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 replacement). Body weight gain (BWG), average daily gain (ADG) and feed conversion ratio (FCR) 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, 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 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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https://doi.org/10.1016/j.vas.2020.100128

Received 28 April 2020; Received in revised form 8 June 2020; Accepted 18 June 2020

Available online 20 June 2020

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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-Micolosan, Roibu & Castrura, 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 food 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 calorimeter. 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. zeyheri 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

| Table 1 | Ingredient and chemical composition of the diets. |
| --- | --- | --- | --- | --- |
| Ingredients (g/kg) | 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 |
| Wheat bran | (0) | (12.5) | (25) | (37.5) |
| Soyabean oil | 136.00 | 145.00 | 147.00 | 201.00 |
| Limestone | 21.00 | 19.00 | 18.00 | 4.00 |
| DL-Methionine, 99% | 19.00 | 16.00 | 17.00 | 14.00 |
| L-Lysine HCL 98.5% | 0.00 | 2.00 | 2.00 | 2.00 |
| 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 | 240.40 | 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 | 17.02 |

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 housed in a cage (60 cm x 60 cm x 80 cm: length, with and height, respectively). The quail were given a 2-day habituation period during which they were treated with piperazine (Kylon 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 light-dark cycle was provided: with lights on from 09:00 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: 

\[ BWG = \frac{\text{final body weight} - \text{initial body weight}}{\text{duration (days) of feeding trial}} \]

Average daily gain (ADG) was computed using the equation: 

\[ ADG (g) = \frac{\text{body weight gain}}{\text{duration (days) of feeding trial}} \]

Feed conversion ratio (FCR) was computed using the equation: 

\[ FCR = \frac{\text{feed intake (g)}}{\text{weight gain (g)}} \]

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 decapitiation 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.

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

**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)           | 24.18 ± 0.76   |

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

(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 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).
Importantly, the feed’s dietary ns = not signi- fied on empty carcass weight as well as dressing although effects of fatty foods on consumer health. meat. Meat with less fat, especially saturated fats, is preferable considering the negative effects of fatty foods on consumer 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 study confirmed the presence of flavonoids, saponins, tannins and terpenoids (Mldoda, 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 3
Effect of dietary M. zeyheri seed meal on growth performance, feed intake and feed utilisation efficiency of Japanese quail.

| Parameter                      | Diet 1                  | Diet 2                  | Diet 3                  | Diet 4                  | Significance |
|--------------------------------|-------------------------|-------------------------|-------------------------|-------------------------|--------------|
|                                | Week                    | Dietary treatments      |                         |                         |              |
| Initial live weight            | 147.50 ± 19.68          | 151.50 ± 15.33          | 149.75 ± 22.4          | 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)                 | 1.50 ± 3.21             | 12.25 ± 5.06            | 11.25 ± 4.86           | 9.81 ± 2.59             | ns           |
| Weekly ADG (g)                 | 1.10 ± 7.54             | 10.50 ± 4.50            | 10.25 ± 5.18           | 10.88 ± 2.58            | ns           |
| Total BWG (g)                  | 4.60 ± 8.82             | 41.25 ± 11.06           | 39.75 ± 10.39          | 37.50 ± 6.21            | ns           |
| Total FI (g)                   | 605.66 ± 34.98b         | 581.93 ± 26.77b         | 563.99 ± 24.12a        | 557.56 ± 12.19**        | **           |
| Weekly FI (g)                  | 124.07 ± 13.89b         | 120.27 ± 11.95b         | 113.66 ± 8.59a         | 85.40 ± 4.10a           | ***          |
| Weekly FCR                     | 1.64 ± 0.31             | 1.47 ± 0.40             | 1.42 ± 0.37            | 1.34 ± 0.21             | ns           |
| ADG (Trial)                    | 1.64 ± 0.31             | 1.47 ± 0.40             | 1.42 ± 0.37            | 1.34 ± 0.21             | ns           |
| Final live weight              | 193.50 ± 16.87          | 192.75 ± 7.01           | 189.50 ± 12.46         | 185.64 ± 9.85           | ns           |
| Weekly BWG (g)                 | 138.79 ± 16.83b         | 132.94 ± 9.01b          | 123.66 ± 11.04ab       | 115.57 ± 4.36e          | **           |
| Weekly ADG (g)                 | 1.54 ± 0.63             | 1.32 ± 0.43             | 1.32 ± 0.46            | 1.35 ± 0.20             | ns           |
| Total BWG (g)                  | 46.00 ± 8.82            | 41.25 ± 11.06           | 39.75 ± 10.39          | 37.50 ± 6.21            | ns           |
| Total FI (g)                   | 605.66 ± 34.98b         | 581.93 ± 26.77b         | 563.99 ± 24.12a        | 557.56 ± 12.19**        | **           |
| Weekly FCR                     | 1.64 ± 0.31             | 1.47 ± 0.40             | 1.42 ± 0.37            | 1.34 ± 0.21             | ns           |
| ADG (Trial)                    | 1.64 ± 0.31             | 1.47 ± 0.40             | 1.42 ± 0.37            | 1.34 ± 0.21             | ns           |

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"ns" = not significant, p > 0.05. *** p < 0.01. ** p < 0.0001.

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

| Parameter                      | Diet 1                  | Diet 2                  | Diet 3                  | Diet 4                  | Significance |
|--------------------------------|-------------------------|-------------------------|-------------------------|-------------------------|--------------|
|                                | Week                    | Dietary treatments      |                         |                         |              |
| 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             | 1.29 ± 0.74             | 1.43 ± 0.59             | 0.27 ± 0.14             | ***          |
| Abdominal fat (%)              | 1.39 ± 0.85             | 0.66 ± 0.37             | 0.75 ± 0.30             | 0.15 ± 0.07             | ***          |

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"ns" = not significant, p > 0.05. *** p < 0.0001.

"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

Acknowledgements

We acknowledge the technical assistance rendered by the University of the Witwatersrand’s Central Animal Service unit and the university’s Faculty of Health Sciences Research Committee and the National Research Foundation (RSA) for funding the study.

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