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EFFECT OF GRADED LEVELS OF DIETARY TOMATO WASTE ON PERFORMANCE AND CARCASS CHARACTERISTICS OF JAPANESE QUAIL REARED UNDER INTENSIVE SYSTEM

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ABSTRACT: This study was carried out to evaluate the effects of partial replacement of soybean meal (SM) with tomato waste (TW) in Japanese quail diets on the resulting yield, internal organs, and carcass characteristics. Eighty unsexed 1-day-old chicks were housed in battery cages with cardboard boxes used as solid floors and randomly assigned to 1 of 4 dietary groups, 46.2% SM, 44.2% SM + 2% TW, 42.2% SM + 4% TW, or 40.2% SM + 6% TW, over a 6 weeks growth period. Yields and carcass characteristics were then determined. Data were analysed using the General Linear Model (GLM) procedures followed by a response procedure for surface regression analysis (Proc RSREG; SAS 9.4) to describe the parameters' responses to graded levels of dietary tomato waste. Repeated measures analysis showed significant week × diet interaction effects on feed intake (FI, P = 0.03), body weight gain (WG, P = 0.0006), feed conversion ratio (FCR, P = 0.002), protein efficient ratio (P = 0.0001), and growth efficiency (P = 0.0001). By supplementing the diets of quails with a 2% inclusion level, a diet significantly affected quails' FI on weeks 1, 2, 3, and 6. A diet containing 2% TW significantly affected live weight (LW), hot carcass weight (HCW), and cold-dressed weight (CDW). It is concluded that the dietary supplementation with 44.2% SM + 2% TW seemed ideal for optimum performance in Japanese quails based on the insignificant change in feed intake and growth efficiency results compared to 46.2% SM for weeks 1 and 2. Further research is needed on the application method that could be used to enhance the utilization of tomato waste in Japanese quails.

Keywords: Carcass characteristics, Dietary replacements, Growth performance, Japanese quails, Tomato waste.

INTRODUCTION

Due to domestic birds' short gestation and generation intervals, high productivity, rapid turnover rate, higher feed efficiency, and cheap land and labour needs, poultry products including meat and eggs have been encouraged for regular intake to fulfill the protein deficit (Olawumi, 2015). In many countries, including Botswana, the Japanese quail (*Coturnix coturnix japonica*) is quickly gaining recognition as a source of meat and eggs. In contrast to other poultry species, the Japanese quail has a sexually dimorphic body structure, with females being larger than males (Sezer et al., 2006). Bonos et al. (2010) reported that female quail have heavier carcasses and bodies than their male counterparts.

As a result of the lack of animal protein caused by the declining supply of meat and eggs in developing nations, rearing Japanese quail as food is seen as another aspect of poultry farming (Illgner and Nel, 2000; Agiang et al., 2011; Dalle Zotte and Cullere, 2024). The Japanese quail produces meat and eggs that are highly prized for their distinctive flavor (Ayaşan, 2013). Furthermore, the Japanese quail serves as a laboratory animal (Ophir et al., 2005), and has unique traits notably quick growth rates which allow the bird to be sold for human consumption at 5-6 weeks of age (Hemid et al., 2010). Compared quails to chickens and found that quails reach sexual maturity earlier leading to a small generation gap, have higher laying rates, and significantly reduced space requirements (Hemid et al., 2010).

The escalating costs of cereals and imported feedstuffs for chicken diets have driven a search for substitute ingredients that will be available as by-products from domestic agricultural producers (Adeniji and Oyeleke, 2008; Okello et al., 2023; Dou et al., 2024). The increased production of soybeans is causing worry because of greenhouse gas emissions and the devastation of wildlife habitats (Siamabele, 2018). Rahman et al. (2016) posited that utilizing alternate feed materials in chicken rations is a crucial aspect of effective poultry production in countries experiencing a food shortage. In many parts of the world, using alternative feed ingredients such as tomato pomace with a high protein value of 17-24% (Lu et al., 2022) for chicken diets is crucial to the poultry industry's success (Yitbarek, 2013). Therefore, the current experiment was conducted to determine the effect of feeding graded levels of tomato waste on the growth, slaughter performance, and carcass characteristics of Japanese quail reared under an intensive system. It was

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hypothesized that replacing soybean meal (SM) with tomato waste in quail diets would not affect growth, slaughter performances, and carcass traits.

MATERIALS AND METHODS

Description of the study area

The study was conducted at BUAN farm in South-East Botswana. The farm is located at coordinates 24°34'54.41" S 25°58'14.64" E (Google Earth Pro, 2022). The farm is about 15 km north of Gaborone and is at an elevation of 978 m (Google Earth Pro, 2022). The vegetation type is Savannah, with tall grasses, bushes, and trees. Precipitation in Gaborone is about 457 mm per year (Climate-Data.Org, 2022). In Gaborone, the average temperature of the coldest month (July) is 13.5 °C, and that of the warmest month (January of 2022) is 26°C.

Source and sample preparation

Tomato waste was procured from the NAFTEC Investments plant in Selebi-Phikwe, located 404 km northeast of Gaborone, the capital of Botswana. Tomato waste was dried for 4 days in February 2023 (Aragaw et al., 2021) by spreading it in the sun. After reducing the particle size of the dried tomato waste by hand, it was run through a grinder (Polymix PX-MFC 90 D model, Kinematica™, Switzerland) and passed through a 1 mm sieve. Thereafter, samples were weighed and stored at room temperature in the Nutrition Laboratory storage room at BUAN before being subjected to chemical analysis and later used in this experiment.

Proximate analyses

Tomato waste was subjected to preliminary analysis using the Association of Official Analytical Chemists (AOAC) International methods before diet formulations. After formulations were performed, subsamples of the experimental diets (TW0, TW2, TW4, and TW6) and tomato waste were analysed using methods from AOAC (2005). For dry matter (DM), method number, 930.15 was used. Ash content was determined by ashing at 550 °C for about 6 hours (AOAC, 2005; method number 924.05), whereas nitrogen was determined using the Kjeldahl method (AOAC, 2005; method number 984.13). The percentage of nitrogen was multiplied by 6.25 to determine crude protein (AOAC, 2005; method number, 920.39). Energy content was determined using a bomb calorimeter and measured in joules. Fat was determined using AOAC, (2005); method number, 920.39. Crude fiber was determined following AOAC, (2005); method number, 978.10. Neutral detergent fiber (NDF), and acid detergent fiber (ADF) were determined by refluxing 0.45 g of samples with neutral detergent and acid detergent solutions respectively, for 1 hour using the ANKOM^{2000} fiber analyser (ANKOM Technology, NY, USA). Acid detergent lignin (ADL) was determined by using the ADF residue that was solubilized by 72 % sulphuric acid, leaving the lignin (ADL), which was determined gravimetrically (AOAC, 2005; method number, 973.18). Table 1 shows results from a proximate analysis of tomato waste.

Table 1 - Proximate analysis (%, unless otherwise stated) of tomato waste used in this experimental trial

Parameter	Value
Dry Matter	95.84
Ash	1.58
Crude protein	20.1
Energy (J)	22
Fat	13
Crude fiber	55
Neutral detergent fiber	56
Acid detergent fiber	60
Acid detergent lignin	25

J= Joule

Diet formulations and composition of experimental diets

The following four isocaloric dietary treatments were formulated using Excel spreadsheet 2010 by partially substituting SM with tomato waste in the diets of Japanese quail: TW0 = Diet with no tomato waste (control); TW2 = Diet with 2% SM replaced with tomato waste; TW4 = Diet with 4% SM replaced with tomato waste; TW6 = Diet with 6% SM replaced with tomato waste. The ration was prepared following the National Research Council (1994). Table 2 presents the ingredients and the calculated composition of the regular diet that was in mash form.

Table 2 - Composition of experimental diets (%, unless otherwise stated) used in the experimental trial

Ingredient [1] / Diets [2]	Starter (%)				Grower (%)			
	TW0	TW2	TW4	TW6	TW0	TW2	TW4	TW6
Maize	42.31	42.31	42.31	42.31	55.79	55.79	55.79	55.79
Sorghum	9.84	9.84	9.84	9.84	9.93	9.93	9.93	9.93
Soybean meal (SM)	46.20	44.20	42.20	40.20	32.70	30.70	28.70	26.70
Tomato waste (TW)	0	2	4	6	0	2	4	6
DCP	0.17	0.17	0.17	0.17	0.02	0.02	0.02	0.02
Premix	0.50	0.50	0.50	0.50	0.47	0.47	0.47	0.47
Salt	0.36	0.36	0.36	0.36	0.36	0.36	0.36	0.36
Limestone	0.10	0.10	0.10	0.10	0.20	0.20	0.20	0.20
Lysine	0.12	0.12	0.12	0.12	0.18	0.18	0.18	0.18
Methionine	0.40	0.40	0.40	0.40	0.35	0.35	0.35	0.35
Calculated nutrient content								
Metabolisable energy (MJ/kg)	12.13	12.12	12.30	13.38	13.38	13.38	13.40	13.40
Crude protein	25.90	25.40	24.90	24.40	21	20.50	20	19.60
Calcium	9.10	9	9	8.90	8.80	8.70	8.70	8.60
Phosphorous	5.40	5.30	5.20	5.10	2.20	2.10	2	1.90
Lysine	13.80	13.80	13.90	13.90	19.60	19.60	19.70	19.70
Methionine	5.20	5.20	5.20	5.20	4.90	4.90	4.90	4.90

[1]Ingredient: TW = Tomato waste; DCP = Dicalcium phosphate; Premix supplying per kg feed: 12,000 IU vitamin A, 5,000 IU vitamin D3, 80 mg vitamin E, 7 mg vitamin K, 5 mg thiamine, 6 mg riboflavin, 6 mg pyridoxine, 0.02 mg vitamin B12, 60 mg niacin, 15 mg pantothenic acid, 1.5 mg folic acid, 0.25 biotin, 10 mg vitamin C, 500 mg choline chloride, 100 mg Zn, 120 mg Mn, 20 mg Fe, 15 mg Cu, 0.2 mg, Co, 1 mg I, 0.3 mg Se. [2]Diets: TW0 = Diet with no tomato waste; TW2 = Diet with 2% of SM replaced with tomato waste; TW4 = Diet with 4% of SM replaced with tomato waste; TW6 = Diet with 6% of SM replaced with tomato waste.

Experimental design

A total of 80-day-old unsexed quail chicks with an initial weight of 7.6 ± 0.152 g were acquired from Makhaya Quail farm in Gaborone. Japanese quails were randomly assigned to 4 dietary treatment groups at 20 chicks per treatment in a completely randomized design. The treatments were replicated 4 times with 5 chicks in each pen (experimental unit). The one-day-old chicks were housed in battery cages with cardboard boxes used as solid floors and were randomly assigned to 1 of 4 dietary groups, 46.2% SM (TW0), 44.2% SM + 2% TW (TW2), 42.2% SM + 4% TW (TW4), or 40.2% SM + 6% TW (TW6), over a 6 weeks growth period. Yields and carcass characteristics were then determined.

Bird management

The poultry house and equipment were cleaned two weeks before the arrival of quail chicks by using clean water and disinfected with Kenosan detergent from Shield Vet Gaborone. Virocid was used to disinfect the ceiling, walls, and floors. To eradicate and sterilize bugs from the base post crevices, formalin and a salt mixture were applied to the floor, wall junctions, and the surrounding region. Throughout the experimental period, the 750 ml water fonts were used and cleaned daily, and 1 kg feed trays were used. Feed was weighed and replaced every day. Quails were kept in battery cages with firm floors made of cardboard boxes. Sunflower husks were utilised as litter to make the dwelling more comfortable as recommended by Amedu et al. (2018). Feed and water were provided *ad libitum*. The illumination schedule was 23 hours per day for the first week, and thereafter 16 hours per day until the end of the experiment (Manyeula et al., 2019). The temperature of 32°C was maintained using electric heaters for the first two days and then decreased by 1°C every other two days until the third week, and thereafter a temperature of 20°C was maintained for the remainder of the feeding period. Mortality was recorded as it occurred throughout the experimental period.

Data collection procedure

Growth performance parameters

Feed was weighed using Adam's electronic scale sensitive to 0.01 g (Adam scale Pty Ltd, Gaborone, Botswana) in the morning (feed offered) and the following day the refusals were re-weighed and FI was then calculated by subtracting feed offered from the refusal (Tamburawa et al., 2018) as shown in formula 1.

$AWFI\ (g/week) = Feed\ offered\ (g) - feed\ refusal\ (g)/7days$...............1

Quail chicks were individually weighed at the beginning of the experimental trial using Adam's electronic scale and subsequently weekly. Weekly weight gain was calculated using formula 2.

$AWWG\ (g/week) = Finish\ weight\ (g) - start\ weight\ (g)/7days$.................2

The feed conversion ratio was calculated by dividing feed consumption by body weight gain (BWG) as shown in formula 3.

$FCR = Feed\ intake\ (g)/weight\ (g)$.....................3

Weekly protein consumed (PC, g/bird) was calculated by multiplying the concentration of crude protein (CPd) in the diet (g/kg DM consumed) by weekly feed intake (FI) g/bird) as illustrated in formula 4.

$PC\ (g/bird) = Feed\ intake\ (g)\ X\ crude\ protein\ of\ the\ diet$..................4

The protein efficiency ratio (PER, g/g) was calculated by dividing mean body weight gain (AWG) by the mean protein consumed (PC) as shown in formula 5.

$PER\ (g/g) = Body\ weight\ gain\ (g)/protein\ consumed$................5

Growth efficiency was calculated by dividing BWG (g) by initial weight (g) as shown in formula 6.

$GE = Body\ weight\ gain\ (g)/initial\ weight\ (g)$.........................6

Slaughter procedure

All the Japanese quails were humanely sacrificed to evaluate the size of internal organs and carcass characteristics following a 6-week feeding trial. The night before slaughter, feed was withdrawn to clear the digestive system. The following morning quails were weighed (pre-slaughter weight) to determine the slaughter weight (SLW). Japanese quails were then transported to the BUAN slaughterhouse where they were electrically stunned and bled for 5 minutes by cutting the jugular vein following a procedure by Mnisi et al. (2021). Quails were then soaked for 2 minutes in the heated water (60 °C) for easy de-feathering as described by Narinc et al. (2014). Quail carcasses were then weighed, and all the internal organs were removed using a sharp knife. The carcasses were then individually weighed as hot carcass weight (HCW) and stored in the chiller at -4 °C for 24 hours. The entire internal organs (liver, gizzards, proventriculus, spleen, abdominal fat, heart, small and large intestines) were then separated and weighed. After 24 hours, the carcasses were weighed again to determine cold carcass weight (CCW), and the external parts (drumstick, thighs, breast muscle, wings, and back) were dissected (Mnisi et al., 2021) and weighed individually to determine their weight. Wings were detached by cutting at the humeroscapular joint, cutting it through the rib head to the shoulder girdle, and pulling the vertebrae out intact (Alikwe et al., 2010).

Determination of carcass yield, cuts, and internal organ weights

Internal and external organs were obtained and expressed as the fraction of HCW as shown in equation 7.

$Internal\ and\ external\ organs\ = \frac{Weight\ (External\ and\ Internal\ organ)(g)}{HCW\ (g)}\ X\ 100$............7

Hot carcass yield was calculated by dividing HCW by pre-slaughter weight following equation 8.

$Hot\ carcass\ yield\ percentage = \frac{Hot\ carcass\ weight\ (g)}{Live\ weight\ (g)}\ X\ 100$.....................8

The dressing out percentage was calculated by dividing HCW by pre-slaughter weight as shown in equation 9.

$Dressing\ out\ (\%) = \frac{Carcass\ weight\ (g)}{Body\ weight(g)}\ X\ 100$...................9

The breast muscle percentage was calculated by dividing breast muscle weight by HCW as shown in equation 10.

$Breast\ muscle\ (\%) = \frac{Breast\ muscle\ (g)}{Hot\ carcass\ weight(g)}\ X\ 100$....................10

The drumstick percentage was calculated by dividing drumstick weight by HCW as shown in equation 11.

$Dumstick\ (\%) = \frac{Drumstick\ (g)}{Hot\ carcass\ weight(g)}\ X\ 100$......................11

Data analyses

The growth performance data were checked for interaction with time; where the interaction existed, data were analysed using repeated measures shown in model 1 and if no interaction existed, data were analysed using the general linear model procedure (GLM) of SAS (2013) version 9.4 for a completely randomized experimental design with pen as the experimental unit shown in model 2.

$Y_{ijk} = \mu + \tau_i + w_j + w\tau_{ij} + e_{ijk}$ ....model 1

Where, Y_{ijk} = ijk[th] response variable; μ = General mean; τ_i = i[th] treatment effect (tomato waste); w_j = j[th] week effect; $(w\tau)_{ij}$ = ij[th] interaction between week and diet effect; e_{ij}= random variation$\sim N(0.\sigma_e^2)$.

$Y_{ij} = \mu + \tau_i + e_{ij}$..........model 2.

Where, Y_{ij} = ij[th] response variable; μ = General mean; τ_i = i[th] treatment effect (tomato waste); e_{ij}= random variation$\sim N(0.\sigma_e^2)$.

The Tukey's Studentized (HSD) Range Test in the SAS (2013) was used to separate the means when the Analysis of Variance indicated the existence of a significant difference between the treatment means. Furthermore, all data were evaluated for linear and quadratic effects using polynomial contrasts. Response procedures for surface regression analysis (Proc RSREG; SAS 9.4, 2013) were applied to describe responses of parameters to graded levels of tomato waste in the diets fed to Japanese quails following the quadratic model: $y = ax^2 + bx + c$, where y = response variables, a and b are the coefficients of the quadratic equation; c is the intercept; x is dietary tomato waste level (%). The significance level was declared at $P < 0.05$.

RESULTS

Growth performance

Repeated measures analyses showed overall significant week × diet interaction effects on FI (P = 0.03), weight gain (P = 0.0006), FCR (P = 0.002), protein efficiency ratio (PER) (P = 0.0001), and growth efficiency (GE) (P = 0.0001) but not on protein consumed (P = 0.10). Diet significantly affected quails' FI at weeks 1, 2, 3, and 6 only (Table 3). In weeks 1, 3, and 6 quails fed on TW0 and TW2 diets had significantly higher FI than those fed diet TW6. Quails fed on TW4 diets had significantly similar FI to those fed on TW0, TW2, and TW6 diets. In week 2, quails fed on TW0 and TW2 diets had significantly higher FI than those fed on TW4 and TW6 diets which were statistically similar. In weeks 4 (P = 0.20) and 5 (P = 0.08), diets did not affect FI. The regression analysis in Table 4 revealed that FI decreased linearly in weeks 1, 4, and 6 as tomato waste inclusion levels increased. In week 2, FI increased linearly with tomato waste. However, decreased quadratic trends in FI were observed in weeks 3 and 5 as tomato waste levels increased in the diets.

The results in Table 3 showed significant dietary effects in weeks 2, 3, and 4 but diets did not significantly affect PER in weeks 1, 5, and 6. In week 2, quails fed on TW0 and TW2 diets had significantly higher PER compared to those fed TW4 and TW6 diets, which were statistically similar. In weeks 3 and 4, quails fed on TW0 diet had significantly higher PER than those fed TW2, TW4, and TW6 diets, which did not differ significantly. Regression analysis revealed that PER linearly decreased in weeks 1 and 6 (Table 4). However, there was a linear increase in week 2 in PER as tomato waste levels increased. Increasing quadratic effects were observed in weeks 3 and 4 with increased dietary tomato waste levels. In week 5, neither linear nor quadratic trends were observed in PER as dietary tomato waste increased.

The results revealed no significant dietary effects in weeks 5 and 6 in growth efficiency (GE) (Table 3). However, significant differences were recorded in weeks 1, 2, 3, and 4. At weeks 1 and 2, quails fed on TW0 and TW2 diets had significantly higher GE followed by those fed TW4 diet and lastly, those fed on TW6 diet. In weeks 3 and 4, quails fed on TW0 diet had higher GE followed by those on TW2 and TW4 diets which were statistically similar and lastly, those fed on TW6 diet. Regression analysis results in Table 4 revealed that PER linearly decreased in week 1 and linearly increased in week 5 with increased dietary levels of tomato waste. However, a negative trend was observed on GE in response to increases in dietary levels of tomato waste at 2, 3, 4, and 6 weeks of age.

Table 3 - Weekly feed intake, protein efficiency ratio, and growth efficiency of Japanese quails fed graded levels of tomato waste as partial replacement of soybean meal

	Diets [1]						Significance [3]	
Parameter	TW0	TW2	TW4	TW6	SEM [2]	P value	Linear	Quadratic
Feed intake (g/quail)								
Week 1	6.56[a]	6.54[a]	5.96[ab]	5.87[b]	0.149	0.0091	*	NS
Week 2	8.78[a]	8.67[a]	7.29[b]	7.19[b]	0.140	< 0.0001	*	NS
Week 3	12.80[a]	12.76[a]	12.27[ab]	12.25[b]	0.090	< 0.0001	*	*
Week 4	17.69	17.51	17.16	16.95	0.250	0.1978	*	NS
Week 5	28.08	27.96	27.56	27.03	0.280	0.0847	*	*
Week 6	33.51[a]	33.13[a]	32.78[ab]	31.95[b]	0.220	0.0018	*	NS
Protein efficiency ratio								
Week 1	0.99	0.92	0.90	0.91	0.020	0.0831	*	NS
Week 2	2.61[a]	2.58[a]	2.26[b]	2.24[b]	0.050	0.0001	*	NS
Week 3	2.76[a]	2.45[b]	2.43[b]	2.38[b]	0.030	< 0.0001	*	*
Week 4	1.51[a]	1.28[b]	1.2 9[b]	1.28[b]	0.020	< 0.0001	*	*
Week 5	0.81	0.79	0.78	0.80	0.010	0.4425	NS	NS
Week 6	0.67	0.65	0.63	0.63	0.010	0.0579	*	NS
Growth efficiency								
Week 1	1.33[a]	1.32[a]	1.14[b]	1.10[c]	0.005	< 0.0001	*	NS
Week 2	1.87[a]	1.86[a]	1.80[b]	1.74[c]	0.010	< 0.0001	*	*
Week 3	1.00[a]	0.81[b]	0.80[b]	0.78[c]	0.005	< 0.0001	NS	*
Week 4	0.77[a]	0.47[b]	0.46[b]	0.44[c]	0.010	< 0.0001	NS	*
Week 5	0.32	0.32	0.32	0.27	0.020	0.1034	*	NS
Week 6	0.24	0.24	0.24	0.23	0.010	0.0008	*	*

[a,b,c]In row, means with common superscripts do not differ significantly. [1]Diets: TW0 = Diet with no tomato waste; TW2 = Diet with 2% of soybean meal replaced with tomato waste; TW4 = Diet with 4% of soybean meal replaced with tomato waste; TW6 = Diet with 6% of soybean meal replaced with tomato waste. [2]SEM =standard error of mean; [3]Significance: * = Significant difference (P <0.05); NS = Not significant.

Table 4 - The linear and quadratic trends on weekly feed intake (g/bird), weekly protein efficiency ratio, and weekly growth efficiency of Japanese quails fed graded levels of tomato waste as partial replacement of soybean meal

Parameter	Equation	P value	R^2
Feed intake (g/quail)			
Week 1	Y = 6.5 (± 0.7) – 0.8 (± 0.6) X	0.0001	0.69
Week 2	Y = 8.8 (± 1.2) + 0.6 (± 1.0) X	0.0002	0.70
Week 3	Y = 12.5 (± 0.7) + 0.5 (± 0.571.1) X- 0.2 (±0.09) X^2	0.0300	0.70
Week 4	Y = 17.7 (± 0.5) – 1.0 (± 0.4) X	< 0.0001	0.82
Week 5	Y = 28.0 (± 0.4) – 0.1 (± 0.3) X - 0.2 (±0.1) X^2	0.0020	0.92
Week 6	Y = 33.5 (± 1.2) – 1.4 (± 1.0) X	0.0030	0.50
Protein efficiency ratio			
Week 1	Y = 0.99 (± 0.02) – 0.05 (± 0.02) X	0.0300	0.41
Week 2	Y = 2.2 (± 0.1) + 0.05 (± 0.05) X	0.0020	0.67
Week 3	Y = 2.7 (± 0.04) – 0.2 (± 0.03) X+ 0.02 (±0.005) X^2	< 0.0001	0.80
Week 4	Y = 1.5 (± 0.02) – 0.1 (± 0.02) X+ 0.01 (±0.003) X^2	0.0010	0.81
Week 6	Y = 0.7 (±0.01) – 0.02 (±0.01) X	0.0100	0.45
Growth efficiency			
Week 1	Y = 1.3 (± 0.03) – 0.06 (± 0.02) X	< 0.0001	0.76
Week 2	Y = 1.7 (± 0.01) + 0.05 (± 0.01) X- 0.05 (±0.002) X^2	0.0100	0.85
Week 3	Y = 0.81 (± 0.04) + 0.08 (± 0.03) X - 0.02 (±0.005) X^2	0.0100	0.50
Week 4	Y = 0.5 (± 0.1) + 0.1 (±0.04) X - 0.02 (±0.01) X^2	0.0100	0.50
Week 5	Y = 0.3 (± 0.02) + 0.03 (±0.01) X	0.0500	0.36
Week 6	Y = 0.2 (± 0.01) + 0.03 (±0.01) X - 0.01 (±0.001) X^2	0.0002	0.73

The results showed that diet affected average weight gain at weeks 1, 2, 4, and 6 only but did not affect the weight gain of quails at weeks 3 and 5 (Figure 1). At week 1, quails fed on TW0 diet had significantly higher WG than those fed on TW2, TW4, and TW6 diets. In week 2, quails fed on TW0 and TW2 diets had significantly higher WG than those fed on TW4 and TW6 diets. Significantly higher WG was recorded in week 4 in quails fed on TW0 and TW2 diets than those fed on TW6 diet. However, quails on TW4 diet had statistically similar WG to those fed on TW0, TW2, and TW6 diets. In week 6, quails fed on TW0 diet had significantly higher WG compared to those fed on TW2 diet followed by TW4 and lastly TW6. At 3 and 5 weeks of age, diet did not significantly affect WG of quails.

The results showed that there were significant dietary effects in week 2 only (Figure 2). However, there were no dietary effects in FCR at weeks 1, 3, 4, 5, and 6. In week 2, quails fed on TW0 and TW2 diets had significantly lower FCR compared to those fed on TW4 and TW6 diets which were statistically similar. The regression analysis results revealed that FCR decreased linearly from week 1 to 2 and then increased linearly from week 2 to 6.

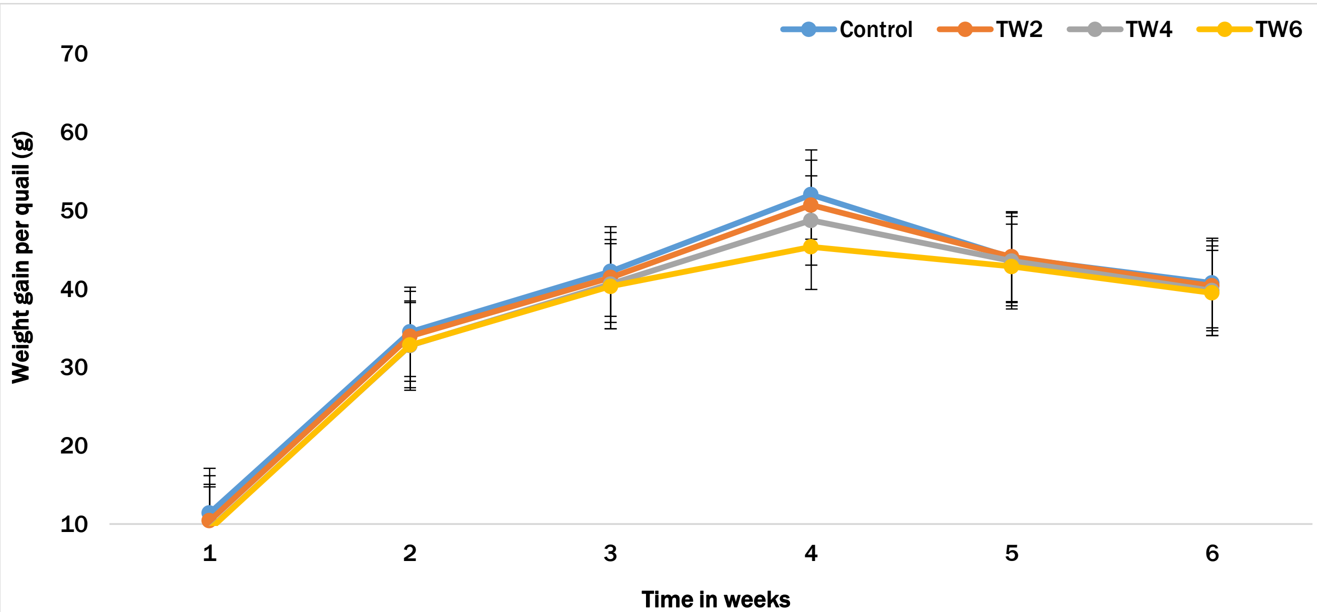

Figure 1 - Weekly weight gain of Japanese quails fed graded levels of tomato waste as a partial replacement for soybean meal.

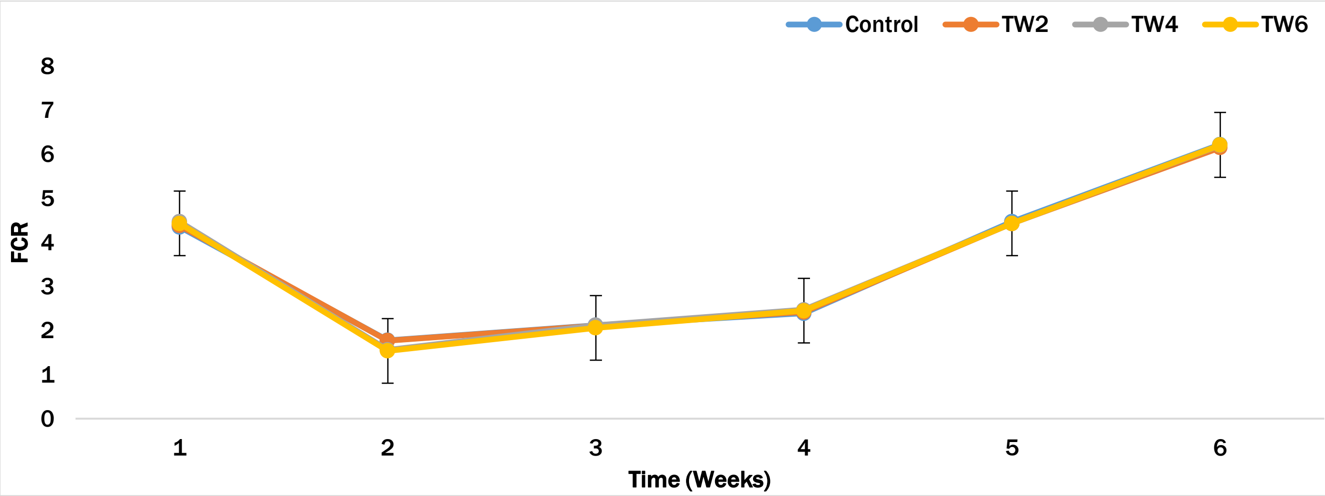

Figure 2 - Weekly FCR of Japanese quails fed graded levels of tomato waste as partial replacement of SM.

Carcass characteristics

Diets affected (SLW), (HCW), and (CDW) but did not affect (CL) and dressed weight percentage (Table 5). Quails fed on the TW0 diet had significantly higher SLW followed by those fed on the TW2 diet, and lastly, those fed on the TW4 and TW6 diets, which were statistically similar. Similarly, quails fed on the TW0 diet had significantly higher HCW and CDW than those fed on the TW2, TW4, and TW6 diets. However, quails fed on the TW4 diet had significantly similar HCW and CDW compared to those fed on the TW2 and TW6 diets. Regression analysis showed positive trends in SLW of Japanese quails with tomato waste inclusion levels (Table 6). Linear decreases were recorded in SLW, HCW, and CDW with increased tomato waste inclusion levels. No significant linear and quadratic trends for dressed percentage were detected.

Table 5 - Effects of feeding graded levels of tomato waste (g, unless otherwise stated) as partial replacement of soybean meal on carcass characteristics of six weeks old Japanese quails

Parameter [1]	Diets [2]						Significance [4]	
	TW0	TW2	TW4	TW6	SEM [3]	P value	Linear	Quadratic
SLW	220.89[a]	207.13[b]	200.36[c]	195.07[c]	1.49	< 0.0001	*	*
HCW	165.60[a]	156.44[b]	151.55[bc]	147.06[c]	1.25	< 0.0001	*	NS
CDW	165.45[a]	156.31[b]	151.43[bc]	146.95[c]	1.24	< 0.0001	*	NS
CL	0.15	0.13	0.12	0.11	0.02	0.50	NS	NS
Dressed (%)	75.00	75.5	75.67	75.17	0.31	0.43	NS	NS

[1]Parameter: SW= Slaughter weight; HCW = Hot carcass weight; CDW = Cold dressed weight; CL = Chilling loss. [2]Diets: TW0 = Diet with no tomato waste; TW2 = Diet with 2% of soybean meal replaced with tomato waste; TW4 = Diet with 4% of soybean meal replaced with tomato waste; TW6 = Diet with 6% of soybean meal replaced with tomato waste. [3]SEM= Standard error of the mean. [4]Significance: NS = Not significant; * = Significant; [abc]Within a row, different superscripts denote significant differences ($P < 0.05$) between treatments.

Table 6 - Linear and quadratic trends of carcass characteristics of Japanese quails fed graded levels of tomato waste as partial replacement of soybean meal

Parameter	Equation	P value	R^2
SLW	$Y = 220.5 (\pm 1.6) - 7.3(\pm 1.3) X + 0.5 (\pm 0.2) X^2$	0.02	0.87
HCW	$Y = 165.2 (\pm 1.4) - 4.7(\pm 1.1) X$	< 0.0001	0.83
CDW	$Y = 164.9 (\pm 1.4) -4.7(\pm 1.1) X$	< 0.0001	0.83

[1] Parameter: LW= Live weight (g); HCW = Hot carcass weight (g); CDW = Cold dressed weight (g); CL = Chilling loss (g).

Diet significantly affected the quail back only but did not affect the drumstick, wings, thighs, and breast (Table 7). Quails fed on the TW0 diet had significantly heavier backs than those fed on the TW4 and TW6 diets. Quails fed on diet TW2 had significantly similar back weights to those fed on TW0 and TW4 diets. Quails fed on the TW4 diet had a lighter back but were statistically similar to quails fed on diets TW2 and TW6. The regression analysis revealed linear decreases for the drumstick [$y = 12.9 (\pm 0.4) - 0.1(\pm 0.3) X$; $R^2 = 0.29$; $P = 0.01$] as dietary levels of tomato waste increased. Neither linear nor quadratic effects were observed on wings, thighs, back, and breast.

Diet significantly affected the liver and heart weights only but did not affect the weights of gizzards, proventriculus, spleen, and fat (Table 8). Quails fed on TW0 diet had significantly heavier liver followed by those fed on TW2 diet and lastly Quails fed on TW4 and TW6 diets had statistically similar liver and hear weights. Quails fed on TW0 diet had heavier hearts than those fed TW4 and TW6 diets. However, quails fed on TW2 diet had significantly similar heart weights with those fed on TW0, TW4, and TW6 diets. The regression results showed that there were linear decreases for liver with incremental levels of tomato waste [y = 1.6 (± 0.1) – 0.05 (± 0.3) X; R^2 = 0.31; P = 0.03]. However, proventriculus increased linearly [y = 0.3 (± 0.02) + 0.02 (± 0.02) X; R^2 = 0.22; P = 0.04] with tomato waste incremental levels. No significant linear and quadratic trends were observed on gizzards, spleen, fat and heart.

Diet significantly affected the weight of the small intestines but did not affect the length of the small intestines, and length and weight of the large intestines (Table 9). Quails fed on the TW0 (4.55 %) diet had heavier small intestines than those fed on the TW4 and TW6 diets. However, the quails fed on TW2 diet had significantly similar small intestines weights with those on TW0, TW4, and TW6 diets. The regression analysis results showed a quadratic decrease on small intestines weight with tomato waste levels [y = 3.2 (± 0.2) - 0.3 (± 0.1) X + 0.1 (± 0.02) X^2; R^2 = 0.28; P = 0.01]. No significant linear and quadratic trends were observed on small and, large intestines length, and large intestines weights.

Table 7 - Effects of feeding graded levels of tomato waste (%HCW), as partial replacement of soybean meal on external organs of six weeks old Japanese quails

	Diets [2]						Significance [4]	
Parameter [1]	TW0	TW2	TW4	TW6	SEM [3]	P value	Linear	Quadratic
Drumstick	11.06	11.65	11.19	10.78	0.29	0.23	NS	NS
Wings	8.07	8.06	8.06	8.07	0.01	0.72	NS	NS
Thighs	21.00	20.52	20.28	20.15	0.53	0.68	NS	NS
Back	18.65[a]	18.12[ab]	17.15[bc]	17.25[c]	0.31	0.01	*	NS
Breast	37.97	37.30	36.97	36.48	0.67	0.29	NS	NS

[1]Diets: TW0 = Diet with no tomato waste; TW2 = Diet with 2% of soybean meal replaced with tomato waste; TW4 = Diet with 4% of soybean meal replaced with tomato waste; TW6 = Diet with 6% of soybean meal replaced with tomato waste. [2]SEM= Standard error of the mean. [3]Significance: NS = Not significant; * = Significant; [abc] Within a row, different superscripts denote significant differences (P < 0.05) between treatments.

Table 8 - Effects of feeding graded levels of tomato waste (%HCW), as partial replacement of soybean meal on internal organs of six weeks old Japanese quails

	Diets [2]						Significance [4]	
Parameter [1]	TW0	TW2	TW4	TW6	SEM [3]	P value	Linear	Quadratic
Liver	3.62[a]	3.39[b]	3.19[c]	3.12[c]	0.04	< 0.0001	*	NS
Gizzards	2.03	2.08	2.05	2.04	0.02	0.13	NS	NS
Proventriculus	0.40	0.40	0.43	0.39	0.02	0.34	NS	NS
Spleen	0.18	0.08	0.08	0.08	0.05	0.47	NS	NS
Abdominal fat	0.07	0.19	0.08	0.08	0.06	0.42	NS	NS
Heart	0.83[a]	0.80[ab]	0.75[b]	0.76[b]	0.01	0.01	*	NS

[1]Diets: TW0 = Diet with no tomato waste; TW2 = Diet with 2% of soybean meal replaced with tomato waste; TW4 = Diet with 4% of soybean meal replaced with tomato waste; TW6 = Diet with 6% of soybean meal replaced with tomato waste. [2]SEM= Standard error of the mean. [3]Significance: NS = Not significant; * = Significant; [abc] Within a row, different superscripts denote significant differences (P < 0.05) between treatments.

Table 9 - Effects of feeding graded levels of tomato waste (%, unless otherwise stated) as partial replacement of soybean meal on intestines of six weeks old Japanese quails

	Diets [2]						Significance [4]	
Parameter [1]	TW0	TW2	TW4	TW6	SEM [3]	P value	Linear	Quadratic
Small intestines (cm)	60.00	60.00	60.00	59.17	0.92	0.89	NS	NS
Small intestines (%)	4.55[a]	4.39[ab]	3.88[b]	3.85[b]	0.18	0.03	NS	*
Large intestines (cm)	12.58	12.22	11.88	11.58	0.40	0.36	NS	NS
Large intestines (%)	0.77	0.77	0.75	0.75	0.05	0.94	NS	NS

[1]Diets: TW0 = Diet with no tomato waste; TW2 = Diet with 2% of soybean meal replaced with tomato waste; TW4 = Diet with 4% of soybean meal replaced with tomato waste; TW6 = Diet with 6% of soybean meal replaced with tomato waste. [2]SEM= Standard error of the mean. [3]Significance: NS = Not significant; * = Significant; [a,b,c] Within a row, different superscripts denote significant differences (P < 0.05) between treatments.

DISCUSSION

Growth performance

Repeated measures analysis showed significant week x diet interaction effects on weekly FI, WG, FCR, PER, and GE, demonstrating that tomato waste inclusion influenced quail growth performance over time. The significantly lower FI in quails fed TW6 diets in weeks 1, 3, and 6 suggest that the higher inclusion levels reduced FI. Common organoleptic characteristics associated with tannin compounds are astringency and bitterness which reduce voluntary FI (Choi and Kim, 2020) which could be linked with FI reductions. Similarly, Tabeidian et al. (2011) reported that growth performance was lowered even at modest inclusion levels of tomato waste at 3% in the starter and 9% in the finisher phase of broiler chicks. In contrast, Shehata et al. (2018) and Muhammad et al. (2023) reported increased feed consumption when tomato pomace-containing diets were fed to laying Japanese quails at 2.5 and 5% inclusion levels. This discrepancy could be due to the different species (broilers *vs.* Japanese quails) used. It is noted that different poultry species act differently when exposed to the same diet (Mnisi and Mlambo, 2018). Quails fed on the TW0 diet had similar feed intake to TW4, TW2, and TW6 suggesting that tomato waste at 6% inclusion did not affect the voluntary FI of quails, suggesting that the diet (tomato waste) can be used up to 6% inclusion level. This is in line with the findings of Mohammed et al. (2021) who reported that supplementing tomato pomace at 6% did not affect FI of broiler chicks. Contrary to our expectations, in week 2, quails fed on TW0 and TW2 diets had significantly higher FI than those fed on other diets, suggesting that tomato waste can be used at 2% inclusion without affecting the palatability of the diets. Lower FI of quails fed TW4 and TW6 diets could be due to tannins that exert a bitter taste resulting in decreased feed consumption (Hassan et al., 2020). The physicochemical characteristics of the entire diet are greatly affected by a little alteration in an ingredient during diet formation.

In weeks 4 and 5, diet did not affect FI suggesting that tomato waste inclusion rates up to 6% can produce similar results as the control diet. This could be linked with the maturity of the GIT of Japanese quails which efficiently handled the fiber contents of the diets. These results agree with Gungor et al. (2024) who reported that the supplementation of dried tomato pomace to broiler diets up to 10% had no significant effect on FI. Similarly, Jouzi et al. (2015) found no significant difference between the diet groups supplemented with 5% dried tomato pomace and the control group of Japanese quails.

Quails fed on TW0 and TW2 diets gained more weight in weeks 1, 2, 4, and 6, indicating that they were able to use the nutrients in the diets implying that the ANFS such as tannins, pectins, and insoluble fiber were negligible. These ANFs temper with feed utilization (Szabo et al., 2019). The bioactive components found in tomato waste include lycopene and ß-carotene, which have substantial antioxidant capacity (Szabo et al., 2019). Lycopene is a powerful antioxidant that can protect muscle cells from the damaging effects of reactive oxygen species and biomolecule destruction (Mezbani et al., 2019). Our results agree with Sahin et al. (2008) who reported that a 5% inclusion level of tomato waste in broiler diets improved the body weight of broiler chickens.

At weeks 3 and 5 diet did not significantly affect the weight gain of quails, suggesting that tomato waste could be incorporated into the diet without affecting Japanese quails' feed utilization. This was due to statistically similar FI, nutrient intake, and feed utilisation. In line with our results, Nikolakakis et al. (2004) reported no significant differences in body weight and BWG on growing quails fed on diets containing tomato pulp at 5 and 10% levels. Contrary to this finding, Alagawany et al. (2021) noted a significant improvement in body weight and BWG when quails were fed on 6% sundried tomato pomace at 3 to 5 weeks of age compared to those fed on the control diet. The current result implies that sun-dried tomato waste can replace SM by 6% in the quail diet without detrimentally affecting weight gain.

There were no significant dietary effects on FCR at weeks 1, 3, 4, 5, and 6 implying that tomato waste can be used in quail diets as partial replacement of SM. In agreement with our results, Jouzi et al. (2015) obtained no significant effect on FCR in growing Japanese quails fed on tomato powder at 2, 4, 6, and 8% inclusion levels. Similar to the weight gain, at week 2, quails fed on TW0 and TW2 diets in this study had comparable FCR suggesting that the quails utilized the feed regardless of the fiber content in the diet. The quails fed on TW4 and TW6 had improved FCR probably due to the high fiber content that is responsible for the improvements in villus height and overall epithelial cell arrangement which increases nutrient absorption and hence better FCR. In addition, high fiber content increases the retention time of the digesta along the GIT, causing optimum digestion and absorption of nutrients for anabolic purposes.

Fiber is known to be involved in the modification of the intestinal length, villus height, crypt depth, as well as, the passage rate and size through different segments of the intestines (Rezaei et al., 2018; Tejeda and Kim, 2021). However, as fiber increased the FCR began to increase from weeks 2 to 6 due to the presence of tannin and pectins that cause a reduction in nutrient absorption due to the formation of insoluble complexes with proteins leading to poorer FCR observed. It is known that monogastric animals do not produce the cellulolytic enzymes required to break down the fiber but utilise the microbial enzymes in their caeca, though less efficient in degrading fiber (Jha and Mishra, 2021). Additionally, fiber has been considered a diluent of the diet and is known to increase the passage rate of the gastrointestinal tract owing to the reduction of nutritional utilization (Mateos et al., 2012). Hosseini-Vashan et al. (2016)

found that supplementing 5% tomato pomace increased broiler FCR during heat stress. In contrast with the present results, Lira et al. (2010) reported that using more than 20% tomato pomace in the diet of broiler chickens from 1 to 28 days may decrease FCR. The current results indicated that tomato waste inclusions possibly interfered with the use of nutrients in the rations at higher inclusion levels of tomato waste. The current results suggest that the inclusion of tomato waste at 4 and 6% compromised FCR.

The comparison between the average body weight and the amount of protein in the diet is known as the protein efficiency ratio (PER) which is influenced by the productivity of the animals (Ratriyanto et al., 2017). The rise in PER values in the present study indicates that the birds were able to use the protein they consume more effectively. In this study, quails fed on TW0 and TW2 diets in week 2 had similar PER suggesting that tomato waste can be used at the inclusion of 2% without affecting the PER. There is very limited literature on the PER of poultry-fed tomato waste. There was a significant reduction in PER at weeks 3 and 4 in quails fed tomato-based diet, suggesting that the inclusion of tomato waste in diets above 2% hindered protein utilization. This implies that as the tomato waste increases, the tannins and pectins that bind protein increase resulting in protein utilisation being hindered. Also, the feed was slowly digested since the quails do not produce the cellulolytic enzymes required to quickly break down fiber. This implies that the inclusion of tomato waste as a partial replacement of SM compromised PER. No significant dietary effects were noted at 1, 5, and 6 weeks of age across diets, suggesting that protein utilization was similar to the control diet. This implies that tomato waste can be incorporated in the quail diets at 2% without compromising the PER.

Quails fed on TW0 and TW2 diets at 1 and 2 weeks of age had significantly higher GE compared to those fed TW4 and TW6 diets, indicating that tomato waste reduced the GE when included in the quail's diets at higher levels. This reduction in GE could be due to the presence of pectins, tannins and fiber which increase with increasing tomato waste inclusion levels. According to Brenes et al. (2016) and Mnisi et al. (2022), anti-nutrients inhibit protein utilisation and nutrient digestibility owing to depressed growth. Furthermore, it is speculated that the capacity of the gut is very limiting in young quails; hence their inability to produce enough fibrinolytic enzymes that help in the digestion of fiber. Our results are in line with Cavalcante et al. (2007) who reported the negative effect of tomato waste in the early stages of quail life due to great sensitivity of young chicks to ingestion of diets with high fiber content. Fiber is a naturally occurring plant component associated with physiological, structural, and functional changes in the GIT (Deehan et al., 2022). At weeks 3 and 4, quails fed on tomato-based diets had reduced GE suggesting that tomato waste impaired growth when included at higher levels i.e. above 2% inclusion level. Increasing the inclusion level of tomato waste in the diet led to an increase in tannin contents, which interfered with protein utilization, thus suppressing growth. Therefore, the inclusion of tomato waste as a partial replacement for SM compromised GE. In agreement with our results, Tabeidian et al. (2011) found that growth performance in broilers was lowered even at a modest inclusion rate of 3% in the starter phase and 9% in the finisher phase.

Carcass characteristics

Among the variables that are known to affect carcass features in birds include age, sex, diet, genetics, and conditions of slaughter (Young et al., 2001). In this study, the results showed that diet had an impact on HCW, CDW, and SLW, and TW6 diets showed notably greater HCW and CDW in Japanese quails. This was due to reduced FI in tomato-based diets. In this study, the inclusion of tomato waste in diets linearly decreased carcass yield, HCW, CDW, CL, and weight of drumsticks, thigh, wing, and breast. This observation may be related to the lower FI observed in quails fed on diet containing tomato waste, which led to inadequate nutrient uptake for muscle growth and ineffective weight gains. This suggests that feeding tomato waste to quail could have a negative impact on the viability and profitability of quail businesses at high inclusion levels. These results agree with Jouzi et al. (2015) and Lira et al. (2010) who reported a linear decrease in carcass yield, wings, breast, and drumstick when quails were fed on diets containing 8% of tomato waste. In contrast to our results, Yitbarek (2013) reported that broilers fed a diet containing 5% tomato pomace had a higher carcass yield than other treatments. However, broiler chicks fed a diet containing 15% dried tomato pomace showed a lack of significant difference on carcass characteristics suggesting that tomato pomace can be used at 15% without detrimental effect on carcass characteristics.

The gastrointestinal morphology of poultry is related to variations in dietary fiber content as an adaptation mechanism to make use of the high levels of fiber (Jha et al., 2019). The lower liver weights on tomato-based diets in the present study could have been triggered by a negligible concentration of secondary plant compounds such as pectins and tannins in tomato waste, which require detoxification by the liver when available in the diets. This lower liver weight is linked with less ANFs in the diet. A previous study of Leke et al. (2018) showed that the heart and gizzard weights were not significantly affected by dietary tomato waste at 0, 3, 6, 9, and 12% inclusion levels. In contrast with our results, Mateos et al. (2012) observed that birds fed fibrous diets had enlarged gastrointestinal organs. Nevertheless, despite the presence of crude fiber in the tomato waste-containing diets in this study, examination of the visceral organs (fat, spleen, proventriculus, and gizzards) revealed no significant effects. It is likely that dietary tomato waste levels as high as 6% were not enough to cause physio-anatomical changes in the fat, spleen, proventriculus, or gizzards.

Mateos et al. (2012) found that the gastrointestinal organs of birds fed fibrous diets were larger. Moreover, Nikolakakis et al. (2004) found that the amount of dietary tomato pulp supplementation had no significant impact on the weight and length of the quail intestines. Despite the higher crude fiber content of the diets, the control group's small intestines were heavier than those of the tomato waste-containing diet implying that tomato waste diets did not promote the growth of the intestines. The current findings suggest that the inclusion of tomato waste as a partial replacement of SM compromised the weights of the small intestines.

CONCLUSION AND RECOMMENDATIONS

The inclusion level of tomato waste up to 6% as a partial replacement for soybean meal compromised the growth performance of Japanese quails. Higher tomato waste inclusion levels negatively affected slaughter liveweight, cold dressed weight, hot carcass weight, back weight, small intestines weight, liver weight, and heart weight of Japanese quails. The present results showed that higher inclusion levels of tomato waste compromised the performance of Japanese quails. The 2% inclusion level was more efficient compared to other inclusion levels. Therefore, it is recommended that where higher dietary levels of tomato waste are desired, fiber-degrading strategies including enzymes such as pectinases be used in Japanese quail diets. Further investigations on the amino acid profile of tomato waste need to be carried out.

DECLARATIONS

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Authors' contribution

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Ethical approval

This study was conducted in line with the Ethics Committee Guidelines provided by the Faculty of Animal and Veterinary Sciences at the Botswana University of Agriculture and Natural Resources (BUAN). BUAN Ethics Committee approval number: BUAN-ACUC-2023-03.

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Consent to publish

All authors agreed to the publication of this manuscript.

Data availability

The datasets used and/or analysed during the current study are available from the corresponding author upon reasonable request.

Competing interests

The authors declared no competing interests.

REFERENCES

Adeniji AA and Oyeleke MM (2008). Effects of dietary grit inclusion on the utilisation of rumen content by pullet chicks. Journal of Applied Science Research, 4(10): 1257-1260. https://www.aensiweb.com/old/jasr/jasr/2008/1257-1260.pdf

Agiang EA, Oko OOK and Essien GE (2011). Quails response to aqueous extract of bush marigold (*Aspilia Africana*) Leaf. American Journal of Animal and Veterinary Sciences, 6(4): 130-134. https://doi.org/10.3844/ajavsp.2011.130.134

Alagawany M, Madkour M, El-Saadony MT and Reda FM (2021). *Paenibacillus polymyxa* (LM31) as a new feed additive: Antioxidant and antimicrobial activity and its effects on growth, blood biochemistry, and intestinal bacterial populations of growing Japanese quail. Animal Feed Science and Technology, 276: 114920. https://doi.org/10.1016/j.anifeedsci.2021.114920

Alikwe PCN, Faremi AYA and Egwaikhide PA (2010). Biochemical evaluation of serum metabolites, enzymes and haematological indices of broiler chicks fed with varying levels of rumen epithelial scraps in place of fish meal protein. Pakistan Journal of Scientific and Industrial Research, 3(2): 27-31. Google Scholar

Amedu E, Tuleun CD, Yisa AG, Okpala EJ, Dabi DP and Muduudtai UR (2018). Performance of growing Japanese quails (*Coturnix Coturnix Japonica*) fed different levels of peeled cooked sun-dried sweet potato (*Ipomea Batatas*) meal diets. African Journal of Food, Agriculture, Nutrition and Development, 18: 13588-13601. https://doi.org/10.18697/ajfand.83.15760

AOAC (2005). Official Methods of Analysis of the Association of Official's Analytical Chemists, 18th ed.; Association of Official Analytical Chemists: Arlington, VA, USA. method number, 920.39, 924.05, and 984.13. https://www.cabidigitallibrary.org/doi/full/10.5555/19951414840

Aragaw S, Urge M, Zeryehun T and Lemma F (2021). Effect of dried tomato waste meal on growth performance and carcass characteristics of Cobb 500 broiler chicks. Livestock Research for Rural Development, 33(5): 65. http://www.lrrd.org/lrrd33/5/3365fethu.html

Ayaşan T (2013). Effects of dietary inclusion of protexin (probiotic) on hatchability of Japanese quails. Indian Journal of Animal Science, 83(1): 78-81. https://epubs.icar.org.in/index.php/IJAnS/article/download/26451/12103/58179

Bonos EM, Christaki EV and Florou-Paneri PC (2010). Performance and carcass characteristics of Japanese quail as affected by sex or mannan oligosaccharides and calcium propionate. South African Journal of Animal Science, 40(3): 173-184. https://doi.org/10.4314/sajas.v40i3.2

Brenes A, Viveros A, Chamorro S and Arija I (2016). Use of polyphenol rich grape by-products in monogastric nutrition. A review. Animal Feed Science and Technology, 211: 1-17. https://doi.org/10.1016/j.anifeedsci.2015.09.016

Cavalcante SB, Fuentes MFF, Freitas ER, Espindola G and Brag C (2007). Effect of including coconut bran in diets for chickens cut. Revista Ciência Agronômica, 38(3): 297-303. Article link

Choi J and Kim WK (2020). Dietary application of tannins as a potential mitigation strategy for current challenges in poultry production: A Review. Animals (Basel), 10(12): 2389. https://doi.org/10.3390/ani10122389

Climate-Data.org (2022). Climate data for cities worldwide. http://en.climate-data.org

Dalle Zotte A, and Cullere M (2024). Rabbit and quail: Little known but valuable meat sources. Czech Journal of Animal Science, 69(2):39-47. https://www.agriculturejournals.cz/pdfs/cjs/2024/02/02.pdf

Deehan EC, Zhang Z, Riva A, Amert AM, Perez-Muñoz ME, Nguyen NK, et al. (2022). Elucidating the role of the gut microbiota in the physiological effects of dietary fiber. Microbiome, 10: 77. https://doi.org/10.1186/s40168-022-01248-5

Dou Z, Dierenfeld ES, Wang X, Chen X, and Shurson GC (2024). A critical analysis of challenges and opportunities for upcycling food waste to animal feed to reduce climate and resource burdens. Resources, Conservation and Recycling, 203:107418. https://doi.org/10.1016/j.resconrec.2024.107418

Google earth pro software (2022). Google earth pro-Inc. https://earth.google.com/web/

Gungor E, Altop A and Erener G (2024). Effect of fermented tomato pomace on the growth performance, antioxidant capacity, and intestinal microflora in broiler chickens. Animal Science Journal, 95(1): e13885. https://doi.org/10.1111/asj.13885

Hassan ZM, Manyelo TG, Salaledi L and Mabelebele M (2020). The effects of tannins in monogastric animals with special reference to alternative feed ingredients. Molecules, 25: 4680. https://doi.org/10.3390/molecules25204680

Hemid AEA, Abd El-Gawad AH and El-Wardany I (2010). Alleviating effect of some environmental stress factors on productive performance in Japanese quail 2. Laying performance. World Journal of Agricultural Sciences, 6(5): 517-524. http://www.idosi.org/wjas/wjas6(5)/8.pdf

Hosseini-Vashan SJ, Golian A and Yaghobfar A (2016). Growth, immune, antioxidant, and bone responses of heat stress-exposed broilers fed diets supplemented with tomato pomace. International Journal of Biometeorology, 60(8): 1183-92. https://doi.org/10.1007/s00484-015-1112-9

Illgner P and Nel E (2000). The geography of edible insects in sub-Saharan Africa: A study of the mophane caterpillar. Geography Journal, 166: 336-51. https://doi.org/10.1111/j.1475-4959.2000.tb00035.x

Jha R and Mishra P (2021). Dietary fiber in poultry nutrition and their effects on nutrient utilization, performance, gut health, and on the environment: A review. Journal of Animal Science and Biotechnology, 12: 51. https://doi.org/10.1186/s40104-021-00576-0

Jha R, Fouhse JM, Tiwari UP, Li L and Willing BP (2019). Dietary fiber and intestinal health of monogastric animals. Frontiers of Veterinary Science, 6: 48. https://doi.org/10.3389/fvets.2019.00048

Jouzi H, Vali N and Pourreza J (2015). The effects of tomato pulp powder supplementation on performance and some blood parameters in Japanese quail (*Coturnix Japonica*). Journal of Agricultural and Biological Science, 10(3): 103-107. Google Scholar

Leke JR, Mandey JS, Ratulangi F and Najoan M (2018). Effect of tomato (*Solanum lycopersicum* L.) protein on carcass and meat quality of kampong chicken. Journal of the Indonesian Tropical Animal Agriculture, 43(1): 35-42. https://doi.org/10.14710/jitaa.43.1.35-42

Lira RC, Rabello C-V, Ludke MDCMM, Ferreira PV, Lana GRQ and Lana SRV (2010). Productive performance of broiler chickens fed tomato waste. Ras Brasil Zootechnology, 39(5): 1074–1081. https://doi.org/10.1590/S1516-35982010000500018

Lu S, Chen S, Li H, Paengkoum S, Taethaisong N, Meethip W, Surakhunthod J, Sinpru B, et al. (2022). Sustainable valorisation of tomato pomace (*Lycopersicon esculentum*) in Animal Nutrition: A Review. Animals (Basel), 12(23): 3294. https://doi.org/10.3390/ani12233294

Manyeula F, Mlambo V, Marume U and Sebola NA (2019). Nutrient digestibility, haemo-biochemical parameters and growth performance of an indigenous chicken strain-fed canola meal-containing diets. Tropical Animal Health and Production, 51: 2343-2350. https://doi.org/10.1007/s11250-019-01949-4

Mateos GG, Jimenez-Moreno E, Serrano MP and Lazaro RP (2012). Poultry response to high levels of dietary fiber sources varying in physical and chemical characteristics. Journal of Applied Poultry Research, 21: 156-174. https://doi.org/10.3382/japr.2011-00477

Mezbani A, Kavan BP, Kiani A and Masouri B (2019). Effect of dietary lycopene supplementation on growth performance, blood parameters and antioxidant enzymes status in broiler chickens. Livestock Research for Rural Development. 31(12): 12. https://www.lrrd.org/lrrd31/1/bahma31012.html

Mnisi CM and Mlambo V (2018). Canola meal as an alternative dietary protein source in quail (*Coturnix coturnix*) diets - A review. Acta Agriculturae Scandinavica, Section A - Animal Science, 68(4): 207-218. https://doi.org/10.1080/09064702.2019.1679873

Mnisi CM, Mhlongo G and Manyeula F (2022). Fruit pomaces as functional ingredients in poultry nutrition: A review. Frontiers in Animal Science, 3: 40. https://doi.org/10.3389/fanim.2022.883988

Mnisi CM, Mlambo V, Kumanda C and Crafford A (2021). Effect of graded levels of red grape pomace (*Vitis vinifera* L.) powder on physiological and meat quality responses of Japanese quail. Acta Agriculturae Scandinavica. Animal Science, 70(2): 100-106. https://doi.org/10.1080/09064702.2021.1923796

Mohammed LS, Sallam EA, Edris SN, Khalifa OA, Soliman MM and Shehata SF (2021). Growth performance, economic efficiency, meat quality, and gene expression in two broiler breeds fed different levels of tomato pomace. Veterinary Research Communications, 45: 381-397. https://doi.org/10.1007/s11259-021-09819-x

Muhammad MD, Chand N, Naz S, Alhidary AA, Shah AA, Khan RU and et Al. (2023). Adaptation to heat stress in broilers using dried tomato pomace and zinc: Effects on growth performance, oxidative stress, intestinal features and humoral immunity. Pakistan Journal of Zoology, 1-8. https://dx.doi.org/10.17582/journal.pjz/20220308070343

Narinc D, Kamaran E and Aksoy T (2014). Effects of slaughter age and mass selection on slaughter and carcass characteristics in 2 lines of Japanese quail. Poultry Science, 93: 762-769. http://dx.doi.org/10.3382/ps.2013-03506

National Research Council (1994). Nutrient requirements of poultry. 9th rev. ed. National Academy of Sciences, Washington, D.C. https://books.google.co.bw/books?hl=en&lr=&id=bbV1FUqRcM0C&oi=fnd&pg=PT13&dq=National+Research+Council+(1994).&ots=IlhS2FhuQA&sig=E44-d87IDtlM5GGF1hdgZt5ar7A&redir_esc=y#v=onepage&q=National%20Research%20Council%20(1994).&f=false

Nikolakakis I, Banakis D, Florou-Paneri P, Dotas V, Giannenas I and Botsoglou N (2004). Effect of dried tomato pulp on performance and carcass characteristics of growing quails. Archiv fur Geflugelkunde, 68(1): 34-38. Available at: https://www.european-poultry-science.com/effect-of-dried-tomato-pulp-on-performance-and-carcass-characteristics-of-growing-quails,QUlEPTQ5NjE2NjYmTUlEPTE2MTAxNCZQQUdFX1RQTD1QcmludHByZXZpZXcuaHRtJk1FVEFfUk9CT1Q9T0ZG.html

Okello AO, Otieno DJ, Nzuma JM, Kidoido MM and Tanga CM (2023). Smallholder farmers' willingness to pay for commercial insect-based chicken feed in Kenya. International Food and Agribusiness Management Review, 26(1):67-87. https://doi.org/10.22434/IFAMR2022.0047

Olawumi SO (2015). Carcass characteristics of Coturnix quail as affected by sex and housing system. International Journal of Agriculture, Forestry and Fisheries, 3(3): 76-79. http://www.openscienceonline.com/journal/archive2?journalId=706&paperId=1652

Ophir AG, Persaud KN and Galef BG J (2005). Avoidance of relatively aggressive male Japanese quail (*Coturnix coturnix japonica*) by sexually experienced conspecific females. Journal of Comparative Psychology, 119(1): 3-7. https://psycnet.apa.org/doi/10.1037/0735-7036.119.1.3

Rahman ANMA, Hoque MN, Talukder AK and Das ZC (2016). A survey of Japanese quail (*Coturnix coturnix japonica*) farming in selected areas of Bangladesh. Veterinary World, 9(9): 940-947. https://doi.org/10.14202/vetworld.2016.940-947

Ratriyanto A, Indreswari R and Nuhriawangsa AMP (2017). Effects of dietary protein level and betaine supplementation on nutrient digestibility and performance of Japanese quails. Revista Brasileira de Ciência Avícola, 19: 445-454. https://doi.org/10.1590/1806-9061-2016-0442

Rezaei M, Torshizi MAK, Wall H and Ivarsson E (2018). Body growth, intestinal morphology and microflora of quail on diets supplemented with micronised wheat fiber. British Poultry Science, 59: 422-429. https://doi.org/10.1080/00071668.2018.1460461

Sahin N, Orhan C, Tuzcu M, Sahin K and Kucuk O (2008). The effects of tomato powder supplementation on performance and lipid peroxidation in quail. Poultry Science, 87: 276-283. https://doi.org/10.3382/ps.2007-00207

Sezer M, Berberoglu E and Ulutas Z (2006). Genetic association between sexual maturity and weekly live-weights in laying type Japanese quail. South African Journal of Animal Science, 36(2): 142-148. https://doi.org/10.4314/sajas.v36i2.3997

Shehata SF, Kamel ER, Abo-Salem MES and Atallah ST (2018). Effect of some dietary supplementation on economic efficiency of growing Japanese Quails. Benha Veterinary Medicine Journal, 34: 219–231. https://dx.doi.org/10.21608/bvmj.2018.54243

Siamabele B (2021). The significance of soybean production in the face of changing climates in Africa. Cogent Food & Agriculture, 7: 1933745. https://doi.org/10.1080/23311932.2021.1933745

Statistical Analysis Systems (2012). SAS 9.4. Qualification tools user's guide. SAS Institute Inc: Cary N.C. https://www.sas.com/en_us/home.html

Szabo K, Dulf FV, Diaconeasa Z and Vodnar DC (2019). Antimicrobial and antioxidant properties of tomato processing byproducts and their correlation with the biochemical composition. LWT-Food Science and Technology, 116: 108558. https://doi.org/10.1016/j.lwt.2019.108558

Tabeidian SA, Toghyani M, Toghyani M and Shahidpour A (2011). Effect of incremental levels of dried tomato pomace with and without dietary enzyme supplementation on growth performance, carcass traits and ileal protein digestibility of broiler chicks. Journal of Animal and Veterinary Advance, 10: 443-448. https://www.cabidigitallibrary.org/doi/full/10.5555/20113076649

Tamburawa MS, Zango MH, Khaleel AG and Makinde OJ (2018). Response of finisher broilers fed toasted cotton seed cake meal-based diets. Wayamba Journal of Animal Science, 10: 1641-1647. Google Scholar

Tejeda OJ and Kim WK (2021). Role of dietary fiber in poultry nutrition. Animals, 11: 461. https://doi.org/10.3390/ani11020461

Yitbarek MB (2013). Effect of feeding different levels of dried tomato pomace on the performance of Rhode Island Red grower chicks in Wolaita Zone, Southern Ethiopia. Asian Journal of Poultry Science, 7(1): 27-33. https://doi.org/10.3923/ajpsaj.2013.27.33

Young LL, Northcutt JK, Buhr RJ, Lyon CE and Ware GO (2001). Effects of age, sex, and duration of post-mortem aging on percentage yield of parts from broiler chicken carcasses. Poultry Science, 80: 376-379. https://doi.org/10.1093/ps/80.3.376