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Research Paper

Ingestibility and digestibility of Brachiaria brizantha in dwarf goats in the Kisangani region (DRC)

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Summary
This study determined the ingestibility of the varieties Xaraes, Piata, Marandu and Locale of Brachiaria brizantha and the digestibility of the crude proteins of these varieties to verify the hypothesis according to which the ingestibility of these forages and the digestibility of their crude proteins at the vegetative stages (beginning, full and end tillering) are sufficient in goat diet.
After cultivation in an experimental device of complete random blocks of the aforementioned varieties, their administrations to goats and laboratory analyses, the results showed that the ingestibility of fodder and the digestibility of crude proteins of B. brizantha vary depending on variety and vegetative stage.
The ingestibility of different varieties at the beginning of tillering, full and end tillering vegetative stages varied from 50.52 to 57.90 g DM/kg $W^{0.75}$for Xaraes; from 49.95 to 58.22 g DM/kg $W^{0.75}$for Piata; from 50.35 to 52.41 g DM/kg $W^{0.75}$for Marandu, and from 43.53 to 53.44 g DM/kg $W^{0.75}$for Locale; while the crude protein digestibility of different varieties and at the aforementioned vegetative stages varied from 43.09 to 53.61% for Xaraes; 47.51 to 53.22% for Piata; 33.77 to 69.31% for Marandu and 45.00 to 70.47% for Locale. Analysis of variance indicates that there are very highly significant differences between varieties and between vegetative stages for forage ingestibility and crude protein digestibility. Compared to the maintenance needs of goats, the digestibility of crude proteins of the above-mentioned varieties is more than sufficient. The ingestibility of fodder of different varieties is satisfactory at different vegetative stages, being less than 79 g DM/kg $W^{0.75}$.
Key words: *Ingestibility, Digestibility, Variety, Vegetative stage, Brachiaria brizantha.*

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I. INTRODUCTION

The Democratic Republic of Congo is a large, exceptional terrestrial tropical biome and constitutes one of the world's reservoirs of biodiversity, including grazed ecosystems (Asimonyio et *al*., 2015; Baelo et *al*., 2016; Ngbolua et *al*., 2014; Kambale et *al*., 2016).

Natural pastures play an important role in feeding tropical livestock (Angonyissa and Sinsin, 1998). To this end, the study of fodder resources is a necessity in the Kisangani region, in order to cope with a general decline in the productivity of ruminant breeding in the region. The fodder resources of the Kisangani region are dominated by a few grasses, the main ones of which, despite their hardiness and adaptability, have very limited fodder quality, which affects livestock yield.

Therefore, any effort to increase animal production in Kisangani implies the installation of pastures with forage species of good quality from both an agronomic and nutritional point of view. In the tropics at low and medium altitudes, grasses of the genus Brachiaria are recognized for their forage capacity (Klein et al.,2014).

In the surroundings of Kisangani, we find a few species of the Brachiaria genus but ignorance and/or lack of knowledge of the fodder potential of these plants would be at the root of the fodder crisis in livestock farms. Hence the need to study the possibility of exploiting species of the Brachiaria genus in fodder crops in Kisangani. It is in this context that the present work was initiated to determine the ingestibility of fodder and the digestibility of crude proteins of the four varieties of *B. brizantha* at the vegetative stage in goats. This study aims to verify the hypothesis that the forage ingestibility and protein digestibility of *B. brizantha* in goats varies according to vegetative stage and variety, and are consistent with the needs of livestock at the early, full and late tillering vegetative stages.

The interest of the present work is obvious because it specifies the quantity of crude proteins that can benefit livestock which ingest varieties of *B. brizantha* from different vegetative stages. Indeed, knowledge of the ingestibility and digestibility of grasses in a given region is essential for a better composition of livestock rations, because it provides data for the formulation of food supplements consistent with the region where the fodder grows (Rivière, 1978).

II. ENVIRONMENT, MATERIALS AND METHODS

2.1. Environment

The trials were carried out in Kisangani on the grounds of the Yangambi Faculty Institute of Agronomic Sciences (IFA-Yangambi) and on the Mugbamboli farm 20 km from the city center on the old Buta road.

The geographic coordinates obtained by GPS GARMIN MAP 625 at the center of the experimental field at Mugbamboli are: altitude: 403 m; latitude: 00° 37' 54.1" N; longitude: 25° 17'50.5" E; while those of the IFA, taken from the center of the experimental field are: altitude: 370 m; latitude: 00° 30’ 48.9’’ N; longitude: 25° 09’ 52.8” E. Figure 1 shows the geographical location of the experimental sites.

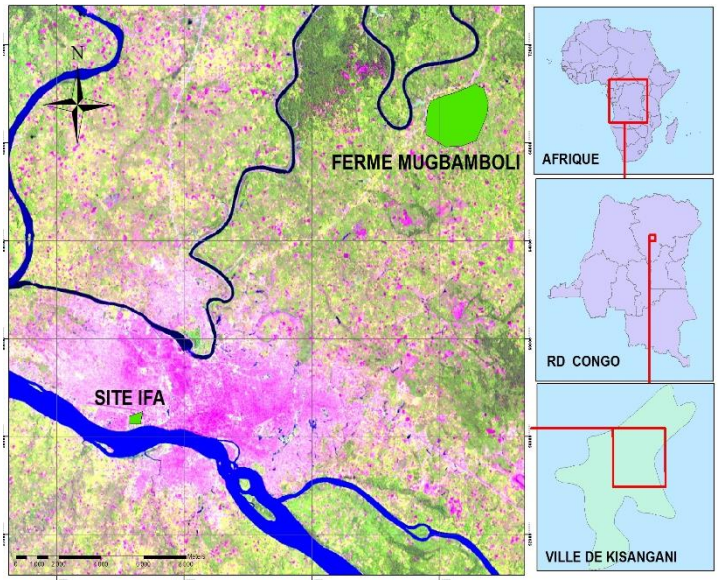

Figure 1: Geographic location of IFA sites and Mugbamboli farm

The Kisangani region belongs to the Köppen climate type Af. This is a humid tropical climate in which the average temperature of the coldest month is greater than 18°C and the monthly rainfall amount of the driest month is greater than 60 mm (Goffaux, 1990). The annual rainfall pattern has a double periodicity. The main and secondary maxima are in October and May respectively, while the main and secondary minima are in January and July respectively. The air humidity is quite high. The monthly average is around 77 to 82%.

The city of Kisangani is watered by two hydrographic networks: the Congo River and the Tshopo River. The Mugbamboli farm is drained by the Tshopo river and by two streams which flow into it: Ngenengene and Mugbamboli.

The soils of the Mugbamboli farm have the general characteristics of the soils of the Kisangani region. The bedrock is made up of sandstone systems (red sandstone, schists and quartzite) and the overburden is made up of clay-sandstone layers (red clay, collateral sandstone). These soils are classified in the Lindian system (Upper Precambrian) and have the general characteristics of the soils of the central basin. They are generally acidic (pH around 4.5) and poor in primary minerals (Van Wambeke and Evrard, 1954). In addition, it should be noted that the phytogeographic classification of Congo proposed by Ndjele (1988), places the entire Kisangani region of which our experimental sites are part, in the central-eastern district of Maïko of the central forest sector of Wildeman, Congolese domain, Guineo-Congolese region (White, 1979).

2.2 Materials

2.2.1 Biological materials

The main biological material studied is the grass *Brachiaria brizantha* made up of four varieties (Xaraes variety, Piata variety, Marandu variety and Locale variety) each harvested at the beginning, full and end tillering stages. The goat constitutes the secondary material allowing the evaluation of the varieties of *Brachiaria brizantha*.

The ingestibility and digestibility of *Brachiaria brizantha* varieties were determined in equatorial forest dwarf goats from the Opala territory in the DRC.

2.2.2 Technical materials

Technical equipment includes agricultural tools (machetes, axes, hoes, spades, wheelbarrows, milestones, decameters, cutters, stakes, etc.) and laboratory equipment (oven, desiccator, muffle furnace, digester, distiller, burette, pipette, Satorius precision balance, various laboratory glassware); data recording and processing equipment (pens, notebooks, computer and its accessories, etc.) and transport vehicles (bicycle, motorcycle, automobile, whaleboat and canoe).

2.3 Methods

2.3.1 Experimental devices

The ingestibility and digestibility of *B. brizantha* varieties was studied on forages produced in an experimental design of complete randomized blocks comprising four treatments and four repetitions, the plan of which is presented in figure 2

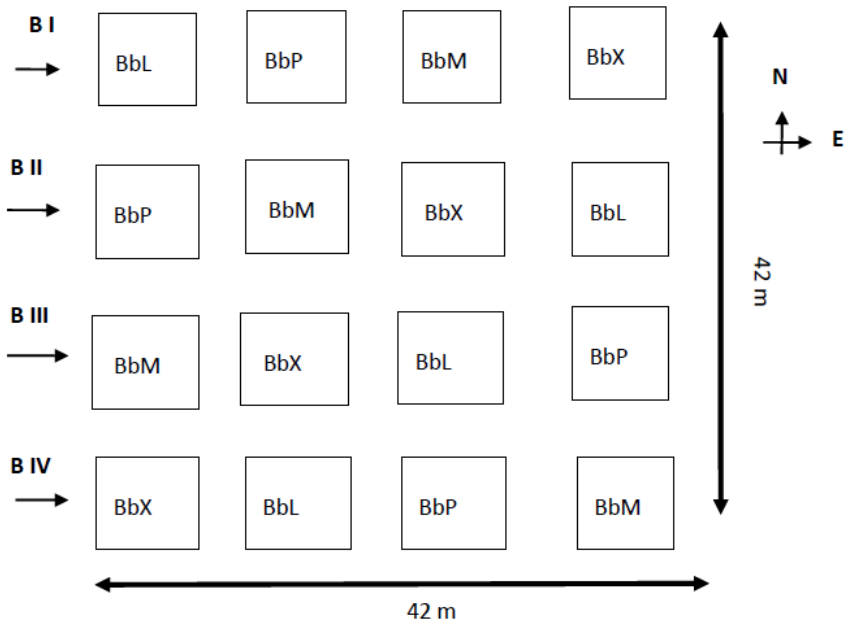

Figure 2. Field experimental setup

BbL, BbP, BbM and BbX are respectively the plots containing the Locale, Piata, Marandu and Xaraes variety of Brachiaria brizantha, while BI, BII, BIII and BIV are the blocks.

At the goat farm the system used was a complete system comprising twelve digestibility cages built on either side of a service corridor in two series of six cages each, in a building six meters long and five meters wide. Each cage had a feeder and a drinker placed on the service corridor side as can be seen in figure 3.

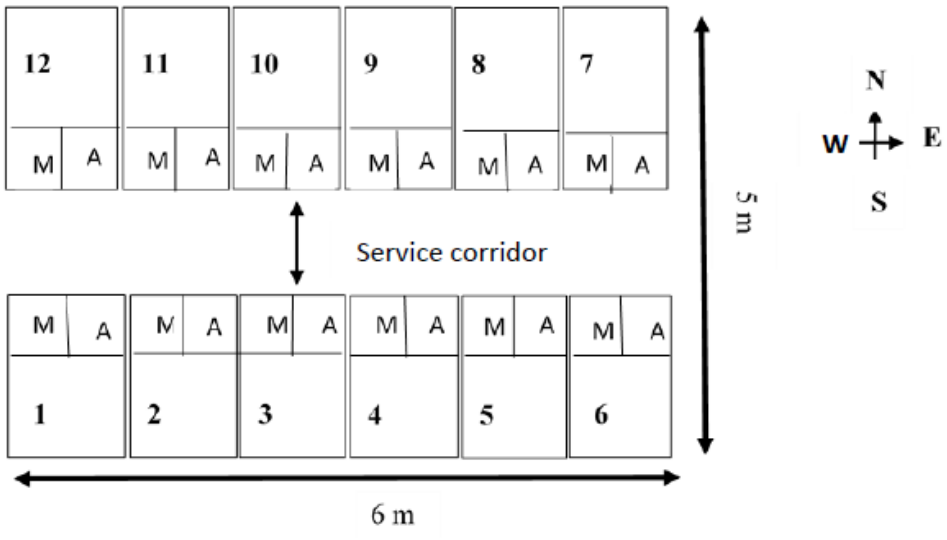

Figure 2: Experimental setup at the goat farm

Legend: The numbers 1 to 12 indicate digestibility cages while the letters A and M mean drinker and feeder respectively.

2.3.2 Determination of forage ingestibility and crude protein digestibility

The experiment focused on young males aged 7 to 8 months. These animals had undergone conditioning which consisted of bathing with VECTOCID® (deltamethrin), deworming with Albendazole (Albenor 2500, bolus), injection of multivitamin (mulitistar) and oxytetracycline (Oxystar 20% L.A), in order to carry out experiments on healthy animals.

The ingestibility and digestibility of each variety of *B. brizantha* from different vegetative stages (early, full and late tillering) were studied on 12 subjects at each of the vegetative stages.

The animals were weighed individually in order to determine the quantities of fodder to offer them. These quantities were determined with regard to the dry matter needs of goats which, according to Rivière (1978), is 2.75 kg of DM/100 kg of live weight in male meat-producing goats. Then the goats were placed in cages of 0.324 m^3 (0.9 x 0.6 × 0.6 m) built from boards and placed 0.3 m from the ground.

To allow the animals to adapt to their new diet and new environment, a period of one week was observed, during which the quantities of fodder to be offered were adjusted. Thus the quantity to be distributed per animal was set at 3 kg of DM/100 kg of live weight. After the adaptation period, the fodder to be evaluated was distributed to each animal in accordance with its weight. Water was constantly made available to the animals.

The fodder to be tested was previously chopped and mixed to avoid sorting the animals. Throughout the trial, the quantities of fodder distributed and refused were weighed and recorded in the data sheets for the determination of ingestibility, while the faeces were collected on the fourth day according to Boudet (1975) and packaged while awaiting laboratory analyzes to determine the digestibility of crude proteins.

The ingestibility of the fodder was determined according to the method used by de Richard and *al*., (1989); Xandé and *al*., (1989); and Demarquilly and *al*., (1998). In this method the ingestibility of the fodder is obtained from the quantities offered and refused over a period of 24 hours, by applying the formula $\mathbf{I = VIDM/W^{0.75}}$, with **VIDM = Qo – Qr**, where:

VIDM = voluntarily ingested dry matter;

Qo = quantity of dry matter offered;

Qr = quantity of dry matter refused;

$W^{0.75}$ = metabolic weight (W is the live weight of the animal).

To determine digestibility, crude protein was determined in the forages offered and in the feces. The determination of the crude protein (CP) content was made by the Kjeldhal method (FAO, 2016).

The Kjeldahl process is based on the principle of the transformation of nitrogenous organic materials into ammonia under the action of concentrated and boiling sulfuric acid. This method is carried out in three essential stages: mineralization or attack or even digestion, distillation and titration.

- Mineralization

The operation consists of attacking the organic matter hot with concentrated sulfuric acid in the presence of a catalyst. Under these conditions, the nitrogen of organic compounds is mineralized into ammonium sulfate according to the reaction

$$(C, H, N, O, S, N, P) \xrightarrow[\text{Catalyst}]{H_2SO_4} CO_2 + H_2O + SO_2 + PO_4^{3-} + CO + NH_4^+ + SO_4^{2-}$$

- Alkalization and distillation

A basic extract neutralizes sulfuric acid and transforms $NH4^+$ into ammonia following the following reaction:

$NH_4^+ + OH^- \longrightarrow NH_3 + H_2O$

The ammonia thus formed is carried by water vapor towards an excess boric acid solution. The latter reacts with ammonia according to the reaction:

$H_3BO_3 + NH_3 \longrightarrow NH_4H_2BO_3$

- Titration

The quantity of $NH_4H_2BO_3$ formed is determined by titration with strong acid (H_2SO_4 0.01N). The mixed Tashiro indicator is used to locate the equivalent point.

$HR + NH_4H_2BO_3 \longrightarrow H_3BO_3 + NH_4R$

The nitrogen content is given by the following expression:

$$\%\ \textbf{Nitrogen} = \frac{\textbf{meqN} \times \textbf{N} \times \textbf{V1} \times \textbf{V2}}{\textbf{W} \times \textbf{V3}} \times \textbf{100}$$ Where:

- meqN is the milliequivalent of nitrogen
- N is the normality of the titrant;
- V1 is the volume of the titrant;
- V2 is the total volume of the mineralized material;
- V3 is the volume of the mineralized material, used for distillation;
- W is the weight of the test sample and
- 100 is the conversion factor in %

% CP = % Nitrogen x f, where f is conversion factor from % Nitrogen to % CP. (f = 6.25 for fodder).

Protein digestibility was determined according to the method of Rivière (1978) cited by Jarrige (1981). This method consists of estimating apparent digestibility by calculating the digestive utilization coefficient (D.U.C.) which expresses the percentage of food retained by the body, and is obtained by the general expression

$$D.U.C.apparent = \frac{\text{Ingested element} - \text{fecal element}}{\text{Ingested element}} \text{ x } 100$$

Thus the digestibility of crude proteins (dCP) was calculated by the formula

$$dCP = \frac{\text{Ingested CP} - \text{fecal CPF}}{\text{Ingested CP}} \text{ x } 100$$, where CPF stands for crude proteins of food origin.

III. RESULTS AND DISCUSSION

3.1 Ingestibility and digestibility of Brachiaria brizantha in goats

The results on forage ingestibility and protein digestibility of *B. brizantha* varieties at the early, full and late tillering stages are presented in Table 1.

Table 1. Mean values of ingestibility and digestibility of *B. brizantha* from the variety × vegetative stage interaction

Varieties	Vegetative stages	I (g VIDM /kg $W^{0,75}$)	dCP (%)	DCP (% DM)
Xaraes	beginning tillering	$55,42^{abc}$	$43,09^{cd}$	6,36
	Full tillering	$50,52^{d}$	$53,61^{b}$	9,29
	End tillering	$57,90^{ab}$	$49,39^{bc}$	6,86
Piata	beginning tillering	$51,91^{cd}$	$47,51^{cd}$	6,57
	Full tillering	$49,95^{d}$	$53,22^{bc}$	7,1
	End tillering	$58,22^{a}$	$51,06^{bcd}$	6,28

Marandu	beginning tillering	52,41^{cd}	33,77^{e}	3,84
	Full tillering	51,60^{cd}	52,43^{bc}	7,45
	End tillering	50,35^{d}	69,31^{a}	8,83
Locale	beginning tillering	53,44^{bcd}	46,78^{cd}	6,80
	Full tillering	50,61^{d}	45,00^{d}	7,11
	End tillering	43,53^{e}	70,47^{a}	9,02
p-value		0,0000***	0,00000***	

I: ingestibility VIDM: voluntarily ingested dry matter
dCP: digestibility of crude proteins DCP: Digestible crude proteins
Means with the same letters, no significant difference for p > 0.05 according to Tukey
***: very highly significant difference

It appears from Table 1 that the variety and vegetative stage factors interacted. The interaction analysis (ANOVA 1, and table 1 in the appendices) showed that
- Vegetative stage influences ingestibility at 18.8% and digestibility of crude proteins at 93.9%.
- Variety influences ingestibility at 65.6% and crude proteins digestibility at 3.1%.

The evolution of ingestibility and digestibility of *B. brizantha* following vegetative stage is shown in figure 2.

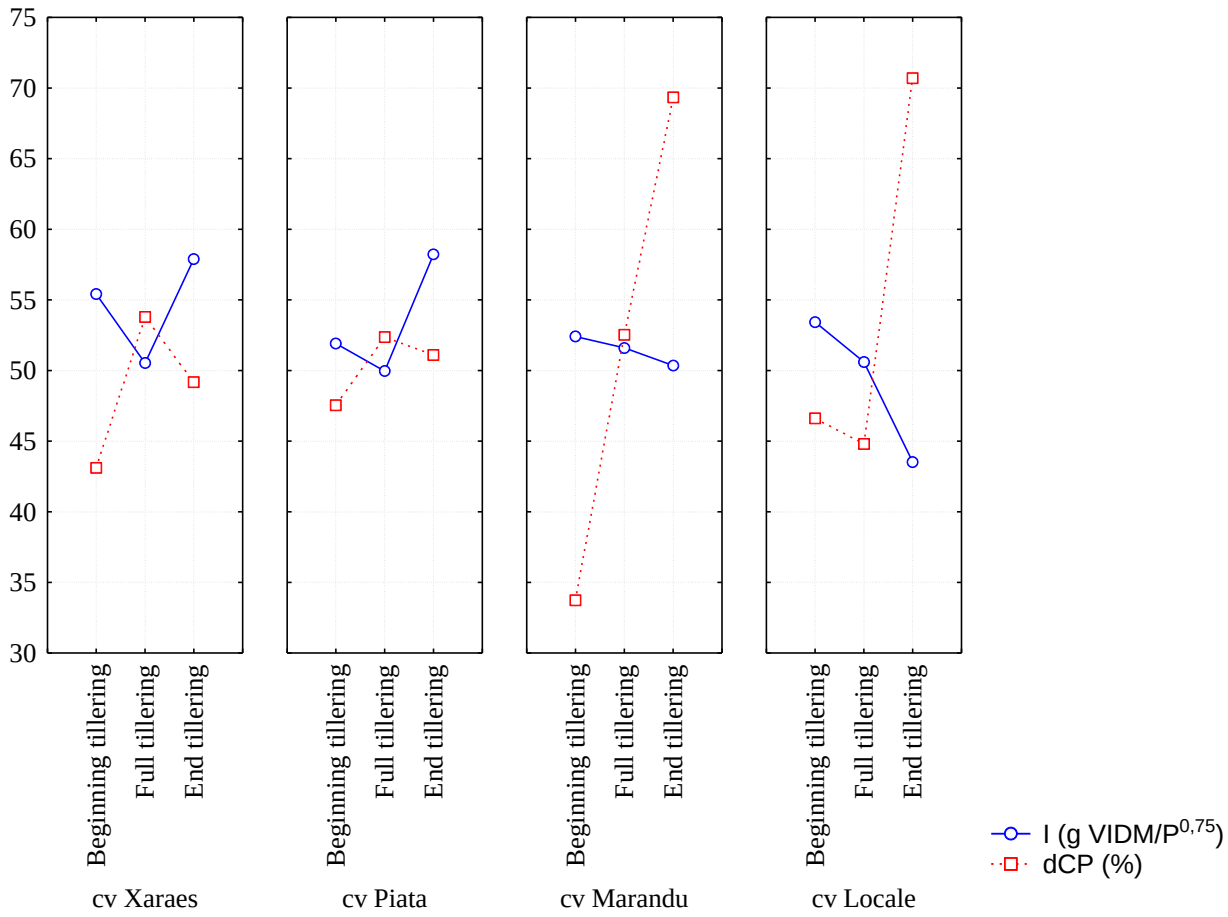

Figure 2. Variation in ingestibility and digestibility according to age of *B. brizantha*

It appears from Figure 2 that the protein digestibility of the Marandu variety increases almost uniformly from the early tillering stage to the late tillering stage.

The results on ingestibility (55.42; 50.52 and 57.90 g DM/kg $W^{0.75}$ for Xaraes; 51.91; 49.95 and 58.22 g DM/kg $W^{0.75}$ for Piata; 52.41; 51.60 and 50.35 g DM/kg $W^{0.75}$ for Marandu; 53.44; 50.61 and 43.53 g DM/kg $W^{0.75}$ for Locale respectively at the beginning, full and end of tillering) reveal that ingestibility was slightly low at full tillering for all varieties while it was more or less high at late tillering for Xaraes and Piata. It also varied depending on variety. This variability in ingestibility would be a function of the variation in the quality of the

fodder at the different vegetative stages from the point of view of digestible carbohydrates and crude fiber which would affect palatability.

Indeed, according to Klein et *al*. (2014) the palatability of grasses for herbivores depends on the texture of their tissues, their odor (which depends on the quantities of unpleasant or repellent substances), their content of toxic substances or tannins, and especially their richness in digestible carbohydrates (celluloses, soluble sugars, etc.) and nitrogenous materials. Ingestibility varies greatly depending on the fiber content, which has a bulky effect on the digestive tract. The more nutritious the food, the less the quantity ingested, because the animal's needs are quickly satisfied.

Concerning the digestibility of crude proteins, the results (43.09; 53.61 and 49.39% for Xaraes, 47.51; 53.22 and 51.06% for Piata; 33.77; 52.43 and 69, 31% for Marandu; 46.78, 45.00 and 70.47% for Locale respectively at the beginning, full and end of tillering) reveal that the digestibility varied differently from the beginning of tillering to the end of tillering depending on the varieties. This variation pushes us to formulate some points of view. In Xaraes and Piata the peak of digestibility is obtained at the full tillering stage while in Marandu and locale, the peak appears at the end of tillering stage.

The content of undesirable cell wall constituents (notably lignin and constitutional silica) and the level of vitamins A, B, C and D in the fodder would partly explain this difference. The synthesis of undesirable parietal constituents would be more preponderant in Xaraes and Piata in the late tillering stage while in Marandu and Locale it would be evident later.

Indeed, according to Klein et al. (2014) lignification affects the digestibility of nitrogenous materials which are in some way trapped in the fibers; this physical effect combines with the biochemical effect of tannins. According to Gillain (1953), vitamins A and B increase the digestibility of proteins while vitamins A, B, C and D reduce the digestibility of proteins.

Considering the results obtained, it appears that the varieties studied will satisfy the maintenance needs of goats, which according to Rivière (1978) is 3.5% (at DM) of digestible proteins. The Marandu and Locale varieties at the end tillering stage are better and will largely cover maintenance and production needs. Thus, the hypothesis for the crude protein digestibility parameter is confirmed.

IV. CONCLUSIONS AND SUGGESTIONS

The study of the ingestibility and digestibility of *B. brizantha* varieties showed highly significant differences between varieties and between vegetative stages.

The study showed that ingestibility depends more on the "variety" factor (65.6%) than on the "vegetative stage" factor (18.8%). The ingestibility (g DM/kg of $W^{0.75}$) at the different vegetative stages depending on variety is presented in the following order:

- For Piata: end of tillering (58.22 g) > full tillering (49.95) = beginning of tillering (51.91 g);
- For Xaraes: end of tillering (57.90 g) > beginning of tillering (55.42 g) = full tillering (50.52 g);
- For Marandu: end of tillering (50.35 g) = full tillering (51.60) = beginning of tillering (52.41 g);
- Local: start of tillering (53.44 g) > full tillering (50.61 g) < end of tillering (43.5 g).

Thus, the Piata, Xaraes and Marandu varieties are more ingested at the end of tillering stage while the Locale variety is more ingested at the beginning of tillering stage. However, the ingestibility values of these varieties at the different vegetative stages are lower than 79 g DM/kg of $W^{0.75}$ (value reported by Rivière, 1978 for goats). Thus, the varieties studied seem economical and satisfactory for feeding goats because they produce satiety at relatively low doses.

The study of the digestibility of crude proteins made it possible to identify the following.

– The crude proteins of the Marandu and Locale varieties are better digested by goats at the late tillering stage (dPB = 69.31 and 70.47% respectively).

– The crude proteins of the Xaraes and Piata varieties are better digested by goats at the full tillering stage (dPB = 53.61 and 53.22% respectively).

– At the start of tillering, the digestibility of crude proteins of the Xaraes, Piata and Locale varieties in goats are similar (dPB = 43.09; 47.51 and 46.78% respectively) and higher than the Marandu variety (dPB = 33 .77%).

– At the full tillering stage, the digestibility of crude proteins of the Piata and Marandu varieties are similar in goats (dPB = 53.22 and 52.43% respectively) and higher than the Locale variety (dPB = 45.00%).

– At the end of tillering stage, the digestibility of crude proteins of the Locale and Marandu varieties in goats are similar (dPB = 70.47 and 69.31% respectively) and higher than the Xaraes and Piata varieties (dPB = 49.39 and 51 .06% respectively).

Ultimately, the Locale variety at the early tillering stage is less interesting for feeding goats because it only slightly covers the goats' production needs in digestible proteins which, according to Rivière (1978) is greater than 3.5% digestible protein at dry matter.

This study is the first to address the variation in ingestibility and digestibility of *B. brizantha* according to vegetative stages and varieties in dwarf goats in the Kisangani ecological region. It is not a finished product, but

rather the progress of research which should expand into the digestibility of different nutrients of *B. brizantha* varieties of different vegetative stages in goats and other herbivores. This is why we hope, in the days to come, to deepen the information on the digestibility of *B. brizantha* varieties by determining in goats, the digestibility of crude fiber at different vegetative stages.

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APPENDICES

ANOVA 1. Ingestibility of *B. brizantha*

Effect	SS	Degree of freedom	MS	F	p
Intercept	65285,54	1	65285,54	33022,81	0,000000
Variety	100,67	3	33,56	16,97	0,000129
Vegetative stage	28,92	2	14,46	7,31	0,008380
Variety*Vegetative stage	210,48	6	35,08	17,74	0,000025
Error	23,72	12	1,98		

ANOVA 2. Digestibility of crude proteins of *B. brizantha*

Effect	SS	Degree of freedom	MS	F	p
Intercept	31704,47	1	31704,47	10226,40	0,000000
Variety	38,96	3	12,99	4,19	0,030336
Vegetative stage	1185,64	2	592,82	191,22	0,000000
Variety*Vegetative stage	1021,20	6	170,20	54,90	0,000000
Error	37,20	12	3,10		

Table 1. Contribution of factors to forage ingestibility and crude protein digestibility of *Brachiaria brizantha* varieties in goats

Factors	Contributions of factors in the interaction (%)	
	I	dCP
Variety	65,6	3,1
Vegetative stage	18,8	93,9

I : ingestibility
dCP: digestibility of crude proteins

Images of *Brachiaria brizantha* varieties aged 30 days (Ngakpa photos)

Brachiaria brizantha : cv Xaraes

Brachiaria brizantha : cv Piata

Brachiaria brizantha : cv Marandu

Brachiaria brizantha : cv Locale