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Nutrient Degradability Evaluation of Complete Feed Pellets and Effect On Performance of Sirohi Goat

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Abstract: In total, 16 different types of crop residue-based complete feed pellets were prepared by replacing paddy straw @ 50%, 75% and 100% with wheat straw, soybean straw, gram straw, *Cajanus cajan* straw, and groundnut straw from roughage portion by maintaining 60:40 roughage: concentrate ratio to study in *vitro* dry matter degradability and it's *in vitro* gas production. Gram straw-based complete feed pellet revealed significantly higher dry matter and crude protein degradability, while higher NDF degradability was reported in *Cajanus cajan* straw based complete feed pellets and higher IVGP in groundnut straw pellets. The gram straw based complete feed pellets was selected as a superior one on the basis of its better IVDMD. Subsequently for the in vivo study, twelve Sirohi adult goat were randomly selected and were fed for the 30 days following standard housing and management. The control group was fed with *ad lib* super napier hay and concentrate as per ICAR 2013, while treatment group was fed *ad lib* gram straw-based pellet. Significantly better growth performance, nutrient utilization, rumen fermentation and low cost of production was in goats of treatment group with non-significant difference in hematological parameters, body condition score and rumen motility. It can be concluded that gram straw based complete feed pellets had more degradable nutrient and improved performance of goat.

Keywords: Crop residues, Complete feed, Nutrient utilization and goat

In order to feed livestock, non-competitive and unconventional agricultural wastes are used since there is a shortage of green fodder and a rising demand for grains for human consumption. The majority of India's dry fodder needs are satisfied by crop residues. But these crop residues are rich in fibre and low in protein, vitamins and minerals and therefore they have low palatability and digestibility. Hence, their use in animal ration is limited (Patil and Patil 2020, Raju et al 2021). To overcome the shortage of green and dry fodder and to make crop residues more palatable and nourishing, processing is necessary and this will be possible by the adoption of complete feed systems. For early evaluation of nutritive value of different crop residue based complete feed pellets, *in vitro* evaluation method was used to evaluate *in vitro* DM, CP and NDF degradability and *in vitro* gas production of different crop residue based complete feed pellets. The effect of superior crop residue based complete feed pellets (based on IVDMD%) on the performance of Sirohi goat was evaluated.

MATERIAL AND METHODS

In total, 16 different types of crop residue-based complete feed pellets were prepared by replacing paddy straw @ 50, 75 and 100% with wheat straw, soybean straw, gram straw, *Cajanus cajan* straw, and groundnut straw from roughage portion by maintaining 60:40 roughage to concentrate ratio. The composition of concentrate mixture used in complete feed pellets is given in Table 1. Representative samples from the different complete feed pellets were analysed for various proximate principles (moisture, CP, EE, CF, total ash, and acid insoluble ash) as per AOAC (2007), and NDF and ADF were estimated by Van Soest method (1991).

***In vitro* study:** Rumen liquor was collected from the goat 3-4 h post-feeding and strained through four layers of muslin cloth. This procedure was carried out by taking dried and ground (particle size < 1mm) each straw-based complete feed pellets as a substrate in a 100ml conical flask for the first stage *in vitro* method (Tilley and Terry, 1963). Similarly, dried residue of other sets of samples were used to estimate IVCPD and IVNDFD percent by estimating CP and NDF by standard procedures. *In vitro* gas production was carried out using the Hohenheim gas test according to procedures of Menke and Stein-gass (1988) described by Santoso et al. (2018). Recorded the gas volume after 2, 4, 8, 12 and 24 h of incubation.

***In vivo* trial: Selection and management of goats:** Twelve healthy adult Sirohi goats of approximately similar body weight (19.08±0.18 Kg) were divided into two groups with six goats each and reared under the same intensive management system. The goats in the control group (group I) were fed *ad lib* super napier hay and 400 g concentrate mixture to satisfy the nutrient requirement as per ICAR 2013. Goats in the treatment group (group II) were fed *ad lib* complete feed pellets containing 60%-gram straw and a concentrate mixture of 40%.

Estimation of dry matter intake, body weight gain, BCS and FCR: Goat's initial and weekly live body weights were recorded. Daily feed intake was recorded by subtracting the feed left over from the feed offered to each goat. Initial body condition score and body condition score every fortnight was recorded. Scoring is done by using the hand to feel for the fullness of muscling and fat cover over and at the lumbar region, brisket region, ribs and into the vertebrae in the loin region. FCR was calculated by dividing weight gain by feed intake.

Metabolic trial and N, Ca and P balance: The metabolic trial was conducted with all 12 goats. A 21-day preliminary and two-day adoption period was followed by a four-day collection period. The goats were kept in individual metabolic cages having provisions for feeding and watering. The goats were offered respective rations and daily dry matter intake, feed refusal, total faeces and urine passed were recorded and collected individually. The samples of super napier hay, concentrate mixture, gram straw-based complete feed pellets and dried faeces were analyzed for proximate analysis , Ca and P (AOAC, 2007), and ADF and NDF by Van Soest (1991). Urine was analyzed for nitrogen as per AOAC (2007).

Rumen liquor profile: The sucked fluid was filtered through the cheese cloth and pH was immediately measured. The filtered rumen liquor was immediately taken for digestion to estimate total nitrogen. 15 ml of rumen liquor was frozen and stored at -20 ^{0}C for determination of TVFA. TVFA was determined using the Markham apparatus as described by Bernett and Reid (1957). The total nitrogen was analyzed as per AOAC (2007). The total bacterial and protozoan count was carried out by the direct method (Smith and Baker 1944).

Body condition score: Body condition score evaluated in the score of 1 to 5 (Canadian scale) where 1 is emaciated and 5 is obese (Lowman et al 1976).

Ruminal motility: The ruminal motility of goats in the control and treatment group was recorded weekly by auscultation of the rumen from the left paralumbar fossa.

Hemato-biochemical parameters: Blood samples were subjected to the haematological analysis (Hb (g/dl), PCV (%), TEC (x 10^6/µl), and TLC (x 10^3/µl)) and the serum was separated as per the standard procedure and was analyzed in a semi-auto analyzer using diagnostic kits for various biochemical parameters.

Cost of production: The cost of each experimental diet was calculated considering the prevailing market price of individual feed ingredients and supplements during the experiment. The cost per kg live body weight of goat reared under different feeding regimens was calculated based on feed consumption data for 0-28 days.

Statistical analysis: For interpretation of the results, the data of the *in vitro* study was analysed by Duncan's Multiple Range Test (DMRT). Used IBM SPSS Statistics 25 software for analysing the data .

RESULTS AND DISCUSSION

Chemical composition of feedstuffs: The chemical composition of different crop residue based complete feed pellets is mentioned in Table 1 to 3. The chemical composition of super napier hay, concentrate mixture and gram straw-based complete feed pellets is given in Table 10.

***In vitro* dry matter degradability:** The highly significant difference was observed in the *in vitro* dry matter degradability of different crop residue-based complete feed pellets with the different levels of replacement as well as within each level of replacement among various types of crop residue based complete feed pellets (Table 4). Significantly higher IVDMD percent was in gram straw based-complete feed pellets followed by *Cajanus cajan* straw, soybean straw, groundnut straw, and wheat straw-based complete feed pellets at 50, 75 and 100% replacement levels. Among the different crop residue-based complete feed pellets significantly higher IVDMD was in the 100% replacement group followed by 75, 50 and 0% replacement groups except IVDMD percent of complete feed pellets having wheat and groundnut straw in the 75 and 100% replacement groups, where a non-significant difference was observed between each other. The IVDMD percent in fully paddy straw-based complete feed pellets and 50% wheat straw-based complete feed pellets showed a non-significant difference. These findings in the present experiment indicated that 75% replacement of paddy straw with wheat straw and 100% replacement of paddy straw with *Cajanus cajan* straw, groundnut straw, soybean straw, and gram straw in the complete feed pellets resulted in better *in vitro* dry matter degradability of crop residue-based complete feed pellets. The significantly higher percent IVDMD was in 100%-gram straw-based complete feed pellets in the present study with all three roughages to concentrate ratios might be due to the higher NFE and lower CF concentration in the gram straw-based complete feed. Chauhan et al (2017) also reported significantly higher IVDMD percent for a 100%-gram straw-based total mixed ration with roughage to concentrate ratio of 55:45.

Table 1. Chemical composition of different crop residue-based complete feed pellets at 50% replacement level with roughage to concentrate in ratio of 60:40

Feed regime	DM (%)	CP (%)	CF (%)	EE (%)	Total Ash (%)	NFE (%)	AIA (%)	NDF (%)	ADF (%)	ADL (%)
Paddy straw (50%) +Wheat straw (50%) based complete feed pellets	92.18	10.58	28.09	1.50	10.45	48.57	2.45	57.69	40.82	9.96
Paddy straw (50%) + *Cajanus cajan* straw (50%) based complete feed pellets	92.23	11.66	26.04	1.60	10.28	50.42	2.14	57.85	39.70	8.73
-Paddy straw (50%) +Groundnut straw (50%) based complete feed pellets	92.20	11.76	26.87	1.74	9.65	49.98	2.15	51.22	36.78	8.61
Paddy straw (50%) + Soybean straw (50%) based complete feed pellets	91.46	11.53	27.36	1.26	9.96	49.89	2.33	54.46	38.82	8.71
Paddy straw (50%) + Gram straw (50%) based complete feed pellets	92.16	11.28	25.16	1.98	10.09	51.49	2.21	54.07	37.70	8.66

Table 2. Chemical composition of different crop residue-based complete feed pellets at 75% replacement level with roughage to concentrate in ratio of 60:40

Feed regime	DM (%)	CP (%)	CF (%)	EE (%)	Total Ash (%)	NFE (%)	AIA (%)	NDF (%)	ADF (%)	ADL (%)
Paddy straw (25%) + Wheat straw (75%) based complete feed pellets	91.86	10.52	28.18	1.54	10.49	49.27	2.40	56.18	40.28	9.79
Paddy straw (25%) + *Cajanus cajan* straw (75%) based complete feed pellets	91.56	11.78	25.52	1.64	10.14	50.92	2.05	56.77	39.20	7.91
Paddy straw (25%) + Groundnut straw (75%) based complete feed pellets	91.60	11.82	26.81	1.81	9.47	50.09	2.52	47.70	32.30	7.75
Paddy straw (25%) + Soybean straw (75%) based complete feed pellets	91.95	11.67	27.08	1.36	9.85	50.04	2.29	52.68	38.32	7.85
Paddy straw (25%) + Gram straw (75%) based complete feed pellets	92.21	11.38	23.64	2.06	9.96	52.96	2.13	52.42	34.40	7.79

Table 3. Chemical composition of different crop residue-based complete feed pellets at 100% replacement level with roughage to concentrate in ratio of 60:40

Feed regime	DM (%)	CP (%)	CF (%)	EE (%)	Total Ash (%)	NFE (%)	AIA (%)	NDF (%)	ADF (%)	ADL (%)
Paddy straw (100%) based complete feed pellets	90.18	10.49	27.96	1.56	11.61	48.38	2.54	58.48	42.70	10.39
Wheat straw (100%) based complete feed pellets	90.81	10.74	28.32	1.48	9.50	49.96	2.34	56.90	39.80	9.60
Cajanus cajan straw (100%) based complete feed pellets	90.17	12.71	24.12	1.67	8.95	52.55	1.76	57.10	38.66	7.11
Groundnut straw (100%) based complete feed pellets	91.74	12.83	25.82	1.78	7.92	51.65	2.57	43.70	30.00	6.84
Soybean straw (100%) based complete feed pellets	91.45	12.62	26.80	1.34	8.41	50.83	2.05	50.48	34.80	7.01
Gram straw (100%) based complete feed pellets	90.27	12.07	22.31	2.06	8.57	54.99	1.91	50.65	31.90	6.96

***In vitro* crude protein degradability:** The highly significant difference was observed in the *in vitro* crude protein degradability of different crop residue-based complete feed pellets with the different levels of replacement as well as within each level of replacement among various types of crop residue based complete feed pellets (Table 5). There was significantly higher percent IVCPD was observed in gram straw-based complete feed pellets followed by *Cajanus cajan* straw, soybean straw, groundnut straw, and wheat straw-based complete feed pellets at 50, 75 and 100% replacement levels except *Cajanus cajan* straw and soybean straw-based complete feed pellets at 75 and 100% replacement levels, which showed a non-significant difference between each other. However, the crop residue-based complete feed pellets in the 100% replacement group showed significantly greater percent IVCPD followed by 75 and 50 and 0% replacement group irrespective of variation in the straws in the complete feed pellets with few exceptions. But with IVCPD of wheat straw-based complete feed pellets, significantly greater percent IVCPD was observed in 100% replacement group followed by 0, 75 and 50% replacement levels. Further, the percent IVCPD of 50% groundnut straw-based complete feed pellets and sole paddy straw-based complete feed pellets revealed a non-significant difference between each other. Similarly, the percent IVCPD of 50% soybean straw-based complete feed pellets did not reveal significant difference with percent IVCPD of 100% paddy straw-based complete feed pellets. These findings indicated that 100% replacement of paddy straw with other straws in the complete feed pellets showed better *in vitro* crude protein degradability. However, 100% paddy straw-based complete feed pellets showed significantly better *in vitro* crude protein degradability than 50 and 75% wheat straw-based complete feed pellets. The availability of greater degradable protein and lower crude fibre in gram straw-based complete feed pellets may account for the significantly higher percent IVCPD. Konka et al (2015) found higher IVCPD in a complete ration containing maize stover than in a complete ration containing black gram straw and red gram straw.

Table 4. *In vitro* dry matter degradability (%) of crop residue-based complete feed pellets with roughage to concentrate in ratio of 60:40

Feed regime	Groups				Significance
	I Replacement of paddy straw 0%	II Replacement of paddy straw 50%	III Replacement of paddy straw 75%	IV Replacement of paddy straw 100%	
Wheat straw-based complete pellets	$45.55^{aB}\pm1.01$	$45.88^{eB}\pm0.84$	$47.68^{eA}\pm0.49$	$47.78^{eA}\pm0.71$	**
Cajanus cajan straw-based complete pellets	$45.55^{aD}\pm1.01$	$54.92^{bC}\pm0.74$	$58.13^{bB}\pm0.36$	$61.63^{bA}\pm0.72$	**
Groundnut straw-based complete pellets	$45.55^{aC}\pm1.01$	$50.87^{dB}\pm0.15$	$56.28^{dA}\pm0.65$	$56.23^{dA}\pm0.46$	**
Soybean straw-based complete pellets	$45.55^{aD}\pm1.01$	$52.64^{cC}\pm0.33$	$57.31^{cB}\pm0.23$	$60.25^{cA}\pm0.88$	**
Gram straw-based complete pellets	$45.55^{aD}\pm1.01$	$55.11^{aC}\pm0.94$	$59.24^{aB}\pm0.26$	$64.37^{aA}\pm0.51$	**
Significance	**	**	**	**	

1. For various replacement interpretations, the data may be read row wise, means bearing different superscripts (A, B, C, D) differ significantly. ** P < 0.01.
2. For interpretations in groups on various straw inclusion, the data may be read column wise, means bearing different superscripts (a, b, c, d, e) differ significantly. ** P < 0.01.

Table 5. *In vitro* crude protein degradability (%) of crop residue-based complete feed pellets with roughage to concentrate in ratio of 60:40

Feed regime	Groups				Significance
	I Replacement of paddy straw 0%	II Replacement of paddy straw 50%	III Replacement of paddy straw 75%	IV Replacement of paddy straw 100%	
Wheat straw-based complete pellets	$54.87^{bB}\pm1.09$	$53.76^{dC}\pm0.41$	$54.07^{dBC}\pm0.13$	$56.22^{dA}\pm0.78$	**
Cajanus cajan straw-based complete pellets	$54.87^{aD}\pm1.09$	$57.42^{bC}\pm1.35$	$60.75^{bB}\pm0.50$	$64.15^{bA}\pm0.29$	**
Groundnut straw-based complete pellets	$54.87^{aC}\pm1.09$	$54.09^{dC}\pm0.51$	$58.00^{cB}\pm0.53$	$60.31^{bcA}\pm0.87$	**
Soybean straw-based complete pellets	$54.87^{aC}\pm1.09$	$55.06^{cC}\pm1.16$	$61.43^{bB}\pm0.33$	$63.41^{bA}\pm0.43$	**
Gram straw-based complete pellets	$54.87^{aD}\pm1.09$	$62.19^{aC}\pm0.99$	$63.19^{aB}\pm0.41$	$66.32^{aA}\pm0.22$	**
Significance	**	**	**	**	

See Table 4 for details

***In vitro* neutral detergent fibre degradability:** The *in vitro* neutral detergent fibre degradability of different crop residue-based complete feed pellets with the different levels of replacement as well as within each level of replacement among various types of crop residue-based complete feed pellets differed significantly with complete feed pellets. The with *Cajanus cajan* straw had a significantly higher IVNDFD percent followed by gram straw, soybean straw, groundnut straw, and wheat straw-based complete feed pellets irrespective of different levels of replacement of paddy straw (Table 6). Among various levels of replacement i.e., 0, 50, 75 and 100%, significantly higher IVNDFD percent was or soybean straw and gram straw-based complete feed pellets with 100% replacement group followed by 75, 50 and 0% replacement groups. Among *Cajanus cajan* straw-based complete feed pellets, significantly higher IVNDFD percent was observed at 100 as well as 75% replacement levels followed by 50 and 0% replacement levels with a non-significant difference between the IVNDFD percent of 75 and 100% *Cajanus cajan* straw-based complete feed pellets. Among the complete feed pellets with wheat straw, significantly higher IVNDFD percent was at 100% replacement levels followed by 75 and 50 as well as 0% replacement levels with a non-significant difference in IVNDFD percent between 0 and 50% replacement levels. In IVNDFD percent of groundnut straw-based complete feed pellets, significantly higher IVNDFD percent was observed at 100% replacement level followed by 75 as well as 50 and 0% replacement levels. The findings in the present experiment suggest that 100% replacement of paddy straw with wheat straw, *Cajanus cajan* straw, soybean straw, groundnut straw, and gram straw in the complete feed pellets resulted in better *in vitro* neutral detergent fibre degradability. Further, the 0% replacement of paddy straw-based complete feed pellets had similar *in vitro* neutral detergent fibre degradability to that of 50% wheat straw-based complete feed pellets. When the complete feed contains roughage and concentrate in proper proportion, in such cases ruminal pH is not reduced drastically and the pH is maintained within normal physiological range, which might have favoured for microbial growth of fibre degrading bacteria. Similarly, Venkateswarlu et al (2013) also reported higher degradability of NDF for complete ration with black gram straw than complete ration with red gram straw.

***In vitro* gas production (IVGP):** The groundnut straw-based complete feed pellets revealed significantly higher IVGP (ml/200mg) at 2, 4, 8, 12 and 24 hr of incubation followed by soybean straw, gram straw, wheat straw and *Cajanus cajan* straw-based complete feed pellets irrespective of roughage to concentrate ratios (70:30, 60:40 and 50:50) and level of replacement (50, 75 and 100%) (Table 7 to 9). Regardless of roughage to concentrate ratio or level of replacement, the 12-24 hr incubation time resulted in significantly higher IVGP (ml/200mg) than the 8-12 hr, 4-8 hr, 2-4 hr, and 0-2 hr incubation periods. There was a decreasing trend in IVGP from 12-24 hr of incubation to 0-2 hr of incubation. Among the different crop residue-based complete feed pellets with 50, 75 and 100% replacement groups, in general higher *in vitro* gas production was observed for crop residue-based complete feed pellets in the 100% replacement group followed by 75 and 50% replacement groups. The comparatively lower IVGP of the crop residue-based complete feed pellets in the 50 and 75% replacement groups might be due to the mixing of paddy straw having high NDF, total ash and lignin content in the complete feed pellets. In the present investigation, significantly greater IVGP for groundnut straw-based complete feed pellets was might be due comparatively low NDF, ADF, ash, and ADL content than the other crop-residue-based complete feed pellets. The higher values of IVGP for groundnut straw-based complete

Table 6. *In vitro* neutral detergent fibre degradability (%) of crop residue-based complete feed pellets with roughage to concentrate in ratio of 60:40

Feed regime	Groups				Significance
	I Replacement of paddy straw 0%	II Replacement of paddy straw 50%	III Replacement of paddy straw 75%	IV Replacement of paddy straw 100%	
Wheat straw-based complete pellets	$51.95^{aC}\pm0.32$	$51.43^{dC}\pm0.10$	$53.57^{eB}\pm0.27$	$55.09^{eA}\pm0.18$	**
Cajanus cajan straw-based complete pellets	$51.95^{aC}\pm0.32$	$63.34^{aB}\pm0.24$	$63.69^{aA}\pm0.11$	$64.05^{aA}\pm0.09$	**
Groundnut straw-based complete pellets	$51.95^{aC}\pm0.32$	$56.09^{cdB}\pm0.32$	$56.04^{dB}\pm0.27$	$56.63^{dA}\pm0.07$	**
Soybean straw-based complete pellets	$51.95^{aD}\pm0.32$	$56.42^{cC}\pm0.23$	$58.11^{cB}\pm0.07$	$60.46^{cA}\pm0.13$	**
Gram straw-based complete pellets	$51.95^{aD}\pm0.32$	$60.99^{bC}\pm0.33$	$62.13^{bB}\pm0.13$	$63.08^{bA}\pm0.05$	**
Significance	**	**	**	**	

See Table 4 for details

Table 7. *In vitro* gas production (IVGP) (ml/200mg) of crop residue-based complete feed pellets at 50% replacement level with roughage to concentrate in ratio of 60:40

Feed regime	*In vitro* gas production at different hrs (ml/200mg)					Significance
	2 hr	4 hr	8 hr	12 hr	24 hr	
Paddy straw (50%) + Wheat straw (50%)-based complete pellets	5.67^{dE}±0.58	11.33^{dD}±0.58	18.67^{dC}±0.58	24.67^{dB}±0.58	35.67^{dA}±0.58	**
Paddy straw (50%) + *Cajanus cajan* straw (50%)-based complete pellets	5.00^{eE}±0.00	9.33^{eD}±0.58	18.33^{eC}±0.58	23.33^{eB}±0.58	35.33^{eA}±0.58	**
Paddy straw (50%) + Groundnut straw (50%)-based complete pellets	11.33^{aE}±0.58	19.33^{aD}±0.58	28.67^{aC}±0.58	36.33^{aB}±0.58	48.33^{aA}±0.58	**
Paddy straw (50%) + Soybean straw (50%)-based complete pellets	8.00^{bE}±0.00	14.00^{bD}±0.00	21.33^{bC}±0.58	28.00^{bB}±0.00	37.67^{bA}±0.58	**
Paddy straw (50%) + Gram straw (50%)-based complete pellets	7.33^{cE}±0.58	13.33^{cD}±0.58	20.67^{cC}±0.58	25.33^{cB}±0.58	36.33^{cA}±0.58	**
Significance	**	**	**	**	**	

See Table 4 for details

Table 8. *In vitro* gas production (IVGP) (ml/200mg) of crop residue-based complete feed pellets at 75% replacement level with roughage to concentrate in ratio of 60:40

Feed regime	*In vitro* gas production at different hrs (ml/200mg)					Significance
	2 hr	4 hr	8 hr	12 hr	24 hr	
Paddy straw (25%) + Wheat straw (75%)-based complete pellets	6.33^{dE}±0.58	11.67^{dD}±0.58	18.67^{dC}±0.58	25.67^{dB}±0.58	36.33^{dA}±0.58	**
Paddy straw (25%) + *Cajanus cajan* straw (75%)-based complete pellets	5.33^{eE}±0.58	9.67^{eD}±0.58	14.00^{eC}±0.00	23.67^{eB}±0.58	35.67^{eA}±0.58	**
Paddy straw (25%) + Groundnut straw (75%)-based complete pellets	11.67^{aE}±0.58	19.67^{aD}±0.58	29.67^{aC}±0.58	37.67^{aB}±0.58	50.33^{aA}±0.58	**
Paddy straw (25%) + Soybean straw (75%)-based complete pellets	8.67^{bE}±0.58	14.33^{bD}±0.58	22.00^{bC}±0.00	30.67^{bB}±0.58	40.67^{bA}±0.58	**
Paddy straw (25%) + Gram straw (75%)-based complete pellets	7.67^{cE}±0.58	13.33^{cD}±0.58	21.67^{cC}±0.58	28.67^{cB}±0.58	39.67^{cA}±0.58	**
Significance	**	**	**	**	**	

See Table 4 for details

Table 9. *In vitro* gas production (IVGP) (ml/200mg) of crop residue-based complete feed pellets at 100% replacement level with roughage to concentrate in ratio of 60:40

Feed regime	*In vitro* gas production at different hrs (ml/200mg)					Significance
	2 hr	4 hr	8 hr	12 hr	24 hr	
Paddy straw (100%)-based complete pellets	4.33^{fE}±0.58	7.67^{fD}±0.58	14.67^{fC}±0.58	21.33^{fB}±0.58	34.33^{fA}±0.58	**
Wheat straw (100%)-based complete pellets	6.67^{dE}±0.58	12.33^{dD}±0.58	21.67^{dC}±0.58	29.67^{dB}±0.58	39.67^{dA}±0.58	**
Cajanus cajan straw (100%)-based complete pellets	6.33^{eE}±0.58	10.33^{eD}±0.58	19.67^{eC}±0.58	27.67^{eB}±0.58	38.67^{eA}±0.58	**
Groundnut straw (100%)-based complete pellets	12.67^{aE}±0.58	20.67^{aD}±0.58	31.33^{aC}±0.58	39.67^{aB}±0.58	53.67^{aA}±0.58	**
Soybean straw (100%)-based complete pellets	9.33^{bE}±0.58	16.33^{bD}±0.58	23.33^{bC}±0.58	32.33^{bB}±0.58	43.67^{bA}±0.58	**
Gram straw (100%)-based complete pellets	8.00^{cE}±0.00	14.33^{cD}±0.58	22.00^{cC}±0.00	30.00^{cB}±0.00	41.33^{cA}±1.15	**
Significance	**	**	**	**	**	

See Table 4 for details

feed pellets might indicate a better nutrient availability for rumen microorganisms. The gas production trend in the current study revealed that increasing the quantities of NDF, ADF, ash, and lignin in the complete feed pellets lowered *in vitro* gas production. Kuliv and Kafilzadeh (2015) reported a positive CP correlation and negative NDF and ADF correlation with gas production and which agrees with the results found in the present investigation.

Daily dry matter intake: There was an increasing trend of dry matter intake from I to the IV week of the experiment in both control and treatment groups (Table 11). The DMI has increased successively due to increased body weights every week to fulfil the requirement. The highest daily dry matter intake was noticed during the IV week of the experiment and which was 856.88g in the control group and 1174.83g in the treatment group. The daily DMI in goats during the study period was significantly higher in the treatment group fed gram straw-based complete feed pellets than in the control group. DMI of crop residue-based complete feed pellets was higher due to more acceptability of complete feed in processed form. Grinding crop residues reduces particle size and pelleting with a concentrate mixture leads to lower bulk density. Therefore, to fulfil the bulk requirements, the DMI intake of complete feed could be improved (Nagalakshmi and Reddy, 2011). Higher DMI of crop residue-based complete processed feed was also reported by Rekhate et al (2008) in calves and Nagalakshmi and Reddy (2011) in lambs. Sihag et al (2008) reported higher DMI in lambs fed black gram-based pelleted complete feed and gram-based pelleted complete feed than the conventional ration.

Table 10. Chemical composition of concentrate mixture, super napier hay and gram straw-based complete feed pellets

Nutrients (%)	Concentrate mixture	Super napier hay	Gram straw based complete feed pellets (R:C=60:40)
Dry matter	91.26	89.38	90.67
Crude Protein	21.78	8.07	12.11
Ether extract	3.14	1.69	1.0
Crude fibre	9.0	37.6	22.42
Total ash	9.04	6.98	9.27
Nitrogen free extract	56.93	45.66	54.4
NDF	23.01	68.41	51.6
ADF	11.04	39.3	31.9
ADL	3.16	6.91	8.26
Hemicellulose	11.97	29.11	19.7
Cellulose	7.88	32.39	23.64
Calcium	0.82	0.48	0.89
Phosphorus	0.89	0.17	0.45

R: C=Roughage to concentrate ratio

Table 11. Performance parameters of goats in control and treatment groups

Sr. No.	Parameters	I week	II week	III week	IV week	Significance
Daily dry matter intake (g)	Control	779.49±26.84[b]	811.56±12.29[b]	845.60±7.14[b]	856.88±2.43[b]	0.01**
	Treatment	959.71±9.55[a]	1061.26±15.41[a]	1169.32±2.33[a]	1174.83±2.57[a]	
Average weekly body weights	Control	19.65±0.21[b]	20.28±0.21[b]	20.96±0.20[b]	21.70±0.23[b]	0.01**
	Treatment	20.19±0.22[a]	21.36±0.20[a]	22.55±0.20[a]	23.77±0.21[a]	
Daily body weight gain (g)	Control	83.81±5.24[b]	90.48±1.46[b]	97.38±8.20[b]	106.19±7.32[b]	0.01**
	Treatment	157.38±12.14[a]	166.91±12.24[a]	169.52±8.93[a]	174.05±5.53[a]	
FCR	Control	10.42±0.95[a]	9.97±0.29[a]	9.71±0.87[a]	9.04±0.64[a]	0.01**
	Treatment	6.76±0.90[b]	7.05±0.83[b]	7.63±0.40[b]	7.45±0.24[b]	
	Treatment	1	1	1	1	
Fortnightly Body condition score	Control	2.67±0.26		2.83±0.41		NS
	Treatment	2.83±0.26		3.08±0.38		

NS-Non-significant, Means bearing different superscripts in columns differ significantly (P < 0.01) **

Weekly body weights and daily weight gain: The significant difference in the average weekly body weights of goats were between the control and treatment groups during the experiment. During the complete experimental period, significant difference in average daily weight gain was between the control and treatment groups. Significantly higher daily body weight gain was in goats in the treatment group than in the goats in the control group. The highest daily weight gain in the goats of the control group was 106.19 g, whereas, 174.05 g daily body weight gain in the goats of the treatment group. The highest daily weight gain was during the fourth week of the study. The higher DMI and nutrient digestibility in the treatment group might have resulted in higher body weight gain in goats of the treatment group.) Venkateswarlu et al (2013) and Islam et al (2017) also reported a significant effect of feeding crop residue-based complete ration on growth rate than the traditional ration.

Feed conversion ratio (FCR): The highly significant difference in the FCR of goats between the groups was observed during the experimental period. The FCR in the control group was in decreasing trend from the I week to the IV week of the experiment, whereas no particular trend for FCR was observed in the treatment group. The significantly better FCR of goats in the treatment group might be due to the better utilization of nutrients in goats of the treatment group than the control group. Proportionate intake of roughage and concentrate through complete feed pellets gives a better rumen environment that stimulates the better utilization of nutrients (Dhuria et al 2009). Similarly, Islam et al (2017) reported a better feed conversion ratio in sheep fed TMR in pelleted form than TMR in loose form. Improved FCR on feeding crop residue-based complete feed was also reported by earliest scientist (Seshaiah et al 2013, Rashid et al 2016, Ahmed et al 2021).

Body condition score: The fortnightly body condition score of goats was non-significant between the groups. Though there was a slight increase in body condition score during I and II fortnight of the study, the difference was statistically non-significant. Slight improvement in body condition score in the treatment group than the control group might be due to more body weight gain in goats of the treatment group. Improved body condition score on feeding crop residue-based complete feed was reported by Ahmed et al (2021), whereas Mishra et al (2013) observed better body condition score in Malpura sheep on utilization of fallen tree leaves up to 20% in complete feed blocks and decreased BCS on 30% inclusion level of fallen tree leaves in complete feed block.

Nutrient utilization: The highly significant difference in the digestibility of DM, CP, CF, EE, NFE, ADF, NDF, hemicellulose and cellulose was observed between the groups (Table 12). Significantly higher digestibility of nutrients was found in the goats of the treatment group fed gram straw-based complete feed pellets than in the control group, indicating the better utilization of gram straw by the goats in complete feed form. The better utilization of nutrients from the complete feed pellets might be due to a uniform supply of nutrients at regular intervals, which helps maintain a steady and healthy rumen environment. Besides, the activities of different ruminal enzymes responsible for fibre degradation have been reported to be higher in animals fed complete ration as compared to animals fed conventional ration (Gupta et al 2006). Earlier scientist also found higher nutrient digestibility in animals fed complete rations in pelleted or block form than the conventional ration (Gupta et al 2006, Nagalakshmi and Reddy 2012, Kishore et al 2014, Mudgal et al 2014, Rashid et al (2016). The higher bacterial activities in goat's rumen on gram straw-based complete feed pellets may be attributed to its better CP and other nutrient degradability (Singh and Kundu 2011).

Nitrogen, calcium and phosphorus balance: The nitrogen, Ca and P intake, nitrogen, Ca and P excretion in faces and urine, as well as nitrogen, Ca and P retention (gm/head/day) in goats were significantly higher in the goats of the treatment group than in the control group (Table 13). The comparatively higher nitrogen, Ca and P retention in the treatment group was due to better nitrogen utilization by the microbes with comparatively more nitrogen intake. Xia et al. (2018) reported a positive effect of higher protein intake on nitrogen intake, excretion and balance in bulls fed a diet with high crude protein. Venkateswarlu et al (2013) also observed positive calcium and phosphorus balance in buffalo bulls fed jowar straw, maize stover, red gram straw and black gram straw-based complete feeds with roughage to concentrate ratio of 60:40.

Table 12. Nutrient utilization of goats in control and treatment groups

Nutrient	Digestibility %		Significance
	Control	Treatment	
Dry matter	60.33±0.27[b]	65.47±0.49[a]	0.01 **
Crude protein	63.69±0.45[b]	67.09±0.43[a]	0.01 **
Crude fibre	59.45±0.40[b]	60.99±0.61[a]	0.05 *
Ether extract	70.00±0.70[b]	73.80±0.73[a]	0.01 **
Nitrogen free extract (NFE)	67.11±0.99[b]	69.71±0.94[a]	0.01 **
NDF	61.49±0.31[b]	64.07±0.47[a]	0.01 **
ADF	53.42±0.44[b]	54.93±0.47[a]	0.01 **
Hemicellulose	71.62±0.22[b]	78.92±0.70[a]	0.01 **
Cellulose	64.21±0.66[b]	71.54±1.07[a]	0.01 **

Means bearing different superscripts in rows differ significantly ($P < 0.01$) **

Table 13. Nitrogen, Calcium and phosphorous balance in goats fed super napier hay and concentrate mixture or gram straw based-complete feed pellets

Particulars	Groups		Significance
	Control	Treatment	
Nitrogen (g/day)			
Intake (g)	19.06±0.70[b]	22.85±0.70[a]	0.01**
Faecal outgo (g)	6.92±0.10[b]	7.51±0.09[a]	0.01**
Urinary outgo (g)	4.65±0.24[b]	5.64±0.29[a]	0.01**
Balance (g)	7.49±0.25[b]	9.70±0.28[a]	0.01**
Balance (%)	39.31±1.34[b]	42.43±1.11[a]	0.01**
Calcium (g/day)			
Intake (g)	5.36±0.02[b]	10.49±0.03[a]	0.01**
Faecal outgo (g)	2.57±0.04[b]	4.68±0.07[a]	0.01**
Urinary outgo (g)	0.14±0.01[b]	0.22±0.02[a]	0.01**
Balance (g)	2.65±0.03[b]	5.59±0.07[a]	0.01**
Balance (%)	49.52±0.61[b]	53.25±0.62[a]	0.01**
Phosphorus (g/day)			
Intake (g)	4.08±0.02[b]	5.30±0.02[a]	0.01**
Faecal outgo (g)	1.73±0.03[b]	2.11±0.02[a]	0.01**
Urinary outgo (g)	0.12±0.00[b]	0.15±0.00[a]	0.01**
Balance (g)	2.23±0.02[b]	3.04±0.03[a]	0.01**
Balance (%)	54.59±0.57[b]	57.38±0.41[a]	0.01**

Means bearing different superscripts in rows differ significantly
**P < 0.01 *P <0.05

Table 14. Rumen fermentation parameters in goats fed super Napier hay and concentrate mixture or gram straw based complete feed pellets

Parameters	Groups		Significance
	Control	Treatment	
pH	6.5±0.0	6.5±0.0	1.000
Total nitrogen (mg/100 ml SRL)	80.73±2.11[b]	91.93±2.11[a]	**
TVFA (mEq/100ml SRL)	10.25±0.26[b]	11.75±0.38[a]	**
Bacterial count x 10^{10}/ml of SRL	1.03±0.02[b]	1.23±0.01[a]	**
Protozoan count x 10^{6}/ml of SRL	1.55±0.06[b]	1.98±0.09[a]	**

Means bearing different superscripts in rows differ significantly. **P < 0.01

Rumen liquor profile: The rumen liquor pH shows non-significant difference between the groups (Table 14). The total nitrogen (mg/100 ml SRL), TVFA (mEq/100 ml SRL), total bacterial count (x 10^{10}/ml of SRL) and protozoan count (x 10^{6}/ml of SRL) in the rumen liquor of goats in the treatment group revealed significantly more concentrations than in the goats of the control group. Rumen motility was not significantly different between groups. Omotoso et al (2021) also reported non-significant difference in the rumen liquor pH of West African dwarf sheep on feeding with mixed rations of crop residues. Nagalakshmi and Reddy (2012), Jadhav (2019), and Shembekar (2019) reported increased concentrations of TVFA and total nitrogen in the rumen liquor on feeding with crop residue-based complete feed either in block or pellets form. Senani et al (2013) also reported a higher total bacterial count in the rumen liquor of Bandur lambs on feeding with ragi straw and maize cobs based complete rations. However, Karimizadeh et al (2017) observed higher protozoan count in the rumen liquor of lambs fed bagasse pit-based complete feed blocks than in the mash and pellets forms.

Hemato-biochemical parameters: The haematological parameters (Table 15) *viz*., Hb (g/dl), PCV (%), TEC (x 10^{6}/µl) and TLC (x 10^{3}/µl) and blood biochemical parameters (Table 16) *viz.*, total protein (g/dl), serum creatinine (mg/dl), total cholesterol (mg/dl), SGOT (U/L), SGPT (U/L), serum albumen (g/dl) and serum globulin (g/dl) differ not significantly between the goats of treatment and control group. Blood glucose (mg/dl) concentration was significantly higher in the goats of the treatment group in comparison to the control. Malik et al. (2020) also observed that the amount of straw or the physical form of the male Beetal goats diet had no influence on blood metabolites or blood cell count. Rumen fermentation pattern changes on feeding with pellet diet, which increases propionate production and that is a source for higher glucose production for cellular growth and development (Huyen et al 2012). The high intake of the TMR diet resulted in an increased supply of precursors for hepatic gluconeogenesis and resulted into higher blood glucose

Table 15. Haematological parameters in goats fed super napier hay and concentrate mixture or gram straw based complete feed pellets

Parameter	Start of experiment		P Value	End of experiment		P value
	Control	Treatment		Control	Treatment	
Hb g/dl	8.20±0.15	8.28±0.16	0.538	8.27±0.15	8.33±0.18	0.496
PCV%	22.77±0.70	22.87±0.78	0.745	22.87±0.71	22.98±0.78	0.793
TEC x 10^{6}/µl	8.37±0.25	8.37±0.22	1.000	8.40±0.24	8.38±0.21	0.901
TLC x 10^{3}/µl	7.53±0.87	7.55±0.83	0.912	7.67±0.85	8.27±0.87	0.253

Note: Hb-Haemoglobin, PCV-Packed cell volume, TEC-Total Erythrocyte Count, TLC-Total Leucocyte Count

Table 16. Blood biochemical parameters in goats fed super napier hay and concentrate mixture or gram straw based complete feed pellets

Parameter	Start of experiment		P Value	End of experiment		P value
	Control	Treatment		Control	Treatment	
Blood glucose mg/dl	47.42±1.77	47.23±1.82	0.863	48.43±1.55[b]	52.48±1.62[a]	*
Total protein g/dl	6.57±0.23	6.60±0.23	0.804	6.62±0.21	6.78±0.20	0.197
Serum creatinine mg/dl	0.97±0.03	0.97±0.03	0.801	0.97±0.03	0.97±0.04	0.871
Total cholesterol mg/dl	61.25±5.73	62.12±5.48	0.794	60.86±6.06	61.62±5.54	0.827
SGOT U/L	179.02±12.03	179.38±15.98	0.965	179.03±12.05	178.48±15.93	0.948
SGPT U/L	8.18±0.82	8.27±0.73	0.937	8.30±1.62	8.18±1.72	0.906
Serum albumen g/dl	3.78±0.17	3.80±0.15	0.830	3.76±0.30	3.81±0.06	0.709
Serum globulin g/dl	2.79±0.17	2.81±0.18	0.897	2.86±0.20	2.97±0.16	0.291

SGOT- Serum glutamic-oxaloacetic transaminase, SGPT-Serum glutamic pyruvic transaminase, Means bearing different superscripts in rows differ significantly. **P < 0.01

Table 17. Cost of production of goats fed super napier hay and concentrate mixture or gram straw based-complete feed pellets

Feedstuff	Groups	
	Control	Treatment
Average Super napier hay intake (Kg)	15 Kg in 28 days	----
Average concentrate intake /goat	11 Kg in 28 days	----
Average Gram straw based complete feed pellet intake/goat	---	34 Kg in 28 days
Cost of feedstuffs	Hay=Rs. 6/Kg Concentrate=Rs. 34/Kg	Complete feed pellets =Rs. 18/Kg
Cost of feeding	Hay=Rs. 88.8/- Concentrate= Rs. 378.	Complete feed pellets= Rs. 600
Cost of processing	----	Rs. 1/Kg of complete feed =Rs. 34
Total feeding cost	Rs. 4667	Rs. 634
Average total weight gain/ goat	2.65 Kg	4.68 Kg
Cost of feeding per Kg of weight gain	Rs. 176.2/Kg	Rs. 135.42/Kg

levels. The blood glucose level found in this experiment agrees with Delany et al (2010) in cow.

Cost of goat production: The goats in the control group with conventional ration have a lower cost of production (Rs. 466/animal) than the treatment group. The average total weight gain in four weeks was higher in the treatment group (4.68 Kg/ animal) than in the control group (2.65Kg/animal). Due to better utilization of nutrients and higher weight gain in goats fed gram straw-based complete feed with roughage to concentrate ratio of 60:40, the cost of feeding per Kg of weight gain was lower in the treatment group (Rs.135/Kg) than in the control group (Rs.176/Kg). Lower feed cost per kg body weight gain on feeding crop residue-based complete feed in different animals was also reported by Kirubanath et al (2003), Afzal et al (2009) and Ahmed et al (2021).

CONCLUSION

The gram straw based complete feed pellets had more degradable dry matter and crude protein, whereas the *Cajanus cajan* straw based complete feed pellets has more degradable neutral detergent fibre. Groundnut straw based complete feed pellets had higher IVGP. The gram straw based complete feed pellets with 60%-gram straw showed improved performance of goat and proved to be economical.

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