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Effects of Dietary Sodium Bicarbonate Supplementation on Eggshell Quality and Hatchability in Thai Native Hens

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ABSTRACT

An investigation was conducted on Thai native hens to determine the effects of dietary sodium bicarbonate ($NaHCO_3$) supplementation on egg production, egg and eggshell quality, fecal moisture content, plasma sodium, and hatchability performance. Two hundred and forty of 24 wk-old hens were used in this study. The birds were housed in individual cage and received 1 of 3 experimental diets. The 3 experimental diets were control layer diet, the control diet added with 1% $NaHCO_3$, and the control diet added with 1.5% $NaHCO_3$. The experiment was conducted for 24 weeks. There were no significant differences in feed consumption, egg weight, yolk weight, albumen weight, Haugh units or fecal moisture content among the three bird groups throughout the experimental period. However, the birds in the two groups having received the diet supplemented with $NaHCO_3$ gave a significantly higher level of yolk color, shell weight, and shell thickness than the control hens transiently ($P<0.05$). Likewise, the hens received the diet added with $NaHCO_3$ had a higher level of plasma sodium concentrations than the birds fed with control diet at 32 and 36 wk of age. A smaller, but still significant, increase in plasma pH was also observed in the fowls having consumed the diet supplemented with 1.5% $NaHCO_3$ at 28 wk of age ($P<0.05$). Hatchability, viability (hatchability of fertile eggs), and body weight of the chick at hatching were not affected by the experimental diets ($P>0.05$).

The results indicated that at moderate temperatures eggshell quality of Thai native hens could be improved by dietary supplementation with 1.5% $NaHCO_3$. This suggested that the response was associated to bicarbonate intakes. However, the beneficial effect was transient that would be resulted from the hens having no access to feed during the dark period, irrespective of bicarbonate content, the time during which eggshell formation occured. Hatchability and viability of chicken embryos were not evident.

Key words: Thai native hens, sodium bicarbonate, eggshell quality, fecal moisture, plasma pH, plasma sodium, hatchability

INTRODUCTION

Sodium is recognized as a major extracellular electrolyte in both humans and animals since it is the principal osmotically active electrolyte in the plasma of animals. It is essential for growth, resistance to disease, economical utilization of feed, and maturity in pullets. Although this mineral is a necessary ingredient of poultry diets, relatively small amounts are required. The requirement of sodium in laying hens for optimum performance has been the subject of investigation for a number of years. Sodium bicarbonate ($NaHCO_3$) is the sodium-containing mineral compound which is

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currently being used in poultry feeds. The supplementation with $NaHCO_3$ as a means of improving eggshell quality has been studied extensively. Several investigators reported greater shell thickness or shell strength if part of the dietary sodium was provided as $NaHCO_3$ rather than as sodium chloride (Frank and Burger, 1965; Howes, 1966). On the other hand, other workers were unable to demonstrate these beneficial effects (Ferguson *et al*., 1974; Ernst *et al*., 1975; Grizzle *et al*., 1992). Still others have observed benefits under specific conditions (Harms and Miles, 1980) or have found variable responses (Latif and Quisenberry, 1968). A recent study has revealed that under heat stress conditions eggshell breaking strength can be improved by supplemental $NaHCO_3$ in feed (Balnave and Muheereza, 1997).

The aim of the study was to improve eggshell quality of Thai native hens by supplementing diet with sodium bicarbonate. However, there was concern that sodium supplementation may adversely affect egg production and produce wet droppings. Therefore, the trial was conducted with Thai native hens, raised in an open sided house as practiced by local farmers, to assess the effect of dietary $NaHCO_3$ supplementation on egg production, eggshell quality, manure moisture and electrolyte balance. Hatchability performance was also examined at the end of the study.

MATERIALS AND METHODS

The experiment was conducted on Thai native hens at 24 weeks of age. The birds were housed in individual cage situated in an open sided poultry shed, and divided randomly into three groups of 80 birds. Each group was divided into 4 replicates, each consisting of 20 hens. The birds in Group 1 (control group) were fed on a commercial layer mash diet for the entire 24-week experimental period. Groups 2 and 3 received the control diet supplemented with $NaHCO_3$ at the level of 1% and 1.5%, respectively, as shown in Table 1. Feed and water were provided *ad libitum*. The birds were maintained at ambient temperatures and on a 16 h light (L):8 h dark (D) photoperiod throughout the study. Daily egg production was determined as the number of eggs per hen per 100 days (percentage of hen-day), and feed intakes were recorded biweekly. All eggs obtained from the last day of each two weeks were assessed individually for egg weight, albumen weight, albumen height, yolk weight, yolk color and eggshell quality.

Eggshell quality was determined by measuring shell thickness and shell weight. On the last day of each four weeks, fecal moisture contents were determined by collecting droppings, over a

Table 1 Composition of experimental diets.

Nutrients	Diet		
	Control (layer diet)	Control+1%$NaHCO_3$	Control+1.5%$NaHCO_3$
Total energy, cal/g	3641.44	3654.62	3613.76
Crude protein, %	17.32	17.14	17.06
Fat, %	2.01	1.99	1.97
Moisture, %	8.40	8.44	8.64
Crude fiber, %	4.76	7.29	7.19
Calcium, %	4.53	4.47	4.44
P, %	1.31	1.29	1.29
NaCl, %	0.83	0.53	0.32

seven-hour period, in aluminum foil containers underneath the individual cages, weighing the fresh droppings, drying them to constant weight at 95 °C for 24 hours by using a dry oven (Model Binder E) and re-weighing. Percentage of moisture content was calculated. On the following day, blood samples (each 5 ml) were collected from the cutaneous ulnar vein of the same birds. The time of sampling was usually between 9.00 and 11.00 a.m. The blood was centrifuged in a Hettich EBA 8S Zentrifugen at 35,000g for 15 minutes and plasma was removed for the measurement of pH and sodium concentrations. The concentration of sodium and plasma pH were assessed using a Cyber Scan (Model PC 5000/5500).

At the end of the experiment (48 weeks of age) hatchability performance was studied by using artificial insemination method. All of the hens were inseminated with fresh semen of Thai native cockerel breeders. The hatching eggs laid during 7 consecutive days, following three days after insemination, were collected and placed in a holding room at approximately 18.0 °C and 80% relative humidity (Austic and Nesheim, 1990). The hatching eggs were incubated in a conventional forced-air incubator (Model Multiplo) according to the commercial practice (North, 1984). On the seventh day of incubation, the eggs were candled, "clear" eggs were removed and broken in order to separate early dead embryos from infertile eggs. On day 18 after incubation, the egg candling was performed again. About 3 h after removing from the setter, eggs with apparently living embryos were transferred to hatching trays and randomly distributed in the hatcher to reduce possible position effects. The hatcher was maintained according to the commercial practice (North, 1984). All chicks were removed at 21 d and 12 h postincubation. The experiment commenced in May 2002 and terminated in January 2003. The average ambient minimum and maximum temperatures were 26.5 ° C and 30.9 °C, respectively. The statistical evaluation of the data was performed by analysis of variance. Repeated measures ANOVA was used where appropriate. Mean values were compared using Duncan's multiple range test to determine significance (Snedecor and Cochran, 1980). Significance was assumed if $P<0.05$.

RESULTS

There were no significant differences among the three experimental groups in feed intake, egg weight or any aspect of egg quality at each period of the study, except for yolk color (Tables 2, 5 and 6).The birds in the control group had significantly lower hen-day production than the birds in the other two groups supplemented with $NaHCO_3$ during 42– 46 weeks of age (Table 3). An increase in yolk color was observed in the treatment groups at some periods (Table 4). The effects of dietary $NaHCO_3$ supplementation on eggshell quality are summarized in Tables 7 and 8. It was apparent that feeding hens with the diet supplemented with $NaHCO_3$ resulted in a slightly beneficial effect on eggshell quality at the initial period of the study as evidenced by the percentage of shell (Table 7) and eggshell thickness (Table 8). Fecal moisture contents did not show any significant differences among groups at each stage of the trial (Table 9).

Plasma sodium concentrations and plasma pH, measured every four weeks, are shown in Table 10. At 32 and 36 weeks of age, the birds fed on the diet added with 1.5% $NaHCO_3$ had a significantly higher level of plasma sodium concentration than the birds fed on the control diet, whereas the birds in the 1% $NaHCO_3$ supplemented group had the medium value. The similar pattern was observed in plasma pH of the experimental birds. At 28 weeks of age, a smaller but significant increase in plasma pH was observed in the hens fed on the diet supplemented with 1.5% sodium bicarbonate. Table 11 presents the effect of dietary supplementation of $NaHCO_3$ on hatchability performance of chicken. On the seventh and eighteenth days of incubation, no significant differences in embryonic mortality were found among the three bird groups. Viability of embryos in the control group was 72.7%, whereas in the group for which the diet added with 1% sodium bicarbonate was 74.8%, and 80.7% for the 1.5%

Table 2 Effects of dietary sodium bicarbonate addition on feed intake and egg weight.

Age (wk)	Feed intake (g/h/d)			Egg weight (g)		
	Control	1%$NaHCO_3$	1.5%$NaHCO_3$	Control	1%$NaHCO_3$	1.5%$NaHCO_3$
24-26	88.2±2.1	85.5±3.6	87.5±3.0	34.7±0.9	36.1±1.6	35.9±1.3
26-28	95.0±2.9	93.6±1.7	96.6±2.5	37.4±0.5	37.4±0.7	36.3±1.6
28-30	95.6±5.4	95.2±1.3	102.0±2.4	38.2±2.7	36.9±0.5	39.3±1.3
30-32	103.9±2.7	99.0±2.8	104.9±5.3	39.8±2.2	39.7±0.6	39.8±1.3
32-34	105.4±4.6	101.3±2.8	108.3±6.2	42.3±1.3	40.8±0.8	41.1±1.6
34-36	105.6±4.0	104.3±4.1	116.5±10.0	43.1±0.7	43.8±1.8	45.3±1.0
36-38	106.3±5.9	98.9±6.1	109.9±8.2	45.1±1.0	43.3±1.2	44.4±1.0
38-40	103.2±5.3	93.4±4.2	99.0±5.8	46.8±0.7	44.3±1.9	45.1±1.3
40-42	118.4±9.4	112.0±8.5	105.1±10.8	45.5±1.0	44.6±1.1	45.9±0.4
42-44	100.1±2.6	101.7±4.8	102.2±11.5	46.7±1.1	45.7±0.7	46.4±1.4
44-46	96.4±3.8	98.9±3.7	102.8±5.7	45.0±0.5	46.4±1.3	45.1±1.2
46-48	95.1±3.4	97.5±5.9	103.6±7.3	46.5±0.7	45.5±2.0	46.6±0.9

There were no significant differences between groups (P>0.05). (mean±stdev) as determined by DMRT.

Table 3 Mean egg production measurements of Thai native hen receiving sodium bicarbonate in their diets (mean±stdev).

Age (wk)	Egg production (%hen-day production)		
	Control	1%$NaHCO_3$	1.5%$NaHCO_3$
24-26	21.6±2.5	17.2±5.5	19.1±3.0
26-28	22.0±4.9	19.2±5.6	22.1±8.0
28-30	24.4±4.4	26.0±3.3	27.1±6.6
30-32	29.1±4.7	26.0±5.7	27.5±3.0
32-34	33.8±5.2	32.0±3.4	29.0±1.7
34-36	33.2±2.4	29.8±3.6	30.6±4.4
36-38	34.7±5.6	32.1±3.6	33.4±3.3
38-40	32.9±2.0	33.5±2.1	37.1±1.4
40-42	35.1±4.9	35.6±3.4	35.7±2.3
42-44	$25.3±2.8^{b}$	$31.3±2.0^{a}$	$33.1±1.9^{a}$
44-46	$26.7±4.2^{b}$	$33.6±3.8^{a}$	$31.4±1.7^{ab}$
46-48	23.4±3.8	27.2±5.2	26.8±0.4

Means within rows with similar superscripts are not significantly different (P>0.05) as determined by DMRT.

$NaHCO_3$ group. However no statistically significant differences in hatchability and viability of embryos, or any aspect of hatchability performance among the experimental bird groups (P>0.05) were noted.

Table 4 Effects of dietary sodium bicarbonate supplementation on egg yolk pigmentation.

Age (wk)	Yolk color		
	Control	1%$NaHCO_3$	1.5%$NaHCO_3$
24	12.1±0.2	11.4±0.5	11.1±0.6
26	12.0±0.6	11.4±0.3	11.7±1.0
28	12.0±0.3	11.9±0.4	12.0±0.2
30	11.6±0.4^{b}	12.0±0.1^{ab}	12.3±0.2^{a}
32	11.3±0.3^{b}	12.0±0.1^{a}	11.2±0.2^{b}
34	11.8±0.2	12.1±0.5	11.6±0.3
36	12.1±0.1	11.9±0.2	12.2±0.1
38	11.7±0.2	11.9±0.3	11.8±0.1
40	11.0±0.2^{b}	11.8±0.2^{a}	11.4±0.2^{ab}
42	11.6±0.2	11.1±0.2	11.5±0.4
44	11.6±0.3	11.8±0.3	11.6±0.3
46	11.4±0.3^{b}	12.0±0.1^{a}	11.8±0.1^{ab}
48	11.5±0.3^{b}	12.2±0.2^{a}	12.1±0.2^{a}

Means within rows with similar superscripts are not significantly different (P>0.05). (mean±stdev) as determined by DMRT.

Table 5 Effects of dietary sodium bicarbonate addition on yolk weight and albumen weight.

Age	Yolk weight (%)			Albumen weight (%)		
(wk)	Control	1%$NaHCO_3$	1.5%$NaHCO_3$	Control	1%$NaHCO_3$	1.5%$NaHCO_3$
24	30.4±0.8	29.6±1.9	29.4±1.4	58.9±0.8	60.0±2.4	59.6±1.4
26	30.2±0.8	30.5±0.7	29.6±1.1	59.0±0.8	57.7±0.9	59.6±1.1
28	31.5±1.0	31.5±0.6	31.0±0.4	57.9±0.6	57.6±0.7	58.1±0.3
30	32.6±1.2	31.3±1.1	35.7±1.1	56.7±1.6	57.9±1.0	58.0±1.3
32	32.2±0.8	32.8±0.7	32.3±0.9	57.4±0.6	57.3±0.8	57.4±0.8
34	32.4±0.6	32.8±0.2	31.9±0.1	57.1±0.6	56.6±0.8	57.8±0.5
36	32.4±0.8	32.3±0.4	31.7±0.7	57.7±0.9	56.9±0.4	58.1±0.5
38	33.2±1.0	32.7±0.8	32.8±0.4	56.7±0.9	57.0±0.9	56.5±0.4
40	33.9±0.6	33.2±0.4	32.6±0.7	56.0±0.4	56.6±0.3	57.0±0.8
42	33.1±0.6	33.2±0.2	33.0±1.3	56.9±0.6	56.5±0.4	56.9±1.3
44	35.1±1.6	32.7±0.4	33.6±1.1	54.7±2.0	57.1±0.6	56.5±1.3
46	33.3±1.0	32.5±0.3	33.1±1.1	56.7±1.0	57.2±0.4	56.6±1.3
48	34.3±0.9	33.6±1.0	33.9±1.4	55.8±0.6	55.9±0.7	56.2±1.4

There were no significant differences between groups (P>0.05). (mean±stdev) as determined by DMRT.

Table 6 Effects of dietary sodium bicarbonate supplementation on Haugh Units (mean±stdev).

Age (wk)	Haugh Units		
	Control	1% $NaHCO_3$	1.5% $NaHCO_3$
24	88.1±4.5	90.8±1.5	92.6±3.2
26	82.1±6.5	85.7±3.5	82.6±4.8
28	87.8±3.1	88.6±5.4	86.2±3.2
30	83.0±1.4	85.6±2.3	83.5±4.4
32	80.5±2.5	78.3±0.8	78.1±1.9
34	81.7±2.9	82.1±0.8	83.3±2.6
36	88.0±1.9	83.0±1.6	83.8±3.5
38	82.8±4.0	84.9±2.9	84.8±2.2
40	81.9±2.9	82.2±1.7	80.8±1.8
42	85.3±0.6	79.0±0.6	81.1±3.0
44	79.4±5.3	84.6±2.8	83.4±3.3
46	81.0±4.2	79.5±1.1	80.0±2.7
48	78.4±4.4	78.0±0.4	79.9±4.2

There were no significant differences between groups (P>0.05) as determined by DMRT.

Table 7 Biweekly shell weights from Thai native hens fed on the diet supplemented with sodium bicarbonate (mean±stdev).

Age (wk)	Shell weight (%)		
	Control	1% $NaHCO_3$	1.5% $NaHCO_3$
24	10.6±0.5	10.3±0.6	10.9±0.2
26	10.7±0.2^{b}	10.6±0.3^{b}	11.6±0.2^{a}
28	10.4±0.7	10.7±0.2	10.7±0.1
30	10.6±0.3^{ab}	10.7±0.1^{a}	10.2±0.4^{b}
32	10.3±0.2	10.5±0.3	10.2±0.3
34	10.4±0.1^{ab}	10.5±0.1^{a}	10.1±0.2^{b}
36	9.7±0.4^{b}	10.6±0.2^{a}	10.1±0.4^{ab}
38	9.9±0.1^{b}	10.1±0.1^{ab}	10.5±0.3^{a}
40	10.0±0.2	10.1±0.2	10.2±0.1
42	9.8±0.2	10.2±0.3	9.9±0.2
44	10.4±0.4	10.1±0.2	9.8±0.2
46	9.9±0.2	10.2±0.3	10.1±0.1
48	9.8±0.3	10.3±0.2	9.8±0.2

Means within rows with similar superscripts are not significantly different (P>0.05) as determined by DMRT.

DISCUSSION

In the study, dietary supplementation with sodium bicarbonate ($NaHCO_3$) in Thai native hens might be achieved up to 1.5% of feed without any adversely effect on feed consumption, egg weight, albumen quality or fecal moisture content throughout the experimental period. These results were in agreement with those reported by previous investigators (Ernst *et al*., 1975) and with those found in hens receiving added salt through the drinking water (Yoselewitz *et al*., 1990). A reduction of egg production noticed in the control group during 42-46 wk of age could result from the

Table 8 Biweekly shell thickness from Thai native hens fed on the diet supplemented with sodium bicarbonate (mean±stdev).

Age (wk)	Shell thickness (μm)		
	Control	1%$NaHCO_3$	1.5%$NaHCO_3$
24	359.6±10.6[b]	370.3±8.0[ab]	382.0±6.3[a]
26	394.9±11.9[b]	391.0±6.7[b]	420.5±13.4[a]
28	386.5±29.9	381.3±8.4	394.1±4.1
30	385.8±4.9	390.3±4.6	365.9±10.3
32	389.5±14.8	392.9±13.1	387.9±18.2
34	399.8±3.9	403.9±8.0	402.8±11.7
36	339.3±16.7	374.8±11.0	362.8±22.8
38	362.5±7.1	367.1±4.9	382.6±9.8
40	355.0±22.5	368.5±17.4	378.3±2.3
42	363.0±9.4	370.3±13.4	364.3±8.2
44	356.2±18.1	363.4±8.8	350.8±9.8
46	356.0±5.5	364.0±6.1	359.6±6.9
48	350.6±13.1	351.2±14.1	351.5±18.5

Means within rows with similar superscripts are not significantly different (P>0.05).

Table 9 Fecal moisture content of Thai native hens receiving the diet supplemented with sodium bicarbonate (mean±stdev).

Age (wk)	Fecal moisture (%)		
	Control	1%$NaHCO_3$	1.5%$NaHCO_3$
24	74.4±8.9	78.9±10.9	73.9±6.5
28	77.0±9.2	75.6±6.9	79.8±4.4
32	73.0±5.2	73.5±6.1	76.5±4.7
36	74.4±3.9	78.6±2.3	75.1±2.6
40	74.1±5.8	77.1±4.1	77.6±4.0
44	75.6±2.6	77.5±3.5	79.9±7.0
48	77.3±3.7	75.2±5.4	77.2±3.1

There were no significant differences between groups (P>0.05) as determined by DMRT.

Table 10 Changes in physiological aspect of plasma of Thai native hen in response to sodium bicarbonate supplementation in the diet (mean±stdev).

Age (wk)	Experimental bird group		
	Control	1%$NaHCO_3$	1.5%$NaHCO_3$
		Plasma sodium concentration (mmol/L)	
24	598.0±90.9	633.9±45.1	633.9±18.4
28	562.2±100.2	612.2±71.9	593.0±33.7
32	640.4±24.9^{b}	720.9±111.8^{ab}	815.5±89.3^{a}
36	647.0±104.1^{b}	737.2±56.6^{ab}	784.0±33.5^{a}
40	660.0±27.1	727.4±108.2	807.9±67.4
44	667.6±99.5	716.6±43.6	704.6±68.5
48	784.0±98.7	706.8±9.0	718.7±63.9
52	749.2±48.8	723.1±22.8	670.9±39.1
		Plasma pH	
24	7.86±0.03	7.81±0.03	7.85±0.04
28	7.78±0.03^{b}	7.83±0.02^{ab}	7.89±0.04^{a}
32	7.86±0.06	7.87±0.05	7.83±0.12
36	7.79±0.14	7.92±0.14	7.80±0.05
40	7.89±0.14	7.81±0.08	7.78±0.13
44	7.82±0.09	7.78±0.04	7.83±0.05
48	7.86±0.07	7.94±0.09	7.83±0.06

Means within rows with similar superscripts are not significantly different (P>0.05) as determined by DMRT.

Table 11 Mortality and hatchability of chicken embryos from different treatment eggs.

	Group		
	Control	1%$NaHCO_3$	1.5%$NaHCO_3$
Number of eggs set	127	147	159
Number of fertile eggs set	81	93	112
Dead embryos (%)			
0 to 7 d	13.3±7.7	13.4±5.3	8.4±5.9
8 to 18 d	2.9±3.4	1.5±3.1	2.0±4.1
19 to 22 d	27.2±7.2	25.1±7.0	19.2±8.9
Hatchability (%)	51.7±9.5	51.1±5.0	53.5±8.1
Viability (%)	72.7±7.2	74.8±7.0	80.7±8.9
Body wt of chicks (g)	29.7±1.1	29.9±0.3	29.9±0.7

There were no significant differences between groups (P>0.05). (mean±stdev) as determined by DMRT.

cessation of egg laying due to broodiness. It was apparent that there were some birds in the control group exhibited brooding behavior. In different avian species, incubation behavior and broodiness are induced by prolactin, a polypeptide hormone secreted from the pituitary gland (El Halawani and Rozenboim, 1993). Sharp *et al*. (1988) demonstrated that prolactin increased incubating behavior in bantam hens as indicated by the increase in nesting behavior, and confirmed by the results of a previous investigation conducted on turkey hens (El Halawani *et al*., 1980). Zadworny *et al*. (1989) reported that prolactin might have the role on reducing plasma estrogen concentrations, and inducing ovarian regression of birds.

The results of this study indicated that the inclusion of $NaHCO_3$ in the diet resulted in an increase in yolk pigmentation as evidenced by a significant increase of yolk color noticed in some periods of the experiment (Table 5). These results were in agreement with those reported by Bushong *et al*. (1972), and Makled and Charles (1987), who indicated that $NaHCO_3$ acted as the enhancer of yolk pigmentation.

In the current work, eggshell quality were improved at ambient temperatures by dietary supplementing with $NaHCO_3$, in agreement with the results of previous studies (Makled and Charles, 1987; Balnave and Muheereza, 1997). The beneficial effects obtained from the present experiment would be associated with the differences of bicarbonate intakes rather than calcium intakes, since similar feed intakes noted with the control and $NaHCO_3$ treatments (Table 2). Makled and Charles (1987) found that improvements in eggshell quality appeared when the daily photoperiod for laying hens increased from 16 to 24 h. Balnave and Muheereza (1997) indicated that a dietary $NaHCO_3$ supplement could improve eggshell quality in laying hens at high temperatures as long as feed was consumed during the period of eggshell formation. They fed laying hens on a diet supplemented with 1%$NaHCO_3$ and maintained the birds on continuous lighting (24 h/d) at temperatures of 30 °C. In this work, the average of maximum temperatures was 30.9 °C, which was comparable to the temperature in the study of Balnave and Muheereza (1997). However, the beneficial effect obtained from the current study was inconsistent. The transient responses to bicarbonate might reflect the fact that under a conventional daily 16 h photoperiod, the bicarbonate would not be consumed during the dark period, the time during which eggshell formation occurred.

An increase in plasma sodium concentrations in the hens receiving 1.5% $NaHCO_3$ supplemented diets would be caused by an increase in sodium intakes. Cohen and Hurwitz (1974) reported that the primary effect of dietary supplementation with one of the ionic components was the increase in its concentration in plasma. However, the significant differences did not prolong, this suggested that the birds eliminated greater amounts of the electrolytes by the renal function. Gorman *et al*. (1997) conducted an investigation to determine the effect of dietary $NaHCO_3$ supplementation on the mineral excretion in broilers. They indicated that dietary $NaHCO_3$ supplementation resulted in an increase in both the absolute retention and urinary excretion of sodium. In the investigation, it was likely that changes in dietary sodium intakes affect acid-base balance. The increased plasma pH was observed in the birds fed on the diet supplemented with 1.5% $NaHCO_3$ at 28 wk of age, this possibly due to an increase in the sodium/chloride ratio of the diet (Table 1). Cohen and Hurwitz (1974) found that dietary $NaHCO_3$ supplementation resulted in an increase in plasma pH and bicarbonate ions. They demonstrated that when the ratio of sodium plus potassium to chloride ((Na+K)/Cl) was higher than 2, metabolic alkalosis was produced. It was well documented that acidosis and alkalosis could be produced by altering the dietary sodium to chloride ratio (Cohen *et al*., 1972; Cohen and

Hurwitz, 1974; Hamilton and Thompson, 1980; Mongin, 1981). Beneficial effects of supplemental $NaHCO_3$ feeding in improvements of hatchability were not evident in this study suggesting that the eggshell quality of the hens in all groups was not significantly different. Roque and Soares (1994) reported that hatchability and viability of embryos were mainly influenced by shell quality of the hatching eggs.

CONCLUSION

At the moderate temperatures (26-30 °C), eggshell quality could be improved by dietary supplementing with 1.5% sodium bicarbonate. This suggested that due chiefly to the increase in dietary bicarbonate intakes. However, the response was inconsistent, which might reflect the fact that under a conventional daily 16 h photoperiod, the bicarbonate would not be consumed during the dark period, the time during which eggshell formation occurred.

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