OPEN ACCESS International Journal of Poultry Science

ISSN 1682-8356
DOI: 10.3923/ijps.2019.

Research Article
Toxicological Assay-Guided and Fabricated Feeding and Drinking Troughs for Intensive Deep-Litter Poultry Farming System

[1]Godwin Ojochogu Adejo, [2]Evelyn UnekwuOjo Adejo, [3]Kelechi Eleanya and [4]Sunday UnenwOjo Adejo

[1]Department of Biochemistry and Molecular Biology, Faculty of Life Science, Federal University, Dutsin-Ma, Katsina, Nigeria
[2]Goshen Farms, Goruba G.R.A., Katsina, Nigeria
[3]Yale School of Forestry & Environmental Studies, New Haven, CT, USA
[4]MOM Orphanage poultry farm, Otutulu Village, Kogi State, Nigeria

Abstract

Background and Objective: Main stream contemporary approach to controlling the impacts of diseases among poultry birds rely largely on curative measures through administration of drugs to infected birds. Most times, as observed in the deep litter poultry farming system, entire flocks including uninfected birds receive treatments they do not need. As such, unguarded use of chemical drugs/antibiotics has led to wastages and accumulation of chemical residues in poultry products with associated health hazards to human consumers. However, wanton and frequent drug usage in poultry is avoidable if feeding and drinking equipment are designed to curb transmission of infection among birds. **Materials and Methods:** Using toxicological assays as guide and with efficiency and simplicity in view, two newly field-tested and recently patented equipments called 'healthy liquid drinking trough (HDT)' and 'healthy feeding trough (HFT)' that systematically exclude contamination of the feeding and drinking channels, thereby, eliminating wide-spread infection and transmission of diseases in the (intensive) deep litter poultry farming system were designed. **Results:** Upon combined usage, they automatically and drastically reduced both the amount and frequency of antibiotics use in poultry by >50%. Additionally, they conferred optimization of feed and water utilization/elimination of wastage by >80%, reduced labour by >70%, reduced production cost by about 15% and reduced chemical residues in poultry meat or eggs by >85%. **Conclusion:** These new technologies are cheap and they require minimal energy input. They are likely to improve safety of poultry products for consumers' health, increase marketability locally and for export. In addition, they can increase output and profit especially among poultry farmers and poor families in developing countries who keep poultry or inevitably utilize poultry products.

Key words: Chemical residue, deep litter farming, food security, infection in feeding, poultry

Received: Accepted: Published:

Citation: Godwin Ojochogu Adejo, Evelyn UnekwuOjo Adejo, Kelechi Eleanya and Sunday UnenwOjo Adejo, 2019. Toxicological assay-guided and fabricated feeding and drinking troughs for intensive deep-litter poultry farming system. Int. J. Poult. Sci., CC: CC-CC.

Corresponding Author: Godwin Ojochogu Adejo, Department of Biochemistry and Molecular Biology, Faculty of Life Science, Federal University, Dutsin-Ma, Katsina, Nigeria Tel: +234(80)68376357

Competing Interest: The authors have declared that no competing interest exists.

Data Availability: All relevant data are within the paper and its supporting information files.

INTRODUCTION

Global demand for poultry products have been on a steady increase over the last decade, with more emphasis on developing countries. There is a strong likelihood that this trend will continue to increase as a result of rapid urbanization, increased income, population growth and unmatched pace of production[1-4]. The global importance of poultry cannot be overemphasized because chicken production contributes significantly to food and nutrition security, livelihood security and poverty alleviation[5-7]. Besides being rich in protein, poultry meat is good source of phosphorus and other minerals and of B-complex vitamins. It contains less fat than most cuts of beef and pork. Poultry meat is low in harmful trans fats but high in beneficial monounsaturated fats-which make up about half of the total[5-7].

Apart from other challenges identifiably faced by the poultry production sector, diseases have either plummeted returns, or wiped out farmers' investments and kept many out of business[8-10]. In a recent report, 90% of broiler farmers considered disease outbreak as a very serious problem and ranked as the number 1 among thirteen (13) major challenges they faced[11]. The fear of damages caused by diseases and disease outbreaks to poultry business has led farmers to resort to very frequent use of antibiotics in order to safeguard their flocks. However, this comes with a price, as the cost of production and chemical residues in poultry products are invariably increased. But the demand for safe, high quality and cheap foods is also on the rise[12-14] and larger population is gaining awareness that their health can either be impacted directly through chemical residue-containing products which causes side-effects, or indirectly by eliciting resistance to antibiotics in humans. An example is chloramphenicol and its metabolites' residues in meat products linked with the aplastic anemia[15]. Antibiotics resistance has resulted to prolonged illness, side effects, need of alternative and more toxic drugs or outright treatment failure and death. Considering these acknowledgeable fears, taking steps toward eliminating or drastically reducing chemical residues in poultry meat and eggs by maintaining high hygiene standards is of utmost necessity. A most significant hygienic step according to Sonaiya and Swan[16] is through supply of clean feed and water via clean feeders and drinkers. The feeders and drinkers popularly used in contemporary deep litter poultry farming which constitutes over 80% of poultry farming system in developing countries[17-18], lack the hygiene-edge. Predictably, most contaminations, infections and spread of diseases among poultry birds have been traced to these channels[19-24]. As such, improvements in this area are highly needed. This article, thus reports interesting findings in the newly designed feeders and drinkers (registered patent #s: NG/PT/NC/2018/2954 and NG/PT/NC/2018/2953 respectively) that are set to revolutionize the current practices with respect to hygienic administration of feed and water to poultry birds in the deep litter farming system. Additionally, observed poultry performance indices and some derived economic advantages are here reported.

MATERIALS AND METHODS

Equipments and services: Repeated design, fabrication, re-fabrication, testing and corrections/adjustments of drinking and feeding troughs were done, until the current optimized form for poultry birds were obtained. They were named Healthy Feeding Trough (HFT) and Healthy Liquid Drinking Trough (HDT), respectively. Contemporary drinkers (bucket and basin types) and feeders (bucket and trough types) were obtained from Madugu House, Katsina. Vaccines and antibiotics were obtained from Madugu House and Haske Vet, while feeds were obtained from VITAL FEEDS®-Gwanza Enterprise, Katsina. Consultancy services were rendered by Dr. Evans Oyolola of HASKE VET®. Services and Veterinary Hospital, Kofar Kwaya-Katsina.

Housing, feeding and medications: The study was done at GOSHEN FARMS, a poultry housing facility in Katsina town in Katsina state, within the core northern part of Nigeria located: 12.5139°N, 7.6114°E. The poultry houses were standard open-sided and naturally ventilated where birds were nurtured on floor litter with wood shavings. In every case, birds used were obtained as day-old chicks from Auction Ventures Ltd., Katsina. Birds were kept in brooding for the required number of days then moved to the chicken houses set up for deep litter poultry farming. Procedures for housing and re-stocking (where applicable, particularly for broilers and cockerels) were strictly followed. Notably, houses and cages including all equipment were fumigated, washed and air-dried for at least 1 week. This was repeated once before introducing the next batch of birds. Their respective pelletized or crumbled poultry feeds and clean water (from municipal supplies) were made available *ad libitum* through their assigned feeders and drinkers. In specifics, broiler birds were fed with the starter and finisher mash between weeks 1-6 and 7-8, respectively. Cockerels were fed with chick, grower and finisher mash at weeks 1-6, 7-17 and 18, respectively. Pullets were given chick mash, grower mash and (at the point of lay, they were maintained on) layer mash at weeks 1-6, 7-21 and 22^{+}

respectively. Each batch of birds was randomly distributed into separate groups, using their feeding and drinking equipment as the basis. Group 1 (G1) had contemporary deep litter drinkers (CDD) and Contemporary deep litter feeders (CDF), G2 (HDT and CDF], G3 (CDD and HFT), G4 (HDT and HFT), G5 (Market samples of deep-litter nurtured broilers, cockerels or layers). Birds were given their necessary routine vaccinations and medications at and as when due. Sick birds were detected as quickly as possible, isolated, examined, treated and duly certified fit by the veterinary doctor before being returned to the batch. But when up to three birds were observed to be sick at the same time or in quick succession within two days in a batch, the entire batch was promptly treated.

Animals and samples used: The entire experiment spanned over $\leq$120 weeks. It involved a total of 1,900 birds made of 1,200 broilers (Ross 308 Agrited brand), 300 cockerels/roasters (Commercial cockerels Greenfield brand) and 400 pullets/layers (ISA Brown Greenfield brand), all raised as chicks from 1 day old. Six batches of broilers made up of 200 birds per batch (bpb) were raised for about 8 weeks each, totaling 72 weeks (approx.). Four batches of cockerels made up of 100 bpb were raised for about 18 weeks each, totaling 72 weeks (approx.) while one (1) batch of pullets/layers made of 400 birds were raised for as long as they remained alive and productive but not more than 120 weeks.

Collection of samples: Samples collected for analyses were: feed and water supplies, swabs from feed trays/troughs and drinking bowls/troughs. While rearing, samples were collected once per week and birds droppings found throughout the whole day in the feeding trays/troughs and drinking bowls/troughs were counted. Every dead bird was removed and subjected to post-mortem examination. Where there was an outbreak within a batch and prognosis was poor, such batch was phased-out, based on Veterinary Doctor's advice. At slaughter or death, tissue samples from the breast, liver and kidney were collected, while five eggs were randomly selected once a week from each experimental group by age twenty-five weeks for chemical residues analysis. However, eggs of birds in isolation and under treatment were excluded.

Analyses of samples for chemical residues: Premi® assay kits obtained from R-Biopharm AG, Germany, were used for rapid antibiotic/chemical residues determination in tissue and egg samples while adhering to manufacturers' instruction and the guidance of other researchers by Kehinde *et al.*[25], Kuptha and Ragavendiran[26] and R-Biopharm AG[27].

Performance indices determination: Feed intake, body weight and other relevant parameters including HHEP, FCR, EFPR, NFEI and PEI, were measured, recorded and calculated using procedures previously reported by Ezieshi *et al.*[28], Martins et al.[29] and TNAU[30]. Percentage Feed wastage elimination (FWEL %) was obtained by the formula:

$$100\text{-\% feed wastage, FW} \tag{1}$$

Where:

$$FW = \frac{100*(FCR_{obtained} - FCR_{reference})}{FCR_{reference}} \tag{2}$$

Water utilization, (WU %) was calculated by measuring the differences between total water supplied (WS) and water unconsumed by birds as:

$$WU\ (\%) = \frac{100*(WS\text{-}WL)}{WS} \tag{3}$$

where, WL is the sum of water unconsumed, losses through accidental knock-over and losses during washing/cleaning).

Production indices were also considered. Labour index (LI) was calculated by summing up points accruing to each aspect which included supply of feed, water and treatment/medications to birds, washing/cleaning of feeding and drinking troughs and sweeping. Each of these aspects requiring up to 15 min of work was allotted 1 point. Where work was done twice per day, 2 points were allotted. Where work was done just once in 2 weeks (14 days), point allotted was 1/14 or 0.07 point. Percentage labour reduction (LR%) was thus calculated as:

$$LR\ (\%) = \frac{100*(LI_{reference} - LI_{obtained})}{LI_{reference}} \tag{4}$$

where, $LI_{reference}$ is the labour index for the reference group in a flock. In this case, the CDD+CDF groups of each flock).

Net profit (NP) was simply calculated as:

$$NP = GI\text{-}PC \tag{5}$$

where, GI is the gross income and PC represents all production costs like chicks purchase, feeds, treatments/drugs/vaccines, labour and miscellaneous like water, wood shaving, transportation, communication).

Percentage (%) added profit (AP) was calculated as:

$$AP\ (\%) = \frac{100*(NP_{obtained} - NP_{reference})}{NP_{obtained}} \quad (6)$$

where, $NP_{(reference)}$ is the net profit for the reference group in a flock. In this case, the CDD+CDF groups of each flock.

NFEI was calculated using the formula:

$$NFEI = \frac{100*[MEM(g) + MBW(g)]}{MFC(g)} \quad (7)$$

Where
MEM = Mean egg mass in grammes
MBW = Mean body weight gain or loss (g) during a given time
MFC = Mean feed consumption per hen (g) during the given period

EFPR is used to find the ratio between the sales of eggs and expenses on feed.

$$EFPR = \frac{\text{Total value of egg produced}}{\text{Total value of feed consumed}} \quad (8)$$

In layers, feed conversion ratio (FCR) (per dozen eggs) takes into consideration the feed intake and egg production. It is the ratio between the feed consumed and the number of eggs produced and calculated as:

$$FCR\ (\text{per doz. eggs}) = \frac{\text{kg feed consumed} \times 12}{\text{Total no. of eggs produced}} \quad (9)$$

Production efficiency index:

$$PEI\ (\%) = \frac{100 \times Av.BW\ (g) \times \text{Livability (days)}}{FCR \times \text{Hen day (days)}} \quad (10)$$

Statistical analysis: Data analyses was performed with basic descriptive statistics using simple percentages, averages and standard deviation in most cases employing the Microsoft Office Excel version 2007 and expressed as Mean±SD. Significance of difference was evaluated by One-way ANOVA and Duncan Multiple Range Test where necessary, with probability set at 5% level of significance.

RESULTS AND DISCUSSION

Infections, hygiene and mortality: There were six batches of broiler birds in the entire experiment. Each of these batches showed high prevalence of infection depicted by the AoI, among the various groups (Table 1). The number of fecal droppings found, 'nFS' in the drinkers 'Dk' and feeders 'Fd' indicated the ease of spread of infections through contamination. The percentage of drug usage '%Rx' was equally very high 'generally'. But contrary situation was observed in the 'HDT+HFT' group in each of the batches, as there were no records of fecal droppings found in their administration channels. Rate of drug usage and mortality were the least in these groups irrespective of the batch. Among the four batches of cockerels/roasters, drug usage was higher, indicative of repeated treatments for infections likely transmitted through fecal droppings found in the contemporary drinkers and feeders used in the other groups (Table 2). However, mortality was no more different from those that used the HDT+HFT where there was not a single fecal dropping found in any of the four different batches. The parity in mortality could be attributable to the resilient nature of cockerels to withstand diseases better than broilers. Moreover, the mortality among the HDT+HFT group was mainly during the brooding stage where the chicks that died were mainly accidental. The relationship between infections, hygiene and mortality was best depicted among pullets/layer birds (Table 3). While the AoI among the other groups that had either or both of the contemporary feeders and drinkers was between 5 and 6 within their short life-span of not more than 56 weeks (about a year) at the longest, the HDT+HFT had a small record of 3 all through their life-span of almost 120 weeks. Also, other groups presented significant nFS in either or both of their allotted feeders and drinkers, higher %Rx usage ranging between 88-95% and mortality of 83-98% while the HDT+HFT group presented as low as 14 in %Rx usage and mortality of 26% in all 117 weeks (2 years and 5 months), after which they were sold off as spent layers.

Chemical residues, drug usage and mortality: Table 4 presents the trend of chemical residues presence in the various products obtained from different birds and groups nurtured with the experimented feeding and drinking troughs. Irrespective of bird type, the percentage that showed positive outcome to chemical residue in breast meat of groups indicated: CDD+CDFm>CDD+CDF>CDD+HFT>HDT+CDF >>HDT+HFT. Liver and kidney samples obtained and examined also showed similar pattern, irrespective of bird type. It was observed that while market samples 'CDD+CDFm' were nurtured with drinking and feeding equipment similar to the experimented CDD+CDF groups, samples from 'CDD+CDFm' groups consistently indicated higher chemical residues. It was found that for fear of losses, commercial

Table 1: Prevalence of infection in feeding and drinking equipment and mortality among broiler chickens

Set	GROUP	AoI	$f_{(I)}$	nTB	nMk	nMu	nFS Dk	nFS Fd	Rx usage (%)	Mortality (%)
Set 1	CDD+CDF	5	3	44	11	1	+3/3	+4/5	88	6
	HDT+CDF	5	2	43	8	0	-/1	+5/5	86	12
	CDD+HFT	5	2	43	9	0	+3/3	-/7	86	10
	HDT+HFT	2	1	19	2	3	-/1	-/7	38	4
	CDD+CDFm	-	-	-	-	-	na	na	-	-
Set 2	CDD+CDF	5	3	46	2	2	+3/3	+5/5	92	8
	HDT+CDF	6	3	44	6	0	-/1	+5/5	88	6
	CDD+HFT	5	3	41	7	0	+2/3	-/7	82	8
	HDT+HFT	2	1	13	3	0	-/1	-/7	26	6
	CDD+CDFm	-	-	-	-	-	na	na	-	-
Set 3	CDD+CDF	5	2	45	5	2	+2/3	+4/5	90	12
	HDT+CDF	5	1	40	7	0	-/1	+5/5	80	6
	CDD+HFT	6	2	42	9	1	+3/3	-/7	84	8
	HDT+HFT	1	1	9	2	0	-/1	-/7	18	4
	CDD+CDFm	-	-	-	-	-	na	na	-	-
Set 4	CDD+CDF	6	3	43	7	2	+3/3	+4/5	86	18
	HDT+CDF	5	2	42	5	0	-/1	+4/5	84	10
	CDD+HFT	5	3	44	8	0	+2/3	-/7	88	16
	HDT+HFT	1	1	11	1	2	-/1	-/7	22	6
	CDD+CDFm	-	-	-	-	-	na	na	-	-
Set 5	CDD+CDF	5	2	44	6	0	+3/3	+5/5	88	12
	HDT+CDF	6	2	41	5	0	-/1	+4/5	82	10
	CDD+HFT	5	3	47	7	2	+2/3	-/7	94	18
	HDT+HFT	2	1	8	1	2	-/1	-/7	16	6
	CDD+CDFm	-	-	-	-	-	na	na	-	-
Set 6	CDD+CDF	7	2	42	7	1	+2/3	+5/5	84	16
	HDT+CDF	5	2	45	3	2	-/1	+5/5	90	10
	CDD+HFT	5	2	43	6	1	+2/3	-/7	86	14
	HDT+HFT	2	1	12	2	0	-/1	-/7	24	4
	CDD+CDFm	-	-	-	-	-	na	na	-	-

CDD: Contemporary deep litter drinkers, CDF: Contemporary deep litter feeders, HDT: Healthy liquid drinking trough, HFT: Healthy feeding trough, CDD+CDFm: Contemporary deep litter drinkers and Contemporary deep litter feeders raised market samples; AoI: Average observed infected per time (within 48 h), $f_{(I)}$: Frequency of infection and antibiotic treatments given stock all through rearing life, nTB: Number of treated birds in course of rearing life, nMk: Number of mortality from known cause, nMu: Number of mortality from non-infectious and unknown cause, nFS: Number of faecal droppings with infectious organisms, Dk: Drinker, Fd: Feeder, Rx: Drugs

Table 2: Prevalence of infection in feeding and drinking equipment and mortality among roaster chickens

Set	GROUP	AoI	$f_{(I)}$	nTB	nMk	nMu	nFS Dk	nFS Fd	Rx usage (%)	Mortality (%)
Set 1	CDD+CDF	4	2	12	3	0	+1/1	+1/2	48	4
	HDT+CDF	4	1	11	2	2	-/1	+2/2	44	4
	CDD+HFT	3	1	14	1	1	+1/1	-/3	56	8
	HDT+HFT	2	0	8	2	0	-/1	-/3	32	8
	CDD+CDFm	-		-	-	-	n/a	n/a	-	-
Set 2	CDD+CDF	4	1	9	1	0	+1/1	+2/2	36	4
	HDT+CDF	3	0	10	1	0	-/1	+2/2	40	0
	CDD+HFT	4	1	12	1	1	+1/1	-/3	48	0
	HDT+HFT	2	0	9	0	1	-/1	-/3	36	4
	CDD+CDFm	-	-	-	-	-	n/a	n/a	-	-
Set 3	CDD+CDF	5	1	23	2	0	+1/1	+2/2	92	0
	HDT+CDF	2	1	7	1	0	- /1	+1/2	28	4
	CDD+HFT	3	1	19	1	1	+1/1	- /3	76	8
	HDT+HFT	1	1	5	2	0	- /1	- /3	20	0
	CDD+CDFm	-	-	-	-	-	n/a	n/a	-	-
Set 4	CDD+CDF	4	1	15	4	0	+1/1	+2/2	60	8
	HDT+CDF	3	0	9	2	0	-/1	+2/2	36	0
	CDD+HFT	2	0	11	3	0	+1/1	-/3	44	8
	HDT+HFT	1	1	6	1	0	-/1	-/3	24	4
	CDD+CDFm	-	-	-	-	-	n/a	n/a	-	-

CDD: Contemporary deep litter drinkers, CDF: Contemporary deep litter feeders, HDT: Healthy liquid drinking trough, HFT: Healthy feeding trough, CDD+CDFm: Contemporary deep litter drinkers and Contemporary deep litter feeders raised market samples, AoI: Average observed infected per time (within 48 hrs); $f_{(I)}$: Frequency of infection and antibiotic treatments given stock all through rearing life; nTB: number of treated birds in course of rearing life, nMk: number of mortality from known cause, nMu: Number of mortality from non-infectious and unknown cause, nFS: Number of faecal droppings with infectious organisms, Dk: Drinker, Fd: Feeder, Rx: Drugs

Table 3: Prevalence of infection in feeding and drinking equipment and mortality among layer chickens

								nFS			
Set	GROUP	AoI	$f_{(I)}$	nTB	nMk	nMu	LS (week)	Dk	Fd	Rx usage (%)	Mortality (%)
Set 1	CDD+CDF	6	5	88	83	3	+6/6	+8/8	41	88	98
	HDT+CDF	6	4	92	69	6	-/2	+8/8	56	92	83
	CDD+HFT	5	5	95	91	4	+6/6	-/10	45	95	92
	HDT+HFT	3	3	14	9	11	-/2	-/10	117	14	26
	CDD+CDFm	-	-	-	-	-	na	na	na	na-	

CDD: Contemporary deep litter drinkers, CDF: Contemporary deep litter feeders, HDT: Healthy liquid drinking trough, HFT: Healthy feeding trough, CDD+CDFm: Contemporary deep litter drinkers and Contemporary deep litter feeders raised market samples, AoI: Average observed infected per time (within 48 h), $f_{(I)}$: Frequency of infection and antibiotic treatments given stock all through rearing life; nTB: Number of treated birds in course of rearing life, nMk: Number of mortality from known cause, nMu: Number of mortality from non-infectious & unknown cause, nFS: Number of faecal droppings with infectious organisms, Dk: Drinker, Fd: Feeder, Rx: Drugs

Table 4: Chemical residue positive chicken products (total number of birds, number positive and percentage)

Groups	Part	Broilers	Roasters	Layers
CDD+CDF	Breast	262, 41 (15.6%)	96, 9 (9.4%)	88, 13 (14.8%)
HDT+CDF		278, 23 (8.3%)	95, 3 (3.2%)	92, 9 (9.8%)
CDD+HFT		275, 35 (12.7%)	96, 5 (5.2%)	95, 11 (11.6%)
HDT+HFT		266, 8 (3.0%)	94, 0 (0.0%)	94, 2 (2.1%)
CDD+CDFm		60, 17 (28.3%)	40, 7 (17.5%)	10, 2 (60.0%)
CDD+CDF	Liver	262, 62 (23.7%)	96, 8 (8.3%)	88, 11 (12.5%)
HDT+CDF		278, 31 (11.2%)	95, 3 (3.2%)	92, 10 (10.9%)
CDD+HFT		275, 51 (18.5%)	96, 4 (4.2%)	95, 11 (11.6%)
HDT+HFT		266, 6 (2.3%)	94, 1 (1.1%)	94, 1 (1.1%)
CDD+CDFm		60, 20 (33.3%)	40, 5 (12.5%)	10, 1 (10.0%)
CDD+CDF	Kidney	262, 79 (30.2%)	96, 18 (10.4%)	88, 12 (13.6%)
HDT+CDF		278, 34 (12.2%)	95, 7 (2.1%)	92, 8 (8.7%)
CDD+HFT		275, 64 (23.3%)	96, 4 (4.2%)	95, 7 (7.4%)
HDT+HFT		266, 5 (1.9%)	94, 1 (1.1%)	94, 1 (1.1%)
CDD+CDFm		60, 26 (43.3%)	40, 8 (20.0%)	10, 2 (20.0%)
CDD+CDF	Eggs	-	-	80, 8 (10.0%)
HDT+CDF		-	-	155, 5 (3.2%)
CDD+HFT		-	-	100, 7 (7.0%)
HDT+HFT		-	-	460, 2 (0.4%)
CDD+CDFm		-	-	250, 24 (9.6%)

CDD: Contemporary deep litter drinkers, CDF: Contemporary deep litter feeders, HDT: Healthy liquid drinking trough, HFT: Healthy feeding trough

farmers using the deep litter poultry farming system have great penchant for administration of drugs to their entire flock as soon as the slightest sign of infection appears. No quarantine exercises are carried out on birds observed to be infected. Careful observation also showed that while other layer groups' drug usage and mortality ranged between 88-92% and 83-98% within less than 1 year of life, they were only 14 and 26% respectively, for over 2 years of life in the HDT+HFT group (Table 3). Furthermore, while the high mortality as recorded in the other layer groups could happen to new entrant farmers, it was a classical presentation of the experiences of most poultry farmers who remain in the business fairly long enough.

In our experiment, all groups were flock-treated only after up to three birds were found to be infected within two days in quick succession, following the advice and prescriptions of the veterinarian. On many occasions, flock treatments were actually avoided. The lowest appearance of chemical residues in eggs was found in the HDT+HFT group of layer (Table 4). The group presented 0.4% chemical residue positive in a total of 460 eggs as against 10% found in the CDD+CDF group. This indicated a 25 times chance of exposure among the CDD+CDF group compared to the HDT+HFT group. Mensah *et al.*[31], reported antimicrobial residues prevalence of up to 1.0 and 23.0% for eggs and laying hens respectively in Nigeria, while in Ghana, it was also as much as 6.8% for eggs.

The superiority of HDT+HFT utilization over the present commonly used feeders and drinkers seem to be more evident here. Egg is one commodity that is commonly or fairly accessible to both the affluent and indigent. The poor and malnourished children especially, can source their animal protein from eggs. Eggs are usually recommended for children from poor and developing countries to meet or provide a reasonable portion of their protein requirements. Consuming eggs that are laden with chemical residues thus becomes counter-productive, as there are inimical effects and consequences. Chemical residues of sulfamethazine, oxytetracycline, furazolidone and chloramphenicol in diet have been reported to cause poor development of fetuses, teeth discolouration in young children, gastrointestinal disorders, poor cognitive development/defects, exacerbate inflammatory responses, cytotoxicity and immuno-pathological problems[32]. By design, the HDT+HFT systematically eliminates these risks.

Poultry birds performance indices: With rising costs, scarcity and competing demands for resources, measuring certain key parameters in poultry farming is important in order to gauge the viability of the venture. Such parameters were tested in this experiment as a way to identify whether the newly designed feeding and drinking troughs have affected the performance of the birds. Among the broilers and roasters (Table 5 and 6), there were no significant differences in the average feed intake (AFI) between the groups that were fed through the CDFs or HFTs but AFI values were significantly lower in the groups that were fed with the HFTs than the CDFs ($p<0.05$). Incidentally, there was no significant difference ($p<0.05$) in the average body weights among all the groups. This is indicative of loss of feed or wastages beyond the actual consumption thresholds of the groups fed through the CDF equipment. It also explains the higher FCR, indicating lower efficiency of feed conversion in the CDF groups, which should not be the case, considering the fact that each group was drawn from the same batch and breed or stock at the same time. In Table 5, wastage of feed was confirmed by the FWEL values being lower among the groups fed with the CDFs accounting for up to 18-20% feed loss or wastage than in the HFT groups where FWEL was as high as 97% (only about 3% feed loss). The same trend was observed in the roasters and layers (Table 6 and 7). Among layers, apart from similar ABWs, the HHEP and mEM were statistically the same ($p<0.05$) irrespective of the type of feeder or drinker they fed and drank from. In all the broiler and roaster groups, no significant difference was observed with respect to livability ($p<0.05$) (Table 5 and 6). Livability ranged from 87.67±4.27% to 95.00±2.10% among broilers and 94.00±4.00% to 98.00±2.31% among the roasters, respectively. But among layer birds, livability was poorest (6%) within less than 1 year in the CDD+CDF group while it was highest (89%) in the HDT+HFT group and for as long as two years period. This is attributable to the low frequency of infection, $[f_{(I)}]$ and average observed infected birds, (AoI), throughout their lives (Table 3). Hen-housed egg production, HHEP (over long period) which is calculated as the total number of eggs laid (or weight gained) during the period divided by the total number of hens housed at the beginning of laying (or housing) period is an important parameter from both the cost of egg (or meat) production viewpoint. It is an excellent parameter for measuring the effects of both egg (or meat) production and mortality among birds. Values of 80% or 295 and above are desirable[30]. All the layer groups in the experiment met the desirability mark of at least 80% (Table 7).

Productive efficiency index (PEI) is necessary in order to uniformly compare flocks of animals. This index is calculated with factors which includes the body weight, livability, age (in days) and feed conversion ratio[33]. Higher PEI values indicate

Table 5: Performance indices (broilers)

Groups	AFI (kg)	ABW (kg)	LIV (%)	FCR	PEI (%)	FWEL (%)	WS (LIT)	WU (%)
CDD+CDF	5.08±0.16^{a}	2.69±0.11^{a}	88.00±4.56^{a}	1.89^{a}	271.36^{a}	82.41^{a}	730.25±29.11^{a}	63.17^{a}
HDT+CDF	5.30±0.18^{a}	2.77±0.13^{a}	91.00±2.45^{ab}	1.92^{a}	266.66^{a}	80.64^{ab}	559.55±23.68^{c}	95.10^{b}
CDD+HFT	4.82±0.13^{b}	2.91±0.07^{b}	87.67±4.27^{a}	1.66^{b}	317.74^{b}	96.80^{c}	714.50±37.69^{ab}	66.13^{a}
HDT+HFT	4.67±0.13^{b}	2.81±0.07^{ab}	95.00±2.10^{bc}	1.66^{b}	315.38^{b}	96.66^{c}	556.70±19.47^{c}	95.44^{b}

Certain values are Mean±SD. No significant difference between values with same superscripts down the column ($p<0.05$)

Table 6: Performance indices (Roasters)

Groups	AFI (kg)	ABW (kg)	LIV (%)	FCR	PEI (%)	FWEL (%)	WS (LIT)	WU (%)
CDD+CDF	22.69±0.49^{a}	5.60±0.11^{a}	96.00±3.27^{a}	4.05^{a}	105.65^{a}	75.65^{a}	1323.68±56.19^{a}	68.98^{a}
HDT+CDF	23.34±0.08^{a}	5.76±0.10^{a}	98.00±2.31^{ab}	4.05^{a}	110.92^{b}	75.78^{a}	1122.00±46.48^{bc}	96.06^{b}
CDD+HFT	17.31±0.78^{b}	5.16±0.21^{ab}	94.00±4.00^{ab}	3.35^{b}	115.49^{c}	97.20^{b}	1212.98±61.02^{abcd}	69.46^{a}
HDT+HFT	17.21±1.01^{b}	5.10±0.36^{ab}	96.00±2.17^{a}	3.38^{b}	115.01^{c}	96.35^{b}	1073.03±83.06^{d}	95.96^{b}

Certain values are Mean±SD. No significant difference between values with same superscripts down the column ($p<0.05$).

Table 7: Performance indices (layers)

Group	AFI (kg)	ABW (kg)	LIV (%)	HHEP (%)	mEM (g)	FCR	NFEI	EFPR	PEI (%)	FWEL (%)	WS (LIT)	WU (%)
CDD+CDF	21.36	1.91^{a}	6^{a}	81.2^{a}	57.8^{a}	2.65^{a}	66.73^{a}	1.78^{a}	41.3^{a}	87.11^{a}	3323.7±24.2^{a}	72.00^{a}
HDT+CDF	40.68	2.08^{ab}	27^{b}	83.6^{a}	58.2^{a}	2.61^{a}	63.28^{b}	1.81^{a}	104.5^{c}	89.07^{a}	6541.0±17.4^{b}	98.78^{b}
CDD+HFT	24.24	1.98^{a}	8^{a}	82.4^{a}	59.8^{ab}	2.40^{b}	67.99^{a}	2.20^{b}	47.1^{ab}	97.80^{b}	3512.6±28.1^{a}	72.90^{a}
HDT+HFT	106.34	2.34^{b}	89^{c}	82.7^{a}	61.2^{bc}	2.37^{b}	63.41^{b}	2.46^{c}	143.7^{d}	99.19^{b}	13443.0±45.6^{c}	98.51^{b}

Certain values are Mean±SD. No significant difference between values with same superscripts down the column ($p<0.05$)

better productivity. Usually, PEI improves as dietary nutrient and energy density increases, while feed conversion ratio decreases[26]. Similar trends were observed in this experiment (Table 5-7). Among the broilers, there was no significant difference between the PEI values of the groups fed with the CDFs which were however, significantly lower (p>0.05) than those fed using the HFTs (Table 5). Among the roaster flock, the PEI increased in the order: CDD+CDF<HDT+CDF<HDT+HFT <or= CDD+HFT. For the layers, PEI which was based on egg production also showed an increase in the order: CDD+CDF <or= CDD+HFT<HDT+CDF <<< HDT+HFT (p<0.05). The HDT+HFT group showed by far, the highest PEI value. This could be attributable to the fact that while the other groups were cut short due to disease outbreak, the HDT+HFT group lived out their full hen lives with no punctuation in their production lives apart from a brief period of moulting. Net feed efficiency index (NFEI), is based on egg production, egg weight, feed intake and body weight gain. The experiment showed generally desirable values (Table 7). Desirable values are above 45 according to TNAU[30]. EFPR values are relevant among layers (Table 7). In this experiment, values varied significantly (p>0.05) with the lower ends recorded in the 'CDD+CDF' and 'HDT+CDF' groups. Higher but significantly different values of 2.20 and 2.46 were obtained in the 'CDD+HFT' and 'HDT+HFT' groups. According to TNAU[30], with desirable values being above 1.4, all the groups may be considered to have met the productivity mark (Table 7). However, the 'HDT+HFT' group presented the highest score. Feed conversion ratio (FCR) is another critical criterion for measuring the performance of a poultry flock, whether for meat or egg production. For broilers (Table 5), 'CDD+CDF' and 'HDT+CDF' groups with FCR values of 1.89 and 1.92 respectively, were significantly higher (p<0.05) than values obtained for 'CDD+HFT' and 'HDT+HFT' groups (both 1.66). According to Obori[34], values ranging from 2.5-3.0 are indicative of good FCR or feed efficiency (kg feed kg^{-1} gain). However, 1.65 has been recently reported by Patricio *et al.*[35]. Among the roasters, the 'CDD+CDF' and 'HDT+CDF' were at par in their FCR values. Meanwhile, there was no significant difference between the 'CDD+HFT' and HDT+HFT' groups where lower FCRs (3.35 and 3.38 respectively) were obtained. Other researchers have recorded FCR ranging from 3.09-4.50 among cockerels/roasters of various strains[36-39]. Among layers, FCR was considered in terms of eggs laid. The 'HDT+HFT' group presented the lowest value of 2.37 FCR per doz. eggs. Highest value of 2.65 was obtained in the 'CDD+CDF' group. According to previous reports, FCR between 1.8-3.5 per doz. eggs have been recorded in Nigeria[34,40].

Water utilization was the next item considered. Water is highly critical that if sufficiency is not guaranteed, running poultry is not feasible. It becomes more important to ensure maximal utilization when there is competing need between humans and animals in an environment of water scarcity like in Katsina state of Nigeria. Birds must have regular and adequate water supply to be efficient. As such, in order to limit wastages as found in the CDDs, new designs that help to harness all available water supplied to the birds are highly required. In this experiment, while the birds utilized between 60-70% of water for actual metabolic purposes when supplied through the CDDs, the HDTs afforded staggering 95-98% water utilization, with the 2-5% balance used in routine cleaning (Table 5-7). A farmer can easily calculate her/his gains when price tags are attached to unit volumes of this scarce resource.

Economics of production indices: The economic advantages of the HFT and HDT were also examined against the contemporary feeding and drinking devices. In Table 8-10, it was evident that labour index points (LIPs) and total costs (TC), decreased in the order: CDD+CDF >CDD+HFT>HDT+CDF>HDT+HFT. Conversely, percentage labour reduction (%) and added profit, increased in the

Table 8: Economics of production indices (broilers)

Groups	TC (N)	Income (N)	LIP	LR (%)	NP (N)	AP (%)
CDD+CDF	65,261.7±2,301.7	126,115.5	6.1	-	60,854	0.0
HDT+CDF	59,170.5±2,574.5	126,706.5	3.1	49.3	67,536	9.9
CDD+HFT	62,083.8±2,540.7	128,491.3	4.6	24.6	66,408	8.4
HDT+HFT	52,937.2±1,480.5	125,581.8	1.6	74.1	72,645	16.2

TC: Total cost, LIP: Labour index point, LR: Labour reduction, NP: Net profit, AP: Added profit, N: Naira

Table 9: Economics of production indices (roasters)

Group	TC (N)	Income (N)	LIP	LR (%)	NP (N)	AP (%)
CDD+CDF	79,172.6±1,557.4	85,757.5	6.1	-	6,585	0.0
HDT+CDF	78,707.7±252.3	86,456.0	3.1	49.3	7,748	15.3
CDD+HFT	60,804.9±2,503.8	68,330.5	4.6	24.6	7,526	12.5
HDT+HFT	57,948.5±3,234.7	68,766.8	1.6	74.1	10,818	39.0

TC: Total cost, LIP: Labour index point, LR: Labour reduction, NP: Net profit, AP: Added profit, N: Naira

Table 10: Economics of production indices (layers)

Groups	TC (N)	Income (N)	LIP	LR (%)	NP (N)	AP (%)
CDD+CDF	231,362.3	240,946.7	6.1	-	9,584.3	4.1
HDT+CDF	422,379.2	488,183.3	3.1	49.3	65,804.2	15.6
CDD+HFT	329,308.5	364,420.0	4.6	24.6	35,111.5	10.7
HDT+HFT	1,452,944.5	1,772,190.0	1.6	74.1	319,245.5	22.0

TC: Total cost, LIP: Labour index point, LR: Labour reduction, NP: Net profit, AP: Added profit, N: Naira

reverse order: CDD+CDF<CDD+HFT<HDT+CDF<HDT+HFT. The implication here is that, whatever profit margin became accruable in the use of purely the contemporary feeding and drinking equipment in the deep litter poultry farming, the utilization of either the HDTs or the HFTs purely as the drinking or feeding devices respectively, added some measure of profits above the contemporary types. However, a full combined use of the HDT and HFT offered the most profits. In this experiment, 16.2, 39.0 and 22.0% added profits were recorded among broilers, roasters and layers where only the HDT and HFT were used as drinkers and feeders.

CONCLUSION

It was generally observed that groups of poultry birds that drank from the CDD presented more adverse impacts of chemical residues in poultry products than the CDF. This was attributed to the understanding that infections are mostly transmitted through fluid intake and drugs are also administered through their drinks. On the contrary, the HDT yielded positive impacts against chemical residues accumulation in poultry products than HFT. However, the combination of HDT+HFT offered greater benefits by curbing infections besides eliminating the concomitant tendencies for unbridled administration of drugs in attempt to maintain birds' health which typically results in the accumulation of chemical residues in the poultry's edible parts. Furthermore, the HDT and HFT are designed to offer far more profound and immediate benefits which include elevated hygiene, drastic reduction in disease/disease outbreak and mortality arising thereof, reduction in drug use, general performance of poultry birds, reduced labour, elimination of feed wastage, maximized water utilization, optimal drug utilization when necessary, reduced production cost and increased profits. They are also highly scalable, portable, easy to install and maintain and requires very little or no education to use. Further research and impact studies may be conducted in order to ascertain the veracities of the present findings as expected for every innovation. However, it may be safe to state at this time and within the confines of our experimental uniqueness that the combined use of the HDT and HFT in poultry management is sure to offer many great benefits to poultry keepers/farmers and the massive population of consumers of their products. Also, the adaptation and utilization of these simple technologies are likely bring a positive shift of paradigm in the deep litter poultry farming especially in countries where safety of poultry products, maximal application of scarce resources, access to complicated machineries and costs are major challenges.

SIGNIFICANCE STATEMENT

This study discovered the protective capabilities of two new innovations against the rapid spread of infectious diseases among poultry birds in the deep liter poultry farming system. The study first buttressed the fact that most poultry diseases are spread through the water and feed troughs used by poultry farmers. This has led to massive losses and accumulation of chemical and antibiotic residues in birds as they have to be inevitably treated. However, the newly innovated equipment eliminates chances of contamination that often lead to the spread of diseases via these channels. This study thus presents the advantages of adopting these simple technologies primarily in the aspect of hygiene elevation, health and safety of poultry products for human consumption, among other economic and social benefits.

REFERENCES

1. Dolberg, F., 2010. Poultry as a tool in human development: Historical perspective, main actors and priorities. FAO Smallholder Poultry Production Paper No. 6, Food and Agriculture Organization of the United Nations, Rome, Italy.
2. Dhama, K., R. Tiwari, R.U. Khan, S. Chakraborty and M. Gopi *et al*., 2014. Growth promoters and novel feed additives improving poultry production and health, bioactive principles and beneficial applications: The trends and advances-a review. Int. J. Pharmacol., 10: 129-159.
3. Heise, H., A. Crisan and L. Theuvsen, 2015. The poultry market in Nigeria: Market structures and potential for investment in the market. Int. Food Agribus. Manage. Rev., 18: 197-222.
4. Juma, C., 2016. If Africa learnt to feed its chickens it could feed its people. http://theconversation.com/if-africa-learnt-to-feed-its-chickens-it-could-feed-its-people-65571.

5. Alemayehu, T., J. Bruno, F. Getachew and T. Dessie, 2018. Socio-economic, marketing and gender aspects of village chicken production in the tropics: A review of literature. ILRI Project Report, International Livestock Research Institute (ILRI), Nairobi, Kenya, July 2018.
6. FAO., 2019. Gateway to poultry production and products. Food and Agriculture Organization of the United Nations, Rome, Italy. http://www.fao.org/poultry-production-products/en/.
7. De Bruyn, J., J. Wong, B. Bagnol, B. Pengelly and R. Alders, 2015. Family poultry production and food and nutrition security. CAB Rev., 10: 1-9.
8. Oyesola, O.B. and M.G. Olujide, 2000. Participation of livestock farmers in Nigerian, Agricultural insurance scheme. A case study of Iseyin L.G.A. Proceedings of the 5th Annual Conference of Animal Science Association of Nigeria, September 19-22, 2000, Port Harcourt, Nigeria, pp: 213.
9. Okoli, I.C., 2003. Incidence and modulating effects of environmental factors on trypanosomosis, peste des petit ruminants (PPR) and bronchopneumonia of West African dwarf goats in Imo State, Nigeria. Livest. Res. Rural Dev., Vol. 15, No. 9.
10. FAO., 2013. Poultry Development Review. Food and Agriculture Organization of the United Nations, Rome, Italy, ISBN: 978-92-5-108067-2, Pages: 120.
11. Olorunwa, O.J., 2018. Economic analysis of broiler production in Lagos State poultry estate, Nigeria. J. Invest. Manage., 7: 35-44.
12. Patterson, J.A. and K.M. Burkholder, 2003. Application of prebiotics and probiotics in poultry production. Poult. Sci., 82: 627-631.
13. Kocher, A., 2006. Interfacing Gut Health and Nutrition: The Use of Dietary Prebiotics and Probiotics to Maximise Growth Performance in Pigs and Poultry. In: Antimicrobial Growth Promoters: Where Do We Go From Here? Barug, D., J. de Long, A.K. Kies and M.W.A. Verstegen (Eds.). Wageningen Acad. Publ., Wageningen, The Netherlands, pp: 289-310.
14. Akinleye, S.B., E.A. Iyayi and K.D. Afolabi, 2008. The performance, haematology and carcass traits of broilers as affected by diets supplemented with or without biomin a natural growth promoter. World J. Agric. Sci., 4: 467-470.
15. Gassner, B. and A. Wuethrich, 1994. Pharmacokinetic and toxicological aspects of the medication of beef-type calves with an oral formulation of chloramphenicol palmitate. J. Vet. Pharmacol. Therapeut., 17: 279-283.
16. Sonaiya, E.B. and S.E.J. Swan, 2004. Small-scale poultry production: Technical guide. Animal Production and Health 1, Food and Agriculture Organization of the United Nations, Rome, Italy.
17. Mgbakor, M.N. and E.N. Chinonso, 2013. Economic analysis of broiler production (a case study of Orumba South L.G.A of Anambra State, Nigeria). Am.-Eurasian J. Agron., 6: 25-31.
18. Maduka, C.V., I.O. Igbokwe and N.N. Atsanda, 2016. Appraisal of chicken production with associated biosecurity practices in commercial poultry farms located in Jos, Nigeria. Scientifica, Vol. 2016. 10.1155/2016/1914692
19. K-State Research and Extension, 1929. Poultry diseases, their prevention and control. Circular No. 106 Revised, Bulletin No. 247, Agricultural Experiment Station, Kansas State Agricultural College, Manhattan, KS., USA., June 1929.
20. Poppe, C., D.A. Barnum and W.R. Mitchell, 1986. Effect of chlorination of drinking water on experimental *Salmonella* infection in poultry. Avian Dis., 30: 362-369.
21. Heyndrickx, M., D. Vandekerchove, L. Herman, I. Rollier, K. Grijspeerdt and L. de Zutter, 2002. Routes for salmonella contamination of poultry meat: Epidemiological study from hatchery to slaughterhouse. Epidemiol. Infect., 129: 253-265.
22. Do Amaral, L.A., 2004. Drinking water as a risk factor to poultry health. Rev. Bras. Cienc. Avic., 6: 191-199.
23. Neves, D.P., T.M. Banhazi and I.A. Naas, 2014. Feeding behaviour of broiler chickens: A review on the biomechanical characteristics. Braz. J. Poult. Sci., 16: 1-16.
24. Trawinska, B., A. Chmielowiec-Korzeniowska, B. Nowakowicz-Debek, L. Tymczyna, T. Bombik, M. Pyrz and M. Tymczyna-Sobotka, 2016. Evaluation of microbial contamination of feces and soil on a laying-hen farm depending on sampling site and season. Rev. Bras. Zootec., 45: 190-194.
25. Kehinde, O.G., K. Junaidu, M. Mohammed and A.M. AbdulRahman, 2012. Detection of antimicrobial drug residues in commercial eggs using Premi® test. Int. J. Poult. Sci., 11: 50-54.
26. Kuptha, V.M. and B.R. Ragavendiran, 2015. Justification of profitable test kit for microbiological viewing of antimicrobials in rooster eggs. SSRG Int. J. Vet. Sci., 1: 15-17.
27. R-Biopharm AG, 2016. Antibiotic residue screening: Premi®Test-Microbial inhibition test for broad spectrum screening of food. R-Biopharm AG, Darmstadt, Germany. http://tuoteluettelo.mediq.fi/liitteet/d377796/.
28. Ezieshi, V.E., M.J. Nworu, F.O. Bandele, R.O. Suleman, B.C. Ojurongbe and J.M. Olomu, 2003. Laying hen productivity in the tropics as affected by stage of egg production, feed restriction, stocking density and time of day. Arch. Zootec., 52: 475-482.
29. Martins, J.M.S., C.M.C. Carvalho, F.H. Litz, M.M. Silveira and C.A. Moraes *et al*., 2016. Productive and economic performance of broiler chickens subjected to different nutritional plans. Braz. J. Poult. Sci., 18: 209-216.
30. TNAU., 2019. Expert system poultry: Layer production indices. Tamil Nadu Agricultural University (TNAU), Coimbatore, India. http://www.agritech.tnau.ac.in/expert_system/poultry/Layer%20Production%20Indices.html.
31. Mensah, S.E.P., O.D. Koudande, P. Sanders, M. Laurentie, G.A. Mensah and F.A. Abiola, 2014. Antimicrobial residues in foods of animal origin in Africa: Public health risks. Rev. Sci. Tech. Off. Int. Epiz., 33: 987-996.

32. Mund, M.D., U.H. Khan, U. Tahir, B.E. Mustafa and A. Fayyaz, 2017. Antimicrobial drug residues in poultry products and implications on public health: A review. Int. J. Food Prop., 20: 1433-1446.
33. Oliveira, K.P., C.F.S. Ferreira, I.F.F. Tinoco, R.R. Andrade and M. Barbari *et al*., 2018. Productive performance of broilers at the final stage of breeding submitted to different levels of metabolizable energy in different thermal environments. Agron. Res., 16: 556-563.
34. Obori, G., 2005. Poultry Care: A complete guide to chicken production. Ganob and Associates Limited, Kaduna, Nigeria.
35. Patricio, I.S., A.A. Mendes, A.A. Ramos and D.F. Pereira, 2012. Overview on the performance of Brazilian broilers (1990-2009). Braz. J. Poult. Sci., 14: 233-238.
36. Kumar, S., P.K. Singh and A. Prasad, 2009. Effect of graded level of dietary energy and protein on the growth performance of cockerels. Indian J. Anim. Nutr., 26: 86-89.
37. Huque, Q.M.E., M.P. Mostari, S. Faruque and M.R. Islam, 2018. Cockerel production: Strategy of family poultry development. Bangladesh Livestock Research Institute, Savar, Dhaka, Bangladesh.
38. Abeke, F.O., S.O. Ogundipe, A.A. Sekoni, I.I. Dafwang and I.A. Adeyinka *et al*., 2008. Response of shika brown cockerels to graded dietary levels of *Lablab purpureus* beans. Asian J. Poult. Sci., 2: 10-16.
39. Lawal, O.A., F.O. Owagboriaye, S.A. Aina, S. Kalejaye and J.A. Adegbite, 2015. Feed utilization and growth performance of cockerels fed with soldier ants (*Dorylus* spp Fabricius) as protein source. Zoologist, 13: 56-61.
40. Oluyemi, J.A. and F.A. Roberts, 2000. Poultry Production in Warm Wet Climates. 2nd Edn., Spectrum Books, Ibadan, Nigeria, ISBN: 9789780290979, Pages: 190.