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Meat quality estimates of rabbit as affected by feeding and processing kind

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Abstract. Rabbit meat is of high demand in Nigeria due to its valued nutritional composition and pleasant sensory quality. The purpose of this study was to evaluate the impact of processing methods and feeding type on the nutritional quality of rabbit meat. Three sets of weaned rabbits were subjected to three types of feeding regimes and processing methods and evaluated for vitamins, cholesterol, and proximate composition in a Randomised Complete Block Design experiment. Mean vitamin B1 varied from 0.092 mg $(100\ g)^{-1}$ for cooked rabbit fed with forage to 0.105 mg $(100\ g)^{-1}$ for uncooked rabbit fed with forage with all variances being almost zero. The result of the cluster analysis of the vitamin contents of the rabbit meat indicated that roasted- rabbit fed with forage and cooked rabbit fed with forage and concentrate clustered at the earliest agglomeration distance of 0.128. This was followed by the clustering of cooked rabbit fed with forage and cooked

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rabbit fed with concentrates at the agglomeration distance of 1.941 and the farthest agglomeration distance of 24.973 was obtained for cooked rabbit fed with forage and roasted rabbit fed with forage. Mean protein of the rabbit meat fell between 17.971 for uncooked rabbit fed with concentrates and 31.489 for cooked rabbit fed with forage and concentrates and the variances forms 2 groups (homoscedastic and independent). The results of the general linear model analysis returned $F_{(8,18:0.05)}$ = 34.58, 55.839.90, 17.75, 23.11, 20.85, 12.32 and 12.36 for ash content, protein, moisture content, fat, crude fibre, carbohydrate and energy that were significant (P < 0.05). Roasting and foraging as established in the present study enhanced nutritional quality of rabbit meat and these offer practical value by addressing consumer demand, advancing quality standards in agricultural production, and recommending optimal processing methods

Keywords: nutrients; homoscedastic; variance; rabbit keeping enterprise; rabbit farming

Introduction

Rabbit meat produced in both intensive and extensive farming systems is valued for its unique properties and high nutritional value. Rabbit is considered a meat producing animal based on its short life cycle, gestation period, and feed conversion ratio. The technological properties and nutritional profile of rabbit are of industrial value as rabbit can be a good raw material for processing, and can be incorporated into value added products for consumers' satisfaction and healthy living.

As reported by T. Daszkiewicz & A. Gugołek (2020), rabbit meat is considered healthier than the other meat traditionally used in the meat products industry due to its specific nutritional characteristics of low fat with a favourable proportion of saturated, monounsaturated. and polyunsaturated fatty acids, low cholesterol and sodium. It is very high in protein (over 30% and approximately 80% of the energy value) with a high share of essential amino acids (lysine, sulphur-containing amino acids, threonine, valine, isoleucine, leucine, and phenylalanine) minerals and vitamins (potassium, phosphorus, selenium, and vitamin B) compared with most types of available meat for consumption, as reported by W. Akindele & A. Adeosun (2022). The consumption of rabbit meat, according to S. Amer *et al.* (2019), has been recommended as a healthier source of dietary protein in the developing countries. Rabbit meat has a high content of B vitamins, in particular B3 and B12 and a low content of sodium, purines and uric acid, according to B. Suvajdžić *et al.* (2023). Rabbit meat has been found to be useful in production of functional foods by B. Pang *et al.* (2020).

Effect of diets composition and feeding systems on the nutritional quality of rabbit meat have been documented by S. Siddiqui *et al.* (2023) and M. Teye *et al.* (2020). This has led to geared efforts in modifications in rabbit diets to meet its adequate nutritional value. This can allow positive exploitation of nutritional aspects of rabbit meat which well fits the current consumer demand for a low-fat meat with a high unsaturation degree of fatty acids and low sodium, cholesterol, and haeme-iron levels. According to G. Frunză *et al.* (2023), it also contribute to balanced diet with possible preventive effects on chronic non-deficiency diseases like obesity, type 2 diabetes, cancer, and cardiovascular diseases. Similarly, feeding practices have been found to play a crucial role in determining the nutritional composition, flavour, and overall quality of meat. Different feed types can affect the growth rate, carcass characteristics, and fat content, ultimately influencing consumer preferences. Additionally, the processing methods employed post-harvest can further modify the meat's sensory attributes, shelf life, and safety.

According to S. Kumar *et al.* (2023), meat quality is determined by several factors, including: nutritional qualities, such as the right amounts of proteins, lipids, and bioactive compounds; sensory attributes, like appearance, texture, and flavour; health benefits, which are dependent on fat and saturated fatty acid (SFA) content, mineral content, and technological factors like processing. Variability in vitamin, cholesterol, nutrient and proximate content of rabbit meat as affected by feed and cooking styles can have significant implications for human nutrition. Understanding how different feeds and cooking methods impact these rabbit meat qualities can help inform dietary choices and promote better health outcomes. Additionally, this research can also provide valuable insights for producers and chefs looking to maximise the nutritional value of rabbit. The purview of this study would cover both the nutritional and health factors including the mineral content, vitamins and cholesterol content, and proximate composition of the rabbit meat as affected by processing and feeding types. The purpose of this study was to assess the effect of three types of feeding regimes and cooking type on the nutritional quality of rabbit meat to improve the potential of rabbit keeping enterprise (RKE).

Materials and Methods

Three sets of weaned Hyela Rabbit at the age of five (5) months were obtained from Onileola Rabbit Farm in Ede, Osun State, Nigeria. The rabbits were housed in semi closed wire cages in three tiers batteries pen made from aluminium nets and poles in the rabbitry. The environmental conditions were adequately monitored to ensure welfare of the rabbits according to Standard guidelines. All the cages were equipped with feeding hoppers and drinking nipples. Each tier of cages was built over separate fecal and urine collectors to maintain high level hygiene and safe collection of rabbit waste for laboratory analyses. The rabbits were fed on three types of feeding regime. The first group of rabbits was fed on forages like Moringa Leaves (Moringa oleifera, Centro/Butterfly peas (*Centrosema pubescens*); Wild sunflower (*Aspilia africana*); Sweet potato Vines and Leaves (*Ipomea batatas*); Sunflower (*Helianthus annuus*); and Milkweed (*Euphorbia heterophyla*). The second group was fed on concentrates called Rabbit Pellet. The concentrate contains Wheat bran, Groundnut meal, Palm kernel meal, Soyabean meal, Cassava peel, Maize, Rice hulls, Sodium Bicarbonate, Salt (Sodium Chloride), Limestone, L-lysine HCl, Toxin Binder, DL-methionine, and Vitamin Premix. While the third group was fed on combination of forage and concentrates, respectively. The rabbits were fed for 90 days after which one rabbit from each group was slaughtered according to the standard guidelines for euthanising rabbits after 24 hour fasting (Institutional Animal Care and Use Committee (IACUC), United States, and Guidelines for the safe handling of wildlife and wildlife products as established by Z. Greatorex *et al.* (2021) and Regulation (EU) 2019/1010 of the European Parliament and of the Council (2019). The slaughtered rabbits were skinned and appropriate parts were packaged and iced in freezer for subsequent processing and laboratory analysis. The favourable environmental conditions were adequately monitored and all the cages were equipped with feeding hoppers and drinking nipples. The study lasted 90 days after which a rabbit from each set was culled and slaughtered according to the standard guidelines for euthanising rabbits after 24h fasting. The slaughtered rabbits were skinned at the slaughter slab of the farm and appropriate parts were packaged and iced in freezer for subsequent laboratory analysis. The study employed a Randomised Complete Block Design that comprise of three feeding regimes (forage, concentrates, and forage with concentrates) as treatments and three processing types (cooking, roasting, and raw) as the blocks. Two parts of meat flesh of thigh of each of the rabbits was subjected to cooking and roasting while the third part was left unprocessed (raw). The experimental materials were designated as RRFF – roasted rabbit fed with forage, RRFC – roasted rabbit fed with concentrates, RRFFC – roasted rabbit fed with both forage and concentrates; CRFF – cooked rabbit fed with forage, CRFC – cooked rabbit fed with concentrates, CRFFC – cooked rabbit fed with both forage and concentrates; URFF – unprocessed rabbit fed with forage, URFC – unprocessed rabbit fed with concentrates, and URFFC – unprocessed rabbit fed with both forage and concentrates.

Proximate composition and mineral content of the rabbit samples were determined using AOAC (2020) method while the cholesterol content was determined using Liebermann-Burchard method described by T. Daszkiewicz & A. Gugołek (2020). The experimental materials were designated as RRFF – roasted rabbit fed with forage, RRFC – roasted rabbit fed with concentrates, RRFFC – roasted rabbit fed with both forage and concentrates, CRFF – cooked rabbit fed with forage, CRFC – cooked rabbit fed with concentrates, CRFFC – cooked rabbit fed with both forage and concentrates, URFF – unprocessed rabbit fed with forage, URFC – unprocessed rabbit fed with concentrates, and URFFC – unprocessed rabbit fed with both forage and concentrates. Data on vitamin A, B1, B2, E, cholesterol, proximate composition including ash content, protein, moisture content, fat, crude fibre, carbohydrate, energy, and mineral components (P, Na, K, Ca, Fe, and Zn) were ethically collected from the animals. The data were subjected to descriptive and inferential statistics, cluster analysis, and general linear model (GLM) analysis using SAS (version 13). The main source of variation for the GLM analysis were the processing and feeding type with 2 (3-1) degree of freedom for both treatment and block while mean of the significantly different variables were separated using Duncan Multiple Range Test (DMRT).

Results

Overview of the data for the rabbit meat parameters (vitamins and cholesterol)

The results of the descriptive statistics analysis of the vitamins and cholesterols contents of the rabbit meat showed that no two samples had mean values for vitamin A that were comparable. The mean vitamin A values were homoscedastic (same variances) and ranged from 0.393 mg $(100\ g)^{-1}$ for RRFC to 0.916 mg $(100\ g)^{-1}$ for CRFC (Table 1).

Table 1. *Descriptive statistics of the vitamins and cholesterol of the rabbit meat*

Sample	VITA (mg/100 g)		VITB1 (mg/100 g)		VITB2 (mg/100 g)		VITE (mg/100 g)		CHOLE (mg/100 g)	
	Mean	Variance	Mean	Variance	Mean	Variance	Mean	Variance	Mean	Variance
CRFF	0.725	0.00013	0.092	0.00001	0.265	0.00005	0.133	0.0000012	30.780	2.56551
RRFF	0.566	0.00013	0.104	0.00000	0.327	0.00005	0.146	0.0000015	23.790	4.01595
URFF	0.432	0.00013	0.105	0.00000	0.335	0.00005	0.093	0.0000015	61.570	0.47472
CRFC	0.916	0.00000	0.095	0.00000	0.319	0.00005	0.109	0.0000005	54.256	0.04340
RRFC	0.393	0.00013	0.103	0.00000	0.314	0.00005	0.137	0.0000005	37.151	0.25228
URFC	0.539	0.00000	0.099	0.00000	0.727	0.00009	0.104	0.0000022	64.088	0.29387
CRFFC	0.572	0.00013	0.102	0.00000	0.453	0.00002	0.125	0.0000022	52.325	0.63296
RRFFC	0.452	0.00013	0.095	0.00000	0.289	0.00014	0.132	0.0000094	30.779	17.76620
URFFC	0.758	0.00000	0.102	0.00000	0.662	0.00006	0.096	0.0000020	42.947	0.68359

Note: CRFF – cooked rabbit fed with forage, RRFF – roasted rabbit fed with forage, URFF – unprocessed rabbit fed with forage, CRFC – cooked rabbit fed with concentrate, RRFC – roasted rabbit fed with concentrate, URFC – unprocessed rabbit fed with concentrate, CRFFC – cooked rabbit fed with forage and concentrate, RRFFC – roasted rabbit fed with forage and concentrate, URFFC – unprocessed rabbit fed with forage and concentrates
Source: experimental data

According to Table 1, the mean vitamin B1 varied from 0.092 mg $(100\ g)^{-1}$ for CRFF to 0.105 mg $(100\ g)^{-1}$ for URFF, with all variances being almost zero. The samples CRFF, RRFF, CRFC, and RRFC were homoscedastic, while URFC, CRFFC, RRFFC, and URFFC were heteroscedastic. The mean vitamin B2 fell between 0.265 mg $(100\ g)^{-1}$ for CRFF and 0.727 mg $(100\ g)^{-1}$ for URFC (Table 1). Mean vitamin E ranged from 0.093 for URFF to 0.146 obtained for both RRFF while the variances were very low and ranged between 0.5×10^{-7} for CRFC and 0.94×10^{-6} for RRFFC. Some of the vitamin E samples of the rabbit meat were the same (Table 1). RRFF had the least cholesterol of 23.790 while the highest cholesterol of 64.088 was obtained for URFC and no 2 rabbit meat samples returned the same cholesterol values (Table 1). The variance was inversely related to the mean cholesterol and they are heteroscedastic. The results indicate that processing (roasting or cooking) has significant impact on the vitamin B1 and B2 and cholesterol obtained from the rabbit meat. The recorded values of vitamin B1, vitamin B2, and vitamin E in the present study further emphasise the potential of rabbit meat as a valuable dietary source.

General linear model (GLM) analysis and mean separation of the vitamins and cholesterols of the rabbit meats

The general linear model analysis of the vitamins and cholesterol of the rabbit meat returned means vitamins that are statistically significant ($P < 0.05$ – Table 2). The $F_{(8,18:0.05)}$ = 1,012.72, 85.84, 1,467.65, 371.91 and 213.71 obtained respectively for vitamin A, B1, B2, E, and cholesterol were significant. Mean vitamin A were partitioned into eight significantly different classes. Mean vitamin A obtained for rabbit meat of CRFC (0.916) was significantly the highest and it is higher than mean vitamin A obtained for rabbit meat of URFC (0.758 – Table 2). The least mean significantly different vitamin A was obtained for RRFC (0.393) and was significantly lesser than mean significantly different mean vitamin A obtained for sample URFF (0.432). Mean vitamin B1 obtained for sample URFF was significantly the highest and not statistically different from mean vitamin B1 obtained for RRFF. Mean vitamin B1 obtained for CRFF (0.092) was significantly the least and it is statistically lesser than mean vitamin B1 (0.095) obtained for both RRFC and RRFFC.

Table 2. *General linear model analysis and mean separation of the vitamins and cholesterol*

Treatment	VIT.A	VIT.B1	VIT.B2	VIT.E	CHOLESTEROL
F-statistics	1,012.72**	85.84**	1,467.65**	371.91**	213.71**
DF	8	8	8	8	8
CRFF	0.725^{c}	0.092^{f}	0.265^{g}	0.133^{c}	30.780^{e}
RRFF	0.566^{d}	0.104^{ab}	0.327^{de}	0.146^{a}	23.790^{f}
URFF	0.432^{g}	0.105^{a}	0.335^{d}	0.093^{g}	42.947^{c}
CRFC	0.916^{a}	0.095^{e}	0.319^{e}	0.109^{e}	54.256^{b}
RRFC	0.393^{h}	0.103^{bc}	0.314^{e}	0.137^{b}	37.151^{d}
URFC	0.539^{e}	0.099^{d}	0.727^{a}	0.104^{f}	64.088^{a}
CRFFC	0.572^{d}	0.102^{c}	0.453^{c}	0.125^{d}	52.325^{b}
RRFFC	0.452^{f}	0.095^{e}	0.289^{f}	0.132^{c}	30.779^{e}
URFFC	0.758^{b}	0.102^{c}	0.662^{b}	0.096^{g}	61.570^{a}

Note: CRFF – cooked rabbit fed with forage, RRFF – roasted rabbit fed with forage, URFF – unprocessed rabbit fed with forage, CRFC – cooked rabbit fed with concentrate, RRFC – roasted rabbit fed with concentrate, URFC – unprocessed rabbit fed with concentrate, CRFFC – cooked rabbit fed with forage and concentrate, RRFFC – roasted rabbit fed with forage and concentrate, URFFC – unprocessed rabbit fed with forage and concentrates
Source: experimental data

Duncan Multiple Range Test (DMRT) partitioned mean vitamin B2 and E into 7 significantly different classes. As per vitamin B2, mean vitamin B2 obtained for URFC (0.727) was significantly the highest and higher than mean vitamin B2 obtained for URFFC meat (0.662 – Table 2). Mean vitamin B2 for CRFF meat was significantly the least (0.265) and it is significantly lesser than vitamin B2 for rabbit meat RRFFC (0.289 – Table 2). Other rabbit meat samples formed significantly different classes between these 2 groups (the significantly highest and significantly lowest classes). Conversely, mean vitamin E for RRFF meat was significantly the highest (0.146) and was significantly higher than vitamin E for RRFC meat (0.137). Vitamin $E_{(CRFF,\ CRFFC\ \&\ RRFFC)} = 0.132 >$ vitamin $E_{(CRFC)} = 0.109 >$ Vitamin $E_{(URFC)} = 0.104 >$ vitamin $E_{(URFF\ \&\ URFFC)} = 0.094$ & 0.096 (Table 2). Highest mean cholesterol (64.088 and 61.57) was obtained for both URFC meat and URFFC meat respectively and were significantly higher than mean cholesterol obtained for CRFC (54.256) and CRFFC (52.325 – Table 2).

The least significantly different mean cholesterol was obtained for RRFF (23.79) while other rabbit meat samples formed independent classes between these 2 groups (highest and least significantly different groups – Table 2). It is evident that rabbit meats fed with forage enhance/retain vitamin B1 and vitamin E with reduced cholesterol. Neither roasting nor cooking enhances any of the vitamins as the raw meats were found to be richer in the vitamins evaluated.

Overview of the data for the rabbit meat parameters (proximate content)

The results of summary statistics analysis for proximate composition indicated that most of the meat samples (CRFF, RRFF, CRFFC, URFF, URFC, and URFFC) returned same ash content of 1.500 and 0.500. Rabbit meat samples in these 2 groups have zero variances while others not in the group sample are homoscedastic (with the same variance of 0.083 – Table 3). The mean ash content obtained for the homoscedastic meat samples were 1.667, 1.833, and 1.667 for CRFC, RRFC, and RRFFC, respectively. The unprocessed rabbit meats returned the least ash content implying that they might likely contain the lower minerals than the processed rabbit samples. Mean protein of the meat falls between 17.971 for URFC and 31.489 for CRFFC. Rabbit meat samples CRFF, RRFF, RRFC, CRFFC, and RRFFC returned the same variance of 0.001, while rabbit samples URFF, URFC, and URFFC returned the same variance of 0.002 (Table 3).

Table 3. *Summary statistics of the proximate component analysis of the rabbit meat*

	_ASH		_PROTEIN		_MOISTURE		_FAT		_CRUFIB	
Sample	Mean	Variance	Mean	Variance	Mean	Variance	Mean	Variance	Mean	Variance
CRFF	1.500	0.000	30.041	0.001	58.500	0.280	5.000	0.000	0.600	0.010
RRFF	1.500	0.000	26.740	0.001	56.200	1.240	3.000	0.500	12.060	182.200
URFF	0.500	0.000	26.740	0.002	62.333	0.103	3.000	0.000	0.333	0.003
CRFC	1.667	0.083	31.332	0.000	56.667	0.023	6.333	0.333	0.733	0.003
RRFC	1.833	0.083	27.380	0.001	48.500	12.130	4.333	0.333	0.367	0.003
URFC	0.500	0.000	17.971	0.002	65.367	13.103	7.333	1.333	0.267	0.003
CRFFC	1.500	0.000	31.489	0.001	31.489	0.001	6.667	0.333	0.433	0.003
RRFFC	1.667	0.083	30.512	0.001	48.367	27.123	5.333	0.333	0.167	0.003
URFFC	0.500	0.000	20.358	0.002	61.000	0.002	6.667	0.333	6.667	0.333

Note: CRFF – cooked rabbit fed with forage, RRFF – roasted rabbit fed on forage, URFF – unprocessed rabbit fed with forage, CRFC – cooked rabbit fed with concentrate, RRFC – roasted rabbit fed with concentrate, URFC – unprocessed rabbit fed with concentrate, CRFFC – cooked rabbit fed with forage and concentrate, RRFFC – roasted rabbit fed with forage and concentrate, URFFC – unprocessed rabbit fed with forage and concentrates
Source: experimental data

The most fatty rabbit meat sample was the URFC (7.333 mg/100 g) and was followed by both CRFFC and URFFC with 6.667 mg/100 g. The least fatty rabbit meat was 3.000 mg/100 g obtained for both RRFF and URFF. This indicates the significance of forage feeds in fats reduction and subsequently making it healthy type of feed for animals which will subsequently impact healthiness to the humans that consume the meat. There is no significant trend in the fat content of the rabbit thus neither the processing nor feeding effects on rabbit meat is discernible in the present study. The rabbit meat samples (RRFF) returned very high crude fibre of 12.060 mg/100 mg and majority of the rabbit meat samples were homoscedastic (with variance of 0.003). The least crude fibre (0.167 mg/100 mg) was obtained for RRFFC (Table 3). The range of the carbohydrate content obtained in the present study was from 3.26% for CRFF to 17.58% for RRFC while the energy content fell between 150.46 Kcal for URFC and 225.867 for RRFFC (Fig. 1).

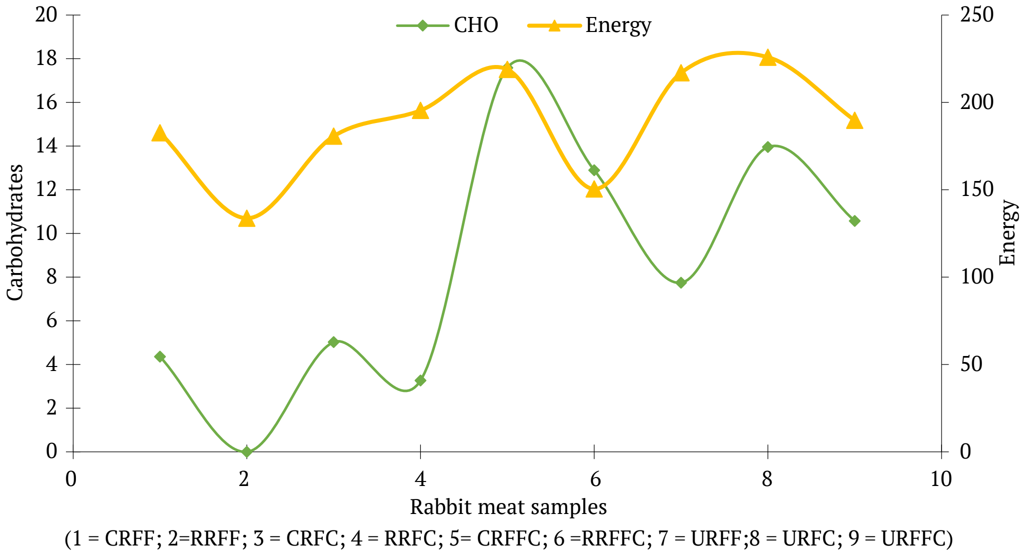

Figure 1. Mean carbohydrates and energy obtained for different rabbit meat samples
Note: CRFF – cooked rabbit fed with forage, RRFF – roasted rabbit fed with forage, URFF – unprocessed rabbit fed with forage, CRFC – cooked rabbit fed with concentrate, RRFC – roasted rabbit fed with concentrate, URFC – unprocessed rabbit fed with concentrate, CRFFC – cooked rabbit fed with forage and concentrate, RRFFC – roasted rabbit fed with forage and concentrate, URFFC – unprocessed rabbit fed with forage and concentrates
Source: experimental data

General linear model analysis and mean separation of the proximate component of the rabbit

The results of the general linear model (GLM) analysis returned significant results for all the proximate composition variables. The statistics, $F_{(8,18:0.05)}$ = 34.58, 55,839.90, 17.75, 23.11, 20.85, 12.32 and 12.36 obtained for ash content, protein, moisture content, fat, crude fibre, carbohydrate, and energy are significant ($P < 0.05$ – Table 4). Mean ash of the rabbit meats were partitioned into 3 significantly different groups including 1) RRFC with mean ash of 1.833 was significantly different from; 2) CRFFC, CRFF, and RRFF having mean ash of 1.500; and 3) URFF, RRFC, and URFFC having mean ash of 0.500 (Table 4). Protein content of rabbit meat sample, CRFFC (31.489) was significantly higher than protein content obtained for CRFC (31.332). Protein content of other rabbit meat follows the trend of – RRFFC (30.512) greater than CRFF (30.041) greater than RRFC (27.380) greater than RRFF (26.740) greater than URFF (25.143). The least significantly different mean protein was obtained for rabbit sample URFC (17.971) and it was significantly lesser than protein content of URFFC (20.358 – Table 5).

Table 4. *General linear model of the proximate component analysis of the rabbit meat*

Treat	ASH	PROTEIN	MOISTR	FAT	CRUDE FIBRE	CHO	Energy
F-statistics	34.58**	55,839.9**	17.75**	23.11**	20.85**	12.32**	12.36**
DF	8	8	8	8	8	8	8
RRFC	1.833^{a}	27.380^{e}	48.500^{f}	4.333^{b}	0.367^{ed}	17.587^{a}	218.867^{a}
CRFC	1.667^{ab}	31.332^{b}	56.667^{cd}	6.333^{a}	0.733^{a}	4.359^{d}	195.400^{b}
RRFFC	1.667^{ab}	30.512^{c}	48.367^{f}	6.667^{a}	0.167^{g}	13.955^{ba}	225.867^{a}
CRFFC	1.500^{b}	31.489^{a}	52.167^{ef}	6.667^{a}	0.433^{cd}	7.745^{dc}	216.933^{a}
CRFF	1.500^{b}	30.041^{d}	58.500^{bcd}	5.000^{b}	0.600^{b}	4.359^{d}	182.600^{b}
RRFF	1.500^{b}	26.740^{f}	56.2^{de}	3.000^{c}	0.500^{bc}	12.060^{bc}	182.000^{b}
URFF	0.500^{c}	25.143^{g}	62.333^{ab}	3.000^{c}	0.333^{def}	5.024^{d}	180.667^{b}
URFC	0.500^{c}	17.971^{i}	65.367^{a}	7.333^{a}	0.267^{efg}	12.060^{bc}	150.467^{c}
URFFC	0.500^{c}	20.358^{h}	61.000^{abc}	6.667^{a}	0.233^{fg}	10.575^{bc}	189.733^{b}

Note: CRFF – cooked rabbit fed with forage, RRFF – roasted rabbit fed with forage, URFF – unprocessed rabbit fed with forage, CRFC – cooked rabbit fed with concentrate, RRFC – roasted rabbit fed with concentrate, URFC – unprocessed rabbit fed with concentrate, CRFFC – cooked rabbit fed with forage and concentrate, RRFFC – roasted rabbit fed with forage and concentrate, URFFC – unprocessed rabbit fed with forage and concentrates
Source: experimental data

Duncan Multiple Range Test partitioned the moisture content into 2 independent classes of the highest moisture content – URFC (65.367%) and the least moisture content (RRFC – 48.5% and RRFFC – 48.367%). Other rabbit meat sample returned moisture content that formed intermediary classes between the group 2 (of highest and least moisture content – Table 4). Duncan Multiple Range Test partitioned mean fat content into 3 significantly different classes. This includes the highest significantly different class – URFC (7.333), RRFFC, CRFFC, and URFFC (6.667), and CRFC (6.333); the average class consisting of both CRFF (5.00) and RRFC (4.333); the least significant class – URFF and RRFF (3.00). Mean crude fibre obtained for CRFC (0.733) was significantly the highest and it is higher than mean crude fibre obtained for CRFF (0.600) while mean crude fibre returned for RRFFC (0.167) was the least (Table 4). Mean crude fibre obtained for other rabbit meat formed intermediary classes between these classes.

The trend of carbohydrate of the rabbit meat is such that RRFC (17.587) ⩾ RRFFC (13.955) ⩾ RRFF and URFC (12.06). Both URFF and CRFC (4.359) were the least significantly different carbohydrate (Table 4). Three significantly different groups were formed by the Duncan Multiple Range Test for the energy content of the rabbit meat. Mean energy obtained for RRFFC (225.867), RRFC (218.867), and CRFFC (216.933) were significantly higher than mean energy obtained for rabbit meat CRFC (195.400), URFFC (189.733), RRFF (182.2), CRFF (182.600), and URFF (180.667). Mean energy obtained for rabbit meat URFC (150.467) was significantly the least (Table 5). These disparities might have been caused by factors such as age, diet, and breed of the rabbits which can also impact the energy content of the meat.

Table 5. Descriptive statistics of the mineral content of the rabbit meat

Sample	Phosphorous		Na		K	
	Mean	Variance	Mean	Variance	Mean	Variance
CRFF	499.333	1.333	35.998	0	201.009	0
RRFF	355	25	69.309	0.045	368.738	0
URFF	215.667	1.333	50.626	0.045	199.456	7.234
CRFC	260	25	39.686	0	174.607	7.236
RRFC	371.667	8.333	67.957	4.533	284.874	0
URFC	202	7	46.938	0.045	201.009	0.045
CRFFC	115.333	0.333	39.809	0.045	185.464	7.373
RRFFC	333.333	108.333	54.313	0.045	354.761	0
URFFC	305.333	20.333	46.938	0.045	41.267	0
	Ca		**Fe**		**Zn**	
Samples	Mean	Variance	Mean	Variance	Mean	Variance
CRFF	41.081	0.104	21.262	0	10.763	0
RRFF	48.162	5.106	39.003	0	19.744	0
URFF	41.267	0	21.098	0.081	10.68	0.021
CRFC	24.308	0.104	18.469	0.081	9.349	0.021
RRFC	46.672	0.104	30.133	0	15.253	0
URFC	41.267	0	21.262	0	10.763	0
CRFFC	41.081	0.104	19.618	0.082	9.931	0.021
RRFFC	35.676	0	37.525	0	18.996	0
URFFC	22.576	0.081	22.576	0.081	11.428	0.021

Note: CRFF – cooked rabbit fed with forage, RRFF – roasted rabbit fed with forage, URFF – unprocessed rabbit fed with forage, CRFC – cooked rabbit fed with concentrate, RRFC – roasted rabbit fed with concentrate, URFC – unprocessed rabbit fed with concentrate, CRFFC – cooked rabbit fed with forage and concentrate, RRFFC – roasted rabbit fed with forage and concentrate, URFFC – unprocessed rabbit fed with forage and concentrates
Source: experimental data

Overview of the data for the rabbit meat parameters (mineral content)

The phosphorous in the rabbit was found to range between 115.333 for CRFFC and 499.333 for CRFF and they were all heteroscedastic except RRFF and CRFC that were homoscedastic (Table 5). The variance ranged between 0.333 for CRFFC and 108.333 for RRFFC and none was zero. The trend of phosphorous obtained in the present study indicated that forage fed rabbit meat have significantly higher phosphorous than the concentrate fed counterpart. Mean sodium ranged between 35.998 for CRFF and 69.309 for RRFF with many homoscedastic groups. The variances obtained for the sodium can be partitioned into 2 groups – 0.000 for CRFF and CRFC, and 0.045 for other rabbit samples (Table 5). The results of the descriptive analysis of the mean potassium of the rabbit means indicated that RRFF returned the highest potassium of 368.738 (mg/100 g) while the least potassium (174.6) was obtained in CRFC. Most of the rabbit samples (0.56) returned zero variance while others were heteroscedastic (Table 5).

Mean calcium of the rabbit meat ranged from 24.30 obtained for CRFC to 48.162 for RRFF with 3 groups of variances – the heteroscedastic (RRFF and URFFC), the zero variance (URFF, URFC and RRFFC) and homoscedastic (CRFF, CRFC, RRFC, CRFFC – Table 5). Mean iron falls between 18.469(unit) for CRFC and 39.003 for RRFF with both zero variance for CRFF, RRFF, RRFC, URFC and RRFFC and homoscedastic variance (0.081) for URFF, CRFC, CRFFC, and URFFC (Table 5). Highest mean zinc (19.744) was obtained for RRFF while the least mean zinc (9.931) was obtained for CRFFC and some rabbit meat samples (URFF and

CRFC = 10.680: CRFF and URFC = 10.763) have the same mean zinc (Table 5). More of the rabbit meat samples (0.56) returned zero variance while the remaining – URFF, CRFC, CRFFC, and URFFC were homoscedastic (having the same variance of 0.021 – Table 5). These findings suggest that roasting effectively preserves certain minerals in rabbit meat, positioning it as the superior method of preparation.

General linear model (GLM) analysis and mean separation of the mineral content of the rabbit meat

The results of the general linear model of the mineral component of the rabbit meat indicated that there exist significant differences between the means obtained for the mineral component. The statistics, $F_{(8,18:0.05)}$ = 1,734.67, 800.13, 5,145.92, 234.17, 5,145.92, and 5,145.92 obtained for phosphorous, sodium, potassium, calcium, iron, and zinc are significant ($P < 0.05$ – Table 6). Mean phosphorous was partitioned into 8 significantly different groups by DMRT. Mean phosphorous obtained for rabbit meat of CRFF (499.333) is greater than that of RRFC (371.667). The least significantly different mean phosphorous was obtained for rabbit meat CRFFC (115.333) and it is significantly lesser than mean phosphorous obtained for rabbit meat URFC (202.00 – Table 6).

Table 6. *General linear model analysis of the mineral content of the rabbit meat*

Treat	PhMg	Na	K	Ca	Fe	Zn
F-Statistics	1,734.67**	800.13**	5,145.92**	234.17**	5,145.92**	5,145.92**
DF	8	8	8	8	8	8
CRFF	499.333[a]	35.998[g]	201.009[e]	41.081[c]	21.262[e]	10.763[e]
RRFF	355.000[c]	69.309[a]	368.738[a]	48.162[a]	39.003[a]	19.744[a]
URFF	215.667[g]	50.626[d]	199.456[e]	41.267[c]	21.098[e]	10.680[e]
CRFC	260.000[c]	39.686[f]	174.607[g]	24.308[e]	18.469[g]	9.349[g]
RRFC	371.667[b]	67.957[b]	284.874[c]	46.672[b]	30.133[c]	15.253[c]
URFC	202.000[h]	46.938[e]	201.009[e]	41.267[c]	21.262[e]	10.763[e]
CRFFC	115.333[i]	54.313[c]	185.464[f]	41.081[c]	19.618[f]	9.931[f]
RRFFC	333.333[d]	54.313[c]	354.761[b]	35.676[d]	37.525[b]	18.996[b]
URFFC	305.333[e]	46.938[e]	213.434[d]	41.267[c]	22.576[d]	11.428[d]

Note: CRFF – cooked rabbit fed with forage, RRFF – roasted rabbit fed with forage, URFF – unprocessed rabbit fed with forage, CRFC – cooked rabbit fed with concentrate, RRFC – roasted rabbit fed with concentrate, URFC – unprocessed rabbit fed with concentrate, CRFFC – cooked rabbit fed with forage and concentrate, RRFFC – roasted rabbit fed with forage and concentrate, URFFC – unprocessed rabbit fed with forage and concentrate
Source: experimental data

Mean phosphorous in other rabbit meat samples were found in between the two groups (of highest and the least). Mean sodium obtained for the rabbit meat, RRFF (69.309) is significantly higher than that mean sodium returned for rabbit meat RRFC (67.957). The next significantly different mean sodium of the rabbit meat was obtained for both CRFFC and RRFFC (54.313) and are significantly higher than mean sodium obtained for rabbit meat URFF (50.626). The least significantly different mean sodium (35.998) was obtained for rabbit meat CRFF and it is significantly lesser than mean sodium obtained for rabbit meat CRFC (39.686 – Table 6). The trends of mean potassium partitioning for rabbit meat are such that; RRFF (368.738) > RRFFC (354.761) > RRFC (284.874) > URFFC (213.434) > URFC (201.009) > > URFF (199.456) > CRFFC (185.464) > CRFC (174.607 – Table 6).

The mean calcium of the rabbit meat, RRFF (48.162) remained significantly the highest and it is higher than mean calcium of the RRFC (46.672). Mean calcium of the RRFC was in turn significantly higher than the one obtained for CRFF, URFF, URFC, CRFFC, and URFFC (41.267) while the next significantly different mean calcium was obtained for RRFFC (35.676). The least significantly different mean calcium was obtained for CRFC (24.308 – Table 6). Mean iron returned for rabbit meat RRFF (39.003) remained the highest and it is significantly higher than mean iron obtained for rabbit meat RRFFC (37.525) which is, in turn, significantly higher the mean iron of the rabbit meat RRFC (30.133). Mean iron in the rabbit meat URFFC (22.576) is the next significantly different class and it is higher than the mean iron obtained for CRFF, URFC (22.262), and URFF (21.098). The least mean iron was obtained for CRFC (18.469) and it is significantly less than mean iron of the CRFFC (19.618 – Table 6). DMRT partitioned mean zinc into 7 significantly different classes which are mean zinc obtained for RRFF (19.744) which is significantly the highest and was followed by mean zinc of the RRFFC (18.996) and it is, in turn, significantly different from the mean zinc returned for RRFC (15.253). Mean zinc obtained for URFFC was the next significantly different class and it is different from the mean zinc obtained for URFC, CRFF (10.763), and URFF (10.680 – Table 6). The least significant mean zinc was obtained for CRFC (9.349) and it is significantly less than 9.931 obtained for CRFFC.

Discussion

The calcium content in this study is higher than those obtained (2.7-9.3) by A. Dalle Zotte & Z. Szendrő (2011). The values of the calcium fall within the USDA threshold of 18mg (United States Department of Agriculture, Nutrient lists from standard reference legacy, 2018). Similarly, the iron (Fe) of the rabbit meat in this study is higher than the recommended 4.8mg of the USDA and what was obtained (1.1-1.3) by A. Dalle Zotte & Z. Szendrő (2011).

The inverse relationship between the mean cholesterol and its variance established in the present study might be responsible for their heteroscedasticity. It is evident that processing (roasting or cooking) has significant impact on the vitamin B1 and B2, and cholesterol obtained from the rabbit meat. This indicates that the methods of processing used can greatly affect the nutritional composition of the meat. This finding is important for researchers and consumers in order to make informed decisions about the preparation and consumption of rabbit meat. This is in accord with the findings of M. Nutautaitė *et al.* (2023) that established relationships between mean and variance of some rabbit meat variables. The mean comparison of vitamin B2, E, and cholesterol levels in various rabbit meat samples of this study provide further valuable insights into the nutritional benefits of forage-fed rabbit meat. R. Gál *et al.* (2022) emphasised the role of rabbit meat as a functional food due to its high vitamin B content, aligning with the current findings that forage-fed rabbits can enhance these levels. In addition, the function of diet in improving the nutritional profile of rabbit meat has been substantiated in various studies (Siudak & Pałka, 2022). Mean proteins (obtained in the present study) are in agreement with mean proteins obtained for livestock meats including rabbit by B. Suvajdžić *et al.* (2023) and S. Siddiqui *et al.* (2023). The protein content obtained in the present study are higher than protein content in rabbit meat reported by A. Gbenge *et al.* (2021), J. Ingweye *et al.* (2021), and M. Suliman *et al.* (2019).

Moisture content has been found to reduce with different types of processing (Akindele & Adeosun, 2022). The moisture contents obtained in the present study were lower than 69.6-79.3% obtained for rabbit in the report of S. Siddiqui *et al.* (2023) and in agreement with the moisture content of rabbit meat in B. Suvajdžić *et al.* (2023). The dissimilitude in the moisture content of rabbit meat in S. Siddiqui *et al.* (2023) and the present study could not be unconnected to differences in the rabbit meat samples and feeding regime in both studies. The fat content obtained in the present study (3.0-7.333) compared favourably with J. Adu *et al.* (2019) and it is higher than the recommended 3.5 g of the USDA and the fat content obtained by S. Siddiqui *et al.* (2023). Forage diets have been established to contain more crude fibre than the concentrated feed (Akindele & Adeosun, 2022) and this coincides with the findings of the present study. In addition, the crude fibre obtained in the present study is slightly lesser than the values established by A. Gbenge *et al.* (2021). This disparity might have been conditioned by differences in the treatments to which rabbit were subjected in the 2 studies. Forage diet is better than concentrate diet in terms of promoting healthy digestion and providing a more natural source of nutrients for livestock. The carbohydrates provided by complete forage diets as established in this study is thus in order for non-harmful development of the rabbit and it is in agreement with Z. Siudak & S. Pałka (2022). The ash content found in this study is comparable to that reported by J. Ingweye *et al*. (2021) and lesser than the ash content obtained by A. Gbenge *et al.* (2021). The ash content can influence the overall nutritional balance of the meat. Higher ash content can indicate a richer mineral profile, which is essential for consumer health (Siddiqui *et al.*, 2023). This is particularly important in diets where meat is a primary protein source.

Forage fed rabbit returned higher crude fibre than rabbits fed with concentrates. This might be conditioned by the high fibre content of the original feed (forage) fed to the rabbit. Forage diets have been established to contain more crude fibre than the concentrated feed (Akindele & Adeosun, 2022). The higher moisture content obtained in the raw unprocessed rabbits may be attributable to the unprocessed nature of the samples while the lower moisture content obtained for the processed samples might be conditioned by the effect of the processing (cooking and roasting) on the meat samples and this coincides with reports by B. Pang *et al.* (2020). Processing and feed type influences carbohydrate content of the rabbit in the present study. The nutritional content of rabbit meat has been established to be correlated with the nutritional values of its feed intake (Yadav *et al.*, 2022). It is obvious from this study that roasted rabbit meat returned higher potassium than cooked rabbit meat and this is attributable to leaching of the minerals into the water during cooking. It has been established that minerals (like calcium, sodium, phosphorous, and zinc) can be lost during cooking (Yadav *et al.*, 2022). It was also established that the least of these minerals is lost during roasting (Dal Bosco *et al.,* 2001). Roasting clearly retained some of the minerals of the rabbit meat, hence making it the best among the rabbit meat and it is in concord with H. Abdel-Naeem *et al.* (2021). The phosphorous content obtained in the present study is higher than the high phosphorous content reported by H. Abdel-Naeem *et al.* (2021) and higher than phosphorous of any other meat in the same report. The zinc content of the rabbit meat in this study was moderately higher than those of J. Ingweye *et al.* (2021) and A. Menon *et al.* (2023). These findings indicate that rabbit meat could potentially be a valuable source of essential minerals such as calcium, iron, and zinc in the diet.

Lastly, the goal of meat quality estimates of rabbit as affected by feeding and processing kind is to evaluate how feeding strategies and processing methods influence the overall quality attributes of rabbit meat. These qualities are critical for enhancing the marketability and health benefits of rabbit meat consumers. Understanding these influences can guide producers in optimising feeding regimens and processing techniques to improve meat quality, thereby increasing consumer demand and satisfaction.

Conclusions

To enhance the promotion of rabbit meat consumption, a robust strategy involves the development of comprehensive information and educational programmes that highlight rabbit meat as a nutritious, flavourful, and premium food option. This can be effectively accomplished by delivering objective and transparent information regarding rabbit meat production, with a particular focus on critical aspects such as safety, quality, and animal welfare. As emphasised in the current study, addressing these issues not only fosters consumer trust but also encourages informed dietary choices, ultimately positioning rabbit meat as a viable alternative in the meat market. Engaging stakeholders through workshops, cooking demonstrations, and community outreach can further amplify awareness and appreciation for rabbit meat, driving its acceptance and integration into mainstream culinary practices. Emphasising the environmental sustainability of rabbit meat production can play a pivotal role in enhancing its consumption. The current study illustrates how methods such as roasting and foraging not only improve the nutritional quality of rabbit meat but also align with sustainable practices. This research significantly enriches understanding of rabbit meat's nutritional value, health benefits, and culinary versatility. It has been demonstrated that rabbit meat serves as a lean protein source, characterised by low cholesterol levels and an abundance of essential nutrients, including iron and B vitamins. Moreover, the study meticulously documents innovative processing and feeding methods that broaden the culinary applications for both chefs and home cooks. Research into the most suitable forage species for optimum rabbit productivity is recommended for future study.

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Conflict of Interest

There is no special interest to declare for this project.

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Оцінка якості м'яса кролика залежно від типу годівлі та методів переробки

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Анотація. М'ясо кролика має високий попит у Нігерії завдяки цінному поживному складу та приємним смаковим якостям. Метою цього дослідження було оцінити вплив методів обробки та типу годівлі на поживну якість кролячого м’яса. Три групи відібраних кроликів були піддані трьом типам режимів годівлі та методів переробки м’яса, яке оцінювалось за вмістом вітамінів, холестерину та основними поживними складниками в умовах експерименту за схемою повного рандомізованого блоку (Randomised Complete Block Design experiment). Середній рівень вітаміну В1 коливався від 0,092 мг на 100 г для вареного м’яса кролика, якого годували рослинним кормом, до 0,105 мг на 100 г для сирого м’яса кролика з тим же типом годівлі, при цьому відхилення були майже нульовими. Результати кластерного аналізу вмісту вітамінів у кролячому м’ясі показали, що печене м’ясо кролика, якого годували рослинним кормом, і зварене м’ясо кролика, якого годували комбінованим кормом, утворювали кластер на найменшій відстані агломерації 0,128. Найбільша відстань агломерації 24,973 була отримана для звареного кролика, якого годували рослинним кормом, і печеного кролика з таким самим раціоном. Середній вміст білка в м'ясі кролика знаходився в діапазоні від 17,971 для сирого кролика, якого годували концентратами, до 31,489 для смаженого кролика, якого годували кормами та концентратами, а дисперсії утворюють 2 групи (гомоскедастичні та незалежні). Результати аналізу загальної лінійної моделі показали $F_{(8,18:0.05)} = 34,58; 55,839,90; 17,75; 23,11; 20,85; 12,32$ і 12,36 для вмісту золи, білка, вологи, жиру, сирої клітковини, вуглеводів і енергії, які є значущими ($P < 0,05$). Методи обробки та годування, як встановлено в даному дослідженні, покращували поживну якість кролячого м’яса, що має практичне значення для задоволення попиту споживачів, удосконалення стандартів якості в аграрному виробництві та розробки оптимальних методів обробки

Ключові слова: поживні речовини; гомоскедастичність; дисперсія; кролівницьке підприємство; кролівництво