The Journal of Animal & Plant Sciences, 29(2): 2019, Page: 402-411
ISSN: 1018-7081

EFFECT OF DIETARY COMPOST LEVELS ON PRODUCTION PERFORMANCE, EGG QUALITY AND IMMUNE RESPONSE OF LAYING HENS

M. T. Khan[1], S. Mehmood[1,*], A. Mahmud[1], K. Javed[2], Saima[3], J. Hussain[1], Y. A. Ditta[3], and M. Waqas[1]

[1]Department of Poultry Production, [2]Department of Livestock Production, [3]Department of Animal Nutrition, Faculty of Animal Production and Technology, University of Veterinary and Animal Sciences, Lahoor-54000, Pakistan

[*]Corresponding author's email: shahid.mehmood@uvas.edu.pk

ABSTRACT

A study was executed to explore the effect of dietary compost level on performance, egg quality, and immune response of laying hens. A total of 150 laying hens (18-week old) were distributed among 5 dietary groups comprising 5 replicates of 6 birds each, under a completely randomized design (CRD). The experimental diets consisted of increasing levels of compost (0. 2.5, 5, 7.5, and 10%), with each diet being iso-caloric and iso-nitrogenous. The recorded data were analyzed by one-way ANOVA under CRD. Hen performance parameters, including feed consumption, body weight, egg production, egg weight, egg mass, feed efficiency, livability, and uniformity percentage, were not affected ($P > 0.05$) by the level compost supplement included in the diet. Although, birds fed the diet containing 10% compost exhibited slightly lower egg production and egg weight compared to other treatments, statistically these differences were non-significant ($P > 0.05$). Similarly, egg quality and immune response in birds fed diets with 10% compost were numerically lowest, but no statistical differences were seen across treatment ($P > 0.05$). Birds fed diets containing compost 10% showed the lowest ($P = 0.0001$) feed cost per kg egg mass. These data indicate that compost can be utilized in layer rations at up to 10% with no negative effects on performance, egg quality, and immune response. Furthermore, the utilization of compost in layer rations may reduce feed cost per kg egg mass.

Key words: compost, laying hen, performance, egg quality, immune response.

INTRODUCTION

Over the past three decades, intensification and rapid growth of poultry industry have given rise to greater environmental challenges. Central among environmental considerations is the production of large amount of wastes, such as poultry litter, manure and dead birds (Bolan *et al.,* 2010). These wastes may pose environmental and health problems if not disposed-off properly (Kelleher *et al.,* 2002; Sharpley *et al.,* 2007). The land application of poultry waste as an organic fertilizer and associated environmental implications (Tiquia, 2005; Borugadda and Goud, 2012) have encouraged authorities to look for cleaner and more useful disposal options. A potentially efficient and cost-effective option for the disposal of poultry waste (litter, dead birds) is to recycle the waste as a feedstuff for use in animal production (Henuk and Dingle, 2003; Tadele, 2015). However, important public concerns regarding the safety of feeding large quantities of poultry waste to animals have limited its acceptability as a feed ingredient (Rankins *et al.,* 2002; Bolan *et al.,* 2010). Raw poultry waste may contain pathogenic microorganisms (Fontenot, 1999; Rothrock *et al.,* 2008) as well as residues of medicinal drugs (Sims and Wolf, 1994), which have the potential to cause illness in animals and humans (Line and Bailey, 2006; Rothrock *et al.,* 2008). Hence, processing of poultry waste to be used as poultry feed is necessary for its improved handling and storage, destruction of potential pathogens and, maintenance or enhancement of palatability (Kawata *et al.,* 2006). This could be achieved through proper composting of litter and dead birds, and optimized feed management practices.

Composting is an aerobic process of organic waste degradation/disposal in which naturally occurring aerobic microorganisms convert organic wastes (litter, dead birds) into a value-added end product (Imbeah, 1998; Capucille *et al.,* 2002; Michel *et al.,* 2002; Ryckeboer *et al.,* 2003, Charnay, 2005; Turan, 2009). High temperature during litter composting kills both animal and human pathogens (Murphy, 1990; Conner *et al.,* 1991; Senne *et al.,* 1994; Lu *et al.,* 2003; Kumar *et al.,* 2007; Wilkinson *et al.,* 2011) and reduces the concentration of most organic pesticides (Fogarty and Tuovinen, 1991; Kawata *et al.,* 2006). As a result, comparatively pathogen free, less toxic, and environmentally friendly product is obtained. This product is considered as safe for animal consumption up to certain levels (Wilkinson *et al.,* 2011). Feeding composted poultry litter to ruminants is well documented and practiced in several countries (Muller, 1975; Caswell *et al.,* 1977; Capucille *et al.,* 2004). However, scanty or no information prevails regarding use of compost in poultry feeds. As such, the present study was designed to explore the effect of dietary compost levels on production performance, egg quality, and immune response of laying hens during the first production phase (18 to 42 weeks).

MATERIALS AND METHODS

All the experiments were approved by the Ethical Review Committee of the University of Veterinary and Animal Sciences (UVAS), Lahore and an ethical certificate was obtained from the Office of Research Innovation and Commercialization before the initiation of the trial.

(I) Preparation and chemical analysis of compost

Preparation of compost: Compost was prepared at the Compost Unit, Ravi Campus, University of Veterinary and Animal Sciences (UVAS), Lahore. For this purpose, two compost bins (primary and secondary), each measuring 7 ft. width × 6 ft. depth × 5 ft. height, were used. Chicken litter and carcasses used in composting was collected from a commercial broiler farm. A typical compost recipe was calculated and prepared by mixing 1/10 part by weight straw (bulking agent), 1 part by weight carcasses, 2 parts by weight poultry litter, and 0 to 1/2 part by weight water. The mixture provided the necessary conditions for successful composting i.e., 55% moisture content and 20:1 to 25:1 C:N ratio. The primary bin was loaded following the standard procedure of bin filling (Ritz and Worley, 2005). Within a few days of waste loading, process of microbial decomposition started with a corresponding rise in temperature. The core temperature was monitored daily by using a 36 inch compost thermometer. The temperature was taken from five different locations of the pile. The duration of the primary or first heating cycle was completed when the temperature of the pile reached its peak (155°F) and then dropped to 129°F. At this stage, the material was shifted from the primary bin into the secondary bin for a second heating cycle. The end of the second heating cycle was indicated by the drop in the temperature to 100ºF. Then, the compost material was moved from the secondary bin to a storage yard for the completion of maturation phase. The maturation phase was completed when the temperature of the pile fell to near the temperature of surrounding (77ºF) and the finished product appeared dark brown to black and was free of unpleasant odors.

Chemical analysis of compost: At the end of maturation phase, compost samples (250 g) were collected from different locations and stored in an air tight polythene bag. The material was then ground and analyzed for dry matter content, crude protein, ether extract, crude fiber, and ash content in the Nutrition Laboratory, UVAS, Ravi Campus. The dry matter content was obtained by oven-drying method, crude protein by Kjeldahl method, ether extract by Soxhlet extraction using anhydrous diethyl ether, and crude fiber content using 12.5% sulphuric acid and 12.5% sodium hydroxide solutions (Naumann and Bassler, 1993). Compost samples were also analyzed for amino acid composition at the Amino Acid Analysis Laboratory, UVAS, Ravi Campus. Metabolizable energy was calculated following NRC (1994) procedures of estimation. Calcium, phosphorus, and ash content were determined according to the procedures of the AOAC (2005). Prior to use in feed, compost samples were tested in the University Diagnostic Laboratory, UVAS, Lahore, for pathogens including *Salmonella*, and *E. coli*. The samples were cultured on suitable media for bacterial load estimation using standard operating procedure (Dunkley *et al.,* 2011).

(II) Feeding trial on laying hens

Study design, birds, and housing: A 25 weeks feeding trial was conducted at the Layer Unit, Ravi Campus, UVAS, Lahore, to explore the effect of dietary compost level on performance, egg quality, and immune response of laying hens during the first production phase (18 to 42 weeks). A total of 150 laying hens (Novogen White, 18-week old) were distributed among 5 dietary groups comprising 5 replicates of 6 birds each, under a completely randomized design (CRD), from 18 to 42 weeks. The experimental diets contained increasing levels of compost (0, 2.5, 5, 7.5, and 10%). The experiment was conducted in a well-ventilated open-sided house with East to West dimension, measuring 6.11 × 6.11 (37.73 m^2). Hens were placed in 25 floor pens (each measuring 0.91 × 0.61 m) on a deep litter system. Iso-caloric (2750 ME kcal/kg) and iso-nitrogenous (16.5% CP) diets (Table 6.2), formulated in accordance with the nutritional requirement of layers (NRC, 1994), were fed *ad-libitum* for a period of 25 weeks. Clean and fresh drinking water was available *ad-libitum* through an automatic nipple drinking system. Same environmental and hygienic conditions were maintained throughout the study. Vaccination and medical care was done as per standard veterinary practice under the supervision of a veterinarian. A light schedule of 16L:8D was followed for the entire study period. The minimum and maximum mean temperature and humidity ranged from 15.2 to 26.4 °C and 55.7 to 76%, respectively.

Data collection

Production performance: The data were recorded for daily feed offered and refusal, biweekly body weight, daily egg number, weekly egg weight, and daily mortality (if any). The recorded data were used to calculate average daily feed intake, percent egg production, cumulative egg mass, feed efficiency, and percent livability. Both the feed intake and egg production were measured on a hen/day basis. Feed intake was measured on a daily basis by subtracting the feed refusal from the total feed offered. Egg production percentage was calculated as the ratio between total egg production and number of females multiplied by 100. Daily egg weight was recorded by using a digital scale with 0.01g precision, whereas egg mass was determined as the egg weight multiplied by total number of eggs. Feed efficiency was determined as kg egg mass produced as relative to the kg feed consumed. Uniformity percentage was measured on the basis of ±10% fluctuation in average body weight. Feed cost per kg egg mass was calculated as the feed cost per unit multiplied by FCR (g/g).

Egg morphometric and quality traits: At each month end, 15 eggs per experimental unit (3 eggs/ replicate) were picked to study egg morphometric and quality traits. Egg weight was obtained by using a digital scale with 0.01 g precision, whereas egg length and egg breadth (width) were recorded with the help of a digital vernier caliper with 0.01 cm precision. Shape index was taken as the ratio between egg width and egg length (Anderson *et al.,* 2004), whereas egg volume and egg surface area were determined using two separate formulae for each parameter and taking the average of the results (Etches, 1996). Eggs were then broken one by one and the egg contents were carefully transferred into a petri dish. Yolk color was obtained with the help of a digital egg tester. Eggshell weight was recorded with the help of a digital scale with 0.01 g precision. Eggshell thickness was measured without vitelline membranes with the help of a dial pipe gauge and was taken as the average of three separate measurements from three different places without cracking the shell. Yolk index was taken as the ratio between yolk height and yolk width, whereas Haugh unit score was measured using the following formula where H = albumin height and W = egg weight:

$$\text{Haugh unit} = 100 \times \log (H - 1.7W^{0.37} + 7.6).$$

Immune antibody response: One week before the end of trial, all the experimental birds were vaccinated via drinking water using commercially available ND (LaSota) and IB (H 120) vaccines, and the antibody responses to ND and IB vaccines were obtained by HI (hemagglutination inhibition) and ELISA techniques, respectively, using commercially available diagnostic kits (BioChek, Gouda, The Netherlands).

Statistical analysis: Before analysis, data were checked for uniformity and homogeneity of variance and verified for normality. The data were then analyzed by one-way ANOVA under CRD using the GLM procedure of Statistical Analysis System (SAS Institute Inc., 2002-04). Duncan's multiple range test was applied to separate treatment means at 5% probability level, considering each pen as experimental unit.

RESULTS AND DISCUSSION

Chemical composition of compost: Chemical analysis and amino acid composition of the compost is shown in Table 1. Compost contained 15.40% CP and 6.54% calcium. These values are very close to those reported (14.48% CP and 6.7% Ca) by Bukhari *et al.* (2017). In the present study, gradual decline in CP content was apparently attributable to microbial degradation and mineralization of organic matter during composting process. The compost prepared by Bukhari *et al.* (2017), however, contained much higher ash contents (42.89%) compared to 19.38% in our study. The gross energy and metabolizable energy contents of the finished compost were 2426 kcal/kg and 1940 kcal/kg, respectively. The finished compost contained undetectable levels of *Salmonella* and *E. coli* as composting was completed by subjecting the organic waste into two heating cycles, which likely reduced pathogenic bacterial counts in the end product as seen by others (Berge *et al.,* 2009). Das *et al.* (2002), likewise, found 99.9% and 100% reduction in *E. coli* and *Salmonella*, respectively, suggesting that longer duration (Bicudo and Goyal, 2003) and high temperature (Imbeah, 1998) during composting kills pathogens (Vinodkumar *et al.,* 2014) and helps control disease outbreaks (Bonhotal *et al.,* 2002).

Production performance: Data on performance measurements is presented in Table 4. No significant differences ($P > 0.05$) in average daily feed intake, bird final body weight, egg production, egg weight, cumulative egg mass, feed efficiency, livability or uniformity percentage were detected across the treatment diets. Birds fed diets containing 10% compost showed the lowest ($P = 0.0001$) feed cost per kg egg mass. Present findings confirmed that litter and dead birds compost, when properly balanced with other ingredients, may be an adequate feed substitute for laying hens. Compost was fed to laying hens at graded levels (0, 2.5, 5, 7.5, and 10%) and the diets were nutritionally balanced, containing a similar nutrient profile. Increasing levels of compost did not impact performance. Although, feeding diets containing 10% compost resulted in slightly lower egg production and egg weight, the difference was not statistically significant ($P > 0.05$). Likewise, other performance parameters like average daily feed intake, bird final body weight, cumulative egg mass, feed efficiency, livability or uniformity percentage were highest in birds fed 10% compost, these differences were not significant ($P > 0.05$). As mentioned earlier, the experimental diets contained similar amounts of energy (2750 kcal/kg), protein (16.5%), calcium (3.55%), and phosphorus (0.70%); therefore, the nutrient profile of diets would not be expected to result in differences in the performance parameters measured here. Furthermore, the similarity in feed intake values in the treatment groups indicated that all diets were consumed by laying hens without palatability problems.

Several studies have documented the use of poultry waste in poultry feed. In this context, Flegal and

Zindel (1969), Flegal (1971a), Flegal (1971b), and Flegal and Zindel (1972) fed laying hens diets containing dried layer manure (DLM) at 10, 20, 30, and 40% levels. Performance characteristics, such as egg production (with the exception of layers fed 10% manure), feed efficiency, and weight gain, decreased with increasing level of manure in the diet. Wolford (1975) fed caged turkey breeder hens rations containing layer manure @ 10%, and observed no differences (P > 0.05) in production and reproduction parameters. Nesheim (1972) worked on four least-cost rations, two of them containing 22.5% DLM, and observed no marked difference (P > 0.05) in the performance in terms of egg production and egg weight. Some variations, however, in feed consumption were attributed to lower energy content in the wheat-bran and dried layer manure diets. Fadika *et al.* (1975) fed growing turkeys an iso-caloric and iso-nitrogenous diet containing 5, 10, and 30% DLM, and found no marked difference (P > 0.05) in growth as measured by weight gain. Flegal *et al.* (1972) fed laying hens rations containing dehydrated layer manure at 0, 12.5 or 25% levels. No significant changes (P > 0.05) in performance parameters were observed between diets. Flegal and Zindel (1971) fed dried poultry waste (DPW) to laying hens, and found no difference (P > 0.05) in egg weight up to 40% level. Quisenberry and Bradley (1968) fed untreated litter and manure at 10 and 20% levels to laying hens and reported better overall performance than the control.

Egg morphometric and quality traits: Data on egg morphometric and quality traits are presented in Table 5. Mean values for egg length, egg breadth, eggshell weight, eggshell thickness, yolk color, shape index, egg volume, egg surface area, yolk index, and Haugh units were not significantly different across treatments (P > 0.05). The hens fed compost at 10% level in the diet produced eggs comparable (P > 0.05) with those of birds fed control diet. Eggshell thickness, measured without membrane, did not differ with diet (P > 0.05), implying that eggs produced by hens fed compost were adequate. Similarly, Flegal and Zindel (1971) fed DPW to laying hens at 40% level and found no effect (P > 0.05) on eggshell thickness. Odunsi *et al.* (2013) fed hatchery waste meal (HWM) to Japanese quail and, likewise, found no difference (P > 0.05) in eggshell thickness. Al-Harthi *et al.* (2009), however, observed improvement (P < 0.05) in eggshell quality when HWM was included in layer ration up to 16% level.

Yolk color often changes with changes in feed formulation, however, different levels of compost in the diet did not (P > 0.05) affect yolk color. These results are in line with Odunsi *et al.* (2013) who indicated non-significant (P > 0.05) effect of HWM on yolk color in Japanese quail. Haugh unit was also not affected (P > 0.05) by different inclusion rates of compost. Although, eggs from birds fed the control diet had the HU score (92.46) numerically and eggs from birds fed 10% level of compost had minimum HU scores (88.60), but statistically this difference was non-significant (P > 0.05). Our results for HU indicate freshness and standard quality of eggs across treatments as scores were all above 72% (Odunsi *et al.,* 2013).

Similarly, other egg quality parameters like egg length, width, shell weight, shape index, volume, surface area, and yolk index were statistically independent (P > 0.05) of dietary treatment. In line with these results, Abiola and Onunkwor (2004) found no effect (P > 0.05) of feeding hatchery waste meal on egg quality characteristics in laying hens. Flegal *et al.* (1972) fed laying hens diets containing dehydrated layer manure at 0, 12.5 or 25% levels. No differences (P > 0.05) in egg quality parameters were observed between groups. Mahmud *et al.* (2015) fed HWM to laying hens and found no difference (P > 0.05) in egg quality when HWM was included in the diet at up 4%, indicating that some egg quality parameters like Haugh unit and yolk index are not necessarily influenced (P > 0.05) by feeding HWM (Odunsi *et al.,* 2013). Biely *et al.* (1972), however, observed a trend for lower HU scores (83.4 vs 82.1) when DPW was included in layer rations at 25% level, implying that internal egg quality may deteriorate by feeding poultry by-product or feather meal in the diet (Senkoylu *et al.,* 2005).

Immune antibody response: Newcastle disease virus (**NDV**) and infectious bronchitis virus (**IBV**) are the most common causes of respiratory illness in poultry; therefore, vaccines, combined live or live and inactivated, are commonly used to minimize or prevent outbreaks due to these pathogens (Awad *et al.,* 2015). The sole purpose of vaccination is to induce protective immunity against infection by certain pathogens like bacteria or virus (Marangon and Busani, 2006; Miller *et al.,* 2009). Non-significant (P > 0.05) effect of diets was observed on immune antibody responses to ND and IB vaccines (Table 6). Although, slightly higher immune antibody levels were observed against ND and IB vaccines in hens fed the control diet compared to those fed diet containing 10% compost; however, statistically this difference was non-significant (P > 0.05). The results may, therefore, suggest that inclusion of compost in laying hen diets at levels tested here is safe and imposed neither stress nor decreased immune antibody responses in laying hens. However, there is evidence that stressors, either nutritional or environmental (Gross, 1985; McFarlane and Curtis, 1989; Maxwell *et al.,* 1992), may lower immunity and decrease immune antibody responses against a variety of particulate antigens, including vaccinations (Siegel, 1985). The scarcity of published data regarding the use of compost in poultry feed and its potential impact on bird immune status makes robust comparisons to similar studies difficult at this time.

Table 1. Chemical profile and amino acid composition of compost on dry air basis.

Chemical composition	%
Dry matter	93.30
Crude protein	15.40
Metabolizable energy (kcal/kg)	1940
Gross energy (kcal/kg)	2426
Crude fiber	17.55
Ether extract	1.74
Ash	19.38
Calcium	6.54
Phosphorus (P_2O_5)	1.93
Potassium (K_2O)	2.40
Sodium	1.28
Sulphur	0.45
E. coli	Nil
Salmonella	Nil
Total amino acids	
Cystine	0.10
Methionine	0.21
Aspartic acid	0.48
Threonine	0.28
Serine	0.32
Glutamic acid	0.77
Glycine	0.42
Alanine	0.47
Valine	0.28
Isoleucine	0.26
Leucine	0.52
Phenylalanine	0.31
Histidine	0.14
Lysine	0.18
Tyrosine	0.11
Arginine	0.25

Table 2. Ingredient composition of experimental diets.

Ingredient (%)	Treatment				
	T1	T2	T3	T4	T5
Corn	56.80	56.80	56.80	56.80	56.80
Rice tips	6.00	4.90	3.90	2.90	1.30
Canola meal	5.00	4.00	3.00	2.00	1.00
Sunflower meal	2.00	2.00	2.00	2.00	2.00
Corn gluten	2.00	2.00	2.00	2.00	2.00
Soybean meal	12.57	12.57	12.57	12.57	12.59
Guar meal	2.00	2.00	2.00	2.00	2.00
Poultry by-product meal	2.00	2.00	2.00	2.00	2.00
Canola oil	0.70	0.70	0.70	0.70	0.90
$CaCO_3$	8.10	7.80	7.30	6.90	6.50
Dicalcium phosphate	1.60	1.60	1.60	1.60	1.60
Lysine SO_4	0.20	0.25	0.28	0.30	0.33
DL-Methionine	0.12	0.12	0.12	0.13	0.13
Threonine	0.00	0.01	0.01	0.03	0.03
Tryptophan	0.01	0.01	0.01	0.01	0.01
L-isoleucine	0.10	0.10	0.12	0.13	0.13
Sodium chloride	0.18	0.18	0.18	0.18	0.18
Sodium bicarbonate	0.12	0.00	0.00	0.00	0.00
Vitamin premix[1]	0.20	0.20	0.20	0.20	0.20
Mineral premix[1]	0.30	0.30	0.30	0.30	0.30
Compost	0.00	2.50	5.00	7.50	10.00

[1]Vitamin-mineral premix provided per kg of diet: Vitamin A (retinyl acetate), 12,000 IU; vitamin D_3 (cholecalciferol), 5,000 IU; vitamin E (DL-α-tocopheryl acetate), 50 mg; vitamin K_3, 3 mg; thiamin, 2 mg; riboflavin, 7 mg; vitamin B_6, 5 mg; vitamin B_{12}, 15 µg; pantothenic acid, 50 mg; folic acid, 1 mg; biotin, 200 µg; Fe, 80 mg; Cu, 10 mg; Zn, 80 mg; I, 1 mg; Se, 0.3 mg.

Table 3. Nutrient composition of experimental diets[1].

Nutrients (%)	Treatment				
	T1	T2	T3	T4	T5
Dry matter	90.09	90.18	90.29	90.49	90.35
Metabolizable energy (kcal/kg)	2758	2753	2752	2751	2747
Crude protein	16.5	16.5	16.5	16.5	16.5
Ether extract	3.80	3.80	3.80	3.81	3.86
Ash	12.25	12.24	12.15	12.16	12.16
Crude fiber	3.60	3.91	4.22	4.53	4.83
Calcium	3.55	3.55	3.55	3.55	3.55
Total phosphorus	0.66	0.70	0.74	0.78	0.82
Sodium	0.16	0.16	0.16	0.16	0.16
Potassium	0.61	0.66	0.70	0.75	0.79
Chloride	0.17	0.17	0.17	0.17	0.17
Lysine	0.82	0.83	0.83	0.82	0.82
Methionine	0.41	0.41	0.41	0.41	0.41
Threonine	0.61	0.61	0.60	0.61	0.60
Tryptophan	0.19	0.18	0.18	0.17	0.17
Cystine	0.32	0.31	0.30	0.29	0.28
Methionine+Cystine	0.73	0.71	0.69	0.68	0.66
Arginine	1.04	1.02	1.00	0.98	0.96
Valine	0.79	0.77	0.75	0.74	0.72
Isoleucine	0.74	0.73	0.74	0.74	0.73
Leucine	1.53	1.51	1.49	1.47	1.45
Histidine	0.43	0.43	0.42	0.41	0.40
Phenylalanine	0.80	0.79	0.78	0.77	0.75
Linoleic acid	1.48	1.47	1.46	1.45	1.48

[1]Diets were formulated on total amino acid basis (TAA).

Table 4. Effect of dietary compost level on production performance of laying hens[1].

Treatment[3]	Parameter[2]								
	ADFI (g/bird)	FBW (g/bird)	EP (%)	EW (g/egg)	CEM (kg/bird)	FE (kg/kg)	LB (%)	UF (%)	FC (PKR)
T1	106	1632	79.40	55.18	7.67	0.413	98.32	97.59	96.99[a]
T2	105	1628	79.00	55.13	7.62	0.412	98.26	97.52	94.78[a]
T3	104	1627	78.00	55.10	7.52	0.410	98.20	97.46	90.37[b]
T4	104	1625	78.00	54.98	7.50	0.411	97.92	96.66	87.61[b]
T5	103	1625	78.00	54.89	7.49	0.412	97.88	97.07	82.54[c]
SEM	0.46	1.15	0.39	0.04	0.04	0.002	0.08	0.44	1.17
P-value	0.503	0.316	0.697	0.206	0.495	0.997	0.232	0.967	0.0001

[a-c]Treatment means within a column bearing different letters are significantly different ($P < 0.05$).
[1]Data are means ± SEM representing 5 replicates (n = 5) with 6 hens per replicate.
[2]ADFI: average daily feed intake, FBW: final body weight, EP: egg production, EW: egg weight, CEM: cumulative egg mass, FE: feed efficiency, LB: livability, UF: uniformity, FC: feed cost per kg egg mass, PKR: Pakistani rupee.
[3]T1: diet containing 0% compost (control), T2: diet containing 2.5% compost, T3: diet containing 5% compost, T4: diet containing 7.5% compost, T5: diet containing 10% compost.

Conclusions: Present findings suggest that compost can be utilized in layer rations up to the level of 10% with no adverse effects on production performance, egg quality, and immune antibody response of laying hens. Furthermore, the use of poultry compost in layer rations may reduce feed cost per kg egg mass.

Acknowledgements: The authors gratefully acknowledge the Punjab Agricultural Research Board (PARB Project No: 582) and the administrations of the Compost Unit and the Layer Unit, and the Department of Poultry Production, Ravi Campus, UVAS, for facilitating and funding the trial.

Table 5. Effect of dietary compost level on egg quality traits of laying hens[1].

Treatment[3]	Parameter[2]									
	L (mm)	W (mm)	SW (g)	ST (mm)	YC	SI (%)	V (mm)[3]	S (mm)[2]	HU	YI
T1	54.29	41.07	6.58	0.36	8.01	75.65	50.38	66.95	92.46	0.42
T2	55.35	41.23	6.44	0.35	7.97	74.47	50.33	66.91	92.40	0.41
T3	53.92	40.63	6.43	0.35	7.84	75.36	50.31	66.89	90.82	0.42
T4	53.73	40.51	6.33	0.35	7.83	75.40	50.20	66.79	88.96	0.40
T5	54.30	40.34	6.32	0.35	7.80	74.29	50.11	66.72	88.60	0.40
SEM	0.45	0.35	0.05	0.001	0.08	0.22	0.04	0.03	0.66	0.003
P-value	0.843	0.934	0.561	0.443	0.912	0.180	0.206	0.205	0.182	0.146

[1]Data are means ± SEM representing 5 replicates (n = 5) with 6 hens per replicate. [2]L: egg length, W: egg width, SW: shell weight, ST: shell thickness, YC: yolk color, SI: egg shape index, V: egg volume, S: egg surface area, HU: Haugh unit, YI: yolk index.
[3]T1: diet containing 0% compost (control), T2: diet containing 2.5% compost, T3: diet containing 5% compost, T4: diet containing 7.5% compost, T5: diet containing 10% compost.

Table 6. Effect of dietary compost level on immune antibody response of laying hens[1].

Treatment[3]	Antibody titer[2]	
	ND (HI titer, log_2)	IB (ELISA titer)
T1	5.10	3520.27
T2	4.98	3477.61
T3	4.81	3464.12
T4	4.71	3373.71
T5	4.69	3337.90
SEM	0.10	35.14
P-value	0.701	0.470

[1]Data are means ± SEM representing 5 replicates (n = 5) with 6 hens per replicate. [2]Hens were vaccinated via drinking water using commercially available ND (La Sota) and IB (H 120) vaccines, one week before blood samples were taken. [3]T1: diet containing 0% compost (control), T2: diet containing 2.5% compost, T3: diet containing 5% compost, T4: diet containing 7.5% compost, T5: diet containing 10% compost.

REFERENCES

Abiola, S.S. and E.K. Onunkwor (2004). Replacement values of hatchery waste meal for fishmeal in layer diets. Bioresour. Technol. 95(1): 103-106.

Al-Harthi, M.A., A.A. El-Deek, Y.A. Attia, F. Bovera, and E.M. Qota (2009). Effect of different dietary levels of mangrove (Laguncularia racemosa) leaves and spice supplementation on productive performance, egg quality, lipid metabolism and metabolic profiles in laying hens. Br. Poult. Sci. 50(6): 700-708.

Anderson, K.E., J.B. Tharrington, P.A. Curtis, and F.T. Jones (2004). Shell characteristics of eggs from historic strains of single comb White Leghorn chickens and the relationship of egg shape to shell strength. Int. J. Poult. Sci. 3(1): 17-19.

AOAC International (2005). Official Methods of Analysis of the AOAC International. 18th Ed AOAC Int. Gaithersburg, MD.

Awad, F., A. Forrester, M. Baylis, S. Lemiere, R. Jones, and K. Ganapathy (2015). Immune responses and interactions following simultaneous application of live Newcastle disease, infectious bronchitis and avian metapneumovirus vaccines in specific-pathogen free chicks. Res. Vet. Sci. 98: 127-133.

Berge, A.C.B., T.D. Glaville, P.D. Millner, and D.J. Klingborg (2009). Methods and microbial risks associated with composting of animal carcasses in the United States. J. Am. Vet. Med. Assoc. 234(1): 47-56.

Bicudo, J.R. and S.M. Goyal (2003). Pathogens and manure management systems: A Review. Env. Tech. 24(1): 115-130.

Biely, J., R. Soong, L. Seier, and W.H. Pope (1972). Dehydrated poultry waste in poultry rations. Poult. Sci. 51(5): 1502-1511.

Bolan, N.S., A.A. Szogi, T. Chuasavathi, B. Seshadri, M.J. Rothrock Jr, and P. Anneerselvam (2010). Uses and management of poultry litter. World's Poult. Sci. J. 66(4): 673-698.

Bonhotal, J., M. Schwarz, and N. Brown (2002). Natural Rendering: Composting Poultry Mortality the Emergency Response to Disease Control. Cornell Waste Management Institute. Deptt. of Crop and Soil Sci.

Borugadda, V.B. and V.V. Goud (2012). Biodiesel production from renewable feedstocks: Status and opportunities. Renew. Sustainable Energy Rev. 16(7): 4763-4784.

Bukhari, M.K.N., S. Mehmood, A. Mahmud, A. Khalique, K. Javed, M. Nadeem, J. Hussain, M.T. Khan, and M.S. Shaheen (2017). Physico-chemical and microbiological characteristics of dead bird and litter compost during winter season. J. Anim. Plant Sci. 27(5): 1440-1447.

Capucille, D.J., M.H. Poore, and G.M. Rogers (2004). Growing and finishing performance of steers when fed recycled poultry bedding during the growing period. J. Anim. Sci. 82(10): 3038-3048.

Capucille, D.J., M.H. Poore, C. Altier, and G.M. Rogers (2002). Evaluation of Salmonella shedding in cattle fed recycled poultry bedding. Bov. Pract. 36(1): 15-21.

Caswell, L.F., K.E. Webb, and J.P. Fontenot (1977). Fermentation, nitrogen utilization, digestibility and palatability of broiler litter ensiled with high moisture corn grain. J. Anim. Sci. 44(5): 803-813.

Charnay, F. (2005). Composting of urban wastes in developing countries: Elaboration of a methodology for a production of compost. Doctorate thesis. Faculty of Sciences and Technology. University of Limoge, Paris, France. 229 p

Conner, D.E., J.P. Blake, J.O. Donald, and J.S. Kotrola (1991). Microbiological safety and quality of poultry mortality composting. Poult. Sci. 70(1): 29.

Das, K.C., M.Y. Minkara, N.D. Melear, and E.W. Tollner (2002). Effect of poultry litter amendment on hatchery waste composting. J. Appl. Poult. Res. 11(3): 282-290.

Dunkley, C.S., D. Cunningham, C. Ritz, K. Dunkley, and A. Hinton (2011). Using mortality compost in vegetable production: A comparison between summer and winter composting and its use in cabbage production. Agric. Food. Anal. Bacteriol. 1(1): 6-14.

Etches, R.J. (1996). Reproduction in poultry. CAB International, Wallingford, UK. pp. 267-397.

Fadika, G.O., J.H. Wolford, and C.J. Flegal (1975). Performance and blood analyses of growing turkeys fed dehydrated poultry anaphage. Res. Rep. Mich. State Univ., Exp. Stn.

Flegal, C.J. (1971a). Dehydrated poultry waste (DPW) as a feedstuff in poultry rations. Livestock waste management and pollution abatement. Proc. Int. Symp. on Livestock Wastes. 305-307.

Flegal, C.J. (1971b). The effect of feeding dehydrated poultry waste on production, feed efficiency, body weight, egg weight, shell thickness and hatching score. Mich. Agric. Exp. Sta. Farm Sci. Res. Rpt. 117, Mich. St. Univ., East Lansing. 31-33.

Flegal, C.J. and H.C. Zindel (1969). Utilization of dehydrated poultry waste by laying hens. Poult. Sci. 48(5): 1807.

Flegal, C.J. and H.C. Zindel (1971). Dehydrated poultry waste (DPM) as a feed stuff in poultry rations. Proc. Int. Sym. on livestock wastes, ASAE, St. Joseph, MI. 305 p

Flegal, C.J. and H.C. Zindel (1972). The utilization of dehydrated poultry waste by laying hens. Poult. Sci. 48: 1807.

Flegal, C.J., C.C. Sheppard, and D.A. Dorin (1972). The effect of continuous recycling and storage on nutrient quality of dehydrated poultry waste (DPW). In Proc. Cornell Agric. Waste Manage. Conf. 295-300.

Fogarty, A.M. and O.H. Tuovinen (1991). Microbiological degradation of pesticides in yard waste composting. Microbiol. Rev. 55(2): 225-233.

Fontenot, J.P. (1999). Nutrient recycling: The North American Experience. Review. Asian-Aust. J. Anim. Sci. 12(4): 642-650.

Gross, W.B. (1985). Effect of exposure to a short-duration sound on the stress response of chickens. Avian. Dis. 34(3): 759-761.

Henuk, Y.L. and J.G. Dingle (2003). Poultry manure: Source of fertilizer, fuel and feed. Worlds. Poult. Sci. 59(3): 350-360.

Imbeah, M. (1998). Composting piggery waste: A review. Bioresour. Technol. 63(3): 197-203.

Kawata, K., K. Nissato, N. Shiota, T. Hori, T. Asada, and K. Oikawa (2006). Variation in pesticide concentrations during composting of food waste and fowl droppings. Bull. Environ. Contam. Toxicol. 77(3): 391-398.

Kelleher, B.P., J.J. Leahy, A.M. Henihan, T.F. O'Dwyer, D. Sutton, and M.J. Leahy (2002). Advances in poultry litter disposal technology – a review. Bioresour. Technol. 83(1): 27-36.

Kumar, V.R.S., K. Sivakumar, M.R. Purushothaman, A. Natarajan, and M.M. Amanullah (2007). Chemical changes during composting of dead birds with caged layer manure. J. Appl. Sci. Res. 3(10): 1100-1104.

Line, J.E. and L.S. Bailey (2006). Effect of on-farm acidification treatments on Campylobacter and

Salmonella populations in commercial broiler houses in northeast Georgia. Poult. Sci. 85(9): 1529-1534.

Lu, H., A.E. Castro, K. Pennick, K. Liu, Q. Yang, P. Dunn, D. Weinstock, and D. Henzler (2003). Survival of avian influenza virus H7N2 in SPF chickens and their environments. Avian. Dis. 47(3): 1015-1021.

Mahmud, A., Saima, M.A. Jabbar, A.W. Sahota, Z. Hayat, and M.Z.U. Khan (2015). Effect of Feeding Hatchery Waste Meal Processed by Different Techniques on Egg Quality and Production Performance of Laying Hens. Pakistan J. Zool. 47(4): 1059-1066.

Marangon, S. and L. Busani (2006). The use of vaccination in poultry production. Rev. Sci. Tech. Off. Int. Epiz. 26(1): 265-274.

Maxwell, M.H., P.M. Hocking, and G.W. Robertson (1992). Differential Leucocyte responses to various degrees of food restriction in broilers, turkeys and ducks. Br. Poult. Sci. 33(1): 177-187.

McFarlane, J.M. and S.E. Curtis (1989). Multiple concurrent stressors in chicks. Effects on plasma corticosterone and the heterophil to lymphocyte ratio. Poult. Sci. 68(4): 522-527.

Michel, F.C. Jr., T.J. Marsh, and C.A. Reddy (2002). Bacterial community structure during yard trimmings composting. In: Microbiology of Composting (ed. H. Insam, N. Riddech, & S. Klammer), Springer, Berlin, Germany. 25-42.

Miller, P.J., C. Estevez, Q. Yu, D.L. Suarez, and D.J. King (2009). Comparison of viral shedding following vaccination with inactivated and live Newcastle disease vaccines formulated with wild type and recombinant viruses. Avian. Dis. 53(1): 39-49.

Muller, Z. (1975). Livestock waste as future energy resources. Proc. 5th Int. ERE Symp. Kuala Lumpur. 287-297.

Murphy, D.W. (1990). Disease transfer studies in a dead bird composter. In: Proceedings of the 1990 National Poultry Waste Management Symposium, Raleigh, North Carolina. National Poultry Waste Management Symposium Committee, Auburn University, Auburn, Alabama. 25-30.

National Research Council (NRC) (1994). Nutrient Requirements of Poultry. 9th Rev. ed. Natl. Acad. Press, Washington, DC.

Naumann, C. and R. Bassler (1993). Methodenbuch, Band III. Die Chemische Untersuchung von Futtermitteln (Darmstadt, Germany, VDLUFA-Verlag).

Nesheim, M.C. (1972). Evaluation of dehydrated poultry manure as a potential poultry feed ingredient. Proc. Waste Mgmt. Res., Proc. Cornell Agri. Waste Mgmt. Conf. 307 p

Odunsi, A.A., A.O. Akinwumi, and O.I. Falana (2013). Replacement value of hatchery waste meal for fish meal in the diet of laying Japanese Quail (*Coturnix coturnix japonica*). Int. Food Res. J. 20(6): 3107-3110.

Quisenberry, J.H. and J.W. Bradley (1968). Nutrient recycling. Second Nat. Poult. Litter and Waste Mgmt. Sem., Texas St. College. 96-106.

Rankins, D.L., M.H. Poore, D.J. Capucille, and G.M. Rogers (2002). Recycled poultry bedding as cattle feed. Vet. Clin. North Amer. Food Anim. Prac. 18(2): 253-266.

Ritz, C.W. and J.W. Worley (2005). Poultry mortality composting management guide. Bulletin 1266. The University of Georgia, Cooperative Extension Service, Athens, GA.

Rothrock, M.J., J.R. Cook, K.L. Lovanh, N.J.G. Warren, and K. Sistani (2008). Development of a quantitative real-time PCR assay to target a novel group of ammonia producing bacteria found in poultry litter. Poult. Sci. 87(6): 1058-1067.

Ryckeboer, J., J. Mergaert, K. Vaes, S. Klammer, D. DeClercq, J. Coosemans, H. Insam, and J. Swings (2003). A survey of bacteria and fungi during composting and self-heating processes. Ann. Microbiol. 53(4): 349-410.

SAS Institute Inc. (2002-2004). SAS/STAT User's Guide: Statistics. Version 9.1. SAS Inst. Inc., Cary, NC.

Senkoylu, N., H.E. Samli, H. Akyurek, A. Agma, and S. Yasar (2005). Performance and egg characteristics of laying hens fed diets incorporated with poultry by-product and feather meals. J. Appl. Poult. Res. 14(3): 542-547.

Senne, D.A., B. Panigrahy, and R.L. Morgan (1994). Effect of composting poultry carcasses on survival of exotic avian viruses: Highly pathogenic avian influenza (HPAI) virus and adenovirus of egg drop syndrome-76. Avian. Dis. 38(4): 733-737.

Sharpley, A.N., S. Herron, and T. Daniel (2007). Overcoming the challenges of phosphorus-based management challenges in poultry farming. J. Soil Water Conserv. 62(6): 375-389.

Siegel, H.S. (1985). Immunological responses as indicators of stress. World's Poult. Sci. J. 41(1): 36-44.

Sims, J.T. and D.C. Wolf (1994). Poultry Waste Management: Agricultural and Environmental Issues. Adv. Agron. 52: 1-83.

Tadele, Y. (2015). Utilization of Farm Animal Organic Waste as Feeds for Livestock and Poultry. Adv. Life Sci. Technol. 32: 73-83.

Tiquia, S.M. (2005). Microbiological parameters as indicators of compost maturity. J. Appl. Microbiol. 99(4): 816-828.

Turan, N.G. (2009). Nitrogen availability in composted poultry litter using natural amendments. Waste. Manag. Res. 27(1): 19-24.

Vinodkumar, G., V.R. Saravanakumar, S. Ramakrishnan, A. Elango, and S.C. Edwin (2014). Windrow composting as an option for disposal and utilization of dead birds. Vet. World. 7(6): 377-379.

Wilkinson, K.G., E. Tee, R.B. Tomkins, G. Hepworth, and R. Premier (2011). Effect of heating and aging of poultry litter on the persistence of enteric bacteria. Poult. Sci. 90(1): 10-18.

Wolford, J.H. (1975). Egg production and fertility of caged turkey breeder hens fed dehydrated poultry anaphage. Poult. Pollut.: Res. Results, Michigan St. Univ.