CARCASS CHARACTERISTICS AND MEAT QUALITY OF BROILER CHICKEN FED DIETS WITH DIFFERENT SALT INCLUSION LEVELS

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Abstract
This study aimed to evaluate the effect of different salt inclusion levels on carcass characteristics and meat quality of broiler chickens. A total of one hundred and forty-four (144) day-old chicks were used. The birds were divided into four treatment groups and each subdivided into three replicates with twelve (12) birds per replicate. Four experimental diets (D_1, D_2, D_3, D_4) were formulated. D_1 (0.00 % common salt level) served as the control, D_2 contained 0.25% common salt, D_3 contained 0. 50% common salt, and D_4 contained 0.75% common salt both at the starter and finisher phases. Each treatment group was assigned to one of the four (4) experimental diets in a completely randomized design. The experiment lasted for eight weeks. Broilers fed the 0.75 % salt diet were significantly higher ($p<0.05$) in liveweight and carcass weight than birds fed the lower salt diets. Thigh and drumstick percentages were least and percentages of gastrointestinal tract, full gizzard, empty gizzard, and liver were highest ($p<0.05$) in birds fed the 0.00 % salt diet. Ether extract from muscles were very low in birds fed the 0.00 % diet compared to counterparts fed the other treatment diets ($p<0.05$). Water holding capacity and drip loss showed significant differences ($p<0.05$) across treatments. Birds on D_3 were juicer, more tender, and more flavored with higher hedonic scores, and were closely followed by birds on the D_4. It was concluded that increase in dietary common salt level up to 0.75 % in broiler diets improved liveweight, carcass characteristics, and organoleptic quality.
Keywords: **Broiler Chickens, Salt, Carcass Characteristics, Organoleptic Quality**

Introduction
The adequate provision of the major minerals in appropriate balance is very important for optimal production of broilers. These minerals greatly influence growth, feed efficiency, bone development, leg health, nerve function and the immune system (Mushtaq, 2010). Among these minerals, sodium has very important physiological functions. Borges *et al*. (2004) observed that sodium has beneficial influence on feed consumption and the rate of liveweight gain of birds. Lata & Mondal (2021) indicated that sodium and chloride are the main electrolytes that support the preservation of the electrochemical gradient in cellular membranes. They play an important role in the acid-base balance because cations are alkalogenic and anions are acidogenic (Wang *et al*., 2019). Several physiological processes such as tissue protein synthesis and enzyme activity require adequate sodium intake for proper functioning (Olanrewaju *et al*., 2007). Owing to the importance of salt as an ingredient in the poultry diet, the National Research Council (NRC,1994) recommended the supplementation with 0.20% and 0.15% of sodium chloride in broiler diets for 0-3 and 4-6 weeks of age, respectively. However, Koreleski *et al*., 2010) showed that at a high level of dietary potassium and a moderate level of dietary chloride, the sodium requirements for adequate chicken performance equaled 1.2-1.7 and 1.25-1.6 g/kg in the starter and grower period, respectively. In the same vein, Oviedo-Rondon *et al*. (2001) and Mushtaq *et al*. (2007) observed improved growth performance of chicken when the sodium content of the feed was increased to 0.2-0.3% which is above the National Research Council (1994) recommendation. Researchers have observed the positive impact of elevated dietary Na levels on feed intake, and consequently, the growth rate of broilers (Watkins *et al*., 2005; Mushtaq *et al*., 2007). Jankowski *et al*. (2012) observed that characteristics of meat and carcasses were somewhat impacted by salt (NaCl) when compared with $NaHCO_3$, as it boosted breast yield in turkeys, whereas sodium deficiency reduced feed utilization and growth rate. Moreover, alternative sodium sources to NaCl increase feed utilization but may have negative effects on breast muscle characteristics (Jankowski *et al*., 2012). However, in a more recent study it was reported that a high-salt diet was harmful to gut health, by causing aggravation of tissue inflammation and autoimmune diseases (Yi *et al*., 2015). Moreover, prior evidence existed suggesting that high-salt diets may cause epithelial proliferation, apoptosis, and altered cellular types (Xiao *et al*., 2005). Due to regular changes in the genetics of broilers because of the unending commercial need to produce fast-growing broilers, there is the need to re-evaluate salt inclusion levels on meat characteristics. Presently, information on the effect of dietary salt inclusion on carcass characteristics and organoleptic quality of broilers is scarce. The objective of this study was to determine the effects of different salt inclusion levels on carcass characteristics and meat quality of broilers.

Materials and Methods
Experimental Diets
Four diets (D_1, D_2, D_3, and D_4) were formulated for each of the starter and finisher phases. They contained 0.00%, 0.25%, 0.50% and 0.75% common salt (NaCl), and replaced the corresponding weight of maize, respectively. The percentages of all other

ingredients were the same across the four dietary treatments. Diets were formulated to satisfy nutrient requirements stipulated for poultry (NRC, 1994).

Table 1: Ingredient composition of the starter diets

Ingredients	Diet 1	Diet 2	Diet 3	Diet 4
Maize	54.00	53.75	53.50	53.25
Soya bean meal	21.75	21.75	21.75	21.75
Palm kernel cake	10.00	10.00	10.00	10.00
Wheat offal	5.00	5.00	5.00	5.00
Bone meal	3.00	3.00	3.00	3.00
Lysine	0.60	0.60	0.60	0.60
Methionine	0.40	0.40	0.40	0.40
Vit|TM	0.25	0.25	0.25	0.25
Salt	0.00	0.25	0.50	0.75
Total	100	100	100	100
Calculated values(%)				
ME (Kcal/kg)	2833	2824.5	2816	2807
Crude protein	21.25	21.25	20.98	20.96

* Provides the following per kg of feed: Vitamin-mineral premix (2.5 kg/1000 kg); vitamin A (10,000,000 IU), vitamin D3 (3,000,000 IU), vitamin E (30,000 IU), vitamin K (2.3 g), vitamin B1 (2.0 g), Riboflavin (5.0 gr), Pyridoxine (3.0 g), vitamin B12 (160 mg), Biotin (60 mg), Niacin (31 g), panthotenic acid (8 g), folic acid (1 g), manganese (85 g), zinc (50 g), iron (25 g), copper (6 g), iodine (1 g), selenium (120 g), cobalt (220 mg), antioxidant (125 g), choline chloride (200 g).

Table 2: Ingredient composition of the finisher diets

Ingredients	Diet 1	Diet 2	Diet 3	Diet 4
Maize	50.75	50.50	50.25	50.00
Soya bean meal	18.00	18.00	18.00	18.00
Palm kernel cake	18.00	18.00	18.00	18.00
Wheat offal	5.00	5.00	5.00	5.00
Fish meal	4.00	4.00	4.00	4.00
Bone meal	3.00	3.00	3.00	3.00
Lysine	0.60	0.60	0.60	0.60
Methionine	0.40	0.40	0.40	0.40
***Premix**	0.25	0.25	0.25	0.25
Salt	0.00	0.25	0.50	0.75
Total	100	100	100	100
Calculated values(%)				

ME (Kcal/kg)	2820	2812	2803.5	2795
Crude protein	19.46	19.44	19.41	19.39

* Provides the following per kg of feed: Vitamin-mineral premix (2.5 kg/1000 kg); vitamin A (10,000,000 IU), vitamin D3 (3,000,000IU), vitamin E (30,000 IU), vitamin K (2.3 g), vitamin B1 (2.0 g), Riboflavin (5.0 gr), Pyridoxine (3.0 g), vitamin B12 (160 mg), Biotin (60 mg), Niacin (31 g), panthotenic acid (8 g), folic acid (1 g), manganese (85 g), zinc (50 g), iron (25 g), copper (6 g), iodine (1 g), selenium (120 g), cobalt (220 mg), antioxidant (125 g), choline chloride (200 g).

Management of Experimental Birds and Experimental Design

A total of one hundred and forty-four (144) day-old unsexed broiler chicks were used for the experiment. The birds were allotted to four treatment groups, with three replicates, and each replicate contained 12 birds in a completely randomized design (CRD). Each treatment group was assigned to one of the experimental diets. All replicates were housed in a pen of similar dimension (4x4ft). Feed and water were provided *ad libitum* for the period of the experiment. Fresh and clean wood shavings were used as litter material over a concrete floor and changed regularly. All necessary vaccinations and other conventional management practices were administered to the birds following the Operating Guidelines in the Teaching and Research Farm, Federal University of Technology, Owerri.

Slaughter of Birds and Determination of Carcass and Internal Organ Weights

At the end of the finisher phase, two birds whose live weights were close to the mean of each replicate were selected, starved of feed for 12 hours, and slaughtered. After exsanguination, the carcasses were scalded in hot water, dressed and eviscerated. The carcass weight was individually determined and the dressing percentage was calculated as the percentage of the carcass weight based on the live weight. The carcass was then portioned following the method described by (Okeudo *et al.*, 2005). The internal organs were carefully separated and weighed. The carcass cuts and internal organs were expressed as percentages of the live weight.

Meat Quality

Water Holding Capacity

The Water Holding Capacity (WHC) was determined as described by Okeudo *et al.* (2007). About 10 g of samples were cut from the left drumstick, weighed (W_0), and wrapped individually with a paper towel. Each sample was crushed in a screw jack. Moisture squeezed out by the crushing process was absorbed by the paper towel and thereafter the residual meat sample was carefully recovered and weighed (W_1).

WHC (%) = $((W_0 - W_1)/(W_0) \times 100$

Cooking Loss

About 40 g samples from the left thigh muscle were cut from each carcass, weighed (W_0) and wrapped in a transparent polythene bag and labeled. These were cooked for 20 minutes under steam. Afterward, samples were cooled and dried with a paper towel and reweighed (W_1).

Cooking loss ((%) = $((W_0 - W_1)/(W_0) \times 100$

Drip Loss

After the broilers were dressed, the left drumstick of each carcass was weighed (W_0) and kept sealed in a plastic container and labeled. The muscles were kept in the refrigerator (7-10 ˚C) for 72 hours. After that, each drumstick was thoroughly wiped with a paper towel and re-weighed (W_1). The difference between the initial weight and the final weight was taken as the drip loss. This was expressed as a percentage of initial weight.

Drip loss (%) = $((W_0 - W_1)/(W_0) \times 100$

Measurement of Ether Extract and Moisture Content

Analyses for proximate composition were undertaken following the methods of AOAC (2000). Another 10 g sample was cut from the left drumsticks of each treatment. These were dried in the oven at 75 ˚C and then ground into a powder. Determination of ether extract values was done using the Soxhlet type of the direct solvent extraction method. The solvent used was petroleum ether (boiling range 40 – 60 ˚C) and extraction carried out for four hours. At the end of extraction, the solvent was evaporated and the flask dried in the oven (at 60 ˚C). Moisture content was determined through oven drying at 105 ˚C for three hours.

Organoleptic Properties

Organoleptic quality/ sensory evaluation was done after 48 hours of refrigerated storage (7-10˚C) of samples. About 50g of samples were cut from the right drumstick of each carcass and labeled. Thereafter, each sample was wrapped in a polythene bag and cooked under steam for 30 minutes. Samples were cooled to ambient temperature and kept in stainless steel food containers. Organoleptic evaluation was carried out using a panel of assessors drawn from the 500-level students of the Department of Animal Science and Technology of the University. The panelists were trained in basic sensory assessment and instructed to evaluate the samples using the 9-point rating scale as described by Sanwo *et al.* (2011).

Statistical Analysis

All data collected for different parameters were subjected to analysis of variance for the completely randomized design. Significantly different means were determined based on the least significant difference test. Computations were carried out using the Minitab Statistical Package.

Results

Carcass and Internal Organ Weights

The carcass characteristics of the experimental birds are shown in Table 3. Live weights and carcass weights were significantly higher ($p<0.05$) in birds fed the 0.75 % salt diet than in birds fed the lower salt diets. However, dressing percentage was higher in birds fed the 0.00 % salt diet than counterparts fed diets supplemented with common salt ($p<0.05$). Indicators of muscularity, such as thigh and drumstick percentages were least ($p<0.05$) in birds fed the saltless diet (0.00 % salt), but these same birds recorded the highest percentages ($p<0.05$) in most internal organs (GIT, full gizzard, empty gizzard, and liver).

Table 3: Effects of different levels of dietary salt on carcass characteristics and percentage organ weights of broiler chicks.

Parameter	0.00%	0.25%	0.50%	0.75%	SEM
Liveweight (g)	1676.60^c	1902.00^b	1902.00^b	1982.60^a	9.87
Carcass weight (g)	1236.50^c	1301.00^b	1378.20^a	1409.40^a	6.48
Dressing Percentage	73.54^a	68.29^c	72.46^a	71.09^b	0.18
Head	2.70^a	2.60^b	2.60^b	2.30^c	0.01
Neck	4.70^a	4.10^c	4.50^b	4.40^b	0.02
Shank	4.00^a	4.10^a	3.90^b	4.00^a	0.01
Thigh	28.30^c	31.10^a	31.00^a	30.00^b	0.01
Drum stick	11.00^c	11.40^b	11.30^b	11.60^a	0.02
Wings	4.70^a	4.50^b	4.50^b	4.30^c	0.01
GIT	6.80^a	5.30^b	5.50^b	5.80^b	0.07
Gizzard full	5.00^a	4.40^b	4.00^c	4.00^c	0.34
Gizzard empty	3.70^a	3.00^b	3.20^b	2.60^c	0.34
Liver	2.30^a	1.70^c	1.70^c	2.00^b	0.03
Heart	0.40^b	0.50^a	0.40^b	0.40^b	0.00

^{abc} Means within the same row bearing different superscripts are significantly different ($P<0.05$).

Meat Quality

Table 4 shows that salt inclusion level had no significant effect on moisture content and cooking loss of muscles ($p>0.05$). Rather, WHC was significantly higher and ether extract significantly lower in the muscle of broilers fed the 0.00 % diet compared to broilers fed the 0.25 %, 0.50 %, and 0.75 % diets ($p<0.05$). The results of sensory evaluation of meats from birds fed different levels of dietary salt are shown in Table 3. Panelists scored the meat from birds fed the 0.50 % salt diet as the juiciest, most tender, and most liked compared to others ($p<0.05$), whilst the meat from broilers fed the 0.75 % salt diet was rated the most flavored and least in off-flavor intensity ($p<0.05$).

Table 4: The effect of different salt inclusion levels on the meat quality of broiler chicks

Parameter	0.00%	0.25%	0.50%	0.75%	SEM
Water holding capacity	1.31^a	0.61^b	0.86^b	0.79^b	0.16
Cooking loss	6.50	6.50	6.50	7.33	0.83
Drip loss	2.93^b	2.91^b	4.25^a	2.83^b	0.41
Ether extract	0.42^b	7.52^a	7.51^a	6.73^a	0.55
Moisture content	69.57	68.30	69.98	65.66	1.74

^{abc} Means within the same row bearing different superscripts are significantly different ($P<0.05$)

Table 5: The effect of different salt inclusion levels on organoleptic qualities.

Parameter$^+$	0.00%	0.25%	0.50%	0.75%	SEM
Juiciness	5.60^b	5.00^b	6.90^a	6.10^b	0.46
Tenderness	5.60^b	5.50^b	7.40^a	6.80^a	0.36
Connective tissue	6.00	5.20	6.10	6.90	0.62
Flavor	5.50^b	4.40^b	5.80^a	6.00^a	0.45
Hedonic Score	5.80^a	5.10^b	6.40^a	6.00^a	0.41
Off-flavor characteristics	5.13	5.00	5.75	4.75	0.45
Off-flavor intensity	5.13^a	5.50^a	4.38^a	3.38^b	0.55

[a,b,c] Means within the same row bearing different superscripts are significantly different ($p<0.05$)
[+]9 - extremely tender/juicy / flavored / like extremely / off-flavored; 8 - very tender /juicy/ flavored / like very much / highly off-flavored; 7 - moderately tender/juicy / flavored / like moderately / off-flavored; 6 - slightly tender/juicy / flavored / like slightly / off-slightly / off-flavored; 5 - neither tender nor tough /juicy nor dry / flavored nor unflavored / like nor dislike / off-flavored nor not off-flavored; 4 - slightly tough/dry/unflavored / dislike slightly / not off-flavored; 3 - moderately tough/dry/unflavored / dislike moderately / not off-flavored; 2 - very tough/dry/unflavored / dislike very much / highly not off-flavored; 1 - extremely tough/dry/unflavored / dislike extremely / not off-flavored.

Discussion

In this study (Table 3), birds fed diets containing no dietary salt (0.00%) had significantly lower life weight, reduced muscularity, and higher weights of the internal organs compared to their counterparts fed diets supplemented with common salt. This is possibly due to low feed intake and lower weight gain. Yu & Robinson (1992) reported that malnutrition manifests itself in a decrease in total muscle weight accompanied by an increase in the relative weights of internal organs. This shows that the inclusion of salt in poultry diets improves palatability. In addition, the essentiality of NaCl in the physiologic control of acid-base balance (Wang *et al*., 2019), tissue protein synthesis, and enzyme activity have been reported (Olanrewaju *et al*., 2007). Thus, the effects of dietary salt levels in animal growth and development go beyond issues of palatability of feed, and more importantly, include modulations on critical internal physiology. Nonetheless, significant differences in internal organ weights may not be due to differences in dietary salt alone, since it has been observed for a long time that the weights of internal organs are inversely related to bodyweights even among animals fed the same diet with adequate salt level (Lawrie, 1991).

Although diet-related differences in moisture content in muscles were not significant, broilers fed diets containing 0.00% salt inclusion level had significantly higher ($p<0.05$) water-holding capacity than counterparts fed other diets (Table 4). A notable observation is the extremely low ether extract level in birds fed the 0.00 % salt diet, which is 5.79% of the average of the other treatments fed the 0.25 %, 0.50 %, and 0.75 % salt diets. This is in line with the findings of Mushtaq *et al*. (2007) that a deficiency of dietary sodium chloride resulted in lowered abdominal fat. The significantly higher WHC of the birds likely fed the 0.00 % salt diet is due to the very low internal fat value. Meat with very low marbling may be unable to hold back meat juice during the crushing process used in measuring WHC. The observed similarity in the values for cooking loss across the four dietary treatments ($p>0.05$) may be due to the similarity in the values for moisture content ($p>0.05$). These are in tandem with Okeudo & Moss (2005) who reported that cooking loss was positively correlated with moisture content as well as Crouse & Koohmaraaie (1990) who had earlier concluded that the release of juice from meat by heating is directly proportional to the hydration of the raw meat.

The results of sensory/organoleptic qualities of meat samples from birds fed the diet containing 0.50% and 0.75% salt inclusion levels were judged by the panelist to be juicer, more tender better flavored as well as higher in the degree of likeness (hedonic rating) on a nine-point category rating than meat from birds fed 0.00% and 0.25% dietary salt inclusion levels (Table 5). Organoleptic quality is strongly associated with a degree of marbling (Lawrie, 1991). In addition, higher salt levels in the meats of birds fed the 0.50 % and 0.75 % salt diets may have contributed positively to the higher eating quality.

Conclusions

This present study showed that increasing dietary salt levels up to 0.75% resulted in better growth performance, carcass characteristics, and organoleptic quality of broilers.

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