Use of vegetable waste as a cost-effective feed resource for growing Kids

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Abstract

This study aimed to evaluate the potential of vegetable market waste (VMW) as a sustainable feed resource for growing kids and comparing its nutritional efficacy against conventional rations. A growth trial of 90 days duration was carried out with twentyfour non-descript male kids (12.15 ± 0.06 kg BW) by dividing into four groups (T1: control; T2: VMW without urea; T3: VMW + 0.5% urea of total dry matter; T4: VMW + 1% urea of total dry matter). All rations were iso nitrogenous. Results revealed that T3 (VMW + 0.5% urea) performed closest to the control, with significantly ($P < 0.05$) higher average daily gain (44.4 vs. 48.9 g/day in T1) and better ($P < 0.05$) feed conversion ratio than other VMW groups (T2 and T4). Nutrient digestibility (DM, OM and CP) in T2 (69.2%, 69.6% and 70.0%) mirrored the control (68.9%, 70.2% and 71.8%), outperforming T1 and T3 ($P < 0.001$). The T3 ration proved to be most economical, reducing feed cost by 23% (₹186/kg) as compared to T1 (₹ 220.60/kg) while maintaining 91% of its growth performance, as well as maintaining relatively high ($P < 0.001$) nitrogen retention (34.8% vs. 39.4% in T1). The study demonstrated that, ration containing VMW with 0.5% urea supplementation and with moderate concentrate mixture inclusion (T3) optimized growth performance, nutrient efficiency and economic viability thus, offering a sustainable alternative feed resource for small-scale goat farming.

Key words: Vegetable waste; goat nutrition; growth performance; digestibility; sustainable feeding.

Introduction

The global livestock sector stands at a critical juncture, facing the dual challenge of meeting escalating demand for animal products while addressing unrelenting environmental sustainability concerns (FAO, 2023). With conventional feed resources becoming increasingly expensive and environmentally taxing, cereal prices having raised by 28% since 2020 (World Bank, 2023) are driving a need for sustainable alternative feed sources has never been more urgent in livestock (Singh et al., 2025). This predicament is further compounded by global agricultural shifts, where approximately 15% of arable land previously dedicated to cereal production has transitioned to high-value fruit and vegetable cultivation in developing nations (IFPRI, 2022). In India, this transition generates approximately 1.81 million tonnes of fruit and vegetable market waste annually, comprising nutrient-rich leaves (35-40%), peels (25-30%) and unsold produce (30-40%) (Wadhwa et al., 2013). Alarmingly, nearly 60% of this biomass is improperly disposed of through landfilling or aquatic dumping, leading to its anaerobic decomposition contributing to 4.7 million metric tons of CO_2 equivalent emissions annually through methane (CH_4) release, a greenhouse gas with 21 times the global warming potential of CO_2 having more than 100-year timeframe (IPCC, 2022). While vegetable market waste (VMW) presents a promising alternative, its utilization is constrained by three fundamental limitations: (1) excessive moisture content (70-85%) promoting rapid spoilage, (2) suboptimal crude protein levels (6-8% dry matter basis) and (3) lignocellulosic complexes (NDF 55-65%) that reduce ruminal digestibility by 30-40% compared to conventional feeds (Wadhwa et al., 2021). For smallholder goat farmers in developing countries, feed accounts for 60–70% of production costs, making cost-effective alternatives critical for economic viability (Devendra, 2007, Ukey et al., 2025). While VMW offers a high fiber and nutrient-rich alternative, its high moisture content, low crude protein (6-8% DM), low palatability and lignocellulosic structure limit its nutritional value and direct use in ruminant diets (Wadhwa et al., 2021). Urea treatment effectively addresses these challenges through multiple mechanisms. The process elevates crude protein content to 12-16% through ammonia release and microbial protein synthesis (Ørskov, 1992). Alkaline conditions (pH 8.5-9.0) facilitate hemicellulose solubilization (Jackson, 1977) and delignification, improving neutral detergent fiber digestibility by 20-30 percentage (Tedesco et al., 2021). Furthermore, the elevated pH creates fungistatic conditions that extend shelf life by 7-10 days in tropical climates (Muck et al., 2018) and reduces coliform counts by 3-4 log units (Weinberg et al., 2003).

Present study employs a randomized complete block (CBD) design to comprehensively evaluate urea-treated VMW as a sustainable feed resource for growing kids (*Capra hircus*), with an objective to evaluate the impact of vegetable market waste rations with varying urea levels on growth performance, nutrient digestibility, and nitrogen retention in growing kids. The study specifically seeks to identify the optimal urea supplementation level that maximizes cost-effectiveness and environmental sustainability while maintaining animal productivity comparable to conventional diets.

Materials and methods

Location

The entire research including growth and digestion trials were carried out at Department of Animal Nutrition, College of Veterinary Science, Tirupathi, Andhra Pradesh. The latitude and longitude of the area of research were located between the northern latitudes of 13°21′54″ and 14°30′40″ and between the eastern longitudes 79°5′42″ and 80°4′10″.

Experimental animals

About 24 non-descript (ND) local male kids of 3-4 months age (12.15 ± 0.06 Kg) were randomly (CRD) divided into four equal groups of six each and a growth trial was carried out for 90 days. The kids were housed individually in pens of 2 X 1 m dimensions in a pucca shed. Feed and water were provided to the animals individually. The animals were dewormed at the start of the growth study and at regular intervals with broad-spectrum anti-helminthics. They were vaccinated against H.S, PPR and Enterotoxaemia prior to the study. The kids were offered with weighed quantity of feed thrice daily morning at 9.00 AM, 12.00 Noon and at 4.00 PM. The left-over feed if any wasweighed and was recorded next day morning to obtain an estimate of feed intake. Fresh drinking water was made available throughout the day and a record of daily water consumed by each animal was maintained. At the end of the growth trial a metabolism trial of one week duration with five-day collection period was carried out. The animals were harnessed with faeces collection bags during the metabolism trial to facilitate the faecal collection.

Dietary regimen

Vegetable Market Waste (VMW) was procured from local market on daily basis every morning. It consisted cauliflower leaves, tomatoes, cabbage, brinjal, carrots, lentils, ladies' fingers and other leafy vegetables (Amaranth, Spinach, Curry leaves etc). Four experimental rations (Table 1) were formulated using VMW, concentrate mixture (having maize-28 parts, SBM-37 parts, DORB-32 parts, mineral mixture-2 and salt-1, so as to contain 22% CP) and Super Napier green fodder (GF). The control ration (T1) contained concentrate mixture

Table 1: Ingredient composition (g) of rations containing VMW offered to growing kids

	T1	T2	T3	T4
Vegetable market waste (g) *	-	1000	1000	1000
Concentrate Mixture (g)	260	300	250	200
Green fodder (g)	1000	450	625	775

*Vegetable market waste in T3 and T4 supplemented with 0.5 % and 1 % urea, respectively

(CM) and green fodder (GF). The T2 ration- contained vegetable market waste+ CM + GF. In T3 ration- vegetable market waste was supplemented with urea (0.5% of DM) + CM+GF, while T4 ration - vegetable market waste was supplemented with urea (1% of DM) + CM+GF. The vegetable market waste was chopped and then specified quantity of urea was evenly sprinkled over it prior to feeding, to ensure uniform distribution in T3 and T4 rations. All rations were isonitrogenous to meet the nutrient requirements of growing kids (ICAR, 2013).

Sample acquisition and analysis

The experimental animals were weighed at fortnightly interval before offering the feed in the morning, throughout the trial period to monitor growth performance. The difference between initial and final weights were termed as total weight gain and the total weight gain when divided with 90 days was termed as average daily gain (ADG). The FCR was estimated by diving total feed intake in kg with total weight gain in kg. A 7-day digestion cum metabolisn trial was conducted during the last-phase of the growth experiment, with daily measurements of feed intake, fecal and urine output. The urine voided was also quantified and collected for seven days. Few drops of 10% (v/v) sulfuric acid were added to each urine collection bottle daily as a preservative.

All samples, including experimental rations and refusals were oven-dried at 65°C, ground to 1-mm particle size and stored for subsequent chemical analysis. During the seven-day collection period the faeces voided during 24 hours was collected and representative samples are preserved for the analysis. Proximate composition analysis followed AOAC (2005) standard methods: dry matter (100°C for 8 h), crude protein (Kjeldahl nitrogen × 6.25), ether extract (Soxhlet extraction), crude fiber (acid-alkali digestion) and ash (600°C muffle furnace). Nitrogen-free extract (NFE) was calculated by difference. Fiber fractions (NDF and ADF) were determined according to Van Soest *et al.* (1991). All analyses were performed in triplicate to ensure data reliability. Growth parameters were calculated in terms of: total weight gain (final BW - initial BW), average daily gain (total gain/90 days) and feed conversion ratio (total feed intake/total weight gain).

Statistical analysis

By applying the general linear model approach and utilizing of SPSS, version 26.0, the resulting data were examined for statistical relevance. The same model, excluding the time impact, was used to examine the growth, ADG, FCR, digestibility coefficients and N retention parameters. The Duncan's multiple range test of significance was applied to compare the treatment means. $P < 0.05$, $P < 0.001$ or 0.0001 were used to test for differences.

Results

The chemical composition of feed ingredients used in the experimental rations is presented in Table 2. Vegetable market waste (VMW) contained 12.0% DM, 5.4% CP and 45.2% NDF, exhibiting lower dry matter and protein content but higher crude fibre than the concentrate (89.0% DM, 22.0% CP and 27.7% NDF). The nutritional profile of VMW indicated 28.6% NFC and 9.8% sugars, providing more readily available energy than green fodder (12.5% NFC, 5.2% sugars), but less than the concentrate (39.3% NFC, 15.0% sugars). Notably, the total ash content (14.5%) of VMW was nearly double that of other feeds, while its lignin content (7.7%) was intermediate between the concentrate (2.6%) and green fodder (8.3%). The cellulose content (24.5%) indicated greater fermentability as compared to green fodder (30.1%) but lower than the concentrate mixture (7.2%). The VMW contained NDF (45.2%) and ADF (32.1%) which was intermediate between concentrate (NDF 27.7%, ADF 9.9%) and green fodder (NDF 65.2%, ADF 38.4%).

The study results revealed significant differences ($P < 0.05$) in the performance of growing kids between dietary treatments. The control group (T1) achieved the best ($P < 0.05$) growth, with final body weight of 16.55 kg and average daily weight gain of 48.9 g/day. In comparison, T2 showed 7% lower average final weight (15.46 kg), 32% slower growth rate (37.0 g/day) (Figure 1) with 31% poorer feed efficiency (FCR 9.15 vs 6.98) (Figure 2), while costing 5% more per kg of weight gained (₹255.30 vs ₹242.82) (Figure 3). The T3 ration proved most economical, reducing feed costs by 23% (₹186.3/kg Wt gain) as compared to T1 while maintaining 91% of its growth performance (44.4 g/day). The T4 ration provided intermediate results, with 19% slower growth than T1 but 21% lower feed cost (₹192/kg Wt gain). The nutrient intake, digestibility coefficients and plane of nutrition indicated significant ($P < 0.001$) variations among treatments for certain parameters (Table 4).

Table 2: Chemical composition of feed ingredients used in the rations of growing kids

Parameter	VMW	Concentrate Mixture	Green Fodder
DM (%)	12.0 ± 0.2	89.0 ± 0.6	25.3 ± 1.0
OM (%)	85.5 ± 0.6	93.8 ± 0.4	90.2 ± 0.8
CP (%)	5.43 ± 0.06	22.0 ± 0.3	10.3 ± 0.5
EE (%)	2.3 ± 0.3	22.0 ± 0.3	2.5 ± 0.3
CF (%)	32.4 ± 1.1	10.5 ± 0.5	45.8 ± 1.3
NFE (%)	26.3 ± 1.2	37.5 ± 0.7	10.1 ± 0.8
Total Ash (%)	14.5 ± 0.6	6.2 ± 0.4	9.8 ± 0.8
Acid Insoluble Ash (%)	2.1 ± 0.3	0.8 ± 0.1	3.5 ± 0.4
NDF (%)	45.2 ± 1.4	27.7 ± 0.8	65.2 ± 1.4
ADF (%)	32.1 ± 1.3	9.9 ± 0.4	38.4 ± 1.3
Hemi Cellulose (%)	13.0 ± 0.1	17.9 ± 0.4	26.8 ± 0.1
Cellulose (%)	24.5 ± 0.8	7.2 ± 0.4	30.1 ± 0.8
Lignin (%)	7.7 ± 0.5	2.6 ± 0.1	8.3 ± 0.5
Total Soluble Sugars (%)	9.8 ± 0.4	15.0 ± 0.6	5.2 ± 0.4
NFC (%)	28.6 ± 1.3	39.3 ± 0.8	12.5 ± 0.9

Table 3: Growth performance of kids fed rations containing VMW

Parameter	T1	T2	T3	T4
Initial Body Weight (kg)	12.15 ± 0.12	12.13 ± 0.10	12.20 ± 0.11	12.13 ± 0.10
Final Body Weight (kg)*	16.55 ± 0.15^{d}	15.46 ± 0.12^{a}	16.20 ± 0.14^{c}	15.83 ± 0.13^{b}
Total Weight Gain (kg)*	12.13 ± 0.10	15.83 ± 0.13^{b}	41.1 ± 1.0^{b}	8.05 ± 0.32^{b}
ADG (g/day) *	48.9 ± 1.2^{d}	37.0 ± 0.8^{a}	44.4 ± 1.1^{c}	41.1 ± 1.0^{b}
FCR*	6.98 ± 0.25^{a}	9.15 ± 0.45^{c}	7.58 ± 0.30^{b}	8.05 ± 0.32^{b}
Cost economics (Rs/ Kg Wt gain) *	242.82 ± 8.50^{d}	255.30 ± 9.20^{c}	186.30 ±6.80^{a}	192.01 ± 6.50^{b}

* Means in a row bearing different superscripts differ significantly (P < 0.05)

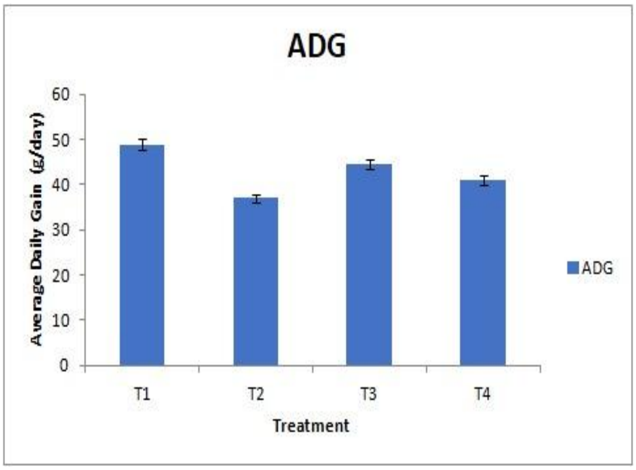

Fig 1. Effect of feeding Vegetable Waste on FCR

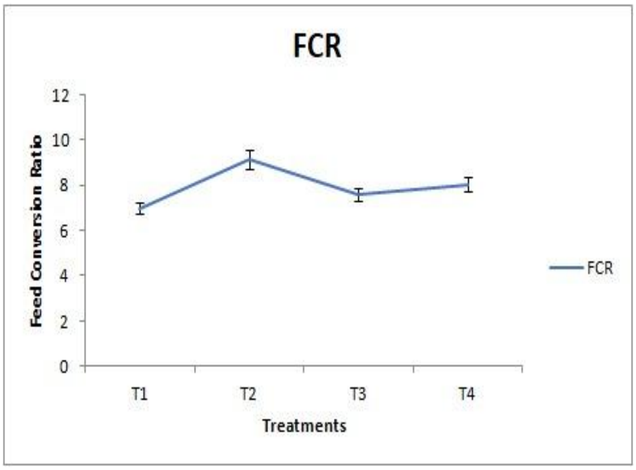

Fig 2. Effect of feeding Vegetable Waste on FCR

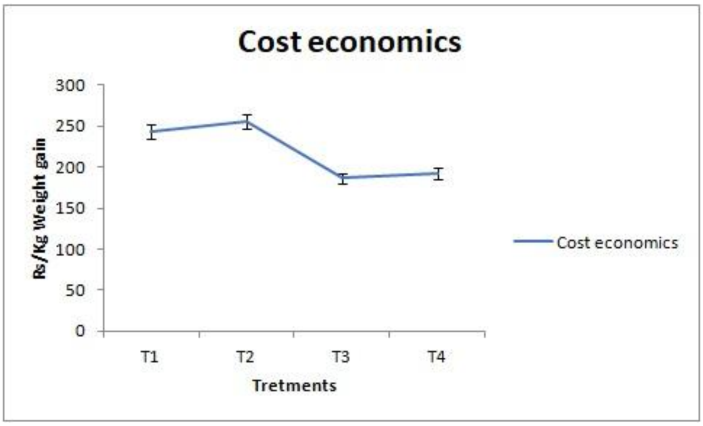

Fig 3. Effect of feeding Vegetable Waste on cost economics

Table 4: Nutrient Intake, Digestibility Coefficients and plane of nutrition of kids fed rations containing VMW

Parameter	T1	T2	T3	T4
Nutrient Intake				
DMI (g/d)	484.0 ± 8.2	502.5 ± 5.1	501.3 ± 4.6	493.8 ± 5.3
DMI (% BW)	3.98 ± 0.07	4.14 ± 0.04	4.11 ± 0.04	4.07 ± 0.04
DCPI (g/d)	82.2 ± 1.5	82.9 ± 0.9	82.7 ± 0.8	81.8 ± 0.9
TDNI (g/d) ***	314.6 ± 5.6[b]	326.6 ± 3.3[b]	325.9 ± 3.1[b]	258.4 ± 2.8[a]
Nutrient Digestibility				
DM (%) ***	68.9 ± 0.5[a]	60.6 ± 0.5[c]	69.2 ± 0.4[a]	63.3 ± 0.6[b]
OM (%) ***	70.2 ± 0.6[a]	66.3 ± 0.5[b]	69.6 ± 0.4[a]	64.6 ± 0.6[b]
CP (%) ***	71.8 ± 0.6[a]	67.3 ± 0.5[b]	70.0 ± 0.4[a]	64.8 ± 0.6[b]
EE (%) ***	74.8 ± 0.5[a]	65.4 ± 0.6[c]	71.5 ± 0.5[b]	60.7 ± 0.8[d]
CF (%) ***	57.1 ± 0.7[b]	51.9 ± 0.6[c]	60.4 ± 0.6[a]	49.8 ± 0.7[c]
NFE (%) ***	70.7 ± 0.6[b]	68.0 ± 0.6[c]	74.9 ± 0.6[a]	59.9 ± 0.8[d]
Plane of Nutrition				
DCP (% of DM) ***	17.0 ± 0.3[a]	16.5 ± 0.2[a]	16.5 ± 0.2[a]	16.6 ± 0.2[a]
TDN (% of DM) ***	65.0 ± 1.2[a]	65.0 ± 0.8[a]	65.0 ± 0.6[a]	52.3 ± 0.6[b]

*** Means in a row bearing different superscripts differ significantly (P < 0.001)

Table 5: N balance of kids fed rations containing VMW

Parameter	T1	T2	T3	T4
Intake				
g/d* **	13.12 ± 0.22[a]	12.46 ± 0.11[b]	12.48 ± 0.13[b]	11.80 ± 0.13[c]
(g/kg MBW) * **	2.58 ± 0.04[a]	2.45 ± 0.03[b]	2.44 ± 0.02[b]	2.31 ± 0.03[c]
N Excretion g/d				
**Faeces ** **	3.70 ± 0.16[b]	4.10 ± 0.12[a]	3.74 ± 0.10[b]	4.23 ± 0.15[a]
Urine* **	4.25 ± 0.18[b]	5.12 ± 0.15[a]	4.38 ± 0.13[b]	5.01 ± 0.14[a]
**Total * **	7.95 ± 0.34[b]	9.22 ± 0.27 [a]	8.12 ± 0.23[b]	9.24 ± 0.29[a]
N Retention				
g/d* **	5.17±0.38[a]	3.26 ± 0.25[c]	4.34 ± 0.21[b]	2.56 ± 0.26[d]
% Intake* **	39.4 ± 2.5[a]	26.1 ± 1.8[c]	34.8 ± 1.6[b]	21.7 ± 2.0[d]
% Absorbed* **	55.2±3.8[a]	38.9 ± 2.9[c]	49.6 ± 2.7[b]	33.1 ± 3.1[d]

Means in a row bearing different superscripts differ significantly (*P < 0.05, **P < 0.01, ***P < 0.001)

The nitrogen balance study (Table 5) revealed significant (P < 0.001) treatment effects on nitrogen utilization in growing kids. The control group (T1) indicated superior (P < 0.001) nitrogen retention (5.17 g/d, 39.4% of intake) as compared to other treatments. While kids received T3 ration performed closest to control with 4.34 g/d retention (34.8%), whereas both T2 and T4 exhibited significantly (P < 0.001) lower retention (3.26 and 2.56 g/d, respectively). Notably, kids in T4 group demonstrated the poorest nitrogen efficiency, with 21.7% retention and elevated urinary nitrogen excretion (5.01 g/d), indicating excessive urea levels impaired microbial protein synthesis.

Discussion

The chemical composition of VMW suggests its viability as a partial concentrate substitute, though its lower protein and energy reflect high moisture and heterogeneity. While elevated ash content enhances mineral intake (Bhatta et al., 2013), the fiber profile requires urea treatment to disrupt lignocellulosic complexes and improve fermentability compared to green fodder.

Superior growth in the control group (T1) aligns with Silanikove (2000) regarding optimized concentrate-to-forage ratios. T2 showed a 32% reduction in ADG, likely reflecting fiber deficiency (Van Soest, 1994). T3 achieved 91% of control growth with a 23% cost reduction, corroborating Patra (2015) that 0.5% urea can effectively replace partial concentrate protein. The FCR in T3 compares favorably with tropical systems (Makkar, 2016). Conversely, the reduced performance in T4 supports Kang et al. (2015) regarding urea thresholds, with poorer FCR reflecting toxicity limits (Patra, 2015; Devendra, 2007). This economic advantage of T3 is significant given feed costs represent 60-70% of production expenses (Bhatta et al., 2013).

High CP digestibility in T1 and T3 indicates efficient protein utilization, whereas the 1% urea level in T4 impaired digestibility, likely due to ammonia toxicity (Zurak et al., 2023). T3 enhanced CF digestibility, potentially through optimized non-fiber carbohydrate and nitrogen balance stimulating fibrolytic microbes

(Kumar et al., 2014). significantly lower TDN in T4 implies the nitrogen load exceeded rumen capacity, leading to energy losses.

Nitrogen retention in T1 aligns with expectations for balanced diets (Hristov et al., 2019). T3 maintained 84% of control retention, confirming that moderate urea compensates for protein limitations in VMW (Dijkstra et al., 2011). The 50% drop in T4 retention demonstrates the metabolic penalty of ammonia overload (Lapierre and Lobley, 2001), which increases energy expenditure for urea synthesis and detoxification (Marini and Van Amburgh, 2003).

Conclusion

Strategic inclusion of VMW in the rations of growing kids not only optimized the growth, but reduced the cost and promotes environmental sustainability. Based on the results obtained it can be concluded that moderate urea supplementation at 0.5% in VMW ration (T3) maintained growth performance, nutrient digestibility and nitrogen retention close to the control, while reducing feed cost by 23%, making it an economically viable option for smallholder goat production.

Conflict of interest

The authors declare that they have no conflict of interest.

Ethical standards

Experiments comply with the current laws of the country in which they were performed.

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