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Effect of mixing paddy straw with molasses and urea on fermentation characteristics and nutritive value of maize silage

MEENAKSHI GOYAL[1✉], RAMAN PREET KAUR[1], RAVI PRAKASH PAL[1] and DEVINDER PAL SINGH[1]

Punjab Agricultural University, Ludhiana, Punjab 141 004 India

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ABSTRACT

The present investigation was aimed at studying the improvement of fermentation and nutritive quality of rice straw-maize silage by the inclusion of different additives. In the experiment, paddy straw and green maize fodder were mixed in ratios of 100:0, 75:25, 50:50, 25:75, and 0:100 for silage preparation. These combinations were made in a triplicate and added with no additive (C), 2% urea (T1), 1% molasses (T2) and a mixture of 2% urea and 1% molasses (T3) in completely randomized design (CRD). The silages were harvested after 45 days and then analyzed for chemical composition, fermentation characteristics and anti-nutritional factors. Results revealed that dry matter (DM), acid detergent fibre (ADF), neutral detergent fibre (NDF), crude fibre (CF), ash and *p*H increased with an increase in the proportion of paddy straw in all combinations. Addition of 2% urea increased *in vitro* dry matter digestibility (IVDMD), crude protein (CP) and total gas production (TGP) of paddy straw and maize fodder silage. Urea treatment considerably reduced the oxalate content and increased the tannin content of paddy straw and maize fodder silage. In the present study, silage prepared by combining paddy straw and maize fodder in ratio of 25:75 had good aroma and fermentation characteristics which can be, therefore, utilized for effective silage making.

Keywords: Fermentation characteristics, Maize fodder, Molasses, Paddy straw, Urea

The adequate supply of nutritive fodder and feed is a crucial factor impacting the productive performance of the animals (Anonymous 2012). India faces a net defect of 61.1%, 21.9%, and 64% in green fodder, dry crop residues and concentrate feeds, respectively (Chaudhary *et al.* 2012). In India the agro-residues in terms of volumes generated (in million metric tons, MMT) were found to be rice straw (112), rice husk (22.4), wheat straw (109.9) sugarcane tops (97.8) and bagasse (101.3) (Saritha *et al.* 2012). Paddy straw (*Oryza sativa* L.) contains 32-43%, 19-25%, 5-9%, 14-16%, and 6-12% of cellulose, hemicellulose, lignin, ash and silica, respectively. Paddy straw is used as part of the nutritional requirements of ruminant in most rice-producing countries. However, low protein content and low digestibility limits the use of paddy straw in the ruminant ration. Thereby, a high proportion of rice straw has been left unused or burnt directly in turn wasting resources and causing environmental pollution, indicating an urgent need for proper disposal of rice straw.

In the past, many attempts were made to increase the digestibility and utilization of the paddy straw. These procedures include biological treatments, physical treatments and chemical treatments. Recently, ensiling can also be considered as an efficient way to improve the palatability and nutritive value of the rice straw (Abo-Donia *et al*. 2022). However, due to its hollow stem, low water-soluble carbohydrates (WSC) and less epiphytic lactic acid bacteria (LAB), successful ensiling of paddy straw is difficult (Cao *et al.* 2010). Studies have reported usage of additives like molasses and urea to improve the fermentation quality of ensiling forage (Cherdthong *et al.* 2021). Many experiments have proved that molasses increase lactic acid fermentation and reduce silage *p*H (Zhao *et al.* 2019). Urea is a source of nitrogen and also serves as a delignifying agent through ammonification (Mapato *et al.* 2010) and it also remove the polymerized silica from the leaf sheath and leaf blade. Ensiling paddy straw with whole green maize plant may help in silage making as maize is rich in water-soluble carbohydrates which are a prerequisite for silage making. This is a viable option to increase dry matter as well as the protein content of the mixture and thereby improving forage quality through the synergistic effects of two crops ensiled together (Geren *et al.* 2008).

Considering the above stated benefits, it was hypothesized that the use of additives in the form of molasses and urea at the right ratio would facilitate the incorporation of more amount of paddy straw in fodder maize-based silage without compromising quality parameters. Consequently, information and application of additives on paddy straw-maize silage are still limited. Hence, the present experiment was conducted to study the effect of amount of paddy straw and type of additives on fermentation characteristics and nutrient quality

Present address: [1]Punjab Agricultural University, Ludhiana, Punjab. ✉Corresponding author email: meenakshigoyal@pau.edu

components in mixed paddy straw and maize fodder silage.

MATERIALS AND METHODS

The present study was conducted in the field and forage evaluation laboratory at the Department of Plant Breeding and Genetics, Punjab Agricultural University, Ludhiana. The present research was carried out on paddy straw and maize fodder.

Silage preparation: Paddy straw (Pusa basmati 1121) was collected from rice field after harvesting and maize fodder (J-1006) was collected from field of Forage and Millet Section, Punjab agricultural university Ludhiana. Mature whole rice plant was thrashed to remove the grain and the rice straw was cut into 3–5 cm using a paddy straw cutter. Maize fodder crop was harvested at milk stage and chopped in to forage of correct length (2-3 cm). Paddy straw and maize fodder were mixed in the ratio of 100:0, 75:25, 50:50, 25:75 and 0:100 for the preparation of silage. These combinations were treated with no additive (C); 2% urea (T1); 1% molasses (T2); 2% urea and 1% molasses (T3), packed in 2 kg plastic bags and stored in the dark room for 45 days. Proximate analysis, fiber fraction, fermentation characteristics, *p*H, NH_3-N, oxalate and tannin content of the silage was estimated after 45 days when the silage was opened.

Chemical analysis: Silage samples were sun-dried and then completely dried in a hot air oven till a constant weight was obtained. This dried silage sample was ground using a Willy grinder to uniform mesh size and stored in a dry place. Dried samples were analysed for CP, EE, CF and total ash (AOAC 2005). Neutral detergent fibre (NDF) and acid detergent fibre (ADF) were analysed according to Van Soest *et al.* (1991).

The tannin and oxalate levels in paddy straw and maize fodder silage were estimated as per the methods of Sadasivam and Manickam (1992) and Abeza *et al.* (1968), respectively.

In vitro fermentation characteristics: For estimating *in vitro* gas production (Menke and Steingass 1988) rumen liquor was collected from fistulated male buffalo calves maintained on 2 kg conventional concentrate mixture, 5 kg green and *ad lib.* wheat straw. About 375±5 mg of moisture-free sample was incubated in a 100 ml calibrated glass syringe with 30 ml of buffered rumen liquor and kept in a water bath maintained at 39°C for 24 h. After incubation, total gas production was calculated and subsequent blank corrections were made. These corrections were made by subtracting the amount of gas produced from the incubation of syringes consisting of buffered rumen fluid without substrate for correcting gas production from fermentation of endogenous substrates.

For estimation of IVDMD (Menke and Steingass 1988), the pellets obtained after centrifugation of incubated samples were fluxed with neutral detergent solution (40 ml; Sodium lauryl sulphate, disodium ethylene diamino tetra acetate, sodium borate decahydrate, disodium hydrogen phosphate, 2-ethoxy-ethanol) for an hour then filtered through G1 crucibles and residues were dried in hot air oven (80°C). The loss in weight was considered as *in vitro* true dry matter digestibility.

Statistical analysis: Statistical analysis was performed by using SAS package (Version 9.3). Mean and standard deviation were calculated and Turkey's test was used to identify the significant differences among all the combinations. The resulting values are indicated in the tables. Significant levels were defined at $P<0.01$.

RESULTS AND DISCUSSION

Proximate analysis: Chemical compositions of paddy straw and maize fodder silage are presented in Table 1. DM and CF were decreased whereas CP and EE were increased with a decrease in the proportion of paddy straw in all combinations of silage. Averaged over treatments, paddy straw and maize fodder ratios 75:25, 50:50, 25:75 and 0:100 decreased the DM by 20.04%, 26.01%, 53.21% and 187.0%, respectively over pure paddy straw. Urea treatment decreased the DM content by 67.14%, whereas molasses treatment significantly ($P<0.01$) increased DM by 2.73% over control. Averaged over ratios, the use of 2% urea and 1% urea and 1% molasses increased the CP content as compared to control. Averaged over treatments, mean ash content increased with the inclusion of maize fodder in paddy straw up to a 50:50 ratio but thereafter a decrease in ash content was observed. The use of 2% urea and 1% urea and 1% molasses decreased the EE content as compared to control. It was observed that the use of 2% urea and 1% urea and molasses decreased the CF content as compared to control. A significant interaction between ratio and treatment (R×T) was observed in proximate analysis.

It was observed that DM declined with a decrease in the proportion of paddy straw in all maize and rice straw-based silage. Similarly, Muhamad *et al.* (2008) also reported that the DM content of pure paddy straw, the mixture of 50% rice straw and 50% maize fodder and pure maize fodder silages decreased from 89.3% to 56.3%. Molasses treatment increased silage quality and DMI but did not improve digestibility and animal performance (Keady 1996). In present study, CP content increased with a decrease in the proportion of paddy straw in all combinations of silage. In previous study, the CP content of pure maize fodder silage, pure paddy straw silage and a mixture of 50% rice straw and 50% maize fodder silages was 12.6%, 11.2% and 14.3%, respectively (Muhamad *et al.* 2018). In the present study, the addition of 2% urea and a combination of 1% urea and % molasses increased the CP content by 12.48% and 5.82%, respectively over the control. The nutrient additives method is a conventional method of increasing the nitrogen level of ensiling materials by increasing the protein content and its digestibility. The ash content is an indicator of the total quantity of minerals found within plant tissue. Ash content decreased with an increase in the proportion of maize fodder in all combinations. Moreover, it was inferred that maize fodder silages exhibited decreased values of ash content when compared to pure rice straw silage

Table 1. Effect of mixing paddy straw with molasses and urea on proximate analysis of maize silage

Treatment	Paddy straw: Maize fodder					Mean	CD (*P*<0.05)
	100:0	75:25	50:50	25:75	0:100		
Dry matter (DM)							
C	65.58±0.67	54.87±0.54	51.17±0.65	42.70±0.40	22.50±0.50	47.36[b]	R=0.70
T1	62.37±0.40	51.23±0.45	49.27±0.17	39.60±0.87	19.43±0.17	44.38[c]	T=0.63
T2	64.63±0.51	54.84±0.53	52.36±0.51	43.70±0.81	25.40±0.64	48.18[a]	R × T=1.40
T3	63.64±0.40	52.83±0.56	50.87±0.05	41.50±0.18	21.70±0.46	46.12[b]	
Mean	64.15[a]	53.44[b]	50.91[c]	41.87[d]	22.35[e]		
Crude Protein (CP)							
C	5.17±0.15	6.03±0.11	6.43±0.20	7.73±0.27	9.87±0.27	7.05[d]	R=0.10
T1	5.47±0.12	7.63±0.28	7.63±0.12	8.27±0.22	10.67±0.63	7.93[a]	T=0.89
T2	5.33±0.17	6.36±0.20	7.53±0.27	7.13±1.55	9.63±0.40	7.19[c]	R× T=0.20
T3	5.43±0.68	7.00±0.17	6.40±0.58	8.40±0.25	9.73±0.12	7.39[b]	
Mean	5.35[e]	6.75[d]	6.99[c]	7.88[b]	9.97[a]		
Ash							
C	11.94±0.07	12.67±0.02	12.62±0.04	11.22±0.02	9.84±0.24	11.66[c]	R=0.38
T1	11.50±0.03	12.27±0.03	12.19±0.18	11.20±0.01	11.65±0.03	11.76[b]	T=0.36
T2	11.99±0.06	11.15±0.04	12.46±0.02	11.89±0.01	10.80±0.04	11.66[c]	R× T=0.79
T3	12.04±0.27	12.93±0.06	12.37±0.04	12.06±0.15	10.57±0.05	11.99[a]	
Mean	11.87[c]	12.35[b]	12.41[a]	11.60[d]	10.72[e]		
Ether Extract (EE)							
C	1.44±0.04	1.50±0.02	1.66±0.12	1.92±0.16	1.90±0.10	1.68[a]	R=0.19
T1	1.38±0.06	1.36±0.06	1.42±0.35	1.55±0.15	1.57±0.12	1.45[c]	T=0.17
T2	1.60±0.02	1.55±0.15	1.58±0.08	1.82±0.28	1.83±0.15	1.67[a]	R× T=0.38
T3	1.44±0.06	1.47±0.03	1.46±0.06	1.76±0.11	1.67±0.04	1.56[b]	
Mean	1.46[c]	1.47[c]	1.53[b]	1.76[a]	1.74[a]		
Crude fibre (CF)							
C	34.50±0.53	29.67±0.40	29.33±0.54	28.47±0.45	28.43±1.09	30.08[a]	R=0.37
T1	31.07±0.77	28.47±0.41	27.30±0.86	27.56±0.38	25.40±1.24	27.96[c]	T=0.33
T2	32.97±0.67	29.23±0.56	28.43±0.72	28.03±1.56	27.57±1.51	29.25[b]	R×T=0.75
T3	30.17±0.47	27.63±0.89	27.20±1.93	27.27±1.65	26.70±1.17	27.79[d]	
Mean	32.27[a]	28.75[b]	28.16[c]	27.83[d]	27.03[e]		

C, without additive; T1, 2% urea; T2, 1% molasses; T3, 2% urea and 1% molasses; R, ratio; T, treatment; CD, critical difference; [ab]Means with different superscripts differ significantly (*P*<0.05).

and a mixture of maize fodder and rice straw silage. An earlier study reported rice straw has higher mineral content (17.0%) than maize fodder (11.5%) silages (Muhamad *et al.* 2018). EE concentrations vary significantly among ensiled corn, paddy straw and the mixture of two crops in different combinations and varied from 1.38-1.90% in all combinations. EE content increased with a decrease in the proportion of paddy straw in all combinations of silage. Various additives used to enhance the ensiling process and nutritional characteristics had a significant (P<0.001) effect on EE content in all silage combinations. In present study, addition of 2% urea and 1% urea and 1% molasses decreased the crude fat content by 15.86% and 7.69%, respectively over control.

The fodder with a low CF percentage is considered of good quality because it enhances protein digestibility (Devendra 1997). In current study, the range of CF lies between 25.40-34.50%. In a previous study, crude fibre content of paddy straw silage was 30-40% (Sheikh *et al.* 2014). It was observed that in present study use of 2% urea and 1% urea and molasses decreased the CF content by 8.58% and 8.24%, respectively over control.

Fiber fraction: Fibre fractions of paddy straw and maize fodder silage are presented in Table 2. NDF, ADF and cellulose were decreased whereas hemicellulose was increased with a decrease in the proportion of paddy straw in all combinations of silage. Averaged over ratios, the use of 2% urea and 1% urea and 1% molasses decreased the ADF content as compared to control. Averaged over treatments, paddy straw and maize fodder ratios 75:25, 50:50, 25:75 and 0:100 decreased the NDF content by 3.77%, 4.13%, 5.28% and 10.72% respectively over pure paddy straw. Averaged over treatments, paddy straw and maize fodder ratios 75:25, 50:50, 25:75 and 0:100 decreased the cellulose content by 5.04%, 8.49%, 11.64% and 17.04% respectively over pure paddy straw silage. Averaged over treatments, paddy straw and maize fodder ratios 75:25, 50:50, 25:75 and 0:100 increased the hemicellulose content by 5.87%, 4.22% and 3.26%, respectively over pure paddy straw. The highest value was observed in maize fodder silage with the

Table 2. Effect of mixing paddy straw with molasses and urea on fibre fractions of maize silage

Treatment	Paddy straw: Maize fodder					Mean	CD (*P*<0.05)
	100:0	75:25	50:50	25:75	0:100		
Neutral detergent fibre (NDF)							
C	73.43±1.76	69.90±1.30	69.27±1.85	68.87±1.42	65.70±1.70	69.44[a]	R=0.34
T1	69.53±2.05	67.47±1.79	67.77±1.21	65.53±1.01	63.03±2.09	66.66[d]	T=0.34
T2	70.97±1.45	68.40±1.01	68.70±1.66	68.50±1.70	64.63±1.32	68.24[b]	R× T=0.67
T3	70.70±2.56	68.50±1.33	67.60±1.75	67.67±1.72	63.70±1.62	67.63[c]	
Mean	71.15[a]	68.56[b]	68.33[b]	67.64[c]	64.26[d]		
Acid detergent fibre (ADF)							
C	49.71±1.90	47.76±1.83	44.76±1.78	42.88±2.00	40.24±1.61	45.07[a]	R=0.73
T1	47.28±1.17	45.29±2.56	42.13±1.87	39.92±1.79	37.29±2.02	42.38[d]	T=0.65
T2	48.23±1.60	46.36±2.32	44.56±1.75	42.32±2.04	39.91±3.08	44.27[b]	R× T=1.45
T3	47.42±1.96	45.93±1.72	42.45±1.95	41.12±1.92	37.56±2.26	42.89[c]	
Mean	48.16[a]	46.34[b]	43.47[c]	41.56[d]	38.75[e]		
Cellulose							
C	47.13±0.25	45.00±0.21	R=0.34	42.53±0.50	40.67±0.41	44.13[a]	R= 0.30
T1	42.10±0.13	40.73±0.42	39.77±0.02	37.43±0.35	36.26±1.10	39.25[d]	T=0.36
T2	46.70±0.27	44.30±1.17	42.60±0.17	41.47±0.35	39.33±0.11	42.88[b]	R× T=0.60
T3	44.27±0.32	41.53±0.30	40.57±0.09	39.97±0.15	37.70±0.36	40.18[c]	
Mean	45.05[a]	42.89[b]	41.56[c]	40.35[d]	38.49[e]		
Hemicellulose							
C	23.72±0.95	24.14±1.04	24.51±0.34	25.49±0.87	25.99±0.12	24.77[a]	R= 0.62
T1	22.25±0.98	22.18±1.12	23.64±0.83	24.61±0.79	24.74±0.95	23.58[d]	T=0.55
T2	22.74±0.47	23.04±0.61	24.14±0.51	26.08±1.96	26.82±0.81	24.66[b]	R× T=1.24
T3	23.28±0.36	22.57±0.71	24.15±1.02	25.55±0.78	24.44±1.99	23.99[c]	
Mean	22.99[d]	22.98[c]	24.11[a]	25.43[b]	25.49[c]		

C, without additive; T1, 2% urea; T2, 1% molasses; T3, 2% urea and 1% molasses; R, ratio; T, treatment; CD, critical difference; [ab]Means with different superscripts differ significantly (*P*<0.05).

addition of 1% molasses treatment. A significant interaction between ratio and treatment (R×T) was observed in fibre fraction.

NDF represents the total fibre fraction that makes up the cell wall of the plant tissue. NDF is a good indicator of feed quality. Forages with high concentrations of NDF generally support less milk production because forages with high concentrations of fibre content have less available energy and are consumed in lesser amounts by livestock (Beauchemin 1991). NDF decreased with an increase in the proportion of maize fodder in all combinations. NDF content of pure paddy straw, pure maize fodder and the mixture of 50% rice straw and maize fodder silages varied from 80.8%, 81.4% and 80.9%, respectively (Muhamad *et al.* 2018). Similar types of findings were also observed in paddy straw silage by Van Soest (2006). Maize silage produced in warm climates tends to present greater concentrations (75.8-80.0%) of NDF and less starch in comparison with corn silage produced in temperature areas (Adesogan 2010). ADF is the percentage of highly indigestible plant material that contains cellulose, lignin and silica. It is a major indicator of digestibility and negatively affects feed quality (Han *et al.* 2003). Low ADF value means higher energy value and digestibility (Goyal *et al.* 2017). ADF content ranged from 37.29-54.38%. It decreased with an increase in the proportion of maize fodder in all combinations. Averaged over ratios, use of 2% urea and 1% urea+1% molasses decreased the ADF content by 6.35% and 5.12% respectively over control. In a previous study, ADF content was higher for urea treated (60.0%) rice straw than for untreated (55.6%) rice straw (Gunun *et al.* 2013). Cellulose is a major component of lignocellulosic biomass and its concentration ranged from 40-50% on a DM basis. Cellulose content ranged from 40.67-47.27%. An earlier study reported cellulose content of pure rice straw, a mixture of 50% rice straw and maize fodder and pure maize fodder silages varied from 40.2%, 22.1% and 28.5%, respectively (Muhamad *et al.* 2018). Averaged over ratios, addition of 2% urea, 1% molasses and a combination of 1% urea and 1% molasses decreased the cellulose content by 12.43%, 2.91% and 9.83%, respectively over control. The hemicellulose content was estimated from the difference between NDF and ADF content. Hemicellulose has dual functions- first, it acts as a link between lignin and cellulose fibres and second, it provides additional rigidity to the whole cellulose – hemicelluloses – lignin network. Hemicelluloses are composed of various components including a backbone of xylans and arabinose side chains. Arabinose side chains are typically more digestible than xylan backbone (Ward 2021). Hemicelluloses ranged from 22.18-26.82%. Hemicellulose content of pure paddy straw, pure maize fodder and mixture of 50% paddy straw and %

Table 3. Effect of mixing paddy straw with molasses and urea on *in vitro* fermentation characteristics of maize silage

Treatment	Paddy straw: Maize fodder					Mean	CD (*P*<0.05)
	100:0	75:25	50:50	25:75	0:100		
Net gas production (NGP; %)							
C	20.75±0.09	38.25±0.13	38.75±0.15	39.00±0.16	57.50±0.23	38.85[c]	R=0.30
T1	25.75±0.11	43.25±0.23	44.00±0.21	43.50±0.22	53.75±0.21	42.05[a]	T=0.36
T2	21.00±0.05	38.50±0.21	38.50±0.19	38.60±0.18	49.25±0.20	37.17[d]	R× T=0.60
T3	21.50±0.10	43.75±0.17	43.25±0.19	44.00±0.19	52.50±0.26	41.00[b]	
Mean	22.25[e]	40.94[d]	41.13[c]	41.27[b]	53.25[a]		
In vitro dry matter digestibility (IVDMD; %)							
C	41.82±1.15	44.10±0.17	45.43±0.54	47.25±0.60	52.37±0.12	46.19[d]	R=0.41
T1	47.77±0.52	52.00±0.25	52.00±0.25	54.48±0.61	65.80±0.52	54.41[a]	T=0.37
T2	42.23±0.35	44.57±0.72	44.07±0.15	48.63±0.50	53.60±0.61	46.62[c]	R× T=0.83
T3	47.45±0.25	49.67±0.75	52.85±0.56	52.83±0.23	60.00±0.19	52.56[b]	
Mean	44.82[e]	46.43[d]	48.58[c]	50.79[b]	57.94[a]		
pH							
C	6.90±0.11	5.01±0.05	5.20±0.10	3.70±0.10	3.46±0.04	4.85[d]	R=0.82
T1	7.62±0.54	6.97±0.05	6.86±0.06	6.86±0.15	6.96±0.05	7.06[a]	T=0.73
T2	6.62±0.12	5.02±0.13	5.46±0.03	4.39±0.16	3.46±0.05	4.99[c]	R× T=0.16
T3	7.65±0.04	6.73±0.10	6.53±0.12	6.76±0.11	3.93±0.05	6.32[b]	
Mean	7.19[a]	5.93[c]	6.01[b]	5.43[c]	4.45[d]		
Ammonia nitrogen (NH3-N; %)							
C	3.80±0.04	4.41±0.01	4.82±0.02	5.81±0.01	6.13±0.02	4.99[ba]	R=0.24
T1	3.80±0.05	4.51±0.03	4.60±0.01	5.60±0.01	5.63±0.01	4.83[c]	T=0.21
T2	3.90±0.01	4.61±0.02	4.70±0.02	5.81±0.02	6.08±0.05	5.02[a]	R× T=0.57
T3	3.71±0.01	4.60±0.01	4.80±0.01	5.71±0.01	6.04±0.01	4.97[b]	
Mean	3.80[e]	4.53[d]	4.73[c]	5.73[b]	5.97[a]		

C, without additive; T1, 2% urea; T2, 1% molasses; T3, 2% urea and 1% molasses; R, ratio; T, treatment; CD, critical difference; [ab]Means with different superscripts differ significantly (*P*<0.05).

maize fodder silages was 21.9%, 40.7% and 39.0%, respectively as reported by Muhamad *et al.* (2018). The highest value was observed in maize fodder silage with addition of 1% molasses treatment.

In vitro rumen fermentation characteristics: Data on *in vitro* fermentation characteristics are presented in Table 3. It was observed that the NGP, IVDMD and NH_3-N were increased and pH decreased with a decrease in the proportion of paddy straw in all combinations. A significant interaction between ratio and treatment (R×T) was observed for in vitro fermentation parameters.

Total gas production varies significantly among ensiled corn, paddy straw and a mixture of two crops in different combinations. Averaged over treatments, paddy straw and maize fodder ratios 75:25, 50:50, 25:75 and 0:100 increased the gas production by 84.00%, 84.85%, 85.48% and 139.32% respectively over pure paddy straw. It was observed that gas production increased with a decrease in the proportion of paddy straw in all combinations. Averaged over ratios, 2% urea and a combination of 1% urea and 1% molasses increased the gas production by 8.24% and 5.53%, respectively over control. In our study, gas production lies between 20.75-57.50%. Gas production is generally a good indicator of digestibility, fermentability of feed and rumen microbial protein production. The *in vitro* gas production was initially used to predict the rumen degradability and the metabolizable energy content of feeds (Menke and Steingass 1988). Many researchers have successfully used this technique to assess the impact of digestibility of feeds through this relationship (Muck *et al.* 2007, Negesse *et al.* 2009) because gas production rates can indicate the rate of digestion of feed in the rumen and thereby affect the rate of passage and dry matter intake of animals.

IVDMD varies significantly among ensiled corn, paddy straw and the mixture of two crops in different combinations. Averaged over treatments, paddy straw and maize fodder ratios 75:25, 50:50, 25:75 and 0:100 increased the digestibility by 6.27%, 8.48%, 13.32% and 29.37%, respectively over pure paddy straw. Averaged over ratios, the use of 2% urea and a combination of 1% urea and 1% molasses increased the digestibility by 17.79% and 13.79% respectively over control. In our study, IVDMD lies between 41.82-65.80%. IVDMD is directly related to the digestibility of animal feed. This is the most important parameter of forage quality. IVDMD content of maize fodder silage was found to be the highest (65.80%) among all the combinations. An earlier study reported IVDMD of rice straw mixed with alfalfa at a ratio of 50:50 was 56.90% (Tang *et al.* 2008). In present study, IVDMD was decreased with increase in paddy straw in maize based silage. Similarly, Kamra *et al.* (1983) observed a significant decrease in the digestibility of the maize silage

Table 4. Effect of mixing paddy straw with molasses and urea on tannin and oxalate content of maize silage

Treatment	Paddy straw: Maize fodder					Mean	CD (P<0.05)
	100:0	75:25	50:50	25:75	0:100		
Oxalate (%)							
C	2.03±0.13	1.85±0.13	1.83±0.12	1.73±0.04	1.59±0.16	1.81[a]	R=0.29
T1	1.93±0.21	1.71±0.12	1.68±0.07	1.66±0.14	1.45±0.12	1.69[c]	T=0.26
T2	1.95±0.19	1.79±0.16	1.81±0.13	1.46±0.44	1.53±0.13	1.71[b]	R×T=0.58
T3	1.87±0.12	1.70±0.13	1.68±0.06	1.71±0.15	1.47±0.12	1.68[c]	
Mean	1.95[a]	1.76[b]	1.75[b]	1.64[c]	1.51[d]		
Tannin (µg/g)							
C	726.0±0.21	811.5±0.32	834.9±0.22	939.8±0.32	1033.4±0.32	869.1[d]	R=30.1
T1	852.6±0.34	906.2±0.23	923.2±0.24	1023.2±0.23	1132.3±0.21	967.5[a]	T=25.0
T2	802.7±0.19	790.4±0.21	879.3±0.20	978.4±0.21	1100.2±0.23	910.2[c]	R× T=66.1
T3	774.5±0.23	845.3±0.21	902.3±0.19	1011.2±0.20	1145.2±0.32	935.7[b]	
Mean	788.9[e]	838.4[d]	884.9[c]	988.2[b]	1102.7[a]		

C, without additive; T1, 2% urea; T2, 1% molasses; T3, 2% urea and 1% molasses; R, ratio; T, treatment; CD, critical difference; [ab]Means with different superscripts differ significantly (P<0.05).

with the increased proportions of paddy straw. In a recent study, a significant decrease in IVDMD was noted with the inclusion of 35% paddy straw in maize fodder (Khanday *et al.* 2021). Further, they reported that upto 25% of incorporation paddy straw caused no adverse impact on digestibility of maize silage.

The *p*H concentrations of the silage vary significantly among ensiled maize, paddy straw and a mixture of two crops in different combinations. Averaged over ratios, the use of 2% urea and 1% urea and 1% molasses increased the *p*H value by 45.36 % and 30.31%, respectively over control. It is an important indicator of silage quality. Properly fermented silage has a much lower *p*H than the original forage. The *p*H value of the silages ranged from 3.5-5.5 and is classified to be pH for good silage (Menesses *et al.* 2007, Lyimo 2016). In our study, the pH ranged from 3.40-7.66 where lowest *p*H was observed in the case of pure maize fodder silage with all the treatments. With the decrease in the ratio of paddy straw in the silage, *p*H also showed a decreasing trend. It was observed that in all the combinations of silages, *p*H increased with addition of urea as an additive.

Averaged over treatments, paddy straw and maize fodder ratios 0:100, 25:75, 50:50 and 75:25 increased the NH_3-N content by 57.11%, 50.78%, 24.47% and 19.21%, respectively over pure paddy straw. Ammonical nitrogen concentration in silage works as an indicator of protein degradability. Low NH_3-N content in silage indicates inhibition of proteolysis during fermentation and consequently the improved efficiency of rumen microbial N synthesis (Nsereko and Rooke 1999). Ammonical nitrogen content varies significantly among ensiled corn, paddy straw and mixture of paddy straw and green maize fodder in different combinations. NH_3 concentration increased with an increase in maize fodder. NH_3-N in all combinations was between 3.0-6.0% of total nitrogen content. Earlier studies reported NH_3-N content of 3.44% of elephant grass silage was lower than Rhodes grass silage (Lyimo *et al.* 2016). A low concentration of NH3-N in maize silages treated with various bacterial and chemical additives was reported by Queiroz *et al.* (2013).

Oxalate and tannin content: The oxalate content was decreased with an increase in the proportions of the maize fodder in all combinations. Averaged over treatments, paddy straw and maize fodder ratios 75:25, 50:50, 25:75 and 0:100 decreased the oxalate content by 10.97%, 11.43%, 18.90% and 29.14%, respectively over pure paddy straw. A significant interaction between ratio and treatment (R×T) was observed for oxalate content (Table 4). Averaged over ratios, the use of 2% urea and 1% urea and 1% molasses decreased the oxalate content by 7.10% and 7.74% respectively over control. In a similar study, a decrease of 6.33% and 10.1% was observed in oxalate content in the silages made of sugarcane tops and paddy straw combination (Kaur *et al.* 2022). Oxalate is the common constituent of many forage crops and may accumulate in the range of 1-15% (w/w) of the dry matter (Nakata 2003). In our study, oxalate content lies between 1.45-2.03%. Paddy straw differs from other straws in having a high content (1-2% DM) of oxalate (Malik 2015).

In present study, tannin content was increased with an increase in the proportions of the maize fodder in all combinations. Averaged over treatments, paddy straw and maize fodder ratios 75:25, 50:50, 25:75 and 0:100 increased the tannin content by 6.37%, 12.26%, 25.36% and 39.77% respectively over pure paddy straw. The addition of additives also increased (P<0.001) the tannin content in all silage combinations. A significant interaction between ratio and treatment (R×T) was observed for tannin content (Table 4). Tannin protects the proteins from microbial hydrolysis, and deamination in the rumen and increase the proportion of dietary amino acids available for post-ruminal absorption (Jayanegara *et al*. 2019). In present study, various additives used to enhance the ensiling process and nutritional characteristics had a significant (P<0.001) effect on the tannin content in all silage combinations. Tannin are broadly distributed in plants such as sorghum, millet, barley, peas, legumes and a wide variety of forage crops (Chung *et al.* 1998).

In paddy straw and maize fodder silage, DM, *p*H, CF, ADF, NDF, cellulose and oxalate content were decreased whereas CP, EE, hemicellulose, NGP, IVDMD, NH_3-N and tannin content was increased with decrease in the proportion of paddy straw in all combinations. Addition of urea increased the *p*H, CP and IVDMD content of paddy straw and maize fodder while cell wall components, ash and EE were decreased. Tannin content was increased with the addition of additives as compared to untreated samples. Finally, it can be concluded that silage prepared from 25:75 ratios of paddy straw and maize fodder produces good aroma and fermentation characteristics which can be utilised for silage making.

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