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Relative Frequencies, Chemical Composition and *in vitro* Organic Matter Digestibility of Forage Consumed by Sheep in Humid Tropic of West Africa

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Abstract: The experiment was conducted during the short dry and the short rainy seasons in 2008. A botanical inventory and relative frequencies of forage selected by Djallonké sheep grazing were developed by observation and hand-plucking. Chemical composition and *in vitro* organic matter digestibility (IVOMD) of hand-plucked material was determined. From July to October, woody plants are a major component of the sheep diet. Sheep selected 40 woody plants and 21 species of herbaceous. During the dry season, grazing occurred more frequently in the fallows. The most frequent woody species belonged to *Elaeis guineensis* and *Fagara zanthoxyloides*. At the rainy season, a high proportion of *Panicum maximum* and *Eleucine indica* were sampled. Crude protein was high in woody leaves at the dry season. Crude fibre were more variable in herbaceous than in woody and herbaceous were generally higher in the levels of fibre. *Chromolaena odorata, Citrus sinensis, Vitex doniana* were very high in IVOMD. *Spondias mombin, Moringa oleifera, Persea americana, Psidium guajava, Dialium guineense* presented lowest values in IVOMD. Among herbaceous, *Andropogon gayanus* and *Panicum maximum* still presented a high value of IVOMD at the dry season. High proteins suggest woody with potential as nitrogen supplements to ruminants fed low quality forage during the dry season.

Key words: Woody, herbaceous, botanical inventory, nutritive value, livestock, sheep.

1. Introduction

In Benin, livestock production represents an important method for supporting the local population, but the production of ruminant livestock has largely been supported through the grazing of available nature pastures [1]. Due to favourable climate in Benin like in other humid regions of Africa, the availability of forage is not a real constraint when ruminants are grazing pastures or through fed. Until now, a greater knowledge of the diet consumed by grazing animals on these pastures is fundamental in order to select and insert them intentionally in the feeding strategy [2].

The *in vivo* organic matter digestibility of tropical forage is the main criterion for determination of nutritive values with the French system [3, 4]. In the Caribbean (French Guyana, French West Indies, Dominica, Cuba) and Burundi, feed tables are based on *in vivo* determination of organic matter digestibility and voluntary dry matter intake by sheep [5, 6]. However, the samples to be tested with *in vivo* studies for establishment of large feed tables are too numerous and the results are generally restricted to experimental conditions under which the measurements were made.

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In addition, *in vivo* digestibility studies is expensive, time consuming and laborious, requires large quantities of forage [7-9] and is largely unsuitable for forages like straw [10, 11] and browses [12, 13]. Not readily applicable to large numbers of samples, or when small quantities of forage are available. It is why these feed tables are limited to only some areas. In order to avoid these problems *in vitro* organic matter digestibility is one of the best methods currently available for estimating digestibility and nutritive quality of diet. This study aimed to identify forage consumed by sheep in south of Benin and to evaluate their *in vitro* organic matter digestibility using pepsin and cellulase technique.

2. Materials and Methods

2.1 Study Areas and Animals

The experiment was carried out on the Atlantic Department in south of Benin. This region is covered by woody or shrubby savannas, which are being replaced extensively by fields and fallows [14]. The climate is Guinean characterized by two rainy seasons and two dry seasons: (1) A long rainy season (March-July) and short rainy season (September-October) and (2) A long dry season (November-March) and short dry season (July-September).

The mean annual rainfall is 1, 200 mm. Average minimum and maximum daily temperatures are 27 and 31 ℃ respectively [15]. The soils are ferruginous throughout the region and hydromorphic along rivers [16]. The pastures were grazed by locally bred West African Dwarf sheep that are widely reared in Benin [17]. Before the experiment started, 24 male sheep, with an average weight of 17.4 kg were treated for intestinal parasites (Vermitan) and trypanosomiasis (Berenil).

2.2 Sampling and Measurements

The experiment was conducted from July 16-October 13, 2008, i.e., over 90 days including a 14-day adaptation period. This period covered the short dry season and the short rainy season. Grazing took place from 0900-1700 h for 8 hours per day. The pastures were natural wooded and shrubby savannas during the short dry season as well as fallows during the short rainy season. Animals received water and mineral blocks salt *ad libitum* when they returned in the sheepfold. Botanical inventory and determination of the nutritive quality of the consumed forage were made from samples collected by hand-plucking method. This technique was used to obtain estimations of the quality of the ruminant's diet because it is rapid, relatively cheap and simple, particularly in heterogeneous grasslands where animals demonstrate great selectivity with respect to fibrous forage [18-20]. During each sampling day, 5 animals were chosen randomly and were observed on the pasture. Daily sampling was carried out during 30 periods of 5 minutes (6 periods per animal) distributed over the whole grazing time with 15 periods in the morning and 15 periods in the afternoon. Species in hand-plucked samples were identified for each animal and counted to give a frequency for each species at the end of the study.

After-wards the samples of each animal were bulked, dried in a laboratory oven for 48 h at 60 ℃ and milled (1 mm sieve, FOSS Electric A/S, Hilleroed, Denmark), before chemical analysis. Milled samples were analyzed for dry matter (DM) by drying samples at 105 ℃ for 24 h in forced air oven (AOAC 967.03). Ash content was measured after igniting samples in a muffle furnace at 550 ℃ for 4 h (AOAC 923.03). Crude protein (CP) was determined by kjeldahl method [21] and crude fibre (CF) by Weende method, according to Kim et al. [22]. Samples were also investigated with enzymatic technique using pepsin (MERCK n° 7190, 1/10000) and cellulase from *Trichoderma viride* (BDH n° 39074) to determine *in vitro* organic matter digestibility (IVOMD) of the forage according to Vanderhaeghe and Biston [23] method. The statistical analysis was carried out using SAS (SAS Inst. Inc., Cary, NC). The frequency

distributions of the hand-plucked species during each season were analysed by chi-square test.

3. Results and Discussion

3.1 Botanical Composition of the Consumed Forage

The relative frequencies of species consumed in the pasture during the short dry season and the short rainy season are presented in Table 1. Animals selected 61 species from July to October (covered the short dry season, July 17-September 15 and the short rainy season, September 15-October 16). The frequencies of the consumed species were significantly different ($P < 0.01$) between the 2 seasons. From July to October, woody plants are a major component of the sheep diet. These plants are especially important for ruminant production during this period of the year when both nutritive value and quantity of herbaceous plants declines because woody species are normally deep-rooted and more likely to remain vegetative or even grow, during drought periods. The differences observed in botanical composition of the forage consumed by sheep between the short dry and the short rainy seasons can be explained by the inaccessibility of the hydromorphic zones from July to September.

At the short dry season, grazing occurred more frequently in the fallows were woody plants, predominantly Euphorbiaceace (8.2%), Moraceae (5.4%) and Mimosoideae (4.1%). During this period, hydromorphic zones were flooded and abandoned (*Brachiaria deflexa, Digitaria horizontalis, Pennisutum polystachion, Sorghum arundinaceum, Amaranthus spinosus, Digitaria horizontalis, Killinga squamulata* disappeared from the samples). The proportion of herbaceous collected on dry soils was lower than at the short rainy season (28.2 vs 46.8%), but the species were generally the same. Some perennial species like *Panicum maximum* and *Eleusine indica* still presented palatable regrowth. The most frequent woody species belonged to Arecacea (*Elaeis guineensis*) and Rutaceae (*Fagara zanthoxyloides*). These woody species were sometimes grazed at ground level, but the majority lopped by the breeder and distributed to the sheep. A high proportion of *Elaeis guineensis* and *Fagara zanthoxyloides* were sampled by sheep. In the south of Benin, vegetation was dominated by *Elaeis guineensis* [14]. The consumption of *Fagara zanthoxyloides* leaves contributes to decrease of nematode egg output [24].

Table 1 Relative frequencies of the species consumed by sheep from July to October (covered the short dry season (July 17-September 15) and the short rainy season (September 15-October 16).

Consumed species	Family	Relative frequency (%)	
		Short dry season	Short rainy season
Woody spp			
Albizia adianthifolia	Mimosoideae	0.9	0.6
Albizia zygia	Mimosoideae	0.8	-
Antiaris toxicaria	Moraceae	0.4	0.3
Blighia sapida	Sapindaceae	-	0.4
Cajanus cajan	Papilionoideae	1.0	0.5
Carica papaya	Caricaceae	-	0.7
Chromolaena odorata	Asteraceae	4.0	3.0
Citrus sinensis	Rutaceae	1.1	-
Coffea arabica	Rubiaceae	0.4	0.5
Cola millenii	Sterculiaceae	0.2	-
Crescentia cujete	Bignoniaceae	0.5	0.3
Dialium guineense	Caesalpinioideae	1.0	-
Draceana arborea	Dracaenaceae	4.4	3.2
Elaeis guineensis	Arecaceae	6.5	4.0
Euphorbia balsamifera	Euphorbiaceae	0.5	0.6

(to be continued)

Consumed species	Family	Relative frequency (%)	
		Short dry season	Short rainy season
Fagara zanthoxyloides	Rutaceae	6.3	3.8
Ficus congensis	Moraceae	0.7	0.7
Ficus exasperata	Moraceae	0.9	0.4
Ficus umbellata	Moraceae	3.4	3.7
Gliricidia sepium	Papilionoideae	2.8	0.7
Irvingia gabonensis	Irvinginaceae	2.3	-
Jatropha curcas	Euphorbiaceae	1.5	2.5
Leucaena leucocephala	Mimosoideae	1.6	0.4
Mallotus oppositifolius	Euphorbiaceae	1.3	0.9
Mangifera indica	Anacardiaceae	1.8	1.8
Manihot glaziovii	Euphorbiaceae	0.8	0.5
Margaritaria discoidea	Euphorbiaceae	4.1	2.9
Morinda lucida	Rubiaceae	1.1	0.7
Moringa oleifera	Myristicaceae	4.4	2.8
Musa spp	Musaceae	2.7	3.5
Newbouldia laevis	Bignoniaceae	2.9	2.3
Persea americana	Lauraceae	0.7	-
Pithecellobium dulce	Mimosoideae	0.8	0.4
Pouteria alnifolia	Sapotaceae	4.1	2.9
Psidium guajava	Myrtaceae	0.7	0.9
Sarcocephalus latifolus	Rubiaceae	0.4	-
Spondias mombin	Anacardiaceae	0.8	2.8
Terminalia catappa	Combretaceae	0.4	0.5
Triumfetta cordifolia	Tiliaceae	3.6	3.3
Vitex doniana	Verbenaceae	-	0.7
Total		71.8	53.2
Herbaceous			
Aeschynomene indica	Papilionoideae	0.4	-
Andropogon gayanus	Poaceae	1.1	1.5
Andropogon tectorum	Poaceae	1.9	2.1
Amaranthus spinosus	Amaranthaceae	-	3.8
Brachiaria deflexa	Poaceae	-	2.5
Centrosema pubescens	Papilionoideae	0.3	2.8
Chamaecrista mimosoides	Caesalpinioideae	0.5	-
Cynodon dactylon	Poaceae	1.4	2.1
Cyperus rotundus	Cyperaceae	-	1.2
Dactyloctenium aepgyptiaca	Poaceae	3.9	3.0
Digitaria horizontalis	Poaceae	-	1.8
Eleusine indica	Poaceae	5.5	4.7
Kyllinga squamulata	Cyperaceae	-	1.2
Panicum maximum	Poaceae	5.5	6.6
Pennisetum polystachion	Poaceae	-	1.0
Peperomia pellucida	Piperaceae	1.2	1.1
Rottboellia cochinchinensis	Poaceae	1.2	2.0
Setaria barbata	Poaceae	0.6	-
Sorghum arundinaceum	Poaceae	-	1.2
Sporobolus pyramidalis	Poaceae	3.5	4.3
Sytlosanthes hamata	Papilionoideae	1.2	4.4
Total		28.2	46.8

At the beginning of the short rainy season, the woody consumption frequency decreased from 71.8 to 53.2%. At this time of the year, the consumption of herbaceous species increased from 28.2 to 46.8 but

grazing was still concentrated in the fallows. A high proportion of *Panicum maximum* and *Eleucine indica* were sampled. In the fact, these species were the plants to present a better regrowth at the short rainy season.

3.2 Chemical Composition and In Vitro Organic Matter Digestibility of the Consumed Forage

The chemical composition and *in vitro organic* matter digestibility (IVOMD) of the hand-plucked samples during the short dry season is presented in Table 2. As in south Benin an in other humid regions of Africa, the availability of forage is not a real constraint in the pasture but the nutritive value of forage decreased widely at the dry season [25]. The measurements of chemical composition and *in vitro organic* matter digestibility during the dry season could help to know how to supplement the poor quality of the forage in this period of the year. These measurements could also help to increase the productivity of small ruminant breeds and thereby smallholder's incomes.

The crude protein (CP) content of woody ranged from 8.9% (*Pouteria alnifolia*) to 30.1% (*Pithecellobium dulce*) and 7.4 (*Eleucine indica*) to 27.2% (*Chamaecrista mimosoides*) for herbaceous. Except *Pouteria alnifolia*, *Draceana arborea* and *Ficus exasperate*, CP was high in woody leaves From July 17-September 15 (covered the short dry season). Crude fibre (CF) were more variable in herbaceous than in woody (35% vs 28%) and herbaceous were generally higher in the levels of CF. The CP of herbaceous were negatively correlated with the CF ($r = -0.63$, $P < 0.01$). Chemical characteristics of the two types of forage were not similar. The protein content of woody plants is high compared with that of grasses. For woody species, correlations were not found among chemical composition while CP of herbaceous were negatively corrected with the CF. On one hand, differences in CP contents between these woody species are probably due in first to differences in stage of growth and type (i.e., twigs, leaves or soft stem) of foliage sampled. On the other hand, differences could be due to differences in protein accumulation in them during growth. Differences could also be due to sampling site and climatic influences on foliage growth and plant nutrient accumulation or soil and management conditions [26, 27]. The change in the grazing areas during time shows the complementarily of the land-units (wooded and shrubby savannas, hydromorphic zones, fallows) and leads to a better distribution of the stocking rate during the rainy season. This change in grazing areas was also reported by Djenontin et al. [28] in North Benin, where fallows are frequented by herds from June to October, while natural savannas are essentially grazed from January to May. This has important implications for the sustainability of the ecosystem.

Mean IVOMD of woody were 55.6% (range 26%-83%). Some woody leaves (*Chromolaena odorata*, *Citrus sinensis*, *Vitex* doniana) were high in IVOMD (> 80%). On the contrary the lowest values were recorded in *Spondias mombin*, *Moringa oleifera*, *Persea americana*, *Psidium guajava*, *Dialium guineense* (26%-35%). Herbaceous IVOMD mean were 55% (range 24%-82%). Among these species *Andropogon gayanus* and *Panicum maximum* still presented a high value of IVOMD at the short dry season. High CP contents were observed in *Albizia adanthifolia*, *Albizia zygia*, *Cajanus cajan*, and *Moringa oleifera* (24.6%, 22.9%, 23.1% and 24.3% respectively) however unexpected *in vitro* organic matter digestibility were noticed (51%, 43%, 53% and 29% IVOMD respectively). Several authors [29-32] reported high phenolic and tannin levels in some African woody. These anti-nutritive factors affect the nutritive value. For this reason, depending on the species, tree woody foliage may be of lower nutritive value as sole feed than as supplement to other feeds. The significance of anti-nutritive factors becomes more evident when woody foliage is the only feed consumed. Tannins found in some woody form complexes with plant proteins which decrease their rate of digestion in the rumen, thereby decreasing rumen ammonia

concentrations and increasing the amount of plant protein bypassing the rumen. Norton [29] indicated that microbial population in the rumen requires a minimum level of ammonia (70 mg N/L) to support optimum activity; lower values are associated with decreased microbial activity (i.e. digestion) and are indicative of nitrogen deficiency. Feeds containing less than 1.3% N (8% CP) are considered deficient as they cannot provide the minimum ammonia levels required. Except for *Eleusine indica* and *Kyllinga squamulata*, all woody and herbaceous plants samples at this period of the season have CP contents generally higher than this value, and may be judged adequate in protein.

In the study, botanical inventory and determination of the nutritive quality of the consumed forage were made from samples collected by hand-plucking method. This method introduces bias in digestibility estimation because hand-plucked herbage may not be representative of the herbage grazed because of the diet selection by grazing sheep [33]. Oesophageal fistula samples have then been use to overcome the inaccuracy of hand-plucking samples [18]. However, these methods require the surgical alteration of experimental animals [4], which is impractical in production situations and can be undesirable from an animal welfare point of view. In addition, these methods is not easily implemented with growing West African Dwarf sheep, because of the size of the sheep oesophagus and behavioural characteristics of the sheep, plus the size and fibrosity of the studied forages. Therefore, hand-plucking method seemed the most appropriate way to obtain estimations of the quality of the small

Table 2 Chemical composition and *in vitro organic* matter digestibility of the hand-plucked forage during the short dry season.

Consumed species	Family	OM	CP	CF	IVOMD
Woody spp					
Albizia adianthifolia	Mimosoideae	95.3	24.6	14.5	51
Albizia zygia	Mimosoideae	93.4	22.9	19.5	43
Antiaris toxicaria	Moraceae	90.1	18.1	15.1	64
Blighia sapida	Sapindaceae	92.5	15.4	18.2	53
Cajanus cajan	Papilionoideae	91.3	23.1	15.6	53
Carica papaya	Caricaceae	86.3	10.3	16.7	79
Chromolaena odorata	Asteraceae	95.1	21.5	23.1	81
Citrus sinensis	Rutaceae	91.8	13.6	20.8	82
Coffea arabica	Rubiaceae	91.1	17.1	22.5	43
Cola millenii	Sterculiaceae	90.2	11.4	19.5	40
Crescentia cujete	Bignoniaceae	91.1	10.1	17.8	59
Dialium guineense	Caesalpinioideae	92.0	18.5	21.2	32
Draceana arborea	Dracaenaceae	87.9	9.4	13.1	35
Elaeis guineensis	Arecaceae	92.8	12.3	24.6	48
Euphorbia balsamifera	Euphorbiaceae	88.2	16.4	14.1	76
Fagara zanthoxyloides	Rutaceae	89.7	13.7	17.3	65
Ficus congensis	Moraceae	85.6	11.3	13.5	54
Ficus exasperata	Moraceae	77.8	9.3	26.8	73
Ficus umbellata	Moraceae	87.1	12.5	15.4	62
Gliricidia sepium	Papilionoideae	92.5	23.8	6.9	56
Leucaena leucocephala	Mimosoideae	91.3	26.2	8.5	72
Irvingia gabonensis	Irvinginaceae	88.1	14.4	17.7	56
Jatropha curcas	Euphorbiaceae	86.1	13.5	15.3	63
Mallotus oppositifolius	Euphorbiaceae	91.3	13.2	16.4	69
Mangifera indica	Anacardiaceae	92.2	16.3	27.4	39
Manihot glaziovii	Euphorbiaceae	91.8	11.4	15.8	46

(to be continued)

Consumed species	Family	OM	CP	CF	IVOMD
Woody spp					
Margaritaria discoidea	Euphorbiaceae	91.3	12.8	17.5	76
Morinda lucida	Rubiaceae	87.5	11.7	21.9	78
Moringa oleifera	Myristicaceae	90.9	24.3	16.4	29
Musa spp	Musaceae	88.6	15.3	26.0	39
Newbouldia laevis	Bignoniaceae	91.7	14.8	22.4	54
Persea americana	Lauraceae	93.1	11.6	27.8	31
Pithecellobium dulce	Mimosoideae	92.0	30.1	28.3	73
Pouteria alnifolia	Sapotaceae	91.3	8.9	25.8	42
Psidium guajava	Myrtaceae	93.0	16.4	24.4	32
Sarcocephalus latifolus	Rubiaceae	91.3	12.6	17.5	56
Spondias mombin	Anacardiaceae	92.8	14.8	17.4	26
Terminalia catappa	Combretaceae	89.5	13.9	16.2	69
Triumfetta cordifolia	Tiliaceae	91.3	14.4	15.9	42
Vitex doniana	Verbenaceae	93.8	17.4	11.9	83
Herbaceous					
Aeschynomene indica	Papilionoideae	92.5	23.1	24.1	73
Andropogon gayanus	Poaceae	93.5	13.2	26.8	73
Andropogon tectorum	Poaceae	90.7	12.9	36.7	82
Amaranthus spinosus	Amaranthaceae	82.6	11.5	13.6	45
Brachiaria deflexa	Poaceae	90.3	15.9	27.9	75
Centrosema pubescens	Papilionoideae	94.7	26.8	12.7	54
Chamaecrista mimosoides	Caesalpinioideae	94.1	27.2	23.7	55
Cynodon dactylon	Poaceae	94.6	8.9	32.1	54
Cyperus rotundus	Cyperaceae	88.7	11.1	38.9	64
Dactyloctenium aepgyptiaca	Poaceae	93.2	13.4	34.6	52
Digitaria horizontalis	Poaceae	92.4	12.5	33.8	62
Eleusine indica	Poaceae	93.3	7.4	35.2	49
Kyllinga squamulata	Cyperaceae	85.8	7.9	36.4	58
Panicum maximum	Poaceae	87.6	14.8	30.1	79
Pennisetum polystachion	Poaceae	89.7	10.2	31.5	68
Peperomia pellucida	Piperaceae	86.1	15.3	16.9	61
Rottboellia cochinchinensis	Poaceae	89.2	8.8	29.2	62
Setaria barbata	Poaceae	81.5	9.3	42.8	24
Sorghum arundinaceum	Poaceae	92.2	15.2	28.5	73
Sporobolus pyramidalis	Poaceae	91.8	12.2	34.3	45
Sytlosanthes hamata	Papilionoideae	89.5	19.4	15.1	75

OM: organic matte ; CP: crude protein; CF: crude fibre; IVOMD: *in vitro* organic matter digestibility

ruminant diet under the conditions of our study. This method gave a better estimate of material consumed by the sheep than analysis of whole plant samples.

4. Conclusion

Relative frequency and the nutritive quality of forage consumed by sheep were evaluated in south Benin from July to October (covered the short dry season and the short rainy season). The study showed that in the tropical humid climate of south Benin forages used in ruminant production systems are extremely variable in terms of their species, chemical composition and *in vitro* organic matter digestibility. High CP, and low CF levels, suggests woody with

potential as nitrogen supplements to ruminants fed with low quality forage during the dry season in south Benin. However several species (*Albizia adanthifolia*, *Albizia zygia*, *Cajanus cajan*, *Moringa oleifera*) *in vitro* organic matter digestibility registered was low. It means that the utilisation of these species in feeding strategy may be limited. It is also clear that the interpretation of the nutritional value of protein in these species required information on the nature and actions of tannins.

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