Nutritional Characterisation of Introduced Improved *Brachiaria* Grasses in Rwanda

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Abstract
A study aimed at characterising nutritive value of introduced *Brachiaria* grasses in Rwanda was conducted. Four *Brachiaria* grasses including, *Brachiaria decumbens* cv. Basilisk, *Brachiaria brizantha* cv. MG4, *Brachiaria brizantha* cv. Piata and *Brachiaria* cv. Cayman with *Panicum coloratum* as control were planted in two contrasting environments of low rainfall in Kirehe district and acidic soils in Nyamagabe district. The experiment was set in a randomized complete block design (RCBD) with four replications and the treatments were harvested after 60 days and 90 days. Data collected were dry matter (DM), crude proteins (CP), organic matter (OM), cellulose, neutral detergent fibre (NDF), acid detergent fibre (ADF) and ash content. Also, *in vitro* gas production was used to estimate metabolisable energy (ME), organic matter digestibility (OMD) and kinetic parameters. The results showed that the DM, CP, NDF, ADF, OM, Cellulose and ash were significant difference ($P<0.05$) among improved *Brachiaria* grasses and increased from 60 to 90 days of harvest except CP which declined with harvesting time. There was significant difference ($P>0.05$) among *Brachiaria* grasses for ME and OMD. Quickly degradable fraction (A) and slowly degradable fraction (B) did differ significantly ($P>0.05$) but rate of degradation (C) varied among species and with harvesting time. Time required producing half of the gas volume ($T_{1/2}$) declined as grasses matured. All improved *Brachiaria* grasses had better nutritional attributes than *Panicum coloratum*. Grasses planted in the low rain-fall had high nutritive values compared to those planted in acid soil prone areas of Rwanda. Nevertheless, the results suggested that improved *Brachiaria* grass could be an alternative forage for dairy farmers in both contrasting environments.

Key words: *In vitro* forage characterisation; improved forages; contrasting environment

Introduction

Livestock is one of the most important agriculture sector in Rwanda. It provides food and improve nutrition, generates income, employment, and is the basis of livelihood of over 68 percent of farmers in Rwanda. It also contributes about 14 percent of national agricultural gross domestic product (NISR, 2019). Despite its significant contribution in Rwandan economy, livestock productivity is low in the region. One of the major factors contributing to low livestock productivity is the inadequate and poor-quality roughages. Therefore, exploration and wider scale cultivation of high yielding and nutritious forage is the most pragmatic option for sustainable increase in livestock productivity in Rwanda. One of the proven options to increase access to high quality forage and enhance livestock productivity is a use of improved *Brachiaria* grass in feeding system. The grass is one of the important tropical forage grasses of African origin. It is widely cultivated in South America and less so in Asia, South Pacific and Australia, and has demonstrated success in transforming beef and dairy industries. It is palatable and nutritious, thus feeding livestock on *Brachiaria* grass significantly increases livestock productivity (Mutimura et al., 2016; 2018). It can also provide several environmental benefits and ecosystem services due to its capability to fix atmospheric carbon into soils, adapted to drought and low fertility soils, and tolerates to pests and diseases. *Brachiaria* grass is considered as climate-smart with multitude of adaptive features to alleviate adversity of climate changes to agriculture and environment. The objective of the study was to evaluate improved *Brachiaria* varieties for adaptation, herbage yield and nutritional values so that it can be integrated into feeding system of livestock farmers in the low rain-fall and acidic soil prone environments of Rwanda.

Materials and methods

Study site

Brachiaria forage trials were established in two contrasting environments, the acidic soil area (Nyamagabe district) and low rain-fall area (Kirehe district). Nyamagabe district is located in the Southern Province (29°56’ E and 2°47’ S). It occupies an area of 1,090 km^2 with an elevation ranging from 1,500 to 2,500 m a.s.l. It receives higher average annual rainfall of 1,636 mm than Kirehe district

(750 mm). However, average annual temperature (16.5°C) in Nyamagabe is lower than in Kirehe district (21°C). Furthermore, the vegetation of Nyamagabe is dominated by *Eragrostis* sp., *Hyparrhenia* sp., *Digitaria* sp. and *Brachiaria decumbens* while Kirehe district is a Savannas woodland with Xerophilous thickets. In addition, soils in Nyamagabe are clayey and acidic with a pH ranging from 4.3 to 4.9. Soils in Kirehe are of sandy loam texture with lower amounts of soil organic matter with a pH > 5.5 (Mutimura and Everson, 2012).

Treatments and Study design

Four improved *Brachiaria* grass cultivars namely, *B. brizantha* cv. Piata, *B. brizantha* cv. MG4*, B. decumbens* cv. Basilisk*, Brachiaria* hybrid cv. Cayman and *Panicum coloratum* (used as control) were planted in Nasho sector of Kirehe district and in Cyanika sector of Nyamagabe district. The experiment was established in a randomized complete block design (RCBD) with four replications. Each plot size was 4 m x 5 m and the space between replication was 1 m. These replicated trials were established at one farm in each district.

Before the trial establishment, soil samples from all farms under trials were collected for soil organic carbon (SOC) and nitrogen (N) determination. The SOC and N were 1.89% and 0.16%, respectively for Nyamagabe while in Kirehe were 1.26% and 0.09%, respectively. Trials were established using vegetative planting materials during the rainy season. Well cured manure was used at the rate of 10 tons per hectare. After the establishment phase, hand hoe was used to remove the weeds from the plots. First harvest was done at 60 days after planting while the second was done after 90 days of age and repeated for two seasons in 2018 and 2019. Herbage from 1 m^2 net harvest area was weighed and a sub-sample of 300 g was taken. One part of the sample was oven dried at 105°C for 24 hours for dry matter determination while other part was oven dried at 60^0C for 48 hours and kept for subsequent analysis.

Chemical composition analysis

Grass samples were taken and procedures to determine the dry matter (DM), crude protein (CP), organic matter (OM), ash, neutral detergent fibre (NDF), acidic detergent fibre (ADF) using AOAC (1995) methods available at the animal nutrition laboratory of Rwanda Agriculture and Animal Resources Development Board (RAB).

***In vitro* gas production**

In vitro gas production was determined by inoculating approximately 200 mg of samples with rumen fluid and buffer solutions (Osuji et al. 1993) in airtight graduated syringes of 100 ml to allow anaerobic fermentation. Rumen fluid was collected from ethically fistulated steers which were kept at RAB, Rubona cattle farm. The steers were fed on Rhodes grass (*Chloris gayana*) with permanent access to water. The mixture was then incubated at 39±1 °C in a water bath. Gas production readings were done at the initial time of incubation and then at every two hours up to 72 hr.

Data from gas production, metabolizable energy and organic matter digestibility were calculated according to Menke et al. (1979; Eq. 1 and 2).

OMD (g/kg DM) = 148.8+8.89G24 +4.5CP+0.651XA Eq. 1

ME (MJ/kg DM) =2.2+0.136G24 + 0.057CP +0.0029CP2 Eq. 2

Where G24 is the gas volume at 24 h after inoculation, CP is crude protein and XA is the ash content (g/100 g).

Kinetics parameters of Brachiaria grass samples were calculated after fitting the data into the model of Schofield et al. (1994; Eq. 3).

$$Y = \frac{G}{1+e^{[2+4c(lt-t)]}} \qquad \text{Eq.3.}$$

Y: Total gas volume at time *t*; *G:* Maximum gas volume at *t*=∞; *c:* Degradation rate (h^{-1}); *lt*: Bacteria colonisation or lag time.

Data analysis

Data on DM, CP, cellulose, NDF, ADF, ASH, ME, OMD as well as kinetic parameters from feed samples were analysed using general linear model procedures of SAS (version 9.4, 2018). Least significant difference (LSD) with significance level of 5% was used for mean comparison.

Results

Figure 1 shows the dry matter (DM) yield of tested grasses. There was a significant difference (P<0.05) between sites and harvesting time and interaction between site and harvesting time. The DM significantly increased from harvest at 60 days and 90 days. Grasses planted at Nyamagabe district had higher DM content than grasses at Kirehe district.

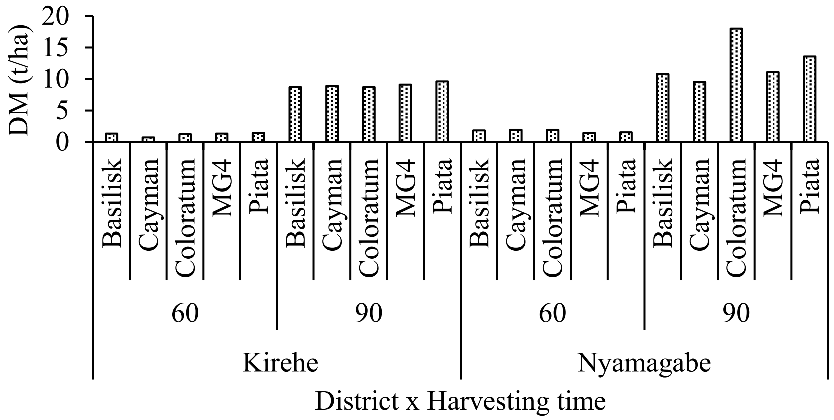

Figure 1: Dry matter production of tested grasses in two contrasting selected sites in Rwanda

Results of chemical composition of tested grasses showed that crude protein (CP) content was different among grass species across sites (P=0.006). However, the CP content declined from 60 to 90 days. Basilisk had the highest CP while *P. coloratum* had the lowest CP. Generally, grasses planted in Kirehe district had higher CP content compared to grasses planted in Nyamagabe district (Table 1).

Natural detergent fibre (NDF) differed significantly among species (P<0.001). The interaction of species and harvest time also differed (P=0.003). *Panicum coloratum* had the highest NDF content (Table 1). The NDF content of *Brachiaria* like other grasses usually increases with maturity, but in Kirehe NDF was slightly decreased in grasses from 60 to 90 days of harvest. Furthermore, acid detergent fibre (ADF) of tested grasses showed significant difference (P=0.012) among species and across sites. *Panicum coloratum* had generally the highest ADF and its increase was observed from 60 days to 90 days (Table 1). In addition, cellulose content in tested grasses also showed significant difference (P=0.012) among species and the interaction of harvest time and site as well. *Panicum coloratum* had the highest cellulose (Table 1). The organic matter (OM) in grasses differed significantly (P<0.001) among species, between sites, as well as between harvesting time. Organic matter of tested grasses increased from 60 days to 90 days of harvest except for *P. coloratum* (Table 1).

The Metabolizable Energy (ME) had slightly significant difference among species (P=0.053) while harvest time was highly significant (P<0.001). Also, sites had a significant effect on ME. Even though grasses planted in Nyamagabe had higher ME than in Kirehe at 60 days, a decrease in ME was observed at 90 days in Nyamagabe but their values were below of grasses planted in Kirehe (Table 1). In addition, organic matter digestibility (OMD) was significantly influenced by harvesting time, sites and the interaction of harvest time and site (P<0.001). There was a decrease of OMD in Nyamagabe district from 60 days to 90 days but increase with time was observed in Kirehe district for *Brachiaria* hybrid cv. Cayman, *Brachiaria brizantha* cv. MG4 and *Brachiaria brizantha* cv. Piata (Table 1).

Table 1: Content (g/Kg of DM) of CP, NDF, ADF, Cellulose, OM, OMD and ME (MJ/kg DM) of *Panicum coloratum* and *Brachiaria* grasses planted in Nyamagabe and Kirehe districts

Site	**DAH**	**Species**	**CP**	**NDF**	**ADF**	**Cellulose**	**OM**	ME	OMD
Kirehe	60	Basilisk	182.7	580.9	311.4	298.2	767.1	5.7	335.4
		Cayman	145.7	617.1	423.3	324.7	756.4	4.2	263.1
		Coloratum	155.2	689.7	448	370.1	808.7	4.9	302.1
		MG4	146.6	629.7	416.3	345.8	761.3	4.7	292.4
		Piata	164.8	605.[1]	381.5	299.6	759.5	5.2	318.5
	90	Basilisk	152	565.2	399.4	256.9	784	4.8	298.7
		Cayman	146.2	549.2	374.2	237.5	786.9	4.9	303.3
		Coloratum	101.9	643.9	500.9	334.8	800.4	4.2	278.2
		MG4	133.9	612	454.9	281.5	772.4	5.0	317.1
		Piata	144.6	576	406.9	263.7	792.3	5.6	352.9

Nyamagabe	60	Basilisk	198.7	471.9	366.2	255.6	759.1	6.1	348.8
		Cayman	174.5	549.3	363.1	273.9	776.9	5.8	347.1
		Coloratum	161.9	672.7	390.4	289.4	854.4	5.3	318.3
		MG4	191.2	550.9	376.6	221.8	775.3	5.8	338.7
		Piata	177.2	540.9	364.5	260.6	790	5.6	332.1
	90	Basilisk	80.3	656.9	346.1	296.9	823.7	3.3	220
		Cayman	86	649.7	358.8	306.4	802.2	3.3	221.5
		Coloratum	60.1	684.3	399.1	337.3	847.7	3.1	211.8
		MG4	109.6	659.9	439.6	270.1	776.6	3.7	240.3
		Piata	82.6	674	391.1	300.6	816.6	3.3	217.8
Level of Significance	Sp		0.006	<0.001	0.012	0.012	<0.001	0.053	0.112
	DAH		<0.001	0.003	0.14	0.632	0.004	<0.001	<0.001
	Site		0.008	0.721	0.041	0.08	<0.001	0.005	<0.001
	Sp*DAH		0.204	0.077	0.577	0.889	0.139	0.174	0.248
	Sp*Site		0.229	0.847	0.548	0.171	0.418	0.158	0.128
	DAH *Site		<0.001	<0.001	0.596	<0.001	0.666	<0.001	<0.001
	Sp*DAH*Site		0.78	0.355	0.538	0.959	0.61	0.378	0.352

DAH: Harvesting time; Sp: Forage species

***In vitro* gas kinetics parameters of the grasses**

There was significant difference ($P>0.05$) for gas production (GP), faster degradable fraction (A) and slowly degradable fraction (B) among species, across sites and harvest time, as well as their interactions (Table 2). The rate of degradation (C) differed ($P<0.05$) among species, harvesting time, interaction between species and harvest time, as well as interaction species-harvesting time-sites. There was an increase of C from 60 days to 90 days for grasses harvested in Kirehe district while a decrease was observed in Nyamagabe district (Table 2). In addition, time required to produce half of gas volume ($T_{1/2}$) differed significantly ($P=0.003$) with the harvest time. Harvesting grasses after 90 days led to higher half time than harvest at 60 days and *Brachiaria brizantha* cv Piata had the shortest $T_{1/2}$ (Table 2).

Table 2: In vitro digestion parameters including, GP (ml/g DM), A (g/kg DM), B (g/kg DM), C (%/h) and $T_{1/2}$ (h) of grasses planted in Nyamagabe and Kirehe districts harvested at 60 and 90 days

Site	**DAH**	**Species**	**GP**	**A**	**B**	**C**	**$T_{1/2}$**
Kirehe	60	Basilisk	60.1	0	67.0	0.021	28.2
		Cayman	99.2	0	11.9	0.021	26.1
		Coloratum	27.0	0	35.6	0.028	27.8
		MG4	17.9	0	54.8	0.032	24.6
		Piata	37.6	0.1	38.0	0.026	34.1
	90	Basilisk	57.5	0	52.5	0.02	51.9
		Cayman	21.8	0.0	23.7	0.032	26.6
		Coloratum	27.2	0.4	27.1	0.022	38.5
		MG4	18.4	0.2	20.1	0.031	23.1
		Piata	24.4	0	25.6	0.036	21.1
Nyamagabe	60	Basilisk	20.9	0.8	20.3	0.031	22.9
		Cayman	22.6	0	87.0	0.035	19.8
		Coloratum	16.0	0.8	15.8	0.041	20.1
		MG4	19.8	0.5	19.7	0.034	22.9
		Piata	14.6	0.4	24.7	0.037	17.9
	90	Basilisk	7.7	0	112.4	0.015	62.1
		Cayman	36.5	0.48	37.8	0.016	56
		Coloratum	29.9	0.46	31.0	0.013	59.4
		MG4	64.4	7.6	41.3	0.014	40.7
		Piata	90.0	0	55.5	0.017	19.30
Level of Significance	Sp.		0.7834	0.4529	0.3905	0.0277	0.1474
	DAH		0.7757	0.4039	0.6325	<0.0001	0.0033
	Site		0.5059	0.1888	0.4205	0.2665	0.4086
	Sp*DAH		0.445	0.4363	0.6126	0.0424	0.1293

Sp. *Site	0.3225	0.469	0.5207	0.1074	0.6662
Sp.*DAH*Site	0.2475	0.525	0.2494	<0.0001	0.2745

DAH: Harvesting time; Sp: Forage species

Discussion

The DM significantly increased from harvest at 60 days and 90 days. Grasses planted in Nyamagabe district where soils are low in pH and high in aluminium toxicity and high rainfall had higher dry matter content than grasses planted in Kirehe district. This shows that tested grasses tolerate poor soils and that the water availability influence on dry matter content. Soil, water availability, climate, and plant species are among factors that influence plants nutritive value and composition (Andueza et al. 2010). The high DM of grasses in Nyamagabe could have been influenced by the high rainfall, as the organic fertiliser had been added to improve soil fertility in both sites.

The CP content declined from 60 to 90 days and this implies that early harvest leads to higher CP. Basilisk had the highest CP while *P. coloratum* had the lowest CP content. Generally, grasses planted in Kirehe district had higher CP content compared to grasses planted in Nyamagabe district. It is worthy to mention that *B. decumbens* cv. Basilisk had the highest CP and it might be due to its ability to resist drought and acidic soils. *Brachiaria* grasses tested had a relatively high CP content at 60 days of harvest which makes them a reliable source of proteins to lactating cows and growing heifers (Mutimura et al. 2016). Furthermore, the NDF content of *Brachiaria* like other grasses usually increases with maturity, but in Kirehe NDF was slightly decreased in grasses from 60 to 90 days of harvest. This could be explained that after harvesting at 60 days, the regrowth was not fast, thus lowering the NDF content. In addition, the ADF content of *Brachiaria* grass was below that of *P. coloratum* (311.4 – 454 g/kg DM). These results were in same range with results reported by Heuzé et al. (2017). This shows that *Brachiaria* could be a better fodder that supplies high energy to a ruminant livestock than *Panicum*. Furthermore, OM content of tested grasses increased from 60 days to 90 days of harvest except for *P. coloratum.* The increase in OM based at 90 days of harvest was also reported by Mutimura et al. (2017) in *Brachiaria* grasses planted on-farm in semi-arid area of Rwanda. The increase of OM with age of the grass might be due to the fact that grass matures and water decreased.

The ME decreased with age of the plants and however, it was higher in Nyamagabe than Kirehe but all had ME below 6.9 MJ/kg reported by Mutimura et al. (2017). However, all *Brachiaria* had the highest ME compared to *Panicum*. This implies that, *Brachiria* could supply more ME than *Panicum*, thus increase ruminant livestock production. Furthermore, *Brachiaria* grasses had a better OMD than *P. coloratum.* There was a decrease in OMD of grasses in Nyamagabe district from 60 days to 90 days but increase with time was observed in Kirehe district for *Brachiaria* hybrid cv. Cayman, *Brachiaria brizantha* cv. MG4 and *Brachiaria brizantha* cv. Piata. The reasons of the decrease of OMD in grasses planted Nyagamabe might be due to the high NDF which can slow the degradability of the grasses by the rumen microbes.

Better rate of degradation (C) was observed in grasses planted in Nyamagabe. The reason might the fact that the grass also had low NDF which could allow rumen microbes to degrade fast the grasses. Aditionally, the time to produce half of gas ($T_{1/2}$) differed also between harvesting time. This might be due to low ADF, NDF and high CP of grasses harvested at 6o days that allow microbes to degrade fast the grasses in the rumen. *Brachiaria* grass cultivars established at on-farm showed discrepancies in terms of nutritional values and biomass production. Piata had high biomass and nutritive values compared to other grasses at both 60 and 90 days of harvest.

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