Review

Cation anion Bbalance in avian diet: (a Review)

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ABSTRACT

All classes of avian have definite requirements for sodium (Na), potassium (K) and chloride (Cl) in the correct amounts for homeostasis. While the concern for electrolyte concentration within the diet is extremely important, of equal importance is the dietary electrolyte balance. It is notably significant that the balance of these three elements be within their acceptable ranges and that none be excessive or deficient within the diet. Acceptable levels for these cations and anions are required in milliequivalents for poultry. Sodium functions in the maintenance of osmotic pressure of body fluid, for protection against excessive body fluids, sustentation of normal muscle irritability, absorption of amino acid and sugars in the small intestine; therefore utilization of digested protein and carbohydrates is diminished with an insufficiency of this cation. Deficiency of Sodium will cause growth reduction, increased feed conversion, gonadal dormancy, bone softening, corneal keratinization, decreased cellular volume and changes in cellular function.

Key words: Cation anion balance, avian diet, Electrolytes, Monovalent minerals.

INTRODUCTION

Dietary sodium, potassium, and chloride are monovalent minerals (Na⁺, K⁺, Cl⁻) sometimes referred to “strong ions” due to their greater effect on acid-base balance of body fluids than divalent ions such as calcium, magnesium, phosphate or sulfate Mongin, (1980). Borges and Maiork, 2002 carried out two experiments using 712 day old chicks to evaluate the electrolyte balance (Na⁺ + K⁺ + Cl⁻) in pre starter broilers diets. In both experiments electrolyte balance was 40, 140, 240 and 340 mEq/kg. Electrolyte balance caused a quadric effect on growth rate, weight gain and feed: gain ratio. There was a linear increase in feed intake when the electrolyte balance was increased by a single supplementation of Na, indicating that this ion stimulates feed intake. The effect of mineral elements, calcium and available phosphorus and the electrolytes sodium, potassium and chloride in the diets on growth and physiology of male broilers chicken were investigated by (Karunajeewa et al, 1986). It was reported by this investigation that minerals cannot be used efficiently without a proper electrolyte balance. Sodium Na⁺ and chloride Cl⁻ nutritional requirements, dietary electrolyte balance and their effect on acid base balance for young broilers was evaluated in two trials conducted by (Randon et al, 2001). It was reported that Na and Cl requirements for optimum performance of young broiler chicken were 0.28 and 0.25%, respectively.

IMPORTANCE OF DIETARY CATION ANION BALANCE IN AVIANS DIET

Three elements that are predominant in satisfying the electrolyte balance within the body are sodium (Na⁺), potassium (K⁺) and chloride (Cl⁻). Sodium and Cl are minerals with important physiological functions in avians and may reduce leg abnormalities. The NRC (1984) recommended a minimum requirement of 0.15 % Na⁺ and Cl⁻ for young broilers. Brittion (1991, 1992) concluded
that to obtained the best body weight gain, the NaCl level should be 0.45%. This level has been confirmed by (Zanardo, 1994). These electrolytes are essential in osmotic pressure regulation and acid base balance. Teeter and Belay, 1995 reported that electrolyte balance guarantees a maximum growth rate and optimum bird performance. Barros et al. 1998 determine the requirement of young broilers chickens to estimate the best FCR and maximum BWG and to observe the metabolic influence of acid base balance. Avian have definite requirements for these elements in the correct amounts for homeostasis known as dietary electrolyte balance (Rondon et al. 2001). Two trials were conducted to determine the Na and Cl requirement and dietary electrolytes balance and its effect on acid base balance. Results of this study showed Na and Cl is essential for maximum performance of growing chickens between 21 to 42 days of age and its best for maximum weight gain (Murakami et al., 2001). Problems associated with poultry heat distress are economically significant and widespread. Exposure to high ambient temperature and high humidity causes altered respiration and other physiological aberrations that generally result in reduced growth. One practice that has been quite effective is the addition of electrolytes in the forms of KCl and NaCl to the drinking water (Smith and Teeter, 1992). A study proposed by Smith, 1994 showed that male birds that received NaCl gained more weight 10.5% than those receiving no water additives. Teeter et al. 1985 reported the use of dietary ammonium chloride NH₄Cl as a potential acidifier and the use of sodium bicarbonate NaHCO₃ as a source of HCO₃⁻ in elevating the effect of chronic heat exposure in broiler chicken. Bottje and Harrison (1985) obtained better growth rate and feed conversion by using carbonated water rather than tap water as a source of water for drinking water for broilers. Purdu et al. (1985) reported that dietary ascorbic acid increase the weight gain of heat exposed layers.

INTERACTION OF SODIUM, CHLORIDE AND POTASSIUM AND ITS IMPORTANCE IN AVIAN NUTRITION

Physiological interactions of Na⁺, Cl⁻ and K⁺ have been evaluated in poultry diets by (Hooge, 1998). The ratios of Na⁺, Cl⁻ and K⁺ in the diets are important Mongin, (1980). The DEB is important in the acid base regulation, which determine the blood pH for better enzymatic efficiency and thus influences the bird growth and performance (Buhtcher and Miles, 1994). While the concern for electrolyte concentration within the diet is extremely important, of equal importance is the dietary electrolyte balance. The electrolyte balance is defined as the Na⁺ + K⁺ + Cl⁻ in milliequivalents (mEq)/kg of diet. It is notably significant that the balance of these three elements be within their acceptable ranges and that none be excessive or deficient within the diet (Rondon et al.

2001). In contrast to potassium, sodium is the major cation in extracellular fluid and is closely associated with chloride and bicarbonate in the management of acid-base balance. Sodium functions in the maintenance of osmotic pressure of body fluid and the protection against excessive body fluid loss (Barros et al. 1998). The permeability of cells and the sustentation of normal muscle irritability are additional functions of sodium. Sodium is also obligatory for absorption of amino acid and sugars in the small intestine; therefore utilization of digested protein and carbohydrates is diminished with an insufficiency of this cation (Kiddi and Kerr, 1998). Likewise, both sodium and chloride aid in nutrient passage and waste removal in cell nourishment and maintenance. While sodium is seldom deficient in the diet, a deficiency of this element will cause growth reduction, increased feed conversion, gonadal dormancy, bone softening, corneal keratinization, decreased cellular volume and changes in cellular function. Current nutritional levels of dietary sodium range from 0.18 to 0.25% for poultry (Murakami et al. 1997).

IMPORTANCE OF SODIUM,CHLORIDE AND POTASSIUM INTERACTION IN DIET OF COMMERCIAL LAYING HENS

Commercial hens are constantly subjected to confinement stress and to heat stress during certain environmental periods. Feed consumption may be severely restricted during hot weather, initiating a decrease in egg production and size, which may be related to sodium. Dietary potassium insufficiency will result in reduced production, egg weight, shell thickness and albumin content. An extreme severe deficiency will result in weakness, inability to stand and death. Cage layer fatigue is associated with electrolyte balance (Teeter and Belay, 1995). Calcium bicarbonate or sesquicarbonate is used in broiler and layer breeder feeds at about 0.1 to 0.3% (2 to 6 lb/ton) for egg shell quality, litter quality, and consistency of egg production especially around peak (Keshavarz, 1991). Sodium assays come out much closer to target when two supplemental sodium sources are used (that is, salt and sodium bicarbonate or sesquicarbonate). The dietary electrolyte balance for caged layers has been estimated at 180 mEq/kg (Na⁺+K⁺+Cl⁻) based on an evaluation of data from several trials. For layers or broiler breeders in normal or cool weather, about 180 or 190 m Eq/kg DEB should be adequate. For hot weather, to stimulate more water consumption to cool the birds, this may be raised to around 200 mEq/kg. These sodium supplements may be used for replacement pullets as well, and have been indicated to be especially useful in hot weather for older broiler breeder pullets in the prelay period (Mongin, 1980).

It was suggested by Whitehead and Shannrn, 1974 that lower concentration of sodium lead to significant
decrease in production and it has been proposed that diets containing 0.38g sodium/kg can be used to enhance egg production. There has been little demonstration of potassium or chloride requirements of laying hen. However, Leach, (1974) estimated the potassium requirement of laying hen as between 1 and 1.5kg/kg of diet. Sauveur and Mongin, (1978) described interrelation ship between dietary concentration of sodium potassium and chloride in laying hens. Interaction was highly significant. Ruiz and Austic, (1993) conducted this to determine the relative acidogenicities of dietary supplements of the anion, chloride, sulfate and monohydrogen phosphate in diets of young Leghorn chicks, conducted this study. Chloride consistently depressed blood pH and blood bicarbonate concentration. Sulfate was acidogenic but less so than chloride, whereas monohydrogen phosphate did not affect blood measures of acid base balance. Kavous, (1993) conducted two experiments to determine the maximum levels of gypsum that can be used safely in the laying rations. The results indicate that gypsum can be used safely in laying hen rations. Lott, (1993) concluded that laying hens at 35-59 weeks needed about 0.21% chloride because 0.11% chloride decrease shell strength and 0.31% chloride decreased egg weight. Young, (1997) suggested that bicarbonate supplementation in hot weather may improve egg shell quality. Supplementing bicarbonate to diets of hens under continuous lighting consistency increases egg shell quality (Balnave and Muheereza, 1997).

BROILERS

Supplemental electrolytes and inophores should be added to the broiler’s intake to boost body levels because of increased excretion during stress and hot weather. The supplementation of potassium is particularly critical during this time frame. A reduction in plasma potassium has been positively correlated with increased bird mortality during heat stress. Zanandro, (1994) demonstrated a 9% increase in weight gain, a 40% increase in water consumption and a lowering of body temperature with broilers receiving electrolyte supplementation. Halley et al, (1987) used broiler cockerels to investigate the effect of altering dietary cation and anion ratios on chick growth, leg abnormalities, bones and blood parameters. Altering the normal levels of cation and anion ratios caused leg abnormalities along with other bone abnormalities. Johnson and Karunajeewa, (1985) studied the effect of mineral elements, calcium and available phosphorous and the electrolytes sodium potassium and chloride in the diet on the growth and physiology of male broiler chickens. The concept of total dietary cation anion and electrolyte balance (Na$^+$ + K$^+$ + Cl$^-$ meq/kg) were compared for their ability to enhance growth and various parameters to 42 days of age. Results of study showed that their was a good relationship between growth and dietary electrolyte balance. This experiment was conducted by McCracken and Stewart, (2001) with Ross broiler chicks to study the effect of diet composition and electrolyte balance on the measurement of diet AME and performance parameters in diets containing high levels of wheat inclusions. It was concluded that addition of electrolytes along with wheat diet to improve performance to level seen with a more commercial diet but that the determination of diet AME, with type of fat addition used in this study, is unaffected by electrolyte balance. Study conducted by Talmadge et al, (1981) showed the concentration of cation anion were altered by varying the levels of calcium and phosphorous in the diets. Meliere and Frobes, (1996) used eight days old chicks to study the effect of adding acid, base or a combination of these to an amino acid corn rich diets. A combination of the sodium and potassium was not detrimental but either cation alone reduces weight gain.

BROILER BREEDER

An increase in hen-housed breeder mortality has occurred since the introduction of the meat type broiler. It is becoming apparent that early protein and critical electrolyte balance are critical factors to be considered in improving breeder hen performance as related to egg production and mortality. Rickets like conditions and severe electrolyte imbalances, especially potassium, are contributing factors seen in the early weeks of sexual maturity. This may be due to the stress of the onset of sexual maturity in a hen that is not physiologically prepared to deal with the predicament (Karunajeewa et al, 1986). Latorre et al, (1986) reported that broiler breeder males given an diet containing 0.67% sodium bicarbonate from 24-54 weeks of age, and exposed to cyclic daily temperature to induce heat stress produce significantly more semen from 24 to 40 weeks and had heavier body weight and better sperm motility from 32 to 39 weeks than males on the control basal diet.

TURKEYS AND TURKEYS BREEDER

The dietary electrolyte requirements for turkeys were assessed some twenty to forty years ago. The industry is dealing with a vastly improved bird in terms of growth rate, feed conversion and yield potential. The dietary potassium requirement of the meat turkey is directly correlated with its growth rate potential. Hooge in (1998) demonstrated breast yield improvements in turkey toms by increasing electrolyte balance from 150 to 250 mEq. Sodium and water turnover were measured in young turkeys fed diets with three concentration of NaCl and kept at 12, 18 or 30 C was studied by (Hurwitz et al,
It was concluded by the study that excess sodium or potassium intakes is handled effectively in the turkeys by increased water intake and excretion. Pang et al. (1979) reported that turkeys poults given feed with 0.25% salt tap plus tap water has shown significant live performance benefits from adding sodium bicarbonate.

**DIETARY ELECTROLYTES AND CHICKEN COCCIDIOSIS CONTROL**

The benefits typically with ionophore, salt, and non-chloride sodium supplement are used to improve litter condition (coccidiosis causes wet litter and preventing it improves litter status), body weight, feed conversion ratio, coccidial lesion scores livability, carcass yield, chillier water uptake, and breast meat yield (Barros et al. 1998). Body weight gain has largely occurred in the starter period. Feed conversion improvement has been primarily in the growing and finishing periods. Mortality reduction has been observed from start to finish. As with other additives that improve gut health, lean meat yield is improved. Carcass chiller water uptake is significantly enhanced by some undetermined mechanism when broilers have been grown on diets containing the sodium supplements (Teeter and Belay, 1995). Within legal limits, this water becomes "saleable meat". The performance of Peterson x Arbor acres broiler chicks to 45 days on recycled litter with live coccidian challenge by water at 14 days and diets with or without sodium bicarbonate or coccidiostat was determined by (Hooge et al. 1998). When they did not add any dietary coccidiostat and 0% sodium bicarbonate then body gain was 1.860 kg, feed /body weight was 1.923 kg/kg, mortality was 17.19% and breast meat % body weight was 11.56 %.

When they added Lasalocid as dietary coccidiostat with 0% and 0.2% sodium bicarbonate respectively they got body weight 1.937 and 1.940 having feed/body weight 1.832 and 1.801 with 9.23 and 4.54 % mortality and breast meat % body wt. was 11.79 and 11.99 respectively. The effect of Monesin as a coccidiostat with 0% and 0.2% sodium bicarbonate respectively they got body weight 1.917 and 1.925 kg respectively on body wt., 1.848 and 1.808 kg/kg respectively on feed/body wt., 10.23% and 3.83% respectively on mortality, 11.30% and 12.47% respectively on breast bone meat. Then they added Salinomycin and Halofuginone as coccidiostats with 0.2% sodium bicarbonate and observed the effects. The effect on body weight was 1.935 and 1.984 respectively while on feed/body weight was 1.824 and 1.781 respectively having mortality 5.40% and 4.54% with breast meat % body wt. 12.89% and 13.21% respectively. Coccidiostats were include at the following levels in mg/kg complete feed; halofuginone, 3: Lasalocid, 99: monensin, 121:and Salinomycin, 66. The performance of Peterson x Arbor acres broiler chicks were also determined when to 45 days when they were fed corn-soy or corn-soy meat diets with sodium supplements, grown on recycled litter, and given a coccidial inoculation by water at 14 days. In corn soy when they provide chicks with NaCl, + NaHCO3 they found increased body weight, high FCR along with low mortality in broilers (Hooge et al. 1998). Limited testing of lasalocid with sodium bicarbonate has shown enhanced effectiveness. Potassium bicarbonate, which is more expensive than sodium bicarbonate, has been found, in combination with either monensin or salinomycin to be only as effective as sodium bicarbonate (Hooge et al. 2000)

**EFFECT OF DIETARY ELECTROLYTE BALANCE ON HEAT STRESS IN BROILERS**

Borges et al. (2003a) used 480 Ross male broiler chicks on new litter for this study to evaluate dietary electrolyte balance exposed to thermoneutral and heat stressed environment. The dietary electrolytes he used were Na⁺, K⁺ and Cl⁻. The results were high intake, weight gain for the electrolytes at 240 mEq/kg treatments in heat stress. Borges et al. (2003b) determine feed conversion ratio of Cobb male broiler chickens from 0 to 42 days of age, in a Brazilian pen trial in summer when they fed 120 mEq/kg of Na⁺ K⁺, Cl⁻. Corn soybean meal based mash diets had salt NaCl alone or in combination with one or more supplements: sodium bicarbonate, ammonium chloride or potassium bicarbonate. It was reported that water intake increased linearly with increasing DEB resulting in better quality of carcass due to reducing stress imposed by high temperature. A routine experiment turned into a heat stress study as a heat wave settled in on the U.K.

During the 29-35 days of age period. During heat stress, mortality was lower by about one half with 0.39 or 0.50% supplemental sodium bicarbonate (0.22 and 0.25% Na) compared to 0.06, 0.17, or 0.28% added sodium bicarbonate (0.13, 0.16, and 0.19% Na). It is concluded that the minimum level of dietary sodium bicarbonate needed to prevent excessive mortality in heat stressed broilers after 28 days of age is about 0.40% (Smith and Teeter, 1992). Pardue et al. (1985) did evaluation of relatively high levels of various mineral supplements in exchange for rice hulls in broiler diets from 21-42 days of age when birds were exposed to constant 30o C (86o F). From the evaluation of 12 different dietary mineral supplements in moderately hot weather (30oC or 86oF) by Pardue et al. (1985) sodium bicarbonate was the most effective supplement for improving broiler live performance during high temperature. The efficiency of different vitamins and electrolytes treatments of drinking water for heat stressed commercial broilers was studied in two experiments by (Peter and Qureshi, 1991). Results of this study showed better weight gain and feed conversion and with reduced mortality related to heat stress. Blood electrolyte balance in chicken is altered during heat stress and potassium can be significantly used to depress heat in heat stressed conditions.
chicken (Teeter et al, 1985). Supplementation of water with potassium chloride has resulted reduced mortality rates in heat stressed broilers (Teeter, 1990). Branton et al, (1986) used ammonium chloride and sodium bicarbonate in drinking water of 42-52 days old broilers. Results of this study showed a reduced environmental stress by increasing water intake along with a low % of mortality. British pen trial at Harper Adams Poultry Research Unit showing heat stress mortality during the 29-35 days period reduced by about half using either 0.39% or 0.50% dietary sodium bicarbonate for broiler chickens (Webster, 1992). Evaluation of relatively high levels of various minerals supplements in exchange for rice hulls in broiler diet from 21-42 days of age when birds were exposed to constant 30°C (Gorman and Blnave, 1994).

Summary

The electrolytes may be divided in to cation (the most important sodium, potassium, calcium and magnesium) and anion (principally chloride, bicarbonate, biphosphate and sulphate ions). Sodium, potassium is interrelated in regulating electrolyte balance. These electrolyte need to be taken together since bird cell require a specific balance of cation and anion to function properly. The primary role of electrolyte is to maintain water and ionic balance. The level of different minerals such as sodium, potassium and chloride are major factors in the creation of osmotic pressure and take part in the buffer system and pH mechanism of the body. These factors are essential for the transmission of nerve impulses through the polarity mechanism of cell membrane. It also takes part in all chemical and physical reactions within the body. During high temperature it regulates the body temperature to decrease heat stress in birds. In this way it is helpful in reducing mortality during summer months. Electrolyte balance also referred as acid base balance is affected by major three factors namely the balance and proportion of these electrolytes, endogenous acid production and the rate of renal clearance. It is the cation anion balance of the body that provides the major mechanism for influencing electrolyte balance in the body when feeding poultry. Failure to maintain the correct electrolyte balance within the cell means that metabolic pathways are diverted to achieve homeostasis at the expense of growth. Electrolyte imbalance causes a metabolic disorder, tibal dyschondroplasia in young broiler chicks. Electrolytes can also affect the metabolism of number of basic amino acids, particularly Lysine and Argnine.

References


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