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Nutritive Value Of Meat From Quails Placed On Diets Boosted With Waterleaf Meal

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Abstract

Background: *The nutritive quality of meat from quails fed diets supplemented with waterleaf meal was assessed in this study.*

Materials and Methods: *Ninety unsexed Japanese quails aged 21 days were shared into three groups of 30 birds each. The groups were split into three replicates of 10 birds each. The waterleaf was harvested at 28 dap and mixed with commercial broiler chicken finisher diets to form dietary groups W0 or control (100% concentrate + 0% waterleaf), W20 (80% concentrate + 20% water leaf) and W40 (60% concentrate + 40% waterleaf). The three groups of quails were randomly allotted to the dietary groups using the Completely Randomized Design for the 21-day study. On the last day of the experiment, three quails per treatment were slaughtered and breast muscle meat used for evaluation of proximate composition, gross energy, mineral, cholesterol and cholesterol fractions. Data was analysed with SPSS statistical software. Means were compared using One-way ANOVA while Tukey Post-Hoc test was used to separate significant means.*

Results: *Results indicate that DM, CP, EE, ash, NFE and GE ranged from 25.00–26.17%, 18.96–19.16%, 3.14–4.61%, 1.93–1.98%, 0.38–0.88% and 5.80–5.52 MJ/kg, respectively, while the Na, K, Ca, P, Mg, Fe, Zn, Se, I, Cu and Mn values in mg/100g ranged from 54.67–55.08, 138.78–139.04, 21.52–22.08, 178.68–179.13 and 79.23–82.14, 3.40–3.64, 7.57–8.10, 0.065–0.077, 3.44–3.90, 2.70–3.04 and 8.21–9.05, respectively. The total cholesterol, HDL, LDL, VLDL and triglycerides in mg/100g as well as lipid peroxidation (MDA/g) ranged from 41.65–42.87, 27.50–41.27, 8.37–19.50, 12.70–14.20, 0.065–0.066 and 83.70–97.91, respectively. There were significant differences ($p<0.05$) among treatment means for all the parameters studied.*

Conclusion: *Supplementation with 40% waterleaf increased the CP, EE, GE, total cholesterol, HDL, LDL, VLDL and lipid peroxide while at 20%, ash, NFE, triglycerides and the minerals increased. It is concluded that though W40 had attractive CP and HDL values, W20 is recommended due to its better mineral profile and lower 'bad' cholesterol level.*

Key words: *Nutrient content, cholesterol profile, mineral, pastured poultry, forage*

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I. Introduction

The poultry industry is the most developed component of the Nigerian livestock sector– providing 25% of Nigeria's GDP contributed by agriculture (Masaki *et al*., 2020). Poultry production is also a fast means to satisfying the increasing demand for animal protein induced by increasing urbanization, growing middle class and projected increase in demand for meat (Mulder, 2017; Sahel Capital, 2015). Most poultry meat and eggs are supplied by domestic chickens, but a substantial share also comes from other poultry species such as ducks, turkeys, guinea fowl and quails. Hence, the relevance of these alternative poultry to stabilizing the rising animal protein deficit in the country need not be over emphasized. Their contribution to alleviating animal protein deficit in the country led to suggestions for diversification of investments in the poultry industry to include these lesser-used species. Practical heeding of this call, plus the outstanding qualities of quails, led to the introduction of Japanese quail into Nigeria by the Nigerian Veterinary Research Institute (Malik *et al*., 2018).

The advantages of quail meat and eggs for Nigeria are numerous. Quail meat and eggs contain first-rate protein, unsaturated fats, minerals and vitamins needed for proper nutrition of Nigerians (Ali and Abd El-Aziz , 2019; Priti and Satish, 2014). Eating quail eggs has been reported to improve eyesight, lift energy levels, support metabolism, minimize high blood pressure, detox the body, avert chronic diseases, diminish gastric ulcers, improve immunity, support sharp memory, activate brain power and calm nervous activity (Ali and Abd El-Aziz , 2019; Tunsaringkarn *et al*., 2013). Furthermore, quails are robustly healthy and naturally immune against most poultry diseases, thus minimizing the use of antibiotics and vaccines in their management (Mnisi *et al*., 2021; Mulaudzi *et al*., 2019). Comparatively, the domestic chicken is plagued by most poultry diseases, hence, can rarely be reared intensively, without investing hard in vaccines, and medicines like antibiotics (Mnisi *et al*., 2021).

To complicate matters, most of these medications are imported at high cost to Nigeria's foreign reserves, as the country's capacity to manufacture local veterinary pharmaceuticals is weak (Okereke *et al*., 2021).

However, sustainable quail production is threatened by high cost of feed, which accounts for more than 70% of the cost of producing quails (Mnisi *et al*., 2021). To minimize the cost of feeding quails, improve farmers' profits and increase the affordability of quail meat and eggs for those in need, alternative feeding systems such as pastured poultry have been recommended. Adoption of pastured poultry production system has been encouraged by the current public awareness on the ability of the system to enhance food quality, coupled with increased demand for organic poultry products and more assertive advocacy favouring pastured poultry production as a mean to improving the welfare of the birds. Though pastured poultry production enhances the selling prices of the products due to its organic labelling, the system needs more labour input to succeed, the birds have a heigthened risk for predator attacks while, the chickens are difficult to control and keep under check (Juber, 2022; El Jeni *et al*., 2021). To obviate this challenges to free-range pastured poultry production and still gain the advantages of pasturing poultry, some farmers harvest the forages and feed their birds under intensive management. One of such forages used for supplemental feeding of poultry is waterleaf. Waterleaf (*Talinum triangulare*) is a leafy vegetable belonging to the *Portulaceae* family, having succulent leaves with low fibre (Ekine *et al*., 2020). It is a rapidly maturing perennial herb vegetable with succulent stem, short and green leaves (Igwe *et al*., 2015). Waterleaf is rich in Ca, Mg, and K besides ascorbic acid and pyridoxine (Ikewuchi *et al*., 2017).

Waterleaf has been extensively tested on domestic chicken to understand its effects on blood chemistry, growth performance, carcass and meat quality (Ekine *et al*., 2020; Nworgu *et al*., 2015; Nworgu, *et al*., 2014a; Nworgu *et al*., 2014b; Etela *et al*., 2007). Meat quality according to Andersen *et al*. (2005) includes inherent properties of meat that determine the appropriateness of meat for consumption, additional processing, storage and retail display with a focus on safety, flavour, texture, water-holding capacity, colour, lipid content and composition, oxidation stability, uniformity and nutritive value. Other meat quality dimensions comprise environmental, ethical and animal welfare aspects of meat production process (Andersen *et al*., 2005). For example, it has been suggested that feeding forages to livestock produces stronger flavoured meat while higher energy density in diets causes weightier carcass, higher fatness and marbling (Kandeepan *et al*., 2009). It is a well established fact that feed (amount and type) consumed by livestock contributes to the quality of meat and meat products (Andersen *et al*., 2005; Kandeepan *et al*., 2009). But there are yet studies on the effect of waterleaf supplementation on the meat quality of broiler quails. This research assessed the nutritive value of meat from quails fed diets supplemented with fresh waterleaf meal. Results could be useful to landless urban and peri-urban farmers, focused on producing organic quail meat, using the cut-and-carry forage system.

II. Materials And Methods

Experimental site

This experiment was carried out at the Poultry Unit, University of Port Harcourt Teaching and Research Farm, Choba, Obio-Akpor Local Government Area, Rivers State. The farm is situated on latitude 4°47'21" North and longitude 6°59'55" East of the equator at 16m altitude. The site falls within the humid rainforest zone of West Africa with a long duration of rainfall (March-November) and a short dry season. Precipitation in September when the study took place averages 367mm in 182 rain days. The temperature ranges from 25-28°C with high relative humidity of more than 80% (Ijeomah *et al*., 2013).

Experimental animals and waterleaf

Ninety (90) brooded Japanese quails of mixed sexes at 21 days of age were used for the study. They were acquired from a local hatchery in Aluu, Ikwere Local Government Area of Rivers State, Nigeria. The waterleaf used for this study was cultivated at the Vegetable Unit, University of Port Harcourt Teaching and Research Farm, Choba, Obio-Akpor Local Government Area, Rivers State. The stems of waterleaf were planted in raised beds measuring 2m x 5m and spaced 15cm x 15cm. Poultry manure was used as fertilizer. These agronomic practices were carried out as reported by (Ndaeyo, 2013). At 28 days after planting, the plants were harvested fresh daily, air-dried to wilt overnight before feeding to the birds.

Experimental design

The study had one control (W0) and two treatments (W20 and W40). The three groups include: W0 (control): the birds were fed 100% concentrate feed with 0% waterleaf supplementation; W20: the birds were fed 80% concentrate feed supplemented with 20% water leaf; W40: the birds were fed 60% concentrate feed supplemented with 40% water leaf. The 90 birds were shared into three groups of 30 birds each. Each group was further divided into three replicates of 10 birds per replicate. At the start of the experiment, the birds were weighed, shared into three groups with the mean initial weight of three groups balanced so that the mean weights for the groups showed no significant difference ($p>0.05$). The group of birds were then randomly allotted to three dietary treatment groups (W0, W20 and W40). The experimental design was the Completely Randomized Design. The study lasted for 28 days.

Experimental diets and feeding

The commercial concentrate finisher diet upon analysis contained 22% crude protein and 2800 kcal ME/kg (Mondry, 2016). The finisher phase ranged from 4^{th}-6^{th} week of the birds' age. The water leaf was mixed at 0% (W0 or control group), 20% (W20 group) and 40% (W40 group). The birds were fed daily at 8.00 hours and 17.00 hours GMT +1. Clean fresh water was offered *ad-libitum*. The feeds were offered in 8-hole flip-top plastic feeders to prevent feed wastage by the birds, a serious issue in quail feeding. The wilted waterleaf was chopped before mixing with the feed at 0, 20 and 40% before being offered to the birds. The proximate composition of the concentrate feed and fresh waterleaf is shown in Table No. 1.

Table No 1: Nutrient content of proprietary broiler diet and fresh waterleaf

Components	Broiler finisher	Fresh waterleaf
DM (%)	89.45	9.88
CP (%DM)	20.95	21.40
EE (%DM)	5.74	1.90
CF (%DM)	6.86	10.88
Ash (%DM)	10.49	33.07
NFE (%DM)	55.96	32.75
GE (kcal/kg)	3028.00	n/a

Management and housing

Experimental birds were housed in wire cages. The quail house was cleaned regularly. Two weeks before the arrival of the birds, the poultry house was scrubbed and disinfected thoroughly with hot water and Hypo disinfectant solution and left to dry off. Also, the feeding troughs and drinkers were washed with the same water and disinfectant solution.

Collection of meat samples

On the last day of the experiment, three quails (one per replicate) per treatment whose weights were the closest to the group average were selected, isolated and fasted overnight while offered drinking water. The next day, they were slaughtered and dressed. Meat was collected from the breast muscle, chilled at 4°C for use nutritional evaluation.

Laboratory analysis of meat

The meat was analysed for dry matter, gross energy and proximate composition (crude protein, ash and ether extract) while nitrogen free extract was calculated by difference. Dry matter was determined by drying the samples at 105°C to a constant weight. The crude protein content was determined by the Kjeldahl method while ether extract was determined by the Soxhlet method. The ash content was determined by heating the samples overnight in an oven at 550°C. The determinations and calculations were according to AOAC (2005).

Some minerals (Ca, P, Na, K, Mg, Mn, Fe, I, Se, Cu, and Zn) were analysed according to the methods of Ribeiro *et al*. (2020). Flame photometer 410 was used for sodium, spectrophotometer for phosphorus while Perki-Elmer Atomic Absorption Spectrophotometer 2380 was used for calcium, manganese, iron and zinc.

Total cholesterol was analysed using the method of Fakolade (2015) wherein absorbance of the sample extract and working standard solutions were read on Spectron spectrophotometer at a wavelength of 625nm and cholesterol was calculated using the formula: Cholesterol (mg/100g) **=** Absorbance of sample extract **x** gradient factor **x** dilution factor ÷ weight of sample taken. The HDL, LDL, VLDL, triglycerides and lipid peroxidation were determined using analytical kits of Diamond Diagnostics, Holliston MA, USA as reported by Attia *et al*. (2017).

Data analysis

Data was analysed with Statistical Package for Social Sciences (SPSS) using descriptive statistics, while comparison of means was done using One-way Analysis of Variance (ANOVA) and Tukey Post-Hoc at 5% level of significance was used to separate significant means (IBM Corp, 2007). Data is presented in tables.

III. Results

Proximate composition of meat from quails fed diets supplemented with waterleaf

Table No. 2 shows the proximate composition and gross energy of meat obtained from quails fed diets supplemented with waterleaf meal. The results indicate that dry matter (DM), crude protein (CP), ether extract (EE), ash, nitrogen free extract (NFE) and gross energy (GE) ranged from 25.00–26.17%, 18.96–19.16%, 3.14–

4.61%, 1.93–1.98%, 0.38–0.88% and 5.80–5.52 MJ/kg, respectively. There were significant differences (p<0.05) among treatment means for all the parameters measured. W20 had the least (p<0.05) DM, CP and EE while W40 had the highest (p<0.05) values for these parameters. W40 recorded the lowest (p<0.05) ash and NFE while W20 had the highest (p<0.05) values for these indices. However, the ash content of W0 was not different (p>0.05) from those of W20 and W40. Also, the least (p<0.05) GE was recorded for W20 while W40 had the highest (p<0.05).

Table No 2: Proximate composition of meat from quails fed diets supplemented with waterleaf

	Waterleaf inclusion levels (%)				
Components	**W0**	**W20**	**W40**	***±SEM***	***p-value***
DM (%)	25.81^b	25.00^c	26.17^a	0.174	0.000
CP (%)	19.04^b	18.96^c	19.16^a	0.031	0.000
EE (%)	4.27^b	3.14^c	4.61^a	0.073	0.000
Ash (%)	1.96^{ab}	1.98^a	1.93^b	0.010	0.049
NFE (%)	0.57^b	0.88^a	0.38^c	0.230	0.000
GE (MJ/kg)	5.81^b	5.80^c	5.52^a	0.002	0.000

$^{a\,b\,c}$ Means in same row with different superscripts are significantly different (p<0.05); DM=dry matter; CP=crude protein; EE=ether extract; NFE= nitrogen free extract; GE= gross energy.

Macro-minerals in meat from quails fed diets supplemented with waterleaf

The macro-minerals profile of meat from quails fed diets supplemented with waterleaf is presented in Table No. 3. Results indicate that Na, K, Ca, P and Mg values of the meat in mg/100g ranged from 54.67–55.08, 138.78–139.04, 21.52–22.08, 178.68–179.13 and 79.23–82.14, respectively. There were significant differences (p<0.05) among treatment means for all the macro-minerals studied. Group W0 recorded the least (p<0.05) Na, K, Ca and P values while W40 recorded the least (p<0.05) Mg value. Also, group W20 had the most (p<0.05) values for all the macro-minerals.

Table No 3: Macro-minerals in meat from quails fed diets supplemented with waterleaf

	Waterleaf inclusion levels (%)				
Minerals (mg/100g)	**W0**	**W20**	**W40**	***±SEM***	***p-value***
Na	54.67^c	55.08^a	54.77^b	0.062	0.000
K	138.78^c	139.04^a	138.91^b	0.038	0.000
Ca	21.52^c	22.08^a	21.64^b	0.085	0.000
P	178.68^c	179.13^a	178.87^b	0.065	0.000
Mg	79.36^b	82.14^a	79.23^c	0.475	0.000

$^{a\,b\,c}$ Means in same row with different superscripts are significantly different (p<0.05); Na=sodium; K= potassium; Ca= calcium; P= phosphorus; Mg= magnesium

Micro-minerals in meat from quails fed diets supplemented with waterleaf

Table No. 4 shows the micro-mineral contents of meat from quails fed diets supplemented with waterleaf meal. The Fe, Zn, Se, I, Cu and Mn values in mg/100g ranged from 3.40–3.64, 7.57–8.10, 0.065–0.077, 3.44–3.90, 2.70–3.04 and 8.21–9.05, respectively. There were significant differences (p<0.05) among treatment means for all the micro-minerals studied. Group W20 had the highest (p<0.05) values for all the micro-minerals. However, the least (p<0.05) values Fe was recorded for group W0 while group W40 had the least values (p<0.05) for other micro-minerals studied.

Table No 4: Micro-minerals in meat from quails fed diets supplemented with waterleaf

	Waterleaf inclusion levels (%)				
Minerals (mg/100g)	**W0**	**W20**	**W40**	***±SEM***	***p-value***
Fe	3.40^c	3.64^a	3.58^b	0.036	0.000
Zn	7.68^b	8.10^a	7.57^c	0.080	0.000
Se	0.070^b	0.077^a	0.065^c	0.002	0.000
I	3.58^b	3.90^a	3.44^c	0.069	0.000
Cu	2.77^b	3.04^a	2.70^c	0.052	0.000
Mn	8.26^b	9.05^a	8.21^c	0.136	0.000

$^{a\,b\,c}$ Means in the same row with different superscripts are significantly different (p<0.05); Fe= iron; Zn= zinc; Se= selenium; I= iodine; Cu= copper; Mn= manganese

Cholesterol fractions in meat from quails fed diets supplemented with waterleaf

Cholesterol and its fractions in meat from quails fed diets supplemented with waterleaf meal are presented in Table No. 5. The total cholesterol (mg/100g), HDL (mg/100g), LDL (mg/100g), VLDL (mg/100g), lipid peroxidation (MDA/g) and triglycerides (mg/100g) values ranged from 41.65–42.87, 27.50–41.27, 8.37–19.50, 12.70–14.20, 0.065–0.066 and 83.70–97.91, respectively. There were significant differences (p<0.05) among treatment means for cholesterol and cholesterol fractions. Group W20 had the least (p<0.05) values for all the parameters studied, except triglycerides, whose least value was recorded for group W40. Meanwhile, group W40 had the highest ($p<0.05$) values for all the parameters except triglycerides whose highest ($p<0.05$) value was recorded for group W20.

Table No 5: Cholesterol and fractions in meat from quails fed diets supplemented with waterleaf

	Waterleaf inclusion levels (%)				
Fractions	**W0**	**W20**	**W40**	***±SEM***	***p-value***
Total cholesterol (mg/100g)	42.38^b	41.65^c	42.87^a	1.776	0.000
HDL (mg/100g)	38.20^b	27.50^c	41.27^a	2.087	0.000
LDL (mg/100g)	17.40^b	8.37^c	19.50^a	1.708	0.000
VLDL (mg/100g)	13.27^b	12.70^c	14.20^a	0.221	0.000
Lipid peroxidation (MDA/g)	0.066^b	0.065^c	0.066^a	0.008	0.000
Triglycerides (mg/100g)	84.97^b	97.91^a	83.70^c	2.272	0.000

[a b c] Means in the same row with different superscripts are significantly different (p<0.05); HDL= high density lipoprotein; LDL= low density lipoprotein; VLDL= very low-density lipoprotein

IV. Discussion

The DM of the meats were within the range reported for different quail strains, productive types, and those fed herbs and forages (Vargas-Sanchez *et al*., 2019; Lukanov *et al*., 2023; Lukanov *et al*., 2018). In this study, the DM improved at 40% level waterleaf, but decreased at 20% level. According to Sabow *et al*. (2021), the DM of meat improved when different levels of dietary *Lactuca seriola* leaves were fed to quails. Nevertheless, improvement in DM content of the meat at 40% waterleaf dietary supplementation may be explained by the exposure of W40 quails to energy deficiency stress. According to Vargas-Sanchez *et al*. (2019), nutrition stress (including energy stress) could affect the chemical composition of meat.

The CP contents were marginally lower than reported for meat from quails fed *Lactuca seriola* leaves (Sabow *et al*., 2021) but within the range for quails of different strains fed herbs and forages and those managed under tropical conditions (Vargas-Sanchez *et al*., 2019; Lukanov *et al*., 2023; Lukanov *et al*., 2018; Gungoren *et al*., 2023; El Tahawy, 2022). The minor differences in CP between this study and the *Lactuca seriola* leaves study could be due to the type of plant fed to the quails and level of inclusion (Sabow *et al*., 2021; Ndaeyo, 2013; Tufarelli *et al*., 2018), which were different in the two studies. The CP content was improved at 40% level of waterleaf inclusion but reduced at 20% level. Though the reduction in CP at 20% level could not be attributed to any obvious reason, the increase in the CP at 40% level might be due to the supplemental protein consumed in the waterleaf and endowed on the meat. This is because according to Tufarelli *et al*. (2018) and Vargas-Sanchez *et al*. (2019), poultry increase forage intake to increase protein intake, when fed low protein diets. Moreso, it has been reported that most commercial poultry diets are deficient in crude protein (Onukwru *et al*., 2022). This is collaborated by the protein content of the commercial concentrate and waterleaf in Table 1.

The EE content was comparable to values obtained for meat of quails fed herbs, forages and natural ingredients, of different ages and sex, reared in the tropics as well as those fed diets supplemented with leaves (Vargas-Sanchez *et al*., 2019; Fakolade, 2015; Genchev *et al*., 2008; Güngören *et al*., 2023; Lukanov *et al*., 2018; Sabow *et al*., 2021). Similar to the trend in DM and CP, the EE increased at 40% level of waterleaf supplementation but decreased at 20% level compared with the control. Nevertheless, all the levels of EE were similar to those reported in most literature, thus affirming the low-fat content of quail meat (Santhi and Kalaikannan, 2017), its key selling point. Hence, the increase in EE at higher level of waterleaf could not have serious implication on the meat because the figure fell within the acceptable range for quail meat.

The ash contents were similar to values reported for quails fed *Lactuca serriola* leaves, of different strains, sex and productive use and reared in the tropics (Sabow *et al*., 2021; Güngören *et al*., 2023; Lukanov *et al*., 2018; El Tahawy, 2022; Lukanov *et al*., 2023). Increasing the level of waterleaf inclusion from 20% to 40% decreased ($p<0.05$) the ash content without obvious reason. But, ash values of both levels of inclusion were similar ($p>0.05$) to the control. This agrees with Sabow *et al*. (2021) that dietary supplementation of quail feed with forages could not change the ash content of the meat.

NFE and starch in meat emanates from animal feed of plant origin, dietary spices and muscular glycogen that is high in rested animals (Miron *et al*., 2004). The NFE values observed in this study were within the range reported in literature (Lukanov *et al*., 2018; El Tahawy, 2022) except W0 and W20 values. The higher levels could not be directly attributed to any reason. However, increasing supplementation of quail diets with waterleaf above 20% level reduced the NFE content. This agrees with Englmaierova *et al*. (2021) that replacing cereal-based diets with forage at more than 20% could not further improve meat quality indices such as NFE.

The GE content of the meats were similar to values reported in literature for different quail lines (Lukanov *et al*., 2018) but lower than that of meat from quails of different sexes and productive types (Lukanov *et al*., 2023). According to Lukas *et al*. (2021), GE content emanates from the organic matter of feed jointly contributed by NFE, CP, CF and EE. Except NFE, all other indices contributing to the GE were highest ($p<0.05$)

for the W40 group. Hence, the higher GE content for W40 could be a carryover effect from the high level of those indices recorded for the W40 group.

The Na of quail meat increased at 20% level of waterleaf inclusion but decreased when the level increased to 40%. The Na contents were close to the figure reported for wild quail and higher than value for farmed quail (Quaresma *et al*., 2022). Differences could be because though farmed, the quails in this study were fed waterleaf, similar to wild quails that feed on forages. This forage feeding regime may have enhanced the Na (mineral) content of their meat (Vargas-Sanchez *et al*., 2019).

Potassium supports normal levels of fluids within cells, muscle contraction and normal blood pressure (FAO/WHO, 2001). The quail meat K increased with inclusion of waterleaf at 20% level then reduced when the waterleaf level was further increased to 40%. Compared to literature values of farmed and wild quails, these values were low (Lukanov *et al*., 2023; Quaresma *et al*., 2022). Difference could be attributed to diverse nutritional exposure for the wild quails (Tufarelli *et al*., 2018), compared to quails in this study, which were confined in cages.

Calcium plays a role in bone mineralization, supporting the skeleton and serving in metabolic processes of the body (FAO/WHO, 2001). The calcium content of the meat increased to the peak at 20% level of waterleaf and reduced when the waterleaf level was further increased to 40%. Compared to literature values, the Ca contents were comparable to values for wild quail but higher than those for farmed quails (Quaresma *et al*., 2022). Differences could be attributed to the supplementation of quails in this study with forage similar to pasturing by wild quails (Vargas-Sanchez *et al*., 2019). This would likely have increased the Ca content in the meat, compared to the control group, but decreased at further increase to 40% because according to Englmaierova *et al*. (2021), replacing cereal-based diets with forage at more than 20% could make no further impact.

Phosphorus play roles in formation of bone and teeth as well as support carbohydrate and fat metabolism (FAO/WHO, 2001). The phosphorus contents of quail meats in this study were lower than values reported for wild and farmed quails (Quaresma *et al*., 2022), but higher than values reported for meat from various lines of domestic quails (Lukanov *et al*., 2023). Differences can hardly be attributed to a specific reason. Nevertheless, inclusion of waterleaf in the diets of quails improved the P content of the meat. However, the increase was more at W20 than at W40 level. All the same, the increase could be attributed the inclusion of fresh waterleaf said to be rich in phosphorus and calcium (Ndaeyo, 2013).

Magnesium plays a role in biochemical reactions of the body, helps to maintain normal nerve and muscle function as well as support healthy immune system (FAO/WHO, 2001). Dietary inclusion of 20% waterleaf in quail diets increased Mg content but at 40% level of inclusion, the Mg level in the meat fell below the control group. This agrees with Englmaierova *et al*. (2021) that forage inclusion in poultry diets made no additional impact beyond the 20% level of inclusion. Nevertheless, compared to literature, the Mg content of the meat in this study was higher than wild and farmed quails (Quaresma *et al*., 2022) but lower than other quails of different sexes and strain (Lukanov *et al*., 2023). This implies that the differences observed in the values could not be traced to obvious reasons. On the whole, inclusion of waterleaf in the diets of quails improved the macro-mineral content of quail meat up till 20% level which started declining at 40% level of inclusion.

Iron is a basic component of haemoglobin, important for children brain development, hormones and cells metabolism (FAO/WHO, 2001). The Fe contents in this study were lower than values reported for meat from wild, farmed and several strains of quails (Quaresma *et al*., 2022; Sabow *et al*., 2021), yet higher than values reported for farmed *Coturnix japonica domestica*. Differences might be attributed to the breed of quails because several authors have identified breed and strain as differentiating factor for quail meat quality (Quaresma *et al*., 2022; Sabow *et al*., 2021). Inclusion of waterleaf in quail diets increased Fe content to peak at W20. Further increases in waterleaf to W40 reduced the Fe content, but, still above that of the control. This implies that inclusion of waterleaf need not exceed 20% to amass maximum Fe in the meat.

Zinc is required for DNA formation, cells growth, protein synthesis, rebuilding of damaged tissues and boosting the immune system (FAO/WHO, 2001). The Zn contents of the meats were higher than values reported for quail meat in several literature (Quaresma *et al*., 2022; Genchev *et al*., 2008; Sabow *et al*., 2021; Vargas-Sanchez *et al*., 2019). Differences may be attributed to breed and farming systems differences (Lukanov *et al*., 2023; Santhi and Kalaikannan, 2017). In addition, Zn content increased upon inclusion of 20% waterleaf but decreased below W0 at 40% waterleaf. This supports the report by Englmaierova *et al*. (2021) that including forage in poultry diets beyond 20% adds nothing to meat quality.

Copper is a co-factor in several enzymes engaged in energy synthesis, iron metabolism, synthesis of neurotransmitters and connective tissues (FAO/WHO, 2001). The Cu contents in the meat were higher than reported in various literature (Vargas-Sanchez *et al*., 2019; Lukanov *et al*., 2023; El Tahawy, 2022). The higher values could be due to quail breeds and farming systems as they impact mineral metabolism in meat (Lukanov *et al*., 2023; Santhi and Kalaikannan, 2017). The Cu increased with inclusion of 20% waterleaf but decreased lower than the control as the waterleaf level peaked at 40%. This is in consonance with reports by Englmaierova *et al*.

(2021) in poultry diets supplemented with forage, meat quality was not affected beyond the 20% level of forage inclusion.

Manganese functions in enzyme systems, metabolism of lipids and carbohydrates and play roles in growth and bone development (Olgun, 2017). The Mn contents of the meats were higher than reported in literature (Quaresma *et al*., 2022). Differences could be due to breed of quails or the farming system as some breeds and management systems retain some minerals in meat than others (Lukanov *et al*., 2023; Santhi and Kalaikannan, 2017). Like in other micro-minerals, Mn increased with inclusion of 20% waterleaf but decreased below the control value when the waterleaf was added to feed at 40%, agreeing with Englmaierova *et al*. (2021) that supplementing diets with forage beyond 20% would unlikely further improve meat quality, including minerals.

The iodine contents of meat in this study were higher than values reported for poultry meat elsewhere (Herzig *et al*., 2007). Differences might be due ability of quails to utilize I more efficiently from this source, effects of goitrogens in the feed and environmental contexts of the feed (Herzig *et al*., 2007). Nevertheless, the impact of supplementary I on meat is not conclusive (Herzig *et al*., 2007).

Selenium neutralizes the toxic effects of heavy metals, ameliorates side effects of vaccinations and thwarts tumours (Ahmad *et al*., 2018). The Se contents in the meat were comparable to values reported for chicken meat (Saeed *et al*., 2024). The Se content increased at 20% level of waterleaf but decreased to a level lower than the control when the waterleaf level was increased to 40%. This agrees with Englmaierova *et al*. (2021) that replacing cereal-based diets with forage beyond 20% could not further improve meat quality. In summary, the Zn, Se, I, Cu and Mn contents of the meat increased to the peak as diets were supplemented with 20% waterleaf but decreased below the control at 40% level.

Total cholesterol contents of the meats were comparable to values reported for meat-type quails, but higher than values reported for dual-purpose and layer-type quails (Lukanov *et al*., 2023). Differences might be due to breed as quails used for the present study were of the meat-type breed. According to Rehman *et al*. (2016), breed of poultry influences the cholesterol content of the meat. Furthermore, inclusion of waterleaf at 20% level decreased the cholesterol content while inclusion at 40% level increased it. This agrees with Tufarelli *et al*. (2018) and Laudadio *et al*. (2014) that though inclusion of dietary alfalfa reduced the cholesterol content of meat from grass-fed poultry, the improved meat quality was not retained beyond the 20% inclusion level.

The HDL values were within the range reported for poultry meat sold in retail markets except W20, which was lower (Attia *et al*., 2017). Also, 20% waterleaf supplementation reduced the HDL while 40% level of waterleaf increased it. HDL cholesterol, otherwise called good cholesterol, retrieves cholesterol from the blood to the liver and flushed it out from the body (Krans, 2020). High levels of HDL indicate lesser risk to heart disease and stroke (CDCP, 2023). This implies that consumption of meat from the W40 group could better support the health aspiration of quail meat consumers.

Compared to literature values (Attia *et al*., 2017), the meat LDL in this study were all low. Differences could be due to feeding of forages to the quails as in the cited literature, the birds' feed were not supplemented with forage. Also, supplementing the feed with 20% waterleaf reduced the LDL content while at 40% level, the LDL value was increased. LDL, also called bad cholesterol, supports the formation of plaque that narrows the arteries, leading to stroke and heart attack (Krans, 2020). Ponte *et al*. (2004) concluded that chicken meat cholesterol fractions like LDL can be minimized by supplementing poultry feed with forage. In this study, this occurred at the 20% level of dietary waterleaf inclusion, beyond which the LDL increased. This agrees with the findings of Englmaierova *et al*. (2021) that beyond the 20% level, the benefit of forage inclusion in poultry feed is reversed. It implies that consumers of quail meat would likely prefer meat from W20 group.

VLDL is bad cholesterol; more harmful than HDL of which greater than half of is triglycerides (Weishaupt, 2021). The VLDL values in this study were reduced at 20% waterleaf inclusion but increased at 40% level of waterleaf as observed for LDL. This indicates similar but more serious atherosclerosis implications for consumers of W40 quail meat.

The lipid peroxidation values were in the acceptable range for meat and values reported for quails fed spices (Sanwo *et al*., 2019). Nevertheless, inclusion of waterleaf in diets decreased peroxide values at 20% level but increased it at 40%. This implies that feeding quails W20 feed could enhance preservation quality of quail meat.

Triglycerides are the major component of VLDL (Weishaupt, 2021). Their level in blood measures heart health, hence, should be minimal in blood and meat (Mayor Clinic, 2022). The meat triglycerides fell within the range reported for meat from broiler chickens fed diets supplemented with some spices (Sanwo *et al*., 2019). The value increased upon supplementation with 20% waterleaf and reduced at 40% supplementation. This indicates that meat from W40 group should be preferable for diet conscious people. However, high triglycerides could be a sign of other more serious issues like obesity, diabetes and hormonal imbalance (Mayor Clinic, 2022).

V. Conclusion

This study evaluated the nutritive value of meat from quails fed diets supplemented with fresh waterleaf. Supplementation with 40% waterleaf increased the CP, EE, GE, total cholesterol, HDL, LDL, VLDL and lipid peroxidation values while at 20% level, ash, NFE, triglycerides and all the minerals increased. It is concluded that though W40 produced attractive CP and HDL values, W20 is recommended because it had a better mineral profile and lower 'bad' cholesterol levels.

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