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Effects of Different Anti-Stressors on Growth, Serum Chemistry and Meat Quality Attributes of Japanese Quail

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ABSTRACT

The aim of the present study was to evaluate the effect of different anti-stressors on growth performance, carcass traits, bloodchemistry and meat quality attributes of broiler Japanese quail. For this purpose, a total of 1,875 quail chicks were procured and arranged according to completely randomized design, birds were divided into 5 treatment groups having 5 replicates of 75 birds each. The treatments consisted of four anti-stressors i.e., synthetic anti-stressors (Vitamin C and Betaine) and natural anti-stressors (Turmeric and Chia Seed) along with a control group. Bird's diets were supplemented with vitamin C, betaine, turmeric and chia seed @ 600 mg/kg, 700 mg /kg, 300 mg/kg and 7,000 mg/kg, respectively. After four weeks, 10 birds per treatment were slaughtered (Halal method), de-feathered, eviscerated and their carcass traits, serum chemistry and meat quality attributes were calculated. Birds supplemented with betaine revealed significantly ($p \leq 0.05$) lower feed intake, glucose, cholesterol, H:L ratio, better weight gain, times of gain, FCR and highest anti-oxidant assay and total viable count. However, carcass traits, processing traits and blood cortisol level did not differ ($p > 0.05$) among the treatment groups. In conclusion, addition of anti-stressors (especially betaine) in the diet of growing Japanese quail had positive influence on growth and serum chemistry.

INTRODUCTION

Japanese quail (*Coturnix japonica*) were initially domesticated as pet song birds or as game birds then with time they were converted into valuable meat type birds (Kayang *et al.,* 2004). Japanese quail is a domestic bird of economic importance for commercial meat production and lay unique flavor eggs (Mahmoud El-Tarabany, 2016). Japanese quail are the best meat producers among all the quails present in the world with an average adult live weight at four weeks of age of 200 grams (Ahmad, 2016). Japanese quails are excellent laboratory animals used for research purposes as they have low maintenance cost, short generation interval (3-4 generation per year), hardy, resist disease, high egg production and require lower space and equipment utility (Minvielle, 2004). Role of environment cannot be denied as commercial and intensive poultry production is associated with various stresses leading to the decrease of productive and reproductive performance of growing chickens, parent birds, and layers (Surai & Fisinin, 2016). Japanese quails are also affected by various environmental and management stresses that affect their productivity during humid hot season (Bello & Sulaiman, 2016).

Pakistan is located in geographical regions of southwestern Asia and situated in both northern and eastern hemisphere, where, July and August are considered to be humid hot months (Daghir, 2009). During these months the birds experience a series of stresses, among these heat stress has been identified as a major problem affecting performance and physiological attributes of chickens (Daghir, 2008). Heat stress is the major cause of declining poultry farming in open sided houses, resulting into emptying 25,000 open sided houses (Akram, 2013) along with decreased performance of laying quail in tropical and subtropical countries (Mahmoud El-Tarabany, 2016). There are different management strategies to counter these stresses i.e., use of high speed cool air to remove bird heat through convection and early age feed restriction to alleviate heat stress (Zulkifli *et al.,* 2000). The vitagene concept of fighting stresses emerged as a new direction in a nutritional research. The vitagenes are responsible for preserving cellular homeostasis in stressful conditions by additional synthesis of heat shock proteins in the body (Surai & Fisinin, 2016). There are also different nutritional strategies being adopted to reduce heat stress in chicken (Sahin *et al.,* 2009). The use of different additives such as ammonium chloride (Smith & Teeter, 1993), Potassium Chloride (El-Deek *et al.,* 2009), Sodium bicarbonate (Hayat *et al.,* 1999), probiotics (Lin *et al.,* 2006), garlic (Adibmoradi *et al.,* 2006), mint (Gill *et al.,* 2002) and yogurt (Zulkifli *et al.,* 2000) are helpful in reducing the deleterious effect of high heat index in broilers. The different anti-stressors in feed like vitamin C (Whitehead & Keller, 2003), betaine (Attia *et al.,* 2005), turmeric (Hosseini *et al.,* 2012) and chia seed (Uribe *et al.,* 2011) showed beneficial responses in reducing the effect of heat stress on birds. Betaine has osmoregulatory properties that reduces negative effect of heat stress on growth performance and enhances survival of poultry by improving cell osmoregulation (Borges *et al.,* 2007). Broilers reared under the supplementation of betaine showed an improvement in growth, feed conversion ratio (FCR) and immune response (Wang *et al.,* 2004). Vitamin C decreases the synthesis and secretion of corticosteroids and alleviates the negative effects of heat stress on bird (Kulkani *et al.,* 2012). The use of vitamin C as an anti-stressor in heat stressed broiler resulted into an increased performance and better carcass quality (Sahin & Kucuk, 2001). Similarly, Chia seed (*Salvia hispanica*) can also be used as an anti-stressor because it is potentially a great source of antioxidants which protect the bird from heat stress and result in better health condition (Uribe *et al.,* 2011). Turmeric is a natural polyphenol that exhibits antioxidant property and alleviates oxidative stress in heat stressed Japanese quails (Sahin *et al.,* 2012). It is also found beneficial in reducing the negative effect of heat stress on broiler's growth performance, production performance and immune system (Hosseini *et al.,* 2012). Despite mushrooming environment-controlled poultry houses throughout the world, temperature and humidity are still core issues in hot and humid areas especially in Pakistan. During this season, particularly in July-August, poultry experience a series of stresses; among these, heat stress is more vigorous and can be eliminated through some feed manipulations. Use of anti-stressor like betaine, vitamin C, KCl, and Chia seed in poultry feeds effectively reduce heat stress. The present study was planned to find out the effect of different anti-stressors on growth performance, carcass traits, blood chemistry and meat quality attributes of broiler Japanese quail.

MATERIALS AND METHODS

The present study was conducted at the Avian Research and Training Centre (ARTC), University of Veterinary and Animal Science, Lahore, Pakistan. A total of 1,875 quail chicks were procured from ARTC hatchery and were arranged in a completely randomized design, birds were divided into 5 treatment groups having 5 replicates of 75 birds each. The treatments consisted of four anti-stressors i.e., synthetic anti-stressors (Vitamin C and Betaine) and natural anti-stressors (Turmeric and Chia Seed) along with a control group. The bird's diets were supplemented with vitamin C, betaine, turmeric and chia seed @ 600 mg /kg, 700 mg /kg, 300 mg /kg and 7,000 mg /kg, respectively for the duration of four weeks. The study was according to the guidelines and code of practices of UVAS, Lahore, Pakistan and ethical approval was also granted.

Housing and Management

The birds were maintained in an octagonal quail shed having a French made 5-tiered battery cage system specially designed for meat type quails [83.61 cm^2/quail during brooding (14 days) and 150 cm^2/quail during growing (28 days)]. The birds were provided with *ad libitum* feed (Table 1), provision of fresh and clean water was ensured by nipple drinker system. The birds were reared under the humid hot season of august and fed on a diet formulated by the following ingredients supplemented with different anti-stressors. The effect of these anti-stressors was observed on growth performance, carcass traits, serum chemistry and meat quality attributes of Japanese quail. After four weeks, 10 birds per treatment were slaughtered (Halal method; Shahdan *et al*., 2016) and blood was collected for the determination of blood chemistry. After slaughtering, the birds were de-feathered, eviscerated and their carcass traits and meat quality attributes were calculated.

Parameter Studied

Data were recorded regarding growth performance (feed intake, body weight, body weight gain, time of gain, FCR and livability) for the duration of four weeks.

Blood chemistry and Carcass traits

At the end of the 4th week, ten birds were randomly picked up from each treatment and 2 ml of blood was collected in marked test tubes from Jugular vein of each bird during slaughtering (Halal method). Serum samples were extracted by centrifugation and stored at -20°C for measuring blood glucose, cholesterol and cortisol. Blood (2 ml / bird) was collected in EDTA containing tubes and blood smear was prepared by using Grunwald-Giemsa stain, and the number of H and L was counted to a total of 100 cells by the method adopted by Gross & Siegel (1983). Carcass traits were recorded regarding live weight, dressed weight, dressing %, liver, gizzard and heart weight and expressed as percentage of body weight.

Sensory evaluation and processing traits

After rearing Japanese quail, Sensory panel test was performed on breast samples by roasting the sample without salt and spice (Castellini *et al.,* 2002). The cooked samples were immediately sliced into pieces and were offered to panelists. For each sensory characteristic, participants were instructed to score the intensity of evaluation on a nine point's hedonic scale for (color, flavor, juiciness, tenderness, oiliness and overall acceptability).

The breast sample was collected, and color measurement was taken at 01-hour post slaughtering. The breast samples packed in trays were placed at chilling temperature. The color was measured using Minolta CR-410 colorimeter, after its calibration using standard white tile CR-A44 at l* = 94.93, a* = -0.13 and b* = 2.55. The pH of the breast meat was measured using pH meter with meat penetrating probe (WTW, pH 3210 SET 2, Germany) from three places of breast. The pH was recorded on 24 hours after slaughtering while keeping carcass in chiller.

Anti-oxidant assay and intestinal viable count

At the end of 4 weeks, total fat content of meat was determined by ether extraction method and meat anti-oxidant assay as total phenolic content, total flavonoid content, total anti-oxidant capacity was determined by spectrophotometry method as described by Khanahmadi (2010), Nile, Khobragade (2010) and Nabasree & Bratati (2007), respectively. At the end of the 4th week, ten birds were randomly picked up from each treatment and Intestinal viable count was counted by viable counting method (AOAC, 1990).

Statistical Analysis

Data were analyzed through one-way ANOVA technique (Steel *et al.,* 1997) using PROC GLM in SAS software. Treatment means were compared through Duncan's (1955) Multiple Range test assuming following mathematical model:

$$Y_{ij} = \mu + \tau_i + \varepsilon_{ij}$$

Whereas,

Y_{ij} = Observation of dependent variable recorded on i^{th} treatment

μ = Population Mean

τ_i = Effect of i^{th} treatment (i = 1, 2, 3, 4, 5)

ε_{ij} = Residual effect of j^{th} observation on i^{th} treatment NID ~ 0, σ^2

RESULTS AND DISCUSSION

Growth Performance

In this study, the birds having vitamin C in their diet showed the highest feed intake (FI) as compared to the birds supplemented with other anti-stressors and the control group. Vitamin C is known to increase the use of corticosteroids and reduce the synthesis of corticosteroid hormones released during stress in birds. By decreasing synthesis and secretion of corticosteroids, vitamin C alleviates the negative effects of stress and increases feed intake (Kutlu & Forbes, 1993). Similar findings were also reported in the study of heat stressed Japanese quail, the vitamin C supplementation significantly increases FI (Sahin *et al.,* 2003). Similarly, improvement in FI of 21 day-old unsexed slow growing broilers were also reported when fed different levels of dietary betaine (Attia *et al.,* 2009). Moreover, the turmeric supplementation in the diet of heat stressed Japanese quail significantly increases cumulative FI when compare to the control treatment (Sahin *et al.,* 2012). However, contradictory studies also reported that supplementation of turmeric in feed of Japanese quail do not affect daily FI (Saraswati *et al.,* 2013). Similarly, turmeric supplementation did not affect FI in heat stressed broilers (Hosseini *et al.,* 2012).

In the present study, maximum body weight gain (BWG) was observed in birds fed with betaine and vitamin C in their diet as compared to the birds supplemented with chia seed, turmeric and the control group, respectively. The important function that betaine performs is the active donation of a methyl group that maintains the cellular water homeostasis (Kidd *et al.,* 1997). It takes part in the synthesis of protein and could be helpful in weight gain of broilers (Rima, 2013). The evidences regarding the use of betaine in heat stress condition proves that it is an important nutrient due to its multiple functions (Eissen & Enting, 2007). The findings of the present study are in accordance with the study of broilers who found that dietary supplementation of betaine improve weight gain in high temperatures (Chen & Chiang, 2002). Similarly, improvement in BWG of 21 day-old unsexed slow growing broilers were also reported when fed different levels of dietary betaine (Attia *et al.,* 2009). However, other study found that betaine supplementation increases BWG in one-day old unsexed chicks of El-salam strain during the first 4 weeks but did not show any effect during 5-8 week of age when fed medium and high levels of betaine (Hassan *et al.,* 2005). Moreover, the dietary supplementation of chia seed causes significant decrease in BWG of broilers when compared to the controls (Ayerza *et al.,* 2002). Similarly, no significant differences in BWG of broilers were observed when compared with low or high level of chia seed supplementation (Ayerza *et al.,* 2002). Another study reported that supplementation of turmeric in Japanese quail did not affect BWG (Saraswati *et al.,* 2013).

In the present experiment, the Japanese quail supplemented with betaine showed better feed conversion ratio (FCR) as compared to the birds supplemented with other anti-stressors and the control group. This might be attributed with the highest body weight of birds in this group due to improved feed consumption that give better feed to weight ratio. The findings of the study are in line with the study of heat stressed broiler who found that FCR improved significantly with the highest amount of betaine (Enting & Eissen, 2007). In the study of 21 day-old unsexed slow growing broilers, betaine showed improvement in FCR when fed different levels of dietary betaine (Attia *et al.,* 2009). Another study reported that betaine supplementation improves FCR in broilers during the first 4 weeks but did not show any affect during 5-8 week of age when fed medium and high levels of betaine (Hassan *et al.,* 2005). However, a contradictory study reported that the dietary supplementation of chia seed causes poor FCR in broilers when compared to the controls (Ayerza *et al.,* 2002). Similarly, no significant differences FCR of broilers were observed when compare with low or high level of chia seed supplementation (Ayerza *et al.,* 2002). Supplementation of turmeric in heat stress broilers did not affect FCR (Hosseini *et al.,* 2012).

The present study observed no difference regarding livability % of birds supplemented with different anti-stressors. The findings of the present study are confirmed by other studies that reported that Betaine is beneficial in reducing the negative effect of heat stress and in enhancing survival of poultry by improving cell osmoregulation (Graham, 2002). Betaine supplementation increases the livability in heat stressed broilers (Khattak *et al.,* 2012). The heat stressed broilers supplemented with betaine in their diet decreases the mortality rate (Khattak *et al.,* 2012). The dietary supplementation of chia has no effect on mortality rate in birds when compared to the controls (Ayerza *et al.,* 2002). A contradictory study also reported that vitamin C supplementation causes no significant differences in terms of mortality rate in the period from 0 to 3 weeks of age in heat stressed broilers. However, significant differences were observed in the periods from 4 to 6 weeks of age (Toplu *et al.,* 2014).

Carcass traits

The present experiment did not find any difference regarding live body weight (LBW) of Japanese quail supplemented with different anti-stressors. The results of this study are in line with the study on heat stressed Japanese quail which reported that vitamin C supplementation has no significant difference in LBW at slaughter when compared to the control in heat stressed Japanese quail (Mehmet *et al.,* 2005). Contrarily, other studies found that vitamin C supplementation resulted in higher LBW at slaughter in heat stressed Japanese quail (Sahin & Kucuk, 2001).

The dressed weight (DW) of Japanese quail reared under different anti-stressors recorded no significant difference. Similar findings also reported that vitamin C supplementation had no significant effect on DW of heat stressed Japanese quail when compared to the control (Imik *et al.,* 2010). However, other studies noted that the vitamin C supplementation resulted increase in cold DW in heat stressed Japanese quail (Kulkani *et al.,* 2012).

This experiment recorded no difference regarding dressing % of birds fed with different anti-stressors. Similar findings also showed that the vitamin C supplementation had no effect on carcass yield when compare with control in heat stressed Japanese quail (Mehmet *et al.,* 2005). The addition of betaine did not affect carcass percentage in heat stressed broilers (Enting & Eissen, 2007). Contradictory studies also reported that in slow growing broilers, better dressing percentage was observed when the birds were fed different levels of dietary betaine (Attia *et al.,* 2009). The vitamin C supplementation resulted in the increase in cold carcass yield in heat stressed Japanese quail (Sahin & Kucuk, 2001).

The results of the present study did not reveal any difference regarding gizzard, liver, heart, shank (SW) and head weight (HW) % of Japanese quail reared under different anti-stressors. Similarly, other studies found no significant influence of dietary betaine on giblets in slow growing chicks (Hassan *et al.,* 2005). However, it was also reported that betaine addition to the diets of broilers reared under acute heat stress improved the giblets percentage especially liver and heart weight % (Attia *et al.,* 2009).

Blood chemistry

Betaine and chia seed supplemented birds showed lower blood glucose and cholesterol level as compared to the control group. This might be attributed to the fact that the production of glucose is directly proportional to the release of glucocorticoid hormone which is being produced under heat stress conditions through gluconeogenesis. Betaine (non-protein amino acid) as an osmoregulatory agent for relief the adverse effect of heat stress and reduces the breakdown of body lipids in heat stress condition and lowers blood glucose and cholesterol (Borges *et al.,* 2007). The results of the present study are in accordance with other studies that found betaine supplementation in heat stressed slow growing broilers to improve the physiological parameters by reducing serum glucose levels (Attia *et al.,* 2009). The vitamin C supplementation may result into significant decrease in serum cholesterol in heat stressed Japanese quail (Sahin *et al.,* 2004). Moreover, turmeric supplementation before sexual maturity (first 30 days) increases serum glucose while turmeric supplementation at 7-8 month of Japanese quail decreases serum glucose (Saraswati *et al.,* 2013).

In this study, no significant difference was reported regarding blood cortisol levels of Japanese quail reared under different anti-stressors. Contradictory studies also reported that vitamin C supplementation in heat stressed broilers reduces plasma corticosterone level and improve their physiological response (Kulkani *et al.,* 2012). The vitamin C supplementation may result into significant decrease in serum corticosterone in heat stressed Japanese quail (Sahin *et al.,* 2004).

The lowest Hetrophil lymphocyte (HL) ratio was recorded in birds supplemented with turmeric. The rise in the blood HL ratio (as a stress indicator) is considered as an indication of overactivation of the hypothalamic-pituitary-adrenal (HPA) axis. Turmeric suppress the activity of HPA and lowers HL ratio (Schmidt *et al.,* 2012) Similar, it was reported that turmeric supplementation decreases HL ratio in heat stressed broiler chicken (Hosseini *et al.,* 2012). Moreover, betaine supplemented broilers had smaller increase in HL ratios (HLR) than those in the control group during heat exposure (Zulkifli *et al.,* 2004).

Meat quality attributes

Sensory evaluation

Betaine supplemented birds showed darker meat color while lighter color was recorded in chia seed fed birds. However, panel did not find any difference regarding breast color results of Japanese quail. In this study no difference was observed regarding the breast meat flavor and juiciness of Japanese quail supplemented with different anti-stressors. Similarly, in broilers fed with chia seed, no significant difference was observed regarding flavor in sensory evaluation (Ayerza *et al.,* 2002). However, other studies reported that broiler chicken supplemented with turmeric resulted in improved flavor and palatability (Hosseini *et al.,* 2012). Betaine supplemented birds showed maximum score, meaning that meat has more tenderness and oiliness whereas minimum tenderness and oiliness score was observed in birds fed with vitamin C.

In this study, panel did not find any difference regarding breast meat overall acceptability of Japanese quail reared under different anti-stressors. Similar findings also reported that in chia seed supplemented broilers, no effect was found regarding acceptance in sensory evaluation (Ayerza *et al.,* 2002). No significant differences in taste preference or flavor were found among chia treatments in laying hens (Ayerza & Coates, 2002). However, contradictory study found that the Japanese quail fed with vitamin C in their diet resulted insignificant improvement in overall meat quality (Imik *et al.,* 2010).

Processing traits

In this study, betaine supplemented birds showed higher redness in meat. However, no difference was observed regarding meat color lightness, yellowness, chroma and hue angle and pH. Similar, there was no effect of vitamin C or betaine supplementation on color and pH of meat in slow growing chicks (Attia *et al.,* 2009). However, contradictory studies noted that initial and ultimate pH values of breast and thigh meat were higher in vitamin C supplemented broilers. The L* value of breast and thigh meat of vitamin C supplemented broilers were significantly lower whereas a* value was higher when compared to the control group (Toplu *et al.,* 2014).

Anti-oxidant assay

In the present study, lowest fat content % was recorded in Japanese quail meat supplemented with chia seed. However, other studies reported that the chia seed supplementation causes no significant effect on fat and cholesterol content among treatments in white (breast) or dark (legs) meat of broilers (Ayerza *et al.,* 2002).

Phenolic are aromatic benzene ring compounds with one or more hydroxyl groups (including polyphenols, Butylated hydroxytoluene, Butylated hydroxy anisole and gallic acid) that are components of plants have strong antioxidant capacity that provide protection against oxidative stress (Steinberg *et al.,* 1989). Total phenolic contents (TPC) are measured in mg GAE/ml unit (Wang *et al.,* 1997). The Japanese quail supplemented with betaine showed highest TPC while lowest TPC has been recorded in vitamin C fed birds. Higher TPC of betaine supplemented diet over vitamin C supplemented diet fed birds might be attributed to the higher magnitude of polyphenols in betaine. Similarly, the concentration of TPC per mg GAE/ml of synthetic vitamin C in broilers was recorded lowest as compared to all other treatment groups (Sujatha *et al.,* 2010).

Findings of the present study indicated that lowest TFC has been observed in betaine supplemented Japanese quail whereas the birds reared under control group showed highest TFC. Lower TFC in meat of betaine supplemented birds might be due to the absence of flavonoids, as flavonoids are a group of plant metabolites (including compounds such as flavones, isoflavones, flavonones, anthocyanins, and catechins) that are components of fruits and vegetables have strong antioxidant capacity (Wang *et al.,* 1997).

Total antioxidant capacity (TAC) is a tool frequently used to assess the antioxidant status of biological samples and can evaluate the antioxidant response against the free radicals produced in stress condition. In this experiment, TAC was observed highest in betaine supplemented Japanese quail meat whereas the lowest TAC was recorded in control group birds. Another study reported that the TAC of synthetic vitamin C in broilers was lower than other treatment groups (Sujatha *et al.,* 2010).

Economics

The birds reared under betaine were more economical as compared to the rest of the treatments. This might be due to the higher weight gain of betaine supplemented birds and relatively lower cost of betaine (Table 3).

CONCLUSIONS

In conclusion, betaine being the most economical anti-stressor, it can be used in diet of growing Japanese quail during humid and hot season, having no detrimental effect on bird's performance.

CONFLICT OF INTEREST DECLARATION

No potential conflict of interest is indicated by the authors.

Table 1 – Composition of experimental ration offered during brooding and rearing phase(0-4 week).

Ingredients	Control	Betaine	Vitamin C	Turmeric	Chia seed
Anti-stressor mg / Kg	--	700	600	300	7000
Corn	57.21	57.21	57.21	57.21	57.21
Sunflower Meal 26%	6.44	6.44	6.44	6.44	6.44
Soy oil	2	2	2	2	2
Soya bean meal 45%	29.88	29.88	29.88	29.88	29.88
Lime stone	1.16	1.16	1.16	1.16	1.16
M D C P	1.73	1.73	1.73	1.73	1.73
Salt	0.38	0.38	0.38	0.38	0.38
Supplement	0.2	0.2	0.2	0.2	0.2
All-met	0.27	0.27	0.27	0.27	0.27
Threonine	0.12	0.12	0.12	0.12	0.12
Lysine sulphate	0.12	0.12	0.12	0.12	0.12
Choline chloride	0.025	0.025	0.025	0.025	0.025
Crude protein%	20	20	20	20	20
M.E kcal/kg	2900	2900	2900	2900	2900

Table 2 – Effect of different anti-stressors on growth performance (4 weeks) of Japanese quail.

Parameters	Control	Betaine	Vitamin C	Turmeric	Chia seed	*p*-value
FI (g)	446.48±12.33[a]	381.10±3.48[b]	473.94±16.98[a]	435.85±19.91[a]	429.78±11.61[a]	0.0029
TG (g)	155.68±2.05[b]	178.98±3.71[a]	176.88±2.61[a]	156.23±1.77[b]	157.31±4.43[b]	0.0001
TOG	20.15±0.31[b]	22.47±0.40[a]	22.67±0.28[a]	20.11±0.27[b]	20.11±0.43[b]	0.0001
FCR	2.87±0.06[a]	2.13±0.04[b]	2.68±0.11[a]	2.79±0.12[a]	2.74±0.06[a]	0.0001
LIV %	83.20±3.64	88.00±1.69	86.13±3.00	88.80±1.91	85.87±3.00	0.6439

Superscripts on different means within row exhibit significant difference ($p \leq 0.0.5$); FI: feed intake; TG: total gain; TOG: times of gain; FCR: feed conversion ratio; Liv: livability %.

Table 3 – Economics of quail production reared under different anti-stressors.

Parameters	Vitamin C	Betaine	Turmeric	Chia Seeds	Control
Feed consumed (g)	473.94	381.10	435.85	429.78	446.48
Cost of day old chick ($)	0.069	0.069	0.069	0.069	0.069
Total feed cost ($)	0.19	0.15	0.17	0.17	0.17
Miscellaneous cost ($)	0.087	0.087	0.087	0.087	0.087
Anti-stressors cost/ feed intake ($)	0.0027	0.00062	0.00023	0.016	0.000
Total cost/quail ($)	0.34	0.31	0.33	0.34	0.33
Total live weight/quail ($)	1.60	1.62	1.42	1.43	1.42
Sale price/ Kg live weight ($)	2.25	2.25	2.25	2.25	2.25
Total sale price / quail ($)	0.42	0.42	0.37	0.37	0.37
Net Profit/ quail ($)	0.073	0.12	0.043	0.033	0.038
Profit / quail (%)	21.09	38.08	13.27	9.74	11.55

Table 4 – Effect of different anti-stressors on slaughter characteristics of Japanese quail.

Parameters	Control	Betaine	Vitamin C	Turmeric	Chia seed	p-value
LW (g)	170.60±3.39	177.40±6.14	181.80±9.43	178.60±6.83	177.60±4.51	0.8010
DW (g)	97.20±2.82	101.80±2.42	104.20±5.51	101.00±4.36	102.80±3.06	0.7509
Dressing %	56.94±0.75	57.52±1.40	57.32±0.58	56.51±0.53	57.86±0.29	0.7899
SW %	2.59±0.18	2.60±0.13	2.44±0.14	2.46±0.09	2.59±0.11	0.8343
HW %	3.63±0.17	4.05±0.13	4.00±0.20	3.80±0.12	4.18±0.17	0.1733
Liver %	2.35±0.27	2.49±0.16	2.34±0.23	2.36±0.11	2.48±0.23	0.9670
Gizzard %	3.50±0.37	3.24±0.24	3.32±0.24	3.68±0.21	3.71±0.14	0.6066
Heart %	0.71±0.12	1.12±0.17	0.98±0.08	1.01±0.20	0.79±0.14	0.3034
Drumstick %	6.92±0.37[a]	6.55±0.12[ab]	5.96±0.37[b]	5.71±0.22[b]	6.31±0.09[ab]	0.0344
Thigh %	8.44±0.27	8.37±0.23	9.00±0.17	8.73±0.40	8.99±0.30	0.3832

Superscripts on different means within row exhibit significant difference ($p \leq 0.05$); LW: Live weight; DW: Dressed weight; SW: Shank weight; HW: Head weight.

Table 5 – Effect of different anti-stressors on meat quality attributes of Japanese quail.

Parameters	Control	Betaine	Vitamin C	Turmeric	Chia seed	p-value
L*	47.10±1.18	45.31±0.64	46.09±1.12	47.02±1.37	44.34±0.65	0.3095
a*	16.89±0.63	15.90±0.74	17.77±0.48	17.43±0.28	17.11±0.53	0.2046
b*	9.97±0.69	8.55±0.22	9.18±0.55	9.97±0.68	8.53±0.51	0.1973
C	19.64±0.84	17.94±0.77	20.01±0.64	20.00±0.52	19.13±0.66	0.2281
h°	29.33±2.18	26.73±1.14	27.22±0.98	29.82±1.49	26.42±0.95	0.3404
pH-ultimate	5.70±0.08	5.71±0.06	5.66±0.03	5.73±0.03	5.60±0.02	0.3923
Sensory Evaluation						
Color	7.07±0.16	7.37±0.20	6.90±0.28	7.17±0.21	6.83±0.16	0.3755
Flavor	6.30±0.24	6.87±0.16	6.37±0.24	6.77±0.21	6.47±0.19	0.2252
Juiciness	6.53±0.27	7.30±0.20	6.58±0.28	6.83±0.16	6.55±0.23	0.0973
Tenderness	6.43±0.24[b]	7.37±0.22[a]	6.37±0.28[b]	6.87±0.21[ab]	6.48±0.16[b]	0.0100
Oiliness	5.87±0.26[b]	6.67±0.19[a]	5.77±0.23[b]	6.13±0.16[ab]	5.95±0.21[b]	0.0285
Acceptability	6.70±0.23	7.10±0.17	9.00±2.29	6.63±0.25	6.80±0.18	0.4566

Superscripts on different means within row exhibit significant difference ($p \leq 0.05$); L*: Lightness, a*: Redness, b*: Yellowness, c: Chroma, h: Hue angle.

Table 6 – Effect of different anti-stressors on meat antioxidant assay and serum chemistry of Japanese quail.

Treatment	Fat %	TPC mg GAE / ml	TFC mg RE / ml	TAC mg AAE / ml	Cortisol (µg/dl)	Glucose (mg/dl)	Cholesterol (mg/dl)	H: L
Control	1.32	62.25	268.562	82.11	0.12±0.06	200.26±14.72[a]	276.40±41.27[a]	0.61±0.13[a]
Betaine	1.12	63.48	103.735	154.712	0.06±0.01	142.64±11.17[b]	148.20±13.41[b]	0.60±0.11[a]
Vitamin C	1.46	60.11	145.195	138.638	0.04±0.01	195.70±10.81[a]	263.20±34.18[a]	0.51±0.07[a]
Turmeric	1.34	63.33	160.677	116.33	0.05±0.02	196.05±6.68[a]	198.60±29.89[ab]	0.21±0.05[b]
Chia seed	0.93	63.51	157.42	107.52	0.09±0.02	158.68±5.00[b]	200.00±23.09[ab]	0.68±0.06[a]
p-value					0.3449	0.0016	0.0397	0.0133

Superscripts on different mean within column show significant difference ($p \leq 0.05$); TPC: total phenolic content, TFC: total flavonoid content, TAC: total antioxidant capacity, HL: heterophil lymphocyte ratio.

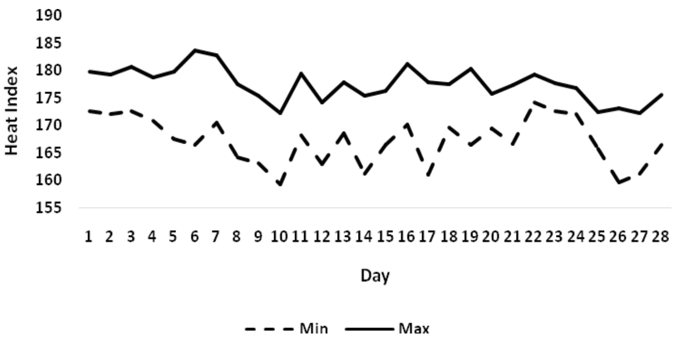

Figure 1 – Daily trend of Heat Index during experimental period

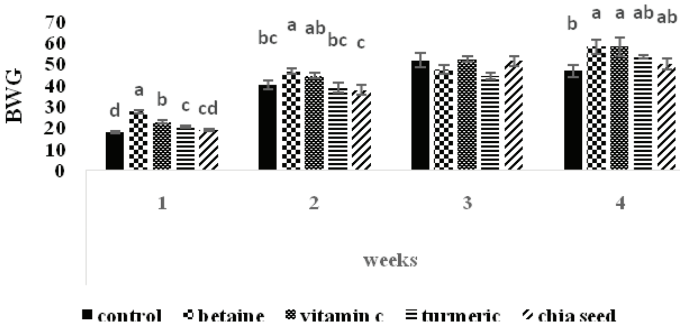

Figure 4 – Trend of weekly body weight gain of Japanese quail reared under different anti-stressors.

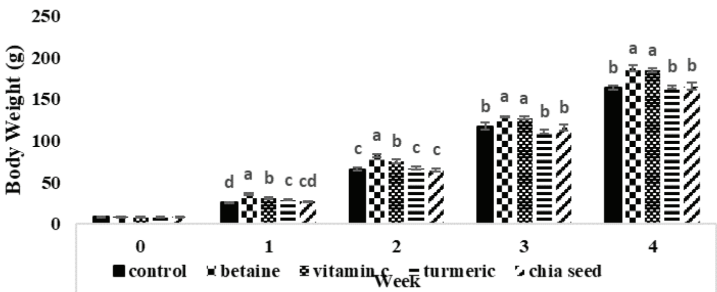

Figure 2 – Trend of weekly body weight of Japanese quail reared under different anti--stressors.

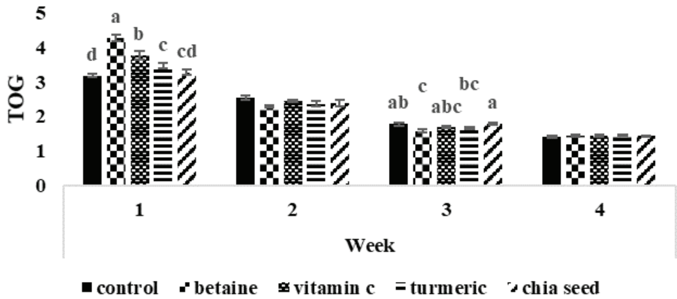

Figure 5 – Trend of weekly times of gain of Japanese quail reared under different anti-stressors.

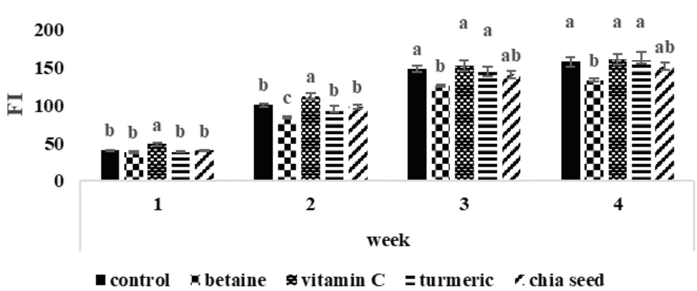

Figure 3 – Trend of weekly feed intake of Japanese quail reared under different anti--stressors.

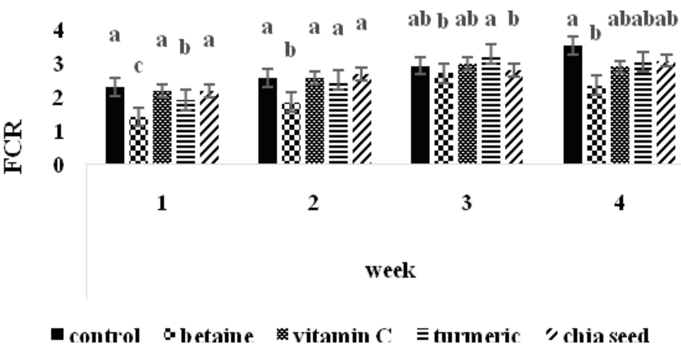

Figure 6 – Trend of weekly feed conversion ratio of Japanese quail reared under different anti-stressors.

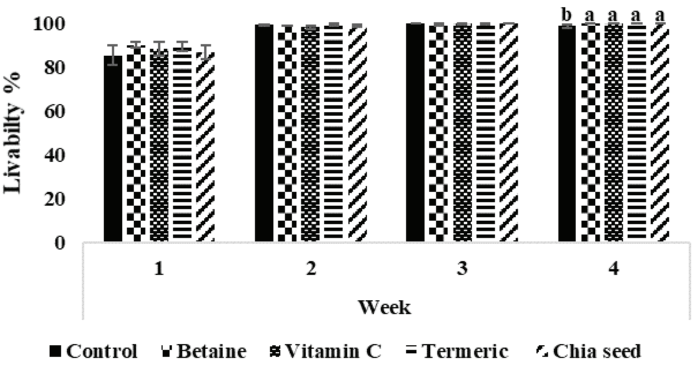

Figure 7 – Trend of weekly livability of Japanese quail eared under different anti--stressors.

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