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EVALUATION OF THE NUTRITIVE VALUE AND FREE CHOICE INTAKE OF TWO AQUATIC WEEDS (*Nephrolepis biserrata* AND *Spirodela polyrhiza*) BY WEST AFRICAN DWARF GOATS

[VALOR NUTRICIO Y CONSUMO DE DOS PLANTAS ACUÁTICAS (*Nephrolepis biserrata* Y *Spirodela polyrhiza*) POR CABRAS AFRICANAS]

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SUMMARY

Aquatic plants are a potential as forage in countries with rivers, streams, brooks, oasis, swamps and dams. The chemical composition, forage acceptability and N-balance of aquatic fern (AF) and duckweed (DW) were studied using West African dwarf goats. Effect of rainy and dry seasons in AF was not noticed for DM, CP, EE, CF, ash and gross energy. Crude protein content however, was highest in leaf (12.76%) but least (4.35%) in the stem and this was contrary for CF content. Young AF was richer in CP (10.45%) but lower in DM (20.35%), EE (1.37%), CF (26.96%) and ash (6.96%) than the matured AF. Duckweed contained 31.5% CP and was more preferred in both the fresh and dried forms by goats than any of the presented forms of AF. Dry matter intake increased at 20% supplementation with grass but decreased apparently at the 40% level than the grass only. N-retention by the goats ranged between 66.75 and 83.70% but it was highest ($P < 0.05$) in DW composed forages. The results showed that aquatic fern and duckweed are potential sources of nutrients but the latter was more preferred than the former by West African dwarf goats.

Key words: Aquatic plants, chemical composition, forage acceptability, nitrogen balance

RESUMEN

Las plantas acuáticas son una fuente potencial de forraje en países con diversidad de cuerpos de agua (ejem. ríos, arroyos y presas). Se estudio la composición química, la aceptabilidad del forraje y el balance de N de *Nephrolepis biserrata* (AF) y *Spirodela polyrhiza* (DW) en cabras africanas. Para AF no se observó efecto de estación (lluvia o sequía) sobre el contenido de MS, PC, EE, Fibra cruda, ceniza y energía bruta. El contenido de proteína cruda fue mayor en las hojas (12.76%) y menor en los tallos (4.35%). Plantas jóvenes de AF fueron más ricas en PC (10.45%) pero con un bajo contenido de MS (20.35%), EE (1.37%), FC (26.96%) y ceniza (6.96%). DW contenía 31.5% PC y tuvo una mayor aceptación tanto en forma fresca como seca que la aceptación observada para AF. El consumo de MS se incrementó cuando del nivel de inclusión fue del 20% pero pareció disminuir con un 40% de inclusión. La retención de N de las cabras fue de 66.75 a 83.70% pero fue mayor ($P < 0.05$) en las dietas con DW. Los resultados mostraron que tanto AF como DW son plantas con potencial forrajero. Las cabras africanas tuvieron una mayor preferencia por DW.

Palabras clave: plantas acuáticas, composición química, preferencia, balance nitrógeno, cabras.

INTRODUCTION

One of the major problems of ruminant production in Nigeria is the scarcity of forages all the year round. Livestock have abundance of pasture to take in the first six months of the rainy season during which animals are well fattened. The other six months are always followed by scarcity of forages as a consequence of the dry period, resulting in standing hay and low quality feed that eventually culminates in growth retardation of the animals (Babayemi et al., 2003).

Although certain tree legumes had been proved for supporting and sustaining ruminants as supplements in the dry season (Lazier, 1984; Rogers, 2002), there are also aquatic weeds yet unexplored as feedstuffs for ruminants in Nigeria. Rivers, streams, brooks, swamps, dams and lakes where many varieties of water plants (e.g. *Nephrolepis biserrata* and *Spirodela polyrhiza*) and are located, surround almost all the regions of Nigeria. The reproductive efficiency of these waterweeds is high (Khan et al., 2002) and therefore, frequently block navigable waters, irrigation canals and aquaculture. However, the plants may be beneficial to small ruminants in the tropics due to the

nutritional properties reported for duckweed (Louis et al., 1980), water hyacinth (Khan et al., 1981), algae (Strain et al., 1986) and azolla (Tamang et al., 1992).

Nephrolepis biserrata (Schott) (Aquatic fern) is an evergreen perennial herb that form congested colonies in very wet soils and along the edges of streams or marshes and are sometimes on surfaces of lake and stagnant water. *Spirodela polyrhiza* (Duckweed) is found in fresh water and it is a major weed for aquaculture in Nigeria, where considerable effort is used for its consistent evacuation. It is a tiny, fragile and free-floating plant with no distinct stem or root. The weed had been reported (NAS, 1976) to be the most vigorous growing plant on earth as it has been observed to double its population in three days or less. Bennet and Woodford (1978) and Boyd and Scarsbrook (1975) suggested using the waterweeds are ideal forage for ruminants could reduce their menace to fish farming, irrigation, drainage canal, water quality, disease carrying water, snail and mosquitoes. Although the aquatic fern and the duckweed are perpetually resident in Nigeria coastal areas and stagnant waters, its utilization by small ruminants is yet to be fully explored. The present study was undertaken to evaluate the nutritive value of *Spirodela polyrhiza* and *Nephrolepis biserrata* for the West African dwarf goats.

MATERIAL AND METHODS

Aquatic fern

The aquatic fern (*Nephrolepis biserrata* (Schott) was collected from a stream within the University of Ibadan in five locations, to coincide with early rain, late rain, early dry season and late dry season in June, September, December (2003) and April (2004) respectively. The area (40 m x 5 m) was identified and demarcated by wire mesh to prevent human intrusion. All the stands of aquatic ferns in the marked area were cut at 10 cm above the ground. The samples were collected according to their morphological stage of growth, young and mature being three and six months old respectively. The harvested samples were separated into three anatomical parts (leaf, stem, leaf plus stem). Harvesting was carefully effected using a sickle to avoid contamination from the soil. Part of the young and old ferns were separately dried as hay and kept in a well-ventilated room within the week of their use. Each anatomical plant part was thoroughly mixed and sub-sampled for further use.

Duckweed

Spirodela polyrhiza was collected from eight fishponds at different farms in Ibadan Metropolis, Nigeria. The weeds were harvested between 2 and 4 weeks of growth. The first batch of the weed was obtained and sun dried as hay, which was kept in a jute bag until ready for use. The second batch of the weed was collected from the pond some hours prior to feeding, being fed to goats at 07:00 h. Since it was to be fed fresh, the weed was packed in basket and well pressed to ease the draining of water.

Free choice intake

Twenty-four WAD goats previously certified fit by the University veterinarian was subjected to free choice feeding to evaluate the acceptability of the two aquatic weeds. In triplicates, 5 kg each of dried and fresh of young and old aquatic fern and fresh and dried of duckweed were strategically placed in the pen in form of cafeteria as reported previously (Bamikole et al., 2004). The wooden feeder (150 cm x 60 cm) was used to enable about 8 animals to conveniently feed simultaneously. The feeders were interchanged everyday to prevent adaptation of the animals to the positions of the troughs. The feeding was allowed from 10:00 to 18:00 h daily and lasted for 14 days. The feed consumed was determined by deducting the orts from the quantity served. The forage or the form of forage preferred was assessed from the coefficient of preference (COP) value, computerized from the ratio between the intake of each individual forage or form, divided by the average intake of the forages (Karbo et al., 1993; Bamikole et al., 2004). Thus, aquatic forage or its form was concluded to be relatively acceptable provided the COP was greater than the unity.

Digestibility and nitrogen balance

Twelve WAD female goats, about one year old and weighing 10 - 15 kg were used to determine the digestibility and nitrogen balance of fresh duckweed (DW) with Guinea grass (GG) as basal diet. The goats were certified free from external and internal parasites and were then allocated in 4 replicates into 3 dietary treatments I (100 % GG), II 80 % GG + 20 DW) and III (60 % GG + 40 % DW). The goats were confined in individual modified (Akinsoyinu, 1974) metabolism cages for a separate collection of faeces and urine. The goats were fed *ad libitum* between 08:00 and 13:00 h daily. Accurately weighed diet was offered and the orts also weighed before the morning feeding to determine the actual intake. Fresh water was provided daily. The trial lasted for 14 days as the first 7 days were used for adjusting the animals to the cages and the last 7 days were used for the collection of faeces and urine in which, aliquots (10%) of each day collection of faeces for each animal were dried at 100 ºC to constant weight. Without addition of antibacterial, the urine was stored in airtight plastic bottles and kept frozen at -20 ºC until required for analysis.

Chemical analysis

Representative sub-samples were dried in a forced-drought oven at 105-110 ºC to constant weight for dry matter determination. Crude protein, crude fibre, ether extract and total ash samples were analyzed by triplicate following the procedures of AOAC (1990). The gross energy content was determined using a ballistic bomb calorimeter.

Statistical analysis

In a completely randomized design, analysis of variance was carried out using the method described by Steel and Torrie (1980). In the event of significant differences, treatment means were compared by Duncan multiple range test (Duncan, 1955).

RESULTS

Shown in Table 1 is the chemical composition of three anatomical parts of aquatic fern. Dry matter and crude protein content were higher in the leaves than any part of the plant. The content of ether extract and ash were similar in the leaves and the stem plus leaves (whole plant). The stem contained more crude fiber and ash than the parts of leaves and stem plus leaves. The gross energy was similar in all the parts of the plant analyzed. Also presented in Table 2 is the chemical composition of the aquatic fern harvested at two different stages of growth. The young plant contained more ($P > 0.05$) crude protein than the old plant while the old plant contained more ($P > 0.05$) DM, EE, CF and ash than the young plant ($P < 0.05$). Gross energy was not different ($P > 0.05$) in both young and old plant. Proximate composition of the duckweed and the experimental diets is shown in Table 3. Crude protein (31.5%) content of duckweed was higher than the 7.4% CP of Guinea grass hay. The crude fiber was lower in duckweed (19.3%) than what was obtained for the grass (47.8%). It was observed that the crude protein increased with a decreasing crude fiber as the level of duckweed in the diet increased.

Table 1. Proximate composition (g/100g DM) and gross energy (Kcal/g) of the three anatomical parts of the aquatic fern.

Anatomical parts	Sub seasons[1]	Dry matter	Crude protein	Ether extract	Crude fiber	Ash	NFE	Gross energy
Stem	ED	15.19	4.41	1.00	30.77	7.98	55.85	3.73
	LD	15.80	4.48	1.00	31.73	7.83	54.98	3.74
	ER	16.00	4.37	1.64	31.28	7.78	54.94	3.74
	LR	16.15	4.41	1.33	31.43	7.53	55.57	3.77
Mean		15.94	4.35	1.24	31.30	7.78	55.33	3.75
		± 0.17c	± 0.18c	± 0.10b	± 0.44a	± 0.15a	± 0.46a	± 0.01
Leaves	ED	27.66	13.05	1.72	22.85	7.65	54.73	3.78
	LD	27.79	12.85	1.58	23.00	7.55	55.03	3.78
	ER	27.45	12.89	1.81	23.13	7.58	54.52	3.77
	LR	27.58	12.23	1.72	24.18	7.31	54.56	3.77
Mean		27.62	12.76	1.70	23.22	7.52	54.73	3.78
		± 0.69a	± 0.32a	± 0.06a	± 0.26c	± 0.21b	± 0.25a	± 0.01
Stem +	ED	23.53	9.63	1.63	28.38	7.24	53.12	3.79
Leaves	LD	23.06	9.43	1.54	29.91	7.17	51.94	3.79
	ER	22.76	9.42	1.63	28.30	7.79	52.87	3.77
	LR	23.27	9.28	1.90	29.59	7.66	51.57	3.79
Mean		23.15	9.44	1.68	29.05	7.47	52.37	3.79
		± 0.42b	± 0.57b	± 0.10a	± 0.40b	± 0.13b	± 0.60b	± 0.01
SEM		3.19	2.55	0.09	2.30	0.10	0.90	0.88

a,b,c means in the same column with the same subscripts are not significantly different ($p>0.05$).
1= ED (Early dry season), LD (Late dry season), ER (Early rainy season) and LR (Late rainy season).
± = standard deviation

Table 2. Proximate composition (g/100 g DM) and gross energy (Kcal/g) of the aquatic fern at two different stages.

Stages of Growth	Sub seasons[1]	Dry matter	Crude protein	Ether extract	Crude fiber	Ash	NFE	Gross energy
Young	ED	20.82	10.58	1.42	27.15	7.02	53.83	3.79
	LD	20.55	10.60	1.38	27.08	6.97	53.97	3.79
	ER	19.99	10.45	1.39	26.82	6.94	54.39	3.79
	LR	20.03	10.17	1.27	26.78	6.79	54.87	3.79
Mean		20.35	10.45	1.37	26.69	6.69	54.27	3.79
		±0.64b	± 0.67a	± 0.06b	± 0.52b	± 0.08b	± 0.50	± 0.00
Old	ED	23.90	7.48	1.48	27.51	8.22	55.31	3.75
	LD	23.88	7.24	1.37	29.34	8.06	53.99	3.75
	ER	24.15	7.33	1.99	28.32	8.49	53.87	3.76
	LR	24.63	6.93	2.03	30.30	8.09	52.92	3.78
Mean		24.14	7.25	1.72	28.80	8.10	54.02	3.76
		± 1.00a	± 0.54b	± 0.08a	± 0.72a	± 0.09a	± 0.35	± 0.01
SEM		1.64	1.53	0.001	0.05	0.03	2.84	0.75

a.b,c means in the same column with the same subscript are not significantly different ($p>0.05$)
1= ED (Early dry season), LD (Late dry season), ER (Early rainy season) and LR (Late rainy season).
± = Standard deviation

Table 4 shows the acceptability of forage and the form of the forage in which, the goats were permitted to have a free choice selection on two aquatic weeds and their different forms. According to COOP, the offered waterweeds and their forms were all accepted. However, a higher preference was shown towards duckweed and less for aquatic fern especially the matured ones.

Nutrient digestibility and N-balance data are shown in Table 5. There was variation in DMI by the goats on diet 1, 2 and 3 with the values 433.52, 439.52 and 320.38 g respectively. There were no significant differences ($P > 0.05$) in DM, CP and CF digestibility of the diets goats. The trend for N-balance (g $d^{-1}kg^{-1}$ BW) showed a situation in which the animal recorded the highest value (1.83), which was significant ($P < 0.05$). Nitrogen retention was also apparently higher ($P < 05$) for goats fed diets 2 (88.70%) and 3 (82.90%) than the value of 66.75% for those on diet 1.

DISCUSSION

Possibly due to the aquatic fern ecological habitat, season did not show a deteriorating effect on its nutrient composition, indicating therefore, its potential to sustain ruminants all year round. On a fresh basis, the average DM in the aquatic fem compared well to the values of 20, 21, 24 and 21 percent reported (NRC, 1981) for oats (*Avera sativa*), banyard grass (*Echinochloa crusgalli*), alfafa (*Medicago sativa*) and napier grass (*Pennisetum purpureum*) but higher than 5 - 9% reported for some water weeds (Khan *et al.,* 2002). The high moisture content of the plant might be a limiting factor in feeding it on fresh basis since animals would eat more of the plant material to enable it get adequate amount of nutrient for body metabolism. Unfortunately, this might not be attainable since the level of feed intake in ruminants is also controlled by the capacity of the digestive tract, particularly the rumen, with animal ceasing, to eat when a certain degree of "fill" has been attained. However, high amount of water in the plant could be ameliorated by dehydrating the harvested plant materials under the sun as wilted or as hay.

The crude protein of the aquatic fern in the present study apparently decreased as the plant matured. Such lowered crude protein at advanced age had also been noticed in other aquatic plants (Bagnall et al., 1973). Thus, when using the plant as forage, it could be strategically cut every twelve weeks to optimize its nutrient value. The analytical studies of the three different anatomical parts of the fern showed the crude protein value was noticeably high in the leaves followed by the leaves plus stem. The lowest CP content was recorded in the stem probably because the stem contained more crude fiber, being that crude fiber is known to be diluents, which decreases CP in plants. The level of the CP in the fern, especially in leaves is high enough to meet the protein requirement of small ruminants. Mean crude fiber of 27. 88% in *Nephrolepis biserrata* obtained in the present study was lower than the value of 33.9% obtained for Napier grass *Pennisetum purpureum* (NRC, 1981) while the value compared well to those of *Cynodon dactyllon* and *Sorghum bicolor* (aerial part, sun dried).

The older fern contained more CF than the young plant probably due to lignification of cells as the plant matures. The stems of the fern contained more CF than the leaves and the leaves plus stem. The reason for this might be due to the fact that as leaves mature, they fall off and are replaced by younger and more photosynthetically active ones while the process of lignification proceeds in the stem, thereby increasing the percent of old stem in the entire biomass. The old aquatic fern contained more ash than the young fern due to the high mineral deposition in the old plant. The absence of seasonal variation in the ash content of the aquatic fern suggests a balance of mineral content throughout the year for the animals consuming it.

Reason for the high preference for duckweed by the goats was not clear. It could nevertheless be linked with its high crude protein content. Small ruminants prefer sweet and generally reject bitter plants (Krueger et al., 1974). Oldham and Alderman (1980) reported that sometimes *ad libitum* intake by animals is increased by an increase in crude protein content of diets.

Table 3. Aquatic fern and duckweed acceptability by West African dwarf goats.

Aquatic plant	Mean daily intake (kg DM)	Coefficient of preference
Aquatic fern		
Young fresh	3.50 ± 0.36	1.16
Young dried	3.20 ± 0.14	1.06
Old fresh	2.43 ± 0.12	0.81
Old dried	1.33 ± 0.26	0.44
Duckweed		
Fresh	4.10 ± 0.16	1.36
Dried	3.53 ± 0.17	1.17

± = standard deviation

Table 4. Proximate composition (g/100 g DM) of *Spirodela polyrhiza* and diets fed to goats.

	DIETS [1]			
Nutrients	100% PM	80% PM + 20% SP	60 PM + 40% SP	100% SP
Dry matter, %	90.0	71.2	76.1	34.0
Crude protein	7.4	12.2	17.1	31.5
Crude fiber	47.8	42.1	36.3	19.3
Ether extract	1.0	1.3	1.5	2.5
Ash	13.7	13.2	12.7	11.2
NFE	30.0	31.2	32.4	35.5

1: PM= *Panicum maximum*, SP= *Spyrodela polyrhiza*

Table 5. Nutrient digestibility (%) and N-balance values for goats fed *Panicum maximum* and varying level of *Spyrodela polyrhiza*.

Nutrients	DIETS			
	1	2	3	SEM
DM intake g/d	433.52^{a}	439.39^{a}	320.38^{b}	7.83
DM faeces g/d	195.61^{a}	171.65^{b}	105.51^{c}	3.33
DM digestibility (%)	55	61	60	3.33
N intake g/d	5.15^{b}	8.60^{a}	8.80^{a}	0.47
N in faeces g/d	1.30^{a}	0.43^{b}	0.92^{ab}	0.16
N in urine g/d	0.43^{b}	0.96^{a}	0.58^{b}	0.033
N-balance g/d	3.44^{b}	7.20^{a}	7.31^{a}	1.35
N-retention (%)	66.75^{b}	83.7^{a}	82.9^{a}	5.81

^{ab}Means on the same row with different superscripts are significantly different ($P < 0.05$).

Crude protein of duckweed was 10-20% higher above ruminant requirement (NRC, 1980). The low crude fiber of the waterweeds is expected to be lower than the conventional forages (Mishra et al., 1987). All goats fed with duckweed and Guinea grass mixtures consumed above 3% of their body weight, which agrees with the value of 3-5% of body weight as DMI recommended for ruminants (ARC, 1980, Devendra 1988). Feeding of Guinea grass when replaced at 20% and 40% by duckweeds did not have effect on digestibility values. Since digestibility of CP, CF and DMI increased as Guinea grass was replaced with the duckweed, further projections could have shown a significant difference at higher level of replacement.

It was noted that the replacement of Guinea grass with duckweed enhanced N- retention appreciably. The reason N-balance values did not reflect the trend observed for nitrogen retention is not clear. It could however be due to some of the weaknesses in N-balance studies. McDonald et al (1982) reported that N-balance is a suitable index for assessing nutrient adequacy but it has to be performed over a long period to minimize experimental errors involved in its determination.

CONCLUSION

Information obtained from this study suggests that aquatic fern and duckweed are high in nutrient and are well acceptable by goats. The study further showed that duckweed is more desirable than aquatic fern and has no detrimental effects on intake and utilization by goats when fed at various levels of supplementation along with Guinea grass.

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