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Growth Performance, Carcass Characteristics, Blood Biochemistry and Immune Response of Japanese Quail Fed at Different Levels of Composted Poultry Waste

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MTK performed the study and wrote the manuscript. SM supervised the trials. AM designed the study. KJ assisted in statistical analysis of the data. JH finalized the manuscript.

Key words
Growth performance, Blood biochemistry, Immune response, Compost, Quail

ABSTRACT

A 4-week study was conducted to evaluate the effect of including compost in the diet on quails' growth performance, carcass yields, blood biochemistry, and immune antibody response. A total of 1200 newly hatched quail chicks (*Coturnix coturnix japonica*) were randomly allocated to five treatment groups. Each treatment group contained 40 birds and experiments were replicated six times using a completely randomized design (CRD). The experimental diets consisted of increasing levels of compost (0, 2.5, 5, 7.5, and 10%), but were otherwise iso-caloric and iso-nitrogenous. Data were analyzed by one-way ANOVA under CRD. Performance parameters, including feed consumption, weight gain, feed efficiency, and mortality at 28 day of age, were not affected ($P>0.05$) by the compost supplement to the diet. There were no differences ($P>0.05$) in carcass yield and relative weights of breast, thigh, wing, liver, gizzard, heart, and abdominal fat for chicks fed compost at any level compared to chicks fed the control diet. Although, a slight reduction in breast and thigh weights was observed in chicks fed compost at 10% level compared to control chicks, but statistically this difference was not significant ($P>0.05$). Similarly, there were no differences ($P>0.05$) in serum biochemical indices, and immune-related parameters among the diets. The experimental group fed compost at 10% showed the lowest ($P=0.0001$) feed cost per kg weight gain compared to control group. These results indicate that it is possible to feed diets containing up to 10% compost to growing meat quails without compromising growth performance, carcass characteristics, serum biochemical indices, and immune antibody response of meat quails. Furthermore, the inclusion of compost in quail diet may reduce feed cost per kg live weight gain.

INTRODUCTION

The poultry industry produces large amount of wastes, such as poultry litter, manure, and dead birds, produced by intensive production (Bolan *et al*., 2010). Improper disposal of poultry waste can create serious pollution and health concerns (Sharpley *et al*., 2007). Disposal in waste pits or lagoons is not adequate and poses serious concerns with possible pollution of ground water, especially in areas with high water tables (Wood *et al*., 2010). On-farm burial is the simplest and least labor intensive of any system (Wilkinson, 2011), but disposal of carcasses by burial can also create nuisance complaints and water quality concerns (Bonhotal *et al*., 2014). Disposal by landfill can lead to potential contamination or degradation of the environment, and surrounding ecosystems (Wilkinson, 2011). Incineration or burning is a biologically safe method of dead bird's disposal and involves minimum labor to operate, but escalating fuel costs and more stringent air quality regulations are major concerns with this disposal option (Bonhotal *et al*., 2014). Hauling to a rendering plant has been the predominant method of carcass disposal. However, investment and operating cost of the rendering plants, and associated transportation cost and potential disease spread are major concerns with this disposal option (Bonhotal *et al*., 2014). On-farm freezers as a preservation technique have limited commercial adoption. One logical solution to dealing with poultry waste (litter, dead birds) is to recycle the waste as a feedstuff for use in poultry feed, which could be possible through proper composting of the litter and dead birds, coupled with appropriate feed management practices. Composting of litter and dead

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birds is one of the many procedures, might be adopted for efficient usage of litter without harming environment (Kumar *et al*., 2007).

Composting is an aerobic biodegradation process (Wilkinson, 2011) that reduces and converts organic waste into a value-added end product (Turan, 2009). In the process of composting, naturally occurring, beneficial microorganisms, such as bacteria, protozoa, and fungi, in the poultry litter break down organic compounds in the substrate into beneficial nutrients (Capucille *et al*., 2002). Composting changes the physical and chemical characteristics of the original substrate. Additionally, heat generated (135ºF to 150ºF) during the process inactivates pathogenic microorganisms (e.g., bacteria, fungi, and viruses) that might be present in the raw waste (Wilkinson *et al*., 2011; Miller *et al*., 2016). As a result, a comparatively germ free, less toxic, safe animal feed ingredient is obtained (Wilkinson *et al*., 2011). Chemical analysis has demonstrated that composted poultry litter contains high concentration of some essential minerals, important for animal nutrition. Several studies have reported the use of dead hens and rendered spent hens in poultry feed (Mutucumarana *et al*., 2010; Xavier *et al*., 2011), but, to our knowledge, no literature exists regarding the use of composted poultry waste in poultry feed. It was hypothesized that addition of compost in quail diets at levels up to 10% could produce similar performance gains as diets without compost while being more cost-effective. This study was, therefore, planned to explore the effect of dietary compost level on live performance, carcass characteristics, compositional profile, serum biochemistry, and immune antibody response of growing Japanese quail.

MATERIALS AND METHODS

Compost preparation, experimental site, birds, and housing

A detailed description of compost preparation and analysis (Tables I and II) can be found in Khan *et al*. (2019). The feeding trial was conducted at the Avian Research and Training (ART) Centre, UVAS, Lahore under experimental animal care procedures approved by the Ethical Review Committee of the UVAS. A total of 1200 straight-run newly hatched quail chicks (*Coturnix coturnix japonica*) were randomly distributed to five treatment groups. Each treatment group contained 40 birds and experiments were replicated six times using a completely randomized design (CRD). The experimental diets consisted of increasing levels of compost (0, 2.5, 5, 7.5 and 10%), but were otherwise iso-caloric and iso-nitrogenous (Tables II). Chicks were maintained in a well-ventilated octagonal shape quail rearing shed equipped with French made five-tiered battery cage system to facilitate watering, feeding, and removal of fecal material. Birds in each group were placed in galvanized wire cages (91×76×31 cm) furnished with an electrical bulb to provide continuous lighting. The temperature and relative humidity (RH) were 34ºC and 62%, respectively, for the first week after hatching, after which, temperature was gradually reduced until it was 21°C by day 28 with RH 65%. Temperature was maintained by hanging curtains on the laterals of the shed. Each cage was furnished with a tray feeder and 2 nipple drinkers for *ad libitum* consumption of feed and water, respectively. From the age of 12 days, tray feeders were replaced with trough feeders, placed in the front section of each cage. Treatment diets were corn-soybean meal based and formulated by using the analyzed composition of feed ingredients to meet the nutritional requirements of growing meat quails (NRC, 1994).

Growth performance and carcass characteristics

Feed consumption and weight gain were recorded weekly, and feed efficiency was calculated. Birds were observed twice daily, and mortalities were removed and their body weights were included in the feed efficiency calculation. Mortality percentage was calculated as the number of birds died as relative to the total number of birds initially introduced multiplied by 100. On reaching 28 day of age, after 4 hours feed deprivation, three quails per replicate nearest to the average weight of the same replicate were selected and slaughtered according to the Halal standards, allowing bleeding for approximately 3 to 4 minutes. Thereafter, each carcass was defeathered, and breast, thigh, liver, gizzard, heart, and abdominal fat were removed and immediately weighed, and the percentages relative to live weight were calculated. Feed cost per kg weight gain was calculated as the feed cost per unit multiplied by FCR (g/g).

Serum biochemistry and immune response

Blood samples (3 mL/sample) were collected from three birds per experimental unit (18 birds/ treatment) at the time of slaughter, using 5 mL disposable syringe without anticoagulant. Subsequently, serum was separated and preserved at –20°C, and the serum biochemical indices, such as total protein, albumin, globulin, glucose, cholesterol, triglycerides, and uric acid, were spectrophotometrically assayed using commercially available diagnostic kits from Merck Specialties Pvt. Ltd. (Kumar and Kumbhakar, 2015). The chicks were vaccinated using commercially available ND (La Sota) and IB (H 120) vaccines, one week before blood samples were taken, and the antibody responses to ND and IB vaccines were determined by HI (hemagglutination inhibition) and ELISA techniques, respectively, using commercially available diagnostic kits (BioChek, Gouda, the Netherlands).

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

Chemical composition	Quantity
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
Amino acid (%)	
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

Statistical analysis

Prior to analysis, data were first verified for normality and homogeneity of variances, after which, the data were analyzed under CRD by one-way ANOVA with the help of the GLM procedure of Statistical Analysis System (SAS Institute Inc., Cary, NC). Treatment means were compared through Duncan's multiple range test at a probability level of P<0.05, considering each cage as an experimental unit.

Table II. Ingredient composition of experimental diets for meat quail.

Ingredient (%)	Treatment[1]				
	T1	T2	T3	T4	T5
Corn	49.00	49.00	46.63	45.33	45.20
Rice tips	6.00	5.00	5.00	5.00	5.00
Canola meal	10.00	6.50	6.40	5.00	0.00
Soybean meal	26.00	27.00	27.00	27.00	30.53
Fish meal	2.00	3.00	3.00	3.00	3.00
Poultry by-product meal	2.00	2.00	2.00	2.00	2.00
Canola oil	2.00	2.00	2.40	2.60	2.30
$CaCO_3$	1.10	0.90	0.50	0.10	0.00
DCP.$2H_2O$	1.10	1.00	1.00	1.00	1.00
Lysine	0.25	0.25	0.25	0.25	0.25
DL-Methionine	0.10	0.10	0.10	0.10	0.15
Threonine	0.07	0.07	0.07	0.07	0.07
Sodium chloride	0.25	0.15	0.15	0.00	0.00
Vitamin premix[2]	0.20	0.20	0.20	0.20	0.20
Minerals premix[3]	0.30	0.30	0.30	0.30	0.30
Compost	0.00	2.50	5.00	7.50	10.00

[1]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.
[2]Provided per kg of diet, vitamin A, 11,000 IU; vitamin D_3, 2,160 IU; vitamin E, 44 IU; vitamin K, 4.2 mg; riboflavin, 8.5 mg; niacin, 48.5 mg; thiamine, 3.5 mg; d-pantothenic, 27 mg; choline, 140 mg; vitamin B_{12}, 33 µg.
[3]Provided per kg of diet, copper, 8 mg; zinc, 60 mg; manganese, 60 mg; iodine, 0.35 mg; selenium, 0.15 mg.

RESULTS AND DISCUSSION

Growth performance and carcass characteristics

Data on performance parameters are shown in Table IV. No significant differences in feed intake, weight gain, feed efficiency, and mortality at 28 days of age were detected across the treatment diets. Similar performance in all groups may be attributed to the similar chemical composition (Table III) and physical form (all the diets were in mesh form) of the diets. Balanced diet, aside from genetics, is the single-most important factor that determines the efficiency of nutrient utilization and growth rate (Khan *et al*., 2018). Inadequate diet may affect the growth of the birds and efficiency of nutrient utilization (Lima *et al*., 2016). The present data, however, indicate that inclusion of compost up to 10% in quail diets did not affect performance for the entire study period, suggesting that including compost at up to 10% of the total diet still provided adequate nutritive benefits.

Table III. Nutrient composition of experimental diets for meat quail[1].

Nutrient	Treatment[2]				
	T1	T2	T3	T4	T5
Dry matter (%)	89.15	88.86	89.03	88.62	89.18
Metabolizable energy (kcal/kg)	2915	2893	2896	2894	2903
Crude protein (%)	21.8	22.0	22.0	21.9	22.00
Ether extract (%)	2.92	4.97	5.32	5.49	5.17
Ash (%)	3.76	6.27	6.32	6.15	6.42
Crude fiber (%)	4.34	4.40	4.77	5.02	5.15
Calcium (%)	0.90	0.99	0.99	1.00	1.10
Phytic phosphorus (%)	0.66	0.73	0.77	0.80	0.84
Sodium (%)	0.18	0.18	0.21	0.18	0.21
Potassium (%)	0.91	0.95	1.00	1.04	1.11
Lysine (%)	1.27	1.33	1.33	1.30	1.31
Methionine (%)	0.47	0.47	0.47	0.46	0.50
Threonine (%)	0.92	0.90	0.90	0.88	0.87
Cystine (%)	0.40	0.38	0.38	0.37	0.35
Arginine (%)	1.42	1.42	1.42	1.39	1.40
Valine (%)	1.07	1.06	1.05	1.03	1.02
Isoleucine (%)	0.91	0.91	0.91	0.89	0.90
Leucine (%)	1.84	1.83	1.82	1.78	1.79
Histidine (%)	0.58	0.57	0.57	0.55	0.55
Phenyl alanine (%)	1.05	1.05	1.04	1.02	1.04

[1]Diets were formulated on total amino acid basis (TAA).
[2]For details of treatments, see Table II.

Table IV. Effect of including compost in the diet on live performance of meat quail[1].

Treatment[3]	Parameter[2]				
	CFI (g/ bird)	WG (g/ bird)	FE	MT (%)	FC (PKR)
T1	431.49	188.88	0.44	7.00	100.91[a]
T2	426.12	183.69	0.43	7.50	97.47[ab]
T3	419.40	179.28	0.43	7.50	93.50[bc]
T4	417.83	177.49	0.42	8.50	89.46[cd]
T5	410.38	171.90	0.42	8.50	85.93[d]
SEM	5.89	2.71	0.004	0.60	1.33
P-value	0.851	0.362	0.559	0.926	0.0001

[a-e]Treatment means within a column bearing the different letters are significantly different (P<0.05).
[1]Data are means ± SEM representing 6 replicates (n=6) with 40 birds per replicate.
[2]CFI, cumulative feed intake; WG, weight gain; FE, feed efficiency; MT, mortality; FC, feed cost per kg weight gain; PKR, Pakistani rupee.
[3]For details of treatments, see Table II.

Similarly, Mutucumarana *et al.* (2010) fed poultry offal meal to Japanese quails at 0, 2.5, 5, 7.5, and 10% inclusion levels up to 5 weeks of age. Performance in terms of feed consumption and live weight gain was not influenced (P>0.05) by the addition of the poultry offal meal to the diet at any level. In contrast, Erturk and Celik (2004) found that feed consumption and body weight gain of female quails fed a poultry offal meal supplemented diet were different from those fed a control diet. Christmas *et al.* (1996), similarly, found a non-significant difference in the performance (P>0.05) of broiler chickens fed a spent hen meal (12%) containing diet. Escalona and Pesti (1987), likewise, observed no difference (P>0.05) in feed efficiency when poultry by-product meal and hatchery waste were included up to the level of 5% into broiler diets. Similarly, Mendonca and Jensen (1989) did not observe any change (P>0.05) in performance parameters (weight gain, feed utilization, and feed conversion ratio) of broiler chickens at 10% inclusion level of poultry by-product meal into diets, concluding that various poultry by-product meals, such as spent hen meal (Douglas and Parsons, 1999), hatchery waste meal (Shahriar *et al.*, 2008; Abiola *et al.*, 2012), feather meal (Ochetim, 1993), feather and blood meal (Xavier *et al.*, 2011) and feather and viscera meal (Klemesrud *et al.*, 1997), can be used in broiler rations without any damage to live performance (Haque *et al.*, 1991; Kirkpinar *et al.*, 2004). Furthermore, improved (P<0.05) growth performance in broilers has also been reported due to the inclusion of animal origin by-products in broiler diet (Bellaver *et al.*, 2005; Laboissiere, 2008).

As described in Table V, carcass yield and relative weights of breast, thigh, wing, liver, gizzard, heart, and abdominal fat were not significantly different (P>0.05) across treatments. Although, a slight reduction in breast and thigh weights was observed in chicks fed compost at 10% level compared to control chicks, but statistically this difference was not significant (P>0.05). Dressing percentage is considered the main parameter for assessing carcass quality (Li *et al.*, 2014). Muscle meat is the main edible part in meat quails. Higher yields of breast and thigh muscle mean higher economic value for meat quails producers (Wen *et al.*, 2017). There is evidence that inadequate diet not only affects the growth of the birds, but also leads decreases in carcass quality (Lima *et al.*, 2016). The present data, however, indicate that supplementation of compost to quails diet from 0 to 28 day of age did not affect (P>0.05) dressing percentage, breast meat yield, leg quarter yield, and relative weights of liver, gizzard, heart, and abdominal fat. In line with these results, Kersey and Waldroup, (1998) pointed out that spent hen meal in broiler diets did not affect (P>0.05) carcass characteristics, including carcass yield, leg quarter yield, breast meat yield, wing yield, and abdominal fat content. Similarly, Shahriar *et al*. (2008) did not observe any change (P>0.05) in carcass yield values of broilers in response to processed hatchery waste supplementation. Hossain *et al*. (2003) fed broiler chickens diets, iso-caloric and iso-nitrogenous, containing 0, 4, and 8% broiler offal, and observed no effect on carcass characteristics (P>0.05). Ochetim, (1993) indicated that supplementary feather meal did not influence (P>0.05) dressing percentage in broiler chickens. Abiola *et al*. (2012) concluded that 10% of fish meal can be replaced with whole hatchery waste meal in broiler diets without detrimental effects on carcass characteristics.

Table V. Effect of including compost in the diet on carcass characteristics of meat quail[1].

Treat-ment[3]	Parameter[2]						
	CY (%)	BR (%)	TH (%)	L (%)	G (%)	H (%)	ABF (%)
T1	64.53	23.13	14.66	2.52	1.94	0.88	1.35
T2	63.97	22.95	14.52	2.53	2.00	0.90	1.29
T3	63.14	22.41	14.35	2.60	2.01	0.92	1.26
T4	62.68	22.18	14.14	2.66	1.97	0.90	1.23
T5	62.33	21.92	13.80	2.85	2.04	0.89	1.20
SEM	0.63	0.35	0.27	0.07	0.04	0.02	0.03
P-value	0.822	0.820	0.892	0.518	0.962	0.994	0.666

[a-b]Treatment means within a column bearing the same letter are not significantly different (P>0.05).
[1]See Table IV.
[2]CY, carcass yield; BR, breast; TH, thigh; W, wing; L, liver; G, gizzard; H, heart; ABF, abdominal fat.
[3]For details of treatments, see Table II.

Serum biochemistry and immune response

The results of serum biochemical profiles (Table VI) and antibody titers against NDV and IBV (Table VII) exhibited no difference (P>0.05) among the dies. Blood parameters are considered good indicators of health status (Rehman *et al*., 2017). Abnormal changes in values of most blood parameters indicate a physiological disorder in the animal's body, but at maximal level of compost, no physiological disorders caused by compost were observed relative to blood biochemistry as can be seen by the normal values of blood profile in all treatment groups. Among the blood parameters, serum total protein, albumin, and uric acid are considered the main criteria for assessing the quality of dietary protein (Alikwe *et al*., 2010), while glucose, cholesterol, and triglycerides are the criteria useful to assess the immune status of animals (Yilmaz Dikmen *et al*., 2016). In this study, diets with different compost levels produced results comparable (P>0.05) with that of the control, suggesting that compost can be utilized with confidence in quail diets up to the level of 10% with no pernicious effects on serum biochemistry. Similarly, Shahriar *et al*. (2008) fed male broiler chicks diets containing 0, 2, 4, 6, and 8% processed hatchery waste for a period of 7-56 days. Results indicated that the triglyceride and cholesterol values were not significant between the diets at 35 day of age, but glucose value of serum was significant among the treatments and increased with the increase in inclusion rate of hatchery waste.

Table VI. Effect of including compost in the diet on serum biochemistry of meat quail[1].

Treat-ment[3]	Parameter[2]						
	TP (g/dL)	AB (g/dL)	GB (g/dL)	GL (mg/dL)	CH (mg/dL)	TR (mg/dL)	UA (mg/dL)
T1	4.18	1.30	2.74	142.57	171.46	91.28	4.00
T2	4.10	1.28	2.78	139.23	177.09	85.20	4.17
T3	4.00	1.28	2.68	136.29	169.44	87.16	4.39
T4	3.96	1.25	2.66	137.78	166.27	82.47	4.53
T5	3.85	1.23	2.61	132.76	162.73	83.98	4.62
SEM	0.11	0.03	0.10	3.85	3.41	2.62	0.11
P-value	0.920	0.963	0.988	0.960	0.763	0.876	0.367

Treatment means within a column bearing the same letter are not significantly different (P>0.05).
[1]See Table IV.
[2]TP, total protein; AB, albumin; GB, globulin; GL, glucose; CH, cholesterol; TR, triglyceride; UA, uric acid.
[3]For details of treatments, see Table II.

Table VII. Effect of including compost in the diet on immune antibody response of meat quail[1].

Treatment[3]	Antibody titer[2]	
	ND (HI titer, log_2)	IB (ELISA titer)
T1	4.21	3511.91
T2	4.19	3499.18
T3	4.16	3489.25
T4	4.08	3474.89
T5	4.02	3460.07
SEM	0.04	9.16
P-value	0.566	0.443

Treatment means within a column bearing the same letter are not significantly different (P>0.05);
[1]See Table IV.
[2]Birds were vaccinated via drinking water using commercially available ND (La Sota) and IB (H 120) vaccines, one week before blood samples were taken.
[3]For details of treatments, see Table II.

The hallmark of an immune system is to defend against diseases. Immunity refers to responses by an animal's body to foreign substances, such as microbes. Determination of immune responses against a variety of pathogens, including vaccinations, helps in assessing the immune status of animals. In this study, dietary compost levels did not result in significant immune antibody response changes (P>0.05) in comparison to control diet. As mentioned earlier, the nature of an optimal immune response is influenced by several factors, such as nutrition, environment, age, genetics, and the infection status of the bird (Kogut, 2009). Among these factors, diet is of utmost importance. There is increasing evidence of the sensitivity of immunity to nutrient supply (Galyean *et al*., 1999). Inadequate diets or diets containing harmful agents act as adverse stimuli for immune system. Low feed, and thereby nutrient, intake may compromise immune function (Faluyi *et al*., 2015). Compost used in this study was checked safe and diets used were properly balanced, containing an adequate nutrient profile. Therefore, no effect of dietary compost levels on immune-related parameters may be attributed to the similar chemical composition, similar feed intake, and adequacy of the diets. Due to lack of information about the possible effects of compost on the immune antibody response of Japanese quail, direct comparison cannot be made with previous studies.

CONCLUSIONS

These results suggest that it is possible to feed diets containing up to 10% compost to growing meat quails without any malicious effects on growth performance, carcass yields, serum biochemistry, and immune response of meat quails. Furthermore, the inclusion of compost as a feed resource in quail diets may reduce feed cost per kg live weight gain.

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Statement of conflict of interest

The authors declare that there is no conflict of interests regarding the publication of this article.

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