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Production performance of broiler breeders under cage versus floor housing systems

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Abstract

Research trials were conducted at commercial farms (n=20,000) to evaluate the production performance of meat-type floored and cage housed Hubbard breeder flocks during 1st egg lay cycle under controlled environment. Hens (n=20,000) were divided into two groups, housed in cages (n=10,000) or floored (n=10,000) and were artificially inseminated weekly. The cage housed hens consumed 10% less (P<.01) feed, than floored hens. Feed intake gradually increased (P<.01) from pre-peak through peak stage of egg lay and then declined after the peak, supplemented (P<.01) by the interaction of housing and production stages. Consequently, the trend for feed conversion ratio (FCR) per dozen of eggs was reversed (P<.01) both for floored (3.80±0.86 kg) and cage housed (2.65±0.45 kg) hens. Survival rate was higher (P<.01) in cage housing (99.74±0.07) by (0.05%) than floor (99.69±0.09) that declined with advancement in stage of production. Floored hens were heavier (P<.01) than cage housed hens whereas the cockerels' weight was similar (P>.05). Cage housed flocks had (3%) more (P<.01) egg lay (70.60±12.75) with 4% more (P<.05) settable eggs (95.99±14.00) that hatched (86.46±4.24) better (P<.01) than floored flocks (67.35±15.04; 91.99±14.00; 84.46±8.95). The quality of chicks was equally (P>.05) better in both housings that improved (P<.01) with advancement in production. Neither egg quality parameters nor weight of chicks they hatched differed (P>.05) with housing although significantly (P<.01) increased as the production stage advanced. The levels of biochemical and haematological parameters were almost similar (P>.05) in all flocks. Better performance of caged flocks leads us to recommend cage housing.

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Introduction

The global challenge will continue to reside to provide an affordable, safe, and sustainable food supply (Reardon *et al.*, 2013; Potts 2009). Increasing preference for processed and safe white meat has declined the share of cereal grains in the total budget for food (Chisanga and Zulu-Mbata 2017; Tschirley *et al.*, 2013; Alexandratoss and Bruinsma 2012). Resultantly, the producers have to adopt innovative farming practices to improve the economic efficiency of their farms (Njoya and Picard 1994).

In its pursuit to fulfill the increasing demand, besides successful technical advances in genetic selection, nutrition and disease control, the poultry industry has attempted to double the stocking density of existing farms through multitier cage housing systems (Badubi and Ravindran, 2004; Tauson 2005). The innovative housing systems used in laying hens production are enriched cages, aviary systems, and free range, having different technical features (Lay *et al.*, 2011 and Singh *et al.*, 2009). Such systems are designed to balance animal health and welfare in accordance with the demands of consumers and the poultry sector (Sumner *et al.*, 2008). Enriched cage systems are one of the alternative systems developed to remedy the deficiencies of conventional cage systems relating to animal welfare. These systems provide each hen with a larger usable area and are furnished with equipment that helps them exhibit their natural behavior, such as a nest, scratching area and perching (Van Horne 2003). But researchers fear high capital investment (Bell, 2006), energy consumption (Matthews *et al.*, 2015) and operating and production costs per hen (Gocsik *et al.*, 2015), in the uptake of this technological innovation. Thus, the flock performance in the prevailing housing systems needs a thorough investigation to validate one of them for commercial use (Groen *et al.*, 1998), although such information is hard to obtain from the breeder (Faridi *et al.*, 2011; Yassin *et al.*, 2012; Duffy and Nanhou 2003). Therefore the current study is aimed at comparing the production performance of broiler breeders in floor and enriched cage housing systems to facilitate the entrepreneur in opting for one of them.

Materials and methods

To compare the performance of broiler breeders maintained on floor and cages, the following approach was followed:

Study location

The field study was carried out in commercial poultry farm located in Lahore, Pakistan. The city is characterized by a long (December-January) and short (August) raining season. The experiment was conducted from November 2015 through April 2106 under controlled environment where the ambient temperature averaged between 40 and 45°C with Relative Humidity (RH) ranging from 65-90% in hot humid July to August months. The average house temperature and RH during the experimental trials were 21-24°C and 50-65% respectively.

Birds and experimental conditions

The trials included 20,000 Hubbard Boiler Breeder female day-old chicks housed. Chicks were first brooded and raised on littered floor until they were 18 weeks of age and then divided randomly into two groups. Group-1 was maintained on floor having 10,000 hens selected randomly and shifted to 10 equal compartments/replicates with 1,000 hens per replicate. Hens in Group-2 (n=10,000) were randomly shifted to 10 compartments in the cage housing system that accommodated 1,000 hens per replicate. All the flocks were artificially inseminated on each 7th day. Each of the four sheds had a floor space of 18800 square feet. In battery cages manufactured by Guangzhou Guangxing Poultry Equipment Company Limited (http://www.cnguangxing.com), hens were housed in Hot Dip Galvanized 3 tier cages, measuring 658 cm^2 area per female bird and 3 birds per cage, 1645 cm^2 area per male bird and one male per cage. The floor houses were equipped with semiautomated feeders being picked up 15 minutes after feeding, thereby reducing hen housed floor space requirement to 1.88 square feet per bird. It is 13% less than the usually required for layers in tropical climates (Maba, 2008 and Banga-Mboko *et al.*, 2007). Cage housed hens occupied 0.89 square feet floor area per hen.

The floored flocks were provided with nests. Wheat straw served the purpose of substrate in the floored pens. Both cage housed and floored flocks were watered through automatic drinkers and fed manually. The cage housing had the facility of automatic manure removal daily. Both type of flocks observed similar lighting schedule of 16 light hours with 60 LUX and 8 dark hours with zero light intensity during the entire production period.

Feeding and vaccination

Feed was formulated as per management guidelines for Hubbard Classic M99 breed. It contained 2750 Kcal kg^{-1}, 16% crude proteins, 3.5% calcium (Ca) and 0.06% methionine (M) (Banga-Mboko *et al.*, 2007). The floor housed hens and cockerels were daily offered 118 and 110 g respectively on 25^{th} week that peaked at 175 for hens on 29^{th} week and at 142 per day/bird for cockerels on 52^{nd} week. The caged house hens and cockerels were daily offered 105 and 97 g a bird on 25^{th} week that peaked at157 on 29^{th} week for hens and at 100 on 54^{th} week for cockerels (Table-1). The flocks were vaccinated against Newcastle, IB, Coccidiosis, Mareks, IB Variant, IBD (live & attenuated), ILT, AI H9, *E. coli*, IBH and EDS etc. (Table-3).

Insemination

All hens were inseminated with fresh and pooled semen on 7^{th} day throughout production period. Semen was collected from cockerels on alternate days. Semen taken from each 3-4 cockerels used to be pooled together, mixed with 0.4 cc diluent (30% Beltsville Poultry Semen Extender; Hudson *et al.*, 2016) that approximately made final volume of 2cc and gently stirred to inseminate 28-32 hens. Each injector contained 2 million sperms with average penetration value of >60.

Three persons were involved in the insemination process. The first person carefully caught and restrained one hen at a time with his hands. The second person carried out abdominal massage of the breeder hens according to the method of Lake and Stewart (1978) and as soon as there was partial aversion of the cloaca, he exerted a controlled pressure on the lower abdomen for aversion of the vagina. Thereafter, a tuberculin syringe with pooled semen was inserted into the hen's vagina by another person, who released the semen intravaginally as soon as the hen's vagina was felt to relax.

Settable eggs were collected from hens and properly tagged. Daily fertile egg collections were transported to the incubation and hatching facilities and stored at 16° C for a maximum period of seven days before incubation in a Buckeye incubator (Lopen Group, Mill Lane Lopen, South Pertheron Somerset, TA 13 5JS, England) at 37.6°C as procedure adopted by Tona *et al.* (2003). Percent fertility and hatch were recorded through candling at 18^{th} and 21^{st} days of incubation and at hatching, respectively.

Blood Profiling

Blood Sampling

3ml of blood was sampled from the brachial vein of randomly selected birds (Bermudez and Stewart-Brown, 2008); 2ml was tested for biochemical properties of serum whereas the remaining 1ml was poured in a vial and mixed with 2mg of ethylene-diamine tetra-acetic acid (EDTA) to study blood hematology.

Haematology

White cells in the blood (WBC) were counted by preparing a film of blood and then fixing and staining it with Giemsa-Wright stain. Manual method was used to quantify WBC with the help of a haemacytometer. Packed cell volume (PCV) was also manually recorded through capillary tubes of a microhaematocrit by centrifuging for 5 minutes at 2500 rpm (Campbell, 1988).

Biochemical Parameters

Total protein, alkaline transferase, alkaline phosphatase, phosphorous (P), calcium (Ca), magnesium (Mg), triglyceride, cholesterol and glucose levels were quantified through an Autoanalyzer of Technicon RA 1000 model (Technicon Instruments Corporation, Tarrytown, New York, USA).

Egg and chick parameters

1% eggs per replicate were randomly taken, weighed on a digital scale and broken to separate the albumen, yolk and shell. Each constituent was then separately weighed to measure its contribution to the total weight of egg. After hatch, chicks were vent sexed to record sex segregated values of chicks' weight. To serve this purpose, a sample of 1% chicks per replicate was sacrificed to record weight of residual yolk. Inactive, below 25g in weight, unhealthy, having any physical abnormality like lameness, twisted head etc. were graded in B category and the rest were marked A grade chicks.

Body weight

Random samples from male and female birds were taken to record body weight on weekly basis.

Hatchability

Eggs were set in forced-air incubator for 18 days at 99-99.5°F and 60-65% (83-88°F wet bulb) relative humidity (RH) and transferred to hatcher where temperature and humidity were 98.2°F to 98.5° F and 90% respectively.

Statistical analysis

Data were processed using version 22 of the SPSS software. ANOVA was performed and mean values for input and output variables obtained from the littered floor pen and cage housed flocks were compared among treatments using the LSD at 1% and 5% significance levels.

Results

This research trial studied the production performance of broiler breeders in floor versus cage housing systems. Results of the trials are given below.

Effect of housing system on feed efficiency

Floored hens and cockerels consumed 10% more (P<.01) feed than cage housed flocks on a daily basis (Table-2). Feed intake gradually increased (P<.01) from pre-peak through peak stage of egg lay and then declined after the peak. Housing and production stages interacted significantly (P<.01). Weekly feed intake by cockerels followed a similar trend. Consequently, the trend for FCR per dozen of eggs was reversed. This difference in feed intake was consistent throughout production period. The gap in FCRs between the two housing systems narrowed during peak but widened again after the egg lay started decline.

Effect of Housing System on Flock Mortality and Body Weight

The mortality ratios and body weights of birds housed in cages or floored houses are compared in Table-2. Survival rate was higher (P<.01) in cage housing (99.74±0.07) by (0.05%) as compared to floor housing (99.69±0.09) with gradual decline with advancement in stage of production.

The type of housing and stage of production did not interact for flock survival ratio. Floored hens were heavier (P<.01) than cage housed hens whereas the cockerels' weight was similar (P>.05) in both housing. Body weights of both sexes gradually inclined as the flock progressed in stage of production supplemented (P<.01) by the interaction of housing and production stage.

Effect of Housing on Total Egg Lay, its Hatchability and Quality of Chicks it Hatched

Cage housed flocks (Table-2) laid more eggs (P<.01) that hatched better (P<.01) than floored flocks. Both the traits gradually improved (P<.01) from pre-peak to peak stage of production and declined after peak with significant (P<.01) interaction of housing and production stage for hatchability only.

The quality of chicks was equally (P>.05) better in both housings that improved (P<.01) with advancement in production stage without any influence (P>.01) by the interaction of housing and production stage.

Table 1. Weekly Feeding Schedule for Floored and Cage Housed Broiler Breeders.

Production Stage	Flock Age (Week)	Hen Feed ($g\ bird^{-1}\ day^{-1}$)		Rooster Feed ($g\ bird^{-1}\ day^{-1}$)	
		Floor	Cage	Floor	Cage
Pre-Peak	25	118	105	110	97
	26	126	109	114	97
	27	150	125	116	97
	28	168	148	118	97
	29	175	157	120	97
Peak	30	175	157	120	97
	31	175	157	122	97
	32	170	155	122	97
	33	170	155	124	96
	34	170	154	125	95
	35	170	154	127	95
	36	170	154	130	95
	37	169	153	130	95
	38	169	153	133	95
	39	169	153	133	95
	40	169	153	134	95
Post Peak	41	168	153	134	95
	42	168	152	136	95
	43	168	152	138	95
	44	167	152	140	95
	45	167	152	140	95
	46	167	152	140	95
	47	167	152	140	95
	48	167	152	140	95
	49	166	152	140	95
	50	166	151	140	95
	51	166	151	140	95
	52	166	151	142	95
	53	166	151	142	99
	54	166	151	142	100
	55	166	151	142	100
	56	166	150	142	100
	57	165	150	142	100
	58	165	150	142	100
	59	165	150	142	100
	60	165	150	142	102
	61	165	150	142	102
	62	165	150	142	102
	63	165	150	142	102
	64	165	150	142	104
	65	165	150	142	104

Effect of housing on egg quality traits

Table-3 compares egg quality traits between housing systems and among production stages. The percentile proportion of settable eggs was 4% higher ($P<.05$) in cages as compared to floor that improved before peak ($P<.01$) and sustained later without any contribution by the interaction of housing with production stage ($P>.05$). An equal but opposite trend was recorded for eggs unfit for incubation. Neither egg constituents (Albumen, Yolk and shell) or their proportional contribution to the total egg weight (%Albumen, %Yolk and %Shell) nor weight of male or female chicks they hatched differed ($P>.05$) with housing although significantly ($P<.01$) increased as the production stage advanced. Heaviest (P<.01) eggs were laid in the post peak stage of egg production, followed by peak and pre-peak stages. Consequently, the weight of egg constituents and their contribution to the total egg weight followed the same pattern. None of the egg quality trait was affected (P>.05) by the interaction of housing and stage of production.

Table 2. Effect of Housing on Performance Traits (Means±SE) Before, During and After Peak Stages of Production of Weekly Inseminated Floored and Cage Housed Broiler Breeders.

Parameter	Housing systems		Production Stages			P values		
	Floor	Cage	Pre-Peak	Peak	Post Peak	Housing	Prod. Stage	Interaction
Hen daily feed intake (g bird^{-1} day^{-1})	166.45±7.02	151.36±4.78	150.65±18.46	162.45±8.36	158.54±7.63	<0.001*	<0.001*	<0.01*
Rooster Daily Feed Intake (g bird^{-1} day^{-1})	134.74±8.78	97.38±2.91	107.95±10.39	111.45±16.31	119.42±21.47	<0.001*	<0.001*	0.04*
Rooster Weekly Feed Intake (g week^{-1} day^{-1})	622±40	450±13	499±48	515±75	551±99	<0.001*	<0.001*	<0.01*
%Mortality	0.31±0.09	0.26±0.07	0.20±0.06	0.21±0.02	0.33±0.08	<0.001*	<0.001*	0.06
Rooster Body Weight (g)	4413±484	4413±334	3737±56	4050±158	4663±280	0.09	<0.001*	<0.01*
Hen Body Weight (g)	3598±145	3755±158	3322±149	3586±88	3762±109	<0.001*	<0.001*	<0.01*
FCR (kg dozen eggs^{-1})	3.08±0.86	2.65±0.45	3.36±1.76	2.31±0.16	3.07±0.48	0.002*	0.003*	<0.01*
%Egg Lay	67.35±15.04	70.60±12.75	59.22±23.39	84.54±2.48	63.41±9.28	0.011*	<0.001*	0.44
%Hatchability	84.46±8.95	86.46±4.24	77.28±19.96	88.55±1.90	85.18±3.66	<0.001*	<0.001*	<0.01*
%A-Grade Chicks	96.86±5.41	96.48±5.14	83.18±1.04	94.72±4.87	99.32±0.47	0.242	<0.001*	0.99
%B-Grade Chicks	3.16±5.41	3.52±5.14	16.82±0.67	5.28±4.87	0.68±0.47	0.242	<0.001*	0.99

* Significant effect for the same parameter.

Effect of housing on blood profiles

The levels of biochemical parameters namely total protein, alkaline transferase, alkaline phosphatase, phosphorous (P), calcium (Ca), magnesium (Mg), triglyceride, cholesterol and glucose were almost similar (P>.05) among the broiler breeder flocks housed on floor or in cages. Haematological parameters followed (P>.05) a likewise trend (Table-4). Stage of production caused variation (P<.01) in the blood profiles of flocks except WBC, ALT, triglyceride, Cholesterol and Calcium. Neither biochemical nor haematological parameters varied (P>.05) with the interaction of housing and stage of production.

Discussion

Effect of housing system on feed efficiency

Birds in battery cages consumed 10% less (P<.01) feed than the floored birds. This was expected from laying hens housed in multitier innovative cage system. This result is in conformity with Al-Awadi *et al.* (1995) who reported more food consumption by floored hens and contrasts with Banga-Mboko *et al.* (2010). Al-Awadi *et al.* (1995) attributed higher feed consumption to the spillage of feed from the feeders on floor and to the hens' requirement for extra energy for movement on floor. Floored hen consumed 3.08±0.86 kg feed to produce one dozen eggs against 2.65±0.45 kg consumed by cage housed hens. Both the feed intake per bird and egg lay contributed to this variation in FCR in the two housing systems. Resultantly, the gap in FCRs between the two housing systems narrowed during peak but widened again after the egg lay started decline.

These results are in line with the findings reported by Al-Rawi and Abu-Ashour (1983), Anderson and Adams (1994), Abrahamsson *et al.* (1996), Van Horne (1996), Azeroul (2005) and Pistikova *et al.* (2006). However, Hargreave (1982) and Al-Rawi and Abu-Ashour (1983) observed better performance for floored flocks. Climate caused this difference being controlled in the current trials and hot during the reference trials.

Effect of Housing System on Flock Mortality and Body Weight

The better flock survival rate in the modern cage housing systems (99.74±0.07) as compared to floor housing (99.69±0.09) may be attributed to several management factors that favored health and hygiene. Cage housing increased birds' spatial density, eased the control of microclimate, simplified waste disposal, reduced labor costs and eased the supervision of individual birds for health and production status additionally (Pistikova *et al.*, 2006); Azeroul (2005); Abrahamsson *et al.* (1996); Van Horne (1996); Anderson and Adams (1994) and Al-Rawi and Abu-Ashour (1983). Frequent manure removal facility in multitier cage housing ensured cleanliness and uniform feed allowance per bird in the current trials, being more particularly required for the nutrition of less active birds to maintain sound health. Flock body weight gradually inclined with stage of production. Birds gain weight with their advancing age (Penfold *et al.*, 2000). Housing significantly affected the hens' body weight only supplemented by the interaction of housing and production stage. Age effect on female breeders is more significant than on male breeders (Brommer and Rattiste, 2008).

Table 3. Effect of Housing on Egg Quality Traits (Means±SE) Before, During and After Peak Stages of Production of Weekly Inseminated Floored and Cage Housed Broiler Breeders.

Parameter	Housing systems		Production Stages			P values		
	Floor	Cage	Pre-Peak	Peak	Post Peak	Housing	Prod. Stage	Interaction
%Settable eggs	91.99±14.00	95.99±14.00	76.58±35.99	97.12±2.03	96.09±2.06	0.04*	<0.001*	1.00
% Non-Settable eggs	8.00±14.00	4.00±14.00	23.42±35.99	2.87±2.03	3.90±2.06	0.04*	<0.001*	1.00
Egg Weight (g)	64.51±5.07	64.51±5.09	53.05±3.41	62.91±2.34	67.51±1.00	0.95	<0.001*	1.00
Albumen (g)	38.16±2.72	38.16±2.73	32.20±2.00	37.06±1.10	39.84±0.57	0.97	<0.001*	1.00
%Albumen	59.19±0.96	59.20±0.97	60.71±0.86	58.92±0.82	59.02±0.74	0.94	<0.001*	1.00
Yolk (g)	19.26±2.98	19.26±2.98	14.35±0.94	17.01±0.68	21.22±1.79	1.00	<0.001*	1.00
%Yolk	29.71±2.84	29.71±2.84	27.05±0.16	27.04±0.15	31.42±2.39	0.98	<0.001*	1.00
Eggshell (g)	8.10±0.70	8.10±0.71	6.70±0.40	7.69±0.45	8.56±0.07	0.99	<0.001*	1.00
%Eggshell	12.56±0.31	12.56±0.32	12.64±0.16	12.21±0.42	12.69±0.12	0.92	<0.001*	0.99
Yolk sac (g)	4.92±0.38	4.92±0.38	4.04±0.25	4.80±0.17	5.15±0.07	0.98	<0.001*	1.00
♂Chicks weight (g)	45.18±3.66	45.18±3.67	37.13±2.53	44.01±1.84	47.30±1.08	0.97	<0.001*	1.00
♀Chicks weight (g)	42.03±3.45	42.03±3.46	34.49±2.40	41.10±1.93	43.95±1.12	0.98	<0.001*	1.00

* Significant effect for the same parameter.

Effect of housing system on total egg lay, its hatchability and quality of chicks it hatched

Cage housed hens laid 3% more eggs than floored hens. Li *et al.*, (2011) significantly associated increased egg production with reduction in feed intake. 10% low feed intake might have contributed to the hike in egg lay by caged hens as compared to floored hens. Abrahamsson *et al.* (1996) and Awoniyi (2003) reported high egg production in cages. However, the battery cage system produced 2% more weak shelled or shell-less eggs, being visible on egg belts whereas such eggs goes unnoticed in floor housed flock. This additional 2% count ultimately reflected in the total egg lay in the cage housing (Table-3). The cage system thus provided more accurate production record to better judge the breed potential. Such findings have been previously reported by Awoniyi (2003), Abrahamsson *et al.* (1996), Al-Awadi *et al.* (1995) and Anderson & Adams (1994). They attributed this difference in egg lay to hens' behavior on littered floor. It is generally understood that in floored flocks shell-less, poor shelled, or cracked eggs have more exposure to breakage when hens peck at them. Hens will eat the broken egg very quickly and thus goes unrecorded. In the advanced aviary systems, all the laid eggs, instead, roll onto the egg collection belt, being out of the hens' reach (Abrahamsson *et al.*, 1996).

Percentile hatch by cage housed flocks was 2% higher than floored flocks. This significant difference may be attributed to hygienic, clean and uniform eggs laid by hens housed in the modern avian cage housing systems. The competition for feed is more critical than cage as more birds have to eat from one feeder on floor. Unequal intake of feed by floored birds drops flock uniformity and the consequently laid eggs of different sizes reduce the percentile hatch. Hatchability inclined with phase of production from pre-peak to peak and then decline. Low percentile of hatch during pre-peak phase of lay shows similar trend reported by Brillard (2003), Penfold *et al.* (2000), Mahmoud *et al.* (1996) and McDaniel *et al.* (1996). Fertility decreases in flocks after peak with advancement in the hen's age that alter her physiology and also with the advancing age of the rooster resulting in physical problems. Thus, both heavy body weight and increasing age lower fertility of broiler breeders (Bramwell *et al.*, (1996).

Table 4. Effect of Housing on Blood Profiles (Means±SE) Before, During and After Peak Stages of Production by Floored and Cage Housed Broiler Breeders.

Parameter	Housing types		Production Stages			P values		
	Floor	Cage	Pre-Peak	Peak	Post Peak	Housing	Prod. Stage	Interaction
%Heamotocrit	32.12±0.09	32.13±0.07	32.21±0.06	32.17±0.06	32.08±0.07	0.14	<0.01*	1.00
WBC (x103 ul)	8890±60	8891±59	8882±51	8885±54	8894±63	0.92	0.42	1.00
%Heterophil	37.43±0.10	37.45±0.08	37.53±0.07	37.49±0.07	37.40±0.08	0.20	< 0.01*	1.00
%Lymphocytes	53.32±0.26	53.33±0.26	53.42±0.26	53.38±0.25	53.29±0.24	0.81	< 0.01*	1.00
%Monocytes	3.68±0.09	3.69±0.08	3.77±0.07	3.73±0.06	3.64±0.07	0.16	< 0.01*	1.00
%Eosinophil	3.41±0.09	3.42±0.08	3.50±0.07	3.47±0.07	3.37±0.08	0.36	< 0.01*	1.00
%Basophil	2.02±0.07	2.03±0.06	2.111±0.04	2.07±0.04	1.98±0.05	0.19	< 0.01*	1.00
Albumen (g dl^{-1})	3.68±0.11	3.69±0.12	3.77±0.103	3.73±0.011	3.64±0.11	0.55	< 0.01*	1.00
ALT (IU/L)	7.81±0.07	7.83±0.05	7.91±0.04	7.87±0.03	7.78±0.05	0.06	< 0.01*	1.00
AST(IU/L)	119.36±2.18	119.86±2.18	119.70±2.22	119.66±2.20	119.57±2.19	0.15	0.94	1.00
Total Protein (g dl^{-1})	3.77±0.07	3.78±0.08	3.87±0.04	3.83±0.05	3.74±0.06	0.22	< 0.01*	1.00
Glucose (mg dl^{-1})	254.01±24	255±25	272±8	264±14	246±27	0.93	< 0.01*	1.00
Triglyceride (mg dl^{-1})	72.54±1.68	72.53±1.73	72.62±1.72	72.58±1.71	72.49±1.70	1.00	0.90	1.00
Cholesterol (mg dl^{-1})	171±8	172±9	169±3	170±4	171±10	0.99	0.37	1.00
Calcium (mg dl^{-1})	9.28±0.08	9.27±0.09	9.26±0.09	9.27±0.09	9.28±0.07	0.33	0.51	1.00
Phosphorous (mg dl^{-1})	4.21±0.14	4.17±0.13	4.28±0.18	4.24±0.12	4.15±0.13	0.05	< 0.01*	1.00
Magnesium (mg dl^{-1})	1.55±0.06	1.56±0.07	1.64±0.01	1.60±0.02	1.52±0.04	0.10	< 0.01*	1.00

* Significant effect for the same parameter.

Chicks' market grade was not affected by housing although it varied with stage of production. Weight of chicks, after hatch, associates directly with weight of egg. Chick possesses 64-70% of the egg weight (Merritt & Gowe, 1965). Hatchery staff struggle for heavier chicks as they fetch more price in market.

Chicks' quality is the most priority for entrepreneurs. Among prevailing quantitative and qualitative tools of assessing the quality of chicks, weight of chicks is the most common indicators for examining the quality of one-day old chicks (Decuypere *et al.*, 2002; Deeming, 2000). Multiple factors influence chicks' market grade including quality and weight of eggs (Wiley *et al.*, 1950).

The size of egg has a direct relation (Moran, 1990) or correlates positively (Lourens *et al.*, 2006; Seker *et al.*, 2004; Wilson and Suarez, 1993) with chicks' weight they hatch. Light-weight eggs produced lighter chicks (Farooq *et al.*, 2001) that performed poorly compared to chicks hatched from heavier eggs. Ayorinde *et al.* (1994) and Nahm (2001) reported strong positive correlations among pre-incubation egg weight, storage periods and chick weight.

The correlation between weights of eggs and hatched chicks strengthens on 11^{th} day after eggs are incubated and sustains during the rest of incubation period until the eggs are hatched (Wilson, 1991). Older hens tend to lay heavier eggs, and consequently hatch heavier chicks (Dalanezi *et al.*, 2004).

Effect of housing on egg quality traits

Significantly ($P<0.05$) more (4%) settable eggs lay in the cage housing (96±14) than floor (92±14) may be attributed to the more uniform feeding in such advanced housing system. Uniform feeding results in uniform body weight, uniform sexual maturity and hence uniform quantitative and qualitative settable egg lay. More cracked eggs are usually expected in cage housing as eggs roll on collection belts and are more prone to breakage. Eggs were collected manually during the current trials that contributed to less broken eggs thereby increasing the proportion of settable eggs.

In contrast, more dirty eggs in the floor pens further widened the gap in settable eggs. Egg quality, clean environment and better management in innovative cage housing contribute to more settable egg lay (Pistikova *et al.*, (2006); Azeroul (2005); Abrahamsson *et al.* (1996); Van Horne (1996); Anderson and Adams (1994) and Al-Rawi and Abu-Ashour (1983).

The variation in egg traits with advancement in stages of production is associated with flock's age. The consequent increase in egg size and hence egg weight affected weight of the egg components. Egg constituents were lighter during pre-peak period of production. Chicken egg in general, constitutes albumen (58.5%), yolk (31%) and shell (10.5%) that vary with age and strain of flock (Vieira & Moran, 1999).

The weight quality and composition of eggs are strongly influenced by the age of the breeder flock. Mature breeders lay heavier eggs than younger flocks (Dalanezi *et al.*, 2004) but eggs of similar weights can often be laid by hens of different ages. Similarly, hens of similar ages may lay eggs having different weights. It has been reported that weight of the egg rather than flock age influences the weight of the chicks (Pinchasov, 1991).

Increase in the weight of an egg is associated with enlargement of yolk, whereas the rising proportion of albumen causes differences in egg weight laid by same age hens (Lima *et al.*, 2001).

Chicks' weight and the yolk sac they retained were not affected by housing types although varied with stage of production. Weight of chicks, after hatch, associates directly with weight of egg. Chick possesses 64-70% of the egg weight (Merritt & Gowe, 1965).

Hatchery staff struggle for heavier chicks as they fetch more price in market. Among prevailing quantitative and qualitative tools of assessing the quality of chicks, weight of chicks is the most common indicators for examining the quality of one-day old chicks (Decuypere *et al.*, 2002; Deeming, 2000). Multiple factors influence chicks' weight including quality and weight of eggs (Wiley *et al.* 1950).

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The correlation between weights of eggs and hatched chicks strengthens on 11^{th} day after eggs are incubated and sustains during the rest of incubation period until the eggs are hatched (Wilson, 1991).

Male chicks weighed more than female chicks. Older hens tend to lay heavier eggs, and consequently hatch heavier chicks (Dalanezi *et al.*, 2004). Studies have shown that it is the weight of the egg that determines the weight of the chick and that flock age has minimal influence on chicks' quality parameters (Pinchasov, 1991).

Effect of housing on blood profiles

The profiled blood of the hens studied in the current experiment depicted equally sound health status for all the flocks during the entire experimental duration. Neither housing system nor production stage disturbed it, which indicated that changes in flocks' performance may be solely attributed to other factors.

The overall mean values for the studied parameters fall in the normal ranges (Simaraks *et al.*, 2004; Coles, 1986; Dein, 1986).

Blood is profiled to judge the flock health status and is one of the trusted indicators for health status assessment. Biochemical and hematological parameters in poultry birds vary with health and geographic location (Simaraks *et al.*, 2004; Pampori and Igbal, 2007; Ladokun *et al.*, 2008; Islam *et al.*, 2004; Aengwanich *et al.*, 2007) that necessitate to investigate blood profiles of birds to accurately interpret their health dependent performance (Aengwanich *et al.*, 2007; Kral and Suchy, 2000).

Conclusion

In this experiment, we thus evaluated various production parameter of floored and cage housed broiler breeders.

The cage housed hens consumed 10% less (P<.01) feed, had better (P<.01) feed efficiency, laid more (P<0.05) settable eggs, hatched 3% more (P<.01) chicks and had better (P<.01) survival rate than floored flocks. Since all the studied parameters have high economic value, therefore, commercial farmers may prefer innovative battery cages in their business provided birds welfare and environmental safety are ensured.

Recommendation

Commercial producers may gradually shift to enriched cage housing for higher economic efficiency of their broiler breeding farms.

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