EFFECT OF DIETARY SODIUM BICARBONATE ON INTESTINAL HISTOMORPHOMETRY IN BROILER CHICKENS UNDER HUMID TROPICAL CONDITIONS

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ABSTRACT

Heat stress causes morphological alterations and mucosal damage in the intestines of chickens. Sodium bicarbonate (SBC) has been noted to improve intestinal growth. Effect of dietary SBC on intestinal histomorphometry was determined in broiler chickens. A total of two hundred (200) day-old commercial broiler chicks (Ross 308) was divided into 5 five treatment groups comprising 4 replicates and 10 birds per replicate in an experiment that last for 6 weeks. The birds were kept on deep-litter floor in an open-sided poultry house and fed *ad libitum* with either of the 5 diets containing 0, 2, 4, 6 and 8 g SBC per kg feed. The harvested small intestines on day 42 were segmented into duodenum, jejunum and ileum for histomorphometry analysis. In the duodenum, sodium bicarbonate significantly improved villus height, villus width, muscularis thickness, and the villus height to crypt depth (VH:CD) ratio ($P < 0.05$). However, crypt depth was not significantly affected ($P > 0.05$). In the ileum, villus height, muscularis thickness, and VH:CD ratio were significantly influenced by sodium bicarbonate inclusion ($P < 0.005$), villus width and crypt depth did not show statistically significant differences ($P > 0.05$). The jejunum also responded significantly to sodium bicarbonate supplementation. Villus height, villus width, and crypt depth were significantly affected ($P < 0.005$). However, there were no significant differences in muscularis thickness and VH:CD ratio ($P > 0.05$). In conclusion, SBC showed a potential in improving the intestinal mucosa development in broiler chickens. Use 4-6 g/kg SBC in feed to enhance intestinal structure and potentially improve nutrient absorption

Keywords: Heat stress, intestinal growth, duodenum, jejunum, ileum

DESCRIPTION OF PROBLEM

Compared to other domestic animals, broiler chicken is more susceptible to changing housing temperature mostly during growing-finishing phase (2). Heat stress causes morphological alterations and mucosal damage in the intestines of chickens which reduces blood flow, nutrient and oxygen availability, feed digestibility and assimilation (7). (3) reported that an increase in permeability and localized inflammation along the small intestine, that include the duodenum, jejunum and ileum, are significant consequences of heat stress on the intestinal barrier. Heat-exposed birds may exhibit reduced levels of bicarbonate (5), which affect the blood pH and induce in the birds a nutritional requirement for bicarbonate. Sodium bicarbonate serves as a source of sodium and bicarbonate ions, which plays an important role in maintaining acid-base balance and electrolyte equilibrium in poultry (10). This additive may be added to diet of poultry birds to improve the physiological responses, growth performance, and gut health in broiler chickens. Its inclusion in the diets of poultry birds has been associated with improved nutrient digestibility, increased productivity level, improve disease resistance and better immune responses, particularly under heat stress conditions (9; 1). Therefore, the present study aimed at determining of the effect of SBC in diet on intestinal histomorphometry in broiler chickens.

MATERIALS AND METHODS

The experiment was carried out at the poultry unit of the Directorate of University Farms (DUFARMS), Federal University of Agriculture Abeokuta. The farm is located on latitude 7° 10'N, longitude 3° 2'E and altitude 76 m above the sea level. It lies within south-western part of Nigeria with a prevailing humid tropical climate.

Test Ingredient: Feed grade sodium bicarbonate, a white crystalline powder produced by Tianjin Kermel Chemical Reagent Company Ltd. China with a purity of 99.5% was purchased from a reputable laboratory in Ibadan, Oyo state.

Experimental animals and management: A total of two hundred (200) day-old commercial (Ross 308) broiler chicks were purchased from a reputable hatchery in Ibadan and used for the study. The brooder house as well as other equipment was thoroughly disinfected before the arrival of the chicks. The birds were kept in a deep-litter floor in an open-sided poultry house. The birds were floor brooded for two weeks on a wood shaving. Birds were distributed into five treatments (0g, 2g, 4g, 6g and 8g SBC) and four replicates (10 birds per replicate). Coal pots was used as the source of heat during the brooding period. In order to boost their immunity against viral infection, chicks were vaccinated against Newcastle disease and infectious bursal disease. The chicks were fed *ad libitum* with commercial starter mash for the first 3 weeks and thereafter with finisher mash for the next 3 weeks.

Data collection: The small intestine of 20 birds were harvested. The weight and length of each segment were measured using a scale and tape respectively. The intestines were divided into three segments: duodenum (from the gizzard outlet to the end of the pancreatic loop), jejunum (from the pancreatic loop to Meckel's diverticulum), and ileum (from Meckel's diverticulum to the ileocecal junction). These tissue samples were preserved in formalin to maintain their structure, then processed through a series of steps including dehydration, clearing, and embedding in paraffin wax. Thin sections were cut from the wax blocks, placed on slides, and stained (usually with Hematoxylin and Eosin) to highlight key features. The slides were examined under a microscope, and detailed images were taken. Measurements such as villus height, villus width, crypt depth, and muscle thickness were recorded. The ratio of villus height to crypt depth (VH:CD) was calculated to assess gut health.

RESULTS AND DISCUSSION

Table 1 shows the impact of dietary sodium bicarbonate supplementation on the intestinal histomorphometry of broiler chickens. In the duodenum, sodium bicarbonate significantly ($P < 0.05$) improved villus height, villus width, muscularis thickness, and the villus height to crypt depth (VH:CD) ratio. However, crypt depth was not significantly affected ($P > 0.05$). In the ileum, villus height, muscularis thickness, and VH:CD ratio were significantly influenced by sodium bicarbonate inclusion ($P < 0.005$), villus width and crypt depth did not show statistically significant differences ($P > 0.05$). The jejunum also responded significantly to sodium bicarbonate supplementation. Villus height, villus width, and crypt depth were significantly affected ($P < 0.005$). However, there were no significant ($P > 0.05$) differences in muscularis thickness and VH:CD ratio.

Intestinal morphology is the main indicator of gut health, with villus height (VH) and crypt depth (CD) commonly used to assess the functional status of the small intestine. In this study, dietary supplementation with SBC positively influenced several key morphological parameters, particularly in the duodenum. Villus height was significantly increased in SBC treated birds, especially at 4 g/kg, suggesting a better developed mucosal surface and enhanced nutrient absorption. Villus width followed a similar pattern, with wider villi observed across all SBC groups. Muscularis thickness also improved, with the greatest increase seen at 6 g/kg, indicating strengthened intestinal motility. Although crypt depth did not vary significantly, the VH:CD ratio improved, with the highest values recorded in the 6 g/kg group. A higher VH:CD ratio is associated with increased epithelial maturity and absorptive efficiency. These findings are consistent with previous studies of (8), which reported improvements in villus height and muscularis thickness linked to better electrolyte balance. The improvements observed may be attributed to the buffering action of sodium bicarbonate, which helps maintain a stable and alkaline intestinal environment. This favourable pH supports epithelial integrity and may promote enterocyte survival and proliferation, as suggested by (12). In the ileum, villus height and muscularis thickness increased, particularly at 6 and 8 g/kg, indicating potential benefits for epithelial turnover and nutrient absorption. However, villus width and CD in this region did not change significantly, suggesting that SBC's effects on epithelial regeneration and lateral expansion are more pronounced in the duodenum. SBC supplementation resulted in modest increases in villus height and crypt depth, with no significant changes in muscularis thickness or VH:CD in jejunum. These findings are in line with earlier work by (4) who linked improved jejunal morphology to better nutrient transport and intestinal immunity. Increased VH:CD ratios, particularly at 4–6 g/kg, indicate balanced epithelial turnover and enhanced gut development. SBC may therefore play a role in protecting gut morphology under stress by buffering intestinal pH and supporting mucosal regeneration. This is especially relevant for broilers raised in challenging environments. Similar morphological improvements have been reported in birds fed lower protein diets, with increased villus height contributing to better digestion and absorption (11). Additionally, wider villi may improve contact between digesta and absorptive cells, while a thicker muscularis layer enhances gut motility and digesta transit (13). In addition, a deeper crypt may indicate faster tissue turnover to permit renewal of the villus, which suggests that the host's intestinal response mechanism is trying to compensate for normal sloughing or atrophy of villi due to inflammation from pathogens and their toxins (6).

	Sodium bicarbonate (g/kg)						
Parameter	**0**	**2**	**4**	**6**	**8**	**SEM**	**P value**
Duodenum							
Villus height (µm)	57.3^{b}	84.3^{a}	85.2^{a}	84.6^{a}	82.4^{a}	4.23	0.000
Villus width (µm)	8.32^{c}	14.2^{b}	17.4^{b}	15.1^{b}	23.4^{a}	1.45	0.000
Crypt depth (µm)	27.8	29.1	29.6	26.1	32.4	3.21	0.719
Muscularis thickness (µm)	9.58^{c}	18.6^{b}	18.5^{b}	26.8^{a}	18.3^{b}	1.59	0.000
VH:CD	2.24^{b}	2.94^{ab}	3.68^{ab}	4.32^{a}	2.86^{ab}	0.45	0.019
Ileum							
Villus height (µm)	62.9^{b}	58.9^{b}	90.9^{a}	75.4^{ab}	74.6^{ab}	4.91	0.000
Villus width (µm)	14.3	12.9	20.1	17.0	15.8	2.09	0.238
Crypt depth (µm)	26.0	31.6	25.0	29.7	35.8	4.15	0.364
Muscularis thickness (µm)	13.0^{b}	16.5^{b}	18.1^{b}	27.3^{a}	30.6^{a}	2.13	0.000
VH:CD	4.05^{a}	2.16^{b}	4.08^{a}	3.63^{ab}	2.47^{b}	0.55	0.039
Jejunum							
Villus height (µm)	70.4^{b}	72.3^{b}	89.2^{a}	84.6^{ab}	71.3^{b}	5.16	0.032
Villus width (µm)	12.7^{b}	16.9^{ab}	18.0^{ab}	20.6^{a}	22.3^{a}	2.15	0.030
Crypt depth (µm)	27.4^{b}	19.6^{c}	25.6^{bc}	37.3^{a}	22.2^{bc}	2.57	0.000
Muscularis thickness (µm)	13.1	17.6	16.0	17.2	19.7	2.95	0.247
VH:CD	3.09	3.70	3.87	2.45	4.08	0.482	0.124

^{abc} Means within same row and bearing different superscripts differ significantly ($p<0.05$)

CONCLUSION AND APPLICATION

i. Sodium bicarbonate supplementation generally enhances intestinal morphology, particularly villus height and width in the duodenum and jejunum, and muscularis thickness in the duodenum and ileum.
ii. The optimal supplementation level varies by intestinal segment and parameter, 4–6 g/kg shows the most pronounced effects in this study.
iii. These findings indicate that sodium bicarbonate supplementation can be a

useful dietary intervention to enhance intestinal morphology, but the dosage should be tailored to target specific intestinal segments and parameters.

iv. Use 4-6 g/kg SBC in feed to enhance intestinal structure and potentially improve nutrient absorption

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