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Red milkwood (*Mimusops zeyheri*) seed meal can replace maize meal in Japanese quail finisher diets without compromising growth performance, feed economy and carcass yield

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ABSTRACT

Mimusops zeyheri is widely distributed in sub-Saharan Africa and its seed meal (MZSM) has a higher energy content than maize meal (MM). We evaluated the potential of MZSM to substitute MM in Japanese quail finisher diets by determining its effects on growth performance, feed intake (FI) and feed utilisation efficiency, abdominal fat deposition and carcass yield. In a completely randomised design thirty-two 5-weeks old male Japanese quail were allocated to four diets wherein MZSM replaced MM at 0%, 12.5%, 25% and 37.5% (gross energy basis) and fed *ad libitum* for 4 weeks. Initial and weekly body weight, final body weight (FBW) and daily FI were measured. Body weight gain (BWG), average daily gain (ADG) and feed conversion ratio (FRC) were computed. At the end of the trial, following a 4-hour fast, the quail were weighed then humanely slaughtered and dressed. Carcass weight and dressing percent were determined. Abdominal fat was weighed. MZSM did not affect ($P > 0.05$) the quail's FBW, BWG, ADG, FCR, carcass weight and dressing percent. MZSM at 37.5% inclusion decreased ($P < 0.0001$) FI in weeks 1 and 2 and total FI of the quail. Dietary *M. zeyheri* seed meal decreased ($P < 0.0001$) abdominal fat mass. Use of MZSM would be most economic at 37.5% inclusion because despite decreasing total FI, growth performance was similar to control. *M. zeyheri* seed meal can be used as a dietary energy source in Japanese quail finisher diets without compromising growth performance, feed utilisation efficiency and carcass yield.

1. Introduction

About 98% of the poor and undernourished in developing countries depend on poultry meat and eggs for animal-derived protein for human consumption (Achilonu, Nwafor, Umesiobi & Sedibe, 2018). In Sub-Saharan Africa (SSA) 80% of rural households are actively involved in chicken production (Kryger, Thomsen, Whyte & Dissing, 2010). In this region poultry farming is a viable enterprise for the self-employed (Bamidele et al., 2019). Commercial poultry production SSA and in South Africa (SA) is a significant contributor to gainful employment. The demand for broiler chicken meat continues to increase in SSA and SA and is envisaged to continue increasing annually up to 2050 (Thornton, 2010). Compared to red meats, broiler chicken meat is relatively more affordable as its price per unit mass is lower (Tan, De Kock, Dykes, Coorey & Buys, 2018). When compared to red meats, chicken meat has a higher protein, lower fat (saturated fat and cholesterol) content thus making it a healthier product (Kim, Do & Chung, 2017; Qi et al., 2018). Its high essential amino acids and essential fatty acids content (Alagawany et al., 2019; Kim et al., 2017) makes it an important source of these essential nutrients which are required for the normal development of the human brain in the foetus *in utero* and in growing children (Mazza, Pomponi, Janiri, Bria & Mazza, 2007). In addition to its affordability and a healthier nutrient profile, the demand of chicken meat in SSA is fuelled by an increase in human population, expansion of urban settlements and improvement in incomes (Thornton, 2010). Despite the South African poultry industry being the most developed in SSA, local production fails to meet demand and imports make up the deficit (Berkhout, 2019). Inspite of the more health beneficial nutritional profile of chicken meat compared to red meats, use of genetically improved chicken breeds in rural areas is beset with challenges of their high feed, housing and veterinary costs. This makes it costly for those at the risk of deficiency in animal protein intake to produce genetically improved chicken hence the need for alternative poultry species. Japanese quail have a short generation interval, are small and require less space and food compared to chicken (Sakamoto et al., 2018). However Japanese quail meat has more

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protein with a high concentration of essential fatty acids (Nasr, Ali & Hussein, 2017) and less saturated fat compared to chicken meat (Lonita, Popescu-Miclosana, Roibu & Custrura, 2008). They thus can be farmed as sources of protein for human consumption, especially in resource-limited rural and urban communities of SSA.

Cereal grains which are a staple food source in SSA constitute 60–75% of poultry feeds (Panda, Zaidi, Rama Rao & Raju, 2014). These cereal grains which are dietary energy sources in poultry feeds, account for 70–80% of the poultry production costs (Baéza et al., 2015; Begli, Torshizi, Masoudi, Ehsani & Jensen, 2016). The high contribution of cereals in poultry diets and the huge cost of dietary energy in poultry feeds limit the potential exploitation of quail as sources of meat and eggs for human consumption in resource poor communities. In order to facilitate the production of Japanese quail and mitigate the challenge of deficiencies of protein of animal origin in rural communities, alternative non-conventional dietary energy sources for poultry feeds need to be developed (Onunkwo, Anyaegbu, Adedokun & Odukwe, 2015). Sub-Saharan Africa is richly endowed with indigenous fruit bearing trees (IFBTs) whose seeds are potential sources of nutrients (Chivandi et al., 2010). The Red milkwood (*Mimusops* zeyheri), an IFBT, is widely distributed in SSA (Janick & Paull, 2008) and its fruit pulp is consumed by animals, birds and humans (Chivandi, Davidson, Pretorius & Erlwanger, 2011). Findings from our laboratory have shown that the seed meal from dehulled *M. zeyheri* seed has a protein content (9.3%) similar to that of maize but a higher energy (24.34 ± 0.56 MJ/kg DM *vs* 17 MJ/kg DM) and calcium content (Chivandi, Davidson & Erlwanger, 2011). Thus *M. zeyheri* seed meal can potentially be used as a calcium-rich dietary energy source in quail feeds. However plant-derived non-conventional nutrient sources, including *M. zeyheri* seeds, contain phytochemicals which can have anti-nutritional effects (Chivandi, 2012) that may compromise feed intake and utilisation efficiency as well as productive performance. We therefore evaluated the potential of *M. zeyheri* seed meal (MZSM) to partially replace maize meal (MM) as a dietary energy source in Japanese quail finisher diets by determining its effects on feed intake and feed utilisation efficiency, growth performance, carcass yield and abdominal fat deposition in Japanese quail.

2. Material and methods

2.2. Mimusops zeyheri seed: source and chemical assays

M. zeyheri seeds used were extracted from fruits harvested from trees in Matopos National Park, Zimbabwe. Dehulled *M. zeyheri* seeds were ground into a meal using a blender (Household Grain Mill, Bioexcel, Jiangsu, China). The seed meal's proximate (dry matter, crude protein, ash and ether extract) content was determined as described by the Association of Analytical Chemists (AOAC, 2006: method numbers 934.01. 942.05, 954.01 and 920.39, respectively) and its fibre (NDF and ADF) content as described by Van Soest, Robertson and Lewis (1991). Its gross energy content were determined using a bomb calorimetry. Standard procedures were used to determine the calcium and phosphorus content of the *M. zeyheri* seed meal. Briefly, 0.5 g of the meal sample was digested in concentrated nitric acid and perchloric acid at 200 °C to generate the digest solution (Zasoski & Burau, 1977). The digest solution was then used to spectrophotometrically determine the calcium and phosphorus content of the *M. zyeheri* seed meal using inductively coupled plasma-atomic emission spectrometry (ICP-AES) on a Varian Liberty 200 spectrometer (Varian, Perth, Australia) as explained by Huang and Schulte (1985).

2.3. Sources of other feed ingredients and diet formulation

Maize grain (yellow), canola oil and salt (sodium chloride) were bought from Makro Wholesalers (Woodmead, Johannesburg, SA). Trouw Nutrition Group (Isando, Johannesburg, SA) supplied the vitamin-mineral premix, methionine and lysine. Wheat bran, feed grade limestone and soyabean meal were purchased from Meadow Feed Company (Johannesburg, SA). Prior to use the maize grain was milled. Four Japanese quail finisher diets (isocaloric and isonitrogenous) were formulated to meet the nutrient requirements of finishing Japanese quail as prescribed by the National Research Council (NRC,1994). In the diets MZSM replaced MM on a gross energy basis at 0%, 12.5%, 25% and 37.5%, respectively. Dietary ingredients (as fed) and chemical composition of the diets are shown in Table 1.

Table 1
Ingredient and chemical composition of the diets.

Ingredients (g/kg)	Dietary treatments			
	Diet 1	Diet 2	Diet 3	Diet 4
Soyabean meal	403.00	407.00	415.00	395.00
Yellow maize meal	410.00	364.00	316.00	263.00
M. zeyheri seed meal	0.00	36.00	74.00	110.00
	(0)	(12.5)	(25)	(37.5)
Wheat bran	136.00	145.00	147.00	201.00
Soyabean oil	21.00	19.00	18.00	4.00
Limestone	19.00	16.00	17.00	14.00
DL-Methionine, 99%	2.00	2.00	2.00	2.00
L-Lysine HCL 98.5%	1.00	1.00	1.00	1.00
Salt	4.00	5.00	5.00	5.00
Vitamin and mineral premix	4.00	5.00	5.00	5.00
Total	**1000**	**1000**	**1000**	**1000**
Calculated chemical composition				
Dry matter (g/kg)	924.60	914.30	902.30	907.50
Crude protein (g/kg)	240.50	240.40	240.60	240.60
Ether extract (g/kg)	46.10	50.60	57.00	62.90
Calcium (g/kg)	8.20	8.30	8.60	8.40
Phosphorus (g/kg)	4.60	4.40	4.20	4.20
Gross energy (MJ/kg)	17.03	17.02	17.02	17.07

The figures in parenthesis show the percent replacement of MM with MZSM on a gross energy basis. *M. zeyheri* seed meal inclusion is on a % gross energy contribution of maize meal.

2.4. Ethical clearance and quail management

The University of the Witwatersrand Animal Ethics Screening Committee awarded ethical clearance for the study (AESC number: 2017/08/56/B) and handling of the quail compiled with the internationally accepted Helsinki principles and guidelines in animal experimentation.

Thirty-two 5-weeks old male broiler quail used in the feeding trial were bought from Rockliff Farm, East London, South Africa and transported, with strict adherence to prescribed rules and regulations governing the movement of poultry and livestock between provinces in the country, to the University of the Witwatersrand's Central Animal Service. Each quail was individually house in a cage (60 cm x 60 m x 80m: length, with and height, respectively).The quail were given a 2-day habituation period during which they were treated with piperazine (Kyron Laboratories Pty Ltd, Johannesburg, South Africa), an anti-helminth, at 90 mg/L in drinking water. Each cage had a cardboard box for shelter and perches for environmental enrichment. Clean wheat straw was used for bedding which (bedding) was changed twice weekly. Feed and clean drinking water were provided *ad libitum* and room temperature was maintained at 25 ± 2 °C. A 12-hour lighting cycle was provided: with lights on from 19:00 h to 07:00 h.

2.5. Study design and measurements

The 32 five-weeks old male Japanese quail (mean initial body weight 156 ± 16.97 g) were, in an interventional completely randomised design, allocated to four dietary treatments ($n = 8$) wherein MZSM replaced MM on a gross energy basis 0%, 12.5%, 25% and 37.5%, for diets 1 through to 4 respectively and fed for 4 weeks.

2.5.1. Measurement of body weight

Following the determination of each bird's initial body weight (IBW) after the 2-day habituation period, each quail's body weight was measured twice weekly on an electronic balance (electronic balance (Snowrex EQ-1200, Snowrex International Company, Taipei, Taiwan) as part of the growth and health monitoring routine.

2.5.2. Determination of feed intake

Daily feed in (FI) of each quail was determined by subtracting refusals from the total feed given the previous morning. Feed offered and refusals were weighed on an electronic balance (Snowrex EQ-1200, Snowrex International Company, Taipei, Taiwan).

2.6. Computations: body weight gain, average daily and feed conversion ratio

The body weight gain (BWG) of each bird over the experimental period was computed using the equation: BWG = final body weight – initial body weight. Average daily gain (ADG) was computed using the equation: ADG (g) = body weight gain / duration (days) of feeding trial and FI was computed using the equation: FI (g) = feed offered – feed refusals; with feed offered weighed in the morning and refusal weighed the following day in the morning. Feed conversion ratio (FCR) was computed using the equation: FCR = feed intake (g) / weight gain (g).

2.7. Terminal procedures and measurements

At the feeding trial end, the quail were subjected to a 4-hour fast prior to slaughter but with *ad libitum* access to drinking water. Immediately following the fast each quail's final body weight (FBW) was measured. Each quail was then humanely killed by decapitation with a guillotine. Feathers were plucked out and each bird's abdomen was then dissected through a midline incision. Viscera and abdominal fat were carefully dissected out. The weight of the abdominal fat, and empty carcass weight were then determined on an electronic balance (Snowrex EQ-1200, Snowrex International Company, Taipei, Taiwan).

2.8. Statistical analysis

Data are presented as mean ± SD and data analysis was done using GraphPad Prism 5 software (Graph-Pad Software Inc., San Diego, CA, USA). Weekly within group data were analysed using repeated measures ANOVA and other multiple-group data were analysed using the one-way analysis of variance. The differences between the treatment means were determined using Tukey's *post hoc* test and significance was set at 5%.

3. Results

3.1. Chemical nutrient content of *M. zeyheri* seed meal

Table 2 shows the proximate, fibre, gross energy and calcium and phosphorus content of the *M. zeyheri* seed meal used as an ingredient in the experimental diets.

Table 2
Proximate, fibre, mineral and energy content of *M. zeyheri* seed meal.

Constituent	Mean ± SD
Proximate component (g/kg DM)	
Dry matter	957.20 ± 11.00
Organic matter	923.80 ± 9.00
Crude protein	92.00 ± 15.00
Ash	33.40 ± 3.00
Ether extract	252.80 ± 68.00
Fibre (g/kg DM)	
Neutral detergent fibre	243.40 ± 25.00
Acid detergent fibre	73.80 ± 14.00
Macro-minerals (g/kg DM)	
Calcium	85.00 ± 4.00
Phosphorus	14.00 ± 0.00
Energy (MJ/kg DM)	
Gross energy	24.18 ± 0.76

Data presented as mean ± standard deviation, DM – dry matter basis.

3.2. Performance measures: growth, feed economy and carcass yield

No mortality was recorded during the study. Table 3 below shows the effect of dietary MZSM on the growth performance [FBW, weekly and total BWG and ADG and on the feed economy [FI and weekly and FCR (trial)] of the quail. The effect of dietary MZSM on surrogate markers of meat yield (empty carcass and dressing percent) as well on abdominal fat mass are shown in Table 4. Dietary MZSM had no effect ($P > 0.05$) on the FBW, weekly and total BWG and ADG (weekly and trial) of the quail. In week 1 quail fed MZSM at 37.5% replacement of MM's gross energy contribution in the diet (diet 4) had the lowest ($P < 0.0001$) FI and in week 2 they still had significantly lower FI compared to counterparts fed MZSM at 0% and 12.5% of MM's energy contribution to the diets, respectively. Quail fed diet 3 and 4 (25% and 37.5% MZSM inclusion, respectively) had significantly lower ($P < 0.01$) total FI compared to counterparts feed diet 1. Dietary MZSM had no effect ($P > 0.05$) on the empty carcass mass and dressing percent of the quail but at all levels of replacement of MM's contribution to dietary energy it significantly reduced ($P < 0.0001$) the abdominal fat mass of the quail compared to that from quail fed the control diet.

4. Discussion

This study determined the chemical nutrient composition of dehulled *M. zeyheri* seed meal and the formulated test diets wherein the seed meal was used to partially substitute maize meal as dietary energy source in Japanese quail finisher diets. Dietary effects of the *M. zeyheri* seed meal on the growth performance, feed intake and utilisation efficiency and meat yield were evaluated. The proximate evaluation of the MZSM showed it to contain 24.18 ± 0.76 MJ/kg DM gross energy, 9.2% CP all comparable to the 24.34 ± 0.56 GE MJ/kg DM and 9.3% CP reported by Chivandi et al. (2011).These findings mirror those reported by Chivandi et al. (2011) and the seed meal's gross energy content was still found to be higher than that of maize meal.

We showed that dietary *M. zeyheri* seed meal did not affect the quail's FBW and their weekly and total BWG, ADG and FCR, carcass weight and dressing percent but at all levels of inclusion it decreased abdominal fat mass. Importantly at 37.5% inclusion, dietary *M. zeyheri* seed meal decreased FI of the quail in weeks 1 and 2 and total FI. These findings suggest that the partial dietary substitution of maize meal by dehulled *M. zeyheri* seed meal did not compromise the quail's growth performance as measured by FBW, BWG, ADG and FCR. Importantly, our findings suggest that it might be profitable to substitute maize meal with *M. zeyheri* seed meal at 37.5% for despite mediating significant decreases in weekly and total FI, growth performance, as measured by BWG and ADG, and feed utilisation efficiency as determined by FCR, were not compromised. This shows that the quail consumed less feed for similar growth; hence had more efficient feed utilisation. Compared to carbohydrates and protein, fats have a higher energy density. Diet 4 had the highest (computed) ether extract (fat) content. It could be therefore that at 37.5% inclusion, the quail met their dietary energy requirements at a lower feed intake. Unlike maize production which has added costs in tilling, sowing, weeding, fertilising and insect pest control, *M. zeyheri* seed meal can potentially be utilised at to replace maize at 37.5% (GE basis) in Japanese quail finisher diets to reduce the production costs. Birds are sensitive to the dietary energy concentration and adjust their feed intake to meet energy requirements (Leeson, Caston & Summers, 1996; National Research Council, 1994).

Table 3
Effect of dietary *M. zeyheri* seed meal on growth performance, feed intake and feed utilisation efficiency of Japanese quail.

Parameter	Week	Dietary treatments				Significance
		Diet 1	Diet 2	Diet 3	Diet 4	
Initial live weight		147.50 ± 19.68	151.50 ± 15.33	149.75 ± 22.4[a]	148.14 ± 14.61	ns
Final live weight		193.50 ± 16.87	192.75 ± 7.01	189.50 ± 12.46	185.64 ± 9.85	ns
Weekly BWG (g)	1	14.00 ± 3.21	12.25 ± 5.06	11.25 ± 4.86	8.91 ± 2.59	ns
	2	11.50 ± 7.54	10.50 ± 4.50	10.25 ± 5.18	10.88 ± 2.58	ns
	3	10.75 ± 4.40	9.25 ± 2.61	9.26 ± 3.20	9.43 ± 1.40	ns
	4	9.75 ± 4.33	9.24 ± 2.61	9.25 ± 3.19	8.88 ± 1.81	ns
Total BWG (g)		**46.00 ± 8.82**	**41.25 ± 11.06**	**39.75 ± 10.39**	**37.50 ± 6.21**	**ns**
Weekly ADG (g)	1	2.00 ± 0.46	1.75 ± 0.72	1.61 ± 0.69	1.26 ± 0.37	ns
	2	1.64 ± 1.08	1.50 ± 0.64	1.47 ± 0.74	1.55 ± 0.37	ns
	3	1.54 ± 0.63	1.32 ± 0.43	1.32 ± 0.46	1.35 ± 020	ns
	4	1.39 ± 0.62	1.32 ± 0.37	1.32 ± 0.46	1.26 ± 0.26	ns
ADG (Trial)		**1.64 ± 0.31**	**1.47 ± 0.40**	**1.42 ± 0.37**	**1.34 ± 0.21**	**ns**
Weekly FI (g)	1	124.07 ± 13.89[b]	120.27 ± 11.95[b]	113.66 ± 8.59[b]	85.40 ± 4.10[a]	***
	2	138.79 ± 16.83[b]	132.94 ± 9.01[b]	123.66 ± 11.04[ab]	115.57 ± 4.36[a]	**
	3	170.88 ± 11.26	162.06 ± 12.25	160.71 ± 7.79	157.42 ± 5.87	ns
	4	171.93 ± 15.19	166.66 ± 8.26	165.96 ± 8.54	164.88 ± 8.39	ns
Total FI (g)		**605.66 ± 34.98[b]**	**581.93 ± 26.77[ab]**	**563.99 ± 24.12[a]**	**557.56 ± 12.19[a]**	**
Weekly FCR	1	8.86 ± 2.09	9.82 ± 4.41	10.10 ± 2.73	9.58 ± 5.97	ns
	2	12.07 ± 7.69	12.66 ± 5.43	12.06 ± 4.05	10.62 ± 4.79	ns
	3	15.89 ± 4.96	17.51 ± 2.53	17.37 ± 2.49	16.69 ± 2.91	ns
	4	18.10 ± 3.61	18.01 ± 3.80	17.92 ± 5.66	18.56 ± 3.87	ns
FCR (Trial)		**13.10 ± 3.77**	**14.09 ± 2.32**	**14.11 ± 3.22**	**14.82 ± 1.95**	**ns**

ns = not significant, $p > 0.05$. ** $p < 0.01$. *** $p < 0.0001$.
[ab] Within row means with different superscripts are significantly different at $p < 0.05$.
ADG – average daily gain, BWG – body weight gain, FCR – feed conversion ratio, FI - feed intake. Diet 1 – 0% inclusion of *M. zeyheri* seed meal (control), Diet 2 – 12.5% *M. zeyheri* seed meal inclusion on energy basis, Diet 3 – 25% *M. zeyheri* seed meal inclusion on energy basis, Diet 4 – 37.5% *M. zeyheri* seed meal inclusion on energy basis, $n = 8$ for diet 1 to 3 and 7 for diet 4, data presented as mean ± standard deviation.

Importantly, the feed's dietary fibre content affects the birds' dietary energy intake (Rougière & Carré, 2010). Similarities in the quail's FBW, BWG, ADG and FCR across dietary treatments we report suggest that as an energy source *M. zeyheri* seed meal did not compromise dietary energy supply to the quail. Additionally its fibre content was of no consequence to the quails' ability to extract energy from nutrient digestion and absorption. In Japanese quail, an ADG of 1.2–23 g/day, FCR values ranging from 11.81–65.63 and empty carcass weight ranges of 116.40 g-127.52 g are reported (Mnisi & Mlambo, 2018; Almeida, Oliveira, Ramos, Veiga & Dias, 2002; Karthika & Chandirasekaran, 2016; Randall & Bolla, 2008; Vali, 2008). We report ADG, FCR and empty carcass mass ranges of 5.43 g-6.57 g, 9.20–22.57 and 124.71 ± 12.08 g-134.63 ± 20.07 g, respectively, which are within the ranges reported in literature. This further supports our assertion that *M. zeyheri* seed meal can potentially be exploited as an energy source in Japanese quail finisher feeds. In poultry and other livestock production, carcass yield is a critical performance trait as it estimates the potential product (meat) yield. In our study dietary *M. zeyheri* seed meal had no effect on empty carcass weight as well as dressing although at 37.5% inclusion (GE basis) it significantly decreased abdominal fat. The late growth phase is characterised by a decreased in lean deposition and an increase in fat deposition, especially abdominal fat. The critical goal in poultry production is to increase carcass yield and decrease abdominal fat mass (Fouad & El-Senousey, 2014) and it is known that abdominal fat positively correlates with carcass fat (Becker, Spencer, Mirosh & Verstrate, 1981). We report similarities in carcass yield across dietary treatments but with significant decrease in abdominal fat at 37.5% *M. zeyheri* seed meal inclusion. Two critical inferences can be drawn from our findings: dietary *M. zeyheri* did not compromise carcass yield and its use at 37.5% of the MM's GE contribution could potentially reduce carcass fat and possibly result in the production of leaner and healthier quail meat. Meat with less fat, especially saturated fats, is preferable considering the negative effects of fatty foods on consumer metabolic health. It is difficult to explain the decreased abdominal fat mass harvested from the quail carcasses fed *M. zeyheri* seed meal based diets. However, Acimovic, Kostadinovic, Puvaca, Popovic and Urosevic (2016) report that phytochemicals in feed ingredients decrease abdominal fat content in birds. Qualitative assays on the *M. zeyheri* seed meal used in the current confirmed the presence of flavonoids, saponins, tannins and terpenoids (Mdoda, 2019). We thus speculate that the significant decrease in the quails' abdominal fat yield with dietary *M. zeyheri* inclusion could have been mediated by the

Table 4
Effect of dietary *M. zeyheri* seed meal on empty carcass mass, dressing percent and visceral fat mass of Japanese quail.

Parameter	Dietary treatments				Significance
	Diet 1	Diet 2	Diet 3	Diet 4	
Empty carcass (g)	134.63 ± 20.07	131.38 ± 9.98	128.63 ± 12.65	124.71 ± 12.08	ns
Dressing percent (%)	70.05 ± 4.64	68.11 ± 3.48	67.81 ± 3.94	66.95 ± 3.46	ns
Abdominal fat (g)	2.75 ± 1.72[d]	1.29 ± 0.74[c]	1.43 ± 0.59[b]	0.27 ± 0.14[a]	***
Abdominal fat (%)	1.39 ± 0.85[d]	0.66 ± 0.37[c]	0.75 ± 0.30[b]	0.15 ± 0.07[a]	***

ns = not significant, $p > 0.05$. *** $p < 0.0001$.
[abcd]Within row means with different superscripts are significantly different at $p < 0.05$, Diet 1 – 0% inclusion of *M. zeyheri* seed meal (control), Diet 2 – 12.5% *M. zeyheri* seed meal inclusion on energy basis, Diet 3 – 25% *M. zeyheri* seed meal inclusion on energy basis, Diet 4 – 37.5% *M. zeyheri* seed meal inclusion on energy basis, $n = 8$ for diets 1 to 3 and 7 for diet 4, Data presented as mean ± standard deviation.

phytochemicals in the meal.

5. Conclusion

Dehulled *M. zeyheri* seed meal can be used to partially replace maize meal as a dietary energy source without compromising growth performance, feed utilisation efficiency and meat yield of male Japanese quail and its use is likely to be most economic at 37.5% dietary inclusion. Additionally the use of dehulled *M. zeyheri* seed meal could be potentially lead to the production of lean Japanese quail meat.

Ethical clearance

This study was cleared by the Animal Ethics Screening Committee and the birds were handled as prescribed by international conventions in the use of animal in experiments.

Declaration of Competing Interest

As authors we declare that there is no conflict of interest

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