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Nutritional Characteristics of Silage and Hay of Pearl Millet at Four Phenological Stages

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Abstract: In dry land cropping of semiarid regions is important to harvest forage as early as possible in order to avoid frost damage incidence. The possibility of advancing, depend on the forage quality when harvested at early growth stages and the method used to preserve it. The objective of this study was to evaluate the productivity and nutritive value of pearl millet harvested at four different stages of maturity for Silage (S) and Hay (H) methods of conservation. A randomized complete block design with five replications in a split plot outline was used for the methods of forage conservation. The open pollinated variety ICMV-221 was used. The ages of maturity at harvest were: Boot stage (B), female Flowering (F), Milk stage (M) and Dough stage (D). The production of total Dry Matter (DM ha^{-1}) increased with maturity ($p<0.002$). In contrast, DM from re-growth was higher ($p<0.0001$) when forage was cut at B stage. This led to the total DM ha^{-1} resulted similar throughout four stages of maturity. During haymaking, there was a loss of grain by fauna which affected most of the variables studied. Protein Content (PC) varied ($p<0.01$) from 6.93-11.35% with lowest values during M and D hay stages. The highest NDF, ADF and lignin content were observed during M and D hay stages. Apparent digestibility of dry matter was higher in silage than hay. Age of cutting only affected the digestibility of hay. It was concluded that the stage of maturity of pearl millet did not affect the quality of silage showing silage generally better nutritional value than hay. The loss of grain of haymaking in this study indicates that in the presence of fauna (lagomorphs, rodents and birds), pearl millet is adequate for haying only at booting and flowering stages. Re-growths were stronger in booting, compensating lower production of dry matter from the main stem during early cuttings.

Key words: Pearl millet, forage, maturity stages, nutritive value, lagomorphs, birds

INTRODUCTION

In arid and semiarid regions, shortage of forage during drought originates recurrent states of malnutrition in rangeland animals which reflects in weight loss, poor reproductive performance and lower overall production. The forage production with corn or sorghum crops for cattle supplementation during dry season is an essential strategy to improve productivity and sustainability. However, the erratic rainfall distribution rarely covers the water requirements of these crops. This situation along with the risks of presence of early frost causes frequent damages in both crops and urged the generation of strategies to produce forage in the short time left by these events in low and uncertain conditions of water availability.

Recently, pearl millet has been evaluated, observing that it produces less dry matter per hectare than corn or sorghum in good moisture or watering conditions but produces more dry matter and energy than corn or sorghum in poor rainfall conditions. The previous situation is due to the genetic origin of pearl millet, it has developed strategies to avoid drought due to low water requirements and early bite giving it competitive advantages over other crops under stress conditions of semi-arid regions (Payne, 2000). In addition, pearl millet has shown to be of good nutritive value, high digestibility and protein content, frequently matching and even surpassing corn and sorghum forage.

Despite the advantages that pearl millet displays, it is important to determine the possibilities to harvest in early stage whether it is for silage making or haying in order to reduce the period in which the crop is still exposed to environmental conditions. One of the mayor factors that affects the nutritional value and total forage production is the stage of maturity at which the crop is harvested and silage making (Cummunis, 1970, 1981; Center *et al*., 1970; Filya, 2004). To the extent that increasing maturity of

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plants generally occurs alterations in the bromatologic composition of forage such as higher dry matter production and lower crude protein content little information is available on pearl millet regarding the variations along with its maturity. It is therefore, necessary to determine the changes that occur during the maturation process of the plant to determine which phenological stages are more suitable for hay harvesting, considering both the nutritional value and production of dry matter per hectare.

Another one of the factors affecting forage quality is the method of conservation. Forages are generally conserved as silage or as hay while tall crops such as corn, sorghum and pearl millet are generally ensiled it is possible that they can be conserved as haymaking especially pearl millet because it is a slender-stemmed plant. The present study was designed:

- To assess the productivity and nutritive value of pearl millet harvested in booting, flowering, grain milky and grain dough stages
- To evaluate the nutritional quality of these forages conserved as silage and hay

MATERIALS AND METHODS

Experimental conditions: The study was conducted at San Luis Experiment Station INIFAP, located in the municipality of Soledad de Graciano Sanchez, S.L.P. (22°14'03"N, 100°53'11"W and 1835 elevation). Climate is considered desert dry and cold BsKw (wi) according of Koppen modified by Garcia. Annual mean temperature is 16.8°C with a minimum of 10°C and a maximum of 26.3°C; mean rainfall is 332.2 mm. The dual purpose pearl millet variety ICMV-221, introduced from ICRISAT (International Crops Research Institute for Semi Arid Tropics) was used, applying the technological package suggested by INIFAP.

An experimental area of 500 m^2 of pearl millet crop was established on June 19, 2009, after application of irrigation (precipitation during the growing cycle was null having to apply 3 more watering at intervals of 21 days). The area was divided into five blocks of 16 rows of 5 linear meters each. Each block was divided into four plots of 4 rows ×5 m linear which were randomly assigned to four growth stages to harvest: booting (E), female Flowering (F), Milky (M) and grain Dough Stage (GD). In each plot, 2 rows were assigned to conserve as silage and the other 2 rows to conserve as hay.

For silage making, forage was harvested by hand, weighed, chopped and emptied out in plastic bags of 20 kg capacity of green forage. For haymaking, forage was harvested and air dried for 5 days. Subsequently it was left under shade to finish the drying process. When forage moisture content was such that allowed its ground, proceeded to chop the whole plant. From each sample of silage or hay making, representative sub-samples were taken for laboratory analysis.

Forage production: After samples from silage were ground, sub-samples were taken to determine dry matter content. Fresh forage weights and dry matter content were used to estimate the yield of dry matter per hectare. Moreover, dry matter production of re-growth of established plants was evaluated. Dry weight at the time re-growth reached the flowering stage was obtained. Finally, production of the first harvest and re-growth were added to calculate total dry forage production.

Laboratory analysis: Forage's samples were analyzed for Dry Matter (DM), Crude Protein (CP), Ash (A), Ether Extract (EE), Neutral Detergent Fiber (NDF) Acid Detergent Fiber (ADF), Acid Detergent Lignin (ADL), Nitrogen Linked to acid detergent fiber (NL), Protein Available (PA), Calcium (Ca) and Phosphorus (P) determinations. With this data, dry matter Digestibility was estimated (DMS) using the formula suggested by Goering and van Soest (1970).

Statistical analysis: Results of forage yield and quality were analyzed by ANOVA using a model that included fixed effects for plant growth stages at the time of harvest, conservation methods and interaction. When differences were found at 0.05 level, Student t-test was applied to compare means at the same level. Analysis was carried out with JMP Star Statistics package.

RESULTS AND DISCUSSION

Dry matter content of the forage harvested in dough stage was significantly ($p<0.05$) higher than all other growth stages while the other three developmental stages showed similar DM content (Table 1). In contrast Organic Matter content (OM) was similar ($p>0.05$) in all stages of harvest in both silage and hay as well. The percentage of CP was kept between 6.93 and 10.98%, detecting differences due to maturity, method of conservation and interaction ($p<0.01$). The hay harvested in M and D showed significantly lower percentages of CP compared with silage and hay in B and F stages.

Ash Content (C) ranged from 12.45-13.95% but there were no significant differences ($p>0.05$) attributable to treatment or interaction while the content of phosphorus

Table 1: Chemical composition of forage in pearl millet ICMV-221 harvested in four growth developmental stages and conserved as silage or hay

	Silage				Hay				Significance		
Variables	B	F	M	D	B	F	M	D	DS	MC	Ds×MC
DM	21.67	23.22	23.05	26.87	-	-	-	-	0.050	-	-
OM	87.09	86.96	87.18	86.88	86.78	87.56	86.89	86.05	0.231	0.456	0.348
CP	9.63	10.26	10.98	9.18	11.35	9.68	6.93	7.77	0.010	0.010	0.001
EE	5.51	5.24	6.06	6.68	5.08	4.84	4.56	5.93	0.001	0.001	0.001
NL	0.58	0.25	0.27	0.32	0.83	0.37	0.41	0.41	0.050	0.050	0.050
AP	6.00	8.68	9.31	7.20	6.16	7.37	4.37	5.22	0.001	0.001	0.001
A	12.92	13.04	12.82	13.12	13.22	12.45	13.11	13.95	0.231	0.456	0.348
P	0.22	0.18	0.17	0.21	0.24	0.21	0.12	0.14	0.001	0.001	0.200
Ca	0.54	0.48	0.54	0.54	0.71	0.68	0.78	0.77	0.001	0.001	0.200
NDF	56.47	61.87	57.80	55.64	62.62	65.28	67.98	66.85	0.001	0.001	0.001
ADF	36.82	37.12	35.05	40.51	40.46	39.75	44.23	41.55	0.001	0.050	0.001
ADL	3.71	4.70	4.30	4.45	4.95	5.56	5.70	5.90	0.050	0.001	0.050

DM = Dry Matter; OM = Organic Matter; CP = Crude Protein; EE = Ether Extract; NL = Nitrogen Linked to acid detergent fiber; AP = Available Protein; A = Ashes; P = Phosphorus; Ca = Calcium; NDF = Neutral Detergent Fiber; ADF = Acid Detergent Fiber; ADL = Acid Detergent Lignin; B = Boot stage; F = Flowering; M = Milk grain stage; D = Dough grain stage; DS = Developmental Stage effect; MC = Method of Conservation Effect; Ds×MC = interaction between Developmental stage and Method of Conservation effects

was lower ($p<0.001$) in the hay in M and D in comparison with other forages. Calcium was higher ($p<0.001$) in the hay compared with silages in all stages of maturity. The NDF percentage was higher in the hay ($p<0.001$) and tended to decrease in silage in M and D stages. Similarly, ADF percentages were higher ($p<0.001$) in the hay but only in the case of B and M, detecting an interaction effect ($p<0.001$) between age and method of conservation. The highest concentration of ADF was observed in the hay in M stage ($p<0.05$).

In the pH of silages, differences ($p<0.005$) due to maturity were detected. The silage harvested in the B, M and F stages showed lower pH ($p<0.05$) than in D (4.07, 4.16, 4.36 and 5.78 in B, F, M and D, respectively).

Dry matter production per hectare was estimated in general from cuts that were made at the same time for both methods of preservation. Crop growth development at the time of harvest affected the production of forage. Cuts were made at 53, 66, 85 and 102 days after planting in the stages of booting, flowering, grain milky and dough stage, respectively. Dry matter production was increased ($p<0.002$) with maturity to the point of flowering, then remained relatively constant. Thus the maximum DM production was obtained at flowering and milky stages (Table 2).

The grade of development of the plant at harvest time affected significantly ($p<0.0001$) the capacity for re-growth. The second cut was performed when the plants reached the flowering stage which occurred at 49 and 54 days in boot and flowering stages from the first cut while in the milk stage, re-growth was very poor and did not reach flowering therefore, the cut was made in a vegetative stage at 39 day from the first cut. The development of re-growth was faster after cutting in boot and flowering stages. By the contrary at dough grain stage there was virtually no re-growth. Thereby, re-growth of harvest in boot stage produced higher ($p<0.0002$) amount of dry matter than flowering or milky stage (2919.34, 1563.42 and 645.07 kg ha^{-1}, respectively Table 2) while the cut in dough grain stage had a marginal production and was not quantified. Thus, total dry matter production was similar ($p>0.05$) in the four developmental stages of pearl millet plant.

Table 2: Production of dry matter forage for the first cut and re-growth (second cut) in pearl millet ICMV-221 harvested at boot stage, flowering, grain milky and dough stage (kg ha^{-1})

Developmental stage*	1st cut	2nd cut	Total
Boot	3670.78^{b}	2919.34^{a}	6590.12^{a}
Flowering	5210.87^{a}	1563.42^{b}	6774.29^{a}
Milk grain	5196.16^{a}	645.07^{bc}	5841.23^{a}
Dough grain	5047.09^{a}	0.00^{c}	5047.09^{a}

$^{a-c}$Data with different letter in the same row are different (Tukey; 0.05)

Estimated digestibility of DM (DMD) varied with maturity ($p<0.001$), preservation method ($p<0.001$) and interaction ($p<0.02$). Since it was variable, it was estimated from components of nutritional value in which concentrations of NDF and ADF played an important role however, variation followed similar trends. The highest digestibility (Table 3) was observed in silage, varied from 61.0-68.3% while in hay ranged from 57.5-62.3%. Similar trend were observed in silage and hay between the stages of B and M but in D showed a divergent trend (66.8 vs. 57.5% in silage and hay).

Dry matter digestibility and digestible dry matter production (DDM ha^{-1}) followed similar trends (Table 3). The highest production of DMD were obtained in silage ($p<0.002$) but maturity stage had no effect ($p>0.05$). Production of CP ha^{-1} was affected by maturity, method of conservation and interaction ($p<0.05$). Productions were similar in both methods of conservation in the stages of B and F while higher ($p<0.05$) in silage in the stages of M and D.

The study was conducted to verify whether the pearl millet forage could be harvested early, even before

Table 3: Production of forage in pearl millet ICMV-221 harvested at different growth stages. Cuts were made at 53, 66, 85 and 102 days in the Boot stage (B), Flowering (F), Milk stage (M) and Dough stage (D), respectively

	Silage				Hay				Significance		
Variables	B	F	M	D	B	F	M	D	DS	MC	Ds×MC
DMD	68.3	61.9	64.0	66.8	62.3	58.3	59.1	57.5	0.001	0.001	0.050
DM ha^{-1}	2.29	3.03	3.07	2.90	2.29	3.03	3.07	2.90	0.002	-	-
DMD ha^{-1}	0.25	0.32	0.33	0.34	0.23	0.30	0.31	0.29	0.069	0.002	0.891
CP ha^{-1}	0.36	0.53	0.57	0.46	0.42	0.51	0.36	0.39	0.022	0.044	0.018

DS = Developmental Stage; MC = Method of Conservation; Ds×MC = Interaction between Developmental stage and Method of Conservation

flowering without affecting quality or quantity of forage harvested. Results indicate that forage harvested at boot stage showed a similar nutritional value to forage harvested at later stages of development or maturity, although dry matter yield was lower. However, higher vigor and re-growth production helped compensate this lower production from the first cut.

In general, there was significant interaction between age at the time of cutting and method of conservation. Silages were better than the hays in most of the variables studied but the effect of maturity affected differently each of the variables of production and quality. There were two factors associated with the interaction between maturity stage and method of conservation that affected some of the variables studied. On one hand, pearl millet showed a large number of tillers (Maiti and Bidinger, 1981) whose share in total harvested forage increases with advancing maturity of the main stem; this led to improved quality silages with maturity especially in terms of digestibility and protein content. On the other hand, the hay harvested at maturity stages lost grain due to fauna during the drying process masking their quality as forage.

With plant maturity, forage begin to reduce the leaf: stem ratio (Albrecth *et al*., 1987) while starting the formation and filling of grain. During this process nutrients in the leaves are translocated to the grain (Center *et al*., 1970) which accelerates the process of lignification that occurs in the cell walls of structural organs (Jung and Vogel, 1992), gradually reducing digestibility of the leaves and stems. It is well documented that digestibility of forages decreases with increasing concentration of lignin (Van Soest, 1983). It has been generally seen a compensation of elevated digestibility in the grain (Cummunis, 1970) composed mostly of highly water-soluble starch (McAllan and Phipps, 1977). Since the share of grain in the total plant weight increases proportionally with advancing maturity (Cummunis, 1970) in mature forage digestibility tends to increase although, in a moderate manner due to this elevated digestibility of the grain is offset by the low digestibility of the leaves and stems (Filya, 2004). In these stages of maturity, the proportion of dry matter provided by grain can be as high as 40% of the total plant (Perry and Compton, 1977) in which its loss has serious repercussions on total nutritional value. This is consistent with what was observed in the present study where the hay harvested at grain maturity lost grain, along with the consequent reduction of nutritive value.

CP percentage remained at high levels in all forages, except in hays at milky and dough stage in which grain loss experienced by fauna caused a significant CP reduction. It has been generally observed that forage tends to decrease in CP content with advancing maturity however, in the present study this did not happen, probably due to forage harvested in grain dough stage, the tillers cushioned this fall therefore, they maintained a similar level to the other forages. In general, forages have a high proportion of leaves in the vegetative growth stage and because the higher content of CP is found in leaves, the CP in these forages is usually high.

Dry matter production per hectare increased with maturity due to on one hand to the stage of development of the crop which in earlier stages of grain continues accumulating nutrients (Perry and Compton, 1977) and on the other hand, the tillers are growing both in quantity and size while the crop matures (Maiti and Bidinger, 1981). With the harvest in boot stage, even though forage production was lower than that obtained in the more advanced stages of maturity, the period required for harvest was about half that required for the stages of dough grain (13, 32 and 49 days less with regard to the stage of flowering, milky and dough stage, respectively). Even, the cutting of re-growth corresponding for the cut in the boot stage was performed on the same date as the first cut in dough stage. This advance could mean a reduced risk of crop loss due to early frosts especially when rainfall conditions force late plantings.

The lower production obtained in the first cut of the boot stage was compensated by increased production of the second cut (re-growth) which together gave rise to similar yields ($p>0.05$) in all stages of maturity (Table 2). The weak capacity of re-growth after cut in the milk and dough stages could be due to the own plant physiology which when it is cut in a stage of advanced maturity losses that capacity, mainly because during the first cut, tillers are also being cut which in that moment are found in an advanced vegetative stage (before booting) and due to climatic conditions especially low temperatures which could inhibit the development of whole plant.

The pH values observed in pearl millet silages are greater to those found in corn silage or sorghum-sudan silages (Akdeniz *et al*., 2005). The higher pH found in the stage of D in this study could be due to higher dry matter content. It could also be associated with lower content of CP since a higher content of CP propitiates fermentation and reduction of pH and consequently, the conservation of forage.

CONCLUSION

Results indicate that the forage harvested at boot stage show a similar nutritional value to those of forages harvested at later maturity stages although, dry matter yield is lower. However, the greatest vigor of re-growth allowed from a second cut, compensate that lower production. The grain loss experienced by the hay harvested at the milk and dough stages originated higher quality values of forage for hay or silage harvested early.

The possibility of obtaining good quality forage over a period of 53 day (boot stage) assumes a reduced risk of crop loss due to frost in plantings made at a late time when rain presence is delayed. However, when rain comes in a timely manner, it is possible to obtain a second cut, equaling production of dry matter obtained with the cut in a grain dough or milky stage.

The harvest of forage of pearl millet crop in early stages, allows its conservation either in the form of silage or hay which permits farmers of scarce resources to have forage for the dry season economically.

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