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Effect of Maturity on Production Efficiency, Nutritive Value and *in situ* Nutrients Digestibility of Three Cereal Fodders

[1]Sohail Hassan Khan, [2]Abdul Ghafar Khan, [1]Mohammad Sarwar and [2]Atiya Azim
[1]Institute of Animal Nutrition and Feed Technology, University of Agriculture, Faisalabad, Pakistan
[2]Department of Animal Nutrition, National Agriculture Research Center, Islamabad, Pakistan

Abstract: This study was conducted to compare productive potential and nutritional worth of maize (*Zea mays*), sorghum (*Sorghum bicolor*) and millet (*Pennisetum americanum*) fodders. These fodders were grown in experimental plots (1.8×6 m of each) according to Completely Randomized Design. Each fodder was manually harvested at three physiological stages i.e., pre heading (CS1), heading (CS2) and milk stage (CS3). The results showed that green fodder, Dry Matter (DM), Crude Protein (CP) and Total Digestible Nutrient (TDN) yields (ton ha^{-1}) increased with the advancement of age of all fodders. The maximum yield of three fodders was noticed at milk growth stage. Higher green fodder and DM yield was observed in millet than those of maize and sorghum fodders. Whereas, higher CP yield was noticed in maize than those in sorghum and millet fodders. However, TDN yield was similar in both maize and millet fodders. The DM, Neutral Detergent Fibre (NDF), Acid Detergent Fibre (ADF), Acid Detergent Lignin (ADL) and Water Soluble Carbohydrate (WSC) contents increased ($p<0.05$) in all three fodders with advancing age. However, CP, TDN and Metabolizable Energy (ME) contents decreased ($p<0.05$) in all fodders with the advancement of their growth. *In situ* DM, Organic Matter (OM) and NDF digestibilities of three fodders decreased ($p<0.05$) with the advancement of age both at 24 and 48 h of ruminal incubation. The DM, OM and NDF digestibilities of maize, sorghum and millet fodders decreased with advancing age by 11.10, 18.48 and 14.08%; 10.24, 11.25 and 12.18% and 12.59, 18.36 and 23.69%, respectively at 48 h of ruminal incubation. Based upon biomass and nutrient yields, the milk growth stage was the best physiological stage irrespective of the type of fodders.

Key words: Neutral detergent fibre, acid detergent fibre, acid detergent lignin, water soluble carbohydrates, total digestible nutrients, digestibility

INTRODUCTION

Production of good quality fodder is of a great importance for the economical ruminant production. Both quantity and quality of fodder are influenced due to soil variation (Yar and Waheed, 1991), plant species (Kaiser and Piltz, 2002), climatic conditions (Siefers *et al*., 1997), water supply (Rashid and Salim, 1989), stage of growth (Kim *et al*., 2001), frequency of cutting (Bilal, 1998) and agronomic practices (Rehman and Khan, 2003).

Stage of growth is one of the most important factors influencing nutritional quality of fodder (Fariani *et al*., 1994). Sullivan (1973) reported that the nutritive value of a fodder depended upon the

Corresponding Author: Sohail Hassan Khan, Poultry Research Institute, Murree Road, Shamsabad, Rawalpindi, Pakistan Tel: 92-051-9290172 Fax: 92-051-9290171

morphological and physiological changes. As the fodder matures, the cytoplasmic portion of the cell reduces and the quantity of protein, lipids, soluble carbohydrates and soluble minerals decrease. The protein and lipid contents of forage are negatively correlated to the maturity of fodder (Cleale and Bull, 1986). However, Dry Matter (DM) content increases with advancing the age of fodder (Azim *et al*., 1989). Similarly, the cell wall contents increase and cell wall become lignified with maturity of fodder (Kim *et al*., 2001). However, the quality of fodder is very high at an early stage of growth, but yield of DM per unit area is very low (Fariani *et al*., 1994). Therefore, in order to get more nutrients per unit area, the optimum time, keeping in view its nutritive value and DM yield, of harvest must be considered. Firdous and Gilani (1999) suggested that maize fodder should be cut preferably between 8th to 9th week after sowing to obtain maximum nutritious and digestible feed for livestock. Firdous and Gilani (2001) suggested that optimum harvesting for sorghum was at flowering stage. Similarly, Grewal *et al*. (2003) suggested that millet fodder might be harvested at pre-boot stage of maturity. Utley *et al*. (1995) compared the Crude Protein (CP) yield of spring crop and late summer crop of pearl millet with maize fodder. Crude protein yield for maize fodder was 30% greater than that of first crop millet and twice the amount produced by the second crop millet.

Variation in the contents of structural carbohydrate occurred with seasonal changes as well as growth stage (Singh, 1976). Digestibility of cell contents and cell wall contents decreased with maturity of maize and sorghum fodder (Havilah *et al*., 1995). In contrast to the above findings, DeBoever *et al*. (1993) reported that maturity stages (from milk dough to hard dough stages) had no clear effect on Organic Matter (OM) digestibility when 14 maize fodder samples were investigated.

Little information is available on the yield/ha and nutrient availability of maize (*Zea mays*), sorghum (*Sorghum bicolor*) and millet (*Pennisetum americanum*) in Pakistani environment. An attempt is, therefore, made to determine comparative production efficiency (yield ha^{-1}), nutritive value of local maize, sorghum and millet fodders at their different physiological stages.

MATERIALS AND METHODS

Fodders

Maize, sorghum and millet fodders were grown in the experimental field of Animal Nutrition Institute, National Agricultural Research Center (NARC) Islamabad, Pakistan in the year, 2004. Soil type at the site was well drained calcareous silt loam. Akbar, Hegari and NARC-5 varieties of maize, sorghum and millet, respectively, were grown for this study. The experiment was conducted according to Completely Randomized Design. Each fodder plot size was 1.8×6 m. The meteorological data were recorded by Agro-meteorological Department at NARC, Islamabad, Pakistan during the experimental period (Table 1).

Seed Germination Test

To determine the percentage of viable seed, 100 seeds of each experimental fodder were placed on moist filter paper in petri dishes and kept at room temperature following the standard techniques

Table 1: Meteorological data during Kharif season (2004)

Month	Rainfall (mm)	Relative humidity (%)	Temperature (°C)	
			Max	Min
April	10.5	42.5	32.6	15.1
May	3.1	33.0	39.1	19.7
June	130.4	46.8	38.4	23.2
July	64.8	52.1	37.9	23.7

Altitude 518 m; Latitude 33° 42'; Longitude 73° 08'. *: Source: Agro Meteorological Department, National Agricultural Research Center, Islamabad, Pakistan (Annual Report, 1998/1999) as described by Myers (1952). The seed germination rate of each experimental fodder was found to be in the range of 95-97%. The results were very close to the recommendation of fodder section at NARC, Islamabad. Before applying the seeds to field, foreign materials (weed, other seed, stone and soil) were removed from the seed of each fodder.

Cultivation of Fodders

Seed of maize, sorghum and millet was sown at rates of 100, 75 and 15 kg ha^{-1}, respectively (Ahmad *et al*., 2003) using hand drill. The rows were 30 cm apart (Hussain *et al*., 1995). The field was fertilized uniformly at the rate of 60 kg each of N and P ha^{-1} in such a way that full dose of phosphorus (diammonium phosphate) and half of nitrogen (urea) was applied at the time of sowing (Ahmad *et al*., 2003). The remaining half dose of nitrogen was applied after one month of sowing. During the experimental period, the field was irrigated thrice from dam water with an interval of 15-21 days. One hoeing was done before the first irrigation.

Harvesting of Fodder

The fodders were manually harvested at three stages of maturity. Maize, sorghum and millet fodders were harvested at pre-heading (CS_1), heading (CS_2) and milk stage (CS_3). Green fodder yield ha^{-1} was recorded at all stages of maturity. The DM, CP and Total Digestible Nutrient (TDN) yield ha^{-1} were calculated on the basis of chemical analysis.

The samples of each fodder cut at three vegetative stages of maturity were chopped in a locally manufactured chopper. Samples were dried at 55°C and ground to particle size of 2 mm through a Wiley mill. These samples were analyzed for DM, CP using method described by AOAC (1990), Neutral Detergent Fibre (NDF), Acid Detergent Fibre (ADF), Acid Detergent Lignin (ADL) by the methods of Goering and Van Soest (1970) and Water Soluble Carbohydrates (WSC) by the procedure of Dubois *et al*. (1956) and modified by Johnson *et al*. (1966). Total digestible nutrient and Metabolizable Energy (ME) contents of each fodder samples cut at three vegetative stages were calculated by the equations of Wardeh (1981) and Moe and Tyrrell (1976), respectively.

***In situ* Digestibility**

Four grams of dried samples in duplicate were weighed into dacron polyester bags having average pore size of 50 μm with dimension of 7"×4" (Orskov, 1980). These bags were closed and tied with nylon fishing line before placing in the dorsal sac of the rumen of two sheep fitted with permanent ruminal canola (40 mm diameter). The sheep were fed the same fodder as were being incubated in their rumens. This was done to avoid the effects of diet on the ruminal fermentation of the feedstuffs (Clark and David, 1990). All bags, including empty bags to act as blank, were simultaneously incubated in the rumen for 24 and 48 h after removal from the rumen, bags were washed in running tap water until the rinse was clear. The bags were then dried in a hot air oven at 60°C for 48 h and then weighed back and the residues were stored for subsequent analyses. The *in situ* digestibility for DM, OM and NDF at 24 and 48 h of ruminal incubation was calculated according to the procedure described by Sarwar *et al*. (1995).

Statistical Analysis

Data of chemical composition and digestibility of fodders at three vegetative stages were statistically analyzed by using Completely Randomized Design. Duncan's Multiple Range tests were used to compare the treatment means (Steel and Torrie, 1980).

RESULTS AND DISCUSSION

Green Fodder Yield

The green fodder yields of millet (19.57 ton ha^{-1}) and sorghum (19.77 ton ha^{-1}) were higher ($p<0.05$) than that of maize (17.89 ton ha^{-1}) harvested at pre heading stage (Table 2). However, no difference ($p>0.05$) in yield was noticed between millet and sorghum fodders. The green fodder yield of millet (36.49 ton ha^{-1}) was higher ($p<0.05$) than those of sorghum (32.45 ton ha^{-1}) and maize (31.37 ton ha^{-1}) harvested at heading stage. Similarly, the green fodder yield of millet (48.39 ton ha^{-1}) was higher ($p<0.05$) than those of sorghum (46.38 ton ha^{-1}) and maize (46.06 ton ha^{-1}) harvested at milk stage. However, no difference ($p>0.05$) in yield was observed between sorghum and maize fodders.

The results of the present study were consistent with those of Paroda (1976), Bhatti (1996) and Hinjra (1996) who reported a higher green fodder yield of millet than those of sorghum and maize fodders. They explained that higher yield of millet was due to its high leaf-to-stem ratio. Yar and Waheed (1991) reported that the range of green fodder yield of six millet fodder varieties harvested at full mature stage ranged from 36.73-50.47 ton ha^{-1}. These yield values are comparable to the green fodder yield of millet fodder (48.39 ton ha^{-1}) of the present study.

Dry Matter Yield

The DM yield of millet (8.67 and 16.84 ton ha^{-1}) was higher ($p<0.05$) than those of maize (7.33 and 15.38 ton ha^{-1}) and sorghum (7.30 and 15.80 ton ha^{-1}) fodders harvested at heading and milk stages, respectively (Table 3). However, the DM yield of millet (3.06 ton ha^{-1}) was lower ($p<0.05$) than those of sorghum (3.58 ton ha^{-1}) and maize (3.47 ton ha^{-1}) fodders harvested at pre heading stage. The results of this study were concordant to annual report (1998-99), which stated that the DM yield of millet fodder was higher than that of maize fodder. Weiss and Wyatt (2000) reported 15.90 ton ha^{-1} DM yield of maize fodder at mature stage, which was comparable to the present study (15.38 ton ha^{-1}).

Crude Protein Yield

The CP yield was higher ($p<0.05$) in maize (0.57, 0.86 and 1.53 ton ha^{-1}) than those of sorghum (0.36, 0.69 and 1.16 ton ha^{-1}) and millet (0.29, 0.70 and 1.17 ton ha^{-1}) fodders when harvested at pre heading, heading and milk stages, respectively (Table 4). Similar findings were reported by Utley *et al.* (1995) who noticed that CP yield of maize fodder was 30% higher than that of millet fodder at mature

Table 2: The comparative green fodder yield (ton ha^{-1}) of maize, sorghum and millet fodders at three vegetative stages of growth

Fodders	Cutting stages	Yield
	CS_1	17.89^a
Maize	CS_2	31.37^b
	CS_3	46.06^c
	SE	2.04
	CS_1	19.77^a
Sorghum	CS_2	32.45^b
	CS_3	46.38^c
	SE	2.40
	CS_1	19.57^a
Millet	CS_2	36.49^b
	CS_3	48.39^c
	SE	2.07

Mean in the same column bearing different superscripts were significantly, ($p<0.05$) different, *: CS_1, CS_2 and CS_3 stand for pre heading, heading and milk stages, respectively

Table 3: The Comparative dry matter yield (ton ha^{-1}) of maize, sorghum and millet fodders at three vegetative stages of growth

Fodders	Cutting stages	Yield
	CS_1	3.47^a
Maize	CS_2	7.33^b
	CS_3	15.38^c
	SE	1.50
	CS_1	3.58^a
Sorghum	CS_2	7.30^b
	CS_3	15.80^c
	SE	0.80
	CS_1	3.06^a
Millet	CS_2	8.67^b
	CS_3	16.84^c
	SE	0.50

Mean in the same column bearing different superscripts were significantly ($p<0.05$) different, *: CS_1, CS_2 and CS_3 stand for pre heading, heading and milk stages, respectively

Table 4: The Comparative crude protein yield (ton ha^{-1}) of maize, sorghum and millet fodders at three vegetative stages of growth

Fodders	Cutting stages	Yield
	CS_1	0.57^a
Maize	CS_2	0.86^b
	CS_3	1.53^c
	SE	0.80
	CS_1	0.36^a
Sorghum	CS_2	0.69^b
	CS_3	1.16^c
	SE	1.00
	CS_1	0.29^a
Millet	CS_2	0.70^b
	CS_3	1.17^c
	SE	1.25

Mean in the same column bearing different superscripts were significantly ($p<0.05$) different, *: CS_1, CS_2 and CS_3 stand for pre heading, heading and milk stages, respectively

stage. In the present study, CP yield of maize fodder was about 31% higher than that of millet fodder at milk stage. In the present study, CP yield of sorghum fodder (1.16 ton ha^{-1}) at milk stage was comparable (1.10 ton ha^{-1}) to that reported by Bhatti (1996).

Total Digestible Nutrient Yield

The TDN yield of millet (1.67 ton ha^{-1}) was lower ($p<0.05$) than those of maize (2.16 ton ha^{-1}) and sorghum (1.99 ton ha^{-1}) fodders harvested at pre heading stage (Table 5). However, the TDN yield of millet (4.69 ton ha^{-1}) was higher ($p<0.05$) than those of maize (4.29 ton ha^{-1}) and sorghum (3.99 ton ha^{-1}) fodders harvested at heading stage. Whereas, the TDN yield of millet (8.78 ton ha^{-1}) and maize (8.76 ton ha^{-1}) were higher ($p<0.05$) than that of sorghum fodder (8.37 ton ha^{-1}) harvested at milk stage. The results of the present study in which TDN yield of maize fodder was 8.76 ton ha^{-1} at milk stage are substantiated by the results of Azim *et al*. (2000) and Kim *et al*. (2001).

Influence of Maturity on Nutrient Concentration

The DM, NDF, ADF, ADL and WSC contents increased ($p<0.05$) as the fodders grew in age. However, the CP, TDN and ME contents reduced ($p<0.05$) as the fodders advanced in age (Table 6). The results of the present study were concordant with those of Sarwatt *et al*. (1989) and Church (1991) who reported decreased cell soluble contents and increased NDF and DM contents with advancement in the age of fodders. Schake *et al*. (1982) reported reduced CP content of sorghum as the fodder advanced in age. Church (1991) observed that DM and fibre contents were increased from early

Table 5: The comparative total digestible nutrient yield (ton ha^{-1}) of maize, sorghum and millet fodders at three vegetative stages of growth

Fodders	Cutting stages	Yield
	CS_1	2.16^a
Maize	CS_2	4.29^b
	CS_3	8.76^c
	SE	0.79
	CS_1	1.99^a
Sorghum	CS_2	3.99^b
	CS_3	8.37^c
	SE	1.00
	CS_1	1.67^a
Millet	CS_2	4.69^b
	CS_3	8.87^c
	SE	0.90

Mean in the same column bearing different superscripts were significantly ($p<0.05$) different, *: CS_1, CS_2 and CS_3 stand for pre heading, heading and milk stages, respectively

Table 6: Dry matter, crude protein, cell wall contents, water soluble carbohydrate, total digestible nutrient and metabolizable energy (%DM) of experimental fodders at different stages of maturity

		Fodders		
Parameters	Cutting stages	Maize	Sorghum	Millet
Dry matter	CS_1	19.37^c	18.11^c	15.69^c
	CS_2	23.38^b	22.48^b	23.76^b
	CS_3	33.40^a	34.06^a	34.81^a
	SE	2.04	2.38	2.77
Crude protein	CS_1	16.34^a	10.10^a	09.50^a
	CS_2	11.75^b	09.42^b	08.00^b
	CS_3	09.91^c	07.37^c	06.94^c
	SE	0.95	0.41	0.38
Neutral detergent fibre	CS_1	63.73^c	65.71^c	65.76^c
	CS_2	65.60^b	66.55^b	66.86^b
	CS_3	68.72^a	69.03^a	69.75^a
	SE	0.73	0.50	0.61
Acid detergent fiber	CS_1	31.83^c	35.63^c	37.93^c
	CS_2	33.70^b	37.48^b	39.78^b
	CS_3	36.80^a	40.60^a	42.90^a
	SE	0.72	0.73	0.73
Acid detergent lignin	CS_1	02.90^b	03.83^c	04.16^c
	CS_2	03.36^b	04.40^b	06.10^b
	CS_3	05.33^a	05.69^a	06.90^a
	SE	0.38	0.28	0.41
Water soluble carbohydrate	CS_1	08.52^c	06.84^c	06.50^c
	CS_2	10.25^b	09.26^b	07.50^b
	CS_3	11.25^a	11.06^a	10.48^a
	SE	0.40	0.61	0.60
Total digestible nutrient	CS_1	62.19^a	55.43^a	54.45^a
	CS_2	58.53^b	54.66^b	54.08^a
	CS_3	56.92^c	53.00^c	52.69^b
	SE	0.79	0.36	0.32
Metabolizable energy	CS_1	02.32^a	02.01^a	01.97^a
(Mcal kg^{-1})	CS_2	02.15^b	01.98^b	01.95^a
	CS_3	02.09^c	01.91^c	01.90^b
	SE	0.04	0.02	0.01

Mean in the same column bearing different superscripts were significantly ($p<0.05$) different, *: CS_1, CS_2 and CS_3 stand for pre heading, heading and milk stages, respectively

bloom to hard dough stage of growth of sorghum fodder, whereas, CP contents decreased with increasing maturity of fodder. Similarly, other workers (Kim and Voigtlaender, 1985; Gupta and Sagar, 1987) reported that the cell wall contents of fodder increased with the increase in their age. However, Hunt *et al*. (1989) and Kohan and Allen (1995) reported that concentration of NDF and ADF in whole plant of maize decreased as maturity proceeded from early one third milk line to late (black lager maturity). This decline in concentration of NDF and ADF might be due to accumulation of starch in grains. Morphological differences in cell wall contents were attributed to differences in the concentration and composition of their lignin and carbohydrate fraction in fodders (Fritz, 1989).

The present study supported the findings of Thomas and Thomas (1985) and Bolsen *et al*. (1992) who reported that the WSC increased as the fodder advanced in growth. However, Bolsen *et al*. (1983) and Havilah and Kaisar (1992) reported that average WSC contents of sorghum, wheat and barley at dough, late dough and hard grain of growth decreased, which might be due to accumulation of starch in grains. In the present study, WSC content in maize fodder at heading stage was 10.25%, which was comparable with the findings of Azim *et al*. (2000). Kim *et al*. (2001) reported that TDN value of maize fodder was higher at an early stage of growth and it decreased with increasing maturity. The reduced TDN may be because of increased cell wall contents as the plant advanced in age. Thomas and Thomas (1985) also reported that ME value of fodder crop decreased with advancing maturity of crop.

In situ Nutrients Digestibility

In situ DM, OM and NDF digestibilities of all three fodders decreased ($p<0.05$) with the advancement of age at 24 and 48 h of ruminal incubation (Table 7). The percent reduction in the digestibility of DM, OM and NDF at 48 h ruminal incubation, was 11.10, 18.48 and 14.08%; 10.24, 11.25 and 12.18% and 12.59, 18.36 and 23.69% of maize, sorghum and millet fodders, respectively, harvested at enhanced maturity. The results were in agreement with those of Russel *et al*. (1992) and Havilah *et al*. (1995) who reported that DM, NDF and OM digestibilities of maize fodder decreased with increasing age. Similarly, Goto *et al*. (1991) and Cherney *et al*. (1993) reported that DM, NDF and OM digestibilities of millet, oat, sorghum and other grasses decreased with the advancement of age. Hunt *et al*. (1989) reported that *in situ* DM digestibility of whole maize plant was 53.7% at an early maturity after 24 h of ruminal incubation. This value was close to the DM digestibility of maize fodder (53%) incubated for 24 h, when harvested at an early maturity in the present study. Fariani *et al*. (1994) reported that rumen degradation of DM reduced ($p<0.05$) with advancing age of the grass. The reduced DM and NDF digestibility of matured fodders can be ascribed to the reduced leaf-to-stem ratio (more stem, fewer leaves) because a greater portion of the total DM and NDF was associated with stem tissue.

Table 7: Effect of type of fodder and stage of age on *in situ* digestibility in sheep

		Incubation Period (h)					
		DM (%)		OM (%)		NDF (%)	
Fodders	Cutting stages	24	48	24	48	24	48
Maize	CS_1	53.00^a	71.12^a	65.66^a	81.33^a	47.90^a	65.82^a
	CS_2	46.90^b	66.08^b	64.50^b	74.16^b	43.92^b	61.90^b
	CS_3	43.75^c	63.22^c	62.00^c	73.00^c	38.55^c	57.53^c
	SE	1.35	1.16	0.54	1.30	1.23	1.20
Sorghum	CS_1	51.50^a	69.57^a	64.56^a	80.00^a	45.75^a	64.70^a
	CS_2	45.25^b	64.35^b	63.50^b	73.00^b	42.00^b	60.02^b
	CS_3	37.90^c	56.71^c	61.00^c	71.00^c	33.80^c	52.82^c
	SE	1.97	1.87	0.53	1.36	1.77	1.73
Millet	CS_1	44.20^a	63.07^a	64.00^a	78.00^a	43.30^a	62.25^a
	CS_2	40.40^b	59.38^b	62.00^b	71.50^b	37.80^b	56.80^b
	CS_3	35.00^c	54.19^c	59.00^c	68.50^c	28.50^c	47.50^c
	SE	1.34	1.29	0.73	1.40	2.16	2.15

Means in the same column bearing different superscripts were significantly ($p<0.05$) different, *: CS_1, CS_2 and CS_3 stand for pre heading, heading and milk stages, respectively

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