml of 33% $Na_2CO_3$ solution was added to the ashed and cooled samples, and then dried carefully in an oven and ashed again at 750°C for 2 hr. Ten ml of 3N HCl was added to dissolve ashed sample. Barnes (1966) have suggested the addition of 2% (w/v) $NH_4Cl$ to the sample and standard solution to control the interference from iron on chromium absorption by atomic absorption spectrophotometer. Therefore in chromium assay, 2% $NH_4Cl$ was added in each sample.

The ground eggshell samples were ashed at 750°C for 2 hr and then cooled. The ashed samples were slightly moistened by water, and then 10 ml 3N HCl was added. The subsequent procedures were the same as used in feed analysis.

Calcium and magnesium concentrations in the plasma were measured by diluting 0.05 ml of plasma to 10.00 ml with 0.1% Lanthanum solution ($La_2O_3$) and quantitatively determined by atomic absorption spectrophotometer.

### *Statistical Analysis*

All data were subjected to analysis of variance, and where a significant difference existed, means were further subjected to Duncan's new multiple range test (Steel and Torrie, 1980). Probability of 5% was used to evaluate the significant differences between treatment means.

## Results and Discussion

### Laying Performance

Feed consumption and egg production of the birds were affected by the dietary calcium levels (table 2). Feed consumption was significantly reduced by the diet with 1% calcium.. As the dietary calcium level was increased to above 2%, the feed consumption became normal with the ducks consumed about twice as much as hens ($P < 0.05$). However, egg production was significantly decreased ($P < 0.05$) by feeding diets with 1 or 2% calcium. There was no significant difference ($P > 0.05$) in egg production between ducks and chickens except those fed 1% calcium diet. A decrease in feed consumption by the 1% calcium treatment probably was due to the decline in egg production. According to the statement of Sykes (1983), egg formation increased the energy and calcium requirements of the hen. It might be reasonable to think that total feed intake would increase in proportion to the rate of egg production.

The eggshell breaking strength, eggshell thickness, egg weight, shell weight and percent shell of duck eggs generally were significantly superior to hen's eggs (table 3 and 4) when both fed the diets with the same calcium level. With the exception of 4 and 5% calcium groups, in which the eggshell thickness and percent shell of duck eggs were not significantly higher than those of hen's eggs. Shell quality in both ducks and hens was improved with increased dietary calcium level. And when the calcium level was increased up to 5%, the eggshell quality was not significantly improved. These results were in agreement with the findings of Harms and Waldroup (1971), Scott *et al.* (1971) and Kuang and Shen (1986). Three percent and 4% calcium levels were sufficient to maintain maximum shell quality for both ducks and hens.

From data for laying performance, we found that the response obtained with 1% calcium treatment in ducks was different from that in hens. The Leghorn hens fed the diet with 1% calcium still maintained the egg production rate at the level of 55.9%, but eggshell quality was poor and almost did not have any economic value since most of those eggs were thin-shelled or soft-shelled. On the contrary, the rate of egg production for ducks was dropped seriously to 19%, but shell quality was well maintained. This might be due to the fact that ducks laid intact-shelled eggs only. This also implied that the influence of low calcium level(1%) upon ovulation in ducks was more sensitive than in Leghorn hens.

TABLE 2. EFFECTS OF DIETARY CALCIUM LEVELS UPON FEED CONSUMPTION AND EGG PRODUCTION OF BROWN LAYING TSAIYA DUCTS AND WHITE LEGHORN HENS

| Dietary Ca | Feed consumption[1] | | Egg production[2] | |
|---|---|---|---|---|
| | Duck | Hen | Duck | Hen |
| (%) | (g/bird/day) | | (%) | |
| 1.0 | 151.0$^{b}$ | 95.0$^{b}$ * | 19.1$^{c}$ | 55.9$^{c}$ * |
| 2.0 | 215.2$^{a}$ | 105.3$^{ab}$ * | 82.9$^{b}$ | 77.1$^{b}$ |
| 3.0 | 224.1$^{a}$ | 109.6$^{a}$ * | 97.1$^{a}$ | 90.8$^{a}$ |
| 4.0 | 210.0$^{a}$ | 115.0$^{a}$ * | 98.1$^{a}$ | 95.2$^{a}$ |
| 5.0 | 205.4$^{a}$ | 104.9$^{ab}$ * | 91.4$^{ab}$ | 92.4$^{a}$ |
| Pooled S.D. | 20.9 | 6.4 | 17.7 | 17.5 |

[1] Feed consumption was expressed on as fed basis.
[2] Hen-day; for 7 days after 8-day preliminary period.
[a-c] Values followed by different letters in the same column are significantly different ($P < 0.05$).
*Within each treatment and each parameter, means having significant difference between duck and hen ($P < 0.05$).

TABLE 3. EFFECTS OF DIETARY CALCIUM LEVELS UPON EGGSHELL BREAKING STRENGTH AND EGGSHELL THICKNESS OF BROWN LAYING TSAIYA DUCKS AND WHITE LEGHORN HENS

| Dietary Ca | Eggshell breaking strength | | Eggshell thickness[1] | |
|---|---|---|---|---|
| | Duck | Hen | Duck | Hen |
| (%) | (kg) | | (mm) | |
| 1.0 | 3.96$^{c}$ | 2.00$^{c}$ * | 0.352$^{c}$ | 0.264$^{d}$ * |
| 2.0 | 4.66$^{b}$ | 3.48$^{b}$ * | 0.377$^{b}$ | 0.348$^{c}$ * |
| 3.0 | 4.90$^{ab}$ | 3.85$^{ab}$ * | 0.398$^{a}$ | 0.379$^{b}$ * |
| 4.0 | 4.95$^{ab}$ | 4.22$^{a}$ * | 0.404$^{a}$ | 0.394$^{ab}$ |
| 5.0 | 5.23$^{a}$ | 4.27$^{a}$ * | 0.410$^{*}$ | 0.397$^{a}$ |
| Pooled S.D. | .65 | .51 | .027 | .022 |

[1] Shell membrane removed.
[a-d] As footnote in table 2.
*As footnote in table 2.

TABLE 4. EFFECTS OF DIETARY CALCIUM LEVELS UPON EGG WEIGHT, SHELL WEIGHT AND PERCENT SHELL OF BROWN LAYING TSAIYA DUCKS AND WHITE LEGHORN HENS

| Dietary Ca | Egg weight | | Shell weight[1] | | Percent shell[2] | |
|---|---|---|---|---|---|---|
| | Duck | Hen | Duck | Hen | Duck | Hen |
| (%) | (g) | | (g) | | (%) | |
| 1.0 | 58.8[b] | 53.8[b] | 5.40[c] | 3.41[c] * | 8.92[b] | 6.39[d] * |
| 2.0 | 62.4[a] | 56.5[ab] * | 5.80[bc] | 4.80[b] * | 9.28[b] | 8.49[c] * |
| 3.0 | 63.3[a] | 56.8[ab] * | 6.28[ab] | 5.33[a] * | 9.90[a] | 9.39[b] * |
| 4.0 | 63.4[a] | 56.1[ab] * | 6.37[a] | 5.56[a] * | 10.04[a] | 9.92[a] |
| 5.0 | 65.6[a] | 57.4[a] * | 6.62[a] | 5.63[a] * | 10.09[a] | 9.82[a] |
| Pooled S.D. | 4.8 | 4.0 | .66 | .46 | .71 | .55 |

[1]Plus shell membrane.

[2]Percent shell $= \frac{\text{weight of dried shell with membrane}}{\text{egg weight}} \times 100$

a-dAs footnote in table 2.

*As footnote in table 2.

**Calcium Metabolizability**

Metabolizability of calcium for birds was varied according to the dietary calcium levels (table 5). With the exception of 1% calcium group of ducks, there was a general trend that the metabolizability of calcium was decreased with the increases in calcium level in the diet. This was in consistent with reports of Hurwitz and Bar (1969), Atteh and Leeson (1983) and Keshavarz (1986). They indicated that the calcium metabolizability of hens was decreased as the dietary calcium level increased. When the calcium content of the diet reached up to 3-5%, there were no significant difference between ducks and Leghorn hens. The ducks fed on the diet containing 1% calcium had lower calcium metabolizability which might be associated with very low rate of egg production and hence, with low calcium requirement. Hurwitz

TABLE 5. COMPARISON OF METABOLIZABILITY AND RETENTION OF CALCIUM IN BROWN LAYING TSAIYA DUCKS AND WHITE LEGHORN HENS FED DIETS WITH DIFFERENT LEVELS OF CALCIUM

| Dietary Ca | Calcium metabolizability | | Calcium intake[1] | | Calcium retained[2] | |
|---|---|---|---|---|---|---|
| | Duck | Hen | Duck | Hen | Duck | Hen |
| (%) | (%) | | (g/bird/day) | | (g/bird/day) | |
| 1.0 | 43.02[b] | 76.49[a] * | 1.83[c] | 1.20[c] * | 0.81[c] | 0.92[c] |
| 2.0 | 62.84[a] | 74.68[a] * | 4.95[d] | 2.50[d] * | 3.01[b] | 1.87[b] * |
| 3.0 | 57.06[a] | 58.85[b] | 7.50[c] | 3.78[c] * | 4.26[ab] | 2.22[ab] * |
| 4.0 | 45.63[b] | 52.39[c] | 9.21[b] | 5.05[b] * | 4.18[ab] | 2.60[a] * |
| 5.0 | 43.52[b] | 42.56[d] | 11.10[a] | 5.74[a] * | 4.85[a] | 2.46[a] * |
| Pooled S.D. | 12.48 | 7.64 | .66 | .26 | .66 | .26 |

[1]Calcium intake = feed consumption x analyzed dietary calcium concentration.

[2]Calcium retained = calcium intake x % calcium metabolizability.

a-eAs footnote in table 2.

*As footnote in table 2.

and Bar (1965) and Hurwitz *et al.*, (1973) showed that the calcium absorption during shell calcification was increased. Atteh and Leeson (1983) also indicated that the calcium retention by laying hens was higher than that by non-laying hens.

The average calcium intake of a duck per day was nearly twice the quantity of a hen (table 5). As calcium intake was multiplied by the percentage of calcium metabolizability, the amount of calcium retained per bird per day was obtained. In the 1% calcium group, there was no significant difference between ducks and hens. Increasing dietary calcium level above 2%, ducks retained significantly greater amount of calcium with 1.6 to 1.9 times higher than that of Leghorn hens. This indicated that ducks might have higher capacity for calcium absorption than hens. When the calcium content reached to the normal levels of 3 to 5%, the amount of calcium retained in both ducks and hens tended to become steady without any significant change.

**Calcium and Magnesium Level in the Plasma**

Plasma calcium concentration was influenced by the calcium level of the diet (table 6). In both ducks and hens, the calcium concentration in the plasma increased with the increases of the calcium levels in the diet up to 4%. With the exception of the 1% calcium treatment, the plasma calcium content of ducks was approximately 7-10 mg/dl higher than that of hens. This exhibited that the duck had to maintain a higher calcium level in the plasma to support the higher rate of calcium deposition in egg shell. In the treatment group with 1% calcium, the plasma concentration was similar in both ducks and hens. This response was in consistent with the nonsignificantly different amount of retention in the same treatment from table 5.

Duck receiving 1% calcium diet had significantly lower plasma magnesium content than hen. Increasing calcium level in diets above 2%, the plasma magnesium concentration of ducks was higher than hens but not always significantly different. According to the analysis of variance, the main effect of species on plasma magnesium was not significant.

**Calcium and Magnesium Content in the Eggshell**

Generally speaking, it was recognized that eggshell consisted mainly of $CaCO_3$ (97%), $MgCO_3$ (1%) and $Ca_3(PO_4)_2$ (1%). In order to see the possible effect of magnesium on eggshell quality, the contents of calcium and magnesium of the eggshell were analyzed. Data presented in table 7 showed that the duck eggshell had significantly higher calcium content and significantly lower magnesium content than did the eggshell from hens. Magnesium content in the duck eggshell was not affected by the dietary calcium level. However, magnesium content of the eggshell in Leghorn hens was significantly decreased ($P < 0.05$) as the dietary calcium level was increased from 1 to 3%, and remained constant as the dietary calcium was increased from 3 to 5%. This agrees with the report of Holder and Huntley (1978) who indicated that magnesium content of eggshell was significantly higher in eggs from the hens fed 2.5% calcium than those fed 3.5% calcium. It seemed that magnesium content in the shell may have relation with shell quality. From regression analysis of all egg samples, we found that there was a negative correlation between magnesium content of the shell and eggshell thickness ($r = -0.84$ and $P < 0.05$ for hen's egg; $r = -0.41$ and $P < 0.05$ for duck's egg). This was in agreement with the finding of Atteh and Leeson (1983). On the contrary, Brooks and Hale (1955) observed that the stronger shells contained higher concentration of magnesium than did the weaker shells and suggested that there was a direct connection between the magnesium content in the shell and the physical

TABLE 6. INFLUENCE OF DIETARY CALCIUM LEVELS ON CALCIUM AND MAGNESIUM CONCENTRATION IN THE PLASMA OF BROWN LAYING TSAIYA DUCKS AND WHITE LEGHORN HENS

| Dietary Ca | Calcium | | | Magnesium | | |
|---|---|---|---|---|---|---|
| | Duck | Hen | | Duck | Hen | |
| (%) | (mg/dl) | | | (mg/dl) | | |
| 1.0 | 25.7[c] | 25.2[b] | | 3.3[b] | 4.2[a] | * |
| 2.0 | 36.7[b] | 26.0[b] | * | 4.3[a] | 3.8[b] | * |
| 3.0 | 40.5[ab] | 33.4[a] | * | 4.3[a] | 4.0[ab] | |
| 4.0 | 45.2[a] | 36.6[a] | * | 4.7[a] | 4.2[ab] | * |
| 5.0 | 40.1[ab] | 32.4[a] | * | 4.2[a] | 3.9[ab] | |
| Pooled S.D. | 9.4 | 5.7 | | .75 | .44 | |

[a-c]As footnote in table 2.

*As footnote in table 2.

TABLE 7. INFLUENCE OF DIETARY CALCIUM LEVELS ON CALCIUM AND MAGNESIUM CONTENTS IN THE EGGSHELL OF BROWN LAYING TSAIYA DUCKS AND WHITE LEGHORN HENS

| Dietary Ca | Calcium | | Magnesium | | Calcium per eggshell[1] | |
|---|---|---|---|---|---|---|
| | Duck | Hen | Duck | Hen | Duck | Hen |
| (%) | (%) | | (%) | | (g) | |
| 1.0 | $38.6^a$ | $37.5^a$ * | $0.12^a$ | $0.62^a$ * | $2.05^b$ | $1.26^c$ * |
| 2.0 | $38.1^{ab}$ | $36.5^{ab}$ * | $0.14^a$ | $0.45^b$ * | $2.21^{ab}$ | $1.75^b$ * |
| 3.0 | $37.1^c$ | $35.5^b$ * | $0.13^a$ | $0.33^c$ * | $2.33^{ab}$ | $1.92^{ab}$ * |
| 4.0 | $37.5^{bc}$ | $36.4^{ab}$ | $0.12^a$ | $0.33^c$ * | $2.39^{ab}$ | $2.03^a$ * |
| 5.0 | $38.6^a$ | $36.0^b$ * | $0.13^a$ | $0.31^c$ * | $2.54^a$ | $2.02^a$ * |
| Pooled S.D. | 1.19 | 1.79 | .02 | .04 | .20 | .11 |

[1] Calcium per eggshell = shell weight(from table 3) x calcium %.
[a-c] As footnote in table 2.
*As footnote in table 2.

properties of the shell. Therefore, the conflict still existed as to how does the magnesium content in the shell influence shell quality. In this experiment, as the dietary calcium level was increased from 1 to 5%, the calcium deposited in each eggshell was 2.05 to 2.54g for ducks (table 7) which was significantly ($p < 0.05$) higher in comparison with 1.26 to 2.02 g calcium for hens. It indicated that the rate of calcium secretion into the eggshell for ducks was faster than that for hens.

The difference in the laying performance between ducks and hens might be caused by several factors, such as (1) time intervals for oviposition, (2) fluctuation of blood calcium during egg formation, (3) the pH value in the intestinal tract and so on.

It is generally recognized that the Leghorn hens lay eggs in the daytime. However, ducks generally lay eggs at night. For example, the oviposition time for laying Tsaiya ducks was between 0:00 to 8:00 a.m. (Ma, 1968) and for Khaki Campbell ducks, 97% of eggs were laid before 0700 hr (Simmons and Hetzel, 1983). Accordingly, most eggshell was formed in daytime in ducks with continuous eating to provide calcium for eggshell formation. In hens, much of the shell calcification occurred at night when chickens generally ceased to eat (Mongin and Sauveur, 1974) and the calcium level in the digestive tract gradually declined (Roland *et al.*, 1973). Thus calcium from skeleton might be mobilized for shell formation in the early morning. Studies using tracer have shown that 28 to 40% of calcium in the shell was supplied from the skeleton even when laying hens were on diet with adequate calcium level (Mueller *et al.*, 1964; Farmer et al., 1986). Recently, Farmer *et al.* (1986) indicated that the greater the dependency on skeletal calcium, the less the quantity of calcium deposited in the eggshell.

The fluctuation of total blood calcium during egg formation in ducks was different from that in hens. For laying Tsaiya ducks, blood calcium reached a peak at 1500 hr during shell calcification (Cheng and Shen, 1985). However, the level of plasma calcium in Leghorn hens was decreased during shell calcification at night (Winget and Smith, 1958; Velde *et al.*, 1986). This difference might be one of the reason for causing the higher magnesium content of the eggshell in Leghorn hens. When the eggshell was divided into 4-5 strata, the magnesium content was gradually increased from the inside stratum to the outside (Brooks and Hale, 1955; Itoh and Hatnao, 1964). Itoh and Hatnao (1964) also demonstrated that larger quantity of magnesium was secreted into shell during the few hours prior to oviposition. We postulated that when plasma could not supply enough calcium for shell deposition, then the magnesium ion would be substituted for calcium (Ksp. $CaCO_3 = 4.8 \times 10^{-9}$; Ksp. $MgCO_3 = 1 \times 10^{-5}$).

It is predicted that the high magnesium level in the eggshell of hens might respond to the insufficient calcium level in plasma for secreting during shell formation. For example, hens fed 1% calcium diet had the lower plasma calcium content which might cause more magnesium being secreted into eggshell resulting in poor eggshell.

The pH in gizzard of ducks was 2.3 which was lower than hen's 4.7 (Sturkie, 1976). It seemed that the higher acidity in the gizzard for ducks might help to dissolve calcium more completely and to facilitate intestinal calcium absorption.

From this study, we concluded that ducks could retain significantly more calcium and maintain higher plasma calcium level which might be the reason for larger eggs with better shell quality by ducks.

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