

- [54] **COMPOSITION AND METHOD FOR TREATING HEAT STRESS**
- [75] Inventor: **Robert G. Teeter**, Stillwater, Okla.
- [73] Assignee: **Board of Regents for Oklahoma State University**, Stillwater, Okla.
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*Primary Examiner*—Sam Rosen  
*Attorney, Agent, or Firm*—Head, Johnson & Stevenson

[57] **ABSTRACT**

A method of reducing respiratory alkalosis (high blood pH) and enhanced productivity (rate of weight gain) in poultry during periods of chronic or acute heat stress (high heat and humidity) involving the steps of supplementing the birds' diet (feedstuffs and/or water) with acids (hydrogen ion donor) and bicarbonate donors (NaHCO<sub>3</sub>). The addition of an acid donor as a poultry fee or water additive significantly reduces the alkalosis induced mortality rate and enhances the rate of weight gain (up to 30 percent). By including NaHCO<sub>3</sub> in the ration, the rate of gain is further enhanced (an additional 9 percent). The further intentional addition of a sodium free, chloride ion donor also promotes increased rate of gain. The use of a H<sub>2</sub> antagonist (cimetidine) to reduce stomach acid production is also beneficial.

**18 Claims, No Drawings**

## COMPOSITION AND METHOD FOR TREATING HEAT STRESS

### BACKGROUND OF THE INVENTION

#### 1. Field of the Invention

This invention relates to improved feedstuffs and/or water for poultry and methods for their use. More specifically, this invention relates to a poultry feed or water additive and dietary changes which alleviate respiratory alkalosis and associated increased mortality, decreased egg shell thickness and decreased growth rate that occur during periods of severe heat stress.

#### 2. Description of the Prior Art

It is generally known that poultry such as chickens, geese, turkeys, quail, pheasants and the like are particularly susceptible to poor productivity (reduced growth rate, feed efficiency, egg shell quality and high mortality) during periods of environmental heat stress (high temperatures and high relative humidity). Controversy exists in contemporary scientific literature regarding the occurrence of alkalosis in heat stressed birds and consequently, no therapeutic treatment for alkalosis founded or based on direct scientific evidence is available and to the best knowledge of the inventor, no direct knowledge of a poultry bicarbonate ion requirement during heat stress existed prior to the present invention.

It is known that heat stress substantially reduces the growth rate of broiler chicks. Diets have been altered to reduce this problem via reducing the heat increment of the diet with fat supplementation (H. L. Fuller et al; "Effect of Heat Increment of the Diet on Feed Intake and Growth of Chicks Under Heat Stress", Proc. Maryland Nutr. Conf., pp 58-64, 1973) and improved the amino acid balance (P. W. Waldroup et al; "Performance of Chicks Fed Diets Formulated to Minimize Excess Levels of Essential Amino Acids", Poultry Sci., 55:243-253, 1976). It has also been suggested that the decline in growth rate results directly from reduced feed intake (R. L. Squibb et al; "Growth and Blood Constituents of Immature New Hampshire Fowl Exposed to Constant Temperatures of 99° for 7 Days", Poultry Sci., 38:220-221, 1959). It has been demonstrated that the growth rate of heat stressed broilers can be increased by force feeding at a level exceeding ad libitum feed intake (M. O. Smith et al; "Feed Intake and Environmental Temperature Effects Upon Growth, Carcass Traits, Ration Digestibility, Digestive, Passage Rate and Plasma Parameters in Ad Libitum and Force-Fed Broiler Chicks" Poultry Sci., 62: 1504 abstr., 1983). It is also generally known that blood alkalosis precipitated through altering the Na/Cl ratio (S. Hurwitz et al; "Sodium and Chloride Requirements of Chick; Relationship to Acid-Base Balance", Poultry Sci., 52:903-909, 1973) reduces both the feed consumption and growth rate of chicks; however, the studies were not thermal stress, per se.

At high ambient temperatures, evaporative cooling through panting is an important means of heat loss for fowl (G. M. Jukes, "Transport of Blood Gases", In: Physiology and Biochemistry of the Domestic Fowl, Vol. 1 Bell and Freeman, eds., Academic Press, N.Y., 1971). Hyperthermic panting has precipitated respiratory alkalosis (S. A. Richards; "Physiology of Thermal Panting in Birds", Ann. Biol. Anim. Biophys., 10:151-168, 1970). However, respiratory alkalosis has not been consistently observed in fowl exposed to thermal stress. Parker et al ("Thermal Stress Effects on

Certain Blood Characteristics of Adult Male Turkeys", Poultry Sci. 50:1287-1295, 1971) observed that the pH in the male turkey decreased when exposed to thermal stress, while Kohne et al ("Changes in Plasma Electrolytes, Acid-Base Balance and Other Physiological Parameters of Adult Female Turkeys Under Conditions of Acute Hyperthermia", Poultry Sci., 54:2034-2038, 1975) reported that acute hyperthermia produced profound alkalosis, but chronic hyperthermia ("Acid-Base Balance, Plasma Electrolytes and Production Performance of Adult Turkey Hens Under Conditions of Increasing Ambient Temperature", Poultry Sci., 54:2038-2045, 1975) has no effect. Darre et al ("Time Course of Change in Respiratory Rate, Blood pH and Blood pCO<sub>2</sub> of SCWL Hens During Heat Stress", Poultry Sci., 59:1598 abstr., 1980) observed that pH increased in a curvilinear fashion as leghorn hens were exposed to increasing ambient temperature changes. Siegel et al ("Blood Parameters of Broilers Grown in Plastic Coops and on Litter at Two Temperatures", Poultry Sci., 53:1016-1024, 1974) found no difference in blood pH for broilers reared under continuous 35° C. versus thermoneutral conditions. This result agreed with Vo et al ("The Effect of High Temperatures on Broiler Growth", Poultry Sci., 54:1347-1348 abstr. 1975), but contradicted the work of Bottje et al ("Effect of an Acute Heat Stress on Blood Flow in the Coeliac Artery of Hubbard Cockerels", Poultry Sci., 62:1386-1387 abstr., 1983) wherein it was reported that blood pH was elevated. And, Parker et al ("Effect of Thermal Stress on Adult Male Turkeys", Poultry Sci., 49:1425 abstr, 1970) reported that heat stress had no effect on blood pH other than the fact that pH was more variable among heat stressed birds than thermoneutral controls. Although the reasons for these discrepancies are not clear, they may include the degree of thermal stress, type of stress (acute versus chronic), blood collection site or the like and in view of the teachings of the present invention may involve the sampling time relative to the respiratory state of the birds. According to the present invention, it is observed that the birds exposed to chronic thermal stress exhibit a respiratory cycle of panting and non-panting phases which result in an oscillation between normal and alkalotic blood conditions.

### SUMMARY OF THE INVENTION

In view of the prior art, I have discovered that poultry exposed to heat stress suffer from specific chemical imbalances which are most readily detectable in panting birds and which when corrected, increased poultry production. I have established that heat stressed poultry suffer from periodic or cyclic occurrences or bouts of blood alkalosis and bicarbonate ion deficiency. In view of these discoveries, I have developed a poultry feed and/or feedstuff additive/supplement as well as methods of use for alleviating heat stress induced chemical imbalances in poultry.

Thus, the present invention provides a method of treating heat stress in poultry comprising the step of supplementing the diet of the poultry with from about 0.3 weight percent to about 3 weight percent of hydrogen ion donor. The present invention further provides a method of treating heat stress in poultry comprising the step of supplementing the diet of the poultry with about 0.5 weight percent of a bicarbonate ion donor. Further, according to the present invention, the diet of heat

stressed poultry is supplemented with about 0.5 weight percent to about 1 weight percent of a sodium free, chloride ion donor. The present invention further provides for combining the aforementioned methods of supplementing the diet of poultry experiencing heat stress and in particular, supplementing the diet of the poultry with from about 0.3 weight percent to about 3 weight percent of hydrogen ion donor and about 0.5 weight percent of a bicarbonate ion donor. In specific embodiments of the present invention, the hydrogen ion donor is  $\text{NH}_4\text{Cl}$  or  $\text{HCl}$ , the bicarbonate ion donor is  $\text{NaHCO}_3$  and the sodium free, chloride ion donor is  $\text{CaCl}_2$ .

It is an object of the present invention to provide a poultry raiser with a means of improving the productivity of birds raised during periods of heat and/or high relative humidity stress. It is a further object to provide a method and feed additive that will during period of heat stress significantly alleviate the problems of reduced growth rate, decreased feed efficiency, reduced egg shell thickness and increased mortality rate. It is an object of the present invention to provide a method and feed additive that will prevent heat stress induced respiratory alkalosis in poultry. Fulfillment of these objects and the presence and fulfillment of other objects will be apparent upon complete reading of the specification and claims contained herein.

#### DESCRIPTION OF THE PREFERRED EMBODIMENTS

According to the present invention, the previously observed reduced growth rate, feed efficiency, egg shell thickness and increased mortality rate for poultry and other birds during periods of heat stress caused by high temperatures or high temperatures and high humidity are related to chemical imbalances induced by or resulting from the heat stress. Specifically, according to the present invention, the occurrence of respiratory alkalosis is cyclic or oscillatory in that the increase in blood pH is in phase with the respiratory cycle of panting and non-panting phases of the heat stressed bird. In other words, the high blood pH, alkalosis, occurring during the panting stage of the heat stressed fowl returns to a more normal value for pH range upon cessation of panting. Thus, the blood pH in panting birds (e.g.,  $\text{pH}=7.395$  at  $32^\circ\text{C}$ .) drops back to a lower value (e.g.,  $\text{pH}=7.28$  at  $32^\circ\text{C}$ .) reminiscent of a non-panting normal value of a non-heat stressed bird (e.g.,  $\text{pH}=7.28$  at  $24^\circ\text{C}$ .) Acute thermal stress, obtained by quickly elevating ambient temperatures (e.g., from  $32^\circ$  to  $41^\circ\text{C}$ .) over a twenty minute period) creates an even further increase in blood pH (e.g.,  $\text{pH}=7.521$ ).

Further, according to the present invention, the heat stressed birds suffer from a bicarbonate ion deficiency which is also related to the reduced rate of weight gain even though the bicarbonate ion on an acid/base analysis would further promote alkalosis (i.e., unfavorable  $\text{pK}_a$ ). Thus, according to the present invention, including 0.5%  $\text{NaHCO}_3$  in the diet of birds subjected to chronic heat stress, enhances body weight gain even though it tends to increase blood pH in non-panting birds. Further, adding 0.13 up to 1%  $\text{NH}_4\text{Cl}$  to diets decreases blood pH and increases body weight gain. The effects appear to be linear with respect to  $\text{NH}_4\text{Cl}$  doses up to 1%  $\text{NH}_4\text{Cl}$ , but drop off as the dose approaches 3%  $\text{NH}_4\text{Cl}$  and actually precipitate blood acidosis at these higher dosages. Supplementing a 1%  $\text{NH}_4\text{Cl}$  diet with 0.5%  $\text{NaHCO}_3$  results in a synergistic

weight gain. Manipulating the sodium to chloride ratio by adding a sodium free chloride salt (e.g.,  $\text{CaCl}_2$ ) further increases body weight gain and slightly reduces the severity of alkalosis. Thus, according to the present invention, the blood alkalosis that limits growth rate of broiler chicks or the like reared under chronic thermal stress and the respiratory alkalosis and weight gain depression attributed to thermal stress can be partially alleviated by diet.

In order to explore and evaluate the concepts and features of the present invention, a series of experiments was performed using live chickens. Unless otherwise indicated, each experiment involved Arbor Acre x Lan-cet chicks which were fed a corn/soybean meal starter diet during the first four weeks post-hatching. On the first day of the fourth week, following an overnight fast, the chicks were weighed and randomly allotted to experimental groups (20 birds per treatment). The birds were individually housed for three weeks in  $30.5 \times 38.1$  cm wire cages within thermostatically and humidistatically controlled chambers under continuous tungsten filament lighting. Week one was utilized to adapt all birds to test rations as follows:

#### BASAL RATION COMPOSITION FOR EXPERIMENTS

Ingredient	Name	%
Ground Corn Grain	4-02-931	48.0
Soybean meal (44%)	5-04-604	35.0
Corn oil	4-07-822	6.0
Meat + bone meal	5-00-388	5.0
Dicalcium Phosphate	6-01-080	1.0
Calcium Carbonate	6-01-069	.9
Vitamin Mix	—	.5
NaCl	6-14-013	.3
DL-Methionine	—	.2
Trace Mineral	—	.1
Ground Polyethylene	—	3.1

<sup>1</sup>Atlas of Nutritional Data on United States and Canadian Feeds

and to increased chamber temperature ( $5^\circ\text{C}/\text{day}$ ) to  $32^\circ\text{C}$ . (80% relative humidity) for heat stress birds while control birds were maintained under thermoneutral condition of  $24^\circ\text{C}$ . (65% relative humidity). Feed and water were continuously available. Body weight gains and feed consumption were tallied weekly. All dietary additions were made at the expense of polyethylene. Where blood data are reported, blood was obtained via jugular venipuncture and pH was immediately analyzed utilizing a Corning blood pH/gas analyzer. Data were subjected to analysis of variance using the General Linear Model of the statistical analysis system (A. J. Barr et al; "A User's Guide to SAS", Statistical Analysis System Institute, Inc., Carry, N.C., 1976). The following Examples represent the specific experiments performed and the respective results.

#### EXAMPLE I

The purpose of this experiment was to measure blood pH of broiler chicks raised in thermoneutral and heat stressed environments. Sixty birds were assigned to three groups of twenty birds each of which the first two groups were subjected to the thermostressed environment. The blood pH,  $\text{CO}_2$  and  $\text{HCO}_3^-$  concentrations were determined on the last day of the experiment as follows: Group 1 while panting; Group 2 non-panting and Group 3 at random without regard to respiratory state. Twenty birds of Group 3 were assigned to the thermoneutral environment and bled at random since these birds did not pant. The results, (TABLE I), demonstrate that birds suffer from blood alkalosis only

while panting which explains the confusion in the literature as heat stressed birds do not pant continuously. Additionally, the study demonstrates that heat stressed birds have lower blood concentrations of CO<sub>2</sub> and HCO<sub>3</sub><sup>-</sup> raising the possibility that they may respond to CO<sub>2</sub> and/or HCO<sub>3</sub><sup>-</sup> supplementation.

TABLE I

Parameter	Thermoneutral	Heat Stress	Pooled SEM
Body wt. gain <sup>a</sup> (g)	913 <sup>b</sup>	427 <sup>c</sup>	45
Feed consumption <sup>a</sup> (g)	2173 <sup>b</sup>	1123 <sup>c</sup>	62
<b>Blood pH</b>			
Non-panting	7.280 <sup>b</sup>	7.280 <sup>b</sup>	—
Panting	—	7.395 <sup>b</sup>	.020
Random	—	7.309 <sup>b</sup>	—
<b>Blood CO<sub>2</sub></b>			
Non-panting	18.6 <sup>b</sup>	9.1 <sup>c</sup>	—
Panting	—	5.9 <sup>c</sup>	.81
Random	—	6.7 <sup>c</sup>	—
<b>Blood HCO<sub>3</sub><sup>-</sup></b>			
Non-panting	8.14	3.3 <sup>c</sup>	—
Panting	—	4.8 <sup>c</sup>	.73
Random	—	—	—

<sup>a</sup>Averaged across non-panting, panting and random pH sampling groups  
<sup>b</sup>Values within a major parameter with unlike superscripts differ (P < .05).

EXAMPLE II

The purpose of this experiment was to evaluate the

sis. Results, (TABLE III), demonstrate that equal molar dietary additions of HCl and NH<sub>4</sub>Cl increase growth rate but not to the same degree. The differing response is likely dependent upon the acid's anion content and its pK<sub>a</sub>. The study also illustrates that supplemental hydrogen ions are of value during heat stress but not necessarily during growing periods exposing birds to more ideal temperature.

TABLE III

Treatment	Body Weight Gain (g)		Feed Efficiency	
	Thermo-neutral	Heat Stressed	Thermo-neutral	Heat Stressed
Poultry Ration	978 <sup>a</sup>	423 <sup>a</sup>	.41	.37
Poultry Ration + 1% NH <sub>4</sub> Cl	872 <sup>b</sup>	597 <sup>b</sup>	.38	.38
Poultry Ration	798 <sup>c</sup>	572 <sup>b</sup>	.38	.38

<sup>abc</sup>Values within a heading classification with unlike superscripts differ (P < .05).

EXAMPLE IV

This experiment was conducted to determine the potential of manipulating the sodium/chlorine ratio to reduce blood pH and thereby decrease the deleterious effects of heat stress induced alkalosis. Results, (TABLE IV), demonstrate that reducing the sodium to chlorine ratio tends to lower blood pH and enhance productivity but that the response is not as effective as adding a hydrogen ion donor.

TABLE IV

Treatment	Body Weight Gain (g)		Feed Consumption (g)			Blood pH Hot	
	TN <sup>a</sup>	Heat Stress	TN	Heat Stress	TN	Non-Panting	Panting
Basal Diet	933 <sup>b</sup>	442 <sup>d</sup>	2617 <sup>b</sup>	1949 <sup>c</sup>	7.290 <sup>dc</sup>	7.294 <sup>dc</sup>	7.381 <sup>b</sup>
Basal Diet + 1% NH <sub>4</sub> Cl	—	553 <sup>c</sup>	—	1945	—	7.195 <sup>d</sup>	7.305 <sup>bc</sup>
Basal Diet + .5% CaCl <sub>2</sub>	—	481 <sup>cd</sup>	—	—	—	7.330 <sup>bc</sup>	7.354 <sup>bc</sup>
Basal Diet	—	474 <sup>d</sup>	—	—	—	7.256 <sup>dc</sup>	7.332 <sup>bc</sup>

<sup>a</sup>Thermoneutral  
<sup>bcd</sup>Values within a major heading classification with unlike superscripts differ (P < 0.5).

potential of acids (hydrogen ion donors) as therapeutic agents to correct the periodic heat stress induced alkalosis. Ammonium chloride was utilized as the model hydrogen ion donor. The results, (TABLE II), demonstrate that providing birds with supplemental hydrogen ions reduces the severity of alkalosis and significantly increases (P 0.05) growth rate. Caution must be utilized however, for too much acid can apparently cause blood acidosis and negate the beneficial effect.

TABLE II

Treatment	Body Weight Gain (g)		Feed Consumption (g)			Blood pH Hot	
	TN <sup>a</sup>	Heat Stress	TN <sup>a</sup>	Heat Stress	TN <sup>a</sup>	Non-panting	Panting
Basal diet	933 <sup>b</sup>	442 <sup>d</sup>	2617 <sup>b</sup>	1949 <sup>d</sup>	7.290 <sup>c</sup>	7.294 <sup>c</sup>	7.381 <sup>b</sup>
Basal diet + 3% NH <sub>4</sub> Cl	—	484 <sup>dc</sup>	—	2011 <sup>dc</sup>	—	7.290 <sup>c</sup>	7.357 <sup>bc</sup>
Basal diet + 1% NH <sub>4</sub> Cl	—	553 <sup>c</sup>	—	2173 <sup>c</sup>	—	7.195 <sup>cd</sup>	7.305 <sup>bc</sup>
Basal diet + 3% NH <sub>4</sub> Cl	—	454 <sup>d</sup>	—	1958 <sup>dc</sup>	—	7.090 <sup>d</sup>	7.215 <sup>d</sup>

<sup>a</sup>Thermoneutral  
<sup>bcd</sup>Values within a major heading classification with unlike superscripts differ (P < .05).

EXAMPLE III

This experiment was conducted to compare the potential of two hydrogen ion donors, NH<sub>4</sub>Cl and HCl, to demonstrate that more than one hydrogen ion donor may be utilized to correct the heat stress induced alkalo-

sis blood pH. Drugs have the potential to repartition body hydrogen stores and consequently increase body weight gain and decrease mortality. Surprisingly, including cimetidine in the diet also reduced abdominal fat con-

tent which may also constitute a new application for this drug type.

TABLE V

	Heat Stress Cimetidine Level (ppm)				
	Basal	10	30	100	300
Blood pH	7.46 <sup>a</sup>	7.42 <sup>ab</sup>	7.39 <sup>ab</sup>	7.31 <sup>b</sup>	7.36 <sup>ab</sup>
Gain (g)	407	400	414	420	439
Mortality (%)	64 <sup>a</sup>	42 <sup>bc</sup>	37 <sup>bc</sup>	37 <sup>bc</sup>	4.23 <sup>a</sup>
Proventriculus pH	1.92 <sup>c</sup>	2.41 <sup>bc</sup>	2.28 <sup>9bc</sup>	.305 <sup>ab</sup>	4.23 <sup>a</sup>
Abdominal Fat % body wt.	1.80 <sup>a</sup>	1.2 <sup>b</sup>	1.2 <sup>b</sup>	.98 <sup>b</sup>	.94 <sup>b</sup>

<sup>abc</sup>Means within a row classification with unlike superscripts differ (P < .05).

## EXAMPLE VII

This experiment was conducted to evaluate HCO<sub>3</sub><sup>-</sup> and hydrogen ion donors for synergism in reducing the deleterious effect of heat stress. The birds, housing, environmental conditions and poultry rations were as described in EXAMPLE V with the exception that the experiment was conducted for three weeks. Results, (TABLE VII), demonstrate that the beneficial effects of including a hydrogen ion donor and HCO<sub>3</sub><sup>-</sup> in poultry rations are additive. And, like the previous EXAMPLE, the results indicate that dietary bicarbonate supplementation improves both gain and feed efficiency independent of any favorable effect upon blood pH.

TABLE VII

Treatment	Body Weight Gain (g)				Feed Consumption (g)			Blood pH Hot		
	TN		Heat Stress		TN		Heat Stress		Non-Panting 32° C.	Panting 32° C.
	24° C.	32° C.	24° C.	32° C.	24° C.	32° C.	24° C.	32° C.		
Basal Diet	933 <sup>b</sup>	422 <sup>d</sup>	2617 <sup>b</sup>	1949 <sup>c</sup>	7.290 <sup>d</sup>	7.294 <sup>d</sup>	7.294 <sup>d</sup>	7.38		
Basal Diet + 1% NH <sub>4</sub> Cl	—	553 <sup>dc</sup>	—	2173 <sup>c</sup>	—	7.195 <sup>d</sup>	7.30	7.30		
Basal + 1% NH <sub>4</sub> Cl + .5% NaHCO <sub>3</sub>	—	594 <sup>c</sup>	—	2139 <sup>c</sup>	—	7.276 <sup>d</sup>	7.29	7.29		

<sup>bcd</sup>Values within a major heading classification with unlike superscripts differ (P < .05).

## EXAMPLE VI

Growing broilers were used in this experiment as a model. The chickens were randomly divided into four groups, each containing 25 individually caged chickens. Two groups were raised within environmental chambers maintained under continuous 32° C. and 80% relative humidity while the other two groups were in environmental chambers maintained at 24° C. and 60% relative humidity. The environmental chamber maintained at 32° C. constitutes the environmental heat stress while the chamber maintained at 24° C. the more ideal environmental temperature. Body weight gains, feed efficiency, and blood pH were monitored (TABLE VI).

TABLE VI

Treatment	Body Weight Gain (g)		Gain/Feed		Non-Panting	
	Heat Stress		Heat Stress		Heat Stress	
	24° C.	32° C.	24° C.	32° C.	24° C.	32° C.
1. Standard Poultry Ration	864 <sup>b</sup>	407 <sup>c</sup>	.45	.36	7.28	7.304
2. As 1 + .5% NaHCO <sub>3</sub> Percent Desirable Improvement	866 <sup>b</sup>	444 <sup>c</sup>	.45	.37	7.29	7.367
	+2	+9.1	0	+2.8	-.1	-.9

<sup>b</sup>Values within a major heading classification with unlike superscripts differ (P < .05).

The effects of sodium bicarbonate (0.5%) addition to a poultry ration on thermostressed chick growth are favorably reflected in weight gain and feed efficiency, but blood pH is adversely affected. Dietary addition of 0.5% NaHCO<sub>3</sub> increased (P 0.10) rate of gain by 9% and numerically increased feed efficiency. Blood pH of the panting heat stressed group did not differ (P 0.1) between the 0 and 0.5% NaHCO<sub>3</sub> levels though pH values for non-panting birds tended to increase (P 0.1) with NaHCO<sub>3</sub> addition. Any beneficial effects of NaHCO<sub>3</sub> on weight gain are due to the HCO<sub>3</sub><sup>-</sup> ion, independent of pH as alkalosis would not be favorably impacted by dietary HCO<sub>3</sub><sup>-</sup> (pK<sub>a</sub>)=10.25. This positive gain response with NaHCO<sub>3</sub> confirms that which has been generally observed in the other experiments.

## EXAMPLE VIII

This experiment was conducted to evaluate the potential of hydrogen ion donors and HCO<sub>3</sub><sup>-</sup> ions to reduce the mortality of poultry subject to acute (39° C., 74% relative humidity) heat stress. Treatments were replicated 6 times with 6 birds per replicate. Results, (TABLE VIII), demonstrate that acid supplementation dramatically reduces bird mortality while the bicarbonate ion increased mortality. Mortality was inversely correlated (R=0.98) with blood pH suggesting that blood pH may be directly associated with bird mortality.

TABLE VIII

	Thermoneutral		Heat Stressed	
	Mortality (%)	Blood pH	Mortality (%)	Blood pH
Poultry Ration	.0	7.29 <sup>a</sup>	37.3 <sup>a</sup>	7.443 <sup>a</sup>
Poultry Ration + .75% NaHCO <sub>3</sub>	.0	7.30 <sup>a</sup>	44.5 <sup>a</sup>	7.517 <sup>a</sup>
Poultry Ration + 1% NH <sub>4</sub> Cl	.0	7.18 <sup>b</sup>	3.4 <sup>b</sup>	6.241 <sup>b</sup>

<sup>abc</sup>Means within a heading classification differ (P < .05).

## EXAMPLE IX

Ten laying hens were fed a meal containing alkali to stimulate the blood alkalosis of heat stressed birds. Birds receiving the diet laced with 8% borax suffered from alkalosis and had reduced egg shell thickness similar to layers exposed to environmental heat stress. In view of

this, hydrogen ion donors may be of value to improve egg shell quality of layers exposed to environmental heat stress.

The hydrogen ion donor according to the present invention can generally be any acid or salt that hydrolyzes to provide an increase in the hydrogen ion concentration (i.e., the salts of a weak base and strong acid) as well known in the art provided no deleterious or toxic side effects are present. Thus, the hydrogen donor according to the present invention would include by way of example, but is not limited thereto; common consumable acids such as hydrochloric acid, citric acid, acetic acid, propionic acid, phosphoric acid and the like and consumable ammonium salts such as ammonium chloride, ammonium nitrate or other salts formed from weak bases and strong acids and the like. The sodium free bicarbonate ion donor according to the present invention can generally be any bicarbonate source that has a preponderance of cations other than sodium. The source does not have to be pure calcium bicarbonate or the like, but preferably is to be predominantly sodium free. Thus, again by example, but not limited thereto, the sodium free bicarbonate ion donor would include calcium bicarbonate, potassium bicarbonate, magnesium bicarbonate and mixtures thereof.

In view of the novelty associated with the discovery and verification of specific chemical imbalances occurring during respiratory panting of poultry and subsequent novelty associated with the discovery that the deleterious effects of these chemical imbalances can be alleviated by dietary changes, the present invention in the broadest sense encompasses any food or water additive that can temporarily induce the desired change in the blood pH of the fowl. Thus, any additive or supplement, drug or the like that repartitions poultry metabolism inducing the desired increase in blood acidity is contemplated as being equivalent for purposes of treating heat stress in birds. Thus, the concept of introducing a hydrogen blocker or hydrogen antagonist such as the exemplified cimetidine is felt to be equivalent for purposes of this invention. Also, it is felt that agents or additives that result in ketosis (although generally considered as being undesirable) for purposes of treating or alleviating the effects of heat stress according to the present invention is desirable and useful. Thus, the concept of intentionally subjecting the birds to massive quantities of protein (protein toxicity) or the use of other known ketosis inducing substances such as acetoacetic acid or  $\beta$  hydroxybutyric acid to temporarily reduce blood pH is also felt to be within the scope of the present invention. In other words, the novelty associated with the present invention further involves recognition that the chemical imbalances produce such drastic changes in the rate of growth, shell thickness and mortality rate that the use of feed or water supplements and the use of metabolic interfering processes that would in thermoneutral conditions be considered deleterious are in these circumstances appropriate.

The actual method of administering the additive to the poultry can be essentially by any method or technique well known in the art, including incorporating the additive into the feedstuff or water or both. Preferably, the overall dosage rates as previously expressed in terms of a weight percentage range represent the total of the supplement (whether supplied by feedstuff or water) as a function of the weight of the feedstuff consumed by the bird. It should also be appreciated that the previously identified hydrogen donor ion range is speci-

fied in terms of the exemplified ammonium chloride and although considered characteristic of most additives, the upper and lower limits can vary somewhat when the specific molecular weight of the additive is taken into consideration. Thus, the preferred 1 weight percent ammonium chloride is equivalent to about 0.68 weight percent hydrochloric acid and for other higher molecular weights the optimum value as well as the upper and lower limits can be further adjusted. It should also be appreciated that the preferred concentration or dosage rate will vary according to the severity of the heat stress. Thus, water administration represents a particularly attractive method of introducing the desired additive or supplement into the diet of the bird in that the desired amount can be varied from moment to moment. In this manner, the additive concentration can be changed as the temperature varies from day to day or even from daylight to nighttime and the like. In the water administration technique, the previous weight ratio of the hydrogen ion donor ( $\text{NH}_4\text{Cl}$ ) can be expressed as a weight percent hydrogen ion introduced per unit mass of feedstuff consumed (i.e., about 0.056 to about 0.56 weight percent). In such water management applications, the environment can be continuously monitored and appropriate rate of acid can be added to the water according to the feed rate of the poultry involved. Such a system, in principle, can be totally automated.

The advantages of using the dietary additives and processes of the present invention are numerous. In addition to the ease of application, control and monitoring of results, implementing the present invention results in improved rate of growth during periods of heat stress wherein the rate of growth is severely inhibited. The present invention further results in improvements in the mortality rate during periods of chronic and acute heat stress as well as improving egg shell thickness during similar heat stress periods. Consequently, the present invention provides significantly increased feed efficiency and overall improved economics for the poultry industry.

Having thus described the invention with a certain degree of particularity, it is to be understood that the invention is not limited to the embodiments set forth herein for purposes of exemplification, but is to be limited only by the scope of the attached claims, including a full range of equivalents to which each element thereof is entitled.

I claim:

1. A method of treating heat stress in poultry comprising the step of supplementing the diet of said poultry with from about 0.3 weight percent to about 3 weight percent of a hydrogen ion donor.
2. A method of claim 1 wherein said hydrogen ion donor is  $\text{NH}_4\text{Cl}$ .
3. A method of claim 1 wherein said hydrogen ion donor is  $\text{HCl}$ .
4. A method of claim 2 wherein said  $\text{NH}_4\text{Cl}$  is from about 0.3 weight percent to about 1 weight percent.
5. A method of claim 3 wherein said  $\text{HCl}$  is about 0.68 weight percent.
6. A method of treating heat stress in poultry comprising the step of supplementing the diet of said poultry with from about 0.3 weight percent to about 3 weight percent of a hydrogen ion donor and about 0.5 weight percent of a bicarbonate ion donor.

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7. A method of claim 6 wherein said hydrogen ion donor is NH<sub>4</sub>Cl and said bicarbonate ion donor is NaHCO<sub>3</sub>.

8. A method of claim 6 further comprising the step of supplementing the diet of said poultry with from about 0.5 weight percent to about 1 weight percent of a sodium free, chloride ion donor.

9. A poultry feedstuff comprising for every 100 parts by weight of feedstuff from about 0.3 weight percent to about 3 weight percent of a hydrogen ion donor and about 0.5 weight percent of a bicarbonate ion donor.

10. A poultry feedstuff of claim 9 wherein said hydrogen ion donor is NH<sub>4</sub>Cl and said bicarbonate ion donor is NaHCO<sub>3</sub>.

11. A poultry feedstuff of claim 9 further comprising for every 100 parts by weight of feedstuff from about 0.5 weight percent to 1 weight percent of sodium free, chloride ion donor.

12. In a poultry feed composition consisting essentially of ground grains and grain oils the specific improvement comprising: from about 0.3 weight percent

to 3 weight percent of a hydrogen ion donor and about 0.5 weight percent of a bicarbonate ion donor.

13. An improved poultry feed of claim 12 wherein said hydrogen ion donor is NH<sub>4</sub>Cl and said bicarbonate ion donor is NaHCO<sub>3</sub>.

14. An improved poultry feed of claim 12 further comprising from about 0.5 weight percent to about 1 weight percent of a sodium free, chloride ion donor.

15. A method of treating heat stress in poultry comprising the step of supplementing the diet of said poultry with from about 0.056 weight percent to about 0.56 weight percent of hydrogen ion.

16. A method of claim 15 wherein said hydrogen ion is added to the drinking water of said poultry.

17. A method of treating heat stress in poultry comprising the step of supplementing the diet of said poultry with from about  $2.83 \times 10^{-6}$  moles H<sup>+</sup>/g body wt/day to about  $7.92 \times 10^{-5}$  moles H<sup>+</sup>/g body wt/day.

18. A method of claim 17 wherein said moles H<sup>+</sup> are added to the drinking water of said poultry.

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