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Chemical Composition, *In vitro* Digestibility and Carbohydrate and Protein Fractions of Zuri Fodder at Different Days of Harvest

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ABSTRACT

In the present study, Zuri fodder was evaluated for chemical composition, oxalate content, *in vitro* digestibility and carbohydrate and protein fractions at different days (15, 20, 25,30 and 35) of harvest in its second cut. The mean CP content in Zuri fodder at different days of harvest was 14.6 per cent. The per cent oxalate content was highest (2.96) in the Zuri fodder harvested at 15 days as compared to mature fodder (1.65) at 35 days, with moderate content (1.89) at 30 days of harvest. The average *in vitro* digestibility (%) of DM and OM was 66.2 and 73.1, respectively, in Zuri fodder at different days of harvest. High lignin (% NDF), while low NSC (% DM) and starch (% NSC) were observed in Zuri fodder harvested at 35 days as compared to other stages. The mean NDICP and ADICP content (% CP) were 44.4 and 11.9, respectively, in Zuri fodder. The carbohydrate fractions (% CHO) revealed that carbohydrate fraction A (CA) was highest at 35 days of harvest, while fraction C (CC) was lowest at 15 days of harvest in Zuri fodder. Data on protein fractions (% CP) showed that protein fraction (PB_2) was highest (17.7) at 35 days, while PB_3 was highest (35.8) at 15 days of harvest in Zuri fodder. It is concluded that Zuri fodder harvested at 30 days contained moderate oxalate content, revealed better *in vitro* digestibility and carbohydrate and protein fractions which reflects better nutrient intake.

KEYWORDS: Carbohydrate fractions, Days of harvest, Oxalate content, Protein fractions, Zuri fodder

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INTRODUCTION

Forages contribute the major portion of ruminant feeds and high quality green fodder is required for economical dairy production. Several factors like lack of quality feed and fodder, genetic deterioration etc. will influence the productivity of dairy animals (Datta, 2013) in our country. Green forages generally meet the requirements for maintenance and moderate levels of production in ruminants (Das et al., 2015). Decreased arable land for fodder cultivation, increased human population and urbanization, escalating cost of feed ingredients etc. are the critical constraints for profitable animal production in developing countries. Introduction of high yielding forage varieties is one of the best alternative to overcome the shortage of forage (Mahr-un-nisa and Sarwar, 1998). Hence, cultivation of perennial fodders with higher biomass per unit area is the immediate solution to meet the current livestock production. Consequently, high yielding forages including a number of varieties of Guinea hybrids have been introduced in many parts of the world, including India.

The Zuri fodder (*Panicum maximum* cv. BRS Zuri) is a result of mass selection in populations derived from *Panicum maximum* collected in Tanzania, East Africa. Zuri means “good” and “beautiful” in Swahili, the language spoken in Kenya. The cultivar Zuri presented a leaf percentage of 87%, which was higher than cv. Tanzania-1 (77%) and Colonium (63%). The crude protein contents varied from 11 to 15% in the leaves and from 7 to 12% in the stems of Zuri fodder. It was selected based on productivity, vigour, support capacity, animal performance, resistance to grasshoppers and leaf spot caused by *Bipolaris maydis*. Zuri reached annual production of 21.8 MT/ha/year. Determination of nutritive value of fodders through *in situ* involves maintenance of fistulated animals and is tedious and expensive. A number of solvents and procedures have been used for the fractionation in feeds (Krishnamoorthy et al., 1982). Carbohydrate and protein fractionation (Sniffen et al., 1992; Licitra et al., 1996) accurately define rumen bacterial and whole animal requirement to assess feed utilization and to predict production responses. Further, the oxalate content of forages determines the optimum stage of harvest dictating the nutrient digestibility (Anthony and Thomas, 2014). Evaluation of chemical composition and accurate prediction of forage biological value and performance of animals is the need of hour for their optimum utilization in ruminant feeding. Hence, the present study was undertaken to evaluate the chemical composition, oxalate content, *in vitro* digestibility and carbohydrate and protein factions of Zuri fodder at different days of harvest.

MATERIALS AND METHODS

The green fodder of Zuri variety was procured from the cultivated fields of Livestock Farm Complex (LFC), NTR College of Veterinary Science, Gannavaram. First cut was done on 75th day of plantation. Subsequently, the fodder was harvested on 15^{th}, 20^{th}, 25^{th}, 30^{th} and 35^{th} day in the second cut and evaluated for its chemical composition, oxalate content, *in vitro* digestibility and carbohydrate and protein fractions. The chopped, dried and ground Zuri fodder was evaluated for proximate composition (AOAC, 2007), forage fibre constituents (Van Soest et al., 1991) and Calcium and Phosphorus (Talapatra et al., 1940) at different days of harvest. The fodder samples were analysed for oxalate content at different days of harvest (Abaza et al., 1968). Further, Zuri fodder was evaluated for *in vitro* DM and OM digestibility (Tilley and Terry, 1963) at different days of harvest with strained rumen liquor (SRL) collected from rumen cannulated adult male Murrah buffalo bulls maintained on the same fodder diet for a period of 60 days.

The carbohydrate fractions *viz*., A, B_1, B_2 and C of Zuri fodder at different days of harvest were estimated using procedures of Sniffen et al. (1992). These fractions are based on degradation rates of feed stuffs. Fraction 'A' is soluble and is sugars and organic acids, fraction B_1 is instantly degradable and is (starch and soluble fibres), fraction B_2 is slowly degradable and is available cell wall and fraction C constitute unavailable cell wall. Starch content of feed samples was determined by the procedures of Clegg (1956). The feed CP was divided in to five fractions-A, B_1, B_2, B_3 and C, which sum to unity and were estimated as per procedures of Licitra et al. (1996). The five fractions have different rates of ruminal degradation (kd). Fraction A (NPN) is the percentage of CP that is instantly solubilized at time zero, which is assumed to have a degradation rate (k_d) of infinity. Fraction C is determined chemically as the percentage of total CP recovered with ADF (ADIN) and is considered to be un-degradable. The remaining B fractions (PB_1, PB_2 and PB_3) represent potentially degradable true protein in the rumen. The amounts of each of these 3 fractions that are degraded in the rumen are determined by their fractional rates of degradation (k_d) and passage (k_p). The data was analysed statistically (Snedecor and Cochran, 1994) using SPSS 17.0 version.

RESULTS AND DISCUSSION

The chemical composition and cell wall constituents of Zuri fodder is presented in Table 1. The DM content of harvested fodder at different days (15, 20, 25, 30 and 35) ranged from 13.39 to 16.86 per cent. Further, the CP, EE, NFE and total ash (%) contents were higher in Zuri fodder harvested on 15 days (16.9, 3.2, 43.7 and 17.6) and lower at 35 days (12.2, 2.4, 38.4 and 12.6), respectively, except for CF (%) which was higher at 35 days (34.1) and lower on 15 days (18.4) of harvest. The mean CP content in Zuri fodder (14.68 %) is similar to the values in Guinea grass varieties reported by earlier workers (Buldgen et al., 2001; Fernandes et al., 2014 and Jusoh et al., 2014). However, lower (Ramakrishnan et al. 2016; Carvalho et al. 2017; Maciel et al. 2018) and higher (Oni et al., 2010) CP values were reported in Guinea varieties compared to the values of the present study. The mean calcium and phosphorus (%) content were 0.46 and 0.39, respectively, in the Zuri fodder, which are in line with the findings of Areghore (2002) and Rusdy (2014) in Guinea grass varieties. The NDF, ADF, hemi-cellulose, cellulose and ADL contents were higher in Zuri fodder harvested at 35 days and lower on 15 days of harvest. The mean NDF content of Zuri fodder in the present study is 68.3 per cent. Lower NDF values (Tokita et al., 2015) and higher values (Das et al., 2015 and Maciel et al., 2018) compared to the present study were reported in various Guinea grass varieties. The mean ADL content of fodder in the present study is 4.56 per cent which is in agreement with the reports of Kondo et al. (2015). However, lower (Jusoh et al., 2014) and higher (Musco et al., 2016) values were reported in Guinea varieties compared to the present study. These differences in proximate composition and cell wall constituents observed in the present study with Zuri fodder as compared to other Guinea grass varieties might be attributed to the differences in breeding, variety of cultivar used, stage of harvest, type of soil, season, cultivation practices etc.

The oxalate content in Zuri fodder harvested during early stages was high when compared to that in late stages (Table 1). It is reported that oxalate is the common anti-nutritional factor present in almost all the fodder varieties which leads to poisoning when fed in large quantities. The total oxalate content in Zuri fodder increased linearly with successive cuts and also with different seasons (Rahman et al., 2011

Table 1. Chemical composition (% DM basis) and *in vitro* digestibility (%) of Zuri fodder at different days of harvest

Nutrient	Days of Harvest						
	15	20	25	30	35	Mean ± SE	P Value
Dry Matter	13.9^{a}	14.1^{ab}	15.2^{bc}	16.1^{cd}	16.8^{d}	15.2 ± 0.34	0.009
Organic Matter	82.3^{a}	84.2^{b}	86.2^{c}	86.9^{d}	87.3^{d}	85.4 ± 0.50	0.000
Crude Protein	16.9^{c}	16.8^{c}	14.4^{b}	12.8^{a}	12.2^{a}	14.6 ± 0.56	0.000
Ether Extract	3.21^{b}	2.90^{ab}	2.84^{ab}	2.64^{a}	2.42^{a}	2.80 ± 0.09	0.000
Crude Fibre	18.4^{a}	22.1^{b}	27.4^{c}	31.3^{d}	34.1^{d}	26.7 ± 1.60	0.030
Total Ash	17.6^{d}	15.7^{c}	13.7^{b}	13.0^{a}	12.6^{a}	14.5 ± 0.50	0.000
Nitrogen Free Extract	43.7^{b}	42.3^{b}	41.5^{ab}	40.1^{ab}	38.4^{a}	41.2 ± 0.63	0.061
Neutral Detergent Fibre	63.0^{a}	65.5^{b}	68.0^{c}	71.1^{d}	73.8^{e}	68.3 ± 1.06	0.000
Acid Detergent Fibre	37.1^{a}	38.8^{b}	41.0^{c}	43.1^{d}	45.1^{e}	41.0 ± 0.78	0.000
Hemi-cellulose	25.8^{a}	26.7^{ab}	27.0^{ab}	28.0^{ab}	28.7^{b}	27.2 ± 0.38	0.122
Cellulose	30.0^{a}	31.0^{a}	32.1^{ab}	33.8^{ab}	35.4^{b}	32.5 ± 0.69	0.059
Acid Detergent Lignin	3.75^{a}	4.25^{a}	4.69^{a}	4.93^{a}	5.18^{a}	4.56 ± 0.27	0.537
Silica	3.32^{a}	3.59^{a}	4.17^{a}	4.32^{a}	4.51^{a}	3.98 ± 0.33	0.808
Calcium	0.47^{a}	0.48^{a}	0.43^{a}	0.50^{a}	0.44^{a}	0.46 ± 0.01	0.473
Phosphorus	0.44^{a}	0.45^{a}	0.36^{a}	0.36^{a}	0.33^{a}	0.39 ± 0.02	0.143
Oxalate	2.96^{e}	2.55^{d}	2.33^{c}	1.89^{b}	1.65^{a}	2.26 ± 0.09	0.000
***In vitro* Digestibility (%)**							
IVDMD	72.2^{d}	68.1^{c}	66.9^{c}	64.8^{b}	59.1^{a}	66.2 ± 1.17	0.000
IVOMD	78.4^{c}	74.7^{c}	73.4^{b}	70.9^{ab}	67.9^{a}	73.1 ± 1.09	0.004

Each value is a mean of three observations
Figures bearing different superscripts across the row differ significantly ($P<0.05$, $P<0.01$)

Table 2. Carbohydrate and protein components of Zuri fodder at different days of harvest

Parameter	Days of Harvest						
	15	20	25	30	35	Mean ± SE	P Value
Carbohydrate Components							
Lignin (% NDF)	5.97^{a}	6.48^{a}	6.90^{a}	6.93^{a}	7.0^{a}	6.66 ± 0.37	0.921
NSC (% DM)	10.0^{ab}	9.42^{ab}	10.59^{ab}	8.81^{ab}	6.36^{a}	9.03 ± 0.58	0.274
Starch (% NSC)	72.1^{d}	67.1^{c}	63.6^{bc}	60.4^{ab}	58.3^{a}	64.3 ± 1.41	0.000
Protein Component							
SP (% CP)	46.4^{d}	43.2^{c}	40.3^{b}	37.9^{b}	34.7^{a}	40.5 ± 1.13	0.000
NPN (%SP)	73.1^{a}	72.3^{a}	74.4^{a}	73.0^{a}	71.9^{a}	72.9 ± 0.42	0.654
BIP (% CP)	53.6^{a}	56.7^{b}	59.6^{c}	62.0^{c}	65.2^{d}	59.4 ± 1.13	0.000
NDICP (% CP)	41.4^{a}	42.7^{ab}	44.5^{bc}	46.0^{cd}	47.5^{d}	44.4 ± 0.62	0.000
ADICP (% CP)	5.67^{a}	8.02^{b}	10.6^{c}	16.1^{d}	19.0^{e}	11.9 ± 1.36	0.000

Each value is a mean of three observations
Figures bearing different superscripts across the row differ significantly (P<0.05, P<0.01)

Table 3. Carbohydrate and protein fractions of Zuri fodder at different days of harvest

Parameter	Days of Harvest						
	15	20	25	30	35	Mean ± SE	P Value
Carbohydrate Fraction (% CHO)							
CA	2.65^{a}	2.83^{a}	3.15^{a}	3.48^{a}	3.87^{a}	3.20 ± 0.22	0.172
CB_1	7.17^{b}	6.27^{b}	6.71^{b}	5.33^{ab}	3.71^{a}	5.84 ± 0.41	0.132
CB_2	75.5^{a}	75.6^{a}	73.1^{a}	74.6^{a}	76.5^{a}	74.8 ± 0.91	0.945
CC	14.5^{a}	15.9^{a}	16.3^{a}	16.5^{a}	17.1^{a}	16.0 ± 0.92	0.955
Protein Fraction (% CP)							
PA	33.9^{d}	31.3^{c}	30.0^{c}	27.7^{b}	24.9^{a}	29.6 ± 0.86	0.000
PB_1	12.4^{b}	11.9^{b}	10.3^{a}	10.2^{a}	9.75^{a}	10.9 ± 0.33	0.000
PB_2	12.1^{a}	13.9^{ab}	15.1^{b}	16.0^{bc}	17.7^{c}	14.9 ± 0.59	0.019
PB_3	35.8^{b}	34.7^{b}	33.8^{b}	29.8^{a}	28.5^{a}	32.5 ± 0.81	0.000
PC	5.67^{a}	8.02^{b}	10.6^{c}	16.1^{d}	19.0^{e}	11.9 ± 1.36	0.000

Each value is a mean of three observations
Figures bearing different superscripts across the row differ significantly (P<0.05, P<0.01)

and Pathmasiri et al., 2014). The mean oxalate content at different days of harvest in Zuri fodder is 2.26 per cent, which is in agreement with the values (1.5-3.1 per cent) reported by Pathmasiri et al. (2014) in Guinea grass varieties. In contrast, Ajayi and Babayemi (2008) and Rahman et al. (2011) reported lower oxalate content (0.47 per cent) as compared to the values observed in the present study. On the other hand, Onyeonagu et al. (2013) and Rahman et al. (2013) reported higher oxalate content in Guinea grass when compared to the values observed in the present study. These differences in oxalate content in different varieties of Guinea fodder might be attributed to differences in clipping intervals, seasonal variation and type of soil. Further the oxalate content of the plant varies with many internal and external factors like fertilizer management, forage species, harvesting practices and seasonal variations etc.

(Rahman et al., 2011). The safer levels of soluble oxalate content in cultivated grass varieties viz., Napier etc. is less than 2 per cent (Patel et al., 2013). Feeding of early cut Zuri fodder (15-20 days) may cause oxalate toxicity, while the late cut fodder revealed lower nutrient digestibility. Hence, the Zuri fodder harvested at 30 days with moderate oxalate content (1.89 %) and high nutrient digestibility is the recommended optimum age of harvest for ruminant feeding.

The *in vitro* DM digestibility (IVDMD %) of Zuri fodder (Table 1) ranged from 59.1 to 72.2 with a mean value of 66.27 and decreased with increased days of harvest. Similar findings were reported for IVDMD (61.5 to 67.3 %) by earlier workers (Paulino et al., 2015 and Tokita et al., 2015), while lower (Branco et al., 2010) and higher (Cavalcante et al., 2014) values were reported in Tanzania grass. Higher dry matter digestibility of grasses at early clipping interval may be attributed to their shorter ruminal lag time and faster rate of disappearance because of less lignification and high proportion of cell soluble material at early maturity (Sarwar et al., 2006). The study indicated that the *in vitro* OM digestibility (IVOMD %) of Zuri fodder ranged from 67.9 to 78.4 with a mean value of 73.1. In line with the present findings Musco et al. (2016) reported IVOMD in Guinea grass varieties as 73.1 to 77.3 per cent. Similar findings were also reported by earlier workers (Aganga and Tshwenyane, 2004; Fernandes et al., 2014). In contrast, lower digestibility of OM was reported (Evitayani et al., 2004; Kavana et al., 2007) in *Panicum maximum* compared to the values of the present study. Variations in digestibility of DM and OM may be attributed to their relationships in chemical composition, leaf to stem ratio, plant height, geographic location, climatic factors, different varieties and harvest interval (Difante et al., 2009; Bora et al., 2011 and Euclides et al., 2016).

The carbohydrate and protein components of Zuri fodder (Table 2) revealed that mean lignin (% NDF) content was 6.66 per cent. Similar value (6.4 per cent) was reported by Tedeschi et al. (2002) in *Panicum maximum*, while lower values (Gupta et al., 2011 and Das et al., 2015) were reported in Guinea grass varieties compared to the present study. The mean NSC (% DM) content of the Zuri fodder is 9.03. In contrast, Gupta et al. (2011) and Singh et al. (2012) reported higher values, while Das et al. (2015) reported lower values in Guinea grass varieties compared to the present study. Further, the mean starch (% NSC) content of Zuri fodder (64.36) was lower than the value (36.4) reported by Gupta et al. (2011). The mean SP (% CP) content of Zuri fodder (40.5) was higher than the values (25.1 to 29.3 per cent) in Guinea grass varieties (Gupta et al., 2011 and Das et al., 2015). Further, NPN (% SP) content of the Zuri fodder (72.9) is in agreement with the value reported (70.8) by Das et al. (2015) in Guinea grass. The mean NDICP and ADICP (% CP) of Zuri fodder were 44.4 and 11.9 and were lower than the values (50.5 and 29.1 to 24.8 %), respectively, in Guinea grass varieties (Gupta et al., 2011 and Das et al., 2015). Data revealed that the fodder contained better carbohydrate and protein components at 30-35 days of harvest.

The mean carbohydrate fractions (% CHO) *viz*. CA, CB_1 and CC values of most of the tree and shrubs were higher, while CB_2 content was lower as compared (Table 3) to the values reported in Zuri fodder (Gupta et al., 2011; Kamble et al., 2011; Singh et al., 2012 and Das et al., 2015). Further, the fractions (CA and CB_2) are higher at 30-35 days of harvest in Zuri fodder which is an indication of presence of highly soluble sugars, organic acids and starch. The carbohydrate fraction (CC) reported in the present study is 16.0. Lower CC fraction in Zuri fodder may be attributed to the presence of low amount of insoluble or non-degradable part of carbohydrates compared to other Guinea varieties. This indicates presence of higher degradable carbohydrate portion in Zuri fodder when compared to that in trees and shrubs. Higher CA, CC and lower CB_2 fractions were reported in Timothy and alfalfa when compared to respective fractions in Zuri fodder (Yu et al., 2003). The mean protein fractions (% CP) of the Zuri fodder *viz*. PA, PB_1, PB_2, PB_3 and PC were 29.6, 10.9, 14.9, 32.5 and 11.9, respectively.

Lagunes et al. (2018) reported similar PB_1 (10.1), lower PA, PB_3 and PC (16.9, 24.9 and 9.4) and higher PB_2 (38.1) values in *Megathyrsus maximus* as compared to the present study. On other hand Yu et al. (2003) reported lower PA, PB_3 and PC and higher PB_1 and PB_2 values in alfalfa as compared to the values in the present study. However, the present study indicated that PA, PB_1 and PB_3 fractions were higher, while PB_2 and PC fractions were lower when compared to the values of Guinea grass (Gupta et al., 2011 and Das et al., 2015). Data revealed that the fodder contained better carbohydrate and protein fractions at 30 days of harvest.

CONCLUSION

It was concluded that Zuri fodder had moderate oxalate content, better *in vitro* nutrient digestibility and optimum CB_1, CB_2 and PB_3 fractions indicating the better nutritional value. Hence, it is suggested that the Zuri fodder can be better utilized at 30-35 days of harvest than matured stages for ruminant feeding.

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