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CARCASS CHARACTERISTICS OF JAPANESE QUAILS (*COTURNIX COTURNIX JAPONICA*) FED DIETS CONTAINING DIFFERENT LEVELS OF MALTED RED SORGHUM AS AN ENERGY SOURCE

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ABSTRACT: This study evaluated the effects of five dietary levels of malted red sorghum (i.e., 0, 25, 50, 75, and 100%) on the carcass characteristics of Japanese quails raised under an intensive system. A total of 160 unsexed quail chicks were randomly assigned to five dietary treatments in a completely randomised design. After six weeks of feeding, carcass traits, external cuts, and internal organ weights were measured and analysed. The results showed no significant differences (P > 0.05) in live weight, hot carcass weight, and dressing out percentage across treatments. Similarly, the proportions of external cuts and most internal organs (gizzard, liver, heart, and spleen) were not affected by the dietary treatments. However, significant differences (P < 0.05) were observed in the weights of the bursa of Fabricius, caeca, and large intestines at inclusion levels of 0, 25, 50, 75 and 100%, suggesting possible physiological adaptations. Overall, these findings suggest that malted red sorghum can be a sustainable alternative feed ingredient for Japanese quails, with minimal negative impact on carcass quality and organ development.

Key words: Bursa of Fabricius, Carcass characteristics, Carcass yield, Japanese quail

1.INTRODUCTION

Japanese quails (*Coturnix coturnix japonica*) are becoming more popular in poultry farming because they grow quickly, mature early, and produce high-quality meat (Prabakaran and Ezhil, 2020). Quail's low maintenance cost, which is linked with its small body size (80-300 g), coupled with its short generation interval (3-4 generations per year), resistance to diseases and high egg production contributed to it being used as a laboratory animal (Vali, 2008). A previous study by Ioniţă *et al.* (2011) reported that quail meat, compared to chicken and duck meat, has a lower fat content and a higher amount of omega-3 fatty acids, vitamins A and C, making it a preferred healthy choice. Saeed *et al.* (2023) stated that oleic, linoleic, palmitic, and stearic acids are the most prevalent fatty acids in quail meat. Oleic acid accounts for approximately one-third of the total fatty acids in the quail breast meat, and it is 47.7 and 37.1% higher than in broiler and duck meat, respectively. Quail meat is considered good because of its high oleic acid content and is associated with a reduced risk of cardiovascular diseases.

According to Lima *et al.* (2023), quail meat has a moderate cholesterol level of about 64 to 72 mg per 100 grams of meat, which is lower than many other poultry meats. For example, chicken breast meat typically contains around 70 to 76 mg of cholesterol per 100 g, while duck meat has approximately 75 to 76 mg per 100 g. Pigeon breast meat, on the other hand, tends to have a lower cholesterol content, ranging from 23.6 to 44.4 mg per 100 g (Marareni *et al.,* 2024). These values suggest that quail meat is a relatively healthy option in terms of cholesterol content when compared to other common poultry meats. This makes it suitable for people who prefer to eat meat with lower cholesterol content (Vargas-Sánchez *et al.,* 2019).

As the demand for quail meat increases, farmers are looking for locally available feed ingredients to lower production costs without negatively affecting the birds' growth or meat quality. Maize is the main energy source in quail diets, but its price is rising because it is also used for both human and livestock consumption; hence, the search for alternative energy sources such as sorghum. According to Botswana Agricultural Marketing Board (2020), the retail prices per tonne for sorghum and maize are P2600 (USD 194.56) and P2500 (USD 187.08), respectively.

One promising option is malted red sorghum. Sorghum has a comparable price to maize and has better nutritional value after malting. Malting reduces anti-nutritional factors (ANFs) and enhances digestibility, making it easier for quails to absorb nutrients from their feed (Moses *et al.*, 2022). However, the inclusion of malted red sorghum in quail diets might affect carcass traits such as live weight and dressing out percentage, which are important for producers and consumers. Furthermore, the type of feed given to quails, especially the energy source, significantly affects important carcass traits such as live weight, dressing out percentage, breast muscle yield, and fat (Nasar *et al.*, 2016). These traits depend on the birds' genetics, management, and nutrition (Taleb *et al.,* 2024). Good carcass traits lead to improved meat quality, higher meat yield, and healthier birds (Khan *et al.,* 2023). These traits also help farmers make improvements in breeding, making quail meat safer and more nutritious. Moreover, the weight and size of the meat cuts affect the price and profit in the quail industry; hence, it is important to feed quails properly to help them efficiently grow muscle and fat. The type of energy source in quail diets has a major impact on these traits (Gharanjik *et al.,* 2024).

According to Mnisi *et al.* (2023), the quality of quail meat depends on a steady supply of energy, usually from grains. Malted red sorghum could become an alternative energy source with nutritional benefits comparable to maize. Therefore, this study aimed to evaluate the carcass characteristics of

Japanese quails fed graded levels of malted red sorghum in their diets under an intensive production system.

2.MATERIALS AND METHODS

The study was conducted following the Botswana University of Agriculture and Natural Resources' Ethics Committee's standards for the welfare and ethics of animals (Ethics Number BUAN-2020-08).

2.1. Experimental site.

The study was conducted at the Botswana University of Agriculture and Natural Resources (BUAN), Poultry unit, Content Farm Sebele, Gaborone, Botswana, from 30th October 2024 to 11th December 2024. BUAN is located 24°36' 40.90'S and 25' 13.35'E and is at an altitude of 994 m above sea level. Gaborone receives average annual rainfall of 538 mm with daily temperatures ranging between 18°C (minimum) and 32°C (maximum) (Mojeremane *et al.*, 2014; Monau *et al.*, 2017). The laboratory work was conducted in the nutrition laboratory of the Department of Animal Science, BUAN.

2.2. Experimental design and quail management.

A Completely Randomised Design (CRD) was used. A total of 160, 2-week-old unsexed Japanese quail chicks bought from a local farmer in Gaborone, Botswana, were individually weighed on arrival using an electronic scale (Mettler Pte. Ltd., Singapore) sensitive to 0.01g. The experiment comprised five dietary treatments, with each treatment consisting of 32 quails. Treatments were balanced for weight and replicated four times, with 8 chicks per replicate. Quails were housed in battery cages equipped with conical feeders and drinkers. Water and feed were supplied *ad libitum* while a continuous 24-hr. light was applied. Five experimental diets were used in this present study. The diets included control, as diet 1 (0% sorghum), diet 2 (25% malted red sorghum), diet 3 (50% malted red sorghum), diet 4 (75% malted red sorghum) and diet 5 (100% malted red sorghum). The starter, grower and finisher diets were fed from 2 to 4 weeks, 5 to 6 weeks, and 7 to 8 weeks, respectively. The ingredients and chemical composition are shown in Tables 1 and 2.

2.3. Slaughtering procedures and carcass measurements.

After a six-week feeding period (at the end of the trial period, i.e., 8 weeks of age), feed and water were removed 12 hours (hr.) before slaughter to allow for the digestive tract to clear. Three quails from each replicate of the five dietary treatments were randomly chosen and weighed (pre-slaughter weight) to obtain live weights (LW). Quails were transported to the BUAN slaughterhouse, where they were electrically stunned and humanely sacrificed by decapitation, involving the severing of both carotid arteries and jugular veins by a knife, following a procedure described by the EFSA Panel on Animal Health and Welfare (AHAW, 2024). Quail carcasses were scalded in hot water maintained at 70°C for 45 seconds to facilitate feather removal, following the method described by Walita *et al.* (2017). The carcasses were weighed after internal organs were removed using a sharp knife to obtain hot carcass weight (HCW). The carcasses were stored in a chiller at 4°C for 24 hrs. The internal organs, such as the bursa of Fabricius (BOF), caeca, gizzard, heart, large intestines, small intestines, liver, and spleen, were separated and weighed individually. After 24 hr. post-mortem, the carcasses were weighed again to determine cold carcass weight (CCW). The external cuts (drumstick, vertebrae, back, breast, thigh, and wing) were cut into individual portions (Mnisi *et al.*, 2023) and weighed. The dressing out (%) was calculated by dividing HCW by live weight (LW) and then multiplying by 100 (Benhura *et al.*, 2010; Moses *et al.* 2022).

The internal organs were obtained and weighed, and expressed as the fraction of LW (Tougan *et al.*, 2013) using the formula below.

Internal organs yield = (Organ weight (g)/ (LW (g)*100

The external cuts weight was obtained and expressed as the fraction of HCW (Moses *et al.,* 2022) as shown below.

External cuts yield = (Carcass part weight (g)/ (HCW (g)*100

2.4. Statistical Analysis.

Data on carcass traits, internal organs, and external cuts were analysed using one-way analysis of variance (ANOVA) to determine the effect of dietary treatments. The analysis was performed using General Linear Model (GLM) procedures of SAS software 9.4 (SAS, 2014) according to the following model:

$Yij = \mu + Ai + Eij$

Where Yij is the response variable (carcass parameters), μ is the overall mean, Ai is the treatment effect, and Eij is the error term. Treatment means were separated using Tukey's Studentized (HSD) Range Test. Furthermore, all the data were evaluated for quadratic and linear effects using polynomial contrasts. Response procedures for surface regression analysis (Proc RSREG; SAS 9.4, 2014) were performed to describe responses of parameters to malted red sorghum in the diets fed to Japanese quails following the quadratic model: $y = ax^2 + bx + c$, where y = response variables, a and b are the coefficients of the quadratic equation; c is the intercept; x is malted red sorghum (%). The significant differences were declared at $P < 0.05$.

3.RESULTS AND DISCUSSION

3.1. Carcass traits.

The effects of malted red sorghum on carcass traits of Japanese quails are presented in Table 3. Japanese quails fed diets with varying levels of malted red sorghum showed no significant difference ($P > 0.05$) in dressing out (%), LW and HCW. The regression analysis also showed no significant linear or quadratic trends ($P > 0.05$) for LW, HCW and dressing out (%) of Japanese quails fed diets containing different levels of malted red sorghum.

Although there appeared to be a numerical increase in LW with the inclusion of malted red sorghum, the differences were not significant ($P > 0.05$). In disagreement with the present results, Emami *et al.* (2012) found that quails on a 100% decorticated brown sorghum diet showed significantly higher LW and carcass dressing out (%) compared to those on control diets.

Dietary treatments did not affect ($P > 0.05$) the HCW of Japanese quails. This result is consistent with the previous study by Emami *et al.* (2012), who found that reconstituted (malted) sorghum grain can effectively replace maize in quail diets without negatively affecting carcass traits (HCW, dressing out (%), breast and thigh muscle yield). The lack of notable differences in HCW implies that protein accumulation and overall tissue development in Japanese quails were not negatively affected by the malted red sorghum inclusion levels.

No significant differences ($P > 0.05$) in the dressing out (%) were observed among the treatment diets. The findings on dressing out (%) align with those of Emami *et al.* (2012), who found that substituting maize with reconstituted (malted) sorghum grain did not negatively impact the dressing out (%) in Japanese quails. In another study involving broiler chickens, Moses *et al.* (2022) reported that malted sorghum-based diets yielded similar dressing out (%) to those of maize-based diets, further supporting the potential of malted red sorghum as a potential alternative energy source to maize in poultry diets.

3.2 External cuts.

The regression analysis exhibited that Japanese quails fed diets containing different levels of malted red sorghum showed no significant ($P > 0.05$) linear or quadratic trends for drumstick, vertebrae, back, breast, thigh and wing (Table 4). The results from Table 4 imply that dietary treatments had no significant ($P > 0.05$) impact on the proportions of drumstick, vertebrae, back, breast, thigh, and wing. These findings agree with those of Younis *et al.* (2019), who demonstrated that sorghum, including its malted or processed forms, can replace maize or other energy sources in quail diets without negatively affecting carcass composition or the yield of specific cuts. The consistency in the proportions of external cuts indicates that muscle development and carcass structure remained unaffected by varying levels of malted red sorghum, supporting its use as a feasible alternative feed ingredient in poultry diets. Moses *et al.* (2022) also reported that malted red sorghum had no significant negative impact on carcass yield or muscle development in poultry, thus emphasising its role as a sustainable alternative to conventional energy sources.

3.3 Internal organs.

The internal organs yield (%) relative to the HCW of Japanese quails fed varying levels of malted red sorghum diets are presented in Table 5. Dietary treatment did not affect ($P > 0.05$) gizzard, heart, small intestines, liver and spleen yield. These results suggest that increasing the levels of malted red sorghum did not affect the developmental size of the organs. A previous study by Khaleel *et al.* (2021) also found that the liver yield percentage did not vary despite dietary inclusion levels of sorghum. The findings on the spleen in the present study agree with those of Alamuoye and Ojo (2015), who reported consistent spleen yield percentages relative to the carcass in poultry fed diets with different fibre and grain compositions, indicating maintained immune function.

Notably, significant differences ($P < 0.05$) were observed in the bursa of Fabricius (BOF) percentages. The BOF yield percentage was significantly higher in Japanese quails fed on a 25% malted red sorghum diet, while those on the 50% malted red sorghum diet recorded the lowest yield (Table 5). Japanese quails fed the control, 75%, and 100% malted red sorghum diets had BOF percentages that did not differ ($P > 0.05$). The results on the BOF in the present study are consistent with those of Moses *et al.* (2022), who reported variations in organ weights and offal yield percentages when broilers were fed malted sorghum diets, with some sorghum varieties causing increases in certain organ weights, which may also be the case with quails. The variations in BOF percentage with different dietary levels of sorghum may indicate subtle immunomodulatory effects linked to diet composition. Furthermore, Alamuoye and Ojo (2015) highlighted that the BOF is sensitive to nutritional changes, which could explain the observed differences. The consistent BOF percentage observed across dietary treatments in the current study suggests that malted red sorghum, even at high inclusion levels, does not negatively affect the immune health of Japanese quails.

A significant difference ($P < 0.05$) in caecal yield percentage was observed among treatment groups, with Japanese quails fed 50% of a malted red sorghum diet showing the highest caecal percentage (0.81%) compared to other treatments. These findings agree with those of Khaleel *et al.* (2021), who found that dietary fibre affects the development of gut organs and immune response in quails. This indicates that diets high in fibre can lead to beneficial changes in gut morphology, such as possible enlargement of the caecum. The increased caecal percentage in this study may indicate improved fermentation ability and nutrient absorption, probably due to the dietary fibre found in malted red sorghum. This change could be a physiological adjustment to the nutrients provided by the sorghum-rich diet. The results on the caecal percentage are in agreement with those of Khaleel *et al.* (2021), who reported that the diet composition influences the development of gut organs and immune function in quails.

As shown in Table 5, the large intestine yield percentages were significantly higher ($P < 0.05$) in Japanese quails fed a 25% malted red sorghum diet, higher than the control diet, 75% and 100% malted red sorghum diets. These findings align with those of Khaleel *et al.* (2021), who demonstrated that moderate inclusion of sorghum (25-50%) or other fibrous feed components can promote the development of specific organs, such as the large intestine, possibly due to increased fermentative activity and microbial proliferation. However, higher levels of malted sorghum did not lead to larger intestines. Too much fibre might have reduced nutrient absorption or change gut movement, stopping further growth. This also explains why the caecum was larger for the 50% malted red sorghum diet but did not increase more with higher levels. Overall, moderate fibre content helps gut development, while elevated levels may have negative effects on digestion and organ size.

The percentage yield of the small intestine in the present study showed no significant differences (P > 0.05) among treatment diets. The lack of change in small intestine percentage in this study corresponds with the findings by Moses *et al.* (2022), who indicated that the small intestine is relatively resilient to change in dietary fibre, resulting in its functional integrity being maintained. The similarity in small intestines' mean weights indicates that the digestive and absorptive functions remained unaffected by the addition of malted red sorghum.

4.CONCLUSION

The findings of this study revealed that dietary inclusion of malted red sorghum did not significantly affect quail carcass traits. In addition, the internal organs, such as the gizzard, liver, heart, and spleen, were not negatively affected by the inclusion of malted red sorghum in quail diets. However, significant changes were noticed in the relative weights of the caeca, large intestine, and bursa of Fabricius across treatments, indicating some physiological adaptation to the dietary changes. Overall, these results suggested that malted red sorghum can replace maize as an energy source in Japanese quail diets without negatively affecting carcass traits.

Table (1): Ingredients and calculated composition of experimental diets of Japanese quails at different feeding phases

Ingredient	Diets		
	Starter	Grower	Finisher
Soya cake (46.5%)	77.90	49.41	27.14
Full-fat soya	32.40	37.80	37.80
Sunflower (36%)	5.40	5.40	8.10
Gluten (60%)	10.80	10.59	5.51
Lysine (SINT 78%)	0.68	0.73	0.82
Methionine (DL 98%)	0.85	0.68	0.59
Tryptophan	0.04	0.04	0.06
Threonine (98%)	0.07	0.19	0.23
Wheat bran	6.35	21.60	21.60
Feed Lime (Fine)	4.77	3.56	2.79
Mono Dicalcium Phosphate (WS>70%)	2.43	0.84	0.07
Salt (Fine)	0.50	0.45	0.39
Sodium bicarbonate	0.90	0.80	0.88
Choline CL (60%)	0.24	0.24	0.24
Cycostat (Robenidine 6.6%)	0.14	0.14	0.14
Toxfin	0.27	0.27	0.00
Salcurb Liquid	0.27	0.27	0.27
Intella Fit Plus (1 kg/tonne)	0.27	0.27	0.27
Broiler starter PMX1 + Gold + Syn (2 kg/tonne)	0.54	0.00	0.00
Broiler grower (2 kg/tonne)	0.00	0.54	0.54
Total (g/kg)	**144.82**	**133.82**	**107.44**
Calculated composition (%)			
Moisture	9.94	9.95	10.06
Protein	24.99	22.00	18.00
Fat	4.48	5.07	5.27
Calcium	1.00	0.75	0.60
Available phosphorus	0.55	0.44	0.35
Sodium	0.18	0.16	0.16
Chloride	0.21	0.21	0.21
Potassium	0.97	0.86	0.74
ME (MJ/Kg)	12.1	12.5	11.3

ME = Metabolisable Energy; PMX = Premix; WS = water solubility.

Note: Basal diets were formulated without malted sorghum and maize. After formulation, each phase diet was divided into five portions (50 kg bags), and malted sorghum was added at 0, 25, 50, and 100% levels by replacing white maize on a weight-to-weight basis.

Table (2): Replacement levels of white maize with malted red sorghum in the diets of Japanese quails during the starter, grower, and finisher phases (kg per 50 kg of feed)

Diets	Ingredient	0%	25%	50%	75%	100 %
Starter	Maize	25.04	18.78	12.52	6.26	0.00
	Malted red sorghum	0.00	6.26	12.52	18.78	25.04
Grower	Maize	27.24	20.43	13.62	6.81	0.00
	Malted red sorghum	0.00	6.81	13.62	20.43	27.24
Finisher	Maize	32.51	24.38	16.26	8.13	0.00
	Malted red sorghum	0.00	8.13	16.26	24.38	32.51

Table (3): Effects of substituting maize with malted red sorghum in the diets of Japanese quails on carcass traits

Parameters	Malted Red Sorghum levels (%)					SEM	*p*-value	Significance	
	0	25	50	75	100			Linear	Quadratic
Live weight (g)	275.00	300.83	306.67	294.17	297.50	13.13	0.51	NS	NS
Hot carcass weight (g)	187.500	189.17	193.75	196.70	190.83	8.71	0.94	NS	NS
Dressing out (%)	68.18	62.88	63.18	66.87	64.14	2.50	0.94	NS	NS

Table (4): Means of external cuts yield (% of hot carcass weight, or otherwise stated) of Japanese quails fed diets containing different levels of red malted sorghum

External Cuts	Malted red sorghum levels (%)						*p*-value	Significance	
	0	25	50	75	100	SEM		Linear	Quadratic
Drumstick	4.59	4.82	4.36	4.22	4.73	0.21	0.24	NS	NS
Vertebrae	14.69	15.39	16.36	13.59	15.01	1.25	0.62	NS	NS
Back	12.22	12.32	12.03	12.62	13.55	0.86	0.74	NS	NS
Breast	33.85	34.38	36.28	32.94	35.02	1.36	0.49	NS	NS
Thigh	7.27	6.67	7.22	6.71	7.00	0.42	0.77	NS	NS
Wing	7.27	4.04	3.81	3.77	3.80	0.21	0.56	NS	NS

Diets: Diet 1 = (0% malted red sorghum), Diet 2 = (25% malted red sorghum), Diet 3 = (50% malted red sorghum), Diet 4 = (75% malted red sorghum), Diet 5 = (100% malted red sorghum); NS = not significant; SEM = Standard error of mean.

Table (5): Means of internal organs yield (% of live weights, or otherwise stated) of Japanese quails fed diets containing different levels of red malted sorghum

Internal organs (%)	Malted red sorghum (%)					SEM	p-value	Significance	
	0	25	50	75	100			Linear	Quadratic
Bursa of Fabricius	0.26[ab]	0.33[a]	0.21[b]	0.28[ab]	0.31[ab]	0.03	0.02	NS	NS
Caeca	0.59[b]	0.74[ab]	0.81[a]	0.66[ab]	0.58[b]	0.06	0.03	NS	**
Gizzard	1.99	2.10	2.08	2.03	1.82	0.10	0.31	NS	NS
Heart	0.76	0.74	0.77	0.80	0.87	0.04	0.14	**	NS
Large intestine	0.35[b]	0.54[a]	0.43[ab]	0.35[b]	0.35[b]	0.05	0.02	NS	NS
Small intestine	1.43	1.65	1.81	1.81	1.58	0.16	0.43	NS	NS
Liver	1.51	1.81	1.85	1.53	1.56	0.12	0.11	NS	**
Spleen	0.08	0.11	0.10	0.10	0.09	0.01	0.65	NS	NS

[ab]Means in the same row with different superscripts are significant ($p < 0.05$). Diets: Diet 1 = (0% malted red sorghum), Diet 2 = (25% malted red sorghum), Diet 3 = (50% malted red sorghum), Diet 4 = (75% malted red sorghum), Diet 5 = (100% malted red sorghum); SEM = Standard error mean; NS = not significant, ** = $p < 0.05$.

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