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Nutrient digestibility and growth response of goat kids fed total mixed ration with crop by-products

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Abstract
A total mixed ration, or TMR, is a feeding strategy in which roughage, concentrate, and supplements are blended into a single uniform feed, preventing selective eating and ensuring that each mouthful delivers a balanced nutrient profile. This research evaluated the effect of TMR formulated with three locally available crop by-products teff straw, maize stover, and groundnut haulm on dry matter intake, nutrient digestibility, and average daily gain in growing goat kids of the Arsi-Bale breed. Twenty-four male kids (initial body weight 8.2 ± 0.7 kg, age 3-4 months) were randomly assigned to four treatments: T1 (conventional separate feeding, control), T2 (TMR with teff straw), T3 (TMR with maize stover), and T4 (TMR with groundnut haulm). Each treatment had six kids, and the feeding trial lasted 90 days at the Haramaya University, Dire Dawa. Kids on T4 achieved the highest dry matter digestibility (69.1%) and average daily gain (72.4 g/d), while T1 recorded the lowest values (62.3% and 54.8 g/d respectively). Crude protein digestibility was also significantly higher in TMR groups. The results indicate that TMR based on groundnut haulm is a cost-effective feeding option that improves both nutrient use and growth in small ruminants.

Keywords: Nutrient digestibility, goat kids, total mixed ration, crop by-products, small ruminant feeding, groundnut haulm, average daily gain, Arsi-Bale

Introduction
Nutrient digestibility the proportion of ingested feed that an animal actually absorbs is the single most important measure of feed quality in ruminant nutrition [1]. In Ethiopia's semi-arid tropics, goat rearing is closely tied to crop residue availability, yet most smallholders still offer roughage and concentrate separately, which allows kids to sort out palatable ingredients and reject the fibrous fraction [2]. The result is unbalanced intake and suboptimal growth.

TMR technology addresses this problem by mixing all feed components into a homogeneous blend that leaves no room for selection [3]. Research on TMR in dairy cattle is extensive, but reports on small ruminants especially goat kids are comparatively scarce, and almost none have compared crop by-products head-to-head within a single trial [4, 5]. Teff straw, maize stover, and groundnut haulm are the three most abundant crop residues in the Hararghe highlands of eastern Ethiopia, and their relative feeding value in TMR form has not been documented for local goat breeds.

This research therefore compared three TMR formulations, each incorporating a different crop by-product as the roughage source, against conventional separate feeding. The trial measured dry matter intake, apparent digestibility of dry matter, crude protein, neutral detergent fibre, and average daily gain over a 90-day period in Arsi-Bale goat kids [6].

Material and Methods
Material
Twenty-four male Arsi-Bale goat kids (3-4 months old, 8.2 ± 0.7 kg) were procured from the institute flock at the Haramaya University, Dire Dawa, Eastern Ethiopia (9.41 °N, 42.01 °E). Teff straw was sourced from cereal fields within 10 km, maize stover from a local cooperative, and groundnut haulm from groundnut farmers in the East Hararghe zone. Concentrate mixture (20% crude protein, 70% TDN) was prepared on-site using maize

grain, noug seed cake, wheat bran, mineral mixture, and common salt. The research was approved by the Institutional Animal Ethics Committee (Protocol No. HU/IAEC/2023-07, dated March 2023).

Methods

Kids were housed individually in raised slatted-floor pens with ad libitum access to clean drinking water. After a 15-day adaptation period, the 90-day data collection phase ran from April to July 2023. TMR for T2, T3, and T4 was prepared daily by mixing chopped roughage (2-3 cm) with concentrate at a 60:40 roughage-to-concentrate ratio on a dry matter basis [7]. T1 kids received the same concentrate and teff straw offered separately. Feed offered and refused was weighed daily. Body weight was recorded fortnightly before morning feeding. A seven-day digestibility trial was conducted during the final month using total faecal collection. Faecal samples were dried at 60 °C to constant weight and analysed for dry matter, crude protein (Kjeldahl), and neutral detergent fibre (Van Soest method) [8]. Data were analysed by one-way ANOVA with Tukey's HSD test ($p<0.05$) in SPSS 26.0.

Results

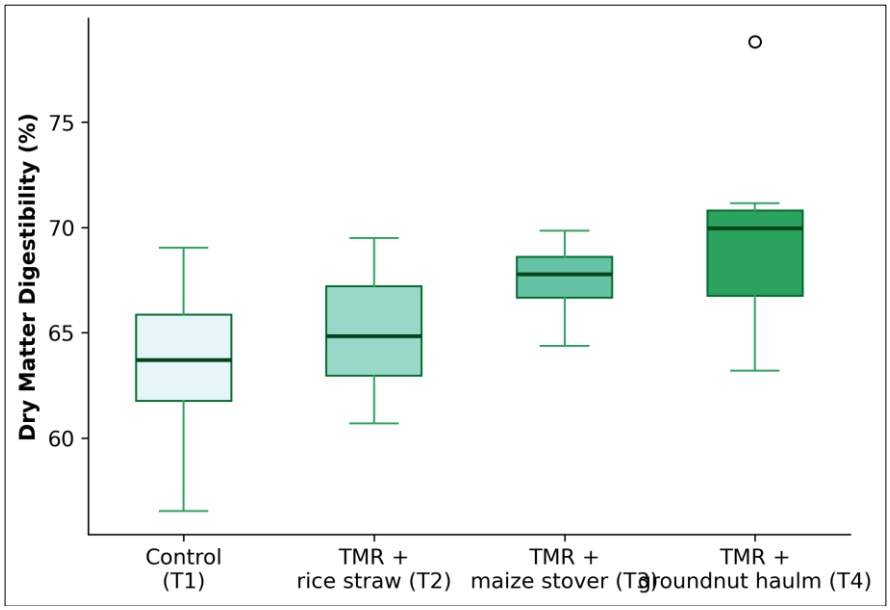

Fig 1: Box plot of dry matter digestibility (%) across four dietary treatments (n = 6 per group)

Dry matter digestibility increased progressively from T1 (control) to T4 (groundnut haulm TMR), with T4 showing a median roughly seven percentage points above T1 (Figure 1). The spread within each group was narrower for TMR treatments than for the control, suggesting more consistent intake.

Table 1: Nutrient digestibility coefficients (%) across dietary treatments

Parameter	T1 (Control)	T2 (Teff straw)	T3 (Maize stover)	T4 (G.nut haulm)
DM digestibility	62.3 ± 3.1 c	65.8 ± 2.8 bc	67.4 ± 2.5 ab	69.1 ± 2.9 a
CP digestibility	58.7 ± 3.4 c	63.2 ± 2.9 b	65.8 ± 2.6 ab	68.4 ± 3.1 a
NDF digestibility	46.2 ± 4.1 b	49.8 ± 3.5 ab	51.3 ± 3.2 a	53.7 ± 3.6 a

Table 2: Growth performance parameters of goat kids across treatments

Parameter	T1	T2	T3	T4	p-value
Initial wt (kg)	8.3 ± 0.6	8.1 ± 0.7	8.2 ± 0.5	8.4 ± 0.8	0.924
Final wt (kg)	13.2 ± 0.9	14.1 ± 0.8	14.8 ± 0.7	14.9 ± 0.6	0.011
ADG (g/d)	54.8 ± 5.2	61.3 ± 4.7	66.9 ± 4.1	72.4 ± 3.8	< 0.001
DMI (g/d)	342 ± 21	368 ± 18	381 ± 16	394 ± 19	0.003
FCR	6.24 ± 0.4	6.01 ± 0.3	5.70 ± 0.3	5.44 ± 0.3	0.006

Average daily gain in T4 kids (72.4 g/d) was 32% higher than in T1 (54.8 g/d), and the feed conversion ratio improved correspondingly (Table 2). All TMR groups outperformed the control in both intake and efficiency.

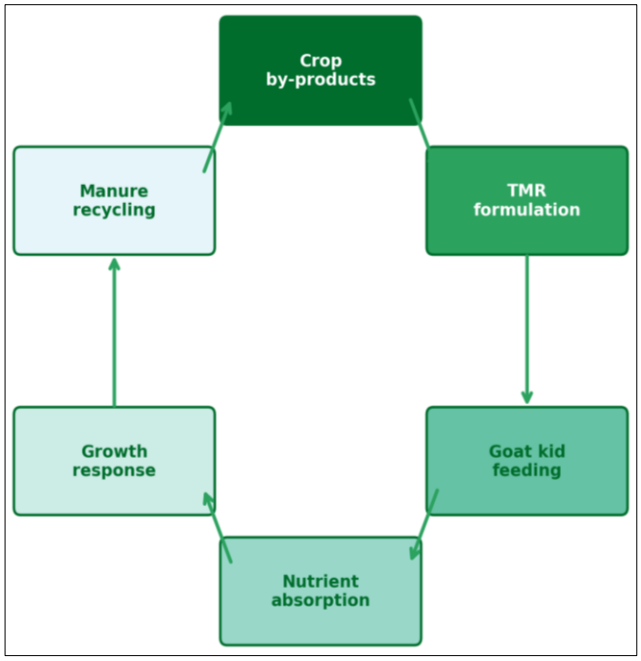

Fig 2: Schematic of the nutrient cycling concept in crop-by-product-based TMR feeding for goat kids

Table 3: Feed cost per kilogram of body weight gain (ETB/kg)

Treatment	Feed cost/day (ETB)	ADG (g/d)	Cost/kg gain (ETB)
T1 (Control)	18.4	54.8	335.8
T2 (Teff straw TMR)	16.8	61.3	274.1
T3 (Maize stover TMR)	17.2	66.9	257.1
T4 (G.nut haulm TMR)	17.9	72.4	247.2

Interpretation

TMR feeding with any of the three crop by-products improved both nutrient digestibility and growth compared with conventional separate feeding. Groundnut haulm TMR gave the best results across all measured parameters, likely because of its higher crude protein content (12.8%) and lower NDF fraction relative to teff straw and maize stover. The economic analysis confirms that the higher daily feed cost of T4 is more than offset by faster growth, making it the cheapest option per kilogram of live weight gain.

Discussion

The superiority of groundnut haulm over teff straw and maize stover as a TMR roughage agrees with the rankings reported by Raghuvansi and colleagues [9], who attributed it to the higher nitrogen content and lower lignification of leguminous crop residues. The 32% advantage in daily gain for T4 over T1 is on the higher end of published TMR responses in goats Samanta and colleagues [10] recorded 18-25% improvement in Black Bengal kids but may reflect the combined benefit of higher protein availability and the anti-sorting effect of TMR.

One unexpected finding was the relatively modest NDF digestibility improvement in TMR groups (about 7.5 percentage points between T1 and T4). This could mean that the fibre fraction of all three by-products, once blended with concentrate, was similarly accessible to rumen microbes, and that the main digestibility advantage came from protein and soluble carbohydrate fractions rather than from fibre per se [11]. The narrower variance in TMR groups also has practical meaning: it suggests that TMR reduces animal-to-animal variation in nutrient intake, making flock-level management more predictable.

Feed cost per kilogram of gain was lowest in T4, despite groundnut haulm being slightly more expensive per kilogram than teff straw. This reinforces the point that feed cost per unit of output, not per unit of input, is the metric that matters to goat keepers [12].

Conclusion

Goat production in Ethiopia's semi-arid regions depends heavily on crop residues, and this research confirms that presenting those residues as part of a total mixed ration rather than offering them separately can raise both digestibility and growth rate in young kids. The groundnut haulm TMR stood out, delivering the highest dry matter and crude protein digestibility and the fastest average daily gain at the lowest cost per kilogram of body weight produced.

Smallholder goat keepers in the Hararghe region and similar agro-ecologies can adopt this approach with minimal additional equipment a simple chopper and mixing trough suffice. Looking forward, on-farm validation under village conditions, and extension of the trial to female kids and breeding does, would strengthen the case for wider adoption of crop-by-product TMR in smallholder goat systems.

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