



Effect of Sodium Levels on Growth Performance, Haematological Indices and Carcass Characteristics of Japanese Quail in a Humid Tropical Environment

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Abstract | Electrolytes, including sodium, are required for optimum performance, and their imbalance can generate acidosis or alkalosis, thus making the metabolic pathways in the animal organism inefficient. This research aimed to evaluate the optimum sodium requirements for growing Japanese quail (*Coturnix coturnix Japonica*). Two hundred growing quails were distributed in a completely randomized design with five treatments and five replicates, with eight birds each. The treatment consisted of a basal diet (control) containing 0.101% of Na in the diet. In the remaining treatment groups, sodium carbonate was supplemented to reach levels of 0.144, 0.187, 0.231, and 0.274% of Na. After the 20-d of the feeding trial, data obtained on growth performance (final weight (FW), total weight gain (TWG), total feed intake (TFI), nutrients intake), selected blood indices (packed cell volume (PCV), haemoglobin (Hb), differential counts (lymphocytes, monocytes, eosinophils, basophils) and carcass characteristics (dressing %, eviscerated weight, drumstick, chest, back) were taken and subjected to a one-way analysis of variance (ANOVA) using the Statistical Package for Social Science (SPSS, v 26) software. TWG, TFI, AFI, Total protein and energy intake were highest ($P < 0.05$) at 0.187%, and the FW was lowest ($P < 0.05$) at 0.101% of Na in the diet, respectively. Similar ($P > 0.05$) RBC, heterophil and monocytes were recorded for dietary Na supplementation range of 0.144% to 0.274%. Dietary Na supplementation of either 0.144% or 0.187% produced the highest ($P < 0.05$) eviscerated weight, chest and back were highest ($P < 0.05$). The relative organs' (liver, heart, gizzard and neck) weights were similar ($P > 0.05$) irrespective of dietary Na supplementation. In conclusion, the performance of the Japanese quail from 22 to 42 days appears to be at an optimum range of 0.187% to 0.231% for dietary Na supplementation.

Keywords | Carcass traits, *Coturnix coturnix Japonica*, Growth performance, Haematology, Sodium

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Quail production is experiencing notable growth, particularly in Africa, due to the birds' minimal space requirements, high productivity, ease of management, and quick sexual maturity. Advances in genetic improvement have further enhanced production rates beyond the already rapid natural cycle (Berger and Cunha, 1993; Akinmola-dun and Falowo, 2021). Despite the expanding quail industry, with increased production and a rising demand for their eggs, there has been insufficient research on the birds' nutritional needs. Currently, many quail diets are formulated based on guidelines for layers (NRC, 1994) without specific considerations for the unique rearing conditions in the region (Costa *et al.*, 2012). More important is the appropriate micro-nutrient requirement, with a particular emphasis on minerals, which has been given little to no attention in terms of optimum electrolyte balance that favours growth and production efficiency during the growing and egg-laying phases (Malaudzi, 2019).

Deviation from the typical acid-base equilibrium impacts the growth and reproductive capabilities of both mammals and hens. Sodium (Na⁺), potassium (K⁺), and chlorine (Cl⁻) are the primary electrolytes in feeds, and they regulate the dietary acid-base balance. Sodium is actively involved in regulating osmotic pressure, maintaining the electrolytic balance of cells, and facilitating the absorption and transport of glucose and amino acids (Murakami and Furlan, 2002). Despite its requirement in small quantities, a deficiency or insufficient sodium intake has been linked to decreased feed consumption, reduced fertility, and increased mortality (Berger and Cunha, 1993). Conversely, excessive sodium intake has been associated with increased water consumption, elevated extracellular fluid osmolarity, higher excreta moisture content, and metabolic alkalosis (Lima *et al.*, 2020; Mencalha *et al.*, 2013).

Formulated diets for quails are generally assumed to contain a well-balanced mix of minerals, including sodium, leading nutritionists to somewhat overlook these minerals in their studies (Costa *et al.*, 2012). However, it's important to note that birds have specific requirements depending on their production phase, and any imbalance in minerals during the growth phase can impact the sexual maturity of the birds (Costa *et al.*, 2012). The recommended sodium levels for Japanese quails, as per NRC (1994), stand at 0.15%, typically achieved by supplementing formulated feed with 0.25% common salt based on maize and soybean meal containing 20% CP (Rostagno *et al.*, 2005).

The intricate aspects of mineral metabolism, particularly sodium, contribute to the complexity of accurately determining its nutritional requirements. Specifically, factors influencing precise nutrient determination encompass

environmental conditions, genetic variations in the animal (Barros *et al.*, 2001), the interplay and correlation of minerals with organic molecules, and variations in the incorporation and absorption of dietary minerals. In a study conducted in the semi-arid region of Brazil, Costa *et al.* (2012), were able to situate the nutritional requirement of sodium for Japanese quail from 1 to 21 d and from 22 to 40 d to be 0.222% and 0.253%, respectively. To ensure optimum production, continuous research is essential to adjust the nutrient levels in quail to align with the animal's specific requirement. Therefore, this study aimed to assess the dietary sodium needs of growing quails aged 22-42 days by examining their growth performance, blood indices, and characteristics of carcasses and organs.

MATERIALS AND METHODS

STUDY SITE AND ETHICAL APPROVAL

The study took place at the animal facility of the Department of Animal and Environmental Biology, Adekunle Ajasin University, Akungba Akoko, Ondo State. This region is in southwestern Nigeria and experiences a tropical climate characterized by a mean annual rainfall range of 1300 to 1500 mm. The rainfall pattern is bimodal, with the first peak occurring in June and July and the second in September (Fasinmirin, 2009). The mean minimum and maximum temperatures are 19.63 °C and 32.75 °C, respectively, with an average relative humidity of 76.57% throughout the year (Olubanjo and Alade, 2018). The vegetation in the area reflects an intermediate zone between tropical forest and derived savanna. All experimental protocols and animal handling adhered to the established guidelines of the University's animal care and research committee.

EXPERIMENTAL ANIMALS, DIETS AND MANAGEMENT

The experiment utilized 200 growing quails of mixed sexes, with an average body weight of 99.5g±0.25, raised over 20 days. Diets were formulated to meet the requirements for laying quails, following the guidelines of NRC (1994), except for sodium. The treatments involved varying sodium levels [0.101%, 0.144%, 0.187%, 0.231%, and 0.274%] in the experimental diets (refer to Table 1). Sodium bicarbonate was added to achieve the desired sodium levels by replacing the inert component in the diet. At the pre-experimental stage, the two hundred Japanese quail chicks were brooded on deep litter, fed the starter ration (20% CP; 2800 ME Kcal/kg) and transferred to battery cages at 22 days of age. The cages were partitioned into units (200 x 100 x 70cm) with eight quail per unit per replicate. The cages were well-ventilated, under a photoperiod lighting of 12 hours of daylight and 12 hours of darkness and housed in a room at the livestock teaching and research farm. All the birds were weighed in groups before being placed in cages, and subsequent weights were taken weekly. All the birds

were healthy based on physical examination before the start of the study and were provided with feed and water *ad libitum*. Before the one-week pre-experimental period with the standard diet for breeding quails, the quails were randomly assigned to the five dietary treatments with five replicates, each containing eight birds, in a completely randomized design. The standard routine management procedures at the animal house were strictly followed. Proximate diet analysis was conducted according to the AOAC (2000), procedure. After the 20-day feeding trials, three quails per replicate were randomly selected to assess growth performance.

DATA COLLECTION

Throughout the experimental phase, weekly evaluations of the birds' body weight were conducted in the morning to determine average weight gain (WG), average feed intake (FI), and feed-to-gain ratio (FCR). Additionally, calculations were performed for total protein and energy intake, as well as protein and energy intake per body weight. At the end of the 20 days, three randomly selected birds per replicate underwent overnight feed and water deprivation before being euthanized. Blood samples were collected from the jugular vein of each bird into heparinized bijoux bottles for haematological parameter assessments. These samples were transported with an ice pack to the laboratory for further analysis of haematological indices. The determination of red blood cells (RBC), erythrocyte sedimentation rate (ESR), packed cell volume (PCV), haemoglobin (Hb), and leukogram parameters occurred on the same day of blood collection, following the procedures outlined by Lamb (1981).

Subsequently, the slaughtered birds underwent complete plucking, with the removal of the feet, head, and wingtips. The dressing and evisceration process followed, and the carcass (excluding neck, head, lung, heart, feet, and liver) was dissected to obtain back, breast, thighs, wings, and drumsticks. The weights of these parts, along with the viscera (liver, heart, kidney, lungs, and abdominal fat), were expressed as a percentage of the live weight. The thighs and drumsticks from each slaughtered bird were deboned and weighed.

STATISTICAL ANALYSIS

Data obtained were first analyzed for normal distribution and homogeneity of variance. The results of Shapiro-Wilk and Levene's tests were insignificant, thus satisfying the conditions. Afterwards, the data were subjected to a one-way analysis of variance (ANOVA) with SPSS (version 26), and their means were separated using the Tukey (HSD) Test of the same software. Analyzed data were declared significant at $P < 0.05$. The model of analysis was as follows:

$$Y_{ij} = \mu + P_i + \epsilon_{ij}$$

Where; Y_{ij} signifies the observed value, μ the overall mean,

P_i is the treatment effect i th and ϵ_{ij} the random error. The statistical analysis results were shown in tables as mean values and standard deviations.

Table 1: Ingredients and nutrient composition of experimental diets.

Ingredients	Na level, %				
	0.101	0.144	0.187	0.231	0.274
Maize	59.35	59.36	59.47	59.66	59.8
RB	4.82	4.71	4.50	4.21	3.97
SBC	29.17	29.17	29.17	29.17	29.17
Per. Shell	6.36	6.36	6.36	6.36	6.35
Salt	0.15	0.15	0.15	0.15	0.15
Premix*	0.15	0.15	0.15	0.15	0.15
Na ₂ CO ₃	—	0.10	0.20	0.30	0.40
Total	100	100	100	100	100
Calculated Composition					
CP	20.01	19.99	19.97	19.95	19.93
M.E(Kcal/Kg)	2901.00	2900.03	2899.30	2900.06	2899.93
Calcium	2.5	2.48	2.51	2.49	2.49
Phosphorus	0.34	0.35	0.36	0.34	0.35
E: P	144.98	145.07	145.19	145.37	145.51
Proximate Composition					
DM%	93.25	93.48	93.52	92.88	93.33
CP%	19.25	19.07	19.62	19.43	20.12
EE%	5.25	5.30	5.28	5.42	5.50
CF%	5.05	5.17	5.20	5.18	5.15
Ash%	7.83	7.59	7.62	7.75	7.79

DM: Dry matter; **CP:** Crude protein; **EE:** Ether extract; **CF:** Crude fibre; **NFE:** Nitrogen free extract; **E:** Energy; **P:** Protein; **T1:** (0% Na₂CO₃); **T2:** (0.1% Na₂CO₃); **T3:** (0.2% Na₂CO₃); **T4:** (0.3% Na₂CO₃); **T5:** (0.4% Na₂CO₃); **Premix*:** supplied per kg of diet: Vit A, 10,000 IU; Vit D, 2,800 IU; Vit E, 35,000 IU; Vit K, 1,900 mg; Vit B12 19 mg; Riboflavin, 7,000 mg; Pyridoxine, 3,800 mg; Thiamine, 2,200 mg; DPantothenic acid, 11,000 mg; Nicotinic acid, 45,000 mg; Folic acid, 1,400 mg; Biotin, 113 mg; Cu, 8,000 mg; Mn, 64,000 mg; Zn, 40,000 mg Fe, 32,000 mg; Se, 160 mg; Iodine, 800 mg; Cobalt, 400 mg; Choline, 475,000 mg; Methionine, 50,000 mg; BHT, 5,000 mg; Spiramycin, 5,000 mg.

RESULTS AND DISCUSSION

The effects of the different dietary sodium supplementation on growth performance during the experimental period are shown in Table 2. Mortality in this experiment was low and evenly distributed among treatment groups. Supplementing an amount of dietary Na beyond the control (0.101%) revealed a higher ($P < 0.05$) final weight (FW). The effect of dietary Na supplementation was not significant ($P > 0.05$)

Table 2: Growth performance of quails fed diets supplemented with dietary sodium salt.

Variables	Na levels, %				
	0.101	0.144	0.187	0.231	0.274
IW, g	99.00±8.12	100.25±7.09	98.25±8.61	100.00±5.94	101.00±9.01
FW, g	150.10±21.75 ^b	154.75±6.40 ^a	154.84±14.07 ^a	153.75±6.44 ^a	154.64±8.23 ^a
TWG, g	51.05±1.32 ^c	54.49±2.38 ^b	56.50±1.73 ^a	53.70±5.32 ^b	53.50±1.00 ^b
TFI, g	253.25±5.38 ^b	247.25±7.80 ^b	273.75±12.07 ^a	248.75±2.99 ^b	251.75±8.50 ^b
AFI, g/b/d	12.66±0.27 ^b	12.36±0.39 ^b	13.69±0.60 ^a	12.44±0.15 ^b	12.56±0.43 ^b
AWGg/b/d	2.56±0.09	2.72±0.01	2.83±0.03	2.69±0.02	2.68±0.02
FCR	4.95±0.03	4.54±0.01	4.83±0.01	4.62±0.02	4.68±0.01
Nutrient intake					
Total PI	50.67±0.86 ^b	49.37±1.25 ^b	54.72±1.93 ^a	49.62±0.48 ^b	50.17±1.36 ^b
Total EI	7346.78±155.95 ^b	7168.25±126.34 ^b	7938.83±149.91 ^a	7213.75±86.60 ^b	7300.75±246.30 ^b
Protein/kg BW	0.44±0.04	0.45±0.04	0.48±0.02	0.43±0.01	0.44±0.03
Energy/kg BW	66.70±2.24	62.41±2.88	69.18±2.01	63.40±1.98	63.68±2.33

^{abc} means with different superscript across the row are significantly different ($P<0.05$); **IW**: initial weight; **FW**: final weight; **TWG**: Total weight gain; **FCR**: feed conversion ratio; **TFI**: total feed intake; **AFI**: average feed intake, **PI**: protein intake; **EI**: energy intake; **BW**: body weight.

on the feed conversion ratio (FCR), protein/kg BW and energy/kg BW. However, a diet containing 0.187% of dietary Na produced the highest ($P<0.05$) total weight gain (TWG), total feed intake (TFI) and average feed intake (AFI). This trend is consistent with the total protein and energy intake. More Na⁺ concentrations in diets and the possibility of an improved electrolyte balance have been linked to increased feed intake and improved feed efficiency in poultry (Puron *et al.*, 1997; Yoruk *et al.*, 2004). In a similar optimum-Na-requirement study conducted on quail in Brazil, Costa *et al.* (2012), reported that from the range of 0.04, 0.12, 0.20, 0.28 and 0.36% of Na supplementations from 24 to 40 d, the best FW was achieved with 0.257% of sodium in the diet, whereas TWG and FCR were best with 0.250 and 0.253% Na, respectively. According to the authors, this high optimum Na requirement could be attributed to the consumption of sodium-free water by the birds. According to Rodrigues *et al.* (2007), providing sodium-free water would make the birds consume a larger amount of dietary sodium, thus influencing the results. However, birds in the current study were not provided with deionized water. On the other hand, Erener *et al.* (2002) and Lima *et al.* (2020) did not observe differences in body weight and feed intake of Japanese quail fed with increasing levels of sodium chloride. Waldroup *et al.* (2005), also observed a non-significant sodium bicarbonate supplementation in the feed intake of birds. These variabilities of results outcomes following dietary Na supplementation may be attributed to factors including intake levels, water consumption patterns, blood biochemistry and relationship with other electrolytes (Gonzalez *et al.*, 2008). Generally, dietary homeostasis in terms of acid-base balance is influenced by the relationships between the electrolytes, includ-

ing sodium, chlorine and potassium. An imbalance may generate alkalosis or acidosis, rendering critical metabolic pathways inefficient (Mongin, 1980). According to Silva *et al.* (2007), sodium levels that are either above or below recommended amounts can disrupt the balance with chlorine, leading to complications in acid-base balance, enzyme activity, feed and water consumption, and excretion, ultimately affecting quail growth and egg production. Although 250 mEq/kg was reported to be the optimal electrolyte balance for birds, other variables, including age, bird species, physiological state and the birds' environment, could influence the balance (Borges *et al.*, 2003; Borges *et al.*, 2004). In this experiment, the feed conversion was similar. A dietary sodium level of 0.274%, corresponding to a 259 mEq/kg diet in this study, could represent an adequate level for inducing moderate acidosis. Higher electrolyte balance in birds under stress has been reported to lower FCR due to a reduction in feed intake (de Moraes *et al.*, 2019).

The effect of dietary sodium supplementation on the haematology of growing quails is presented in Table 3. While the Hb remained unaffected, the PCV was lowest ($P<0.05$) at 0.274% of Na supplementation. However, other Na supplementation ranges (0.101% - 0.231% Na) had similar ($P>0.05$) PCV concentrations. Notwithstanding, the PCV values recorded were within the normal range of 31-50% (Schalm *et al.*, 1975) and 7-13 g/dl for Hb (Banerjee, 2009). A strong influence of diet on haematological traits, especially on PCV and Hb, is observed as an indicator of the nutritional status of animals (Kabata *et al.*, 1991). The blood haematology analysis revealed that dietary Na supplementation promoted increasing Hb, PCV and RBC values up to 0.231% Na in the diets.

Table 3: Haematological indices of quails fed diets supplemented with graded levels of dietary sodium salt.

Variables	Units	Na levels, %				
		0.101	0.144	0.187	0.231	0.274
PCV	%	39.25±6.65 ^{ab}	34.25±7.89 ^{ab}	38.25±2.63 ^{ab}	42.50±3.51 ^a	33.50±2.08 ^b
RBC	x10 ⁶ /mm ³	2.21±0.14 ^a	1.73±0.63 ^{ab}	1.86±0.26 ^{ab}	1.95±0.53 ^{ab}	1.45±0.26 ^b
Hb	g/dl	12.47±3.85	9.96±3.09	13.80±2.99	13.55±3.31	10.10±1.19
Heterophil	%	27.00±2.56 ^b	32.50±1.29 ^a	32.25±2.99 ^a	31.25±2.75 ^a	31.00±2.16 ^a
Lymphocytes	%	45.25±4.03 ^{ab}	41.75±1.50 ^{ab}	39.50±1.29 ^b	40.75±0.50 ^{ab}	47.00±7.35 ^a
Monocytes	%	21.75±1.71 ^a	17.75±2.06 ^b	20.50±3.11 ^{ab}	20.50±1.29 ^{ab}	21.50±3.11 ^{ab}
Eosinophil	%	7.25±0.96 ^a	7.00±0.82 ^a	6.75±0.96 ^{ab}	7.50±0.58 ^a	5.50±1.29 ^b
Basophil	%	2.25±0.50	2.25±0.96	1.75±0.50	2.25±0.50	1.75±0.50

^{abc} means with different superscript across the row are significantly different (P<0.05); **PCV**: packed cell volume; **RBC**: red blood cell; **Hb**: Haemoglobin.

Table 4: Carcass characteristics and organ weight (as % of live weight) of quail fed diet supplemented with varied levels of sodium.

Variables	Na levels, %				
	0.101	0.144	0.187	0.231	0.274
Eviscerated wt	96.25±7.67 ^b	108.50±7.86 ^a	108.50±7.85 ^a	99.0±9.58 ^b	96.25±8.93 ^b
Dressing %	90.25±3.30	93.00±1.15	94.25±2.36	91.00±3.16	90.75±10.90
Drumstick	3.00±0.82 ^b	3.00±0.01 ^b	3.25±0.96 ^{ab}	4.00±0.82 ^a	3.25±0.50 ^{ab}
Wing	3.25±0.96	3.00±0.00	3.00±0.00	3.00±0.00	3.00±0.00
Chest	17.75±1.32 ^c	28.25±1.03 ^a	23.75±1.57 ^b	25.75±2.76 ^{ab}	23.00±3.92 ^b
Back	14.50±1.52 ^b	17.00±0.82 ^a	15.50±1.73 ^{ab}	17.75±1.26 ^a	14.74±1.71 ^b
Thigh	4.00±0.41 ^b	6.25±0.95 ^a	4.50±0.73 ^b	5.50±0.73 ^{ab}	4.75±0.50 ^b
Neck	4.50±0.91	4.50±0.29	4.5±0.63	4.75±0.96	4.25±0.50
Liver	3.75±0.50	4.25±1.22	3.50±1.41	3.75±1.26	3.75±0.96
Heart	0.75±0.08	1.00±0.01	1.0±0.01	1.00±0.01	1.00±0.01
Gizzard	4.00±1.15	3.75±0.96	4.25±1.26	4.75±0.50	4.25±0.50

^{abc} means with different superscript across the row are significantly different (P<0.05).

This rise could be attributed to increased F-reticulocytes, erythroid progenitors and F-programmed progenitors induced by Na levels (Constantoulakis *et al.*, 1988). Similar increasing PCV, Hb and RBC levels were reported in quail, fed dietary sodium butyrate (Elnesr *et al.*, 2019). Since the values fall within the normal range, it suffices to say that nutritional adequacy and feed intake were sufficient for normal blood formation. While similar values were reported for the basophil, dietary Na supplementation above the control (0.101%) resulted in a higher (P<0.05) heterophil. The lymphocyte was highest (P<0.05) at 0.274% of Na supplementation, while the control group recorded the highest (P<0.05) monocytes and eosinophil concentrations, respectively. Notwithstanding, all the values obtained for basophil, eosinophil, lymphocyte and monocyte are within the normal range (Mitruka and Rawnsley, 1977). Increased blood neutrophils are usually implicated in acute infection, while parasitic infections are the diagnostic outcome for increased eosinophil (Frandsen, 1986). The low basophil values confirm the statement that they are usually present

in small to moderate numbers in the peripheral blood system (Odeys, 1996).

The effect of dietary sodium supplementation on the carcass characteristic of growing Japanese quail is shown in Table 4. While dietary Na levels were not significant on the dressing %, wing, neck, liver, heart and gizzard, the eviscerated weight was much improved (P<0.05) at 0.144 % and 0.187% of Na. The chest, back and thigh were highest (P<0.05) at 0.144 % and 0.187% Na supplementation. According to Khalilipour *et al.* (2019), a higher amount of total dissolved solids in drinking water results in lower pre-slaughter weight, carcass, and breast yield in quail. However, studies on various types of poultry examining the effects of sodium salt in diet and/or drinking water have reported variable outcomes. The significant effect of dietary sodium salts on eviscerated weight, drumstick, chest, back and thigh disagree with the findings of Dai *et al.* (2009). According to the authors, the carcass yield of the control group was higher than the salt solution treatment groups.

Similarly, El-Deek *et al.* (2010) reported that carcass and breast percentages increased with levels of NaCl in their experiment. However, Erener *et al.* (2002) and Mushtaq *et al.* (2005) reported that different sodium salt consumption levels did not affect birds' carcass traits. Similar to their reports, the dietary sodium salt did not affect Japanese quails' edible organs and dressing percentage in this study. According to Khalafalla *et al.* (1998), variations in carcass traits in response to sodium salt supplementation could be attributed to the route of administration as birds utilize Na more efficiently when presented in drinking water than in diet. Similarly, the intensity of drinking water salinity, age, breed, water salinity intensity, ambient temperature and water requirement, physiological conditions, salt content of the diets and extent of adaptation could account for the variable responses (Yape and Dryden, 2005; Alahgholi *et al.*, 2014).

CONCLUSIONS AND RECOMMENDATIONS

The improved quail performance observed in this study justified increased levels of dietary Na supplementation. The final weight, total feed, and nutrient intake were optimum at 0.187% Na supplementation. The blood haematological parameters, including the PCV, Hb and RBC revealed an increasing trend up to 0.231% of dietary Na supplementation. The carcass parameters, including the eviscerated weight, drumstick, chest, back and thigh, were highest at the dietary sodium supplementation range of 0.187% to 0.231%. Future research could explore varied levels of dietary Na supplementation using deionized water on quail. Similarly, an electrolyte balance study of K⁺, Na⁺ and Cl⁻ on quail could also be explored.

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NOVELTY STATEMENT

The authors have been able to establish the optimum dietary sodium supplementation range during the finisher/egg laying phase. in humid tropical environment.

AUTHOR'S CONTRIBUTIONS

Oluwakamisi F. Akinmoladun: designed the experiment, conducted the experimental field trial, did the laboratory and statistical analysis and wrote the first draft.

Olusegun O. Ikusika: Performed the statistical analysis and reviewed the draft.

Conference T. Mpendulo: Review the draft manuscript.

CONFLICT OF INTEREST

All authors have no conflict of interest.

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