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In vitro evaluation of paddy straw based complete feed pellets as livestock feed

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Wheat and paddy are the traditional crops cultivated in northern India for producing cereal grains besides yielding equal or higher quantity of straws of respective crops. The dairy animals in Punjab and Haryana are fed wheat straw to meet the basal DM requirements. Even after meeting their requirements, the wheat straw is surplus in these states. Only landless, marginal and lower middle-class farmers feed paddy straw (PS) to their livestock in these states (Bakshi and Wadhwa 2011). Therefore, almost entire quantity of PS available after harvesting is surplus. Efforts are afoot to manage the lose bulky PS. Primary objective of the present investigation was the provision of an innovative system-based approach to pelletize PS with other feedstuffs so as to prepare pellets with required density for effective transportation, handling and for utilization as livestock feed. It will fill critical missing links in the biomass value and supply chain. Agricultural waste biomass is critical to livestock feeding, especially when there is shortage of feedstuffs and natural calamities worsens it further. This study will have a positive impact on air and soil quality as well as reduction of hazardous/toxic substances and air emissions. The PS based complete feed pellets (CFPs) can easily be stored and transported to vulnerable areas.

The PS available after harvesting with combine was collected from the field using reapers, rakers and baled by tractor driven fully automatic stationery balers (Kaur *et al*. 2007). The baled PS is shredded/ground, mixed with other feedstuffs and densified as pellets. The CFPs containing roughage to concentrate ratio of 55:45 were prepared in a pelletizing plant fitted with 8 mm stationary dye in the Department of Animal Nutrition, GADVASU, Ludhiana. The CFPs were 8 mm in diameter and 2 to 4 cm in length. The roughage portion in the CFPs was made up of PS and alfalfa hay. With the increase in PS level from 15 to 30%, the level of alfalfa hay was reduced from 40 to 25%. The level of concentrate mixture was fixed at 45% in all the groups. The sundried PS and alfalfa hay were ground in a hammer mill. The ground material was taken in to the mixer via bucket elevator. The ground PS and alfalfa hay were mixed with concentrate mixture (Maize 13, wheat 13, deoiled mustard cake 8, mustard cake 13, soybean meal 9, rice bran 13, deoiled rice bran 14, molasses 10, guar gum 4, mineral mixture 2 and common salt 1% each) and pelletized. Unlike earlier studies, where molasses was used as a binder (Bakshi and Wadhwa 2021, Wadhwa *et al.* 2021b), guar gum was used as a binder in the present study. The pellets were made by dry pelleting process without steaming the material. The bulk density of different pellets was calculated as the ratio of the material mass to the container volume (Liu *et al*. 2013).

The nutritional value of PS-based pellets was evaluated by *in vitro* gas production technique (IVGPT; Menke *et al*. 1979, Menke and Steingass 1988). Three rumen fistulated male buffalo calves used as donor for rumen liquor were maintained on 2 kg conventional concentrate mixture (Maize 32, barley 20, soybean meal 15, groundnut extraction 15, paddy bran 15, mineral mixture 2 and common salt 1% each), 2 kg green fodder and *ad lib.* wheat straw. About 375±5 mg finely ground pellets were incubated with buffered rumen fluid in triplicate in a water bath at 39°C for 24 h in 100 ml calibrated glass syringes (Haberle Labortechnik, Germany). After 24 h, the volume of gas produced in each syringe was recorded and 5 ml aliquot of fluid from each syringe was taken and mixed with 1 ml of 25% meta-phosphoric and kept for 1 h at ambient temperature. Then it was centrifuged at 5500 rpm for 10 min, and the clear supernatant was collected and stored at -20°C until analyzed. The volatile fatty acids were estimated (Cottyn and Boucque 1968) using Netchrom 9100 gas chromatograph. The contents of syringes were transferred to spout-less beaker, boiled with neutral detergent solution for assessing the true OM digestibility. The fermentation attributes related to hydrogen recovery, VFA utilization index and microbial biomass synthesis, efficiency of conversion of fermented hexose energy to VFA and efficiency of conversion of fermented hexose energy to methane energy were calculated adopting procedures described in an earlier publication (Wadhwa *et al*. 2021a). The finely ground samples of CFPs were analyzed for DM, N and total ash (AOAC 2007), cellulose (Crampton

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Table 1. Ingredients and chemical composition of PS based complete feed pellets

Parameter	Complete feed pellets				PSE	p value
	PS-15*	PS-20	PS-25	PS-30		
Ingredient composition, %						
PS	15	20	25	30		
Alfalfa hay	40	35	30	25		
Concentrate mixture	45	45	45	45		
Chemical composition, %						
Ash	13.80	13.95	14.18	14.35	0.10	0.258
OM	86.21	86.05	85.82	85.65	0.10	0.258
CP	17.40^{c}	16.85^{c}	15.76^{b}	14.35^{a}	0.63	<0.001
EE	3.31	3.20	3.10	2.99	0.10	0.135
NDF	49.30^{a}	49.93^{a}	50.55^{a}	53.60^{b}	0.81	0.001
Cellulose	16.00^{a}	16.70^{ab}	17.60^{b}	20.00^{c}	0.58	0.001

PS-15*, complete feed pellets containing 15% PS; PS-20, complete feed pellets containing 20% PS; PS-25, complete feed pellets containing 25% PS; PS-30, complete feed pellets containing 30% PS.

and Maynard 1938) and other cell wall constituents (Van Soest *et al*. 1991). Hemicellulose was determined by the difference in NDF and ADF. The data were analyzed by one way ANOVA (Snedecor and Cochran 1994) using SPSS (2009) version 16.0 and the means were tested for the significant difference by Tukey's-b test.

The bulk density of PS varies depending on the physical form, it may take. The bulk density of loose PS varied between 13 to 18 kg/m^3 on DM basis (Migo 2019), while in case of baled (3ft Length × 1.5ft Width × 1.25ft Height) PS, it varied between 175-230 kg/m^3 depending on the moisture content in PS at the time of baling (Kaur *et al.* 2007). In the present study, the bulk density of CFPs containing 15 to 30% PS varied between 580.28 to 603.57 kg/m^3. Earlier studies revealed that it varied between 560.33 to 655.35 kg/m^3 depending on the level of PS (Bakshi and Wadhwa 2021). Nguyen *et al.* (2018) also reported that the density of rice straw pellets with an 8 mm diameter is 600–700 kg/m^3 dry matter basis.

The CFPs were prepared successfully and contained 14.35 to 17.4% CP and 2.99 to 3.31% EE. With the increase in PS in the CFPs, the total ash (P>0.05), NDF and cellulose content increased (P<0.01) linearly, while that of OM, EE (P>0.05) and CP content decreased (P<0.01) linearly (Table 1). Similar trend was observed in an earlier study, where PS was increased linearly up to 60% with the decrease in alfalfa hay in the PS based pellets (Bakshi and Wadhwa 2021). These pellets can be fed exclusively to any category of ruminants as these meet the recommended levels of CP and EE along with other nutrients in the complete feed of low to medium yielders (NRC 1989, 2001).

The net gas production (NGP), true OM digestibility and partitioning factor (PF) were not affected (P>0.05) by the level of PS in the CFPs (Table 2). However, Bakshi and Wadhwa (2021) observed significant decrease in these parameters. The NDF digestibility increased (P<0.01), while ammonia production (P<0.01) and ME content decreased (P<0.05) with the increase in PS level in CFPs. The decline in the ME content in the CFPs was mainly low ME and high silica content in PS (Van Hung *et al*. 2020). The total and individual VFAs concentration decreased (P<0.01) with the increase in PS in CFPs, confirming the earlier report (Bakshi and Wadhwa 2021). Amongst different groups, the best acetate to propionate ratio was observed in CFPs containing 25 and 30% PS. The relative proportion of acetate and butyrate was not affected by the level of PS in CFPs, but relative proportion of propionate (P<0.01) and that of isovalerate (P<0.05) were improved with the increase in PS in CFPs.

The hydrogen consumption declined, while the hydrogen recovery improved non-significantly with the increase in level of PS in the CFPs. The efficiency of rumen fermentation (P<0.05), efficiency of conversion of fermented hexose energy to VFA energy and efficiency of conversion of fermented hexose energy to methane energy declined (P<0.01) with the increase in the level of PS in CFPs, resulting in depressed (P<0.01) microbial biomass production (Table 2). Wadhwa *et al*. (2021b) observed that feeding of iso-nitrogenous and iso-caloric CFPs containing 35% PS can be utilized effectively without affecting the health, nutrient utilization and performance of buffalo calves. It was concluded that CFPs containing graded levels of PS can be developed successfully. However, the efficiency of nutrient utilization, VFA production and microbial biomass production declined at higher levels of PS in CFPs.

SUMMARY

This study was taken up to find out if paddy straw (PS) based complete feed pellets (CFPs) could be prepared by using guar gum as a binder in place of molasses and to assess *in vitro* nutritional worth as livestock feed. The 8 mm CFPs contained roughage to concentrate ratio of 55:45. The roughage portion was made up of PS and alfalfa hay. With the increase in PS level from 15 to 30%, the level of alfalfa hay was reduced from 40 to 25%. The CFPs were prepared successfully and contained 14.35 to

Table 2. Effect of level of PS in complete feed pellets on the *in vitro* net gas production, digestibility of nutrients, VFA production and efficiency of rumen fermentation

Parameter	Complete feed pellets				PSE	p value
	PS-15*	PS-20	PS-25	PS-30		
In vitro studies						
NGP	120.44	115.55	114.02	112.22	1.57	0.327
NDFD	26.87^{ab}	23.57^{a}	25.47^{a}	30.85^{b}	1.06	0.015
TOMD	60.69	59.71	59.23	58.89	-	0.339
PF	3.19	2.94	2.29	2.13	-	0.186
NH_3	0.025^{c}	0.023^{b}	0.023^{b}	0.021^{a}	0.01	0.005
ME	6.98^{b}	6.74^{ab}	6.63^{ab}	6.55^{a}	0.07	0.040
Volatile fatty acid production, mM/dL						
TVFA	6.15^{b}	6.39^{b}	4.17^{a}	4.27^{a}	0.39	<0.001
Acetate (A)	3.68^{b}	3.80^{b}	2.42^{a}	2.48^{a}	0.25	0.001
Propionate (P)	1.42^{b}	1.54^{b}	1.05^{a}	1.09^{a}	0.08	0.001
Butyrate	0.67^{b}	0.71^{b}	0.45^{a}	0.47^{a}	0.04	<001
Isovalerate	0.244	0.237	0.243	0.237	0.002	0.586
A:P	2.59^{b}	2.47^{b}	2.29^{a}	2.27^{a}	-	0.035
Relative proportion, %						
Acetate	59.84	59.47	58.03	58.08	0.70	0.146
Propionate	23.09^{a}	24.10^{ab}	25.18^{b}	25.53^{b}	0.50	0.015
Butyrate	10.89	11.11	10.79	11.01	-	0.512
Isovalerate	3.97^{a}	3.71^{a}	5.83^{b}	5.55^{b}	0.50	0.002
Energetic efficiency of fermentation in the rumen						
E, %	76.88^{b}	76.22^{ab}	76.80^{ab}	75.86^{a}	-	0.040
E_1, %	64.73^{b}	64.85^{b}	64.04^{a}	63.87^{a}	-	0.002
E_2, %	26.18^{b}	26.02^{b}	25.15^{a}	25.26^{a}	-	0.001
HR	39.36	41.87	40.34	42.13	0.65	0.050
HC	0.077	0.069	0.074	0.068	-	0.047
VFA UI	3.42	3.15	3.29	3.13	-	0.051
MBM	162.12^{b}	154.94^{b}	105.22^{a}	108.35^{a}	9.90	0.001

PS-15*, complete feed pellets containing 15% PS; PS-20, complete feed pellets containing 20% PS; PS-25, complete feed pellets containing 25% PS; PS-30, complete feed pellets containing 30% PS; NGP, Net gas production ml/g DM/24h; NDFD, Neutral detergent fibre digestibility %; TOMD, True OM digestibility %; PF, Partitioning factor; ME, Metabolizable energy MJ/kg DM; TVFA, Total volatile fatty acids mM/dL; E, Efficiency of rumen fermentation; E1, efficiency of conversion of fermented hexose energy to VFA energy; E2, efficiency of conversion of fermented hexose energy to methane energy; HR, hydrogen recovery; HC, hydrogen consumed; VFAUI, volatile fatty acid utilization index; MBM, microbial biomass g/day. Figures with different superscripts in a row differ significantly.

17.4% CP and 2.99 to 3.31% EE. The bulk density varied between 580.28 to 603.57 kg/m^3. With the increase in PS in the CFPs, the NDF and cellulose content increased and CP content decreased linearly. The NGP, true OM digestibility and partitioning factor were not affected by the level of PS in the CFPs. The NDF digestibility increased, while ammonia production and ME availability decreased with the increase in PS level in CFPs. The total and individual VFAs concentration decreased with the increase in PS in CFPs. The relative proportion of propionate and that of isovalerate were improved with the increase in PS in CFPs. The efficiency of rumen fermentation, efficiency of conversion of fermented hexose energy to VFA energy and efficiency of conversion of fermented hexose energy to methane energy declined with the increase in the level of PS in CFPs, resulting in depressed microbial biomass production. It was concluded that CFPs containing graded levels of PS can be developed successfully. However, the efficiency of nutrient utilization, VFA production and microbial biomass production declined at higher levels of PS in CFPs.

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