Effect of graded levels of red grape pomace (Vitis vinifera L.) powder on physiological and meat quality responses of Japanese quail

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Abstract

This study evaluated the effect of dietary red grape pomace (RGP) powder on physiological and meat quality responses of Japanese quail. Three hundred quail birds were randomly distributed to five dietary treatments formulated as follows: a negative control diet without antibiotics (NegCon); a positive control diet with antibiotics (PosCon); NegCon diluted with RGP at a rate of 1.5% (RGP15), 3.5% (RGP35), and 5.5% (RGP55). Diet RGP55 promoted higher ($p < 0.05$) overall feed intake (934.3 g/bird) than diet RGP35 (809.2 g/bird). The NegCon diet promoted the highest breast meat lightness (L*) value (46.1) while the lowest value (42.7) was observed in RGP35 meat. In conclusion, quail birds reared on RGP-containing diets had similar physiological and meat quality parameters as those on the antibiotic-containing diet. An optimum inclusion level could not be determined using the physiological and meat quality responses, suggesting a need to investigate higher levels of dietary RGP.

Keywords: Grape pomace, growth performance, meat quality, quail, serum biochemistry

Introduction

The South African poultry industry serves as a major source of affordable animal protein for human consumption with a combined per capita consumption of 46.17 kg of poultry meat and eggs (DAFF, 2019). A rapidly growing human population drives the expansion and diversification of the poultry industry to meet demand for animal protein and thus ensure food and nutrition security. Commercial quail farming has recently emerged as a lucrative enterprise in South Africa. Quail (Coturnix coturnix) birds have low feed requirements, fast growth rates and short generation intervals (Mnisi et al., 2017). In addition, quail birds exhibit strong resistance to several poultry/avian diseases and can easily adapt to local environmental conditions (Nasar et al., 2016).

For optimum performance, intensive quail production uses commercial diets, which contain antibiotic growth promoters (AGP). In-feed AGPs increase feed efficiency, improve growth performance and reduce morbidity and mortality (Engberg et al., 2000; Butaye et al., 2003). However, in-feed AGPs have received widespread criticism due to their role in the development of pathogenic bacterial resistance. Indeed, there is evidence that substantial use of AGP leads to increased antibiotic resistance while contributing to high levels of antibiotic residues in poultry products (Forgetta et al., 2012; Carvalho & Santos, 2016), which are a threat to human health. Furthermore, in-feed AGPs are expensive (Butaye et al., 2003), and as a result, their use increases production costs. Therefore, there is a need to explore alternative natural additives that have nutraceutical properties that can be exploited to improve growth performance and animal product quality and safety.

One such alternative is red grape pomace (RGP), a by-product of grape wine extraction, made-up of peels, seeds, and stems (van Niekerk et al., 2020). Red grape pomace is a rich source of natural bioactive compounds with antioxidant and antimicrobial properties that can be used to control the proliferation of pathogenic microorganisms and improve product quality in quail diets (Jara-Palacios et al., 2015; Abu Hafsa & Ibrahim, 2018). Indeed, several studies have shown that RGP have growth-stimulating effects, and antimicrobial and anti-inflammatory activities that improve animal health, growth performance and product quality (Mendes et al., 2013; Lichovnikova et al., 2015; Brenes et al., 2016). However, a limited number of studies have evaluated this phenomenon in Japanese quail with the majority focusing on broiler chickens (Viveros et al., 2011; Lichovnikova et al., 2015; Turcu et al., 2020). It is, therefore, important to evaluate the feed value of RGP as a functional ingredient in Japanese quail diets because these birds possess a different genetic make-up that may produce different physiological and meat quality responses when compared to broiler chickens. The inclusion of RGP waste in Japanese quail diets is desirable for sustainable intensification, economical feeding, and better product quality. Therefore, this study was designed to investigate the effect of graded levels of dietary RGP on growth performance, serum biochemical parameters, internal organs, and carcass and meat quality characteristics in Japanese quail. We hypothesised that adding RGP in a commercial grower diet would improve physiological and meat quality responses in Japanese quail.

Materials and methods

Study site and ingredients

The study was conducted in spring (7°C – 28°C) at the North-West University Farm (25°86′00″S, 25°64′32″E) in South Africa. Sun-dried red grape pomace was sourced from Blaauwklippen Wine Estate (33.969° S; 18.844° E) in the Western Cape province of South Africa. The RGP was chemically analysed prior to diet formulation and contained 96.6% dry matter (DM), 89.9% organic matter, 11.4% DM crude protein, 40.9% DM neutral detergent fibre, 32.3% DM acid detergent fibre, 18.2% acid detergent lignin, 7.99% DM ether extract, 1.21 AU soluble condensed tannins, and 16.43 g TAE/kg total soluble phenolics as reported in our previous studies (Kumanda et al. 2019; van Niekerk et al. 2020). All other ingredients including the antibiotics (salinomycin (12%) and olaquindox (10%)) were purchased from Optifeeds (PTY) LTD (North West, South Africa).

Table 1. Gross ingredient and chemical composition (g/kg as fed basis, unless stated otherwise) of experimental diets.

	[1]Experimental diets				
	NegCon	PosCon	RGP15	RGP35	RGP55
Red grape pomace	0.00	0.00	15.00	35.00	55.00
Choline Cl (60%)	0.80	0.80	0.80	0.80	0.80
Soya oil cake (46.5%)	245.0	245.0	218.0	174.0	124.0
Fullfat soya	10.0	10.0	10.0	23.0	86.0
Gluten 60	5.00	5.00	9.00	32.00	34.00
Lysine (Sint 78%)	1.39	1.39	2.09	2.81	2.78
Methionine (Dl 98%)	1.42	1.42	1.46	1.16	1.05
Threonine (98%)	0.00	0.00	0.05	0.08	0.00
Yellow maize	709.0	709.0	716.0	703.0	668.0
Feed lime	14.6	14.6	14.4	14.2	13.8
Monodicalcium phosphate	7.00	7.00	7.30	7.50	7.60
Fine-salt	3.29	3.29	3.39	3.17	3.23
Sodium bicarbonate	1.59	1.59	1.43	1.72	1.64
[2]Premix	0.50	0.50	0.50	0.50	0.50
Axtra Phytase	0.10	0.10	0.10	0.10	0.10
Salinomycin (12%)	-	0.05	-	-	-
Olaquindox (10%)	-	0.04	-	-	-
Chemical composition					
Dry matter	893.7	893.7	894.4	896.0	899.3
Metabolisable energy (MJ/Kg)	11.91	11.91	11.90	11.90	11.90
Crude protein	170.1	170.1	170.1	170.1	170.1
Crude fat	33.53	33.53	34.18	36.65	47.66
Crude fibre	25.03	25.03	31.44	40.20	50.77
Calcium	8.21	8.21	8.20	8.20	8.19
Phosphorus	4.99	4.99	4.95	4.88	4.83
Sodium	1.80	1.80	1.80	1.80	1.80
Chlorine	2.81	2.81	3.00	3.00	3.00
Potassium	7.52	7.52	7.22	6.82	6.99
Lysine	9.87	9.87	9.86	9.88	9.98
Methionine + Cysteine	7.32	7.32	7.40	7.58	7.77
Threonine	6.63	6.63	6.44	6.50	6.59
Tryptophan	1.90	1.90	1.86	1.87	2.00

[1]Experimental diets: NegCon = commercial diet without antibiotics; PosCon = commercial grower diet with antibiotics; RGP15 = NegCon treated with 15 g/kg RGP; RGP35 = NegCon treated with 35 g/kg RGP; and RGP55 = NegCon treated with 55 g/kg RGP.

[2]Premix: vitamin A (11000 IU), vitamin D3 (2500 IU), vitamin E (25 IU), vitamin K3 (2.0 mg), vitamin B1 (2.5 mg), vitamin B2 (4.5 mg), vitamin B6 (5.1 mg), niacin (30 mg), pantothenic acid (10 mg), folic acid (0.7 mg), biotin (0.12 g), copper sulphate (8.0 mg), potassium iodide (0.34 mg), ferrous sulphate (80 mg), magnesium sulphate (100 mg), sodium selenite (0.25 mg), and zinc sulphate (79 mg).

Diet formulation and chemical analyses

Five isonitrogenous and isoenergetic experimental diets were formulated (Table 1) by diluting a commercial grower diet with RGP powder (2 mm; Polymix PX-MFC 90 D) as follows: a positive control diet with salinomycin (12%) and olaquindox (10%) antibiotics (PosCon), a negative control diet without antibiotics (NegCon), NegCon diluted with 1.5% of RGP powder (RGP15), NegCon diluted with 3.5% of RGP powder (RGP35), and NegCon diluted with 5.5% RGP powder (RGP55). The diets were formulated separately to avoid contamination and thereafter stored at room temperature in a dry storage area using labelled sacks. The diets were sampled, dried (60°C) and milled (1-mm; Polymix PX-MFC 90 D) before laboratory analyses. Thereafter, the experimental diets were analysed for minerals (Ca, P, Na, Cl and K) following Agri Laboratory Association of Southern Africa guidelines (AgriLASA, 1998). Dry matter, crude protein, crude fat, and crude fibre of the diets were analysed using the Association of Official Analytical Chemists (AOAC) methods (AOAC, 2005). Metabolisable energy and amino acids were predicted using the Near Infrared Spectroscopy (SpectraStar XL, Unity Scientific, Australia).

Statement of ethics and feeding trial

All experimental protocols employed during the feeding trial and slaughtering of the birds were approved by the Animal Production Research Ethics Committee of the North-West University (approval no: NWU-00505-18-A5). A total of 300, two-week-old unsexed Japanese quail chicks were bought from a quail farm (Gauteng, South Africa). Upon arrival at Molelwane farm, the birds were equally allocated to 30 replicate pens (experimental units), in a completely randomised design. Each experimental unit carried 10 birds that were replicated six times per dietary treatment. The size of the pens was 100 cm L × 60 cm W × 30 cm H and were built using wire mesh with slatted floors that require no bedding. The quail, in each replicate pen, were adapted to the five experimental treatments until three weeks of age (132.8 ± 9.28 g initial live-weights) and infrared lamps were used as a source of warmth during cold nights, when ambient temperatures were below 20°C. The temperature (30°C) and humidity (40 - 60%) of the house was monitored daily using a multi-meter device. A digital weighing scale (Explorer EX224, OHAUS Corp, New Jersey, USA) was used to weigh the amount of feed offered and feed refusals each morning prior feeding. Average weekly feed intake (AWFI) was calculated from week four to week seven. All the birds were weighed in a weekly basis to determine average weekly body weight gain (ABWG). The ABWG and AWFI were used to determine feed conversion efficiency (FCE). For the entire duration of the study (days 21 – 49), the birds had free access to clean water and the dietary treatments, and rearing was performed under natural lighting (12 h of daylight).

Slaughter procedure and blood analyses

At seven weeks of age, all the birds were slaughtered in a local poultry abattoir after being electrically stunned. A sharp knife was used to cut the jugular vein and bleeding was allowed for 5 min. While bleeding, blood samples (2 ml) were collected into sterilised tubes from two birds randomly selected per experimental unit. The blood was left to clot at room temperature and thereafter centrifuged to produce sera. An automated IDEXX Vet Test Chemistry Analyser (IDEXX Laboratories Inc., Gauteng, South Africa) was used to determine serum albumin, total protein, amylase, urea, bilirubin, globulin, glucose, cholesterol, albumin-to-globulin ratio

(ALB/GLOB), alanine transaminase (ALT), gamma-glutamyl transferase (GGT), and alkaline phosphatase (ALKP).

Measurements of carcass and internal organ weights

Hot carcass weight (HCW; n = 300) was recorded immediately after slaughter, whereas cold carcass weight (CCW; n = 300) was measured after chilling at 4°C for 24 h. The dressing percentage was calculated using HCW as a proportion to final body weight. Weights of the drumsticks, thighs, and wings, as well as gizzards, proventriculus, livers, and small and large intestines were recorded and expressed as the proportion of HCW (g/100 g HCW).

Meat quality measurement

A portable pH-temperature meter fitted with a spear-type electrode (HI98163, Hanna Instruments, Romania) was used to measure breast meat pH and temperature 24 h post-mortem. The pH meter was calibrated using the standard solutions (pH 4, 7 and 10) provided by the supplier before measurements and every after 10 samples. A Minolta colour-guide (Spectrophotometer CM 2500c, Konika Minolta, Japan) was used to determine breast meat colour coordinates (L* = lightness, a* = redness and b* = yellowness) as described by the Commission International De I' Eclairage (CIE, 1976). The colour coordinates were used to calculate for hue angle and chroma values as described by Priolo et al. (2002).

For cooking loss, breast meat samples were initially weighed before being placed in a foil plate and oven-cooked until an internal temperature of 75°C was reached (Honikel, 1998). After cooking, the samples were cooled for 20 min and reweighed. Cooking loss was calculated as the difference between the weight of raw meat and cooked meat in proportion to the initial weight. Thereafter, breast meat samples were sheared using a Meullenet-Owens razor (A/MORs) shear blade mounted on a Texture Analyser (TA XT plus, Stable Micro Systems, Surrey, UK) to determine the average shear force (N). The filter-paper press method invented by Grau & Hamm (1957) was used to determine the water holding capacity (WHC) of the meat. Drip loss was determined using a method by Zhang et al. (2010), where pieces of meat samples are hanged 4°C for 72 h.

Statistical analysis

Physiological and meat quality data (except for PosCon data) were assessed for linear and non-linear effects of RGP inclusion levels using response surface regression analysis (Proc RSREG; SAS, 2010) according to the following quadratic equation:

$$y = ax^2 + bx + c$$

Where y = response variable; *a* and *b* are the coefficients of the quadratic equation; *c* is intercept; *x* is RGP levels (%) and *-b/2a* is the *x* value for optimal response.

Growth performance, serum biochemistry, internal organs, carcass characteristics and meat quality data was analysed using the GLM procedure of SAS version 9.4 (2010), according to the following linear statistical model:

$$Y_{ij} = \mu + D_i + E_{ij}$$

Where, Y_{ij} = dependant variable, μ = population mean, D_i = effect of diets, and E_{ij} = random error associated with observation *ij,* assumed to be normally and independently distributed. Comparison of least squares means was done using the probability of difference in SAS and $p < 0.05$ was used to declare significance. Gender was not considered as a variable in the statistical model because quail sexing is not practiced at farm level.

Table 2. Overall feed intake and growth performance (g/bird) in Japanese quail (n = 300) fed with diets containing red grape pomace powder.

	[1]Experimental diets						Significance	
	NegCon	PosCon	RGP15	RGP35	RGP55	SEM	Linear	Quadratic
Overall Feed intake	871.3[ab]	888.9[ab]	908.2[ab]	809.2[a]	934.3[b]	27.20	0.513	0.114
Overall BWG (g)	123.5	125.2	124.2	129.7	121.0	12.51	0.963	0.704
Overall FCE	0.142	0.140	0.135	0.159	0.129	0.012	0.809	0.347
Final body weight (g)	263.4	259.5	265.8	266.1	258.9	14.00	0.926	0.984

[1]Experimental diets: NegCon = commercial diet without antibiotics; PosCon = commercial grower diet with antibiotics; RGP15 = NegCon treated with 15 g/kg RGP; RGP35 = NegCon treated with 35 g/kg RGP; and RGP55 = NegCon treated with 55 g/kg RGP.

[2]SEM = standard error of the mean.

Table 3. Serum biochemical parameters in Japanese quail (n = 60) fed with diets containing red grape pomace powder.

[2]Parameters	[1]Experimental diets						Significance	
	NegCon	PosCon	RGP15	RGP35	RGP55	[3]SEM	Linear	Quadratic
ALB/GLOB	0.48	0.45	0.42	0.40	0.38	0.038	0.737	0.633
Albumin (g/L)	15.50	14.88	14.50	16.33	13.50	0.907	0.071	0.077
ALKP (IU/L)	284.5	281.1	200.4	245.8	240.6	43.20	0.294	0.706
ALT (IU/L)	24.00	17.50	17.83	18.33	22.67	6.311	0.841	0.512
Amylase (IU/L)	279.5	271.4	204.0	217.0	292.5	59.62	0.654	0.170
Bilirubin (μmol/L)	14.75	11.25	8.00	11.50	5.17	3.067	0.152	0.691
Cholesterol (mmol/L)	3.74	3.59	4.18	3.69	5.39	0.548	0.091	0.199
GGT (IU/L)	7.75	5.13	5.00	6.33	4.00	1.127	0.946	0.318
Globulin (g/L)	33.50	32.63	34.83	41.00	32.17	4.650	0.914	0.875
Glucose (mmol/L)	11.59	11.97	12.81	13.67	15.45	1.353	0.157	0.069
Total protein (g/L)	49.00	47.50	49.33	57.33	50.50	5.140	0.584	0.765
Urea (mmol/L)	0.60	0.61	0.65	0.63	0.63	0.027	0.904	0.724

[1]Experimental diets: NegCon = commercial diet without antibiotics; PosCon = commercial grower diet with antibiotics; RGP15 = NegCon treated with 15 g/kg RGP; RGP35 = NegCon treated with 35 g/kg RGP; and RGP55 = NegCon treated with 55 g/kg RGP.

[2]Parameters: ALB/GLOB = albumin to globulin ratio; ALKP = alkaline phosphatase; ALT = alanine aminotransferase; GGT = gamma-glutamyl transferase.

[3]SEM = standard error of the mean.

Results

There were no linear and quadratic trends ($p > 0.05$) for overall feed intake and growth traits in response to dietary RGP levels (Table 2). Dietary treatments only influenced overall feed intake, where birds in diet RGP35 (809.2 g/bird) had the least ($p < 0.05$) feed consumed than those in diet RGP55 (934.3 g/bird). Neither linear nor quadratic effects ($p > 0.05$) were observed for serum biochemical parameters as RGP levels increased (Table 3). Likewise, there were no dietary influence ($p > 0.05$) on all serum biochemical indices.

Table 4 shows that there were non-significant linear and quadratic effects for internal organ weights and carcass traits of the birds in response to graded levels of RGP. Similarly, the dietary treatments had no effect on carcass characteristics and internal organ sizes of the birds.

Table 4. Carcass characteristics and internal organ weights (g/100 g HCW, unless stated otherwise) in Japanese quail (n = 300) fed with diets containing red grape pomace powder.

	[1]Experimental diets					[2]SEM	Significance	
	NegCon	PosCon	RGP15	RGP35	RGP55		Linear	Quadratic
Dressing %	64.23	67.19	62.66	59.20	63.66	4.027	0.585	0.728
Hot carcass (g)	167.3	173.7	163.1	153.8	163.6	6.281	0.298	0.422
Cold carcass (g)	165.8	170.4	161.8	152.7	161.6	6.159	0.292	0.478
Thigh	6.51	6.01	5.57	6.18	5.33	0.420	0.150	0.570
Wing	5.02	4.76	4.36	4.75	4.29	0.315	0.243	0.873
Drumstick	5.06	4.67	4.60	4.45	3.90	0.392	0.212	0.866
Liver	3.17	2.89	3.65	2.97	3.14	0.509	0.391	0.989
Proventriculus	0.59	0.56	0.52	0.68	0.54	0.057	0.121	0.452
Gizzard	2.53	2.63	2.36	2.59	2.43	0.131	0.255	0.237
Small intestine	5.12	4.60	5.57	4.88	5.24	0.656	0.506	0.999
Large intestine	1.32	1.22	1.88	1.37	0.47	0.941	0.708	0.386

[1]Experimental diets: NegCon = commercial diet without antibiotics; PosCon = commercial grower diet with antibiotics; RGP15 = NegCon treated with 15 g/kg RGP; RGP35 = NegCon treated with 35 g/kg RGP; and RGP55 = NegCon treated with 55 g/kg RGP.

[2]SEM = standard error of the mean.

Table 5 shows that no linear and quadratic trends ($p > 0.05$) were observed for meat quality parameters except for hue angle [$y = 1.39\ (\pm 0.059) – 0.009\ (\pm 0.0194)\ x$; R2 = 0.233, p = 0.042, numbers in parentheses are standard errors], which linearly declined with RGP levels. Experimental diets had no significant effect on meat quality traits, except on L* ($p < 0.05$). Meat from birds offered NegCon diet had the highest L* value (46.1) whereas the lowest value (42.7) was observed in RGP35 meat.

Table 5. Breast meat quality parameters in Japanese quail (n = 300) fed with diets containing red grape pomace powder.

	[1]Experimental diets					[3]SEM	Significance	
	NegCon	PosCon	RGP15	RGP35	RGP55		Linear	Quadratic
pH	6.69	6.66	6.62	6.58	6.67	0.057	0.500	0.208
Temperature (°C)	11.48	11.49	13.42	11.16	11.55	0.887	0.769	0.548
Lightness (*L**)	46.1^{e}	44.0^{c}	44.7^{d}	42.7^{a}	43.7^{b}	0.044	0.207	0.305
Redness (*a**)	2.58	4.13	3.17	3.48	3.29	0.457	0.059	0.681
Yellowness (*b**)	12.49	13.31	13.19	11.72	12.40	0.406	0.835	0.990
Chroma	12.77	13.99	13.59	12.24	13.66	0.588	0.296	0.595
Hue angle	1.37	1.27	1.34	1.28	1.22	0.049	0.042	0.861
Shear force (N)	5.98	6.43	5.84	6.48	6.79	0.833	0.456	0.970
Cooking loss (%)	19.47	17.27	22.29	14.78	16.34	2.839	0.074	0.587
[2]WHC (%)	3.19	2.96	3.66	3.61	3.31	0.453	0.413	0.631
Drip loss (%)	43.11	42.36	42.78	45.18	44.20	1.397	0.787	0.546

[1]Experimental diets: NegCon = commercial diet without antibiotics; PosCon = commercial grower diet with antibiotics; RGP15 = NegCon treated with 15 g/kg RGP; RGP35 = NegCon treated with 35 g/kg RGP; and RGP55 = NegCon treated with 55 g/kg RGP.

[2]WHC = water holding capacity.

[3]SEM = standard error of the mean.

Discussion

Nutraceutical plants have been demonstrated to possess antibacterial, antioxidant, and conservative activities that promote intestinal functions and gut integrity by reducing subclinical infections and thereby increasing nutrient uptake and growth rates (Huyghebaert et al., 2010; Landy et al., 2011; Mabona et al., 2013). The use of red grape pomace in quail diets could combine the positive effects of improving animal product quality and human health while eliminating antibiotic traces in animal products. In addition, this may prevent problems related with the disposal of RGP into environment (Kumanda et al., 2019). Voluntary feed intake is directly related to the palatability of the feed. Both the negative and positive control groups promoted similar AWFI as the RGP-containing diets, indicating that the inclusion of RGP did not change the palatability of the diets. Nonetheless, diet RGP55 promoted higher overall feed intake than diet RGP35, which could have been due to high fibre content (Bertipaglia et al., 2016). Indeed, the crude fibre content of the diets tended to increase with increasing levels of RGP inclusion. The observed compensatory feed intake could be explained by the extra dietary fibre interfering with nutrient digestion and absorption, despite nutrient density being the same across diets. Such interference would have caused low blood sugar levels prompting the birds on higher fibre diets to consume more feed. No significant linear or quadratic trends were observed for growth traits in response to graded levels of RGP. Furthermore, no dietary effects were observed on overall BWG and FCE in Japanese quail. These findings were in line with those of Mnisi et al. (2017) who reported that the inclusion of Lippia javanica in place of AGP in Japanese quail diets promoted similar body weight gain and FCE. The lack of dietary effects on weight gain and FCE suggests a need to investigate higher inclusion levels of the pomace in quail diets in order for the birds to benefit from the bioactive compounds that comes with the inclusion of the RGP.

Serum biochemical profiling is commonly conducted to monitor nutritional status and diagnose subclinical diseases (Ali et al., 2012) because abnormal clinical conditions are closely associated with biochemical changes. However, reference serum biochemistry values for Japanese quail fed with RGP are scanty. In this study, the inclusion of RGP had no significant effect on serum biochemical parameters, which fell within the normal range reported for Japanese quail (Ali et al., 2012; Mnisi et al., 2017). Although it was expected that the presence of secondary plant compounds such as phenolic acids in RGP would alter the serum biochemical parameters, particularly the liver enzymes, no significant linear and quadratic trends were observed. Similarly, Kumanda et al. (2019) reported that the graded levels of up to 75 g/kg of RGP in broiler chicken diets had no effect on serum biochemical parameters.

In this study, there were no dietary effects on carcass characteristics and internal organ sizes of the birds, which suggests that RGP inclusion did not induce any observable anatomical adaptation responses in the birds. These findings agree with those of Konca et al. (2015), who found that carcass and internal organ weights of Japanese quail are not affected by RGP supplementation up to 60 g/kg. Likewise, Hajati et al. (2015) reported that dietary supplementation of grape seed extract does not affect carcass, liver, and gizzard weights in broiler chickens. Indeed, the liver sizes were not significantly influenced by the dietary treatments, which explains the lack of differences in the serum liver enzymes found in this current study. The inclusion of RGP in quail diets was expected to affect visceral weight due to additional fibre that would have induced anatomical changes as the birds adapt to the bulkiness of the diet. The liver, being the detoxifying organ of the quail, was expected to grow in size in response to higher levels of low molecular weight phenolics found in red grape pomace. Meat pH influences the colour, texture, stability, and flavour of the meat, however, in this present study, all these quality parameters were not affected by dietary treatments except for meat lightness (L*) and hue angle. The RGP-containing diets promoted lower meat L* than the negative control diet, which could be due to the presence of anthocyanins in RGP (Aditya et al., 2018) that might have influenced the coloration of the meat. The hue angle, the common distinction between colours, showed a linear decrease with RGP inclusion, in agreement with the findings of Kumanda et al. (2019) who observed a decrease in hue angle of broiler meat as RGP levels increased. In addition, the shear force, drip loss and WHC were not influenced by the experimental diets suggesting that the inclusion of dietary RGP in Japanese quail diets did not compromise the texture and overall quality of the meat. Turcu et al. (2020) reported that higher level of RGP (60 g/kg) in broiler diets increased thigh meat tenderness, which was correlated with the gelation properties of the protein from the pomace. In this study, the inclusion of RGP in Japanese quail diets promoted similar physiological and meat quality parameters as those on the antibiotic-containing control diet. However, inconsistent findings were also reported by Bennato et al. (2020) where the inclusion of RGP in broiler diets had no effect on meat pH, cooking loss and brightness, but caused variations in drip loss, meat yellowness and redness. This suggests a need for further studies to investigate the effect of RGP on meat quality attributes of Japanese quail. The lack of dietary effects reveals that the use of RGP up to 55 g/kg does not compromise the performance and meat quality of Japanese quail. An optimum inclusion level of red grape pomace powder could not be determined in the present study, which suggests that inclusion levels beyond 55 g/kg would need to be investigated to generate non-linear responses in Japanese quail diets.

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