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Water quality on broiler farms in Southwestern Nigeria and its impact on performance, meat quality and safety

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Abstract
The aim was to comprehend from field survey of broiler farms with different water sources which water quality indicator(s) affect broiler meat production. The classes for the water quality indicators were: (a) Low, (b) Medium (c) High. Performance criteria were: body weight at market (kg), age at market weight (days) and price at market weight (?). Commonly used water sources by broiler farmers in Ekiti and Oyo states were water from wells (54.4%) and boreholes (29.1%). Tested borehole-water samples in the two states had 0.02mg/l of Iron concentration being undesirable (Low) compared to 0.2mg/l Iron in the "Drinking Water Quality Standard for Poultry" (DWQSP). The Lead concentration in the well-water of the two states had 0.04mg/l being undesirable (High) compared to 0.02mg/l in DWQSP. The bacteria for borehole (3.26 cfu/ml) and well-water (0.9 cfu/ml) were desirable (Medium) compared to 10^2 cfu/ml in DWQSP. The fresh skin and flesh (meat) of broiler carcasses had $<10^3$ cfu/g (*Salmonella* and *E. coli* counts) and $<10^5$ cfu/g (Total plate count) within the acceptance limits. The tested water samples from wells and boreholes had ($p<0.0001$) positive correlations among the performance criteria. The correlation (R= 0.76) between price at market weight and body weight at market indicated significant economic value placed on broilers with heavier body weight irrespective of the Water source, its Iron, lead and bacterial concentrations as water quality indicators.

Keywords: Average acceptance level; Body weight at market, Broiler farms, Meat quality and Water sources

Introduction
An important dietary requirement in broiler production is drinking water since broiler consumes by weight an approximately 1.6 to 2.0 times as much water as feed (Fairchild *et al.,* 2006). Also, it is noteworthy that water being the most essential nutrient in poultry is consumed on a weight basis of approximately 1.8g of water for every gram of feed consumed (Pest *et al.,* 1985). The increasing importance of water quality issues in the poultry industry can be seen in its use for production and processing. Water sources (borehole, well, stream, spring and tap) on the broiler farms in these two states which is also use in practice is the harvesting of rainwater (Ajuwon *et al.,* 2002).

Broiler farmers in Ekiti and Oyo states (Southwestern Nigeria) are in the rainforest and derived savannah agro ecological zone where water from well and borehole serve as sources of drinking water for broiler meat production and processing.

Besides, being a critical nutrient that receives little attention until a problem arises; it use in processing is also an important aspect since poor product quality and safety will affect product sales and may pose health risks to humans. Contaminants (microorganisms and chemical elements which could be from agro-chemical and pesticides) in drinking water and water use for processing can leave residues in poultry products (meat and eggs) which adversely affect product sales and may pose health risks to humans (Garcia e*t al.,* 2010).

Water for food (broiler meat) production, needs to be managed in both quantity and quality. Asides, scarcity of water which is a constraint (in dry season); there are other issues of water quality on the broiler farms in these two states more related to broiler production, processing and product quality safety and these includes the presence of bacteria and other microbes, the levels of minerals that occur naturally in the water, and other inclusions from agro-chemical like herbicide and pesticides which could influence broiler performance, the meat quality and product safety. The presence of bacteria and other microbes, the level of minerals that occur naturally (Chloride, Copper, Iron, Lead, Sodium, Sulphate) in the water, other inclusions from agro-chemical like herbicides and pesticides are factors that predicts water quality obtainable on broiler farms (Barton, 1996 and Blake, 2001).

The use of Geographic Information System (GIS) in animal production helps in understanding the concept of location with a view to identifying the agro-ecology and optimizing production in areas where necessary interventions are required (Omodele, *et al.,* 2014a).

Thus, increases in broiler production in the Southwestern Nigeria call for assessing the quality of water use on the farms. This study aimed at assessing from field survey indicator(s) of water quality on broiler farms that could have impacts on performance, meat quality and safety in broiler production with a view to providing database on location for broiler farms in the Southwestern Nigeria.

Materials and Methods

Study area: The study was conducted in Ekiti (which is under Rainforest ecology) and Oyo State (under Southern Guinea Savannah, derived Savannah and Rainforest ecologies) in the Southwestern part of Nigeria. The zones covered in Ekiti were Aramoko, Ikere and Ikole while in Oyo state it was Ibadan zone (which comprises of Ibarapa North, Ibarapa East, Ibarapa Central, Ido, Akinyele, Lagelu, Egbeda, Ona Ara and Oluyole) in the Rainforest/Savannah transition agro-ecology.

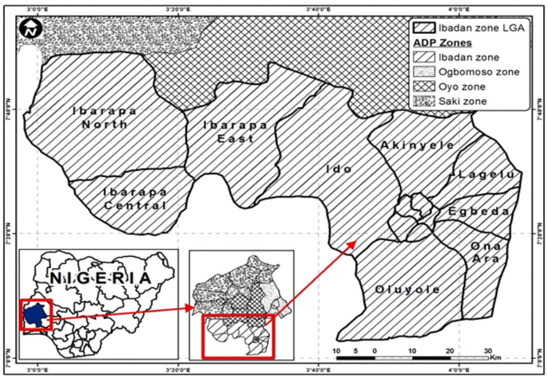

Figure 1a. Oyo state and its local government areas

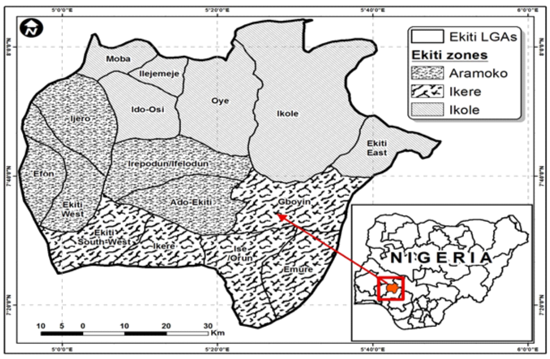

Figure 1b. Ekiti state and its local government areas

Field based questionnaire survey of broiler farms

A total of 250 questionnaires were administered with 120 questionnaires each for the two states administered through the Agricultural Development Programme (ADP). The questionnaires administered through personal interview were 10 in total with each state having 5. The total number of questionnaire returned through personal interview and the ADP officers in the two states amounted to seventy-nine (79) broiler farmers, with 41 for Ekiti and 38 for Oyo state. The questionnaire structure helped to capture information on Production system, water sources, environmental management practices and growth performance. Information on Production systems includes: management system adopted (intensive, semi-intensive and extensive systems); housing system adopted (deep litter and battery cage); breed of broiler raised and the flock size. Feed resources used such as broiler starter, growers mash and broiler finisher. Information on Water sources includes: the sources of water use on the broiler farms (borehole-water, well-water, spring, stream, tap and rainwater) which were served to broilers and the number of times served to birds per day as well as the perception on the availability of water from the source per season.

Information on Environmental management practices includes: type of outlet of waste in the farm, ways of disposing waste adopted by the farm, the distance of the dump to the nearest pen. Information on Growth performance includes: average age of chick at stocking in days, average age at market weight (AMktW) in days, average market weight (MktW) in kilograms (Kg) and average price at market weight (PMktW) in naira (?) which was ? 1,500 for broiler of 2kg body weight as at the time of this study.

Water sampling procedure on broiler farms and analysis

Water was collected from twenty-two (22) broiler farms with eleven (11) water samples collected in Ekiti state and eleven (11) in Oyo state. Containers from freshly manufactured bottle Water Company were bought and used in collecting the water sample. At the point of the water collection the original water from the bottle was discarded and then the bottle was used in collecting water from the source. The water from boreholes and taps on the broiler farms visited were connected to a pipe and a representative fresh sample reaching the water outlet were collected into the bottle. In the case of water collection from the well, the container used in drawing up water from the well was use to collect water and then filled into the emptied bottle with a label on it showing the name of the farm, time of collection and date as well as the location. The water samples were conveyed to the water sample laboratory in a cooler container wherein the water samples were in mixture of ice blocks. Microbiological and chemical analysis of the water samples were carried out to determine bacterial count, coliform count, pH, total hardness, iron (Fe), sodium (Na), lead (Pb), copper (Cu), chloride (Cl), Sulphate (SO_4) and Nitrate (NO_3) (HACH 2003; Leonore *et al.,* 1998).

Adopted classes for drinking water quality standard in broiler meat production

Following Blake 2001, the adopted classes for the drinking water quality for each of the water quality indicators were: (a) Low, (b)

Medium (average and maximum acceptance level) and (c) High (Table 1).

Microbiological analysis of the broiler carcasses

The broiler farms surveyed in Ekiti state had no broiler slaughter house. On the other hand among the broiler farms surveyed in Oyo state there were two that had broiler slaughter house (with borehole as their water source) and from each of these slaughter house five broiler chicken (summed up to a total of 10 broiler chicken) of the same age of 6 weeks with average dressed weight of 1.2kg were purchased and transported to the laboratory in a maintained cold chain where they were subjected to microbiological analyses. The microbiological analyses were carried on both the skin and the flesh (meat) for Microbial load (total plate count), *E.coli*, and *Salmonella sp*. (cfu/g).

Microbial load on the skin and meat

The culture medium use was nutrient agar for microbial load or total plate count. The microbial growths on the skin and meat samples were evaluated at 0 day on. The 10g of pooled breast, thigh and drumstick deboned were minced in a whole sample for each of the 10 broiler which were homogenized with 90ml of 0.1% (W/V) peptone for 1 minute at room temperature using a blender. Appropriate serial dilution was prepared in 0.1% (W/V) peptone water solution. 1ml of homogenate of each sample was spread on petri plates using a pour plate technique. This was incubated at 37 ºC for 24 hours (Heinz and Hautzinger, 2007). All colonies that appeared at the end of the incubation period were counted and the results as the colonies forming unit per gram (CFU/g).

Table 1: Adopted classes for drinking water standard in broiler meat production

Quality indicators	Low	Medium	High
Acidity and Hardness components			
pH	< 6.8	6.8 – 7.5	> 7.5
Total Hardness (ppm)	< 60.0	60.0 – 180	> 180
Nitrogen Compound			
Nitrate (NO_3) mg/l	< 10.0	10.0 – 25.0	> 25.0
Naturally Occuring Chemicals			
Chloride (Cl) mg/l	< 14.0	14.0 – 250	> 250
Copper (Cu) mg/l	< 0.002	0.002 – 0.60	> 0.60
Iron (Fe) mg/l	< 0.20	0.2 – 0.30	> 0.30
Lead (Pb) mg/l	< 0.02	0.02	> 0.02
Sodium (Na) mg/l	< 32.0	32.0	> 32.0
Sulphate (SO_4) mg/l	< 125	125 – 250	> 250
Microbial characteristics			
Total Bacteria (cfu/ml)	0.00	1 – 100	>100
Coliform Bacteria (cfu/ml)	0.00	1 – 100	>100

Source: Blake 2001.

Salmonella load on the skin and meat

The selective culture medium was Xylose Lysine Deoxycholate (XLD) Agar for the isolation of *Salmonella sp.* The ISO-6579: 2002 food microbiology procedure employing the horizontal method for the detection of *Salmonella* from food and animal feeding stuffs was used (ISO Standards catalogue 07.100.30; WHO 2010) was adopted. The 10g of pooled breast, thigh and drumstick deboned were minced in a whole sample for each of the 10 broilers which were homogenized with 90ml of 0.1% (W/V) peptone for 1 minute at room temperature using a blender. Six-fold serial dilution was prepared in 0.1% (W/V) peptone water solution. 1ml of homogenate of each sample was spread on petri plates using a pour plate technique. This was incubated at 37 ºC for 24 hours (Heinz and Hautzinger, 2007). All colonies that appeared at the end of the incubation period were counted and the results as the colonies forming unit per gram (CFU/g).

Escherichia coli load on the skin and meat

The selective culture medium was MacConkey (MCA) Agar for the isolation of *E. coli*. The ISO-16654:2001 food microbiology procedure of the horizontal method for the detection of *Escherichia coli* O157 from food and animal feeding stuffs was employed in this study (ISO Standards catalogue 07.100.30; WHO 2010) was adopted. The 10g of pooled breast, thigh and drumstick deboned were minced in a whole sample for each of the 10 broilers which were homogenized with 90ml of 0.1% (W/V) peptone for 1 minute at room temperature using a blender. Six-fold serial dilution of was prepared in 0.1% (W/V) peptone water solution. 1ml of homogenate of each sample was spread on petri plates using a pour plate technique. This was incubated at 37 ºC for 24 hours (Heinz and Hautzinger, 2007). All colonies that appeared at the end of the incubation period were counted and the results as the colonies forming unit per gram (CFU/g).

Number of bacterial per gram of meat

The objective was to keep bacterial count as low as possible through adequate hygienic measures. In this study the recommendation by Heinz and Hautzinger (2007) were used as a guide for what can be considered microbiologically acceptable limit for fresh skin and meat.

Table 2: Adopted classes for microbiological criteria for fresh meat

Microbial load (Cfu/g)	**Good microbiological standard**	**Critical microbiological condition**	**Not acceptable**
Total plate count per gram	Less than 10000 (i.e. $<10^4$)	Between 10000 and 100000 (i.e. $>10^4$- $<10^5$)	More than 100000 (i.e. $> 10^5$)
Enterobacteriaceae (*E.coli* and *Salmonella sp.*) per gram	Less than 100 (i.e. $<10^2$)	Between 100 and 1000 (i.e. $>10^2$- $<10^3$)	Less than 1000 (i.e. $>10^3$)

Source: Heinz and Hautzinger (2007)

Data analysis

Data were analyzed using Pearson's correlation analysis for single inclusion relationships using SAS 9.2 version, descriptive statistics using bar chart distribution in Excel sheet and using ArcGIS 10.1 ® capabilities for the integration of structured spatial and attribute data of the broiler farms where the questionnaires were administered in the two states (i.e. Ekiti and Oyo).

Results

The field water source questionnaire based

The distribution of water sources in broiler meat production in Ekiti and Oyo states from Seventy-nine (79) field water source questionnaire-based survey shown in Table 3. It was found that the commonly used water sources by broiler farmers in Ekiti and Oyo states were well-water (54.4%) and borehole-water (29.1%).

The uncommonly used water sources rated the least were spring (2.4%) and tap water (2.4%) in Ekiti State while in Oyo State it was water-plant (2.6%) and rain-water (2.6%).

Tested water samples (borehole) in broiler meat production in Ekiti and Oyo states

The water quality indicators (and their remarks i.e. 'classes') for the borehole water used on the sampled farms (in Ekiti and Oyo states) are presented in Table 4. The distribution of the sampled broilers' farms from which water samples were collected and tested (water quality indicators and their 'classes') in Ekiti and Oyo states are presented on maps in figures (Fig. 2a to Fig.5b); Fig. 2a to Fig. 2b depicting the water quality indicators Acidity and Hardness (pH and total hardness), Fig. 3a to Fig. 3b depicting the water quality indicators Naturally Occurring Chemicals (Chlorine, Copper, Iron, Lead, Sulphate and Sodium), Fig. 4 depicting the water quality indicator Nitrogen compound (Nitrate i.e NO_3), Fig. 5a and Fig. 5b depicting the water quality indicators Microbial characteristics (bacterial count and coliform count).

Table 3: Distribution of water sources in broiler meat production in Ekiti and Oyo States

Source of water on Broiler Farms	Ekiti (freq)	% Ekiti	Oyo (Freq)	% Oyo	Total (freq) Ekiti and Oyo	Total % (Ekiti and Oyo)
Borehole water	13	31.7	10	26.3	23	29.1
Rain water	-	-	1	2.6	1	1.3
Spring	1	2.4	-	-	1	1.3
Tap water	1	2.4	-	-	1	1.3
Water plant	-	-	1	2.6	1	1.3
Well water	21	51.2	22	57.9	43	54.4
Borehole water + well water	1	2.4	1	2.6	2	2.5
Well water + rain water	-	-	2	5.3	2	2.5
Borehole + Well water + rain water	4	9.8	1	2.6	5	6.3
TOTAL	41	100	38	100	79	100

Table 4: Water quality (borehole) in broiler meat Production In Ekiti and Oyo States

Quality indicators	Farms	Mean	Standard Deviation	Class (Remarks)
Acidity and Hardness				
pH	7	6.53	0.35	Low : undesirable
Total Hardness (ppm)	7	62.8	36.7	Medium: undesirable
Nitrogen Compound				
Nitrate (NO_3) mg/l	7	0.09	0.25	Low : undesirable
Naturally Occurring Chemicals				
Chlorine (Cl) mg/l	7	51.8	21.7	Medium: desirable
Copper (Cu) mg/l	7	0.00	0.00	Low: undesirable
Iron (Fe) mg/l	7	0.02	0.04	Low: undesirable
Lead (Pb) mg/l	7	0.01	0.01	Low: undesirable
Sulphate (SO_4) mg/l	7	5.62	2.79	Low: undesirable
Sodium (Na) mg/l	7	10.4	5.19	Low: undesirable
Microbial Characteristics				
Bacterial Count cfu/ml	7	3.26	2.76	Medium: Acceptable level
Coliform Count cfu/ml	7	0.34	0.50	Medium: Acceptable level

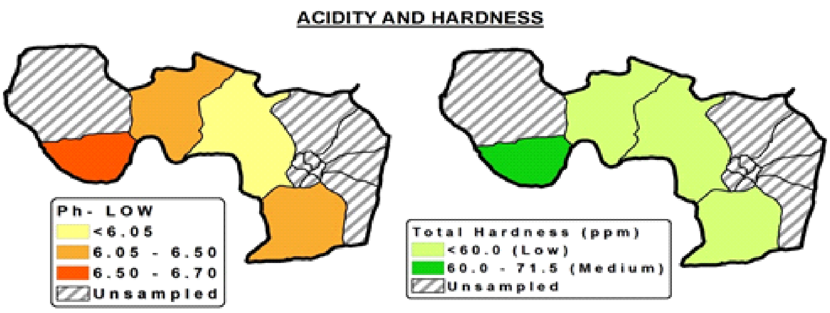

Figure 2a: pH and hardness of water measured from borehole water used for broiler production in Ekiti State.

Figure 2b: pH and hardness of water measured from borehole water used for broiler production in Oyo State.

Naturally occurring chemicals water quality (borehole) in broiler production

The sampled seven (7) different broiler farms having borehole as water source in Ekiti and Oyo state had 0.02mg/l mean value of Iron concentration [with a Standard deviation (STD) of 0.04] which was classified as 'Low' being undesirable (Table 4 and Fig. 3a and 3b nos. 3) in comparison to the 0.3mg/l being the maximum acceptance level (Table 1) of 'Drinking Water Quality Standards for Poultry' (DWQSP) Blake, 2001.

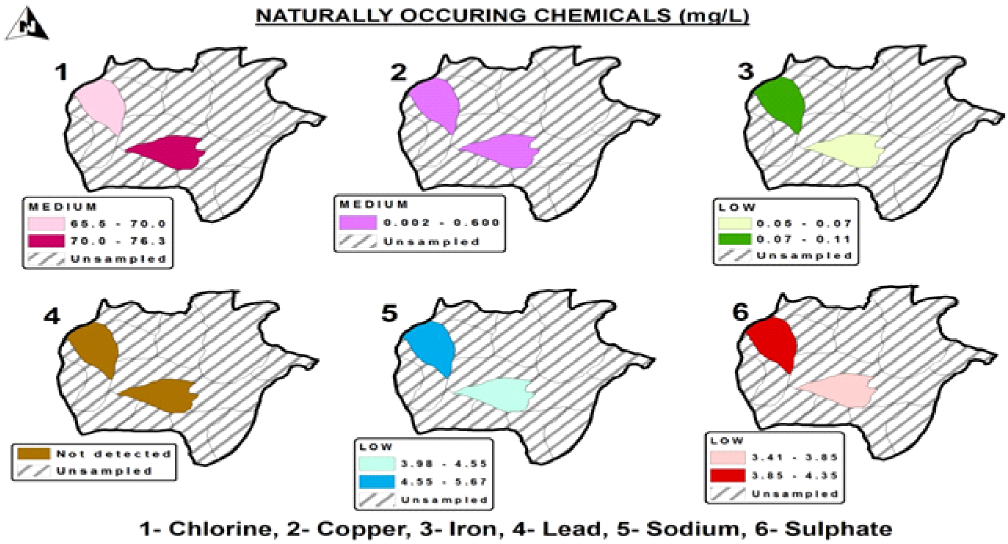

Figure 3a: Chlorine, Copper, Iron, Lead, Sodium and Sulphate of water measured from borehole water used for broiler production in Ekiti State.

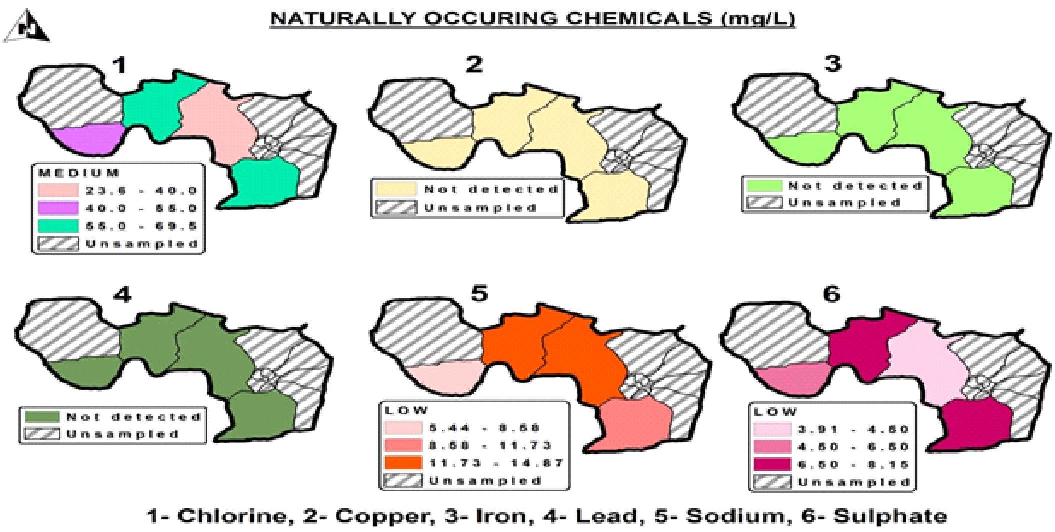

Figure 3b: Chlorine, Copper, Iron, Lead, Sodium and Sulphate of water measured from borehole water used for broiler production in Oyo State.

Nitrogen Compound: Nitrate (No_3)

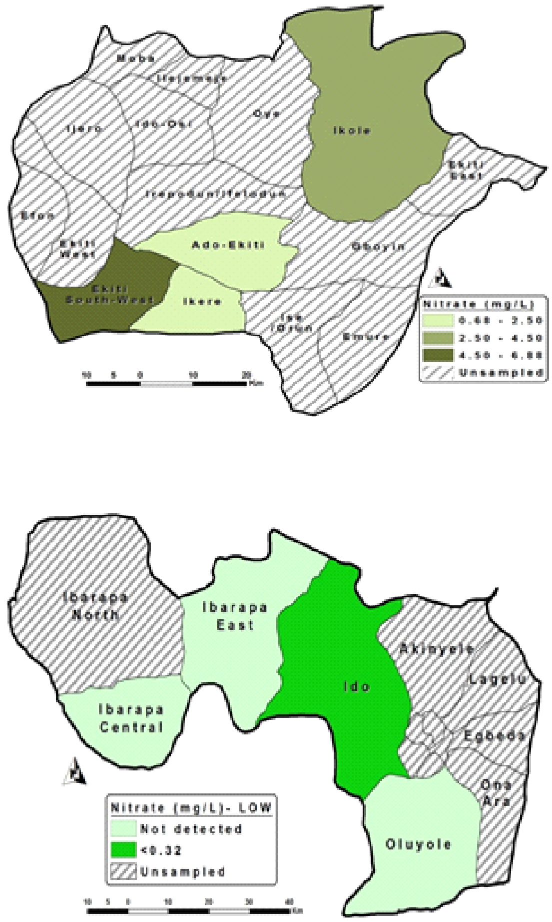

Figure 4: Nitrate (NO_3) of water measured from borehole water used for broiler production in Ekiti State and Oyo States.

Microbial characteristics water quality (borehole) in broiler meat production

The total bacterial and coliform bacteria (Fig. 5a and Fig. 5b) in comparison to the adopted classes (Table 4) were found to be in the 'Medium Class' which could be considered desirable.

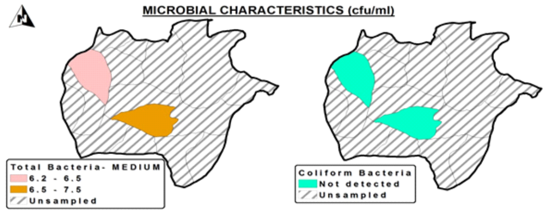

Figure 5a: Total bacteria and Coliform bacteria of water measured from borehole water used for broiler production in Ekiti State.

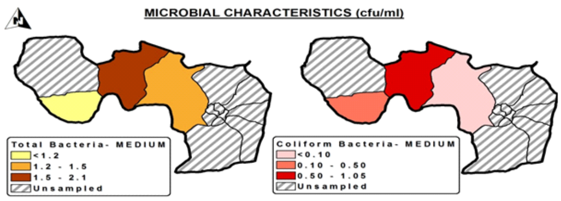

Figure 5b: Total bacteria and Coliform bacteria of water measured from borehole water used for broiler production in Oyo State.

Tested water samples (well water) in broiler meat production in Ekiti and Oyo states

The water quality indicators (and their remarks i.e. 'classes') for the borehole water used on the sampled farms (in Ekiti and Oyo states) are presented in Table 5. The distribution of the sampled broilers' farms from which water samples were collected and tested in Ekiti and Oyo states are presented in figures (Fig. 6a to Fig.9b); Fig. 6a to Fig. 6b depicting the Acidity and Hardnes of water samples, Fig. 7a to Fig. 7b depicting naturally occurring chemicals (Chlorine, Copper, Iron, Lead, Sulphate and Sodium), Fig. 8 depicting Nitrogen compound (Nitrate i.e NO_3), Fig. 9a and Fig. 9b depicting Microbial characteristics (bacterial count and coliform count).

Table 5: Water quality (well water) in broiler meat production in Ekiti and Oyo States

Quality indicators	Farms	Mean	Standard Deviation	Class (Remarks)
Acidity and Hardness				
pH	15	6.03	0.19	Low : undesirable
Total Hardness (ppm)	15	90.55	38.04	Low : undesirable
Nitrogen Compound				
Nitrate (NO_3) mg/l	15	1.91	3.35	Low : undesirable
Naturally Occurring Chemicals				
Chlorine (Cl) mg/l	15	38.73	30.38	Medium: desirable
Copper (Cu) mg/l	15	0.17	0.63	Medium: desirable
Iron (Fe) mg/l	15	0.41	1.0	High: undesirable
Lead (Pb) mg/l	15	0.04	0.11	High: undesirable
Sulphate (SO_4) mg/l	15	9.78	6.33	Low: undesirable
Sodium (Na) mg/l	15	7.79	4.89	Low: undesirable
Microbial Characteristics				
Bacterial Count cfu/ml	15	0.90	2.45	Medium: Acceptable level
Coliform Count cfu/ml	15	6.03	1.33	Medium: Acceptable level

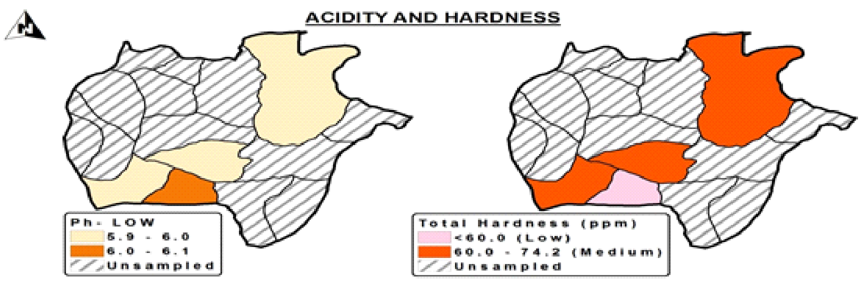

Figure 6a: pH and total hardness of water measured from well-water used for broiler production in Ekiti State.

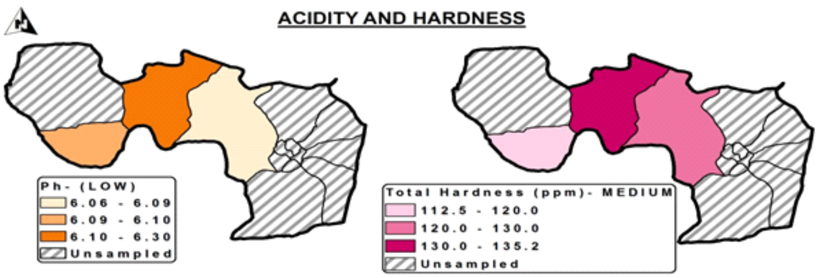

Figure 6b: P^H and total hardness of water measured from well-water used for broiler production in Oyo State.

Naturally occurring chemicals water quality (well water) in broiler meat production

The fifteen (15) different broiler farms having borehole water sources in Ekiti and Oyo states had a mean value of 0.41mg/l of Iron concentration (with a STD of 1.00) and 0.04mg/l of Lead which was in the category of the class "High" being undesirable (Table 5, Fig. 7a and 7b nos. 3) in comparison to 0.2mg/l (Iron) and 0.02mg/l (Lead) the average acceptance level (Table 1) of the DWQSP (Blake, 2001).

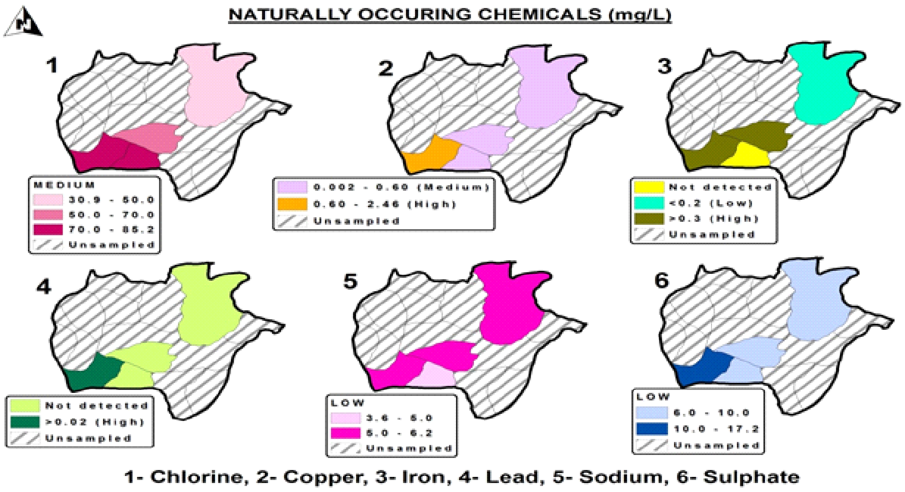

Figure 7a: Chloride, Copper, Iron, lead, Sodium and Sulphate of water measured from well-water used for broiler production in Ekiti State.

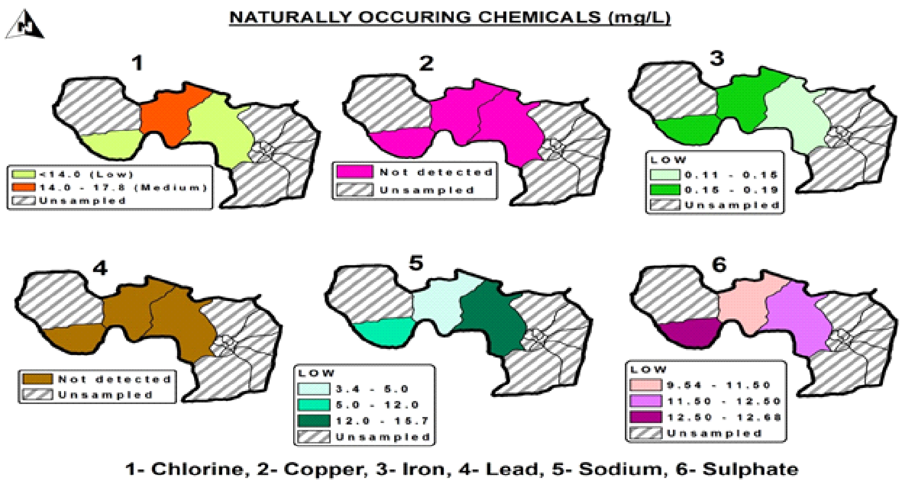

Figure 7b: Chloride, Copper, Iron, lead, Sodium and Sulphate of water measured from well-water used for broiler production in Oyo State.

Nitrogen Compound: Nitrate (No_3)

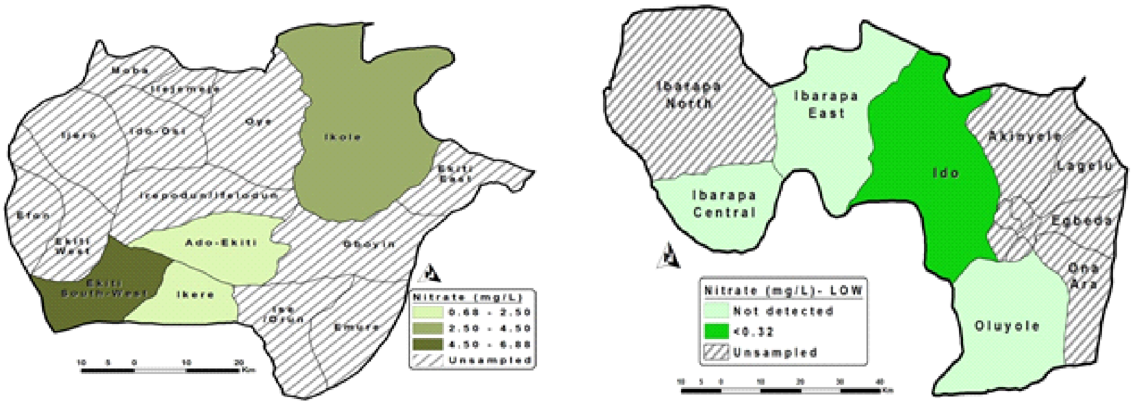

Figure 8: Nitrate (NO_3) of water measured from well-water used for broiler production in Ekiti and Oyo State.

Microbial characteristics water quality (well water) in broiler meat production: The total bacterial and Coliform bacteria (Fig. 9a and Fig. 9b) in comparison to the adopted classes (Table 4) were found to be in the 'Medium Class' which could be considered desirable.

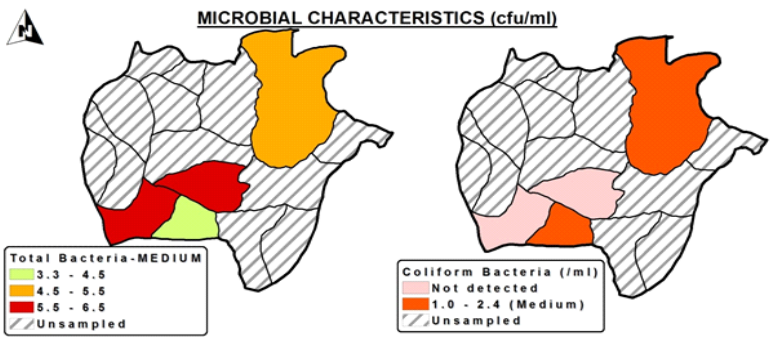

Figure 9a: Total bacteria and Coliform bacteria of water measured from well water used for broiler production in Ekiti State.

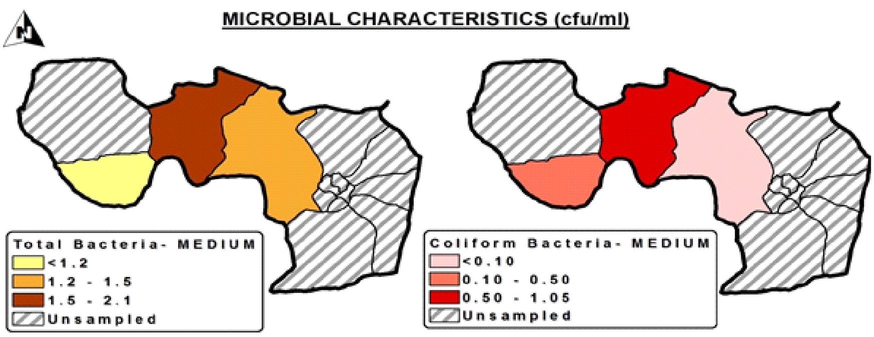

Figure 9b: Total bacteria and Coliform bacteria of water measured from well-water used for broiler production in Oyo State.

Relationship of tested water samples and performance criteria

Pearson's correlation analysis (in SAS version 9.2) applied to the multi-elemental statistical effects of water quality indicators from its sources (borehole and well water – the twenty two tested water samples) as it correlate to average age at market weight (AMktW), average body weight at market (BWMkt) and average price at market weight (PMktW) in naira (?) had significant (p<0.0001) positive correlations observed for the following: (i) between AMktW and BWMkt (ii) AMktW and PMktW (iii) BWMkt and PMktW, (iv) Water Source (WS) and pH (Table 6).

Microbial load or total plate count of broiler chicken carcasses

The result indicated that the microbial load or total plate count numbers did not exceed 100,000 Cfu/g (10^5 Cfu/g) the maximum acceptance level in all tested broiler chicken carcasses for the flesh (meat). However that of microbial load on the skin in some of the carcasses exceeded the maximum acceptance level and was generally higher than those of the flesh or meat (Fig. 10).

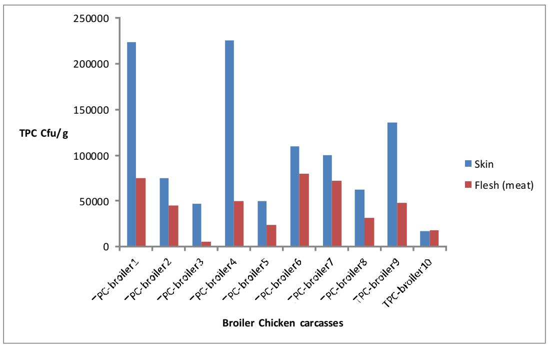

Figure 10: Distribution between total plate counts (TPC) of skin of broiler chicken carcasses and those of the flesh (meat) averaged over the two broiler slaughter houses

***Salmonella* count of broiler chicken carcasses**

The result indicated that the *Salmonella* count did not exceed 1000 Cfu/g (10^3 Cfu/g) the maximum acceptance level in all the tested broiler chicken carcasses for the skin and flesh (meat). The flesh (meat) was *Salmonella* free in the tested carcasses while the skin was in some of the carcasses *Salmonella* free (Fig. 11).

Table 6: Relationships resulting from observations on twenty-two water samples from broiler farms in Ekiti and Oyo states in Southwestern Nigeria

		Significant Correlation	
Variables	**Samples size**	**Positive**	**Negative**
Age at Market Weight	22	ABWMkt (*R* = 0.989** with P<.0001), PMktw (0.756** with P<.0001),	Nil
Weight at Market	22	AAMktW (*R* = 0.989** with P<.0001), PMktw (*R* = 0.764** with P<.0001),	Nil
Price at market weight	22	AAMktW (*R* = 0.756** with P<.0001), ABWMkt (*R* = 0.764** with P<.0001)	Nil
Water Source	22	pH (*R* = 0.698* with P<.0001),	Nil

(**) means very strongly correlated with P<.0001; (*) means strongly correlated with P<0.05

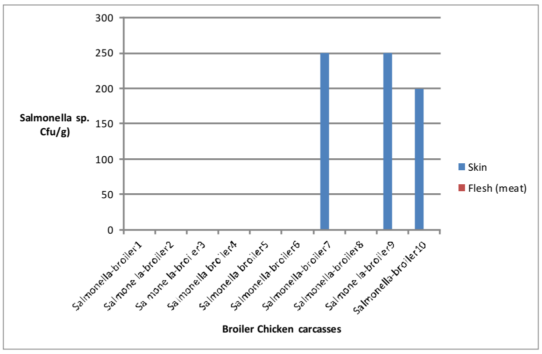

Figure 11: Distribution between *Salmonella* counts of skin of broiler chicken carcasses and those of the flesh (meat) averaged over the two broiler slaughter houses

Escherichia coli count of broiler chicken carcasses

The result indicated that the *E. coli* counts did not exceed 1000 Cfu/g (10^3 Cfu/g) in all tested broiler chicken carcasses for flesh (meat) and on the skin (expect one carcass). However, the *E. coli* counts on the skin were generally higher than those on the flesh or meat (Fig. 12).

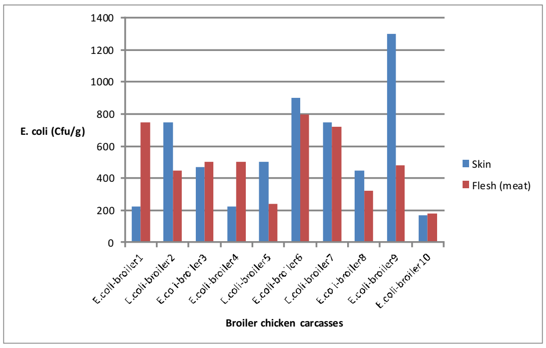

Figure 12: Distribution between *E. coli* counts of skin of broiler chicken carcasses and those of the flesh (meat) averaged over the two broiler slaughter houses

Discussion

It was found that the commonly used water sources by broiler farmers in Ekiti and Oyo states were well and borehole water. The classes in the low and high are undesirable because of their negative impact on broiler performance and meat products this is in harmony with the report of Blake (2001).

There is no significant correlation between Iron and average body weight at market (BWMkt) for both borehole and well water (in both states) and this supports various findings in literatures (Zimmermann, 1998; Barton, 1996; and Fairchild *et al.,* 2006) that at both high and low levels of Iron concentration there is no detrimental effect on broiler performance. Notably, in addition to assessing average body weight at market (increasing meat yield) as a measure of broiler's performance there is need to secure the meat quality. The low level of Iron concentration in the well-water used for drinking water (borehole water in Ekiti and Oyo State) in broiler and no dietary supplementation of iron; may cause deficiency in the Iron content in the meat. Generally, white meat such as meat of broilers, are low in Iron content than red meat, such as beef (Seo *et al.,* 2008). Extra supplementation of Iron in addition to meeting nutritional requirement would enable enrichment of Iron in breast meat of broilers raised in Ekiti and Oyo states for those broiler farms having boreholes with deficiency in Iron content. Though Iron can be supplementated in the feed of broilers (Seo *et al.,* 2008) using Iron in water supplementation will be preferred because water being most essential nutrient in poultry is consumed on a weight basis of approximately 1.8g of water for every gram of feed consumed (Pest *et al.,* 1985 and Fairchild *et al.,* 2006). Iron enriched broiler meat will add value to the nutritional meat quality of broiler; helping to reduce cases of anemia which could lead to tiredness, headaches and loss of concentration. Hence, Iron enriched broiler meat may meet the demand of niche market customers (young children, adolescent, elderly, pregnant women and athlete) looking for such functional product at an affordable price (since in Nigeria price are tagged on broiler based on body weight at market) and thereby contributing to food security.

There is no significant correlation between lead and average body weight at market (BWMkt) for both borehole and well water (in both states) and this contradicts the findings of Rahman and Joshi (2009) in a study where lead was introduced into the drinking water of broilers at 2^{nd} to 6^{th} week of age at 250 ppm and 400 ppm concentrations levels resulting in a significant decrease in final body weight of broiler at both levels of concentrations compared to the control birds. Also, there were reports on Lead supplementation in the feed of broilers which caused linear decreases in body weight gain of the broilers (Bakalli *et al.,* 1995; Ritesh Jaiswal *et al.,* 2017). However, the non-significant correlation between lead and body weight at market in this study could have been that in the feed of the broiler there were adequate levels of calcium and antioxidant presence as well as the high level of resistant to leading poisoning by broiler chicken that consumed the well-water in the two states. This possibilities can be deduce from studies that have demonstrated that the adverse effects of lead toxicity in the feed of broilers can be significantly reduced by the presence of adequate levels of calcium (Bakalli *et al.,* 1995) and antioxidants such as ascorbic acid, α-tocopherol (Vitamin E) & Selenium (Se) and DL-methionine (Ritesh Jaiswal *et al.,* 2017). Besides, Vengris and Mare (1974) reported that chickens were found to tolerate levels of lead as high as 160 mg/kg/day without exhibiting clinical signs or hematological changes in spite of very high levels of lead in the blood (6.2 ppm). Thus, indicating that chickens are more resistant to lead poisoning than humans, horses, dogs and wild fowl such as ducks.

Considering the microbiological characteristics (total bacteria and coliforms) as water quality indicators for the tested water samples borehole and well in the two states (Ekiti and Oyo) being within the limit of acceptable levels it could be recommended that the microbiological characteristics of the tested water samples were not above the critical level to be used in both drinking and processing of broiler meat in harmony with the report of Heinz and Hautzinger (2007). This recommendation is validated from the result obtained from the tested broiler chicken carcasses (skin and flesh) for total plate count, *Salmonella* count and *E. coli* counts which were though within the limit of critical microbiological condition but not unacceptable as outlined by Heinz and Hautzinger (2007).

The BWMkt, AMktW and PMktW for the tested water samples questionnaire based had positive correlation ire spective of the water source (borehole and well water) indicating that in this survey study the performance criteria BWMkt and AMktW were not significantly dependent on water source (WS) as there exist no significant correlation between WS and BWMkt, WS and AMktW, as well as WS and PMktW. The significant positive correlations between PMktW in naira (?) and BWMkt (kg) indicated significant economic value placed on broilers with heavier body weight irrespective of the drinking water sources.

Conclusion

The significant positive correlation between average price at market weight in naira (?)

and average body weight at market in kilogram (Kg) indicated significant economic value placed on broilers with heavier body weight irrespective of the water source, its Iron, lead and bacterial concentrations as water quality indicators. The meat microbiological quality was within the acceptance limits due to the low level of bacterial concentrations as a water quality indicator.

References

Ajuwon, K. M., Matanmi, O. and Daniyan, O. C. (2002) Effect of water sources and ascorbic acid supplementation on egg quality and production parameters of laying hens: Livestock Research for Rural Development (14) 6. Retrieved September 28, 2011, from http//www.Irrd.org/Irrd 14/6/ajuw 146.Htm.

Bakalli, R. I., Pesti, G.M and Ragland W. L. (1995) The magnitude of lead toxicity in broiler chickens. Vet. Hum. Toxicol. 37(1): 15 -19.

Barton, T. L. (1996) Relevance of water quality to broiler and turkey performance. Poult. Sci. 75(7): 854-856.

Blake, J. P. (2001) Evaluating water quality for poultry. Alabama Cooperative Extension System. ANR-1201

Garcia, R. G., Almedia Paz, I. C. L., Caldara, F. R., Naas, I. A., Pereira, D. F., Freitas, L. W., Schwingel, A.W., Lina, N.D.S., Graciano, J. D. (2010) Effect of litter Material on drinking water quality in broiler production. Brazilian Journal of Poultry Science. Vol. 12, pg 165 - 169.

Fairchild, B. D., Batal, A. B., Ritz, C. W. and Vendrell, P. F. (2006) Effect of drinking Water Iron Concentration on Broiler performance. Journal of Applied Poultry Research 15:511-517.

HACH Company, (2003) HACH Water Analysis Handbook. Printed in the U.S.A.

Heinz G and Hautzinger, P. (2007) Meat processing hygiene: In Meat processing technology for small –to medium scale producers. Wood head publisher, 339 – 368pp.

ISO Standards catalogue 07.100.30 . Food Microbiology. 2011

Lenore, S. C., Arnold, E. G. and Andrew, D. E. (1998). Physical and aggregate properties. Standard Methods for the Examination of Water and Waste Water. 20th Edn. Am. Public Health Association, Washington D.C.

Omodele, T, Okere, I.A and Deinne C. E., (2014) Technical assessment of rural development of the poultry meat sector in Ogun State, South Western Nigeria: A Geographic Information System (GIS) approach. *Livestock Research for Rural Development,* Vol. 26 (5) Retrieved July 1, 2014, from http://www.lrrd.org/lrrd26/7/omod26122.html

Pesti G. M., Armato, S.V. and Minear, L. R. (1985) Water consumption of broiler chickens under commercial conditions. Poult. Sci. 64(5): 803 - 808.

Rahman S. and Joshi M. V. (2009) Effect of lead toxicity on growth and performance of broilers. *Tamilnadu J. Veterinary & Animal Sciences 5(2): 59 - 62.*

Ritesh Jaiswal, S.L. Ali , S. Roy, S. Sakya, O.P. Dinani and Sudhir Kumar Jaiswal (2017) Effect of dietary lead exposure on performance and their alleviation by antioxidants in broilers. *Int. J. Pure App. Biosci.* 5 (1): 597-600. DOI:

http://dx.doi.org/10.18782/2320-7051.2432.

Seo S.H., Lee H.K., Ahn J.H. and Paik, I. K. (2008) The Effect of Dietary Supplementation of Fe-methionine Chelate and FeSO4 on the Iron Content of Broiler Meat. Asian-Aust. J. Animal Science 21(1) 103 – 106.

Vengris V. E. and Mare C. J. (1974). Lead poisoning in chickens and the effect on interferon and antibody production. Canadian Journal of Comparative Medicine 38(3): 328 - 335.

WHO (2010). Isolation of Salmonella spp. From food and animal faeces. 5 2010. Laboratory protocol.

Zimmermann (1998) Relationship of drinking water quality and broiler performance on Delmarva. Proceedings of the Maryland Nutrition Conference for feed Manufacturers University of Maryland, College Park, MD 20742.