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Nutritional Profile and *in situ* Ruminal Digestion Kinetics of King Grass and Mott Grass

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Key words
***In situ*, Digestion kinetics, Mott grass, King grass, Nili Ravi buffalo**

ABSTRACT

This study focused on the assessment of a nutritional profile and in situ ruminal degradability of king grass (*Blepharidachne kingii*) and mott grass (*Pennisetum* purpureum) in Nili Ravi buffaloes at the University's livestock farm. Rumen-cannulated buffaloes, weighing approximately 400±32 kg, were used for in situ incubation experiments, receiving a standardized diet and access to clean water throughout the study. Grass species selection, including mott grass and king grass, was based on nutritional suitability for grazing animals. The biomass production for king grass and mott grass using the square meter method was noted as 1170g/m^2 and 1130g/m^2. In situ, biodegradation analyses of grass samples were conducted in the rumen over varying incubation periods. The study revealed that mott grass exhibited marginally higher mean digestibility compared to king grass, with peak degradability observed after 96 h of rumen incubation. Conversely, samples incubated for one hour exhibited the lowest degradability, indicating time-dependent variations in ruminal digestion kinetics.

INTRODUCTION

Pakistan's agricultural sector is a cornerstone of its economy, providing approximately 45% of its total manpower and making a 21% contribution to the National GDP. Within this sector, the livestock industry plays a pivotal role, contributing 56% to agricultural value addition and 12% to GDP. This sector significantly impacts poverty alleviation and economic expansion. Milk, considered the white gold of Pakistan, is the primary agricultural commodity. The country hosts a substantial livestock population, including 30 million cattle, 27 million buffaloes, 54 million goats, 27 million sheep, and 1 million camels, predominantly owned by rural and small-scale farmers, numbering over 8 million (Tahir *et al*., 2019).

Pakistan has the world's second-largest buffalo population and has a rich and extensive history of buffalo domestication. Buffaloes play a crucial role in the national economy by providing milk, meat, and draught power, with buffalo milk being highly preferred due to its high-fat content and nutritional value. Different breeds of buffaloes, such as Nili, Ravi, Nili-Ravi, Kundhi, and Azakheli, are found in Pakistan, with the Nili-Ravi breed being prominent. which constitutes about 76.7% of the

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total buffalo population in Pakistan (Anas *et al*., 2023).

Forages are an essential component of the diet of livestock, especially ruminants, given their significant contribution to dietary requirements despite increasing competition with human food resources (Moorby and Fraser, 2021). Studies on perennial grasses from the Cholistan Desert emphasize their value as feed for different types of ruminants. These studies reveal differences in nutritional aspects like dry matter (DM) content and fiber degradation, which affect how easily these grasses can be digested and their suitability for ruminant diets. Various ruminant species derive distinct nutritional advantages from these grasses, highlighting their crucial role in sustaining livestock productivity across different biological environments (Ihsan *et al*., 2020).

King grass (KG) and mott grass (MG) play crucial roles in buffalo feed production, providing unique nutritional advantages and impacting the microbial communities within the rumen. Studies have shown that KG, in particular, boasts higher protein digestibility and supports the increased presence of Proteobacteria in the rumen environment. This contributes significantly to improved animal health and optimizing nutrient utilization (Hendarto and Setyaningrum, 2022). The quality of fermentation and microbial composition in preserved form of KG are greatly influenced by the timing of harvesting which directly affects lactic acid fermentation and the populations of microbes essential for effective digestion (Li *et al*., 2019).

These additives promote the growth of lactic acid bacteria and enhance the production of organic acids thereby improving both the digestibility of the KG and MG in their preserved form as well as the efficiency of fermentation (Das *et al*., 2022). Despite the challenges posed by high fiber and low water-soluble carbohydrate content in KG and MG, using appropriate ensiling practices with suitable additives can significantly optimize the nutritional quality and availability for buffalo diets (Zi *et al*., 2021). Integrating KG and MG into buffalo feed strategies not only enhances digestibility and fermentation quality but also enriches microbial diversity crucial for the optimal digestive health of ruminants.

Aside from the nutritional value of MG, the ensiled form of fodder is known for its complex digestibility dynamics, with significant implications for estimating energy content and optimizing feed efficiency in ruminants (Novoa-Garrido *et al*., 2020; Stone *et al*., 2020). Given the critical role of forages in livestock diets, it's essential for future research to concentrate on boosting the production efficiency and nutritional quality of local fodder varieties such as MG, oats, and sorghum. This requires addressing challenges such as limited production capacities, agronomic inefficiencies, and resource constraints to meet the growing demand for high-quality feed among diverse livestock breeds (Shaheen *et al*., 2020).

Continuous utilization of fodder crops in livestock production has led to declining nutritional values attributed to soil erosion and mineral depletion, exacerbated by the escalating animal population and the resultant scarcity of forage. This study addresses these challenges by evaluating the nutritional content, dry mass yield, and degradability of KG (*Blepharidachne kingii*) and MG (*Pennisetum purpureum*) at various stages, offering insights into sustainable fodder production for livestock. Specifically, the research aims to comprehensively assess the nutritional profile and in situ ruminal digestion kinetics of these grasses in Nili Ravi buffaloes, focusing on parameters such as DM and neutral detergent fiber (NDF) to determine their suitability as feed resources. By evaluating biomass production, the research seeks to understand the potential yield of KG and MG as feed sources, aiming to optimize their utilization in livestock feeding practices and enhance nutrient intake and digestibility in Nili Ravi buffaloes.

MATERIALS AND METHODS

Buffaloes, fodder selection

Two rumen-cannulated buffaloes, weighing approximately 400 ±32 kg, were housed at the University's livestock farm of The Islamia University of Bahawalpur following protocols approved by the University's Animal Care and Management Committee. Buffaloes were fed a standardized diet comprising of KG and MG based on DM at 1.5% of their body weight (BW), having unlimited access to pure water. Grass samples were harvested at the pre-bloom stage to analyze biomass production and nutrient concentration. After a growth period of three months, at least five random samples per replicate were collected using the square meter method. The harvested fodder was cut into pieces, dried in an electric oven at 55°C for 96h and ground in an electric mill grinder to a particle size of 2 mm. Proximate analysis was conducted following AOAC (1990) guidelines, including the determination of NDF.

Morphological analysis of grasses

For morphological analysis, grasses were clipped at vegetative development peak after eight weeks of sowing. Samples were chopped, dried, ground to 2 mm and ground to 1 mm for nutritional analysis. Biomass production of KG and MG was determined by harvesting random samples using the square meter method (Gondal *et al*., 2021).

Experimental design

Two rumen-cannulated buffaloes were kept on a concrete floor for 14 days to adjust, and then they were incubated in nylon bags for 4 days in order to study the kinetics of ruminal digestion. Nylon bags with a porosity of 50 µm were used to incubate samples of king and MG that had been ground to 2 mm using a Wiley mill. After samples were left to ferment for a duration of 0 to 96 h, the bags were cleaned under running water, dried for 48h at 55°C, and then weighed again in preparation for NDF analysis. Digestion coefficients of DM and NDF were determined following procedures by Krizsan *et al*. (2013).

In situ ruminal digestion kinetics

The parameters studied for in situ ruminal digestion kinetics are (1) DM degradability (DMD): this refers to the proportion of DM in a feed sample that is broken down and utilized by the rumen microbes. Higher DM degradability indicates better feed efficiency and nutrient availability (Van Soest *et al*., 1991). (2) Rate of degradation (Kd): Kd represents the fractional disappearance rate of a feed component such as fiber or DM. A higher Kd value indicates a faster breakdown of feed in the rumen leading to improved nutrient absorption and calculated as the method described by Ørskov and McDonald (1979). (3) Effective degradability (ED): This is the proportion of feed component that is actually degraded in the rumen and is a more realistic measure of feed utilization since some nutrients escape the ruminal degradation due to its passage into to lower digestive tract and calculated as method described by Ørskov and McDonald (1979).

Statistical analysis

Data generated from the laboratory trials were analyzed through regression and general linear model (GLM) using SPSS statistics (V.26.0) Whereas, DM Degradability (DMD) and Effective Degradability was determined by the Equation 1, while the rate of degradability was determined by the Equation 2.

$DMD = a + b \times K_d/(K_d + K_p)$ (Ørskov and McDonald, 1979) …(1)

$Yt = a + b(1\text{-}exp(\text{-}Kdt))$ (Ørskov and McDonald, 1979) …(2)

Whereas, K_d is fractional rate of degradation; K_p = Fractional rate of passage; a is washing loss or washable fraction value for washed samples; b is non-washable fraction (potentially degrable).

RESULTS

Biomass production

The biomass production for KG using the square meter method was noted as 1170 g/m^2. KG yielded approximately 118.37 monds per acre when harvested on day-60. This provides us a projected value for the total yield of KG per acre per year is 710.25 monds considering the 6 harvests per year. Similarly, the biomass production for MG using the square meter method was noted as 1130 gm/m^2. The MG yielded approximately 114.32 monds per acre when harvested at day-60. This figure provides us a projected value for the total yield of MG per acre per year is 685.5 monds considering the 6 harvests per year.

Nutritional composition of grasses

Table I shows the DM content and NDF values of KG (*Blepharidachne kingii*) and MG (*Pennisetum purpureum*).

Table I. Nutritional composition of king grass (KG) and mott grass (MG).

Grass name	NDF	DM
KG	58%	15%
MG	63%	17%

NDF, neutral detergent fiber; DM, dry matter.

In situ ruminal digestion kinetics

Table II shows he in situ ruminal digestion kinetics. (i) KG showed a DMD extent of degradation (b) of 69.68 and 73.11 for sample A and B whereas, the MG exhibited 67.15 and 76.08, showing notable variations. (ii) KG had a Kd of 0.0234 and 0.0251 for sample A and B, while MG showed 0.0383 and 0.0386, respectively. (iii) ED48 was 17.55 and 20.3 for sample A and B for KG and 25.4% and 30.6 for MG, respectively. At 96 h (ED96), KG had 23.80% and 26.47% as compared to MG sample A and B that showed 35.91% and 39.26.

In situ dry matter degradability of forages

KG exhibited lower DMD (66.519% vs. 76.663%) and a slower Kd (0.024 vs. 0.038) compared to MG, with effective degradability at 48 h (18.926% vs. 28.065%) and 96 h (25.142% vs. 37.587%) being significantly lower ($p < 0.05$). The coefficient of determination (R^2) values demonstrated a high level of fit for both grasses (0.924 for KG and 0.876 for MG) (Table III).

In situ comparative NDF degradation kinetics of MG and KG

The extent of NDF degradation (b) at 96 h was higher in MG (70.103%) compared to KG (55.238%), indicating a significant species effect ($p < 0.05$). Similarly, MG exhibited a higher Kd (Kd= 0.024) than KG (Kd= 0.004). Effective degradability at both 48 h and 96 h was also greater for MG, highlighting its superior digestibility compared to KG (Table III).

Table II. In situ ruminal degradation parameters of king grass (KG) and mott grass (MG).

	King DMD (A)	King DMD (B)	Mott DMD (A)	Mott DMD (B)	King NDFD (A)	King NDFD (B)	Mott NDFD (A)	Mott NDFD (B)
b	69.682	73.116	67.155	76.085	47.59	54.57	77.841	74.1
Kd	0.0234	0.0251	0.0383	0.0386	0.0021	0.005	0.02	0.028
ED48	17.551	20.3	25.447	30.681	1.5877	4.4239	15.027	23.55
ED96	23.804	26.479	35.91	39.263	2.5637	6.5279	23.0593	29.54
R2	0.9248	0.9233	0.8625	0.8895	0.9458	0.9505	0.9178	0.929

DMD, dry matter degradability; b, extent of degradation; kd, Rate of degradation; ED48, effective degradability at 48h; ED96, effective degradability at 96 h; (R^2), coefficient of determination.

Table III. In situ dry matter degradability (DMG) and in situ neutral detergent fiber (NDF) parameters of forages.

In situ parameters	DM			NDF		
	KG	MG	Effect of grass spp.	KG	MG	Effect of grass spp.
Extent of degradation (b) at 96 h	66.519	76.663	0.967	55.238	70.103	0.399
Rate of degradation (Kd)	0.024	0.038	0.004	0.004	0.024	0.044
Effective degradability at 48 h	18.926	28.065	0.091	3.006	19.290	0.068
Effective degradability at 96 h	25.142	37.587	0.028	4.546	26.303	0.029
Coefficient of determination (R^2)	0.924	0.876	0.070	0.948	0.924	0.063

b96: extent of degradation at 96 h; kd, rate of degradation; ed48, effective DM degradability at 48 h; ed96, effective degradability at 96 h; R^2, coefficient of determination.

DISCUSSION

The present study compared the nutritional profile and in situ ruminal degradability of KG (*Blepharidachne kingii*) and MG *(Pennisetum purpureum*) in Nili Ravi buffaloes. The findings provide critical insights into the potential of these grasses as feed resources for ruminants, particularly buffaloes.

The DM content of MG (17%) was higher than that of KG (15%), while the NDF content was also higher in MG (63%) compared to KG (58%). These findings are in line with the studies conducted by Murillo *et al*. (2015) and Uvidia *et al*. (2015) which highlighted the superior digestibility and degradability of MG (*Pennisetum purpureum*). Similar findings have been reported by Hendarto and Setyaningrum (2022) who stated that high amount of fiber were noted in the KG as compared to lower digestibility components like lower proteins content when compared with the MG whereas, CP, NDF and ADF values were noticed as 21.9%, 62.2% and 27.4%, respectively. Similarly, for *Lolium perenne* the CP, NDF and ADF values were observed as 17.6% 36% and 22%, respectively. These findings underscore the variation in nutritional profiles among different grass species, highlighting their potential applications in animal feed based on specific dietary requirements. The differences in fiber and protein content may influence the digestibility and energy yield of these grasses, making them suitable for different livestock depending on their nutritional needs and feeding strategies.

The findings of our study are different to the results of Tuturoong *et al*. (2023) who reported the NDF value of KG 73.52 compared to our results which is 58% for KG. Similarly, the variation in the DM contents of KG is 15% vs. 20% which could be due to the extreme of weather condition and stage of maturity at the time of harvest. Tuturoong *et al*. (2023) reported the DMD and NDFD contents in T3 treatment (70% KG+30% concentrate) as 60.25% and 56.37% as compared to our results for KG DMD (69-73%) and KG NDFD (54% to 61%). The slight difference in DMD and NDFD contents might be due to the fact that concentrate was added by 30% along KG.

Conversely, KG yields high biomass making it a valuable plant for improved productivity and land use. Integrating KG with high-nutritional-quality forage plants, such as *Tithonia diversifolia, Morus alba,* and others, could enhance production models with higher carrying capacity and adequate nutritional intake levels suitable for small and medium-sized cattle breeder. However, the results of our study are not inline with the findings of

Martínez and González (2017) who evaluated six varieties of *Pennisetum purpureum*, applying 250 kg per hector per year about urea yield, and the recorded generation of biomass was between 14.1 and 38.8 t of DM hector per year that is much higher than the biomass production of our MG yield.

According to another study conducted by Islam *et al*. (2024), the results were close in line with our study as they demonstrated the DMD value for MG as 64% to 78% for MG and our results for MG DMD were 69%. In another study, the MG exhibited a higher extent of DMD (76.663%) at 96 h compared to KG (66.519%). Kd was also higher for MG (0.038) than for KG (0.024). Effective degradability at 48 h (ED48) was significantly higher for MG (28.065%) compared to KG (18.926%), and at 96 h (ED96), MG had an effective degradability of 37.587%, while KG had 25.142%. These findings highlight the superior digestibility of MG over KG making it a more suitable option for livestock requiring faster nutrient release and higher degradation rates. The notable difference in DMD and Kd values suggests that MG can contribute to more efficient rumen fermentation, leading to better energy utilization by ruminants. In contrast, KG, with its relatively lower degradability, may be better suited for scenarios where prolonged digestion and sustained energy release are desirable. These results indicate that MG is more digestible and degrades faster in the rumen than KG, making it a potentially more efficient feed resource for ruminants. Additionally, the DM content of KG has been reported to range from 36% to 61% (Wijitphan and Lowilai, 2011).

According to another study, the digestibility of NDF and acid detergent fiber (ADF) in KG exhibited a total DM yield (TDMY) varying between 65,707.5 to 71,403.1 kg/ha/year. The percentages for ADF and NDF were 41.7-43.5% and 64.6-66.2%, respectively. Contrastingly, Napier grass exhibited a considerable rise in TDMY with longer cutting intervals, showing a range from 5,230.8 to 12,042.0 kg/rai/year. The ADF and NDF levels for Napier grass stood at 41.7-43.2% and 67.0-69.8%, respectively (Wijitphan *et al*., 2009). When comparing KG and MG, KG stands out for its consistently high TDMY, which highlights its potential as a high-yield forage crop for maximizing biomass production. While both grasses show similar ADF values, the NDF content in KG is slightly lower than that in Napier grass, suggesting potentially better digestibility for livestock. Additionally, research conducted on Indigenous forages administered to goats revealed that Mini elephant grass demonstrated superior ADF and NDF digestibility in comparison to Panicum maximum grass, signifying discrepancies in digestibility among diverse grass species (Cardona *et al*., 2016).

The extent of NDF degradation (b) at 96 h was significantly higher for MG (70.103%) compared to KG (55.238%). NDF degradation (Kd = 0.024) of MG was higher than KG (Kd = 0.004). These findings suggest that MG has a higher fiber content and fiber degradability, enhancing its nutritional value for ruminants. These findings align with the previous study (Li and Zhongqing, 2020) emphasizing *Pennisetum purpureum's* superior digestibility and degradability. Similar trends were observed by (Valencia-Echavarria *et al*., 2020) and (Botero-Londoño *et al*., 2021), who highlighted the differences in nutritional contents between KG and other high-quality forage grasses.

Corresponding to our study, Sarwar and Mahr-un-Nisa (1999) conducted the study on MG to evaluate the lag time, rate, and extent of DM and NDF digestion of MG both alone and in combination with barseem (*Trifolium alexandrinum*). Buffalo calves fed MG supplemented with 25% barseem had a higher DM digestibility (64.1%) than calves given MG alone (57.7%). Its greater NDF concentration could be the cause of the decreased MG DM digestion. Calves fed MG in alone showed a lower NDF digestibility as compared to when supplemented with 25% barseem (58.4%).

The DM and NDF of KG was found to be 15% and 58%, respectively, and in close relation to our study, Li *et al*. (2019) stated that KG's high yield and palatability make it a significant feed source for ruminants in tropical and subtropical regions of the world. However, the KG has a stemmy and coarse structure, with high fiber content and low water-soluble carbohydrates (WSC). The KG's use in ruminant cattle production is restricted due to its lower DM and CP contents. In order to improve KG quality, a study conducted on ensiling the KG, sorghum and natural grass revealed that the different forage sources determined the color and the presence of the fungus of the silage, where sorghum-based silage generally showed the best physical characteristics (Tahuk *et al*., 2020).

KG nutritional composition varies with different cutting intervals. As cutting days increase, fiber content increases while CP content and DM digestibility decrease (Sosa-Montes, 2018). Soil availability and fertilizer management play critical roles in biomass production and nutrient uptake (Linares-Gabriel *et al*., 2018). Further research is needed to optimize fertilization strategies based on agro-climatic and soil conditions to maximize yield (Beyene and Batayo, 2021).

Dwarf elephant grass (*Pennisetum purpureum* cv. mott) is highly valued for its nutritional content and palatability to ruminants. It has more protein and digestibility compared to KG, making it a preferred forage option for ruminants (Sangadji *et al*., 2023). Researchers reported that beside fresh fodder, the proper ensilage management, using additives like molasses, may improve the fermentation quality of MG as preserved fodder form by influencing pH levels, organic acid production, and microbial populations, particularly lactic acid bacteria (Lukkananukool *et al*., 2018).

CONCLUSION

Mott grass (*Pennisetum purpureum*) exhibited superior nutritional value, higher digestibility, and greater biomass production with higher dry matter and NDF contents, faster ruminal degradation, and better effective degradability compared to KG (*Blepharidachne kingii*). Future research should explore long-term feeding impacts, different fertilization and harvesting strategies.

DECLARATIONS

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IRB approval

All experimental procedures involving animals were conducted in accordance with the ethical standards and guidelines for the care and use of experimental animals. The study protocol was reviewed and approved by the Institutional Review Board (IRB) / Ethical Committee of Cholistan University of Veterinary and Animal Sciences (CUVAS), Bahawalpur,

Ethical statement

The trial was conducted while complying the standards and ethical consideration set by the Animal Care and Management Committee (LM/ACMC/399).

Generative AI and AI-assisted technology statement

During the writing and preparation of this manuscript, the AI Assisted technology was solely used for the purpose of enhancing grammar, improving sentence clarity, and refining language flow. All content generated or assisted by the AI tool was carefully reviewed, critically edited, and validated by the authors. No generative AI tool was used for data interpretation, scientific analysis, or the generation of original ideas or conclusions.

Statement of conflict of interest

The authors have declared no conflict of interest

REFERENCES

Anas, M., Farooq, M., Asif, M., Ali, W.R. and Mansoor, S., 2023. A novel insight into the identification of potential SNP markers for the genomic characterization of buffalo breeds in Pakistan. *Animal*, **13**: 2543. https://doi.org/10.3390/ani13152543

AOAC International. 2000. *Official Methods of Analysis. 17th ed. Association of Official Analytical Chemists*, Gaithersburg, MD.

Beyene, T.D. and Batayo, T.B., 2021. Review on diversity and socio-economic contribution of home garden agroforestryin Ethiopia. *J. nat. Sci. Res.*, **12**: 21-35.

Botero-Londoño, J.M., Celis-Celis, E.M. and Botero-Londoño, M.A., 2021. Nutritional quality, nutrient uptake and biomass production of *Pennisetum purpureum* cv. King grass. *Sci. Rep.*, **11**: 13799. https://doi.org/10.1038/s41598-021-93301-w

Cardona, E., Rios, J., Peña, J., Peñuela, M. and Rios, L., 2016. King grass: A very promising material for the production of second generation ethanol in tropical countries. *Biomass Bioen.*, **95**: 206-213. https://doi.org/10.1016/j.biombioe.2016.10.008

Das, P., Devalia, B., Shekh, M., Lunagariya, P., Wadhwani, K. and Sarvaiya, N., 2022. Comparison of nutrient intake and digestibility, rumen fermentation along with body weight gain in cattle and buffalo fed maintenance diet. *Indian J. Anim. Sci.*, **92**: 1332-1336. https://doi.org/10.56093/ijans.v92i11.124959

Gondal, M.R., Rizvi, S.A., Riaz, A., Naseem, W., Muhammad, G., Iqbal, M. and Umer, H., 2021. Apposite sowing techniques to optimize productivity and profitability of berseem. *Pak. J. agric. Res.*, **34**. https://doi.org/10.17582/journal.pjar/2021/34.1.128.135

Hendarto, E. and Setyaningrum, A., 2022. Production and king grass nutritional quality number of sources of nitrogen fertilizer. *HighTech Innov. J.*, **3**: 252-266. https://doi.org/10.28991/HIJ-2022-03-03-02

Ihsan, M., Khan, Z., Khan, M., Ahmad, S., Tahir, M. and Lashari, M., 2020. In situ dry matter, protein and neutral detergent fibre degradation kinetics of Cholistan Desert grasses. *S. Afr. J. Anim. Sci.*, **50**: 334-344. https://doi.org/10.4314/sajas.v50i2.17

Islam, M.R., Garcia, S.C., Islam, M.A., Bashar, M.K., Roy, A., Roy, B.K. and Clark, C.E.F., 2024. Ruminant production from Napier Grass (*Pennisetum purpureum* Schum): A review. *Animal*, **14**: 467. https://doi.org/10.3390/ani14030467

Krizsan, S.J., Jančík, F., Ramin, M. and Huhtanen, P., 2013. Comparison of some aspects of the *in situ* and *in vitro* methods in evaluation of neutral detergent fiber digestion. *J. Anim. Sci.*, **91**: 838-847. https://doi.org/10.2527/jas.2012-5343

Li, M., Zi, X., Tang, J., Zhou, H. and Cai, Y., 2019. Silage fermentation, chemical composition and ruminal degradation of king grass, cassava foliage and their mixture. *Grassl. Sci.*, **65**: 210-215. https://doi.org/10.1111/grs.12235

Li, Z. and Zhongqing, O., 2020. *A dynamic analysis of the rotary cutting system of king grass shredder*. E3S Web of Conferences, https://doi.org/10.1051/e3sconf/202014502080

Linares-Gabriel, A., López-Collado, C.J., Hernández-Chontal, M.A., Velasco-Velasco, J. and López-Romero, G., 2018. Application of soil amendments and their effect in the growth of heliconia. *Ornament. Hortic.*, **24**: 248-254. https://doi.org/10.14295/oh.v24i3.1252

Lukkananukool, A., Thammakarn, C., Srikijkasemwat, K., Aung, M. and Kyawt, Y., 2018. Effect of molasses and fermented juice of epiphytic lactic acid bacteria on the fermentation characteristics and nutrient compositions of cassava leaves silage. *Adv. Anim. Vet. Sci.*, **6**: 388-394. https://doi.org/10.17582/journal.aavs/2018/6.9.388.394

Martínez, R. and González, C., 2017. Evaluación de variedades e híbridos de hierba elefante Pennisetum purpureum y *Pennisetum purpureum* x *Pennisetum glaucum* para la producción de forrajes. *Cuban J. agric. Sci.*, **51**: 477-488.

Moorby, J. and Fraser, M., 2021. New feeds and new feeding systems in intensive and semi-intensive forage-fed ruminant livestock systems. *Animal*, **15**: 100297. https://doi.org/10.1016/j.animal.2021.100297

Murillo, R.., Marcheco, E.C., de la Ribera, J.R., Perdomo, G.Á., Perdomo, P.Á., Panta, K.P. and Murillo, A.Á., 2015. Rendimiento y calidad de dos especies del género Pennisetum en Ecuador. *Rev. Electrón. Vet.*, **16**: 1-10.

Nisa, M.U., Touqir, N., Sarwar, M., Khan, M.A. and Akhtar, M., 2005. Effect of additives and fermentation periods on chemical composition and in situ digestion kinetics of mott grass (*Pennisetum purpureum*) silage. *Asian-Australas. J. Anim. Sci.*, **18**: 812-815. https://doi.org/10.5713/ajas.2005.812

Novoa-Garrido, M., Marcos, C.N., Travieso, M.D.C., Alcaide, E.M., Larsen, M. and Weisbjerg, M.R., 2020. Preserving *Porphyra umbilicalis* and *Saccharina latissima* as silages for ruminant feeding. *Animal*, **10**: 1957. https://doi.org/10.3390/ani10111957

Ørskov, E.R. and McDonald, I., 1979. Estimation of protein degradability in the rumen from incubation measurements weighted according to rate of passage. *J. agric. Sci*., **92**: 499-503. https://doi.org/10.1017/S0021859600063048

Sangadji, I., Patty, C.W., Sitorus, J.D. and Kilmanun, N.G., 2023. Effect of different energy sources on silage of dwarf elephant grass (*Pennisetum purpureum* Cv. Mott) on digestibility and rumen fluid fermentation parameters. *J. Penelit. Pend. IPA*, **9**: 7781-7788. https://doi.org/10.29303/jppipa.v9i9.4988

Sarwar, M. and Mahr-un-Nisa, M.U.N., 1999. In situ digestion kinetics of mottgrass (*Pennisetum purpureum*) with or without supplemental legume at two levels by buffalo calves. *Asian-Australas. J. Anim. Sci.*, **12**: 371-375. https://doi.org/10.5713/ajas.1999.371

Shaheen, H., Qureshi, R., Qaseem, M.F. and Bruschi, P., 2020. The fodder grass resources for ruminants: A indigenous treasure of local communities of Thal desert Punjab, Pakistan. *PLoS One*, **15**: e0224061. https://doi.org/10.1371/journal.pone.0224061

Sosa-Montes, E., 2018. Composición química del pasto king grass (*Pennisetum purpureum* Schumach) a diferente intervalo de corte. *Agro Prod.*, **11**: 134-139.

Stone, J., Garcia-Garcia, G. and Rahimifard, S., 2020. Selection of sustainable food waste valorisation routes: A case study with barley field residue. *Waste Biomass Valoriz.*, **11**: 5733-5748. https://doi.org/10.1007/s12649-019-00816-5

Tahir, M.N., Ihsan, M.Z., Siddiqui, M.H., Ul Haque, M.N., Zahra, N., Chattha, W.S. and Bajwa, A.A., 2024. Appraisal of spatial distribution and fibre degradability of cereal–legume fodders to enhance the sustainability of livestock feed supply in sub-tropics. *Sustainability*, **16**: 4070. https://doi.org/10.3390/su16104070

Tahir, M.N., Riaz, R., Bilal, M. and Nouman, H.M., 2019. Current standing and future challenges of dairying in Pakistan: A status update. *Milk Prod. Proc. Market.*, pp. 1-24.

Tahuk, P.K., Bira, G.F. and Taga, H., 2020. *Physical characteristics analysis of complete silage made of sorghum forage, king grass and natural grass*. IOP conference series: Earth and environmental science. https://doi.org/10.1088/1755-1315/465/1/012022

Tuturoong, R.A., Moningkey, S.A. and Ogi, N.L., 2023. Assessment of the nutritive value of complete feed supplemented with corn stover and king grass on Holstein Friesians dairy cattle. *Pakistan J. Zool.*, **55**: 995. https://doi.org/10.17582/journal.pjz/20211213161234

Uvidia, H., Ramírez, J., Vargas, J., Leonard, I. and Sucoshañay, J., 2015. Rendimiento y calidad del *Pennisetum purpureum* vc Maralfalfa en la Amazonía ecuatoriana. *Rev. Electrón. Vet.*, **16**: 1-11.

Valencia-Echavarria, D.M., Giraldo-Valderrama, L.A. and Marín-Gómez, A., 2020. *In vitro* fermentation of *Pennisetum clandestinum* Hochst. Ex Chiov increased methane production with ruminal fluid adapted to crude glycerol. *Trop. Anim. Hlth. Prod.*, **52**: 565-571. https://doi.org/10.1007/s11250-019-02043-5

Van Soest, P.J., Robertson, J.B. and Lewis, B.A., 1991. Methods for dietary fiber, neutral detergent fiber, and nonstarch polysaccharides in relation to animal nutrition. *J. Dairy Sci.,* **74**: 3583–3597. https://doi.org/10.3168/jds.S0022-0302(91)78551-2

Wijitphan, S. and Lowilai, P., 2011. *Effects of cutting interval on yields and nutritive values of King Napier grass (*Pennisetum purpureum *cv. King grass) under irrigation supply*. Warasan Wichai Mokho.

Wijitphan, S., Lorwilai, P. and Arkaseang, C., 2009. Effect of cutting heights on productivity and quality of King Napier grass (*Pennisetum purpureum* cv. King Grass) under irrigation. *Pak. J. Nutr.*, **8**: 1244-1250. https://doi.org/10.3923/pjn.2009.1244.1250

Zi, X., Li, M., Chen, Y., Lv, R., Zhou, H. and Tang, J., 2021. Effects of citric acid and *Lactobacillus plantarum* on silage quality and bacterial diversity of king grass silage. *Front. Microbiol.*, **12**: 631096. https://doi.org/10.3389/fmicb.2021.631096