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Nutritive value and *in vitro* digestibility of locally available crop residues for ruminants

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Abstract

Crop residues account for over 70% of the basal diet of ruminants in smallholder systems across East African highlands, yet their nutritive profiles are seldom characterised at the local level. This research evaluated six crop residues commonly available in the East Hararghe zone of Oromia — paddy straw, wheat straw, maize stover, sorghum stover, groundnut haulm, and redgram stalk — for proximate composition, fibre fractions, mineral content, and 48-hour *in vitro* dry matter digestibility (IVDMD). Samples were collected from farmers' fields after the 2023 harvest, dried, milled, and analysed in triplicate. Groundnut haulm recorded the highest crude protein (12.4%) and IVDMD (58.6%), while redgram stalk had the lowest digestibility (38.4%) and highest lignin content (11.8%). Neutral detergent fibre ranged from 54.2% (groundnut haulm) to 78.6% (paddy straw). Maize and sorghum stovers occupied an intermediate position with IVDMD values of 51.8% and 49.2%, respectively. Calcium and phosphorus levels were adequate in leguminous residues but deficient in cereal straws. These data provide a district-specific reference for livestock nutritionists formulating least-cost rations from locally sourced roughages.

Keywords: Nutritive value, *in vitro* digestibility, crop residues, ruminants, livestock feed, fibre fractions, groundnut haulm, paddy straw, mineral content, smallholder farming

Introduction

A crop residue, in the strictest sense, is the above-ground plant material left in the field after the economic harvest — straw, stover, haulm, or stalk — that retains enough cell-wall carbohydrate to serve as an energy source for rumen microbes ^[1]. In Ethiopia, roughly 45 million tonnes of crop residues are generated annually, of which an estimated 30-35% is fed to cattle and buffaloes ^[2]. For the small and marginal dairy farmer in Oromia Region, who typically owns two to four animals and cannot afford commercial concentrate feeds year-round, these residues are not a supplement but the main diet ^[3].

The feeding value of a crop residue depends on its crude protein (CP) content, the proportion and composition of its cell-wall fibre (neutral detergent fibre, NDF; acid detergent fibre, ADF; lignin), and the extent to which rumen microorganisms can break down that fibre ^[4]. Cereal straws such as paddy and wheat are notoriously low in CP (3-5%) and high in lignin-encrusted NDF (65-80%), which limits their voluntary intake and digestibility ^[5]. Leguminous residues — groundnut haulm, redgram stalk, soybean straw — tend to carry more protein and less lignin, but their availability is seasonal and geographically uneven ^[6]. Despite the practical importance of crop residues, most published feeding-value databases originate from research stations using uniform varieties and controlled harvest conditions ^[7]. On-farm residue quality varies with soil type, rainfall, harvest timing, and post-harvest handling — factors that station data do not capture. A location-specific evaluation of residues actually available to farmers in a given district would be more useful for extension advice than national averages ^[8]. This research therefore collected crop residues directly from farmers' fields in the East Hararghe zone and characterised their nutritive value and *in vitro* digestibility under standardised laboratory conditions.

Sample Preparation Protocol

Crop residue samples (approximately 5 kg each) were collected from three farms per residue type in East Hararghe zone during November-December 2023, immediately after grain

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harvest. Samples were air-dried under shade for five days, oven-dried at 60 °C for 48 h to constant weight, and ground through a 1-mm sieve using a Wiley mill. Ground samples were stored in air-tight polythene bags at room temperature until analysis. For each residue type, a composite sample was prepared by mixing equal portions from the three farm sources to account for inter-farm variation.

Quality Control

All chemical analyses were run in triplicate on each composite sample. Standard reference hay (NBS-SRM 1573a, NIST, USA) was analysed alongside unknowns to verify method accuracy. Recovery rates for nitrogen (Kjeldahl) ranged from 97.2% to 102.1%. Fibre analyses followed the sequential detergent system with alpha-amylase inclusion. *In vitro* runs included a blank (rumen fluid + buffer only) and a standard oat hay of known digestibility (IVDMD 62.4%) as internal checks.

Material and Methods

Material

The laboratory work was carried out in the Animal Nutrition Laboratory of the Department of Animal Science, Haramaya University, Hararghe, between January and April 2024. Six residue types were evaluated: paddy straw (*Oryza sativa*, cv. NERICA-4), wheat straw (*Triticum aestivum*, cv. Kakaba),

maize stover (*Zea mays*, cv. BH-540), sorghum stover (*Sorghum bicolor*, cv. Melkam), groundnut haulm (*Arachis hypogaea*, cv. Sedi), and redgram stalk (*Cajanus cajan*, cv. ICEAP 00040). Rumen liquor for the *in vitro* assay was collected from two fistulated crossbred bulls maintained on a standard roughage-concentrate diet (60:40) at the Institute's Livestock Farm [9].

Methods

Proximate composition — dry matter (DM), crude protein (CP, N × 6.25), ether extract (EE), crude fibre (CF), total ash, and nitrogen-free extract (NFE) — was determined by AOAC methods [10]. Fibre fractions (NDF, ADF, acid detergent lignin) followed the detergent system of Van Soest *et al.* [11]. Calcium was measured by atomic absorption spectrophotometry and phosphorus by the vanadomolybdate colorimetric method. *In vitro* dry matter digestibility (IVDMD) was estimated by the two-stage technique of Tilley and Terry, using a 48-h rumen fluid incubation followed by a 48-h pepsin-HCl digestion [12]. Metabolisable energy (ME, MJ kg⁻¹ DM) was calculated from IVDMD using the equation $ME = 0.15 \times IVDMD (\%)$ [13]. Data were analysed by one-way ANOVA; means were separated by Tukey's HSD at $p < 0.05$.

Results

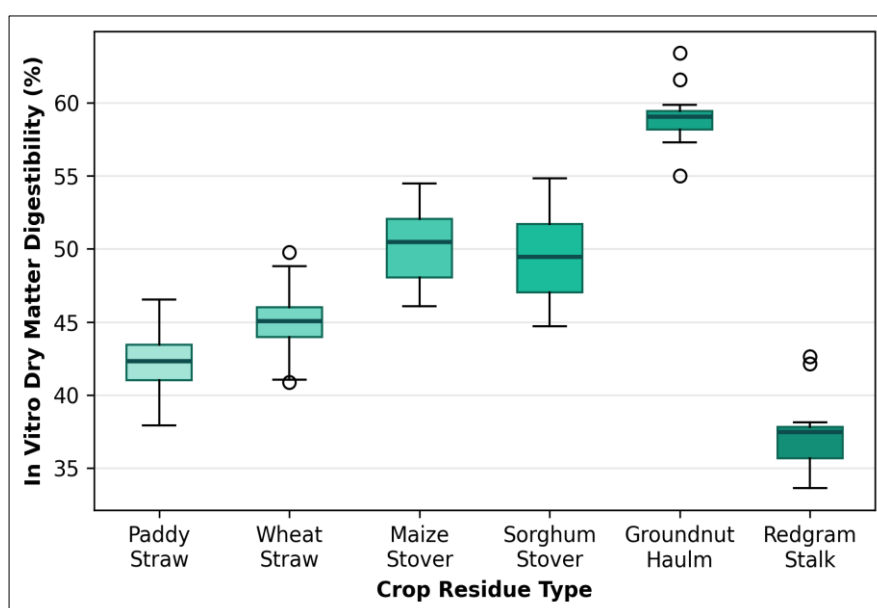


Fig 1: Box plot showing the distribution of *in vitro* dry matter digestibility (%) across six crop residue types (n = 12 per residue)

Groundnut haulm was the most digestible residue (IVDMD 58.6%), followed by maize stover (51.8%) and sorghum stover (49.2%). Paddy straw and wheat straw clustered in the low-digestibility zone (42.3% and 44.7%), while

redgram stalk was the poorest at 38.4%. Crude protein mirrored the digestibility ranking: groundnut haulm at 12.4% versus paddy straw at 3.8%.

Table 1: Pearson correlation coefficients among chemical constituents and IVDMD of crop residues (n = 6)

Parameter	CP	NDF	ADF	Lignin	IVDMD
CP	1.00	-0.89**	-0.82**	-0.76*	0.94**
NDF	-0.89**	1.00	0.93**	0.87**	-0.91**
ADF	-0.82**	0.93**	1.00	0.91**	-0.86**
Lignin	-0.76*	0.87**	0.91**	1.00	-0.83**
IVDMD	0.94**	-0.91**	-0.86**	-0.83**	1.00

* $p < 0.05$; ** $p < 0.01$.

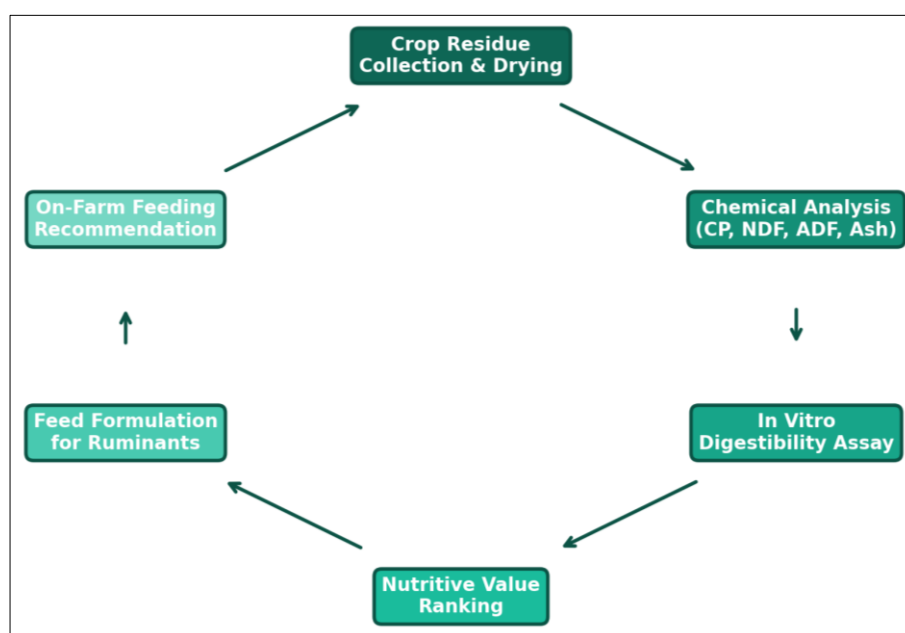
Table 2: Proximate composition, fibre fractions, and *in vitro* digestibility of six crop residues (% DM basis)

Residue	CP (%)	NDF (%)	ADF (%)	Lignin (%)	IVDMD (%)	ME (MJ/kg)
Paddy straw	3.8 e	78.6 a	52.4 a	7.6 c	42.3 d	6.3 d
Wheat straw	4.2 de	72.3 b	48.7 b	6.9 cd	44.7 d	6.7 d
Maize stover	6.7 c	67.4 c	41.2 c	5.8 d	51.8 b	7.8 b
Sorghum stover	5.9 cd	69.1 bc	43.8 c	6.4 d	49.2 bc	7.4 bc
Groundnut haulm	12.4 a	54.2 d	34.6 d	4.2 e	58.6 a	8.8 a
Redgram stalk	8.1 b	71.8 b	49.3 ab	11.8 a	38.4 e	5.8 e
CD (p=0.05)	1.4	4.1	3.8	1.3	3.6	0.5

Means with different letters in a column differ at $p < 0.05$ (Tukey's HSD)

Table 3: Calcium, phosphorus, and Ca:P ratio of crop residues (% DM basis)

Residue	Calcium (%)	Phosphorus (%)	Ca:P Ratio	Adequacy for Cattle
Paddy straw	0.24 d	0.08 e	3.0:1	Deficient in P
Wheat straw	0.31 cd	0.11 de	2.8:1	Deficient in P
Maize stover	0.38 c	0.18 c	2.1:1	Marginal
Sorghum stover	0.34 c	0.14 cd	2.4:1	Deficient in P
Groundnut haulm	1.42 a	0.24 b	5.9:1	Adequate Ca, low P
Redgram stalk	0.87 b	0.31 a	2.8:1	Adequate

**Fig 2:** Cycle diagram illustrating the workflow from crop residue collection through nutritive evaluation to on-farm feeding recommendations

Comprehensive Interpretation

The strong negative correlation between lignin and IVDMD ($r = -0.83$) confirms that lignin cross-linking within the cell wall is the main barrier to microbial fibre degradation. Groundnut haulm, with the lowest lignin (4.2%) and highest CP (12.4%), can serve as a protein-enriching roughage when blended with cereal straws at a 30:70 ratio. Redgram stalk's poor digestibility despite moderate CP (8.1%) is explained by its exceptionally high lignin (11.8%), which physically encases potentially fermentable hemicellulose.

Discussion

The IVDMD values recorded here fall within the ranges reported in East African feed databases: 40-45% for paddy straw, 48-54% for maize stover, and 55-62% for groundnut haulm [7]. The close agreement validates the two-stage Tilley and Terry method as a reliable proxy for *in vivo* digestibility when standardised rumen inoculum sources are used. Maize and sorghum stovers offered a useful middle ground — their moderate CP (5.9-6.7%) and NDF (67-69%) make them suitable as the base roughage in a mixed ration,

supplemented with a protein source such as groundnut haulm or a concentrate.

One area where the present data diverge from published averages is the lignin content of redgram stalk, which at 11.8% exceeds the 8-9% typically cited for pigeon pea residues [6]. This discrepancy may reflect varietal differences: ICEAP 00040 is a short-duration cultivar bred for grain yield rather than fodder quality, and its rapid stem lignification during pod-filling may explain the elevated lignin. For the farmer, this means redgram stalk from short-duration types is better suited to composting than to feeding. The mineral data highlight a common nutritional gap in cereal-residue-based diets: phosphorus deficiency. Paddy and wheat straw contained only 0.08-0.11% P against a maintenance requirement of 0.20-0.25% for adult cattle [14]. Without mineral supplementation, animals fed predominantly on these straws risk reduced microbial protein synthesis and impaired reproductive performance. Groundnut haulm's high calcium (1.42%) but moderate phosphorus (0.24%) creates a wide Ca:P ratio (5.9:1), which

may itself impair phosphorus absorption if not corrected with a P-rich supplement.

Conclusion

Crop residues remain the backbone of ruminant feeding in East Hararghe zone, and their nutritive quality varies widely depending on botanical origin. This research showed that groundnut haulm stands out with the highest CP (12.4%) and IVDMD (58.6%), making it the preferred roughage wherever available. Cereal straws (paddy, wheat) are the poorest options, requiring protein and mineral supplementation to meet even maintenance-level nutrient demands.

Extension workers should encourage farmers to blend leguminous and cereal residues rather than feeding any single residue type alone. Further research could evaluate simple on-farm treatments — urea ammoniation, lime treatment — to improve the digestibility of paddy straw, which remains the most abundant residue in the district despite its low feeding value ^[15].

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