FATE OF INGESTED SODIUM BICARBONATE IN THE FOWL

J.-R. HUNT

Canada Department of Agriculture (1),
Ottawa, Ontario (Canada)

INTRODUCTION

It has been shown by some workers, namely FRANK and BURGER (1965) and HOWES (1967), that the incorporation of sodium bicarbonate in the diet of the hen results in significant improvement in shell quality. FRANK and BURGER reported that a reduced level of dietary chloride was required to bring about the improvement of shell quality but HOWES obtained a response in the presence of 0.4 p. 100 NaCl in the diet with levels of supplemental $NaHCO_3$ as low as 0.125 p. 100.

PEPPER *et al.* (1968) noted that the addition of 0.1 p. 100 $NaHCO_3$ to a diet containing 0.25 p. 100 NaCl (0.05 p. 100 higher in NaCl than that used by FRANK and BURGER) had no effect on shell quality. Similarly, MORRIS (1966) found that the addition of 0.5 p. 100 $NaHCO_3$, in diets of low chloride content, had no effect on shell quality as measured by weight of the shell per unit area. Work in this laboratory, as yet unpublished, has shown that a response in shell quality was not obtained to the addition of $NaHCO_3$ to the laying diet. These diets contained 0.175 p. 100 added NaCl and had supplemental levels of 0.2, 0.4 and 0.6 p. 100 $NaHCO_3$.

The lack of response may be due to the $NaHCO_3$ being converted to CO_2 and expelled through the lungs. The entire digestive tract of the fowl is acidic in nature (FARNER, 1942 ; HERPOL, 1966) and would be unfavourable for sodium bicarbonate to exist in the ionic form. From the results of *in vivo* measurement of crop pH (HERPOL, 1966) it would appear that most of the salt would be converted into carbon dioxide in this portion of the digestive tract.

The object of the work reported here is to determine if presence of $NaHCO_3$ in the diet affects the pH of the digestive tract and to determine the fate of ingested $NaHCO_3$.

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MATERIALS AND TECHNIQUES

The first experiment was designed to determine the effect of $NaHCO_3$ and $CaCO_3$ on the pH of the digestive tract. The four rations described in table 1 were fed to 4 groups of 9 birds each for a period of 4 weeks. The experiment was repeated 3 times. Rations 1 and 2 contained 1.85 p. 100 calcium while rations 3 and 4 contained 3.85 p. 100 calcium. Sodium bicarbonate was added at a level of 0.5 p. 100 to rations 2 and 4. At the end of the 4 week period the birds were anæsthetized with pentobarbitol-sodium administered via the brachial vein. After the birds were in deep anæsthesia, the digestive tract was exposed and the pH of segments measured with a combined electrode (tip = 65 × 7 mm) in conjunction with a Model E300 Metrohm pH-meter. The proventriculus was entered through the gizzard. The duodenum was entered at the top of the loop and the electrode tip immersed its full length down the posterior side of the loop. The

TABLE I

Composition of experimental ration

Ingredients	Ration Number			
	1	2	3	4
	%	%	%	%
Basal	92.00	92.00	92.00	92.00
Ground wheat	7.72	7.50	2.48	2.25
Ground limestone	—	—	5.25	5.25
Sodium bicarbonate	—	0.50	—	0.50
Iodized salt	0.275		0.275	

Basal Ration

Ingredients	%
Ground corn	10.0
Ground wheat	33.5
Ground oats	20.0
Ground barley	10.0
Fish meal (65 % prot.)	2.0
Meat meal (55 % prot.)	2.0
Soybean oil meal (44 % prot.)	5.0
Skim milk powder	1.5
Dehydrated alfalfa meal	3.0
Steamed bone meal	1.25
Ground limestone	3.50
Iodized salt	0.10
Micro ingredients [1]	0.15
	92.00

[1] Supplied vitamin A, 60,000 IU ; vitamin D_3, 67,000 ICU ; riboflavin, 220 ; and manganese sulfate, 5.7 gm per 100 lb. feed.

mid-intestinal reading was taken with the incision at approximately the mid point and the tip was immersed posteriorly to its full length. An incision was made at the cœcal-intestinal junction and the electrode immersed full length in an anterior and posterior direction. Measurement of crop pH was not taken in this experiment.

The second experiment was concerned with the use of carbon labeled $NaHCO_3$ to follow the passage of the bicarbonate in the fowl. A hen was placed in a gas tight chamber, (40 × 18 × 35 cm) having just received 5 μCi of $NaH^{14}CO_3$ in the crop by means of a pipette. By means of a vacuum pump, air was pulled through the chamber, through a drying column and then through a series of three traps containing 50 ml of molar hydroxide of hyamine in methanol as shown in figure 1.

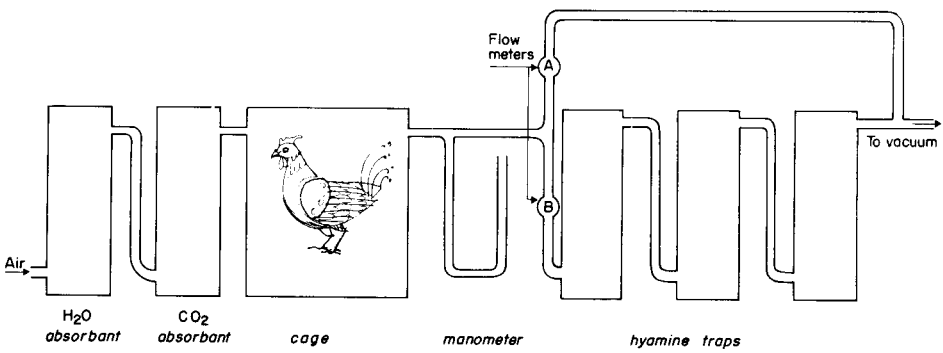

FIG. 1. — $^{14}CO_2$ *collection system*

A system of flowmeters and valves allowed 5 p. 100 of the air drawn through the system to be passed through the hyamine traps. A 0.5 ml sample of hyamine was drawn from the traps at 15 minute intervals for a period of 5 hours. The samples were counted by liquid scintillation using 4 g of omnifluor per liter of toluene. This procedure was carried out on six birds.

Six birds were also given the same dose of labeled $NaHCO_3$ and held in the chamber for 1 hour under similar conditions of negative pressure. On removal they were killed by an overdose of an intravenous injection of pentabarbitol sodium. The œsophagus was clamped off with hæmostats to prevent drainage from the crop and the digestive tract ligated off at the crop, proventriculus, gizzard and duodenum. Each section of gut had 2 ml of 0.2N NaOH injected into the lumen. When the section of gut was removed the contents were washed out with an additional 8 ml of 0.2 N NaOH into a reaction vessel. An excess of HCl was added to the reaction flask and the evolved CO_2 was trapped in hyamine and counted as previously described.

Six birds on a low (0.16 p. 100 added NaCl) and six on a normal (0.4 p. 100 added NaCl) chloride diet were given the same dose of $NaH^{14}CO_3$, in the manner described above, when there was a hard shelled egg in the shell gland. The birds were returned to their individual cages and allowed to have a normal oviposition. If the egg was laid four to six hours after the administration of the labeled bicarbonate, the contents of the egg were discarded, the membranes washed with tap water and the shell dried to constant weight. The shell was broken into small pieces and placed in a reaction flask with 20 ml of distilled water and 0.2 ml of octanol-1. An excess of HCl was added and the evolved CO_2 trapped as previously described.

RESULTS

Effect of diet on digestive tract pH

The mean pH value with their respective S.E.M. for the various segments of the digestive tract are given in table 2. The values are slightly basic compared to one report (HERPOL, 1966) but are more acid in the upper region of the tract when compared with the results of FARNER (1942). Analyses of variance of the results (table 3)

indicates that diet does influence digestive tract pH. Sodium bicarbonate at the 0.5 p. 100 level had no effect on pH, however, calcium carbonate had a highly significant effect when fed at the high level. In both the proventriculus and the gizzard the feeding of the high calcium carbonate diet resulted in a reduced acidity. This

TABLE 2

Mean digestive tract pH values with S. E. M.

	Ration 1 1.8 % Ca	Ration 2 1.8 % Ca 0.5 % $NaHCO_3$	Ration 3 3.8 % Ca	Ration 4 3.8 % Ca 0.5 % $NaHCO_3$
Proventriculus	1.93 ± 0.12	1.83 ± 0.16	2.04 ± 0.14	2.40 ± 0.20
Gizzard	3.70 ± 0.16	3.30 ± 0.20	4.24 ± 0.21	4.46 ± 0.06
Duodenum	6.46 ± 0.04	6.40 ± 0.06	6.46 ± 0.06	6.52 ± 0.03
Mid intestine	7.00 ± 0.11	6.90 ± 0.13	7.00 ± 0.12	7.12 ± 0.11
Anterior cecal-int. junction	7.53 ± 0.05	7.56 ± 0.07	7.69 ± 0.02	7.61 ± 0.04
Posterior cecal-int. junction	6.66 ± 0.11	6.73 ± 0.15	7.05 ± 0.11	7.39 ± 0.06

effect was not evident in the remainder of the tract until the pH was taken in a posterior direction from the cæcal-intestinal junction. Again, the feeding of the high calcium carbonate diet had in alkalizing effect of the gut contents.

There were no interactions between bicarbonate and calcium carbonate for the various segments of the gut when pH was measured.

Fate of ingested $NaH^{14}CO_2$ in the laying hen

Sampling the expelled air from the bird indicated that the majority of the labeled CO_2 is expired by 1.5 hours. A typical graph of the radioactivity of the first and second trap is given in figure 2. In all cases labeled CO_2 was expelled in negligible amounts after 2 hours. This was checked by placing fresh traps in the line after the bird had been in the chamber for 2 hours. In an additional 2 hours of collection only 20 000 counts/mn were trapped out of 4.8 million count/mn. An estimate of the percentage of counts, trapped in expired air, of the total dose indicated some 91-94 p. 100 of the radioactivity was accounted for in the expired air. An account of all the radioactivity could not be made in this test as fecal and residual body $^{14}CO_2$ were not measured. Also the system employed flowmeters and stopcocks to partition the gas stream and this system has some error associated with it as variation in flow rates was noted throughout the experiments.

Counts of radioactivity in the contents of the gut segments indicated that, after 1 hour after administering the tracer, the crop contained 84.34 p. 100 ± 6.79 S.E. of the total activity found in the gut while the proventriculus, gizzard and duodenum had 8.26 ± 3.78, 6.96 ± 3.29 and 0.67 p. 100 ± 0.35 S.E. respectively. The total activity found in the gut was, on the average, equivalent to 0.7 p. 100 of the activity administered 1 hour earlier.

TABLE 3

Analysis of variance of pH value of digestive tract segments

	Proventriculus		Gizzard		Duodenum		Mid Intestine		Anterior cecal-intestinal junction		Posterior cecal-intestinal junction	
	d. f.	M. S.	d. f.	M. S.	d. f.	M. S.	d. f.	M. S.	d. f.	M. S.	d. f.	M. S.
Sub group ..	11	3.04	11	2.30	11	0.03	11	0.24	11	0.08	11	1.26
Treatment ..	3	1.71 (1)	3	7.35 (2)	3	0.06	3	0.22	3	0.13	3	2.97 (2)
Ca	1	3.15 (2)	1	19.35 (2)							1	7.29 (2)
$NaHCO_3$	1	0.64	1	0.24							1	1.09
$Ca \times NaHCO_3$.	1	1.34	1	2.45							1	0.54
Replicates ..	8	3.50	8	1.10	8	0.01	8	0.24	8	0.06	8	0.62
Residual	95	0.44	95	0.41	95	0.06	95	0.39	95	0.07	95	0.31

(1) : Significant effect at $p < 0.01$.
(2) : Significant effect at $p < 0.001$.

The activity of the egg-shell, when the tracer was administered in crop 4 to 6 hours prior to oviposition, was found to be low. The type of diet had no effect on the uptake of activity as the mean counts/mn for the birds on the low and normal chloride was 3.4 $\pm$ 0.3 and 2.7 $\pm$ 0.4 SE of the total counts/mn respectively. This latter point was tested by the *t* test.

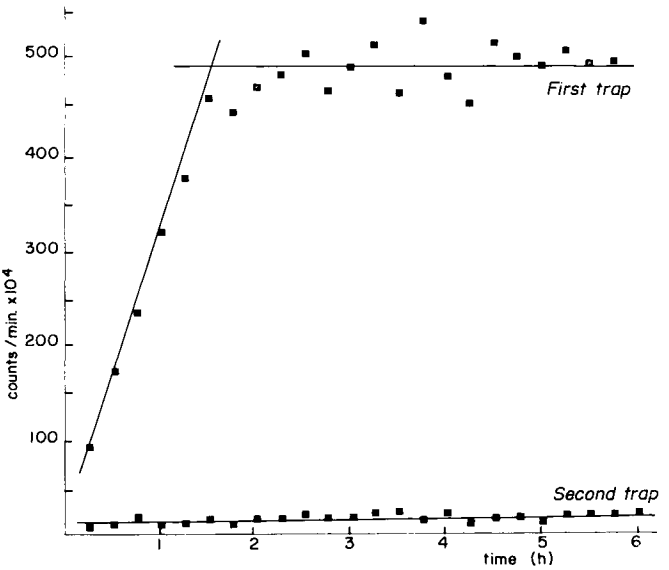

FIG. 2. — *$^{14}CO_2$ count of expired air after administering $NaH^{14}CO_3$ in the crop of the laying hen*

DISCUSSION

The lack of effect of $NaHCO_3$ on the acidity of the proventriculus and gizzard is not surprising since the glandular stomach has considerable ability to secret HCl although it has been noted (MUSSEHL *et al.*, 1933) that higher levels reduce the pH (STURKIE, 1965). The effect of the calcium carbonate had been noted earlier (FARNER, 1943). It is common practice to feed 5 to 7 p. 100 calcium carbonate in poultry feeds to improve shell quality. The action of this material is known to be not through the contribution of calcium (HURWITZ and GRIMINGER, 1962) but the exact mode of action is not known. Speculation of its contribution to provide for the carbonate portion of the shell should await further experimentation.

The rapid expulsion of labeled CO_2 from bicarbonate placed in the crop, through the respiratory system, may explain the difference in response obtained by the various research workers. Since the shell is formed, for a great part, in a period when the bird is not consuming feed, one would expect that there is little bicarbonate to contribute to shell formation as most of it would be expelled through the respiratory system quite rapidly. However, if the blood is capable of retaining more CO_2, as it would under hyperventilation, then bicarbonate in the feed may provide this gas and it may be retained for longer periods.

These experiments do not provide firm evidence but suggest that the bicarbonate is absorbed from the crop. The crop appears to play a very minor role in the absorption of the nutrients (STURKIE, 1965) however, the acidic nature of the crop should convert most of the bicarbonate to the gas state which would pass through the crop wall.

The fact that activity appears in the egg shell indicates that dietary bicarbonate contributes to shell formation. In this experiment the level of chloride in the diet did not influence the amount of labeled carbon that appeared in the egg shell but it must be remembered that the number of experimental birds employed in these experiments was very limited. Further research is required in this area.

SUMMARY

The addition of 0.5 p. 100 sodium bicarbonate de sodium to the diet of the laying hen had no effect on the pH of the proventriculus, gizzard, duodenum, small intestine or large intestine. The addition of 5.25 p. 100 calcium carbonate to the basal diet significantly increased pH in the proventriculus, gizzard and large intestine. There was no interaction between sodium bicarbonate and calcium carbonate on digestive tract pH.

When ^{14}C labeled sodium bicarbonate was introduced into the crop, it was found that the total amount of labeled material expelled as CO_2 in expired air was complete in 1.5 hours. If the digestive tract was ligated 1 hour after the administration of the tracer only 0.7 p. 100 of the dose was found in the tract and 84 p. 100 was present in the crop. The amount of tracer found in the shell when the tracer was administered 4 to 6 hours prior to oviposition was 3.4 p. 100 and 2.7 p. 100 of the total dose for low chloride and normal chloride diets respectively. These differences were not significant.

RÉSUMÉ

DEVENIR DU BICARBONATE DE SODIUM INGÉRÉ CHEZ LA POULE

L'addition de 0,5 p. 100 de bicarbonate de sodium dans le régime de poules pondeuses n'a aucune influence sur le pH du proventricule, du gésier et de l'intestin. L'addition de 5,25 p. 100 de carbonate de calcium dans le régime de base augmente d'une manière significative le pH du proventricule, du gésier et du gros intestin ; il n'y a pas d'interaction entre le bicarbonate de sodium et le carbonate de calcium sur le pH du tube digestif.

Lorsque du bicarbonate de sodium radioactif (^{14}C) est introduit dans le jabot, on constate que la radioactivité maximale sous forme de CO_2 expiré est atteinte après une heure et demie. En cas de ligature du tube digestif une heure après l'administration du radioisotope, on constate que 0,70 p. 100 seulement de la dose est présente dans le tube digestif alors que 84 p. 100 de la radioactivité se retrouve dans le jabot. Lors de l'administration du radioisotope 4 à 6 heures avant l'oviposition, la radioactivité trouvée dans la coquille représente 3,4 et 2,7 p. 100 de la dose originale pour des régimes dont la teneur en chlore est respectivement faible ou normale ; la différence entre ces valeurs n'est pas significative.

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