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Original Research Article

Growth performance, haematology, serum biochemistry and meat quality characteristics of Japanese quail (*Coturnix coturnix japonica*) fed canola meal-based diets

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ABSTRACT

The present study investigated the effect of partial replacement of soybean meal (*Glycine max*) with canola meal (CM) (*Brassica napus*) on the growth performance, haematology, serum biochemistry and meat quality characteristics of female Japanese quails in a 35-day feeding trial. One hundred and forty 6-week-old quails 158.28 ± 11.919 g were randomly allocated to 5 isonitrogenous and isoenergetic experimental diets: control diet (CM0; with no CM inclusion); CM0 with 2.5% (CM25), 5.0% (CM50), 12.5% (CM125) and 17.5% (CM175) soybean meal replaced with CM. Average weekly gain (AWG) and feed conversion efficiency (FCE) were determined. Haematology, serum biochemistry, carcass traits and meat quality parameters were determined at slaughter. Quails fed CM175 had the lowest ($P < 0.05$) feed intake whereas no differences were observed among the other 4 diets. No dietary effects on AWG, FCE and haematological parameters were observed. Serum biochemical parameters were not influenced by diets with the exception of alkaline phosphatase (ALP), where quails fed CM25 had higher ALP (161.0 U/L) than those fed CM0 (37.25 U/L). Quails fed CM25 had the highest chroma (7.39) while those fed CM125 had the lowest (3.58) at 24 h post-slaughter. Diets had no influence ($P > 0.05$) on cooking losses and peak positive force of quail meat. It was concluded that CM can replace soybean in quail diets up to 12.5% without compromising growth performance, health and quality of meat. Inclusion levels beyond 12.5% promoted poor voluntary feed intake and thus may require feed additives to enhance utilization.

1. Introduction

The poultry industry is one of the largest animal agriculture sectors in South Africa. It has evolved rapidly over the past 100 years from backyard household production to highly sophisticated commercial production units (Bolton, 2015). The industry continues to evolve with the addition of new bird species, such as the Japanese quail (*Coturnix coturnix japonica*), to complement the existing species. Although a relatively recent addition to the South African poultry industry, quail farming already contributes high-quality dietary protein for human consumption (Khosravi et al., 2016). Farming quails is economically viable and technically feasible because quails are quite resistant to various diseases, reach sexual maturity at 6 weeks of age and easily adapt to various rearing conditions (Randall and Bolla, 2008). However, the major challenge in the long-term sustainability of quail production remains the cost of dietary protein and the supply of essential amino acids (Wickramasuriya et al., 2015; Rezaeipour et al., 2016). Due to the nature of their digestive system, quails require dietary protein

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of very high quality, much similar to what humans require (Beski et al., 2015). Therefore, there is a direct competition between birds and humans for soybean. This often results in relatively higher prices of soybean on the world market creating artificial food shortages among the poorest societies around the world. According to Scanes et al. (2004), the efficacy of a protein feedstuff for poultry depends on its capacity to supply adequate amount of essential amino acids required by the bird. The quality of soybean meal as a protein source for poultry is unquestionable. However, alternative dietary protein sources are required to help to alleviate the challenge of high feed costs encountered in quail production. Canola meal (CM) is one such relatively inexpensive protein source (34% to 39% CP) that has potential to be used as an alternative to soybean in quail diets (Mushtaq et al., 2007; Beski et al., 2015). Unfortunately, canola contains antinutritional factors, such as glucosinolates, erucic acid, phytic acid, non-starch polysaccharides and phenolics, and also has high fibre content (Bell, 1993; Swick, 1999). These components are known to reduce amino acid digestibility and contribute to suboptimal growth performance of birds offered CM (Wickramasuriya et al., 2015). Furthermore, the lower energy value of CM, when compared to soybean meal, limits its utility in high-energy quail feeds. Nevertheless, genetic selection has successfully reduced the concentration of some undesirable components such as erucic acid and glucosinolates (Woyengo et al., 2014; Canola Council of Canada, 2015).

Encouraging diversification of the South African poultry industry through economical feeding of new entrants, such as the Japanese quail, will help to reduce dependency of the industry on soybean meal, address food and nutrition insecurity, and ensure profitability. Advanced research on the physiological and production parameters of Japanese quail fed CM under intensive management system is scanty (Faruque et al., 2013). This study, therefore, presents a nutritional evaluation of CM as an alternative protein source for Japanese quails. The overall objective of the study was to investigate the effect of graded levels of CM, as partial replacement for soybean meal, on growth performance, haematology, serum biochemistry and meat quality. The study was, therefore, designed to answer the following research question: does partial replacement of dietary soybean with CM affect growth performance, blood parameters and meat quality traits in female Japanese quails?

2. Material and methods

The experiment was approved by the Animal Research Ethics Committee, North-West University (AREC-MC), approved (NWU-00521-16-A9).

2.1. Description of the study site

The feeding trial for female Japanese quails was conducted at the Molelwane Research Farm (North-West University, South Africa) (25°40.459′ S, 26°10.563′ E), which is founded at an altitude of 1,226 m above sea level in the North-West province. The ambient temperatures at the study site range from 27 to 37 °C during summer and from 3 to 25 °C in winter. Annual rainfall ranges from 300 to 600 mm.

2.2. Feed ingredients

Soybean meal (SBM) and all the other feed ingredients, except for CM, were bought from Opti Feeds Pty Ltd., Lichtenburg, South Africa. The CM was purchased from Southern Oil Pty Ltd., Western Cape, South Africa. Both soybean and canola were solvent-extracted meals.

2.3. Diet formulation

Five diets were formulated by replacing SBM in a commercial grower diet with graded levels of CM using Format of Opti Feeds Pty Ltd., Lichtenburg, South Africa. The isonitrogenous and isoenergetic experimental diets were formulated by replacing the SBM component with CM as follows: CM0 = control diet with no CM inclusion, CM25 = control diet in which 2.5% of soybean meal was replaced with CM, CM50 = control diet in which 5% of soybean meal was replaced with CM, CM125 = control diet in which 12.5% of soybean meal was replaced with CM and CM175 = control diet in which 17.5% of soybean meal was replaced with CM, producing 5 dietary treatments as shown in Table 1.

2.4. Chemical analyses

The formulated diets (CM0, CM25, CM50, CM125 and CM175) were milled (Polymix PX-MFC 90 D) to pass through a 1 mm sieve for chemical analyses. Diets were analysed using the methods of AOAC International (AOAC, 2005). Analyses were conducted for laboratory dry matter (DM; AOAC method 930.15), organic matter (OM; AOAC method 924.05) and crude protein (CP; AOAC method

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

Item	Diets				
	CM0	CM25	CM50	CM125	CM175
Canola oil cake	0	25	50	125	175
Yellow maize–fine	698.6	686.9	670.2	618.2	595.1
Prime gluten 60	18.0	13.0	10.3	20.0	24.3
Full fat soya meal	50.7	71.7	104	185	174
Soybean meal (local)	196.7	168	130.7	19.3	0
Limestone powder-fine	14.5	14.2	13.8	12.8	12.2
Mono calcium phosphate	7.2	7.0	6.8	6.1	5.6
NaCl (salt-fine)	3.2	3.2	3.3	3.2	3.2
Sodium bicarbonate	1.7	1.6	1.6	1.6	1.6
Choline powder	0.8	0.8	0.8	0.8	0.8
Lysine	2.8	2.8	2.8	2.9	2.9
L-threonine	0.4	0.4	0.4	0.2	0.0
Methionine	1.9	1.8	1.8	1.4	1.8
Grower-phytase	1.7	1.7	1.7	1.7	1.7
Coxistac	0.5	0.5	0.5	0.5	0.5
Olaquindox	0.4	0.4	0.4	0.4	0.4
Chemical composition					
Dry matter	88.65	88.71	88.82	89.14	89.06
Organic matter	83.84	83.88	83.98	84.32	84.22
ME, MJ/kg	12.1	12.1	12.1	12.1	11.8
Crude protein	18.00	18.00	18.01	18.61	18.94
Crude fat	4.162	4.830	5.363	6.725	6.244
Crude fibre	2.315	2.589	2.892	3.726	4.176
Calcium	0.85	0.85	0.85	0.85	0.85
Phosphorus	0.497	0.506	0.515	0.542	0.563
Sodium	0.18	0.18	0.18	0.18	0.18
Chlorine	0.3	0.3	0.3	0.3	0.3
Potassium	0.763	0.763	0.764	0.740	0.733
Lysine	1.079	1.085	1.091	1.105	1.110
Methionine	0.478	0.476	0.475	0.460	0.520
Threonine	0.705	0.710	0.715	0.729	0.733
Tryptophan	0.187	0.189	0.192	0.197	0.201
Isoleucine	0.739	0.733	0.731	0.744	0.750
Arginine	1.102	1.101	1.102	1.101	1.100
Leucine	1.692	1.662	1.637	1.706	1.728
Valine	0.844	0.847	0.850	0.888	0.908

CM0 = control diet with no canola meal inclusion, CM25 = control diet in which 2.5% of soybean meal was replaced with canola meal; CM50 = control diet in which 5% of soybean meal was replaced with canola meal; CM125 = control diet in which 12.5% of soybean meal was replaced with canola meal; CM175 = control diet in which 17.5% of soybean meal was replaced with canola meal. ME = metabolizable energy.

984.13). Crude fibre was determined using the ANKOM^{2000} Fibre analyser (ANKOM Technology, New York). Amino acids were determined by hydrolysing samples with 6 mol/L HCl (containing phenol) for 24 h at 110 ± 2 °C in glass tubes sealed under vacuum as described by Ravindran et al. (2005). Mineral content (calcium, phosphorus, sodium, chlorine and potassium) was analysed following the guidelines provided by the Agri-Laboratory Association of Southern Africa (AgriLASA, 1998). Metabolizable energy (ME) content was predicted using the near infrared reflectance spectroscopy SpectraStar XL (Unity Scientific, Australia).

2.5. Experimental design

One hundred and forty 1-week-old female Japanese quails were acquired from A and J Services Farm, Palmietfontein, South Africa. The quails were reared using a starter-mash of Opti Feeds Pty Ltd., Lichtenburg and had access to fresh water with infrared lamps heating (until 3 weeks of age) to provide warmth because they are very sensitive to low temperature. At 5 weeks of age, the quails were randomly allocated to 20 replicate pens (experimental units), with each pen carrying 7 female birds. The 5 dietary treatments were randomly allocated to the pens (4 replicate pens per diet) and the quails were reared until they were 10 weeks of age. The quails were allowed to adapt to the pens and diets for a week before the experiment commenced.

2.6. Feeding and bird management

Dietary treatments and fresh water were provided *ad libitum* and average daily feed intake was measured during weeks 6 to 10. The initial live-weights of the quails were measured at the beginning of the experiment (the first day of week 6). Thereafter, average live-weight was measured weekly by weighing all the quails in each pen. The live-weights were used to calculate growth rates. Average weekly feed intake (AWFI) was calculated as the difference between the feed offered and the refusals. Each quail was weighed weekly and the average weekly gain (AWG) was calculated as follows:

$$\text{AWG}\ (t_0,\ T) = \frac{W(T) - W(t_0)}{T - t_0},$$

where t_0 = initial time (day); T = final time (day); $W(T)$ = final body weight (g) and $W\ (t_0)$ = initial body weight (g). Feed conversion efficiency was calculated as weight gained divided by the amount of feed consumed.

2.7. Slaughter procedures, blood collection and analyses

At 10 weeks of age, all female Japanese quails were deprived of feed for a period of 13 h to guarantee the emptiness of the crop as guided by Ari et al. (2013). All quails were taken to Rooigrond chicken abattoir (Mafikeng, South Africa) for slaughter. According to Berg and Raj (2015), all the quails were gas stunned by exposing them to relatively low concentrations of carbon dioxide (<40% by volume in air), and then, once they were unconscious, exposed to a higher concentration (approximately 80% to 90% by volume in air). Thereafter, quails were live-hanged onto a movable metal rack that holds them upside down by their feet. Quails were then slaughtered by cutting the jugular vein with a sharp knife, and they were left hanging until bleeding ended. At the same time, about 4 mL of blood was collected from 2 quails randomly selected from each pen into 2 sets of sterilised bottles (purple-top tubes with anti-coagulant for haematology and red-top tubes without anticoagulant for serum biochemical analysis). Haematological parameters (erythrocytes, haemoglobin, haematocrit, mean corpuscular volume [MCV] and mean corpuscular haemoglobin [MCH]) were determined using an automated IDEXX LaserCyte Haematology (IDEXX Laboratories, Inc.). Mean corpuscular haemoglobin concentration (MCHC) was calculated as the ratio of MCH to MCV. Albumin, alkaline phosphatase, alanine transaminase, amylase, blood calcium, serum cholesterol, creatinine, globulin, blood glucose, lipase, blood phosphorus, total bilirubin, total protein and urea were analysed using an automated IDEXX Vet Test Chemistry Analyser (IDEXX Laboratories, Inc.).

2.8. Internal organs and carcass traits

Upon completion of bleeding, the quails were put in a de-feathering machine. Afterwards, carcasses were immediately taken to the Animal Science Laboratory (North-West University, South Africa) for carcass measurements and meat quality parameters. The weights of the livers, clean gizzards, hearts, wings, thighs and the lengths of the small intestines were determined. Hot carcass weight (HCW) was measured before the carcasses were chilled for 24 h to acquire the cold carcass weight. The dressing out percentage was determined as the proportion of HCW to the slaughter weight.

2.9. Meat quality measurements

2.9.1. Meat pH and temperature measurements

Meat pH and temperature were recorded immediately after 24 h post-slaughter on the breast muscle (central area of the breast) using a Corning Model 4 pH-temperature meter (Corning Glass Works, Medfield, MA, USA) equipped with an Ingold spear-type electrode (Ingold Messtechnik AG, Udorf, Switzerland) according to Stanford et al. (2003). After every 20 measurements, the pH meter was calibrated with pH 4 and pH 7 standard solutions (Ingold Messtechnik AG, Udorf, Switzerland) at a temperature of 2 °C.

2.9.2. Meat colour

Colour of the meat (L^* = lightness, a^* = redness and b^* = yellowness) was determined, immediately after slaughter and 24 h after slaughter, using a Minolta colour-guide (BYK-Gardener GmbH, Geretsried, Germany) on a 20 mm diameter measurement area and illuminate D65 light at 10° observation angle. The colour meter was calibrated using the green standard before measurements. Colour recording was done on the surface of the thigh muscle, which was allowed to bloom for 1 h on a polystyrene tray at 4 °C. Hue angle was calculated as $\tan(\theta) = \frac{a^*}{b^*}$, and chroma was calculated as $\sqrt{a^{*2} + b^{*2}}$ as guided by Priolo et al. (2002).

2.9.3. Cooking losses and meat tenderness

After weighing, breast samples were placed in an oven set at 130 °C for 20 min for determination of cooking losses. The following formula was employed:

$$\text{Cooking losses}\ (\%) = \frac{(\text{Initial weight} - \text{Final weight})}{\text{Initial weight}} \times 100.$$

After determination of cooking losses, breast samples were sheared perpendicular to the fibre direction using a Meullenet–Owens razor shear blade mounted on an Universal Instron apparatus (cross head speed = 200 mm/min, one shear in the centre of each core). The reported value represented the average positive peak force (N) measurements of each sample.

2.10. Statistical analysis

Weekly feed intake, AWG and feed conversion efficiency (FCE) data were analysed using the repeated measures procedure of SAS (2010). Overall feed intake, weight gain, feed conversion efficiency, blood parameters, carcass characteristics and meat quality data were analysed using the general linear model procedure of SAS (2010). The linear statistical model employed was as follows:

$$Y_{ik} = \mu + D_i + E_{ik},$$

where Y_{ik} = dependant variable, μ = population mean, D_i = effect of diets, and E_{ik} = random error associated with observation ik, assumed to be normally and independently distributed. For all statistical tests, significance was declared at $P < 0.05$. Least squares means was compared using the probability of difference option in the LSMEANS statement of SAS.

3. Results

Table 1 shows that the DM and OM content of experimental diets increased as canola levels increased. All dietary treatments were isoenergetic and isonitrogenous. Higher inclusion of canola resulted in higher crude fibre and crude fat content in the diets. Phosphorus levels were also shown to increase with graded levels of CM.

Repeated measures analysis showed no significant ($P > 0.05$) week × diet interaction effect on AWFI, AWG and FCE. Diets significantly affected AWFI in weeks 7 and 8, but not in weeks 9 and 10 (Table 2) with diet CM175 promoting the least AWFI in weeks 7 and 8. Diet CM50 promoted the highest AWFI in weeks 7 and 8. Table 2 shows that there were no significant differences in weight gain and FCE across all weeks.

There was a significant dietary effect on overall feed intake. Table 3 shows that Quails fed CM50 had higher overall feed intake than those offered CM175. The quails fed CM50 had the same ($P > 0.05$) overall feed intake as those fed CM0, CM25 and CM125. However, quails fed CM175 did not significantly differ with those fed diets CM0, CM25 and CM125 in terms of overall feed intake. There was no dietary effect ($P > 0.05$) on overall weight gain and FCE for the entire duration of the study.

For haematological parameters, diet had no significant effect on erythrocytes, haemoglobin, haematocrit, MCV, MCH and MCHC of Japanese quails.

With the exception of alkaline phosphatase (ALP), all biochemical parameters were not ($P > 0.05$) influenced by experimental diets (Table 4). Quails fed CM25 had higher ALP compared to those fed CM0. The quails fed diet CM0 had the same ($P > 0.05$) ALP levels as those fed CM50, CM125 and CM175. The birds fed CM25 did not significantly differ with those fed diets CM50, CM125 and CM175 in terms of ALP content.

Table 5 shows that there were no significant dietary effects on the size of internal organs of quails with the exception of length of small intestines. Quails fed CM50 had the longest small intestines, which did not differ ($P > 0.05$) with those fed CM0. However, the size of small intestines in quails fed CM0 was similar ($P > 0.05$) to those fed CM25, CM125 and CM175. Carcass characteristics and dressing out percentages were not influenced by diets ($P > 0.05$).

For meat quality parameters measured immediately after slaughter, experimental diets had no significant effect on meat pH, temperature, L*, a*, b*, chroma and hue angle of Japanese quails. However, Table 6 shows that meat quality traits measured 24 h post slaughter with the exclusion of meat pH and chroma were not affected ($P > 0.05$) by dietary treatments. Quails fed CM25 had the same ($P > 0.05$) meat pH as those fed CM0 and CM175. Quails fedCM50 and CM125 had the same ($P > 0.05$) meat pH as those offered CM0 and CM175. Meat from Quails fed diet CM25 had higher chroma than those fed diet CM125. However, quails fed CM25 did not differ ($P > 0.05$) from those fed CM0, CM50 and CM175 in terms of meat chroma.

Dietary treatments had no influence ($P > 0.05$) on cooking losses and peak positive force. Cooking losses ranged from 16. 63% to 21.07%. The peak positive force ranged from 4.69 to 5.62 N.

4. Discussion

Determination of growth performance, haematological and biochemical parameters of quails is essential in order to evaluate the effectiveness of diets in optimising bird performance without compromising their health. Including CM in poultry diets at higher levels may be necessary to ensure adequate digestible

Table 2
Weekly feed intake, weekly weight gain and weekly feed conversion efficiency (FCE) in Japanese quails fed graded levels of canola meal (CM).

Item	CM0	CM25	CM50	CM125	CM175	SEM	Significance
Feed intake, g							
Week 7	197.8^{ab}	198.3^{ab}	221.9^{b}	219.4^{b}	188.1^{a}	6.20	**
Week 8	198.3^{ab}	197.0^{ab}	215.6^{b}	212.7^{b}	176.4^{a}	8.30	*
Week 9	216.8	212.7	239.1	212.9	201.3	9.09	NS
Week 10	221.1	207.4	243.0	225.3	203.5	9.38	NS
Weight gain, g							
Week 7	39.68	41.31	46.66	40.25	41.06	4.608	NS
Week 8	18.89	19.37	19.07	21.79	13.50	3.092	NS
Week 9	9.00	6.58	2.85	8.62	6.17	1.862	NS
Week 10	7.93	4.80	5.91	1.32	5.60	2.609	NS
FCE							
Week 7	0.201	0.208	0.209	0.184	0.217	0.019	NS
Week 8	0.095	0.099	0.089	0.103	0.075	0.015	NS
Week 9	0.041	0.031	0.012	0.041	0.030	0.0072	NS
Week 10	0.036	0.026	0.025	0.005	0.027	0.012	NS

CM0 = control diet with no CM inclusion, CM25 = control diet in which 2.5% of soybean meal was replaced with CM; CM50 = control diet in which 5% of soybean meal was replaced with CM; CM125 = control diet in which 12.5% of soybean meal was replaced with CM; CM175 = control diet in which 17.5% of soybean meal was replaced with CM; SEM = standard error of the mean; * = ($P < 0.05$); ** = ($P < 0.01$); NS = not significant.
[a,b] Within a row, different superscripts denote significant differences ($P < 0.05$) between dietary treatments.

Table 3
Overall feed intake, weight gain and feed conversion efficiency (FCE) of 10-week-old Japanese quails fed graded levels of canola meal (CM).

Item	CM0	CM25	CM50	CM125	CM175	SEM	Significance
Feed intake, g	833.9^{ab}	815.3^{ab}	919.6^{b}	870.2^{ab}	769.3^{a}	27.35	*
Weight gain, g	73.25	72.05	74.49	69.82	66.33	5.249	NS
FCE	0.361	0.361	0.335	0.321	0.349	0.024	NS

CM0 = control diet with no CM inclusion, CM25 = control diet in which 2.5% of soybean meal was replaced with CM; CM50 = control diet in which 5% of soybean meal was replaced with CM; CM125 = control diet in which 12.5% of soybean meal was replaced with CM; CM175 = control diet in which 17.5% of soybean meal was replaced with CM; SEM = standard error of the mean; * = ($P < 0.05$); NS = not significant.
[a,b] Within a row, different superscripts denote significant differences ($P < 0.05$) between dietary treatments.

Table 4
Effect of experimental diets on serum biochemical parameters of 10-week-old Japanese quails.

Biochemical parameters	CM0	CM25	CM50	CM125	CM175	SEM	Significance
ALB, g/L	22.00	22.43	18.13	20.0	23.91	1.84	NS
ALP, U/L	37.25^{a}	161.0^{b}	111.1^{ab}	112.9^{ab}	81.82^{ab}	23.48	**
ALT, U/L	41.13	50.29	44.5	37.43	40.82	11.22	NS
AMYL, U/L	588.4	658.4	479.7	557.1	594.0	125.3	NS
CA, mmol/L	2.45	2.98	2.69	2.50	2.41	0.206	NS
CHOL, mmol/L	4.92	3.93	3.55	3.1	3.34	0.691	NS
CREA, μmol/L	11.63	12.43	19.38	15.0	16.36	3.68	NS
GLOB, g/L	30.0	32.29	25.13	27.71	31.0	2.59	NS
GLU, mmol/L	3.85	2.05	3.19	1.50	3.23	1.10	NS
LIPA, U/L	234.9	266.0	255.3	310.3	296.5	43.0	NS
PHOS, mmol/L	4.77	5.20	5.13	5.20	5.15	0.182	NS
TBIL, μmol/L	53.4	59.0	24.3	33.4	65.8	12.82	NS
TP, g/L	52.0	54.71	43.25	47.71	54.91	4.32	NS
Urea, mmol/L	1.28	1.74	1.23	1.63	1.85	0.347	NS

CM0 = control diet with no canola meal inclusion, CM25 = control diet in which 2.5% of soybean meal was replaced with canola meal; CM50 = control diet in which 5% of soybean meal was replaced with canola meal; CM125 = control diet in which 12.5% of soybean meal was replaced with canola meal; CM175 = control diet in which 17.5% of soybean meal was replaced with canola meal; SEM = standard error of the mean; ** = ($P < 0.01$); NS = not significant; ALB = albumin; ALP = alkaline phosphatase; ALT = alanine transaminase; AMYL = amylase; CA = blood calcium; CHOL = serum cholesterol; CREA = creatinine; GLOB = globulin; GLU = blood glucose; LIPA = lipase; PHOS = blood phosphorus; TBIL = total bilirubin; TP = total protein.
[a,b] Within a row, different superscripts denote significant differences ($P < 0.05$) between dietary treatments.

Table 5
Internal organs, carcass characteristics and dressing out percentage of 10-week-old Japanese quails fed graded levels of canola meal (CM).

Item	CM0	CM25	CM50	CM125	CM175	SEM	Significance
Gizzard, g	3.13	3.02	3.17	3.24	3.1	0.22	NS
Heart, g	1.56	1.81	1.56	1.8	1.6	0.16	NS
Liver, g	4.51	4.23	4.5	4.18	3.7	0.37	NS
Wing, cm	9.61	9.06	9.75	9.09	9.56	0.26	NS
Thigh, cm	3.91	3.8	3.85	3.73	3.7	0.14	NS
Small intestine, cm	17.4^{ab}	16.28^{a}	18.57^{b}	16.36^{a}	16.95^{a}	0.36	***
HCW, g	137	117	145.3	125.5	151	11.76	NS
CCW, g	134.6	116.1	143.7	123.3	147.4	11.39	NS
Dressing out, %	55.7	54.8	60.4	58.6	61.7	3.025	NS

CM0 = control diet with no CM inclusion, CM25 = control diet in which 2.5% of soybean meal was replaced with CM; CM50 = control diet in which 5% of soybean meal was replaced with CM; CM125 = control diet in which 12.5% of soybean meal was replaced with CM; CM175 = control diet in which 17.5% of soybean meal was replaced with CM; SEM = standard error of the mean; *** = ($P < 0.001$); NS = not significant; HCW = hot carcass weight; CCW = cold carcass weight.
[a,b] Within a row, different superscripts denote significant differences ($P < 0.05$) between dietary treatments.

Table 6
Effect of graded levels of canola meal (CM) on meat quality parameters of 10-week-old Japanese quails 24 h post slaughter.

Item	CM0	CM25	CM50	CM125	CM175	SEM	Significance
pH	6.48^{ab}	6.56^{b}	6.38^{a}	6.39^{a}	6.43^{ab}	0.035	**
Temperature, °C	16.83	19.83	18.76	17.93	18.55	0.297	NS
L*	50.89	49.35	48.23	49.36	49.49	1.036	NS
b*	5.48	6.79	4.13	3.09	4.01	0.707	NS
a*	2.4	2.71	2.63	1.62	2.16	0.437	NS
Chroma	6.06^{ab}	7.39^{b}	5.12^{ab}	3.58^{a}	4.72^{ab}	0.835	*
Hue angle	1.1	1.2	1.02	1.04	0.97	0.09	NS

CM0 = control diet with no CM inclusion, CM25 = control diet in which 2.5% of soybean meal was replaced with CM; CM50 = control diet in which 5% of soybean meal was replaced with CM; CM125 = control diet in which 12.5% of soybean meal was replaced with CM; CM175 = control diet in which 17.5% of soybean meal was replaced with CM; SEM = standard error of the mean; * = ($P < 0.05$); ** = ($P < 0.1$); NS = not significant; L* = lightness; b* = yellowness; a* = redness.
[a,b] Within a row, different superscripts denote significant differences ($P < 0.05$) between dietary treatments.

amino acids (Khosravi et al., 2016). However, in this study the highest inclusion level of canola (CM175) was seen to reduce AWFI, which could be a result of higher amounts of fibre levels and non-starch polysaccharides in the diet, and in line with the findings of Naseem et al. (2006). However, the negative effect on feed intake was not supported by the findings of Rojas et al. (1985) and Leeson et al. (1987), who reported that canola inclusion of 15% to 20% had no adverse effects on chickens. However, it is important to note the difference in bird species used in these studies because the digestive capacity of chickens and quails may differ when challenged with CM. Several studies have indicated that increased fibre levels reduce voluntary intake, particularly for simple non-ruminants, such as quails, which have limited ability to utilise fibrous diets (Sarıçiçek et al., 2005). Campbell and Slominski (1991) reported that ingestion of glucosinolates can lead to reduced feed intake and liver damage. However, it is important to note that there was no evidence of toxicity as measured by liver size and enzymes suggesting that any antinutritional factors present were not systemically harmful to the quails. Indeed, quails had similar liver weights and alanine transaminase across all experimental diets. This could be because the concentration of glucosinolates in canola has been reduced to very low levels through genetic selection (Campbell and Slominski, 1991). Phytic acid in canola is known to reduce calcium availability (Summers et al., 1988), and this could be the reason why Quails fed CM175 had generally low blood calcium levels. Quails had similar blood protein concentration; this is in line with reports that blood protein is not influenced by partial changes of protein in the diet (Bovera et al., 2007). Diets also had no significant impact on serum albumin; this is not surprising as there is a strong relationship between total protein and albumin (Omidi and Ansari nik, 2013). Bovera et al. (2007) reported that blood urea levels are elevated by increased dietary crude protein, which explains why diets had no significant effect on blood urea, and because the diets were isonitrogenous. High blood phosphorus in quails fed diets with canola can be explained by the inclusion of phytase enzyme, which breaks down phytate—a compound made up of more than 60% of phosphorus (Selle and Ravindran, 2007). The control diet was shown to generally promote high levels of blood cholesterol when compared to canola-based diets, suggesting that feeding canola to quails can reduce cholesterol levels in meat, which is a desirable outcome as far as consumers are concerned. Esonu et al. (2001) reported that haematological constituents demonstrate a physiological response of birds to internal and external environments such as type of feed and behavioural feeding patterns. However, in this study diets had no significant influence on haematological parameters, which fell within the normal range for quails. This suggests that inclusion of CM in place of soybean in quail diets does not negatively influence the physiological status of the birds. Also the noteworthy is the fact that serum creatinine levels were similar across experimental diets indicating that including canola in quail diets has no negative effect on kidney function. Meat quality parameters immediately after slaughter were not influenced by dietary treatments. However, diets were shown to influence the meat pH of 24 h post slaughter, suggesting that meat pH changes with storage time. The longest small intestines were observed in quails fed CM0 and CM50, which is surprising given that longer small intestines can be an adaptive mechanism to deal with increased amount of fibre, as longer small intestines were expected in quails fed higher levels of CM. Diets had no influence on peak positive force, suggesting that substituting SBM with CM does not negatively affect meat texture.

5. Conclusion

This study reveals that CM can be a potential replacement of soybean in Japanese quails' diets because growth performance, physiological status and meat quality parameters were not negatively affected when CM was included. However, precautions may need to be taken when high amounts of canola are used, given that the highest (175 g/kg) canola inclusion level was shown to reduce feed intake in quails. We suggest that the use of feed additives may improve the utilization of CM in quails allowing its inclusion at higher levels.

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