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# Intake and Digestibility of Native and Exotic Grasses Fed *Ad libitum* to Djallonke Sheep in South Benin

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**Abstract:** Native (*Andropogon gayanus*, *Panicum maximum* and *Pennisetum purpureum*) and exotic grasses (*Brachiaria ruziziensis*, *Panicum maximum* cv. C1 and T58) consumed in tropical humid zone were evaluated by estimating their voluntary intake and *in vivo* digestibility. The measurements were performed with 4 male Djallonke sheep (28 kg LW) fed *ad libitum* in metabolic cages, during a 10-days *in vivo* trial, preceded by a 14-days accommodation period. Each grass was studied at 3 stages of development. The samples (distributed grasses, refusals and faeces) were analysed for organic matter (OM), crude fibre (CF), neutral detergent fibre (NDF), acid detergent fibre (ADF), acid detergent lignin (ADL) and crude protein (CP) contents. Voluntary digestible organic matter intake (VDOMI) and voluntary digestible crude protein intake (VDCPI) were calculated (in g $kg^{-1}$ $LW^{0.75}$) as synthetic parameters to compare the grasses. The chemical composition of the distributed forages varied significantly ($P < 0.001$) between species or cultivars and development stages. After 4-5 leaves per tiller stage**,** CP contents decreased in all species and lowest in native species. *Andropogon gayanus* was the most lignified species at any stage of development. At the end of the rainy season, *Pennisetum purpureum* leaves and *Brachiaria ruziziensis* had the highest CP. For all the grasses, CP contents were higher (and CF contents lower) in the consumed material, compared to the offered forages, showing thereby the high selectivity by the sheep. Dry matter intake, OM and CP digestibility varied greatly ($P < 0.001$) between forages and development stages with high interactions between these factors ($P < 0.001$). Voluntary digestible organic matter intake and VDCPI were the highest ($P < 0.05$) for native *Panicum maximum* and *Pennisetum purpureum*. There was a relationship between digestibility and intake parameters, and ADL content of the grasses seems to be an important factor determining at least digestibility.

**Key words:** Tropical grasses, intake, digestibility, Djallonke sheep, humid tropics.

## 1. Introduction

In South Benin, the rainy season extends from March to October, with lower rainfall during August (short dry season). The long dry season lasts 4 months, from November to February, and the mean annual rainfall is about 1300 mm. Bush fallow and natural savannah are the major feed sources for sheep and goats, which are an important component of the farming systems in this region. They provide flexible incomes for the smallholders and have also religious and cultural roles [1-3]. In the traditional free-range system, the small ruminants (2-4 per household) grow very slowly because they graze on low quality pastures or fallow, especially during the long dry season [4, 5]. Research conducted on fodder crops or pastures in South Benin has focused mainly on adapted exotic grasses or legumes, by studying their productivity, chemical composition and theoretical nutritive value under different conditions [6, 7]. Until now, the advice

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given to local development organisations or farmers mainly concern the adaptability and the productivity of several native or exotic grasses. No studies have been carried out on intake and nutritive value of these forages for local small ruminants.

*In vivo* digestibility organic matter is one of the most important characteristics used to evaluate feed nutritional quality [8]. However, in the tropics, *in vivo* digestibility cannot be use as sole selection criterion to dress a nutritive value index of forage resources. Variation in voluntary intake is also a major dietary factor determining level and efficiency of ruminant production, especially when animal may select their feed during grazing [9-11]. As in South Benin and in other humid regions of Africa, the availability of forage is not a real constraint in pastures, measurements and improvement of both intake and digestibility of forages could help to increase the productivity of small ruminant breeds and thereby smallholder's incomes.

The aim of this study was to characterise intake and digestibility of native and exotic grasses well adapted to the environment of South Benin, in as close as possible to those prevailing when ruminants are fed *ad libitum* or selecting their diet when grazing improved pastures.

## 2. Materials and Methods

### *2.1 Species and Fodder Crops*

The experiment was conducted at the University of Abomey-Calavi (Benin). The fodder crops used in the digestibility trials were established on a typical sandy and poorly structured ferruginous soil, with low concentrations of organic matter, N and P [8].

Native (*Andropogon gayanus*, *Panicum maximum*, *Pennisetum purpureum*) and exotic (*Brachiaria ruziziensis*, *Panicum maximum* cvv. C1 and T58) grasses were established in 20 m × 5 m plots (5 plots per species or cultivar). Measurements on animals were made during the rainy season. Before each digestibility trial, the 5 plots of each grass or cultivar were divided into 25 sub-plots of 20 $m^2$, which were successively cut at 1-day intervals in order to strictly maintain the same development stage during adaptation and measurement periods. After each harvest, the plots received 25 kg/ha N in the form of urea to promote the regrowth of the grasses.

During the experimental periods, grasses and cultivars were cut and sampled at three growing stages as follows: 3-4 and 4-5 leaves per tiller for *Andropogon gayanus*, *Panicum maximum* (native and improved cultivars) and *Brachiaria ruziziensis*; 8-9 or 12-17 leaves for *Pennisetum purpureum*; and the flowering stage for all species, except *Pennisetum purpureum,* which was harvested just before flowering.

### *2.2 Digestibility Trials and Laboratory Analyses*

A total of 18 digestibility trials were conducted using West African Dwarf male sheep (28 ± 0.4 kg liveweight) treated for intestinal parasites (Vermitan) and trypanosomiasis (Berenil). These sheep are widely reared in South Benin. The digestibility trials were performed on several groups of 4 sheep. For each vegetative stage of six plants the measurements are made successively.

For each intake and digestibility measurements, the fresh material was daily cut 10-15 cm above ground level for the erected grasses, 30-40 cm for *Pennisetum purpureum* (without stems) and 6-10 cm for *Brachiaria ruziziensis*. After chopping (4-6 cm length), the fresh forages were distributed systematically at 9 a.m. and 16 p.m. to 4 sheep maintained in metabolism cages and randomly affected to each studied forage. Intake and digestibility were recorded over 10-day periods, which followed 14-day preliminary periods. During the collection periods, animals received mineral salt blocks and fresh water *ad libitum*. The forages were daily distributed respecting a rate of refusals of 25%-30% at the stage 3-4 leaves and 35%-40% for the other stages of development. These rates of refusals were fixed according to previous observations on Djallonke sheep grazing a mixed pasture of *Panicum maximum* and *Brachiaria ruziziensis* in South Benin [12].

For each intake and digestibility trial, 10% of the distributed forages and 20% of the refusals and faeces were daily sampled, pooled separately in strong plastic bags and frozen at -18 ℃. At the end of the experiments, the samples were defrosted at ambient temperature, oven-dried for 48 h at 60 ℃, ground to pass a 1 mm screen (FOSS Electric A/S, Hilleroed, Denmark). Dry matter (DM, 105 ℃ for 24 h, AOAC 967.03 method), organic matter (OM, AOAC 923.03) and Kjeldahl nitrogen (N, AOAC 981.10) were determined according to standard methods [13]. Crude protein (CP) concentration was computed as N concentration × 6.25. Crude fibre (CF) was analysed following the method of J.T. Kim [14]. Neutral detergent fibre (NDF), Acid detergent fibre (ADF) and Acid detergent lignin (ADL) was determined according to the method of Van Soest et al. [15].

Voluntary intakes of digestible OM or CP (VDOMI and VDCPI in g $kg^{-1}$ $LW^{0.75}$) were calculated by multiplying intake (g $kg^{-1}$ $LW^{0.75}$) by OM or CP contents and the digestibility coefficients of the consumed forages.

*2.3 Statistical Analyses*

Because some intake and digestibility coefficients of the targeted grasses were highly correlated, a multivariate analysis of variance was used [16] to compare grass species and their stages of development. The model considered for the multivariate analysis is partial nested with factor “sheep” nested to the interaction “species × stage. We used the Wilks lambda statistic for the multivariate test [16].

Some coefficients were excluded from the analysis because they have the same values for all the sheep feeding a grass species at a given stage. They were excluded from the analysis to avoid redundancy that biased the results. For these variables (DM, ADL, OMD, VDOMI and VDCPI), we performed simple ANOVA to compare the grass species according to the intake and digestibility coefficients.

From the results of the multivariate analysis, we noticed that the interaction between species and stage was highly significant. We then created a variable *eij*, *i* being the species number (*i* = 1, 2, 3, 4, 5, 6) and *j* the stage number (*j* = 1, 2, 3). We determined intake and digestibility coefficients that most discriminated grass species at each stage (*eij*), using the stepwise canonical discriminant analysis [17]. The most discriminant coefficients were used in factorial discriminant analysis [16] to describe differences between grass species at each stage of development. Pearson’s correlation coefficients and linear regressions were also used to determine the relationships between intake and digestibility and chemical composition coefficients. For each models of predicting intake and digestibility the normality and homoscedasticity of the residuals as well as the highest coefficients of determination ($R^2$) and the residual standard deviation (RSD) were compared in the validation process.

## 3. Results

The chemical compositions of the forages distributed to the sheep during the digestibility trials are presented in Table 1. The different grasses cover a wide range of morphology and growth characteristics. Therefore, the chemical composition of the distributed materials fluctuates largely between grasses and development stages. Crude protein (CP) varied widely ($P < 0.001$) between development stages, but did not show any significant difference between species. At flowering, CP concentrations showed considerable reductions which were accompanied by net increases in ADL contents, especially in *Panicum maximum* and *Andropogon gayanus*). Neutral detergent fibre (NDF) contents were systematically higher in *Panicum maximum* cv. C1. On the contrary, *Brachiaria ruziziensis* and *Pennisetum purpureum* were relatively poor in fibre. *Brachiaria ruziziensis* had the lowest NDF contents. The ADL contents were the highest in *Andropogon gayanus*.

**Table 1 Dry-matter (DM in %) and chemical composition (g kg$^{-1}$) of the studied grasses.**

| Species | Stages | DM | OM | CP | CF | NDF | ADF | ADL |
|---|---|---|---|---|---|---|---|---|
| *Panicum maximum* | 3-4 leaves | 27 | 915 | 156 | 306 | 657 | 371 | 28 |
| | 4-5 leaves | 35 | 911 | 84 | 309 | 709 | 383 | 33 |
| | Flowering | 24 | 915 | 83 | 348 | 727 | 409 | 70 |
| Mean | | 28.7 $^{A}$ | 914 $^{B}$ | 108 $^{A}$ | 321 $^{AB}$ | 698 $^{AB}$ | 388 $^{A}$ | 44 $^{AB}$ |
| SD | | 5.7 | 2 | 42 | 23 | 36 | 19 | 23 |
| *Pennisetum Purpureum* | 8-9 leaves | 22.0 | 909 | 158 | 290 | 625 | 335 | 27 |
| | 12-17leaves | 19.0 | 911 | 146 | 332 | 659 | 336 | 29 |
| | Flowering$^{+}$ | 24.0 | 928 | 106 | 341 | 702 | 381 | 51 |
| Mean | | 21.7 $^{B}$ | 916 $^{B}$ | 137 $^{A}$ | 321 $^{AB}$ | 662 $^{C}$ | 351 $^{BC}$ | 36 $^{B}$ |
| SD | | 2.5 | 10 | 27 | 27 | 39 | 26 | 13 |
| *Andropogon Gayanus* | 3-4 leaves | 23.6 | 942 | 158 | 281 | 669 | 339 | 41 |
| | 4-5 leaves | 33.0 | 951 | 85 | 287 | 700 | 369 | 58 |
| | Flowering | 33.0 | 950 | 84 | 308 | 727 | 396 | 78 |
| Mean | | 29.7$^{A}$ | 948 $^{A}$ | 109 $^{A}$ | 292 $^{B}$ | 699 $^{AB}$ | 368 $^{AB}$ | 59 $^{A}$ |
| SD | | 5.4 | 5 | 42 | 14 | 29 | 29 | 19 |
| *Brachiaria ruziziensis* | 3-4 leaves | 17.0 | 874 | 163 | 278 | 615 | 308 | 32 |
| | 4-5 leaves | 21.0 | 939 | 126 | 296 | 625 | 346 | 33 |
| | Flowering | 18.0 | 931 | 111 | 301 | 668 | 353 | 47 |
| Mean | | 18.7$^{B}$ | 915 $^{B}$ | 133 $^{A}$ | 292 $^{B}$ | 636 $^{D}$ | 336 $^{C}$ | 37 $^{B}$ |
| SD | | 2.1 | 35 | 27 | 12 | 28 | 24 | 8 |
| *Panicum maximum* cv. C1 | 3-4 leaves | 32.0 | 915 | 141 | 322 | 702 | 360 | 27 |
| | 4-5 leaves | 26.0 | 921 | 105 | 357 | 725 | 362 | 44 |
| | Flowering | 27.0 | 928 | 99 | 361 | 743 | 414 | 50 |
| Mean | | 28.3$^{A}$ | 921 $^{B}$ | 115 $^{A}$ | 347 $^{A}$ | 723 $^{A}$ | 379 $^{A}$ | 40 $^{B}$ |
| SD | | 3.2 | 7 | 23 | 21 | 21 | 31 | 12 |
| *Panicum maximum* cv. T 58 | 3-4 leaves | 25.0 | 913 | 152 | 319 | 655 | 370 | 31 |
| | 4-5 leaves | 31.0 | 907 | 109 | 320 | 666 | 373 | 53 |
| | Flowering | 15.0 | 927 | 103 | 376 | 714 | 423 | 62 |
| Mean | | 22.8$^{B}$ | 917 $^{B}$ | 119 $^{A}$ | 342 $^{A}$ | 682 $^{BC}$ | 392 $^{A}$ | 50 $^{B}$ |
| SD | | 8.1 | 10 | 27 | 33 | 31 | 30 | 16 |
| Source of variation | DF | | | | | | | |
| Species | 5 | *** | *** | NS | ** | *** | *** | * |
| Stages | 2 | ** | *** | *** | ** | *** | *** | *** |

$^{+}$ Just before flowering, FM: fresh materials, DF: Degree of freedom, SD: standard deviation, ns: non significant. * $P < 0.05$; ** $P < 0.01$; *** $P < 0.001$, NS : not significant; Within columns and for each species, means followed by the same upper-case letters are not significantly different ($P > 0.05$).

Selectivity (in term of CP and CF) and dry-matter intake (DMI) by the sheep are presented in Table 2. Significant differences between development stages and species as well as significant interactions ($P < 0.001$) between these two factors were observed for crude protein or crude fibre selectivity and voluntary DMI. Generally, the differences between CF contents in distributed and ingested forages were the highest ($P < 0.001$) at the flowering stage. Consequently, the DMI was the lowest at this stage of development, especially for *Andropogon gayanus* and *Panicum maximum* cv. T58. An exception to this general rule was observed for *Brachiaria ruziziensis*: DMI increase of 10 g between 3-4 and 4-5 leaves per tiller stages or flowering stage. On average, the lowest DMI were recorded for *Andropogon gayanus*, *Panicum maximum* cv. T 58 and

**Table 2 Selectivity (in term of CP and CF) and dry-matter intake (DMI) for the different grasses.**

| Species | Stages | CP (i-d) [1] g kg$^{-1}$ DM | CF (i-d) [2] g kg$^{-1}$ DM | DMI g kg$^{-1}$LW $^{0.75}$ |
|---|---|---|---|---|
| *Panicum Maximum* | 3-4 leaves | 14 $^{b3}$ | -9 $^{b}$ | 71 $^{a}$ |
| | 4-5 leaves | 5 $^{c}$ | -7 $^{b}$ | 71 $^{a}$ |
| | Flowering | 33 $^{a}$ | -57 $^{a}$ | 46 $^{b}$ |
| Mean | | 18 $^{A4}$ | -26 $^{A}$ | 63 $^{A}$ |
| SD | | 13 | 25 | 14 |
| *Pennisetum Purpureum* | 8-9 leaves | 15 $^{a}$ | -13 $^{ab}$ | 66 $^{a}$ |
| | 12-17 leaves | 5 $^{b}$ | -4 $^{b}$ | 56 $^{b}$ |
| | Flowering$^{+}$ | 16 $^{a}$ | -24 $^{a}$ | 54 $^{b}$ |
| Mean | | 12 $^{B}$ | -14$^{BC}$ | 59$^{B}$ |
| SD | | 6 | 13 | 6 |
| *Andropogon Gayanus* | 3-4 leaves | 10 $^{b}$ | -15 $^{a}$ | 60 $^{a}$ |
| | 4-5 leaves | 10 $^{b}$ | - 4 $^{b}$ | 57 $^{a}$ |
| | Flowering | 22 $^{a}$ | - 16 $^{a}$ | 34 $^{b}$ |
| Mean | | 14 $^{AB}$ | -9 $^{C}$ | 50 $^{C}$ |
| SD | | 6 | 11 | 14 |
| *Brachiaria Ruziziensis* | 3-4 leaves | 16 $^{a}$ | -16 $^{a}$ | 45$^{b}$ |
| | 4-5 leaves | 14 $^{a}$ | -32 $^{a}$ | 55$^{a}$ |
| | Flowering | 7 $^{b}$ | -25 $^{a}$ | 54$^{a}$ |
| Mean | | 12 $^{B}$ | -24 $^{A}$ | 51$^{C}$ |
| SD | | 5 | 10 | 5 |
| *Panicum maximum* cv.C1 | 3-4 leaves | 23 $^{a}$ | -19 $^{a}$ | 71$^{a}$ |
| | 4-5 leaves | 20 $^{a}$ | -14 a | 58$^{b}$ |
| | Flowering | 1 $^{b}$ | -19 $^{a}$ | 49$^{c}$ |
| Mean | | 17$^{AB}$ | -17 $^{B}$ | 60$^{B}$ |
| SD | | 8 | 8 | 11 |
| Panicum *maximum* cv.T58 | 3-4 leaves | 22 $^{a}$ | -5 $^{b}$ | 71 $^{a}$ |
| | 4-5 leaves | 1 $^{b}$ | -11 $^{b}$ | 62 $^{b}$ |
| | Flowering | 20 $^{a}$ | -25 $^{a}$ | 30 $^{c}$ |
| Mean | | 15 $^{AB}$ | -15 $^{BC}$ | 54 $^{C}$ |
| SD | | 13 | 10 | 22 |
| Source of variation | DF | | | |
| Species | 5 | * | *** | *** |
| Stages | 2 | *** | *** | *** |
| Species × stages | 10 | *** | *** | *** |

[1] CP contents in ingested forage–CP contents in distributed forage; [2] CF contents in ingested forage–CF contents in distributed forage; [+] Just before flowering, DF: degree of freedom, SD: standard deviation, ns: non significant.* $P < 0.05$; ** $P < 0.01$; *** $P < 0.001$; [3] Within columns and for each stage, means followed by the same lower-case letters are not significantly different ($P > 0.05$); [4] Within columns and for each species, means followed by the same upper-case letters are not significantly different ($P > 0.05$).

*Brachiaria ruziziensis* (50-54 g kg$^{-1}$ LW$^{0.75}$) and the best DMI was recorded with the local accession of *Panicum maximum* (63 g kg$^{-1}$ LW$^{0.75}$).

Digestibility coefficients and voluntary digestible intakes of the grasses are presented in Table 3. *Brachiaria ruziziensis* and *Pennisetum purpureum* presented the highest OM digestibility coefficients. Except for *Andropogon gayanus*, there is no significant difference between the CPD of the different species. The lower mean CPD recorded for this species is mainly linked to a net decrease of this coefficient at flowering stage (46%). A classification of the species or cultivars based on VDOMI and VDCPI showed significantly higher ingestion for native *Panicum*

**Table 3 OM (OMD) and CP (CPD) and CF (CFD) digestibility coefficients and voluntary digestible OM (VDOMI) and CP (VDCPI) intakes of the grasses.**

| Species | Stages | OMD | CPD | CFD | VDOMI | VDCPI |
|---|---|---|---|---|---|---|
| *Panicum maximum* | 3-4 leaves | 71 [a1] | 83 [a] | 69 [a] | 46 [a] | 10 [a] |
| | 4-5 leaves | 70 [a] | 78 [b] | 62 [b] | 46 [a] | 5 [b] |
| | Flowering | 52 [b] | 75 [c] | 54 [c] | 22 [b] | 4 [c] |
| Mean | | 64 [B2] | 79 [A] | 62 [B] | 38 [A] | 6 [A] |
| SD | | 10 | 4 | 7 | 14 | 3 |
| *Pennisetum Purpureum* | 8-9 leaves | 75 [a] | 79 [a] | 75 [a] | 45 [a] | 9 [a] |
| | 12-17 leaves | 66 [b] | 78 [a] | 64 [b] | 34 [b] | 6 [b] |
| | Flowering[+] | 65 [b] | 70 [b] | 60 [c] | 33 [b] | 5 [c] |
| Mean | | 69 [A] | 76 [A] | 67 [A] | 37 [A] | 7 [A] |
| SD | | 5 | 5 | 8 | 7 | 2 |
| *Andropogon gayanus* | 3-4 leaves | 66 [a] | 77 [a] | 64 [a] | 37 [a] | 8 [a] |
| | 4-5 leaves | 63 [a] | 65 [b] | 46 [b] | 36 [a] | 3 [b] |
| | Flowering | 38 [b] | 46 [c] | 43 [b] | 12 [b] | 1 [c] |
| Mean | | 56 [D] | 63 [B] | 51 [C] | 28 [C] | 4 [C] |
| SD | | 15 | 16 | 11 | 14 | 3 |
| *Brachiaria ruziziensis* | 3-4 leaves | 71 [a] | 81 [a] | 71 [a] | 28 [c] | 7 [a] |
| | 4-5 leaves | 70 [a] | 80 [a] | 67 [b] | 37 [a] | 6 [b] |
| | Flowering | 65 [b] | 70 [b] | 65 [b] | 33 [b] | 4 [c] |
| Mean | | 69 [A] | 77 [A] | 68 [A] | 32 [B] | 6 [B] |
| SD | | 3 | 6 | 3 | 4 | 1 |
| *Panicum maximum* cv.C1 | 3-4 leaves | 75 [a] | 88 [a] | 74 [a] | 49 [a] | 11 [a] |
| | 4-5 leaves | 63 [b] | 76 [b] | 63 [b] | 34 [b] | 5 [b] |
| | Flowering | 60 [b] | 66 [c] | 61 [c] | 28 [c] | 4 [c] |
| Mean | | 66 [AB] | 77 [A] | 66 [A] | 37 [A] | 6 [A] |
| SD | | 8 | 11 | 7 | 11 | 4 |
| Panicum *maximum* cv.T58 | 3-4 leaves | 66 [a] | 83 [a] | 66 [a] | 43 [a] | 10 [a] |
| | 4-5 leaves | 64 [a] | 80 [a] | 63 [b] | 36 [b] | 5 [b] |
| | Flowering | 51 [b] | 70 [b] | 58 [c] | 14 [c] | 3 [c] |
| Mean | | 60 [C] | 78 [A] | 62 [B] | 31 [B] | 6 [B] |
| SD | | 8 | 7 | 4 | 15 | 4 |
| Source of variation | DF | | | | | |
| Species | 5 | *** | *** | *** | *** | *** |
| Stages | 2 | *** | *** | *** | *** | *** |
| Species × stages | 10 | *** | *** | * | *** | *** |

DF: Degree of freedom, SD: standard deviation, ns: non significant. * $P < 0.05$; ** $P < 0.01$; *** $P < 0.001$. [+]just before flowering; [1]Within columns and for each stage, means followed by the same lower-case letters are not significantly different ($P > 0.05$); [2]Within columns and for each species, means followed by the same upper-case letters are not significantly different ($P > 0.05$).

*maximum*, *Pennisetum purpureum* and introduced *Panicum maximum* cv. C1. The VDOMI and VDCPI were the lowest in native *Andropogon gayanus*.

Results of multivariate analysis of variance on the intake and digestibility coefficients presented in Table 4 indicate a high significant effect of the interaction “species × stages”. Moreover, high significant effect of each of the two factors (species and stage) was also observed on the intake and digestibility coefficients. Since the interaction between the two factors is significant, a factor treatment that is related to the combinations of the levels of species and stages, $e_{ij}$, was considered and the stepwise discriminant analysis that was performed identified VDCPI, CPD, CFD, DMI, OMD, VDOMI, as the most discriminant coefficients of the species × stage levels (Table 5).

Results of canonical discriminant analysis on the most discriminant coefficients for the species × stage levels indicate that the first two axes controlled 86.1% on the information on the coefficients and were all significant ($P < 0.001$). Table 6 indicates that the first axis is positively correlated with digestibility coefficients (OMD, CPD, CFD) and voluntary intakes of digestible OM or CP (VDOMI, VDCPI) whereas the second axis is negatively correlated with OM and CF.

The projection of the species associated with their stage of development in the system axis defined by the canonical axis (Fig. 1) indicates that all the grasses at 3-4 leaves per tiller and *Pennisetum purpureum* at the 4-5 leaves per tiller have high values for the intake and digestibility coefficients. On the contrary, native *Panicum maximum* and *Andropogon gayanus* at 4-5 leaves per tiller and flowering obtained low values for the above coefficients.

The second axis shows that *Panicum maximum* cv. T 58 at the flowering stage and *Panicum maximum* cv. C1 at 4-5 leaves per tiller obtained high values for CBD.

The correlation between chemical composition, intakes and digestibility of the grasses are presented in Table 7. The CP was positively correlated with VDCPI and CFD. The CF had no effect on intakes and digestibility. Neutral detergent fibre or ADF affected digestibility coefficients, and only ADL limited DMI. The ADL contents adversely influenced intakes and digestibility parameters with a high significant ($P < 0.001$). So, there is a strongly relationship between digestibility and intake parameters, and ADL content of the grasses seems to be an important factor determining at least digestibility.

Using the results provided in Table 7 the best models for predicting intake and digestibility of the grasses are the followings:

OMD = 87.6 – 0.54 ADL ($R^2 = 0.83$; RSD = 3.9);

CPD = 96.1 – 0.48 ADL ($R^2 = 0.64$; RSD = 5.8);

DMI = - 9.8 + 1.03 OMD ($R^2 = 0.61$; RSD = 7.8);

VDOMI = - 47.9 + 0.63 DM + 1.03 OMD ($R^2 = 0.91$; RSD = 3.3);

VDCPI = - 9.47 + 0.17 DM + 0.09 CP ($R^2 = 0.81$; RSD = 1.3).

**Table 4 Results of multivariate analysis of variance on the effect of species and stage on the intake and digestibility coefficients.**

| Source | FValue | NumDF | DenDF |
|---|---|---|---|
| Species | 46.27 | 125 | 137.81 |
| Stage | 347.17 | 50 | 54 |
| Species × stage | 23.72 | 250 | 276.62 |

**Table 5 Most discriminant digestibility coefficients of grass species associated with stage: Wilks' lambda statistics and probabilities.**

| Step | In entered | Fvalue | Wilk's Pr > F | Wilks' Lambda | Pr> Lambda |
|---|---|---|---|---|---|
| 1 | VDCPI | 475.39 | <0.0001 | 0.006 | <0.0001 |
| 2 | CPD | 153.67 | <0.0001 | 0.000 | <0.0001 |
| 3 | CFD | 22.09 | <0.0001 | 0.000 | <0.0001 |
| 4 | DMI | 12.71 | <0.0001 | 0.000 | <0.0001 |
| 5 | OMD | 6.82 | <0.0001 | 0.000 | <0.0001 |
| 6 | VDOMI | 4.04 | 0.0002 | 0.000 | <0.0001 |

**Table 6 Correlations between coefficients and canonical axes.**

| Variable | Can1 | Can2 |
|---|---|---|
| OM | -0.338 | -0.527 |
| CP | -0.039 | 0.194 |
| CF | 0.277 | -0.509 |
| NDF | 0.558 | 0.149 |
| VDCPI | 0.957 | 0.153 |
| OMD | 0.587 | 0.030 |
| CPD | 0.586 | 0.396 |
| CFD | 0.763 | 0.253 |
| VDOMI | 0.577 | -0.067 |

## 4. Discussion

*In vivo* measurement of digestibility and intake for tropical forages are less frequent than from temperate ones, in particular for native tropical grasses. It is recommended to perform digestibility and intake measurements on groups of 6 sheep for take into account animal variability on intake than on digestibility, and more over if animal becomes ill [18, 19].

According to Minson [20], Aumont et al. [21], Wilson [22], or Kozloski et al. [23], the chemical

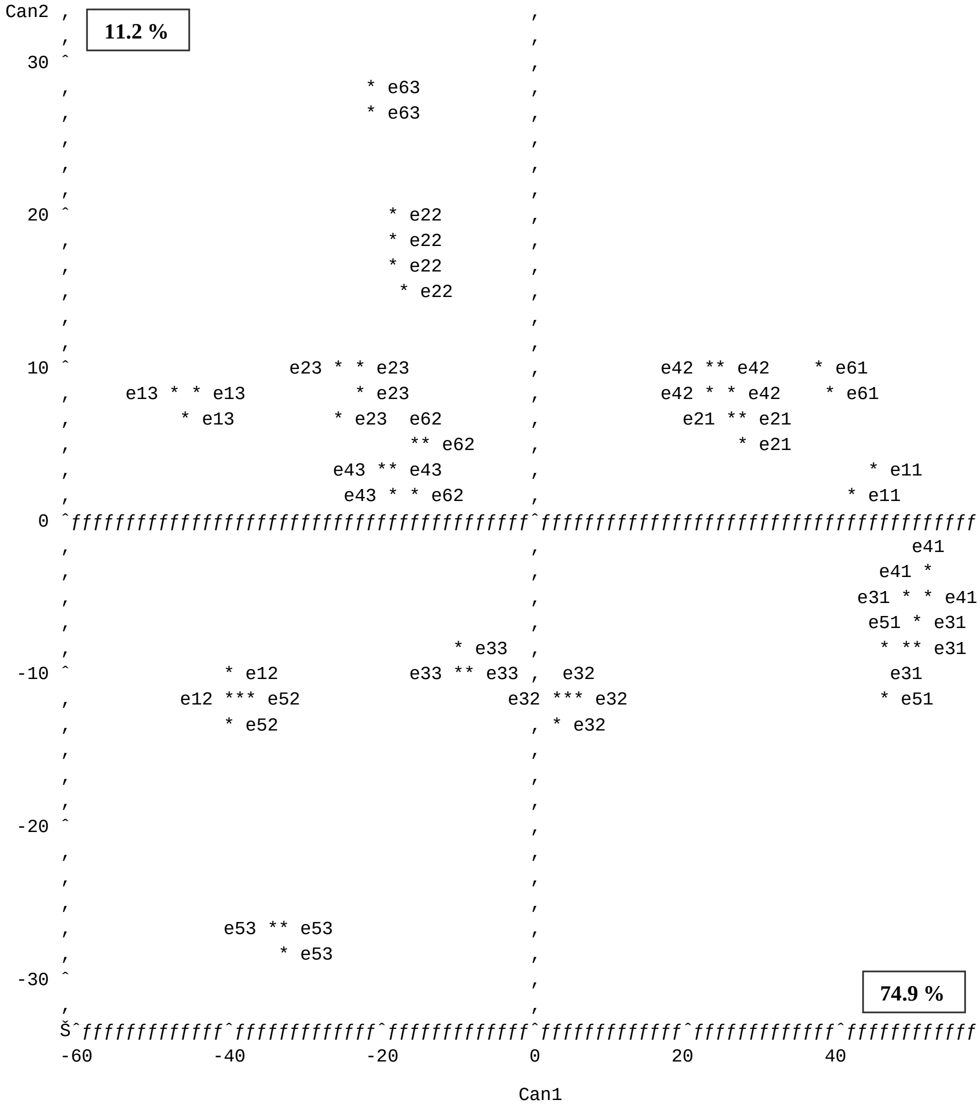


**Fig. 1 Projection of grass species with their stage in the canonical axis system.**

**Table 7 Correlation coefficients (r) of relationships between chemical composition, intakes and digestibility of the grasses.**

| | DMI | OMD | CPD | CFD | VDOMI | VDCPI |
|---|---|---|---|---|---|---|
| DM | 0.395 | -0.073 | -0.180 | -0.348 | 0.293 | -0.052 |
| OM | -0.229 | -0.462 | -0.626** | -0.625** | -0.248 | -0.448 |
| CP | 0.414 | 0.637** | 0.638** | 0.777*** | 0.485* | 0.836*** |
| CF | -0.344 | -0.418 | -0.132 | -0.194 | -0.401 | -0.309 |
| NDF | -0.324 | -0.620** | -0.532* | -0.626** | -0.418 | -0.547* |
| ADF | -0.377 | -0.665** | -0.467 | -0.578* | -0.472 | -0.506* |
| ADL | -0.735** | -0.911*** | -0.800*** | -0.870*** | -0.822 *** | -0.832*** |

* $P < 0.05$; **$P < 0.01$; ***$P < 0.001$.

composition of grass forages express their morphological components (stem and leaves proportion). However, it also depends on factors, beside regrowth age, such as seasons, soil and management conditions [11]. In this study, the experimental forages were chosen according to their adaptation to the environment (soil, climate) of South Benin [7] but differed highly in leaf/stem ratios. Their harvests at different growing stages also create a large range of chemical composition, palatability and nutritive values for sheep. *Brachiaria ruziziensis* was experimented because it has been reported to have lower total fibre and higher CP concentrations compared to other *Brachiaria* species [24, 25]. The three *Panicum* species and *Andropogon gayanus* were compared because they represent different leaf/stem ratios and leaf rigidity. Native *Pennisetum purpureum* studied because its large leaves and its pilosity may have adverse effects on palatability.

The protein and fibre contents recorded for *Brachiaria ruziziensis*, *Panicum maximum* cv. C1 or cv. T58 were in the range of values mentioned for the same species or cvv. in the previous studies [26, 27]. Protein contents in native species (*Panicum maximum* and *Andropogon gayanus*) decreased rapidly while fibre increased during development compared to other grasses. This important fluctuation of chemical composition during development for native species had also been mentioned by several authors [28-30].

Due to N fertilisation, the CP contents recorded in this study were generally high, despite the low fertility of the experimental soil, and agreed with other results obtained on the same site in South Benin [7]. Native *Panicum maximum* especially had high CP contents, but we observed in several other experiments that the CP contents of these local ecotypes greatly increase with N fertilisation [31]. The same observation was made by Pieterse and Rethman [32] for *Pennisetum purpureum*. In our experiment, CP contents in this species were also very high and remained at a high level at later development stage, because it was harvested just before flowering at the end of the rainy season. Low ADL contents were also recorded in this species, because the large and strong stems of this grass, which would have evidently not be consumed by the sheep, were discarded from the distributed material. Under such conditions, the slow decrease in nutritive value recorded for *Pennisetum purpureum* comparatively to the other species is in agreement with other studies [23, 32, 33]. For *Andropogon gayanus*, unexpected low CP and high fibre contents were recorded in this study compared to the values reported by Lascano et al. [34] and Buldgen et al. [35]. This may be due to a decreasing in the CP contents of this forage under wet conditions [36] or to the large variability of the chemical composition linked to the multiple ecotypes existing in the species [35]. These species behaved like an annual grass in our experimental conditions, producing rapidly flowering stems during the rainy season, while it is perennial under semi-humid or dry tropics [7, 35].

Under tropical conditions, it is well known that small ruminants select the more nutritious parts of plants, which are the richest in CP, and ignore older or coarse materials with higher contents in CF [10, 37-39]. During this study we observed that ingested material corresponded essentially to grass limb. Generally, refusals increased with the number of leaves per stem (age of grass) and varied between species according to the importance of the leaf/stem ratio and the size of the leaf midrib. At flowering stage, refusals also greatly depend on the size of the flowering stems and their amount in the offered forages (i.e. higher for *Andropogon gayanus* and native *Panicum maximum* compared to the other grasses). Except in several cases, the selectivity by sheep led to high differences in CP and CF contents between offered and ingested forages as observed by Hadjigeorgiou et al. [37].

The average OM and CP digestibility were lowest in *Andropogon gayanus* and are linked to the high ADL contents of this species and the net decrease of these parameters at flowering stage. For native *Panicum maximum* and *Pennisetum purpureum*, OMD registered in our experiment are very close to those recorded with goats receiving *Panicum* by Bamikole et al. [2] or with cattle fed *Pennisetum* by Kozloski et al. [23]. According to Guerin [36] concerning the relationship between OM digestibility and ruminant performances with tropical forages, the OM digestibility recorded in Table 3 demonstrates that except at flowering stage, high liveweight gains are possible with *Brachiaria ruziziensis*, native *Panicum maximum* and native *Pennisetum purpureum*. If *Andropogon gayanus* is discarded, the average values of CP digestibility are not significant between species and reach those obtained by Bamikole et al. [2] with a tropical grass-legume mixture and goats. This demonstrates that in the experimental conditions of this study (soil, allowance of forage, etc.), 25 kg $ha^{-1}$ N fertilisation between each harvest may provide sufficient N supply to reach acceptable performances with only grass as a feed.

This study was designed with high percentages of refusals for each grass and each stage of development, as recommended by Zemmelink et al. [10] and the selective consumption of animals greatly influence both voluntary intake and digestibility [9, 40]. The DMI was predicted with relative high RSD. It is not surprising because intake was suggested to many factors like plant characteristics (palatability, physical fill) leaf to stem ratio, plant habit and dimensions of stems and leaves, environmental conditions [41-44]. In addition the nutritional habits of small ruminant in tropical humid climate depend on feeding behaviour and therefore during the day and the year the diet can change widely for type of feed and quality of nutrient [45, 46]. This series of factors influence the estimation of voluntary dry matter intake. Improvement in prediction of intake can occur only when the many factors controlling intake have been identified and evaluated. The relative high RSD on DMI was in agreement with most of the published work on this topic of ruminant nutrition [21, 47].

Due to the highly variable characteristics of the grasses and the selectivity by the animals, the real feeding values, based on both ingestion and digestibility, were established by calculating VDOMI and VDCPI for each forage. Based on these parameters, the ranking of the species gave finally unexpected results, showing that native *Panicum maximum* and *Pennisetum purpureum* may ensure the highest performances compared to selected grasses (*Brachiaria ruziziensis*, *Panicum maximum* var. C1 or T58).

## 5. Conclusions

This study confirms that *in vivo* digestibility measurements tropical grass forages are not sufficient to predict the performances of ruminants, because forage allowance greatly influences both intake and digestibility. In the experimental conditions of South of Benin, this study also shows that sustainable sheep production may be developed using native grass species as fodder crops with limited N fertilisation (75-100 N units $ha^{-1}$ $year^{-1}$).


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