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Influence of water salinity levels on growth performance, sensory evaluation, and meat quality attributes of broiler chicken

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Abstract

This study aimed to determine the effect of saline water on feed and water intake, growth performance, broiler meat quality, and consumer sensory characteristics of birds subjected to varying water salinity levels. Four hundred and ninety-one-day-old commercial Ross unsexed broiler chicks (40.90 ± 0.21 grams) were randomly assigned into seven treatments. Each treatment was replicated seven times, using a one-way factorial design for 42 days. The varying levels of saline water: 0, 0.5, 1, 1.5, 2, 2.5, and 3 g salt/L, which the birds were subjected to, formed the treatment for this experiment. The average daily water intake (ADWI), average daily feed intake (ADFI), water-to-feed ratio (W.F.R.), average daily gain (A.D.G.), and feed conversion ratio (F.C.R.) were estimated weekly, post-mortem pH at 24 h, meat color, and sensory evaluation were determined from the breast muscle of each bird. Water salinity affected the ADWI and ADFI ($P<0.01$). The F.C.R. was only affected by weeks of successive feeding ($P<0.01$). The interaction between water salinity × weeks of successive feeding affected the A.D.G. ($P<0.01$). There was no significant difference ($P>0.05$) among the meat pH and color treatment means. The differences were only observed in consumer sensory evaluation, but no difference ($P>0.05$) was observed in meat taste, Texture, aroma, and toughness.
It can be concluded that alternative water sources with salt levels up to 2g/L can be used to raise broilers since they do not affect growth, consumers' meat characteristics, or sensory evaluation.

Keywords: Water resources, broiler chickens, meat quality, consumer evaluation

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Introduction

Climate variability, increasing water demand due to the rising human population, inefficient water resources management and planning, and droughts, especially in arid and semi-arid regions, have increased the scarcity of good water (Mpendulo *et al.,* 2020; Akinmoladun *et* *al.,* 2023). This has led to the use of poor-quality water for livestock consumption and even sometimes for human consumption in some extreme cases. According to Alamer, (2009), water quality assessment is premised on the presence and amount/quantity of total dissolved salts. Total dissolved salts (T.D.S.) are majorly inorganic salts (principally calcium, sodium, potassium, chlorides, bicarbonates, and sulfates) and small amounts of organic matter dissolved in water. FAO, (2017) stated that water is considered good if it contains less than 2.5 g/L of T.D.S. Unlike ruminants, dissolved solids in water above permissible limits compromise broiler chickens' health and production efficiency (Pourreza *et al.,* 2000). Underground water such as wells, canals, streams, and boreholes, most times usually the hope of farmers, especially in the communal areas during prolonged hot seasons characterizing arid and semi-arid regions, contain more dissolved salts than treated water from the tap (Thiex, 2004).

Drinking water high in dissolved salts may cause physiological upset or even death in chickens (SAPA, 2016). According to Alahgholi *et al.,* (2014), water with less than 1,000 ppm of total dissolved solids posed no danger to any poultry class. However, allowing rearing birds to consume water with high total dissolved solids may affect performance because of osmotic regulation changes and its detrimental impact on the optimal regulation of intracellular macromolecules (Kettunen *et al.,* 2001). According to Sumano *et al.,* (2004), T.D.S. levels over 3000mg/L can cause diarrhea, reduce economic performance, and raise chicken death rates. Some studies have shown that moderate salts in drinking water are acceptable and may replace a portion of Na and Cl in the diets of broilers (Balnave & Gorman,1993; Adalberto *et al.,* 2021). However, Watkins *et al.,* (2005) reported that high levels of Na and Cl in water are toxic to poultry. Likewise, Cheeke (2001) reported that water for poultry with dissolved salts content ranging between 3,000-4,999 ppm would cause watery feces and, at its highest level, will cause mortality. In these circumstances, there is a need to determine the saline water levels conducive to the optimal performance of broiler chicken with good meat quality.

All natural waters contain dissolved salts, and their levels vary depending on the water source (Watkins *et al.,* 2005). Surface water from a mountain watershed may have as little as 0.005 % of salts or dissolved solids (Kellems & Church, 1998). Ocean water averages about 3.5 % of dissolved solids, and in nature, many types of salts lead to water salinity, not only table salt. Farmers in rural areas keeping broilers face problems associated with excess consumption of saline water, including wet litter and associated footpad disorder, poor weight gain, and loose droppings (Watkins *et al.,* 2005). Though sodium is a crucial nutrient influencing average animal growth, consumption beyond the threshold level affects growth performance and causes coccidiosis from anion-cation ratio imbalance (Sakamoto *et al.,* 2014). Excessive water salinity may result in death and subsequent economic losses to farmers keeping chickens (Castro et al., 2009; Khalilipour *et al.,* 2019).

According to Muchenje, (2009), the direct addition of salt to meat alters meat characteristics. Adding salt to meat improves its binding and water-holding capacity (Puolanne *et al.,* 2001). Therefore, the characteristics of meat can be altered by the indirect inclusion of salt in chicken drinking water. However, an imbalance in the osmotic regulations could affect meat quality parameters, including meat color, pH, shear force, water holding capacity, and sensory evaluation (Hughes *et al.,* 2014). Therefore, this study investigated the growth performance, meat quality, and consumer acceptability of broiler meat subjected to varying levels of saline water during rearing.

Materials and Methods

Ethical statement and experimental site

The experiment was conducted per international standards and ethical rules regarding the use of animals for experimental purposes. The study was conducted in the Department of Agriculture poultry unit at the University of Zululand (UniZulu), KwaDlangezwa campus. The farm lies 28°51′11″S and 31°51′01″E, with an elevation of about 300 m above sea level. The annual rainfall ranges from 600 to over 1 400 mm with average temperature conditions of about 26°C (Mucina & Rutherford, 2006; Van der Linden *et al*., 2005). The experiment was conducted in compliance with international standards and ethical rules regarding the use of animals for experimental purposes.

Birds management, housing, and experimental design

Four hundred ninety unsexed Ross strains of broiler chickens were randomly assigned and distributed into seven compartments, each containing ten birds. Each of the seven treatments had 70 birds and was replicated ten times per treatment. Drinking water was supplied at varying salinity levels (0.0, 0.5, 1.0, 1.5, 2.0, 2.5, and 3) g/L, as devised by Cheeke, (1991). All the treatments were subjected to the same environmental conditions. The chicks were reared from day-old to slaughter (42 days of age). The chicks were housed in a low-cost housing unit with automated ventilation and temperatures, with a floor covered with 15 cm thick wood shavings. The wood shavings were kept dry throughout the experimental period by replacing the spoiled litter when required. Infrared lamps (75 watts) were used to heat the birds from day one to the end of the second week. A footbath with disinfectants was made available at the entrance of the poultry unit as a measure of biosecurity. On arrival, the birds were offered water containing vitamin stress packs. The feed was provided two hours later. At the same time, the birds received vaccination for Newcastle disease and Gumboro diseases (Ross, 2018). The birds were fed a starter meal from day old until day 21 and a finisher meal from day 22 to day 42.
Light, water, and feed were provided *ad libitum* throughout the trial. The ingredient and nutrient composition of the feed used in the experiment is shown in (Table. 1). The birds were kept in the seven brooding houses for the rest of the trial. At 42 days, 245 birds were deprived of feed for eight hours before slaughter the following day (35 birds per treatment). Slaughter was done quickly, decapitating the heads from the neck using a sharp knife (Dyubele, 2010).

Table. 1: Nutrient composition of the experimental diet

Ingredients	Starter	Finisher
Maize	435	544.1
Soya bean meal	210	130
Fish meal	30.0	30.0
Soya bean oil	14.6	32.7
Dicalcium phosphate	11.5	11.7
$CaCo_3$	11.9	9.3
Salt	3.1	3.0
Vitamin premix[1]	2.5	2.5

Mineral premix[2]	2.5	2.5
L-Lysine	1.7	1.4
DL-Methionine	1.5	0.7
Calculated nutrient content		
ME (MJ/kg)	12.2	13.1
Crude protein (g/kg)	222	184
Met+cys (g/kg)	8.8	7.6
Methionine (g/kg)	5.3	4.6
Lysine (g/kg)	13.3	10.2
Calcium (g/kg)	9.7	8.5
Non-phytate P (g/kg)	4.4	4.2

Measurements

Growth performance

The average daily water intake was determined by subtracting water refused from that offered to the birds divided by seven over the 6-week experimental period. Water losses through evaporation were catered for by providing two drinkers placed in an empty cage next to where the birds were kept to estimate the evaporation rate (Chikumba & Chimonyo, 2014). Average daily feed intake (ADFI) was determined as the difference between the amount of feed given and the amount of feed that remained at the end of each feeding period divided by seven over the entire 6-week experimental period (Akinmoladun & Falowo, 2021). Feed intake was recorded daily at 08h00 from day 1 to day 42. The water-to-feed ratio (WFR.) was determined as the proportion of water to feed consumed during the 6-week experimental period. Average daily gain (A.D.G.) was determined as the total body weight gained by the chicks over the 6-week experimental period (Ikusika *et al.,* 2020). The A.D.G. was measured over the birds' ages of 7, 14, 21, 28, 35, and 42 days. Body weight gain (B.W.G.) was calculated weekly by subtracting the final body weight from the initial body weight for each bird over the six-week experimental period. The feed Conversion Ratio (F.C.R.) was calculated by dividing the ADFI by the B.W.G. The feed conversion ratio was measured at (7, 14, 21, 28, 35, and 42) days of age.

Slaughter and Measurement

Twenty-one birds were randomly selected for slaughtering from each treatment (three per replicate). They were then fasted for eight hours with water offered ad libitum. They were reweighed individually to obtain live body weight before they were sacrificed by cervical dislocation following electrical stunning at 70 V. After bleeding, scalding, plucking, and washing, the feet, head, and neck were removed. After that, the carcasses were eviscerated manually, cutting the neck and through the respiratory system and removing the esophagus. The carcasses were dissected manually into various parts such as breast muscle, back muscle, drumstick, thigh muscle, wings, legs, and giblets (heart, liver, and gizzard). The parts were weighed using a sensitive scale (Camry electronic scale, made in the USA) and expressed in grams.

Physicochemical properties and meat sensory attributes

Following slaughter, two meat samples were carefully cut from the breast muscle and randomly assigned for physicochemical and sensory attributes). After 30 minutes of blooming, color was measured on the meat surface at room temperature (22.12±1.3oC). Meat instrumental color (lightness, *L**, redness, *a** and yellowness, *b**) was measured after 24 hours of slaughter using a Minolta colour-guide 45/0 BYK-Gardener GmbH machine, with a 20mm diameter measurement area and illuminant D65-daylight, 10o observation angle. Three measurements were taken (average reported for each color) by rotating and replacing the color guide by 90o between each measurement.
The post-mortem pH determination of the meat was analyzed using a pH meter (Lutron pH-200S, Digital instrument). Throughout the experiment, the pH meter was standardized with a solution of 7 pH (neutral) and four pH (slightly acidic), as described by Fletcher *et al*., (1999), Berri *et al*.,(2001), and Dyubele, (2010).
A total of 60 panelists (65% females and 35% males) who were students and staff from the University of Zululand were recruited to take part in the sensory evaluation of broiler breast meat. Panelists were recruited based on their willingness to participate in the study and whether the participant was a steady broiler meat consumer. All participants were adults ranging from 18-65 years. Meat samples from each bird of each treatment (0.00 tap water, 0.5, 1, 1.5, 2, 2.5, and 3g salt/L) were used in the sensory evaluation. Meat from each treatment was cooked separately in pots boiled without adding salt for 25 minutes at a temperature of 75 ^{o}C (adopted from the kitchen fact by Christine Gallary).
Sensory evaluation was done in a well-lit room. Members of the consumer panel (n = 60, age > 18 years) were recruited from the survey participants. To prevent the panelists from influencing each other's responses, panelists were made to face back-to-back in rows of tables and chairs about an arm's length apart. Before testing, the panelists were given a brief explanation about the test to be performed, and the consent form was read to them, and each willing was asked to sign the form. All panelists were given a glass of distilled water, a small dish containing each meat sample, a pencil, and the sensory evaluation questionnaire written in English. The sensory characteristics of meat evaluated by the panelists were taste, Texture, aroma, color, overall acceptability, toughness, and saltiness. Each panelist was presented with seven coded boiled meat samples in a randomized order and asked to rate each sample on a 5-point pictorial hedonic scale where 1 = very bad, 2 = bad, 3 = neither bad nor good, 4 = good, and 5 very good. But for salt, 1= not salty, 2= less salty, 3= not sure, 4= moderately salty, and 5= salty. Panelists were requested to evaluate the samples one at a time from left to right. A table of random numbers was used to assign each sample a unique three-digit code. A table of nine random permutations was used to randomize the serving order of the samples. All the participants were taught how to infer and record scores for each attribute tasted. Each participant completed an evaluation form rating the sensory characteristics of each sample with descriptive scales.

Statistical analysis

Water salinity on water and feed intake, including growth performance, was analyzed using PROC MIXED of S.A.S. (2010). The covariance matrix was chosen using the Akaike information criterion to detect the effects of the leading causes of variation (water salinity level and week of successive feeding) and their interactions. Mean separation was done using

PDIFF. Effects were considered significant if P<0.01. The main effects of saline water, the gender of the participant, the age of the participant, and the participant on the consumer's sensory characteristics were analyzed in the PROC MIXED of S.A.S. model (2010). The model included the impact of the main factors (varying levels of salinity water) and the meat quality with sensory attributes. Tukey's post hoc test with a level of significance P<0.05 was applied to indicate the significance of differences between means and comparisons of means. The effects of salt on pH changes in breast muscle and carcass characteristics were analyzed using Post hoc Turkey's test.

Results

The influence of water salinity on the ADWI, ADFI, and WFR. is shown in (Table. 2). The ADWI and ADFI peaked at 1.5 and 2.0 g salt/L and declined at water salinity levels of 2.5 to 3 g salt/L (*P<0.01*). The W.F.R. was similar across all water salinity levels tested (*P>0.05*). The A.D.G. was the largest at water salinity levels of 1.5 and 2.0 g salt/L and declined at 2.5 to 3 g salt/L (*P<0.01*). The F.C.R. was the same across all water salinity levels tested in the current study (*P>0.05*). The influence of water salinity and the week of successive feeding on the A.D.G. is shown in (Table. 2).

Table. 2: Influence of different water salinity concentrations on ADWI, ADFI, W.F.R., A.D.G., and F.C.R. in broilers

Parameter	**Water salinity (g salt/L)**							**S.E. M.**	***P-value***
	0.0	0.5	1.0	1.5	2.0	2.5	3.0		
ADWI (ml)	388^{bc}	384^{abc}	404^{bcd}	462^{d}	408^{cd}	359^{a}	328^{a}	20.8	0.021
ADFI (g D.M./day)	118^{bc}	117^{bc}	117^{bc}	124^{c}	122^{c}	112^{ab}	107^{a}	3.27	0.043
WFR	0.30	0.31	0.29	0.30	0.31	0.31	0.33	0.04	0.105
ADG (g BW/day)	150^{a}	150^{a}	159^{ab}	177^{c}	170^{bc}	152^{a}	148^{a}	4.86	< 0.01
FCR	0.12	0.12	0.12	0.12	0.11	0.12	0.11	0.01	0.305

abcd Within a row, means with different superscripts are statistically different (P<0.05). ADWI: Average daily water intake, ADFI: average daily feed intake, W.F.R.: Water to feed ratio, A.D.G.: average daily gain, F.C.R.: feed conversion ratio, S.E.M.: standard error of mean

Across the six weeks of the experimental period, the A.D.G. increased with the highest value at water salinity levels of 1 to 2 g salt/L and declined at 2.5 and 3 g salt/L (*P<0.05*). The effect of different water salinity levels did not affect the meat color and pH of broiler chicken (Table. 3)

Table. 3: Effects of saline on meat colour and pH of broilers subjected to varying levels of saline water

Parameters							
	0	0.5	1	1.5	2	2.5	3
L*	56.30±1.94	41.94±11.22	41.51±2.64	54.51±2.92	47.54±2.97	48.01±1.68	49.61±0.83
a*	7.46±1.54	13.14±3.00	9.58 ± 3.19	8.02±1.22	9.30±1.31	9.42±0.20	9.13±0.26
b*	19.98±0.80	15.24±4.15	14.62±3.15	18.80±0.90	15.73±0.87	17.24±1.06	19.60±1.46
pH	5.92 ± 0.05	5.76± 0.05	5.84±0.04	5.81±0.05	5.77±0.04	5.87±0.03	5.82±0.04

The effect of different levels of saline water was not significant (*P>0.05*) on broiler chicken meat sensory attributes, including taste, Texture, aroma, and toughness (Table 4). Although there was no specific direction, water saline levels affected (*P<0.05*) the color, acceptability, and saltiness.

Table. 4: Effect of saline water on meat sensory characteristics from broiler birds

Parameters	0	0.5	1	1.5	2	2.5	3
Taste	3.12±0.13	3.23 ± 0.13	3.38 ± 0.11	3.13±0.15	3.19±0.14	3.12±0.13	3.32±0.13
Texture	3.33±0.12	3.46±0.12	3.43±0.13	3.25±0.14	3.35±0.12	3.63±0.22	3.50±0.10
Aroma	3.37±0.10	3.25±0.14	3.38±0.11	3.37±0.13	3.56±0.13	3.48±0.12	3.31±0.10
Colour	3.47±0.10[a]	3.26±0.13[ab]	3.27±0.12[ab]	3.30±0.14[ab]	3.56±0.13 [a]	3.48±0.12 [a]	3.68±0.10 [ac]
acceptability	3.33±0.12[a]	3.04±0.17[abe]	3.10±0.15[abe]	3.10±0.15[abe]	3.59±0.12[abc]	3.32±0.12[a]	3.57±0.12[a]
Toughness	3.33±0.13	3.19±0.14	3.30± 0.12	3.42±0.11	3.26± 0.13	3.17±0.15	3.54±0.12
Saltiness	1.95±0.15[ad]	1.62±0.14[ac]	1.72±0.13[a]	2.00±0.16[a]	2.40±0.17[abe]	2.11±0.15[abe]	2.20±0.17[abe]

Discussion

Findings that the average daily water intake increased as the water salinity increased were expected. This aligns with the findings of Jankowski *et al.,* (2011), who reported that in fast-growing chickens, an intake of dietary sodium higher than that of N.R.C. (1994) recommendations has a beneficial effect on feed consumption. Olanrewaju *et al.,* (2007) also stated that feed intake might be increased by increasing Na levels in poultry diets due to the physiological functions of sodium as an effective enzyme activator in the body. However, in this current study, the intake of saline water beyond 2.5 g salt/L salt concentration reduced feed intake. This may be due to the loss of appetite because of lesions of the appetite center in the lateral nucleus of the hypothalamus, as well as inflammation in the rectum of birds caused by increased dissolved salt concentration (Baumer-Harrison *et al.,* 2023**)**. The result of a reduction in feed intake and water intake beyond 2.5g salt/L dissolved salt inclusion level was corroborated by Afifi *et al.,* (1992), who reported that feed consumption of broiler chickens decreased at high sodium chloride levels in the drinking waters. A similar growth-reduction effect with high water salinity was reported by Khalilipour *et al.,* (2014). Other factors such as feed quality, age, sex of the bird, and environmental temperatures also affect the feed intake. This negatively impacts the growth of the chickens since feed intake is a tangible measure of productivity indices in livestock. The birds used in the current study showed similar water-to-feed ratios across all treatments and thus indicate the potential of the birds to budget for water for metabolic purposes.

Broilers are expected to reach about 2.5 kg live weight at 42 days of age (Ross, 2018). Such standards are needed to be met to ensure tangible economic returns. Broilers provide maximum feed utilization to achieve such growth standards in many ways. One is using good quality water with sufficient sodium chloride, considering that sodium improves the appetites and nutrient uptake in the intestines, thereby ensuring growth (Maldonado-Valderrama *et al.,* 2011). Across the entire experimental period, the birds yielded the most prominent growth rates with increasing water salinity, demonstrating the ability of birds to utilize saline drinking water to ensure maximum performance. However, it is necessary to regulate salinity levels in drinking water for broilers, as excessive salt in drinking water negatively impacts weight gain and can result in death (Honarbakhsh *et al.,* 2007). Findings that the feed conversion ratio was similar across water salinity levels tested were expected. Chickens convert feed and partition towards various activities such as maintenance and growth (Zuidhof *et al.,* 2014). In the current study, chickens converted feed in the same manner, but the partition of feed became less towards growth; hence, growth was inhibited when water salinity rose beyond 2 g salt per liter of drinking water. Findings from the current study agree with Mushtaq *et al.,* (2005), who reported that increased levels of total dissolved solids did not affect the feed conversion ratio.

The ultimate pH of chicken breast meat recorded in this study was similar across the treatment groups. It has been established that the ultimate pH influences the structure of myofibrils and, consequently, the water-holding capacity and meat color (Castellini *et al*., 2002). The similarity in the pH values may suggest that myofibrilla structure and water-holding capacity were not compromised. The similarity in the meat color indices in this study confirms that saline water did not affect meat quality. The study conducted in the Netherlands failed to show any significant relationship between broiler breasts. Sensory characteristics of broiler chicken meat subjected to varying levels of saline water overall had no significant effects on most sensory characteristics. However, broiler chicken meat received higher consumer sensory scores in all treatments. Although flavor is a complex attribute of meat palatability (Calkin & Hodgen, 2007), it depends on the quantity and composition of fat in the meat (Muchenje *et al*., 2009). Age and gender affected meat acceptability; older people showed a very positive acceptance of meat compared to young people (Mtolo *et al.,* 2022). Few studies have been done about the effect of age and gender, but it is usually associated with being choosy (Dyubele *et al*., 2010).

Conclusions

Varying water salinity levels influence water and feed intake and growth performance, but this largely depends on a certain salinity level. In contrast, there were no differences in the meat quality (pH, color, and consumer acceptability) in the broiler breast meat subjected to varying levels of saline water. Water salinity levels greater than 2.0 g salt/L inhibit the average daily feed intake, average daily water intake, water-to-feed ratio, and average daily gain. In contrast, the feed conversion ratio was not affected. Water with high salt levels negatively impacted growth, making 2.0g salt/L the optimum salt inclusion level in drinking water for broilers to ensure maximum growth performance. Therefore, alternative water from lakes, dams, and rivers can be used to raise the broilers because it does not affect meat quality and consumer sensory evaluation. Still, the salinity level should not exceed 2.0g salt/L to guarantee optimum performance.

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Ethical statement

Routine care and experimental protocols used in this study conformed to published guidelines for ethical conduct and reporting of research in Animal Science (Jarvis *et al.,* 2005; Kilkenny *et al.,* 2010).

Author's contribution

Author Contributions: Mpendulo-Conceptualization, Investigation, writing original draft, Methodology, Validation, Formal analysis, Project administration, Supervision, Data curation Ikusika-Writing - review & editing, Validation, Methodology, Project administration, Supervision, Data curation, Resources. Akinmoladun-Writing - review & editing, Formal analysis, Supervision, Validation.

Data Availability Statement

Data for this study are available on request.

Conflict of interest

The authors report no conflict of interest.

References

Adalberto SA, Jordânio IM, Patricia GL and Dermeval AF. (2021). Productive and hematologic responses of country poultry subjected to different housing densities and water salinity levels. Poultry Science. 100 (5):101070. https://doi.org/10.1016/j.psj.2021.101070

Afifi M, Maie FA and Abdel-Maksoud AM. (1992). Salt stress in broiler chicks: 1. Report: effect of salt stress on some productive traits in broiler chicks. Archiv fur Geflugelkunde 56:124-128

Akinmoladun, OF and Falowo, AB. (2021). Energy manipulation of isonitrogenous diets for broiler chickens. South African Journal of Animal Science. 51(1).

Akinmoladun OF, Mpendulo, CT and Ayoola, MO. (2023). Assessment of the adaptation of Nguni goats to water stress. Animal. 17 (8):100911.

Alahgholi M, Tabeidian SA, Majid Toghyani M, Fosoul SS. (2014). Effect of betaine as an osmolyte on broiler chickens exposed to different water salinity levels. Archiv Tierzucht. 57: 4, 1-12.

Balnave D and Gorman I. (1993). A role for sodium bicarbonate supplements for growing broilers at high tem peratures. Worlds Poult Sci J. 49:236-241.

Baumer-Harrison C, Breza JM, Summers C, Krause EG, and de Kloet AD. (2023). Sodium intake and disease: Another relationship to consider. Nutrients. 15(3):535.

Berri C, Wacrenier N, Millet N and Le Bihan-Duval E. (2001). Effect of Selection for Improved Body Composition on Muscle and Meat Characteristics of Broilers from Experimental and Commercial Lines. Poultry Science. 80:833–838.

Bianchi M, and Fletcher DL. (2002). Effects of Broiler Breast Meat Thickness and Background on Color Measurements. Poultry Science. 81:1766–1769.

Bihan-duval E, Millet N and Remigno NH. (1999). Effect of Selection for Increased Carcass Quality and Estimates of Genetic Parameters: Broiler Meat Quality. Poultry Science. 78:822–826.

Brewer MS. (2009). Irradiation effect on meat flavour: A review. Meat Science. 81:1-14.

Calkins CR, Hodgen JM. (2007). A fresh look at meat flavour. Meat Science. 77:63-80.

Castellini C, Mugnai C, Dal Bosco A. (2001). Effect of organic production system on broiler carcass and meat quality. Meat Science. 60:219–225.

Cheeke PR. (1991). Applied animal nutrition: feeds and feeding. Macmillan Publishing; Collier Macmillan Canada, New York, NY

Church DC, Pond GW. (1987). Basic animal nutrition and feeding, 4th edn. Albany Printing Company, USA. 38-40.Collect SR. 2011. Nutrition and Wet Litter Problems in poultry. Animal Feed Science and Technology.173: 65-75.

Dyubele NL, Muchenje V, Nkukwana TT and Chimoyo M. (2010). Consumer sensory characteristics of broiler and indigenous chicken meat: A South African example. Food quality and preference. 21:815-819.

Fletcher DL. (1999). Broiler Breast Meat Colour Variation, pH, and Texture. Processing and products. Poultry Science. 78:1323–1327.

Honarbakhsh SS, Zaghari M and Shivazad M. (2007). Can exogenous betaine be an effective osmolyte in broiler chicks under water salinity stress? Asian-Australasian Journal of Animal Sciences. 20(11):1729-1737.

Hughes JM, Oiseth SK, Purslow PP and Warner RD. (2014). A structural approach to understanding the interactions between colour, water-holding capacity and tenderness. Meat science. 98(3):520-532.

Ikusika OO, Falowo AB, Mpendulo CT, Zindove TJ, Okoh AI. (2020). Effect of strain, sex, slaughter weight on growth performance, carcass yield, and broiler meat quality. Journal of Open Agriculture. 5 (1): 607-616.

Julian RK. (1993). Ascites in poultry, Avian Pathology. 22: 419-454.

Kalimuthu S and Kadirrel RK. (1987). Water quality and chick growth. Indian J Poult Sci 16:15-21.

Kellems RO and Church DC. (1998). Livestock feeds and feeding. 4th ed., Prentice Hall, NJ, USA.

Kettunen H, Peuranen S and Tiihonen K. (2001). Betaine aids in the osmoregulation of broiler chicks' duodenal epithelium and affects water's movement across the small intestinal epithelium in vitro. Comp Biochem Physiol A Mol Integr Physiol 129: 595-603.

Mottram DS. (1998). A review: Flavour formation in meat and meat. Food Chemistry. 62: 415-424.

Mpendulo CT, Akinmoladun OF, Ikusika OO, and Chimonyo M. (2020). Effect of hydric stress on Nguni goats' intake, growth performance, and nutritional status. Italian Journal of Animal Science. 19(1):1071-1078

Muchenje V, Dzama K, Chimonyo M, Strydom PE, Hugo A and Raats JG. (2008). Sensory evaluation and its relationship to physical meat quality attributes of beef from Nguni and Bonsmara steer raised on natural pasture. The Animal Consumption. 2-11.

Muchenje V, Dzama K, Chimonyo M, Strydom PE, Hugo A and Raats JG. (2009). Relationship between pre-slaughter stress responsiveness and beef quality in three cattle breeds. Meat Science. 81: 653-657.

Muchenje V, Dzama K, Chimonyo M, Strydom PE, Hugo A and Raat JG. (2008). Some Biochemical aspect pertaining to beef eating quality and consumer health: A review. Food Chemistry. 112: 279–289.

Mucina L and Rutherford MC. (2006). The Vegetation of South Africa, Lesotho and Swaziland, Strelitzia 19. South Africa National Biodiversity Institute, Pretoria.

National Research Council(N.R.C.). (2007). Nutrients and Toxic Substances in Water for Livestock and Poultry. National Academy of Sciences, Washington, DC., USA.

Ndlebe S, Mpendulo CT, Xazela N and Buthelezi LS. (2017). Influence of water salinity on meat quality attributes and sensory characteristics of broilers. Proceedings in 50th South African Society for Animal Science Congress. 18th – 21st September, 2017, Port Elizabeth, Eastern Cape Province, South Africa

Pourreza J, Nasrollahi H, Samie AH, Mohammad alipour M and Assadian A. (2000). The effects of total dissolved solids (T.D.S.) on performance of broiler chickens. Journal of Science and Technology of Agriculture and Natural Resources. *3*(4):71-82.

Puolanne EJ, Ruusunen MH and Vainionpaa JI. (2000). Combined effects of NaCl and raw meat pH on water-holding in cooked sausage with and without added phosphate. Meat Science. 58 (2001): 1-7.

Raes K, Balcean A, Dirinck P, De Winne A, Claeys E, Demeyer D and De Smet S. (2003). Meta quality, fatty acid composition and flavour analysis in Belgian retail beef. Meat Science. 65 (2003): 1237-1246.

Ross .2018. Ross Broiler Management Handbook. www. Aviagen.com (accessed 20/12/2022).

South Africa Poultry Association (SAPA). (2016). The South African Poultry Industry Profile, Statistics South Africa: STATSA, [Online] Available from: http://www.sapoultry.co.za [Accessed: 20 December 2021].

Tseng AT, Liu BD, Chen M. (2000). Evaluation of transglutaminase on the quality of low-salt chicken meat-balls. Meat Science. 55 : 427-431.

Watkins SE, Fritts CA, Yan F, Wilson ML, Waldroup PW. (2005). The Interaction of Sodium Chloride Levels in Poultry Drinking Water and the Diet of Broiler Chickens. J Appl Poult Res. 14: 55-59.

Van der Linden JP, Siebert SJ, Siebert F, Ferreira DP and Bredenkamp GT. (2005). Vegetation of the Owen Sithole College of Agriculture in Zululand KwaZulu-Natal, Koedoe. 48: 33–56.

Zuidhof MJ, Schneider BL., Carney VL, Korver DR, and Robinson FE. (2014). Growth, efficiency, and yield of commercial broilers from 1957, 1978, and 2005, Poultry Science. 93(12):2970-2982.