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## In situ dry matter, protein and neutral detergent fibre degradation kinetics of Cholistan Desert grasses

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### Abstract

Global climate change is evident and poses serious threats to the sustainability of traditional rangeland livestock production systems. This study tested the feeding potential of perennial grasses of Cholistan Desert for various species of ruminants at different physiological stages. Eight common and nutritionally important grass species (*Cenchrus ciliaris*, *Stipagrostis plumose*, *Panicum antidotale*, *Cymbopogon jwarancusa*, *Cenchrus pennisitiformis*, *Lasiurus scindicus*, *Ochthochloa compressa* and *Vetiveria zizanioides*) were investigated for in situ degradation parameters according to Nordic feed evaluation system (NorFor) standards. The collected, dried and milled grass samples were incubated for 0, 4, 8, 16, 24, and 48 hours to determine dry matter and crude protein biodegradation and additionally for 96 and 168 hours for neutral detergent fibre degradation in the rumens of lactating Nili-Ravi buffalo and Cholistan Desert cows and heifers (two from each species and from each physiological stage). All of these grass species influenced the dry matter, crude protein and neutral detergent fibre degradation fractions significantly. The overall effective degradability of dry matter for asymptotic extent of degradation did not differ. However, the potentially degradable but insoluble fraction and rate of degradation were influenced significantly by the species of the animals. All the proximate parametric characteristics of perennial desert grasses were within the nutrient range for typical ruminant diets except for crude protein. It was concluded that rumen availability of grasses was highly influenced by grass species. However, these grasses are equally nutritionally important for various species of ruminants for example buffalo versus cattle at different physiological stages and heifers versus lactating animals.

**Keywords:** buffalo, *Cenchrus ciliaris*, desert cows, desert forage, feeding value

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### Introduction

Cholistan desert is a part of the Great Indian Desert where it enters into Pakistan from India. It is located at the periphery of the South Punjab and comprises 2.6 million hectares of rangeland (Baig *et al.*, 1980). It has diversified flora that can be grouped into trees, shrubs, herbs and grasses, which serve as grazing ground for 1.32 million head of livestock. The current setting of global climate change is evident and poses serious threats to the sustainability of traditional rangeland livestock production systems. This may result in serious food and water shortages for humankind over the coming decades. On the other hand, the expected demand for meat and milk consumption in global markets would increase exponentially with the expansion in human population.

In this uncertainty, the rangelands are viewed as alternative feed resources for animal production (Ashraf *et al.*, 2013). Grazing patterns of livestock in rangelands depend on the natural ecological systems of grasses, shrubs and trees and their generative and regenerative properties, often with non-renewable inputs. On other words, the livestock graze on vegetation that grows and re-sprouts naturally without agronomic practices (Nardone *et al.*, 2010). Wild grasses are important perennial species of Cholistan Desert, which are grazed by livestock, including cows, goats, sheep and camels (Bebawi & Neugebhorn, 1991; Cavaye, 1991).

These grass species are perennial xero-halophytes, which are easy to establish, have low demands for post-planting care, and occur wild in nature with extraordinary acclimatization under the severe environmental conditions of the desert (Ashraf *et al.*, 2008). They produce a substantial amount of dry matter on saline unproductive desert soils with only intermittent rainfall. The perennial nature of these grasses can result in a sustainable and uninterrupted supply of forage throughout the year. The use of desert forage can have the additional benefits of reducing health hazards because of their antibiotic and antipyretic properties (Hameed *et al.*, 2011). Because of these environmental and socioeconomic benefits, the nutritional content and commercial potential of these grasses should be evaluated.

The potential of these grass species has not been the subject of detailed study. Information about their adoptability, nutritional composition and digestion kinetics is therefore lacking. It is important for many reasons to look for sustainable livestock nutrition and animal forage production in particular in coming decades to fight the adverse effects of climate change. The information about the nutritional compositions of grasses that has been reported by local and international studies lacks data on digestion kinetics, and animals' responses to perennial desert grass species remain under question. Therefore, an in-situ study was planned with nylon bags and actual rumen environment. The experiment was performed to i) evaluate the agro-morphological characters of common Cholistan Desert grasses, their nutritional composition, dry matter yield and neutral detergent fibre biodegradability; and ii) to compare the data of two ruminant species for example buffalo and cattle at two physiological stages for instance heifers and lactating animals. Moreover, the current study would highlight the potential of rangeland grasses for arable farming as climate-resilient fodder to fulfil the forage requirements of the livestock.

## Material and Methods

The perennial desert grasses that were used in this study were collected from various habitats of Cholistan Desert (latitude 27°42' and 29°45' N longitude and 69°52' and 75°24' E) from a range of sites from July to December 2016. High temperatures and low rainfall are prominent features of this sandy desert. The desert has perennial herbaceous cover, although the plant growing seasons are from July to September and January to March.

To collect the forage samples of animal feed-related important grasses, a field survey of Cholistan Desert was conducted, keeping in mind the opinions of animal and plant experts and the points of view of the herders. The samples were collected according to the method described by Ashraf *et al.* (2013). The sampling was performed in triplicate from each grass habitat, and the minimum sampling distance was maintained at least 200 m apart. The stubbles of these grasses were planted at the field research station of Cholistan Institute of Desert Studies, Islamia University of Bahawalpur, Pakistan. All grasses were grown according to standard agronomic practices. Eight grass species were selected for nutritional and rumen degradability trials based on their establishment potential and preference by grazing animals. The grasses that passed the screening trials were *Cenchrus ciliaris*, *Stipagrostis plumose*, *Panicum antidotale*, *Cymbopogon jwarancusa*, *Cenchrus pennisitiformis*, *Lasiurus scindicus*, *Ochthochloa compressa*, and *Vetiveria zizanioides*.

The agro-ecological characteristics, growth cycle and soil habitats of these grasses are provided in Table 1. These grasses were cut after eight weeks of planting at the peak of their vegetative growth for morphological studies. The herbage was harvested 10 cm above the ground surface and stored for subsequent physiochemical analysis. The herbage was chopped with a nominal chop length of 20 mm and laid under the shade to dry. The dried samples were transported to the Livestock Production and Management Section, University College of Veterinary and Animal Sciences, Islamia University of Bahawalpur, Pakistan. For in situ incubation studies, dried samples of the grasses were ground to fine powder to pass through a 2 mm screen. For nutritional analysis, these dried samples were further ground to a size of 1 mm. Plastic jars were used to store the ground dried samples for further analysis.

**Table 1** Agro-ecological characteristics of researched perennial desert grasses along with their soil habitat sampled from various locations of Cholistan Desert

Genus and species <sup>1</sup>	Plant height, cm	Inflorescence length, cm	Growth type	Life cycle	Soil type	Presence
<i>Cenchrus ciliaris</i>	80 - 95	5.2 - 10.7	Therophyte	Perennial	Sand dune	Abundance
<i>Stipagrostis plumose</i>	33 - 40	6.1 - 12.3	Therophyte	Perennial	Sand dune	Abundance
<i>Panicum antidotale</i>	89 - 105	16.3 - 19.6	Hemicryptophyte	Perennial	Sand dune	Rare
<i>Cymbopogon jwarancusa</i>	51 - 63	18.3 - 32.1	Hemicryptophyte	Perennial	Interdunal	Abundance
<i>Cenchrus pennisitiformis</i>	62 - 83	4.2 - 8.5	Therophyte	Annual	Sand dune	Rare
<i>Lasiurus scindicus</i>	99 - 117	19.2 - 26.6	Phanerophyte	Perennial	Sand dune	Abundance
<i>Ochthochloa compressa</i>	23 - 30	1.5 - 4.1	Hemicryptophyte	Perennial	Interdunal	Abundance
<i>Vetiveria zizanioides</i>	180 - 220	22.6 - 28.2	Phanerophyte	Perennial	Sandy loam	Rare

<sup>1</sup> Common names: *Cenchrus ciliaris*: dhaman, *Stipagrostis plumose*: Lum, *Panicum antidotale*: morrot, *Cymbopogon jwarancusa*: khavi, *Cenchrus pennisitiformis*: lidder, *Lasiurus scindicus*: sewan, *Ochthochloa compressa*: gandeel, *Vetiveria zizanioides*: khas

Three replicates of the chemical analyses were performed on the dried grass samples. First, the samples were oven dried (60 °C) for two days to obtain dry matter concentration. To determine the ash content, the dried grasses in measured amounts were put in a muffle furnace at a temperature of 500 - 600 °C for more than five hours (AOAC, 1990; method 923.03). Crude protein (method 7.015) and ether extract (method 7.062) were also determined following procedures of the AOAC (1990). To determine the amylase-treated neutral detergent fibre concentration, the procedure described by Van Soest *et al.* (1991) was used with a slightly modified protocol in which heat stable alpha amylase and sodium sulphite were added to the reaction (Mertens *et al.*, 2002).

The animals were kept at the livestock farm of Islamia University of Bahawalpur and maintained according to the criteria of the University's Animal Care and Management Committee. Eight rumen-cannulated animals, that is, two heifers and two lactating females representing Nili Ravi buffaloes and Cholistan Desert cattle, were used simultaneously for in situ incubation of the grass samples. Live weights of the buffaloes and cows were 519 ± 46 kg and 300 ± 32 kg and they produced 3.34 ± 0.271 kg/day and 5.63 ± 0.207 kg/day of milk, respectively. The animals were fed individually and supplied with fresh drinking water.

The cannulated animals were fed according to NorFor standards for cannulated animals to meet their daily dietary requirements (Volden, 2011). On a dry matter basis, the roughage to concentrate ratio was 80:20 for lactating animals and 90:10 for heifers. The ingredients and nutrient compositions of the diets are presented in Table 2.

For in situ biodegradation profile studies, the grass samples were incubated in the rumen of the experimental animals for different periods. NorFor standards were followed to determine the degradation profiles of the grasses (Åkerlind *et al.*, 2011; Volden, 2011). Sub-samples (approximately 1 g) were incubated for 0, 4, 8, 16, 24, and 48 hours dry matter and crude protein biodegradation and additionally for 96 and 168 hours for neutral detergent fibre degradation. On completion of the incubation time, the bags were removed, washed with tap water and stored at -18 °C. The stored bags were once again washed with tap water in a washing machine for twelve minutes after thawing at room temperature. The dry matter loss and the amylase-treated neutral detergent fibre concentration were determined from the dried residues in the incubated bags.

**Table 2** Ingredients and mean chemical composition of the diets offered to rumen-cannulated animals (g/kg DM unless otherwise stated)<sup>1</sup>

Ingredients (as fed basis)	Lactating animals	Heifers
Sorghum	844	771
Lucerne hay	88	195
Cotton seed cake	30	0
Concentrate mixture	37	34
Forage to concentrate ratio (DM)	80: 20	90: 10
<i>Chemical composition (DM)</i>		
Dry matter	302	360
Crude protein	58	60
Ether extract	18	17
Neutral detergent fibre	583	567
Non-fibre carbohydrates	227	241
Ash	113	113

<sup>1</sup>Number of samples: 5; number of replicates: 2; total number of observations per feed: 10

A first order kinetic model was applied for curve fitting regression analysis (Ørskov & McDonald, 1979). The washable fraction ( $a$ ) or particle loss and non-washable fraction were two broad divisions of the in-situ degradation data. The remaining non-washable segment was sub-divided into possibly degradable ( $b$ ) and totally indigestible fractions.

$$Y_t = a + b(1 - \exp(-kd \times t))$$

Where:  $Y_t$  denotes the degraded fraction at a given time  $t$  and  $kd$  denotes the fractional degradation rate of fraction  $b$ . The effective dry matter degradability ( $ED$ ) was also calculated.

$$ED = a + \frac{bxkd}{kd+kp}$$

The fractional rate of passage ( $kp$ ) was assumed to be 0.05/h for the forages. Previously, several protein evaluation systems had used this value of  $kp$  (Hvelplund & Weisbjerg, 2000).

These data were then analysed with the GLM procedure of Minitab® 16.1.1.0 (State College, Pennsylvania, USA). Each cannulated animal was treated as an experimental unit. The effects of feed, species and physiological stage of the animal were evaluated using this model.

$$Y_{ijkl} = \mu + F_i + S_j + P_k + e_{ijkl}$$

Where:  $Y_{ijkl}$  denotes dependent variable measured with the  $l^{\text{th}}$  animal,

$\mu$  = overall mean,

$F_i$  = effect of feed  $i$ ,

$S_j$  = effect of specie of  $j^{\text{th}}$  animal,

$P_k$  = effect of physiological stage  $k$  and

$e_{ijkl}$  = residual error.

## Results and Discussion

The desert grass species varied significantly in height, inflorescence length, growth cycle, soil habitat and population density (Table 1). Plant height and inflorescence length had two average values; the first was an average of minimum values, and the second an average of maximum values. *Vetiveria zizanioides* produced the tallest plants (220 cm) and *Cymbopogon jwarancusa* had the longest spikes (32.1 cm). All of these grasses were perennial in nature, except for *Cenchrus pennisitiformis*, which is an annual. Most, but not all of these grasses were abundant in the field and were found in the sand dune habitat.

*Vetiveria zizanioides* produced the maximum dry matter content (98.3 g) and was statistically similar to *Ochthochloa compressa* and *Lasiurus scindicus*. The grass species *Stipagrostis plumosa* recorded the minimum dry matter content among all of these species. The crude protein content ranged from 25 to 77.9 g/kg on a dry matter basis and was highest for *Cenchrus ciliaris* and lowest for *Lasiurus scindicus* (Table 3). *Vetiveria zizanioides* produced the maximum dry matter accumulation but had an average amount of crude protein. *Panicum antidotale* had the second highest crude protein content (65.1 g/kg dry matter) after *Cenchrus ciliaris*. Most of these species were lower in crude protein than is recommended for functional ruminant diets (70 - 200 g/kg dry matter). The ash content ranged from 71.3 g/kg for *Stipagrostis plumosa* to 141.7 g/kg for *Ochthochloa compressa*. *Stipagrostis plumosa* had the highest crude fibre content (400 g/kg dry matter), while *Cymbopogon jwarancusa* had the most nitrogen-free extract (570 g/kg dry matter). Ether extract was less than 30 g/kg dry matter for almost all of the species. This is typical of grass plant species in this desert. Among these grasses, *Panicum antidotale* has the highest calculated metabolizable energy content (136 MJ/kg dry matter). This indicates that their nutritional composition is within the desired ranges for nutrient content of diets for ruminants.

**Table 3** Nutrient composition of perennial desert grasses. Values are presented in percentages of dry matter as mean and standard deviation unless otherwise stated

Nutrient		Grass species							
		CC	SP	PA	CJ	CP	LS	OC	VZ
Dry matter	Mean	96.5	93.0	95.6	93.9	96.9	97.2	97.1	98.3
	SD	0.16	1.42	4.37	0.07	0.26	0.28	0.23	0.11
Crude protein	Mean	7.79	4.48	6.51	3.17	3.45	2.50	3.61	4.79
	SD	0.19	0.46	0.39	0.15	0.23	0.06	0.30	0.19
Ether extract	Mean	1.16	0.93	1.50	2.81	1.64	1.16	1.50	1.48
	SD	0.01	0.05	0.03	0.01	0.12	0.05	0.03	0.07
Crude fibre	Mean	31.7	40.0	33.5	20.8	23.7	31.6	24.6	27.5
	SD	2.83	2.33	1.91	0.42	2.05	1.06	1.41	0.92
Nitrogen free extract	Mean	45.1	40.5	37.2	57.0	54.1	51.5	53.2	54.5
	SD	3.20	4.34	3.12	0.64	2.64	1.44	0.56	0.76
Ash	Mean	9.04	7.13	8.40	10.6	14.0	10.4	14.1	9.08
	SD	0.01	0.07	0.31	0.02	0.01	0.01	0.81	0.00
Metabolizable energy <sup>1</sup> (MJ/kg DM)	Mean	12.8	12.6	13.6	13.2	12.7	13.0	12.7	12.4
	SD	0.11	0.30	0.69	0.02	0.08	0.07	0.06	0.06

CC: *Cenchrus ciliaris*; SP: *Stipagrostis plumosa*; PA: *Panicum antidotale*; CJ: *Cymbopogon jwarancusa*; CP: *Cenchrus pennisitiformis*; LS: *Lasiurus scindicus*; OC: *Ochthochloa compressa*; VZ: *Vetiveria zizanioides*

<sup>1</sup> Metabolizable energy was calculated from chemical composition according to MAFF-1 (Ministry of Agriculture, Food and Fisheries) 1986, method 1.

The in-situ dry matter, neutral detergent fibre and crude protein biodegradation parameters were studied separately. The grass species significantly influenced ( $P < 0.001$ ) all fractions of these parameters. The washable fraction (*a*) of dry matter, neutral detergent fibre and crude protein biodegradation are presented in Tables 4, 5 and 6, respectively. The highest washable fraction (0.28) was measured for *Cymbopogon jwarancusa* for dry matter and the lowest was for *Stipagrostis plumosa* (0) for neutral detergent fibre biodegradation. The potentially degradable fractions (*b*) of dry matter ranged from 0.41 to 0.60, of neutral detergent fibre from 0.50 to 0.75, and of crude protein from 0.17 to 0.29. In contrast to the washable fraction, *Stipagrostis plumosa* had the highest value for potentially degradable fraction and *Vetiveria zizanioides* reported the lowest. The fractional degradation rate of fraction *b* (*kd*) and degradability of dry matter at 48 hours of incubation ranged from 0.02 to 0.06 and 0.33 to 0.51, respectively, and were highest for *Cenchrus ciliaris* and the least for *Vetiveria zizanioides*. The *kd* and degradability of neutral detergent fibre degradation at 48 hours ranged from 0.02 to 0.05 and 0.16 to 0.33 and were the highest for *Cenchrus pennisitiformis* and lowest for *Vetiveria zizanioides*. At 169 hours of incubation the neutral detergent fibre degradation ranged from 0.20 to 0.35 and was the highest for *Cenchrus pennisitiformis* and again lowest for

*Vetiveria zizanioides* (Table 5). The *kd* and degradability of crude protein degradation after 48 hours of incubation ranged from 0.02 to 0.11 and 0.12 to 0.20 and were highest for *Panicum antidotale* and lowest for *Cenchrus ciliaris* and *Cenchrus pennisitiformis*. The grasses were ranked in order of decreasing dry matter degradability: *Cenchrus ciliaris* = *Cenchrus pennisitiformis* > *Cymbopogon jwarancusa* > *Panicum antidotale* > *Ochthochloa compressa* > *Lasiurus scindicus* > *Stipagrostis plumosa* > *Vetiveria zizanioides*.

**Table 4** Effect of feed, species or physiological stage of the animal on in situ dry matter degradation kinetics and effective degradability of perennial desert grasses

In situ parameters	Grass species								SEM	P-value		
	CC	SP	PA	CJ	CP	LS	OC	VZ		Feed	Species	Stage
<i>a</i>	0.26	0.15	0.23	0.28	0.25	0.21	0.24	0.20	0.008	<0.001	0.981	0.122
<i>b</i>	0.45	0.60	0.50	0.45	0.49	0.46	0.41	0.42	0.021	<0.001	0.031	0.713
<i>kd</i>	0.06	0.04	0.05	0.04	0.05	0.04	0.04	0.02	0.003	<0.001	0.013	0.708
DMD	0.51	0.39	0.47	0.48	0.50	0.40	0.43	0.33	0.007	<0.001	0.342	0.291

CC: *Cenchrus ciliaris*; SP: *Stipagrostis plumosa*; PA: *Panicum antidotale*; CJ: *Cymbopogon jwarancusa*; CP: *Cenchrus pennisitiformis*; LS: *Lasiurus scindicus*; OC: *Ochthochloa compressa*; VZ: *Vetiveria zizanioides*

*a*: washable fraction *b*: potentially degradable fraction; *kd*: fractional rate of disappearance of fraction *b*; DMD: effective DM degradability at 48 hours of incubation

**Table 5** Effect of feed, species and physiological stage of the animal on in situ neutral detergent fibre degradation kinetics and effective degradability of wild grasses from Cholistan Desert

In situ parameters	Grass species								SEM	P-value		
	CC	SP	PA	CJ	CP	LS	OC	VZ		Feed	Species	Stage
<i>a</i>	0.03	0.00	-0.01	0.04	0.05	0.04	0.08	0.03	0.006	<0.001	0.101	0.997
<i>b</i>	0.64	0.75	0.71	0.63	0.66	0.59	0.53	0.50	0.008	<0.001	0.610	0.853
<i>kd</i>	0.05	0.03	0.04	0.03	0.04	0.04	0.04	0.02	0.002	<0.001	0.109	0.115
NDFD48	0.31	0.21	0.24	0.23	0.33	0.25	0.33	0.16	0.008	<0.001	0.301	0.097
NDFD168	0.34	0.28	0.30	0.28	0.35	0.28	0.32	0.20	0.006	<0.001	0.109	0.070

CC: *Cenchrus ciliaris*; SP: *Stipagrostis plumosa*; PA: *Panicum antidotale*; CJ: *Cymbopogon jwarancusa*; CP: *Cenchrus pennisitiformis*; LS: *Lasiurus scindicus*; OC: *Ochthochloa compressa*; VZ: *Vetiveria zizanioides*

*a*: washable fraction *b*: potentially degradable fraction; *kd*: fractional rate of disappearance of fraction *b*; NDFD48 and NDFD168: effective neutral detergent fibre degradability at 48 hours and 168 hours of incubation, respectively.

The potentially biodegradable fraction and *kd* were influenced ( $P < 0.05$ ) by the species of the animals, while washable fraction and dry matter degradability were not affected ( $P > 0.05$ ) (Table 4). Neither were the neutral detergent fibre degradation fractions influenced ( $P > 0.05$ ) by the species of the cannulated animals (Table 5). The heifers and the lactating animals in the present study did not show any significant difference in the utilization of any of the dry matter fractions ( $P > 0.05$ ). Similar results were observed for the neutral detergent fibre fractions and crude protein. However, lactating animals tended to increase their capacity for neutral detergent fibre and crude protein degradability at both time intervals ( $P = 0.097 - 0.155$  and  $P = 0.070 - 0.197$  respectively). Thus, it can be concluded that the degradation of the nutrients in these desert grasses was independent of the types of animal and their physiological stages.

**Table 6** Effect of feed, species and physiological stage of the animal on in situ crude protein degradation kinetics and effective degradability of wild grasses collected from Cholistan Desert

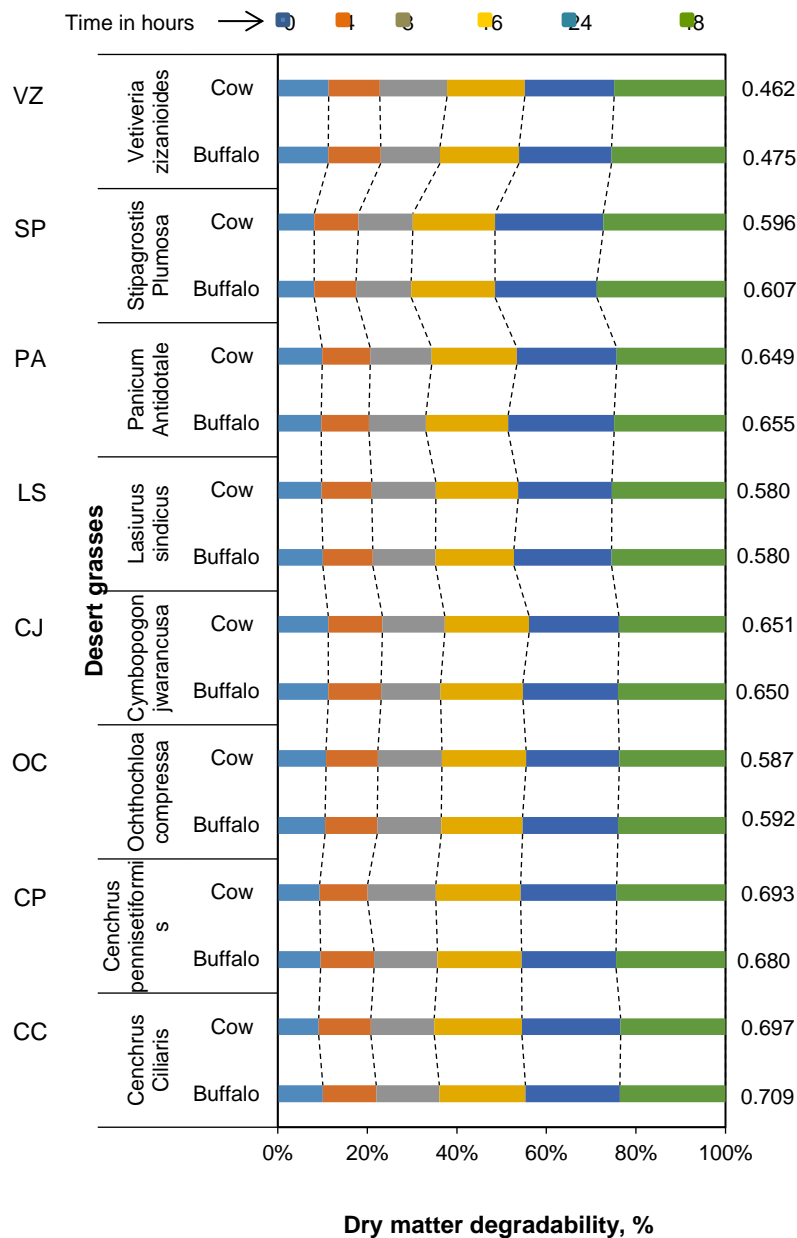
In situ parameters	Grass species									P-value		
	CC	SP	PA	CJ	CP	LS	OC	VZ	SEM	Feed	Species	Stage
<i>a</i>	0.06	0.02	0.03	0.01	0.05	0.01	0.01	0.00	0.010	0.006	0.101	0.907
<i>b</i>	0.29	0.19	0.25	0.28	0.28	0.26	0.17	0.23	0.011	<0.001	0.009	0.753
<i>kd</i>	0.02	0.06	0.11	0.04	0.02	0.04	0.08	0.07	0.007	<0.001	0.768	0.155
CPD48 <sup>2</sup>	0.13	0.12	0.20	0.12	0.14	0.12	0.12	0.14	0.015	0.013	0.008	0.197

CC: *Cenchrus ciliaris*; SP: *Stipagrostis plumose*; PA: *Panicum antidotale*; CJ: *Cymbopogon jwarancusa*; CP: *Cenchrus pennisitiformis*; LS: *Lasiurus scindicus*; OC: *Ochthochloa compressa*; VZ: *Vetiveria zizanioides*

*a*: washable fraction *b*: potentially degradable fraction; *kd*: fractional rate of disappearance of fraction *b*; CPD: effective crude protein degradability at 48 hours of incubation

Cholistan Desert is a productive rangeland that has diversified flora and serves as the milk basket of Pakistan. It includes a variety of wild growing plant species that include perennial grasses with fast growth and good dry matter accumulation. These grasses are excellent halophytes and can tolerate extreme salt levels (Naz *et al.*, 2009). Ahmad *et al.* (2001) reported that *Lasiurus scindicus*, *Cenchrus ciliaris* and *Aristida adscensionis* are the most abundant grass species there. This study confirmed that perennial grasses *Lasiurus scindicus* and *Cenchrus ciliaris* were present in abundance at sand dunes. These wild grasses have never been tested for feeding value, nutritional composition and rumen degradability characteristics.

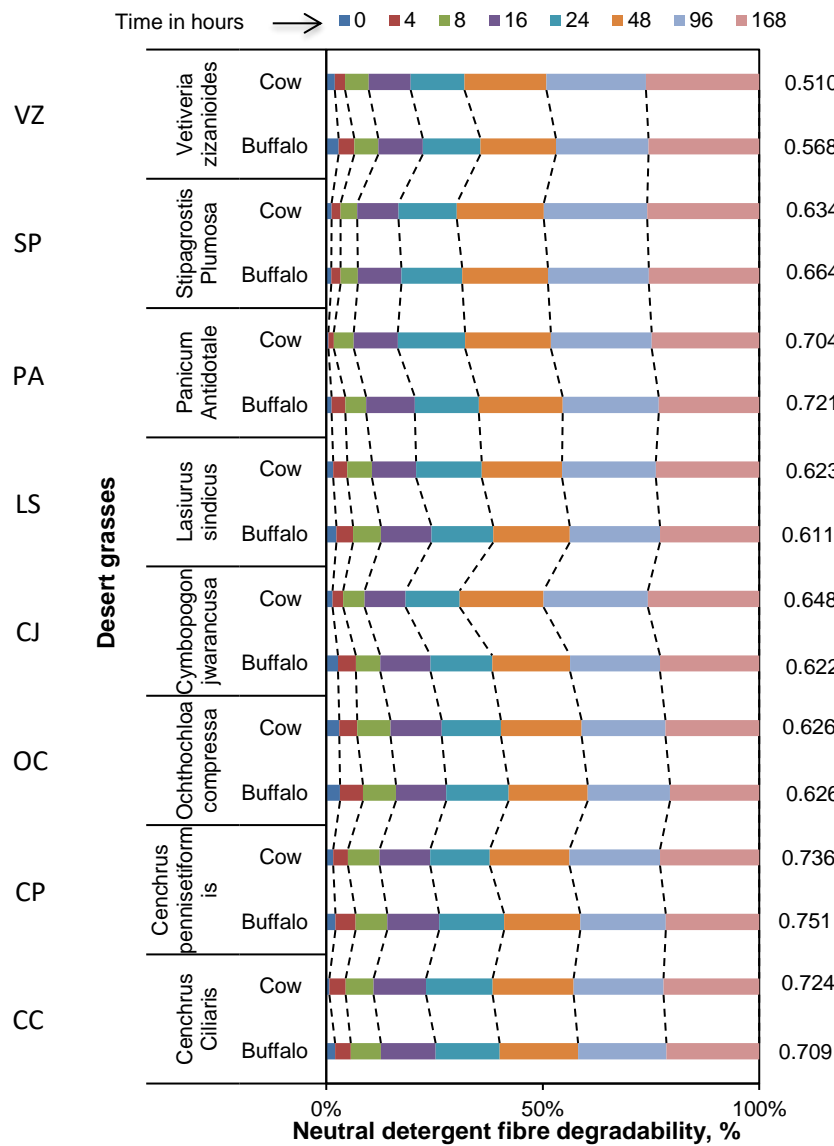
Degradability of the dry matter, neutral detergent fibre, and crude protein by cow and buffalo over time are presented in Figures 1, 2, and 3. The highest crude protein value for *Cenchrus ciliaris* agreed with that of Keba *et al.* (2013) but was lower than that of Sultan *et al.* (2011) and Ashraf *et al.* (2013). Sultan *et al.* (2011) estimated in situ dry matter and neutral detergent fibre digestibility kinetics during a 45-day trial on rumen cannulated buffalo bulls for various cultivated grasses. They found the highest rumen dry matter degradability values for *Panicum antidotale* (0.742) and the lowest for *Vetiver zizanioides* (0.295). The highest estimated neutral detergent fibre degradability values were observed for *Panicum antidotale* (0.679) and the lowest for *Leptochloa fusca* (0.277). The present results agree with those of Sultan *et al.* (2011) for dry matter degradability of grasses. During their experiment on cannulated Nili-Ravi buffalo and Cholistan Desert cattle, Tahir *et al.* (2017) evaluated and observed higher values of rumen dry matter degradation for legume and cereal forages than for range grasses. Habib *et al.* (2013) compared the rumen degradation kinetics in buffalo steers of different origins for oilseed and cereal grains. The present results depicted a significant difference in the rumen degradation kinetics and effective degradability for neutral detergent fibre and crude protein biodegradability. Trials conducted on cannulated riverine buffaloes and cows that were offered tropical forage grasses reported no difference in rumen dry matter and neutral detergent fibre degradability. However, *kd* values were higher in buffaloes than in cows (Franzolin & Dehority, 1999). Linden *et al.* (2014) conducted an experiment in which they offered chopped warm-season grass hay individually for ad libitum intake. They did not observe any differences in digestibility between cows and heifers. However, a difference was found between pregnant and non-pregnant cows. Similarly, Tahir *et al.* (2019) found no differences in dry matter degradability or *kd* values of legume and cereal forages between heifers and lactating animals when these feeds were studied using the in-situ technique. Weiss and Shockey (1991) reported that an increased forage to concentrate ratio did not affect dry matter degradability when high-quality orchard grass and alfalfa silages were the forage sources. It is noteworthy that the heifers and lactating animals were offered a standard diet with different forage to concentrate ratios. The dietary forage to concentrate ratio and processing of forage had a non-significant effect on the extent of digestion of grass cell wall components.



**Figure 1** Degradability of dry matter by cow and buffalo over time of different perennial grasses from Cholistan desert

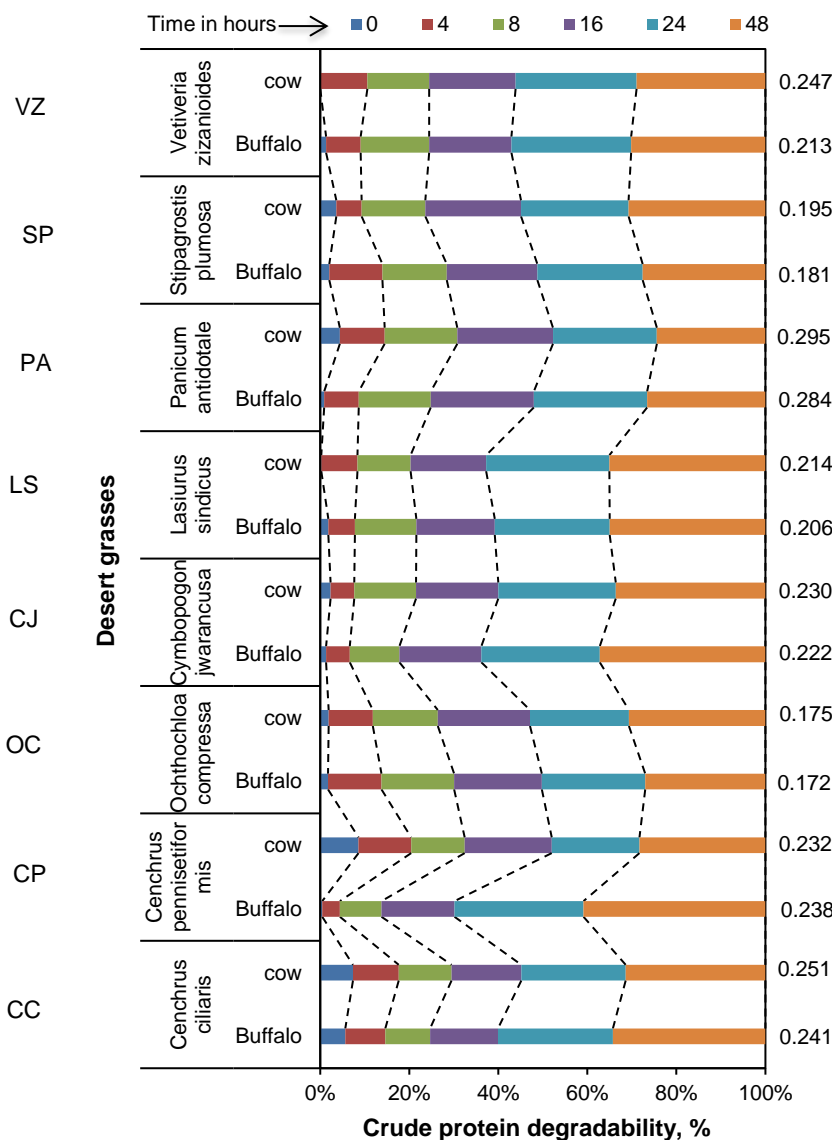
CC: *Cenchrus ciliaris*; SP: *Stipagrostis plumose*; PA: *Panicum antidotale*; CJ: *Cymbopogon jwarancusa*; CP: *Cenchrus pennisetiformis*; LS: *Lasiurus scindicus*; OC: *Ochthochloa compressa*; VZ: *Vetiveria zizanioides*





**Figure 2** Degradability of neutral detergent fibre by cow and buffalo over time of different perennial grasses from Cholistan Desert

CC: *Cenchrus ciliaris*; SP: *Stipagrostis plumose*; PA: *Panicum antidotale*; CJ: *Cymbopogon jwarancusa*; CP: *Cenchrus pennisetiformis*; LS: *Lasiurus scindicus*; OC: *Ochthochloa compressa*; VZ: *Vetiveria zizanioides*



**Figure 3** Degradability of crude protein by cow and buffalo over time of different perennial grasses from Cholistan Desert

CC: *Cenchrus ciliaris*; SP: *Stipagrostis plumosa*; PA: *Panicum antidotale*; CJ: *Cymbopogon jwarancusa*; CP: *Cenchrus pennisetiformis*; LS: *Lasiurus scindicus*; OC: *Ochthochloa compressa*; VZ: *Vetiveria zizanioides*

**Conclusion**

These desert forage grasses, especially *Cenchrus ciliaris* and *Panicum antidotale*, have excellent feeding value and nutritional profile for livestock. They are adaptable and have promising forage yield and nutritional profiles. They are characterized by rapid degradability in the rumen. Thus, they are promising as sources of forage for buffalo and cattle, whether they are lactating or not. The introduction of these grasses would enable use of these desert grasses as alternate forage for sustainable livestock production in future.

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**Authors' contributions**

MNT conceived and designed the investigation. MNT, ZK and MZI conducted the research. MNT, SA, and MHL

analysed the data. MNT and MAK developed new methods and models, and the original manuscript was written by MNT and MZI.

#### Conflict of Interest Declaration

The authors declare that they have no conflict of interest.

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