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CARCASS AND ORGANOLEPTIC CHARACTERISTICS OF MEAT FROM RED SOKOTO GOATS FED SOME ROOT AND TUBER CROP PEELS IN CONCENTRATE SUPPLEMENT DIETS WITH GROUNDNUT (*Arachis hypogea*) HAULM BASAL DIET

By

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Abstract

*This study evaluated root and tuber crop peels as alternative concentrate ingredients for Red Sokoto goats fed a groundnut (*Arachis hypogea*) haulm basal diet, with emphasis on carcass yield, organ development, wholesale cuts, carcass by-products and meat sensory quality. Twenty Red Sokoto bucks, aged 10–11 months and weighing 8.0–9.0 kg, were randomly assigned to five dietary treatments in a completely randomised design, with four animals per treatment. The concentrate diets contained 20% maize offal (T1), yam peel meal (T2), sweet potato peel meal (T3), Irish potato peel meal (T4) or cassava peel meal (T5), offered at 250 g/goat/day with 500 g/goat/day of groundnut haulm. The trial lasted 100 days after a 14-day adjustment period. Three goats per treatment were slaughtered for carcass evaluation, and meat samples were assessed by a 12-member sensory panel. Data were analysed using one-way ANOVA, and significant means were separated with the least significant difference test. Live weight, slaughter weight and dressing percentage were not significantly affected by treatment, whereas meat-to-bone ratio differed significantly, increasing from 2.82 in T1 to 3.54 in T5. Liver, kidney and spleen weights were similar across treatments, while heart and lung weights differed significantly. Most wholesale cuts were unaffected, but loin and thigh proportions differed significantly, with T4 recording the highest values of 8.26% and 3.06%, respectively. Among carcass by-products, only horn weight differed significantly. Juiciness, tenderness, palatability and overall meat quality were significantly affected by diet, whereas flavour, aroma and leanness were not. T3 recorded the highest tenderness, palatability and overall meat quality scores. The findings indicate that root and tuber peel meals can replace maize offal at 20% inclusion without compromising major carcass traits and can support acceptable meat quality, offering a means of reducing reliance on conventional feed ingredients and utilising available agro-residues in Red Sokoto goat production.*

Keywords: Red Sokoto goats; root and tuber peels; carcass characteristics; agro-by-products; meat quality; concentrate supplementation.

INTRODUCTION

Livestock production plays a vital role in supplying high-quality animal protein, especially as global populations continue to increase, however, achieving efficient livestock production depends greatly on meeting the nutritional requirements of animals (Enahoro et al., 2026). Nigeria is expected to experience continued population growth, which will increase the demand for livestock products. According to

the Nigerian Livestock Master Plan, this growth will require improved strategies for sustainable livestock production (Enahoro et al., 2026).

Ruminants possess a specialised digestive system containing diverse anaerobic microorganisms that allow them to break down fibrous plant materials and utilise nutrients from feeds that are difficult for many other animals to digest (Owen, 2016). Ruminant production in northern Nigeria faces serious

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challenges due to seasonal feed shortages. Natural pastures, although inexpensive, cannot support animals throughout the year because prolonged dry periods reduce forage availability and quality. Consequently, animals depend on poor-quality roughages that limit feed intake, nutrient digestibility, and productivity (Ajagbe et al., 2022). The rising cost of conventional feed ingredients, especially maize and other cereals, has increased livestock production expenses. Competition between humans and livestock for these resources further highlights the need for alternative feed ingredients (Ajagbe, 2023).

Agricultural by-products such as cassava peels, yam peels, Irish potato peels, and sweet potato peels are produced in large quantities in Nigeria, and even though these materials are often discarded, they contain useful nutrients and have potential value as alternative livestock feeds (Okechukwu and Jiwuba, 2019). Their proper utilisation can reduce environmental waste and provide affordable feed resources (Ocheja et al., 2020). Studies have shown that agro by-products can improve roughage intake and provide minerals needed for growth, reproduction, and health (Ünlü et al., 2022).

The nutritional status of animals reflects in their carcass (Ocheja et al., 2022).

Meat quality assessments are becoming increasingly important, since consumers are now becoming more quality and health conscious (Ocheja et al., 2025). Therefore, this study evaluates selected agro by-products as feed resources and determines their effects on carcass characteristics of Red Sokoto Goats.

MATERIALS AND METHODS

Study Area

The experiment was conducted at the Teaching and Research Farm of the Federal College of Education (Technical), Gombe. The college is located in Gombe metropolis, along Ashaka Road, in the north-eastern part of Nigeria, and lies between latitude $10^{\circ} 10' N$ to $10^{\circ} 50' 30'' N$ and Longitude $11^{\circ} 01' E$ to $11^{\circ} 40' E$ (Agyo et al., 2021). Gombe metropolis covers about 45–52 km², with a recorded population of about 268,000 people during the 2006 census, with agriculture engaging over 75% of the population. The area is made up of plains, uplands, and isolated hills with a tropical Sudan savannah climate marked by two main seasons: a rainy season and a dry season. The rainy season usually begins around April or May and continues to about September or October, while the dry season extends mainly from November to March/April. Reported annual rainfall ranges from 850 mm to 969.7 mm, with average temperature ranging from 25°C to 40°C. Gombe town has an altitude of about 400–500 m above mean sea level (ACReSAL, 2025).

Experimental Animals and their Management

Twenty (20) growing Red Sokoto bucks with a weight range of 8.0 – 9.0 kg and aged between 10 and 11 months were sourced from the livestock market at Lariski, Bauchi State. They were conditioned to stability by feeding them adequately

for 1 week. The animals were treated with Ivomec at 0.25 mL/goat to control both *endoparasites* and *ectoparasites*. They were also injected with antibiotics (*Oxytetracycline hydrochloride* and *procaine penicillin*) at 3 mL and 2 mL per goat) to take care of scouring, nasal and ocular discharges, and to provide a good health status. The animals were then housed in individual pens with feeding and watering troughs, ear-tagged for identification, and randomly assigned to 5 treatments of 4 animals each. The experiment lasted for 100 days, after an adjustment period of fourteen (14) days. Animals in treatments T₁, T₂, T₃, T₄, and T₅ were fed experimental diets containing 20% Maize Offal, 20% Yam Peel Meal, 20% Sweet Potato Peel Meal, 20% Irish Potato Peel Meal, and 20% Cassava Peel Meal, respectively, at 250 g/goat/day.

Feed Formulation

Five experimental diets were formulated using root and tuber crop peels and designated as Treatments 1 (T₁), 2 (T₂), 3 (T₃), 4 (T₄), and 5 (T₅), respectively. T₁ contained 20% Maize offal, T₂ contained 20% Yam peel meal, T₃ contained 20% Sweet potato peel meal, T₄ contained 20% Irish potato peel meal, while T₅ contained 20% Cassava peel meal at 250g/goat/day, as shown in Table 1 below. The root and tuber peels were obtained from homes and restaurants in Gombe metropolis, soaked, washed to remove impurities, and then sun-dried to reduce moisture content and anti-nutritional factors. Other feed ingredients that made up 80% of the various Treatments are rice offal, groundnut cake, wheat offal, eggshell meal, and table salt. The groundnut cake was ground to reduce particle size, while the eggshells were soaked and washed to remove impurities. The feeds were subsequently compounded according to the percentages shown in Table 1 below. Groundnut haulm was fed at 500 g/goat/day. All the animals were given water *ad libitum*.

Table 1. Composition of Experimental Diets

Ingredients	T ₁	T ₂	T ₃	T ₄	T ₅
Maize Offal	20.00	0.00	0.00	0.00	0.00
Yam Peels Meal	0.00	20.00	0.00	0.00	0.00
SPPM	0.00	0.00	20.00	0.00	0.00
IPPM	0.00	0.00	0.00	20.00	0.00
CRPM	0.00	0.00	0.00	0.00	20.00
Rice Offals	14.00	13.00	14.00	14.00	12.00
GNC	29.00	33.00	31.00	29.00	32.00
Wheat Offal	34.00	31.00	32.00	34.00	33.00
Egg Shell Meal	2.00	2.00	2.00	2.00	2.00
Table Salt	1.00	1.00	1.00	1.00	1.00
Total	100.00	100.00	100.00	100.00	100.00

Calculated Nutrient Contents

Crude Protein	18.84	18.78	17.76	18.84	18.27
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Crude Fibre	13.84	12.89	13.75	12.34	13.01
Metabolisable Energy	2845.4	2843.3	2845.1	2847.4	2846.1
	0	6	7	5	8

SPPM: Sweet potato peel meal, IPPM: Irish potato peel meal, CRPM: Cassava Root peel meal, RO: Rice offals, GNC: Groundnut Cake.

Carcass Characteristics and Sensory Evaluation (Organoleptic Properties) of Meat from Red Sokoto Goats fed with Experimental Diets

At the end of the feeding trial, three animals from each treatment were fasted for twelve hours, but provided with water and were thereafter sacrificed, eviscerated, and dressed, and their carcass parameters evaluated as follows:

- Carcass yield (slaughter weight, dressed weight, dressing percentage, and meat-to-bone ratio).
- Wholesale cuts (Ribs, belly, neck, shoulder, back, head, and thigh)
- Organ weight (liver, lungs, kidneys, heart, and spleen), which was presented as a percentage of slaughter weight
- Carcass by-products (full gut, empty gut, gut content, blood weight, weights of hooves, and Abdominal fat)
- Carcass sensory evaluation/organoleptic properties: juiciness, tenderness, flavour, leanness, palatability, and overall meat quality.

The weight of wholesale cuts and by-products was determined by cutting off the respective parts and weighing them, and later converting the weights to percentages of slaughter weight. The dressing percentage was calculated using the formula:

$$\frac{\text{Dressed weight}}{\text{Live weight}} \times 100 = \text{Percentage}$$

The meat-to-bone ratio was determined by clearly separating the flesh from the bones for each carcass. The flesh and bone were weighed separately, and the ratio between them was determined. Abdominal fat was measured by removing and weighing it from each animal.

The carcass organoleptic properties (sensory evaluation) were determined by cutting four (4) pieces of meat of the same weight (50 g) from the same thigh of each slaughtered goat. The pieces of meat were tied with threads of different colours for each treatment to facilitate easy identification (4 pieces of meat x 3 replicates = 12 pieces of meat/treatment):

T₁ Black

T₂ Green

T₃ Yellow

T₄ Red

T₅ Purple

The pieces of meat were cooked in the same pot for 30 minutes. A twelve-member taste panel assessed the organoleptic properties of the meat. Each panellist tasted a piece of meat from each treatment. The panellists completed the questionnaire provided, which was rated on a scale of 1-5 for each parameter as follows:

Very Good -5

Good -4

Moderate -3

Fair -2

Poor -1

The organoleptic properties considered were juiciness, tenderness, Aroma, leanness, palatability, and overall meat quality. The taste panel assessments were conducted simultaneously. There was a total of sixty (60) assessments (4 pieces of meat x 3 replicates x 5 treatments = 60). The scores for each parameter/Treatment were summed and divided by 12 to obtain the mean score for each parameter. The scores for each parameter were summed to determine the overall carcass quality for each replicate and, hence, each treatment.

Chemical Analysis

Samples of experimental diets, cassava peels, Irish potato peels, sweet potato peels, yam peels, and faeces (after drying in an oven) were prepared for analysis of their proximate composition. The root and tuber peels were analysed for their anti-nutritional, mineral, and phytochemical contents. The protein content of the samples was determined by the Kjeldahl method. Ether extract, crude fibre, and ash content were determined according to standard procedures (AOAC, 2000). The nitrogen-free extract (NFE) was calculated by subtracting the sum of the percentages of crude fibre, ether extracts, crude protein, and ash from 100. The fibre component of each experimental diet was further analysed for Acid detergent fibre (ADF), Neutral detergent fibre (NDF), and Acid detergent lignin (ADL) (Van Soest, 1994).

Data Analysis

The experimental design was a Completely Randomised Design (CRD). Data were analysed using a one-way analysis of variance (ANOVA), and treatment means were compared/separated (where significant differences occurred) using the least significant difference (LSD) test. With the aid of SPSS (2015), the Statistical Package for the Social Sciences version 23.0.

RESULTS AND DISCUSSIONS

Table 2. Proximate Composition of the Experimental Diets

Parameters	Treatments					SEM	LOS
	T ₁	T ₂	T ₃	T ₄	T ₅		
MC	4.06 ^d	5.11 ^b	4.28 ^c	5.12 ^b	5.48 ^a	0.15	***
Crude Protein	20.18 ^a	20.25 ^a	20.05 ^a	20.17 ^a	16.59 ^b	0.39	***
Crude Fat	2.88 ^c	2.93 ^b	2.14 ^d	2.98 ^a	2.13 ^d	0.10	***
Crude Fibre	3.79 ^c	18.75 ^a	2.89 ^d	15.32 ^b	3.13 ^d	1.83	***
Ash	10.61 ^b	10.82 ^b	10.92 ^b	12.18 ^a	7.30 ^c	0.44	***
CHO	58.48 ^c	42.14 ^e	59.71 ^b	44.24 ^d	65.38 ^a	2.44	***
ADF	6.95 ^e	7.59 ^d	8.47 ^b	8.06 ^c	15.22 ^a	0.80	***
NDF	7.58 ^d	8.13 ^d	10.85 ^b	10.07 ^c	13.83 ^a	0.59	***
ADL	2.01 ^b	2.46 ^a	2.56 ^a	2.53 ^a	2.38 ^a	0.06	***

ADF – Acid detergent fibre, MC - Moisture Content, NDF - Neutral detergent fibre, ADL – Acid detergent lignin,
 CHO= 100-(MC +CP+C.Fat+C.Fbr+Ash)

Carcass Yield of Red Sokoto Goats fed Root and Tuber Peel-Based Concentrate Supplement Diets

Table 3 presents the carcass yield characteristics of Red Sokoto goats fed different domestic agro-by-product diets. The traits assessed were live weight, bled weight, dressing percentage, and meat-to-bone ratio. Live weight ranged from 14.75 kg in T₁ to 15.94 kg in T₄. Slaughter weight followed a similar pattern, ranging from 14.21 kg in T₁ to 15.35 kg in T₄. Dressing percentage varied from 44.20 in T₁ to 47.03 in T₃, while the meat-to-bone ratio ranged from 2.82 in T₁ to 3.54 in T₅.

Live and slaughter weights did not differ significantly among the treatments, suggesting that the diets caused little variation in body mass before slaughter or in weight immediately after slaughter. This finding is consistent with Mijinyawa et al. (2022), who studied Red Sokoto bucks fed treated and untreated bagasse with or without enzyme supplementation. They also found no significant difference in hot carcass weight among some dietary groups, although dressing percentage varied between treatments. The dressing percentages reported in their study, 40.72% to 44.11%, are close to the lower values obtained in the present study. Taken together, these findings suggest that properly managed agro-industrial by-products can be included in Red Sokoto goat diets without reducing carcass output.

Dressing percentage ranged from 44.20% in T₁ to 47.03% in T₃. Although the differences among treatments were not significant, T₃ and T₅ produced numerically higher dressing percentages than T₁. Dressing percentage is an important measure of carcass yield because it shows the proportion of live or fasted body weight recovered as carcass after slaughter. Ayanniyi et al. (2021) described dressing percentage as the proportion of carcass obtained after slaughter and noted that factors such as live weight, sex, age,

and gastrointestinal contents can influence it. In their study of West African Dwarf goats, dressing percentages of 34.56%, 45.82%, and 48.76% were reported across age groups. The values recorded in the present study therefore fall within the range expected for indigenous goats.

The clearest treatment response was seen in the meat-to-bone ratio. This ratio increased from 2.82 in T₁ to 3.54 in T₅, and the difference was highly significant. T₁ recorded the lowest value and was significantly lower than T₃, T₄, and T₅. T₂ occupied an intermediate position because its superscript overlapped with both the lower and higher statistical groups, meaning that it did not differ clearly from either T₁ or the better-performing treatments. The higher ratios recorded in T₃, T₄, and T₅ indicate that these carcasses contained more edible meat relative to bone. This is economically desirable because consumers and processors generally favour carcasses with a greater proportion of lean tissue and less bone. Carcass quality is therefore better understood not only from carcass weight or dressing percentage, but also from the amount of edible lean tissue produced. Tadesse et al. (2016) identified rib-eye area and the lean-to-bone relationship as useful indicators of meatiness in goat carcasses. Similarly, Ayanniyi et al. (2023) found that meat-to-bone ratio changed significantly with animal age, showing that carcass composition can vary even when some slaughter traits remain similar.

The present findings are also in line with recent Nigerian studies that have examined alternative feed resources for goat production. Yahaya et al. (2024) reported that cassava peel meal supplementation in Red Sokoto goats affected carcass yield, by-products, and wholesale cuts without causing adverse effects when used at suitable inclusion levels. Ocheja et al. (2025) likewise found that yam peel meal supplementation improved carcass yield and wholesale

carcass cuts in Red Sokoto goats. Together, these reports strengthen the case for using locally available agro-by-products as lower-cost feed resources in small-ruminant production.

The results further agree with Njidda and Titus (2023), who found that replacing soya bean meal with *Gmelina arborea* leaf meal in Red Sokoto goat diets improved some carcass-related responses, including a higher dressing percentage at the 30% inclusion level. In a related study, Eneji, Kalio, and Kennedy-Okoro (2015) reported that cassava peel-based diets did not negatively affect the meat composition of West African Dwarf goats. Their findings suggest that selected crop by-products can be safely incorporated into goat diets when the rations are properly balanced and adequately supplemented.

Overall, the domestic agro-by-product diets did not significantly change live weight, bled weight, carcass weight, or dressing percentage, but they did significantly improve the meat-to-bone ratio. In other words, the diets had a greater influence on carcass composition than on total carcass mass. From a production perspective, T₃, T₄, and T₅ appear more favourable because their meat-to-bone ratios were statistically higher than that of T₁. However, the three treatments did not differ significantly from one another, so the statistical evidence does not support describing T₅ as superior to T₃ or T₄. Rather, the result shows that these higher-performing diets produced meatier carcasses than the control or lowest-performing treatment.

Table 3. Carcass Yield of Red Sokoto Goats fed Some Root and Tuber Peels in Concentrate Supplement Diets

Parameters	Treatments					SEM	LOS
	1	2	3	4	5		
Live Weight (kg)	14.75	15.30	15.39	15.94	15.01	0.29	NS
Slaughter Weight (kg)	14.21	14.74	14.82	15.35	14.46	0.28	NS
Dressing Percentage (%)	44.20	45.73	47.03	45.83	46.89	0.45	NS
Meat: Bone	2.82 ^b	3.17 ^{ab}	3.34 ^a	3.46 ^a	3.54 ^a	0.08	***

a, b, c, d Means on the same row bearing different superscripts differ significantly (p<0.05), SEM = Standard Error of Means, LOS = Level of Significance

Organ Weights from Carcass of Red Sokoto Goats fed Root And Tuber Peel-Based Concentrate Supplement Diets

Table 4 presents the organ weights of Red Sokoto goats fed the different domestic agro-by-product diets, expressed as percentages of live weight. Liver, kidney, and spleen weights were not significantly affected by dietary treatment, whereas significant differences were observed in heart and lung weights. Liver weight ranged from 2.05 in T₂ to 2.16 in T₅, while heart weight ranged from 0.67 in T₁ to 0.83 in T₂. Kidney weight varied from 0.46 in T₅ to 0.53 in T₃, and lung weight ranged from 1.63 in T₁ to 1.99 in T₄. Spleen weight was lowest at 0.15 in T₁ and T₂ and highest at 0.18 in T₅.

As shown in Table 3, the liver, kidney, and spleen weights of Red Sokoto goats remained statistically similar across the domestic agro-by-product diets. In contrast, the heart and lungs responded significantly to dietary treatment. This pattern indicates that most visceral organs were relatively stable, while the heart and lungs showed measurable differences among the treatment groups.

The lack of a significant difference in liver weight suggests that the different domestic agro-by-product diets did not cause noticeable enlargement or reduction of the liver. This is important because the liver performs major metabolic and detoxification functions, and unusual enlargement can sometimes reflect excessive metabolic stress or exposure to

harmful dietary components. The result agrees with Ocheja et al. (2022), who found that supplementing Red Sokoto goats with different forms of neem leaves and concentrate did not significantly alter organ weights; their reported liver values ranged from 2.10 to 2.17% and kidney values from 0.50 to 0.53%. A similar observation was made by Yahaya et al. (2024), who studied Red Sokoto bucks fed graded levels of cassava peel meal as a supplement to neem leaves. Although cassava peel meal affected some carcass and by-product traits in their study, organ weights were not significantly altered, and the authors considered the reported inclusion level safe. This supports the present observation that the test diets did not adversely affect the liver, kidneys, or spleen.

Kidney weight ranged from 0.46 in T₅ to 0.53 in T₃, with no significant difference among treatments. This suggests that the diets did not create a detectable burden on kidney development. Because the kidneys are central to waste removal and fluid regulation, their stable weights across treatments may indicate that the domestic agro-by-products did not interfere with normal excretory organ development. This interpretation is consistent with the organ safety argument reported by Yahaya et al. (2024), where the absence of visceral organ enlargement was taken as evidence that cassava peel meal did not adversely affect internal organ development in Red Sokoto goats. Heart weight, however, differed highly significantly across treatments. T₁ recorded the lowest heart weight, whereas T₂ and T₅ fell within the highest

statistical grouping. The higher values in T₂ and T₅ may be related to differences in body development, circulatory demand, or physiological adaptation to the diets. Olafadehan (2011) showed that feed type can influence haematological and biochemical diagnostic parameters in Red Sokoto goats, suggesting that organ-weight findings are best considered alongside blood and serum measurements.

Lung weight also showed a highly significant response to dietary treatment. T₁ recorded the lowest value, while T₃, T₄, and T₅ were grouped among the highest. This pattern may indicate greater development of thoracic organs in the later treatments or a physiological response associated with differences in diet composition. Jiwuba, Onwujiariri, and Kadurumba (2020) similarly reported significant treatment effects on internal organs in West African Dwarf goats fed diets containing yellow root cassava peel and centrosema leaf

meal, showing that unconventional feed ingredients can influence organ proportions depending on the diet and breed. Spleen weight, on the other hand, did not differ significantly, even though it increased numerically from 0.15 in T₁ and T₂ to 0.18 in T₅. Since the spleen contributes to blood storage and immune function, the absence of a significant difference suggests that the treatments did not produce major changes in this organ. This is consistent with the general pattern in many goat feeding trials, where properly processed agro-by-products used at tolerable levels do not markedly alter organ weights. For example, Ocheja et al. (2022) reported no significant differences in the organ weights assessed in Red Sokoto goats fed different forms of neem leaves.

Table 4. Organ Weights from Carcass of Red Sokoto Goats Fed Root and Tuber Peel-Based Concentrate Supplement Diets (% of Live Weight)

Parameters (%)	Treatments					SEM	LOS
	1	2	3	4	5		
Liver	2.09	2.05	2.11	2.06	2.16	0.02	NS
Heart	0.67 ^b	0.83 ^a	0.78 ^{ab}	0.76 ^{ab}	0.80 ^a	0.02	*
Kidney	0.49	0.51	0.53	0.52	0.46	0.01	NS
Lungs	1.63 ^b	1.79 ^{ab}	1.98 ^a	1.99 ^a	1.94 ^a	0.05	*
Spleen	0.15	0.15	0.16	0.16	0.18	0.00	NS

^{a, b, c, d} Means on the same row bearing different superscripts differ significantly ($p < 0.05$), SEM = Standard Error of Means, LOS = Level of Significance

Wholesale Cuts from Carcass of Red Sokoto Goats fed Root and Tuber Peel-Based Concentrate Supplement Diets

Table 5 shows the percentage distribution of wholesale carcass cuts from Red Sokoto goats fed the different domestic agro-by-product diets. The cuts measured were the head, neck, skin, shoulder, breast/rack, shank, limbs, loins, thigh, and flank. Among these components, the limbs contributed the largest proportion, ranging from 17.77% in T₅ to 18.87% in T₁. Skin was the next largest component, with values between 9.00% and 9.72%, and no significant treatment effect was observed. The head, neck, breast/rack, shank, and flank also did not differ significantly among treatments. Head values ranged from 5.65% to 8.54%, neck values from 5.77% to 6.25%, breast/rack values from 7.63% to 7.98%, and flank values from 7.67% to 8.29%. Loin percentage was lowest in T₁ at 6.92% and highest in T₄ at 8.26%. Thigh percentage also differed significantly, ranging from 2.62% in T₂ to 3.06% in T₄.

Table 5 presents the distribution of the main wholesale carcass cuts, including the head, neck, skin, shoulder, breast/rack, shank, limbs, loins, thigh, and flank. Most of these cuts were not significantly influenced by dietary treatment; the exceptions were the loins and thighs, which differed significantly among treatments ($p < 0.05$). Limbs accounted for the greatest proportion of the carcass cuts, with values ranging from 17.77% in T₅ to 18.87% in T₁. The

relative stability of limb weight may reflect its stronger relationship with skeletal frame, age, and overall body development than with short-term dietary changes alone. Standard carcass evaluation studies have shown that anatomical cuts such as shoulder, ribs, neck, flank, and leg are useful indicators for comparing carcass composition across breeds, diets, and management systems (Colomer-Rocher et al., 1987; Gawat et al., 2023)

The relatively high limb proportions recorded in this study further demonstrate the meat-producing potential of Red Sokoto goats. Adu and Brinckman (2021) reported that the breed has useful meat-production potential, with dressing percentage and carcass measurements indicating a meaningful contribution to chevon production in Nigeria. Similarly, Ayanniyi et al. (2021) compared indigenous Nigerian goat breeds and found that Red Sokoto bucks produced lean meat, although differences among breeds influenced carcass yield and physical meat characteristics. Skin was the second-largest component in the present study, ranging from 9.00% to 9.72%, with no significant treatment effect. This finding is economically relevant because Red Sokoto goats are valued not only for meat production but also for their skins. Adu and Brinckman (2021) note that Red Sokoto skins are of exceptional quality and are known in the leather trade as "Morocco," highlighting the importance of skin yield as an additional carcass by-product. The absence of a significant dietary effect on skin percentage therefore suggests that the treatments did not materially alter this valuable component.

The head, neck, breast/rack, shank, and flank remained statistically similar across treatments. Head values ranged from 5.65% to 8.54%, neck values from 5.77% to 6.25%, breast/rack values from 7.63% to 7.98%, and flank values from 7.67% to 8.29%. This consistency indicates that the domestic agro-by-product diets maintained the general distribution of most wholesale carcass cuts without an apparent negative effect. This agrees with findings from studies on Red Sokoto goats, in which dietary by-products such as cassava peel meal and yam peel meal influenced certain carcass traits but did not uniformly alter all carcass components (Yahaya et al., 2024). The loin showed one of the clearest treatment responses, with a highly significant difference among groups. Loin percentage ranged from 6.92% in T₁ to 8.26% in T₄. Based on the superscripts, T₂ and T₄ were significantly higher than T₁, while T₃ and T₅ were statistically intermediate. Because the loin is an important meat-bearing region, the higher value recorded in T₄ may reflect more favourable nutrient use for muscle deposition in that group. This is consistent with broader evidence that feeding regimen is a major factor affecting growth rate, carcass traits, and meat quality in sheep and goats (Huang et al., 2023).

Thigh percentage also differed significantly among treatments, with the lowest value recorded in T₂ at 2.62% and the highest in T₄ at 3.06%. The higher thigh yield in T₄ adds to the evidence that this treatment may have favoured the development of selected meat-bearing cuts. Bambou et al. (2021) showed that dietary supplementation and slaughter age

can significantly influence dressing percentage, carcass conformation, and other carcass characteristics in goats. In the present study, the higher loin and thigh values under T₄ may therefore be associated with improved nutrient availability, digestibility, or feed conversion from the agro-by-product used in that diet. These findings also agree with Okoh and Omojola (2018), who reported that carcass handling and post-slaughter processing can influence dressing percentage, wholesale cuts, and quality traits in Red Sokoto bucks. Although their study focused on dressing and processing rather than dietary treatment, both sets of findings show that the distribution of carcass cuts in Red Sokoto goats can respond to production and processing conditions.

Taken together, the results show that the tested domestic agro-by-products did not negatively affect most wholesale cuts of Red Sokoto goats. The significant differences observed in the loins and thighs suggest that T₄ may have encouraged better development of some important meat-bearing regions. This has practical value in small-ruminant production, where feed cost is a major challenge and locally available agro-by-products can reduce dependence on conventional feed ingredients when they are properly processed and nutritionally balanced. Yahaya et al. (2024) reported that cassava peel meal used in supplement diets influenced by-products, wholesale cuts and carcass yield in Red Sokoto goats. Ocheja et al. (2025) also found that yam peel meal could be used as a useful feed resource for Red Sokoto goats without adversely affecting carcass yield.

Table 5. Wholesale Cuts from Carcass of Red Sokoto Goats Fed Root and Tuber Peel-Based Concentrate Supplement Diets

Parameters (%)	1	2	3	4	5	SEM	LOS
Head	5.65	8.15	7.49	8.54	7.72	0.51	NS
Neck	5.77	6.25	5.97	6.17	5.80	0.11	NS
Skin	9.00	9.33	9.39	9.72	9.16	0.18	NS
Shoulder	2.25	2.34	2.36	2.44	2.30	0.04	NS
Breast/Rack	7.86	7.97	7.63	7.98	7.91	0.13	NS
Shank	5.56	5.54	5.69	5.83	5.69	0.22	NS
Limbs	18.87	18.27	18.77	18.74	17.77	0.22	NS
Loins	6.92 ^b	7.93 ^a	7.52 ^{ab}	8.26 ^a	7.74 ^{ab}	0.15	*
Thigh	2.74 ^{ab}	2.62 ^b	2.94 ^{ab}	3.06 ^a	2.76 ^{ab}	0.06	*
Flank	7.67	7.95	8.00	8.29	7.80	0.15	NS

^{a, b, c, d} Means on the same row bearing different superscripts differ significantly ($p < 0.05$), SEM = Standard Error of Means, LOS = Level of Significance

Weights of By-Products of Carcass of Red Sokoto Goats fed Root and Tuber Peel-Based Concentrate Supplement Diets

Table 6 presents the carcass by-product measurements of Red Sokoto goats fed the domestic agro-by-product diets. The

variables assessed were blood volume, full gut, gut content, empty gut, hooves, and horns. Blood volume ranged from 353.33 ml in T₃ to 456.67 ml in T₁, with no significant difference among treatments. Full gut weight varied from 2984.82 g in T₁ to 3227.04 g in T₄, while gut content ranged from 1628.08 g in T₁ to 1760.20 g in T₄. Empty gut weight ranged from 1356.74 g in T₁ to 1466.83 g in T₄. Hoof weight was also not significantly affected by treatment, with values between 26.58 g in T₁ and 28.71 g in T₄.

As presented in Table 6, blood volume, full gut, gut content, empty gut, hooves, and horns were measured as carcass by-products. With the exception of horn weight, none of these parameters differed significantly among dietary treatments. This overall stability suggests that the domestic agro-by-product diets had little effect on most non-carcass components of the goats.

The absence of a significant treatment effect on blood volume suggests that the experimental diets did not produce marked differences in the amount of blood recovered at slaughter. Values ranged from 353.33 ml in T₃ to 456.67 ml in T₁, but the differences were not statistically significant. This is consistent with the general expectation that moderate changes in diet may not substantially alter slaughter by-products unless they also affect live weight, health status, hydration, or slaughter conditions. Adu and Brinckman (2021) included drainable blood among the measurable slaughter by-products of Red Sokoto goats, while Ocheja et al. (2023) also treated blood as an important carcass by-product in Red Sokoto goats fed neem-based diets. Full gut weight ranged from 2984.82 g in T₁ to 3227.04 g in T₄, and gut content ranged from 1628.08 g in T₁ to 1760.20 g in T₄. Although T₄ recorded the highest numerical values, these differences were not significant, indicating that the dietary treatments did not substantially change gut fill. This is important when interpreting slaughter weight, empty body weight, and dressing percentage because differences in gut fill can influence these measurements. Webb (2014) noted that dressing percentage in goats should be interpreted carefully because carcass yield is affected by alimentary tract fill, slaughter procedure, age, body weight, and fatness. Empty gut weight ranged from 1356.74 g in T₁ to 1466.83 g in T₄, again with no significant treatment effect. This suggests that the domestic agro-by-product diets did not cause abnormal enlargement or reduction of digestive tract tissues. This agrees with Ocheja et al. (2023), who found that different forms of neem leaves did not significantly affect by-products such as full gut, empty gut, blood, horns, and hooves in Red Sokoto goats. Their inclusion of full gut and blood among the measured by-products also supports the relevance of these variables in carcass assessment.

Hoof weight was not significantly affected by dietary treatment and ranged from 26.58 g in T₁ to 28.71 g in T₄. This is not unexpected, as hoof weight is likely to be more closely associated with age, skeletal growth, breed, and overall body size than with short-term dietary changes. Horn weight was the only by-product that differed significantly among treatments. T₄ recorded the highest horn weight at 9.39 g, whereas T₁ had the lowest value at 7.37 g. T₂, T₃, and T₅ were intermediate and did not differ statistically from either T₁ or T₄. Because horns are hard structural tissues, the observed difference may reflect animal size, mineral utilisation, age-related growth, or individual variation rather than a direct short-term dietary effect alone. The National Research Council (2007) explains that nutrient requirements in goats vary with breed, age, physiological state, and management conditions, reinforcing the need to interpret structural by-products in relation to age, body weight, and mineral nutrition. The findings also fit with studies showing that locally available feed materials can be incorporated into goat diets without harming carcass or by-product traits when the diets are properly balanced. Yahaya et al. (2024) reported that cassava peel meal could be used in supplement diets for Red Sokoto goats, while Njidda and Titus (2023) found that replacing soybean meal with *Gmelina arborea* leaf meal influenced performance, digestibility, carcass traits, and organ weights in Red Sokoto goats. Overall, these studies support the use of domestic agro-by-products as alternative feed resources, particularly for dry-season feeding and lower-cost goat production systems (Yahaya et al., 2024).

From a practical standpoint, the lack of significant differences in blood volume, full gut, gut content, empty gut, and hoof weight indicates that the domestic agro-by-product diets maintained fairly stable by-product yields across treatments. This may be beneficial to goat producers because by-products such as blood, gut, hooves, and horns can have economic value when they are properly recovered and handled. Ocheja et al. (2023) emphasised that livestock by-products, including horns, hooves, stomach contents, bones, blood, and related materials, can be processed, sold, or used as raw materials instead of being discarded as waste.

Table 6. Weights of By-Products of Carcass of Red Sokoto Goats Fed Root and Tuber Peel-Based Concentrate Supplement Diets

Parameters	Treatments					SEM	LOS
	1	2	3	4	5		
Blood Volume (ml)	456.67	423.33	353.33	416.67	403.33	18.90	NS
Full Gut (g)	2984.82	3096.62	3114.91	3227.04	3038.12	59.54	NS
Gut Content (g)	1628.08	1689.06	1699.04	1760.20	1657.16	32.48	NS
Empty Gut (g)	1356.74	1407.55	1415.87	1466.83	1380.96	27.06	NS
Hooves (g)	26.58	28.54	28.08	28.71	27.23	0.79	NS
Horns (g)	7.37 ^b	8.68 ^{ab}	8.72 ^{ab}	9.39 ^a	8.84 ^{ab}	0.26	*

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^{a, b, c, d} Means on the same row bearing different superscripts differ significantly ($p < 0.05$), SEM = Standard Error of Means, LOS = Level of Significance

Organoleptic Characteristics of Meat from Red Sokoto Goats fed Some Root and Tuber Peels in Concentrate Supplement Diets

Table 7 presents the organoleptic characteristics of meat from Red Sokoto goats fed the different domestic agro-by-product diets. Juiciness was highest in T_1 at 4.36, followed by T_5 at 4.27 and T_3 at 4.18. T_2 recorded a score of 3.90, while T_4 had the lowest value at 3.45. Tenderness was also significantly affected by treatment, with T_3 recording the highest score of 4.45, followed by T_1 at 4.09, T_5 at 3.91, and T_2 at 3.72. For flavour, T_5 had the highest score at 4.18, followed by T_1 , T_3 , T_4 , and T_2 with scores of 3.91, 3.72, 3.64, and 3.45, respectively. Aroma scores were highest in T_1 and T_5 , both at 4.18, followed by T_3 at 4.09, T_2 at 3.82, and T_4 at 3.64. Leanness ranged from 3.45 in T_2 to 3.90 in T_3 ; T_4 and T_5 each recorded 3.82, while T_1 had a score of 3.72.

In goat meat sensory assessment, characteristics such as tenderness, juiciness, flavour and overall acceptability are especially important because they shape how consumers judge meat quality (Webb et al., 2005; Gawat et al., 2023). In the present study, meat from T_1 , T_3 and T_5 was judged to be juicier than meat from T_4 . Juiciness is influenced by factors such as water-holding capacity, fat content, and post-slaughter handling, while the naturally lean composition of goat carcasses can sometimes make the meat seem less juicy (Webb et al., 2005; Popiwa et al., 2020). The lowest tenderness score, 3.00, was recorded in T_4 , whereas T_3 had the highest score at 4.45. This means that meat from T_3 was perceived as the most tender and meat from T_4 as the least tender. Because tenderness is a major eating-quality trait, the high score recorded in T_3 suggests that this treatment produced a more desirable meat texture. Popiwa et al. (2020) reported that goat meat quality can be influenced by biological factors such as breed and age at slaughter, as well as carcass handling, while appropriate chilling and post-slaughter ageing can improve tenderness. The present findings therefore indicate that the diet represented by T_3 produced the most favourable tenderness response among the treatments. A similar trend was reported by Bukola et al. (2025), who studied Red Sokoto goats fed graded levels of yam peel meal as a supplement to shea butter leaves and found that tenderness, flavour, and palatability were significantly higher in T_3 than in the other treatments.

Although T_5 recorded the highest numerical flavour score, the difference was not statistically significant, meaning that the diets did not alter flavour perception enough to establish a clear treatment effect. This is encouraging because it suggests that including root and tuber peels in the diets did not

introduce an undesirable flavour into the meat. This agrees with the general observation that goat meat has a distinct species-related flavour and aroma but can remain acceptable to consumers when animals are properly managed and slaughtered (Webb et al., 2005). Aroma also did not differ significantly among treatments, suggesting that the different domestic agro-by-products did not negatively affect the smell of the cooked meat. Aroma matters because it forms part of the consumer's first sensory impression before the meat is chewed, and an unpleasant smell can reduce acceptability even when tenderness is satisfactory. The present result therefore indicates that all treatment groups maintained acceptable aroma characteristics. This agrees with Ocheja et al. (2023), who reported that feeding Red Sokoto goats different forms of neem leaves with concentrate did not significantly affect sensory traits, with juiciness, palatability, and overall meat quality remaining within acceptable ranges. The result is also consistent with findings from crop by-product feeding studies in West African Dwarf goats.

Leanness scores did not show a clear treatment effect, indicating that the diets did not noticeably change the perceived fatness or lean appearance of the meat. This is reasonable because goat meat is generally recognised as a lean red meat with favourable nutritional characteristics, and this naturally low fatness contributes to its growing reputation as a healthier meat option (Webb et al., 2005; Gawat et al., 2023). Eneji et al. (2012) fed goats cassava peel-based diets supplemented with different nitrogen and forage sources and included colour, flavour, tenderness, juiciness and overall acceptability in their sensory evaluation. Similarly, Oyinlola et al. (2025) evaluated goats fed diets containing corn cobs and cassava peels and found significant differences in some organoleptic traits, including tenderness and juiciness, while overall acceptability did not differ significantly.

Palatability differed significantly among treatments. T_3 recorded the highest score at 4.64, followed by T_5 at 4.45. T_1 and T_2 each scored 4.09, whereas T_4 had the lowest value at 3.55. These scores indicate that meat from T_3 and T_5 was more acceptable to the panel than meat from T_4 . Because palatability reflects the combined impression of tenderness, juiciness, flavour and aroma, the strong score in T_3 may be partly explained by its superior tenderness together with its acceptable juiciness. This agrees with previous goat meat studies showing that diet and processing can influence sensory traits and the overall acceptability of meat from goats fed crop by-products (Eneji et al., 2012). Overall meat quality was also significantly affected by treatment. T_3 had the highest overall score at 25.00, followed closely by T_5 at 24.81 and T_1 at 24.36. T_2 recorded an intermediate score of 22.45, while T_4 had the lowest score at 21.09. On this basis, meat from T_3 , T_5 , and T_1 was the most acceptable, whereas T_4 produced the least preferred meat.

Table 7 Organoleptic Characteristics of Meat from Red Sokoto Goats Fed Some Root and Tuber Peels in Concentrate Supplement Diets

Parameters	Treatments					SEM	LOS
	1	2	3	4	5		
Juiciness	4.36 ^a	3.90 ^{ab}	4.18 ^a	3.45 ^b	4.27 ^a	0.11	*
Tenderness	4.09 ^a	3.72 ^{ab}	4.45 ^a	3.00 ^b	3.91 ^a	0.41	*
Flavour	3.91	3.45	3.72	3.64	4.18	0.11	NS
Aroma	4.18	3.82	4.09	3.64	4.18	0.13	NS
Leanness	3.72	3.45	3.90	3.82	3.82	0.13	NS
Palatability	4.09 ^{ab}	4.09 ^{ab}	4.64 ^a	3.55 ^b	4.45 ^a	0.13	*
Overall Meat Quality	24.36 ^a	22.45 ^{ab}	25.00 ^a	21.09 ^b	24.81 ^a	0.42	*

^{a, b, c, d} Means on the same row bearing different superscripts differ significantly ($p < 0.05$), SEM = Standard Error of Means, LOS = Level of Significance

CONCLUSION AND RECOMMENDATIONS

Conclusion

Based on the findings of this study, the following conclusions are drawn:

Root and tuber crop peels can be used as alternative concentrate supplements for Red Sokoto goats fed groundnut haulm-based diets. Their inclusion at 20% in concentrate diets did not negatively affect carcass yield, organ development, meat quality, and organoleptic characteristics. The carcass results showed that the root- and tuber-peel-based diets produced carcass yields comparable to those of the control diet. Treatment 5 improved meat-to-bone ratio, Treatment 3 improved dressing percentage numerically, and Treatment 4 improved some wholesale cuts, particularly loins and thighs. The sensory evaluation showed that the diets did not negatively affect meat acceptability. Treatment 3 produced the most desirable overall meat quality, tenderness and palatability, while Treatment 5 showed strong flavour and aroma responses. This indicates that sweet potato peel meal and cassava peel meal can support acceptable meat quality in Red Sokoto goats.

Recommendations

Based on the findings of this study, the following recommendations are made:

1. Root and tuber crop peels should be considered as alternative concentrate supplement ingredients for Red Sokoto goats, especially in areas where conventional feed ingredients such as maize offal are expensive or scarce.
2. Sweet potato peel meal may be recommended where the production objective is improved meat sensory quality, since Treatment 3 recorded the best tenderness, palatability and overall meat quality, as well as the highest numerical final body weight and total weight gain.

3. Irish potato peel meal may be recommended where the production objective is better feed efficiency, carcass cut improvement and economic return, since Treatment 4 recorded the best numerical feed conversion ratio, highest numerical live and slaughter weights, highest loin and thigh values, highest dietary metabolizable energy and the highest numerical cost-benefit ratio.
4. Extension workers, livestock officers and animal nutritionists should promote the use of properly processed root and tuber peels as a strategy for reducing feed cost, converting domestic waste into useful feed and improving the sustainability of small ruminant production.

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