Dietary Electrolyte Balance (dEB) Status of Commercial Poultry Feeds Sold in the Hot Humid Tropical Environment of Owerri, Southeastern Nigeria

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Abstract: Dietary Electrolyte balance (dEB) reflects the potential of feed to promote homeostasis, support optimal production levels and ameliorate stress due to production indices. This study was conducted to ascertain the status and uniformity of dietary Electrolyte balance (dEB) in commercial poultry feed brands in Owerri, Imo state, Nigeria. The purpose of the experiment was to assess the level of uniformity in the required dietary electrolytes and if the balance for the three major electrolytes were satisfied in the different commercial formulations. By extension, this will reflect the '*substitutionability*' of the different brands in the diet at the different phases of a production cycle. Samples of broiler starter, grower, finisher and layer diets from six (6) different commercial feed brands were analysed in the laboratory for the three major dietary electrolytes - sodium (Na^+), potassium (K^+) and chloride (Cl^-) (measured in mini-equivalents/kg), and compared. The dEB for each formulation was calculated by subtracting the anions from the cations. The results showed that for all the commercial feed formulations, the Na^+, K^+, and Cl^- balance was significantly different ($p<0.05$) across the six brands and indeed widely varied. This is a pointer to the fact that the constituted diets for the different brands of feed studied were not only widely varied in their potential to support normal homeostasis and optimal metabolic activity, but are also varied in their potential to meet set performance objectives. The results confirm the need to exercise caution in the field when substituting one brand for one another during a production cycle. It also opens up the option of electrolyte supplementation via feed and drinking water and perhaps highlights the need for standardization of commercial feed formulations.

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1. Introduction

Dietary electrolytes are commonly known to support a host of body physiologic functions and processes; including synthesis of tissue proteins, maintenance of intracellular and extracellular homeostasis, maintenance of ionic potential across cell membranes and organelles, driving of enzymatic reactions, osmotic pressure regulation, acid-base balance, etc (Mongin, 1981; Borges *et al*., 2004). These make them integral parts of animal nutrition, health, physiology and biochemistry. The most common sources of these electrolytes to the animals are electrolyte salts usually mixed as feed additives during feed formulation and trace minerals contained in their drinking water. Other sources include cereal grains, animal protein ingredients, plant extracts, especially leaf meals and agricultural by products (Kabaija and Little, 1988; Brown, 2010; Ayyat, 2010; Berger, 2011).

Electrolytes provided in diets are important in maintaining acid-base balance, osmotic pressure and electrical potential of cell membranes and are also essential for intracellular and extracellular homeostasis (Borges *et al., 2003*). Among these electrolytes, the monovalent ions (K^+, Na^+, and Cl^-) are the key ones involved in acid-base balance of the body fluids (Mongin, 1981), because they have higher permeability and greater absorption than divalent ions. Animals (birds inclusive) lose electrolytes through their excrements and through the physiologic process of panting. Dehydration is a major cause of electrolyte imbalance, with animals losing electrolytes whenever body fluids are lost and not replaced fairly promptly (Mongin, 1981). When incorrect dietary electrolyte balance occurs, some metabolic pathways are affected and thus, electrolytes supplied in feed are used to maintain homeostasis instead of being used for growth (Borges *et al*., 2003) or to support production. For example, increases in Na^+ and K^+ concentrations in body fluids and tissues promote acidosis. Therefore, a balance of the dietary electrolytes influences optimal growth performance (Mongin, 1981).

Dietary electrolyte balance (dEB) specifically affects the palatability of feed and as such could affect feed intake (Borges *et al.*, 2003). Thus, an imbalance consequently affects production and performance parameters, leading to failure to meet production targets, reductions in profit margins, and subsequent economic losses. Affected animals will have problems with the formation and development of muscles, bone and teeth as well as egg shell (Nwogu, 2013; Ohanaka *et al.*, 2016). There may equally be blood deficiencies, and muscle and enzyme dysfunctions amongst others (Iwu *et al.*, 2013; Nwogu *et al.*, 2015). Dietary electrolyte balance also helps in the regulation and expression of genes, and in the detoxification of body systems (Borges *et al.*, 2004).

Most feed formulations and trials usually do not emphasise the balancing of the three major dietary electrolytes, especially in the hot humid tropical environment where hyperventilation as a result of heat stress may lead to electrolyte imbalance and respiratory alkalosis (Teeter *et al.*, 1985; Franco-Jimenez and Beck, 2007). Under such hyperventilation conditions, the kidney attempts to correct the acid–base balance by renal exchange of bicarbonate into Cl^- with concentration increases in plasma (Belay and Teeter, 1996; Toyomizu *et al.*, 2005). Also, the changes in acid-base balance may lead to decreased feed intake, growth retardation and poor performance under heat stress (Teeter *et al.,* 1985). Mongin (1981) reported that when dietary electrolyte balance is higher or lower than its requirement in the diet, alkalosis or acidosis develops, resulting in growth depression.

The meq/Kg used as the unit for expressing electrolytes is a measure of the power/potential of activity of the electrolyte (Mercks, 2005). Borges *et al.* (2005) observed that a dietary electrolyte balance of 240 meq/kg diet increases Na^+ and K^+ retention and water consumption, and is more favourable under thermo neutral and heat stress temperatures than feed intake. Again, according to Borges *et al.* (2004), the best dEB during the growing phase is between 202 and 235 meq/kg diet. This value range takes into account the fact that Cl^-in the body fluids has an acidogenic effect by reducing blood bicarbonate concentration while Na^+ and K^+have alkalogenic effect (Ruis-Lopez and Austie, 1993; Borges *et al.,* 2007).

This paper discusses the status of dietary electrolyte balance of commercial poultry feeds sold in the hot humid tropical environment of Owerri, south-eastern Nigeria.

2. Materials and methods

Study area: The study was carried out in Owerri, the Imo state capital in South-eastern Nigeria, with the coordinates 5.485°N 7.035°Eand 59 meters above sea level. Imo State itself lies within latitudes 4°45'N and 7°15'N, and longitude 6°50'E and 7°25'E, with a land area of around 5,100 sq km (Figure 1). The geographical and agro climatic characteristics of the area have been described by Ofomata (1975), while the poultry production characteristics of the state has also been described by Okoli (2004a).

Commercial poultry production in the area is basically small to large-scale intensive productions involving the rearing of exotic strains of broilers, pullets and turkeys for meat and egg production. The commercial poultry farmers usually purchase their feeds from dealers on any of the popular commercial feed brands. Most large scale operators however produce their own feeds on-farm.

Commercial poultry feeds sold in the area are usually prepared as mash or pellets, although the mash form is more popular. They are presented in 25kg polythene woven sacks (Okoli *et al.*, 2007).

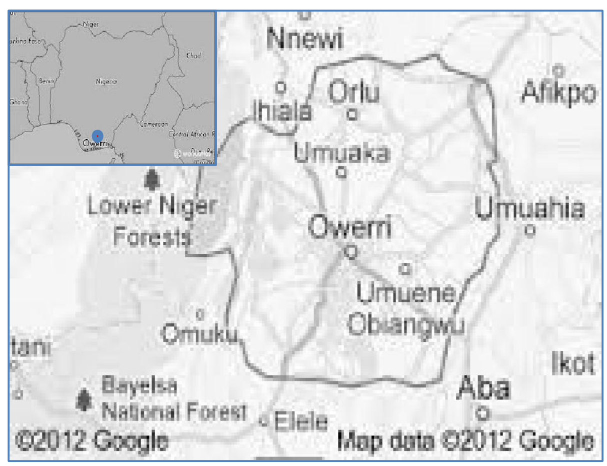

Fig 1: Map of Owerri (Imo state), Eastern Nigeria

Sample Collection: A preliminary field survey was carried out to identify the reputable commercial poultry feeds distributors operating in Owerri town. These were duly informed of the nature and purpose of the research and based on the preliminary survey, the six most popular commercial feed brands distributed in the state were purposively selected for the study and designated A to F. Feed types such as broiler starter mash (BS), broiler finisher mash (BF), grower mash (GM) and layers mash (LM) were sampled at random across the selected brands using the method described by Okoli (2004a).

A total of 24 bulked samples were collected from the six selected commercial feed brands. Each selected feed distributor was visited once during the month of

August 2015. The 24 bulk samples were obtained by sampling three feed bags per feed type making 96 bags of feed sampled across the different feed brands. Each bag of feed was sampled by using a clean metal probe to pierce the feed bag and allowing about 50 g of feed to flow out into a properly labelled plastic container. Samples from three bags representing a feed type from a brand were thereafter homogenised to obtain a representative bulk sample of about 150 g of the feed type. The bulk samples were properly labelled and transported to the School of Agriculture and Agricultural Technology (SAAT) Federal University of Technology (FUTO), Teaching and Research laboratory for subsequent analysis.

Determination of Cation and Anion Contents: The cation contents of the feeds determined were Sodium (Na^+) and Potassium (K^+), while the anion was Chlorine (Cl^-). The cations were determined with the aid of a flame photometer (Jenway Flame Photometer PFP7, UK) according to the method approved by AOAC (1990). The chlorine content was determined according to Mohr's method as described by Skoog *et al*. (1996). The values obtained were used to calculate the dietary electrolyte balance of each feed type across the different brands.

Calculation of Na/K ratios and Dietary Electrolyte Balance (dEB): The Na/K ratios of the different feed types were calculated according to the standard method, while the dEBs were calculated with the aid of the formular ($Na^+ + K^+$) - (Cl^-) i.e. the difference between the cations and the anions (Borges *et al*., 2005).

Data Analysis: Data generated from the study were subjected to one way analyses of variance (ANOVA) to detect significant treatment differences. The means were separated using the Least Significant Difference (LSD) method (SPSS, 2013).

3. Result and Discussion

Broiler Mash: Results from the analysis of the broiler mashes are shown in tables 1 and 2. The highest dEB for the broiler starter mash (Table 1) was recorded in feed brand C and was significantly higher ($p<0.05$) than the values recorded in A, B, and E brands. The table also showed that the Na/K ratio values for BS ranged from 0.09 – 0.61 indicating very wide variations in values. The 0.61 recorded in feed brand B was significantly higher ($p<0.05$) than the other brand values, while values for F was also significantly higher ($p<0.05$) than C and E values. It was however similar to the value recorded in D and F brands. In the broiler finisher mash (Table 2), C and D brands recorded dEB values that were significantly higher ($p<0.05$) than all the others. Feed B, A and E values were similar ($p>0.05$) in their Na/K ratio values and significantly higher ($p<0.05$) than the values recorded in the other brands.

It is interesting that only the D and E brands of starter mash and the B and E brands of the finisher mash values fell within the range of 200 to 240 meq/kg dEB recommended by Borges *et al*. (2004) for growing birds. However, C and F brands of starter and C and D brands of finisher fell within the 250 – 350 meq/kg suggested by Johnson and Karunajeewa (1985). Better performance has been reported in birds aged 1 – 21 days old fed 246 – 315 meq/kg with tibial dyschondroplasia or acid-base disturbance failing to manifest in such birds (Murakami *et al*., 2001). Borges *et al*. (1999) reported growth rate depression in chicks aged 1 – 7 days old as a result of high values of dEB (354 - 360 meq/kg) achieved through supplementation of Na^+ and K^+in their diets. For straight feeding from 1 – 49 days however, a dEB of 240 meq/kg has been recommended (Borges *et al*., 1999; Mongin, 1981). It could therefore be concluded that A and B brands of starter mashes and A, B and F brands of finisher mashes were relatively low in their dEB and needs to be corrected probably by supplementation with Na^+ or K^+.

Table 1: Na/K ratios and dEB of commercial broiler starter ration brands sold in Owerri south-eastern Nigeria

Brand	**K^+**	**Na^+**	**Cl^-**	**Na/K ratio**	**dEB**
A	120.52	17.25	0.27	0.14^{bc}	137.50^{b}
B	105.13	6.9	0.52	0.61^{a}	168.51^{b}
C	237.95	24.63	0.52	0.10^{c}	262.06^{a}
D	181.03	45.33	0.56	0.25^{bc}	225.80^{c}
E	184.1	17.22	0.59	0.09^{c}	200.73^{cd}
F	181.03	68.93	0.66	0.35^{b}	249.30^{ac}
Range				0.09 – 0.61	137.50 – 249.30
Mean				0.26	207.32
SEM				0.082	10.62

Column with different superscripts are significantly different (p<0.05)

Table 2: Na/K ratios and dEB of commercial broiler finisher ration brands sold in Owerri south-eastern Nigeria

Brand	K^+	Na^+	Cl^-	Na/K ratio	dEB
A	131.28	40.71	0.24	0.31 [a]	171.75[bc]
B	147.44	52.63	0.49	0.37 [a]	199.58[bc]
C	247.69	20.28	0.58	0.08 [b]	267.39[a]
D	260.77	28.86	0.35	0.11 [b]	289.28[a]
E	156.92	49.96	0.57	0.32 [a]	206.31[c]
F	162.59	20.61	0.4	0.13 [b]	182.80[bc]
Range				0.08 – 0.37	177.75 – 289.28
Mean				0.22	219.52
SEM				0.052	10.55

Column with different superscripts are significantly different (p<0.05)

According to Johnson and Karunajeewa (1985), the extent of broiler live weight depression from feeding diets with an electrolyte balance greater than 300meq/kg depends on the type of cation added to the diet (Na^+ or K^+) and that the range of the Na/K ratio for optimum growth is 0.5 – 1.8. Nursoy *et al.* (2011) on their part stated that a 0.1 Na/K ratio and 212 meq/kg dEB could be fed to broilers in case of insufficient calcium, while in normal cases 0.3 – 0.5 of Na/K ratio and 259 – 344 meq/kg of dEB should be appropriate for broilers. Again, for such optimum diets, NCR (1994) recommends 0.20% Na, 0.30% K and 0.20% Cl for 0 – 3 weeks of age and 1.15% Na, 0.30% K and 0.15% Cl for 3 – 6 weeks of age. According to Mustahq *et al.* (2005) and Murakami *et al.* (2005), however, under subtropical summer conditions, optimum body weight is attained when the amount of Na^+ and Cl^- are kept at 0.25 and 0.30% for 0 - 28 days and 0.15% Na^+ and 0.23% Cl^- for 21 – 42 days respectively, while the amount of K^+ should be 0.50% and 0.47% for 0 – 21 days and 21 - 42 days respectively for broiler diets (Oliveira *et al.*, 2005).

However, southern Nigerian broilers are fed starter diets from 0 to 28 days, and fed finisher diets from 29 to 49 or 56 days, depending on the age of cropping (Adene and Oguntade, 2006; Ifediba, 2016). The climatic conditions of the production environment in the area are those of average 27^0C and 70% relative humidity with upper limits reaching 32^0C and 80% for extended periods of the year (Okoli, 2004b) implying hot humid conditions.

Therefore, both the Na/K ratios and dEB values recorded in most of the commercial broiler rations may lead to some levels of poor performance of birds, especially during the hot months when heat stress effects are added to depress production performance. Indeed, Ukwu (2013) reported that broiler birds fed such commercial diets for the first three week of life consumed 48.9% less the recommended amount of feed and gained 18.6% less than the recommended weight than expected. At the end of six weeks of feeding such birds have eaten a mean 34.5% less feed and gained a mean 20.8% less the recommended weight. Ohanaka (2016) showed that dietary electrolyte imbalance manifesting as increasing serum Na, K and Ca and decreasing Cl^-could partly explain the reduced feed intake and weight gains in broilers reared in the zone.

Pullet Mash: Tables 3 and 4 show the Na/K ratios and dEB values of the commercial pullet mashes. The Na/K ratios recorded in the B brand grower mash (table 3) was significantly higher (p<0.05) than the values recorded in D, E and F brands but similar to A and C values (p>0.05). The dEB values f C, D and F brands were however significantly higher than others. The values ranged from 0.14 – 0.61 and 127.99 – 302.58 meq/kg feed for the Na/K ratio and dEB respectively. For the commercial layer feeds (table 4), the C brand recorded significantly higher (p<0.05)Na/K ratio value than B, D and E brands, but similar to A an F values (p>0.05). The C brand also recorded significantly higher (p<0.05) dEB value than the other commercial layer brands with the Na/K ratio and dEB values ranging from 0.04 – 0.32 and 161.16 329.61 meq/kg respectively.

According to Senkoyln *et al.* (2005), layer rations formulation to obtain a dietary electrolyte level between 230 and 250 meq/kg, which is also very close to the value suggested for broilers have long been used regardless of heat stress or aging for laying hens, and even for the diets of young laying hens. Sauveur and Mongin (1978) reported no effect on shell weight and surface when dEB was between 160 and 360 meq/kg, while Hamilton and Thompson (1980) on the contrary reported no significant alteration of egg shell quality when dEB was lower than 330meq/kg or higher than 620meq/kg but observed reduction in feed intake and hen day production. They also observed that much lower dEB resulted in depressed blood pH, HCO_5 concentration and egg shell quality, while Gezen *et al.* (2005) concluded that moderate dEB of 256meq/kg improves egg shell qualities such as thickness, strength and decrease of cracked egg ratio. These reports tend to suggest that the range of 161.16 – 329.61 meq/kg recorded in the commercial feeds is optimal. However, the 329.16 meq/kg recorded in the C brand is capable of depressing rate of lay and feed intake in birds consuming such feeds (Hamilton and Thompson, 1980). Again, low Na^+ (91.79 and 105.13 mg/kg) and high Cl^- (0.47 and 0.52 mg/kg) recorded in the A and B grower brands or the very low K^+ (7.49 mg/kg) and high Cl^- (0.50 mg/kg) recorded in the B layer brand, will result in poor feed conversion ratio (Murakami *et al*., 2003). It has been recommended that the ratio of Na: Cl in layer diets should be 1.2: 1 to 2.0:1 (Miles, 2000), outside this range, eggshell quality, feed conversion ratio and excreta moisture will be variably affected (Murakani *et al*., 2003).

Generally, the Cl^- anion content of the different brands all particularly appear to be much lower than industry recommendations and results of other works done by Ahmad and Sarwar (2006). In view of the importance of the Cl^- anion in the maintenance of efficient electrolyte – dependent physiologic transport systems in the animal's body, this could be viewed as a potentially serious shortcoming. Also, since the palatability of feed is so much dependent on the Cl^- anion balance/content, feed consumption and its dependent production factors could be negatively affected.

Table 3: Na/K ratios and dEB of commercial grower ration brands sold in Owerri south-eastern Nigeria

Brand	K^+	Na^+	Cl^-	Na/K ratio	dEB
A	91.79	36.67	0.47	0.40^{ab}	127.99^{b}
B	105.13	63.9	0.52	0.61^{a}	168.51^{bc}
C	189.23	77.1	0.47	0.41^{ab}	265.86^{a}
D	233.33	40.9	0.6	0.18^{c}	273.63^{a}
E	154.37	21.35	0.54	0.14^{c}	175.18^{c}
F	233.08	70.13	0.63	0.30^{bc}	302.58^{a}
Range				0.14– 0.61	127.99– 302.58
Mean				0.34	218.96
SEM				0.07	15.63

Column with different superscripts are significantly different (p<0.05)

Table 4: Na/K ratios and dEB of commercial layer ration brands sold in Owerri south-eastern Nigeria

Brand	K+	Na+	Cl-	Na/K ratio	dEB
A	129.49	32.94	0.27	0.25^{ab}	161.16^{b}
B	178.46	7.49	0.5	0.04^{c}	185.45^{b}
C	250	80.02	0.41	0.32^{a}	329.61^{a}
D	171.79	21.09	0.4	0.12^{bc}	192.48^{bc}
E	198.97	28.96	0.44	0.15^{bc}	227.49^{c}
F	160.36	41.33	0.45	0.26^{ab}	201.24^{bc}
Range				0.04 – 0.32	161.16 – 329.61
Mean				0.19	216.24
SEM				0.042	13.15

Column with different superscripts are significantly different (p<0.05)

Table 5: Coefficient of variations of the overall dEB mean of the different feed types sold in Owerri

Parameters	Overall mean	Standard Dev.	Confidence interval (99%)	% Coefficient of variation
Broiler starter	207.32	43.83	4.0321	21.14
Broiler finisher	219.52	43.51	4.0321	19.82
Grower	218.96	64.44	4.0321	24.43
Layer	216.24	54.39	4.0321	25.15

Table 5 shows the percentage coefficient of variation of the overall dEB values of the different feed types sold in Owerri. The percentage confidence intervals were generally wide, with values ranging from 19.82 to 25.15%. This implies that these overall means cannot be quoted as reference values for feed types in the study area. Such wide variations have also been reported for the physical characteristics (Omede, 2010), moisture contents (Okoli *et al*., 2007 and 2013), nutrient and amino acid contents (Uchegbu *et al*., 2008; Okata, 2016) of commercial feeds produced in Nigeria.

Since dEB is a more direct and proper assessment of the effectiveness of the electrolytes in feed, these results suggest that the different feed brands have very different formulas for electrolyte constitution in their diets, implying that the effectiveness of the different brands in supporting homeostasis and overall physiologic functions could be highly variable. It means that companies and individuals have been left to themselves to set their own standards for the composition of their feeds.

In Nigeria, feed quality schemes are limited to proximate evaluation, which does not present the total picture of feed quality (Okoli *et al*., 2009). There is very limited effort at holistic regulation of the quality of animal feeds released to the public with the resultant effect that feed millers may aim only at making sure that farmers' need of having enough feed, for their animals is met, while compromising quality (Okoli *et al*., 2007).

4. Conclusion and Recommendations

The dEB values recorded in commercial poultry feeds sold in Owerri are generally low with only few of the brands across feed types being high enough to ameliorate heat stressors induced pathophysiologies of poultry in the study environment. The values were also widely varied making it difficult to recommend a reference value for the different feed types. There is the need for a knowledge-based feed quality regulation scheme to be developed for the Nigerian feed industry.

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