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Nutritive value of *Echinochloa pyramidalis*, a forage plant used for treating faecal sludge and wastewater

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Abstract

In developing countries, the developments of treatment options for sanitation adapted to the local conditions have long been neglected. Constructed wetlands are recognized as cost-effective, technically feasible solution for wastewater treatment. The plants commonly grown on these systems are not worldwide available. Their economic and energetic reuse potentials are very limited. With similar characteristics, *Echinochloa pyramidalis* revealed a significant pollution removal capacity, with an attractive market potential because of its quality as forage. Their use on treatment systems provides an opportunity to linking sanitation stewardship to food production. In this study, a series of investigations was conducted to evaluate the effects of sanitation treatment processes under free drainage and flooding conditions on the nutritional potential of *E. pyramidalis* by analysis of their chemical components. The results showed that the nutritive value improved in quality, and *E. pyramidalis* is recommended as a suitable plant for forage production in treatment wetlands.

Keywords

Constructed wetlands; *Echinochloa pyramidalis*; forage; nutritive value; sanitation.

INTRODUCTION

Constructed wetlands (CW) are currently recognised as a cost-effective and technically feasible approach for domestic and industrial wastewater treatment, faecal sludge dewatering, stabilisation, and humification (Koottatep et al. 2004). This eco-technology has raised substantial interest in its potential use for beneficial purposes. To date, the technology is not well-developed in developing countries where effective, low cost treatment options are critically needed (Kivaisi 2001). Though, CWs have enormous potential of application in these countries with warm tropical and subtropical climates favourable for higher biological activity and productivity. However, to be effective, the implementation of this technology in developing countries needs to follow the appropriate context of these countries.

It has been demonstrated long time that there are biomass productions in constructed wetlands (CWs) with *Cyperus papyrus*, *Eichhornia crassipes*, *Phragmites australis*, *Typha latifolia*, *Typha augustifolia* (Boar et al. 1999). Nowadays, biomass productivity of such plants in the system can be considered as valuable opportunities. These wetland plants are the main macrophytes used in CWs are not always available and their economic or energetic reuse

potential is very limited as compare to others, such as *E. pyramidalis* well-known forage plants used to enhance biomass productivity while treating human waste (De Maesener 1997).

In Cameroon, 150–240 tons DM/ha/y of *E. pyramidalis* cultivated on faecal sludge dewatering beds have been reported (Kengne et al.2008). Comparative studies under the same climatic conditions carried out with manure application exhibited high productivity of *E. pyramidalis* (27 DM/ha/y) compared to 5.4 t DM/ha/y in natural environments (Onana et al. 2003).

E. pyramidalis well-known as antelope grass is an erect grass specie of 3 m (rarely 4–5 m) in height commonly called antelope grass (Yabuno 1968). Its rhizomes creep laterally. The plant favours humid environments mainly swampy areas (Anderson *et al.*, 2006) and is also found along rivers (River Niger in Mali, Niger). It is a perennial herb generally soil-attached, but also found floating or submerged (Adebowale 1988). The plant is widely distributed in tropical regions of Africa, America, Asia, and Australia (Anderson et al. 2006, Yabuno 1968) and has been successfully used for wastewater and faecal sludge dewatering in Cameroon (Bojcevska and Tonderski 2007, Kengne et al. 2008). This aquatic plant is known throughout Africa as a particularly rich fodder and forage plant fed to livestock (Adebowale 1988, De Abreu et al. 2006, Scholte 2007). Indeed, the land surfaces it covers are commonly used as pastures (Anderson and Cameron 2006). According to FAO's grass data collection, it achieved a green matter yield of up to 25 tons/ha in Malawi in February. Young plant shoots, grown after the action of fire when shifting cultivation, are more nutritious and very palatable. These nutritional plant shoots have to maintain the nitrogen (N) concentration of 0.66% in the herbivore's diet (Scholte 2007). The nutrient content and the chemical composition of this specie strongly depend on the factors such as cultural systems and physiological stage of maturity (Adebowale 1988). Though *E. pyramidalis*, both as green fodder and hay, is a particularly rich fodder plant for livestock (Adebowale 1988; De Abreu et al. 2006, only a few studies have focused on the growth, biomass production and nutritive value of the plant. To date, little is known about the influence of wetlands treatment processes under free drainage and flooding conditions on the chemical composition of *E. pyramidalis*, especially in terms of cell wall components. Therefore, the aim of this study is to evaluate the effects of wetlands treatment processes under free drainage and flooding conditions on the nutritional potential of the antelope grass as animal feed.

MATERIAL & METHODS

Experimental procedure

A series of investigations were conducted at the experimental field of the University of Yaoundé I, Cameroon located at 760 m above sea level (3°45 N and 11°32 E) from December 2007 to December 2008. Yaoundé has a typical equatorial Guinean climate characterised by two rainy seasons (from September to mid-November and from mid-March to June) and two dry seasons (from mid-November to mid-March and from July to August). Annual rainfall amounts to about 1600 mm and daily temperature varies between 23 and 32 °C. The analysis of plant samples were done carried out at the animal nutrition laboratory of the University of Dschang.

The design of vertical-flow constructed wetlands (VFCW) with a media arrangement was adapted from Koottatep et al. (2005) were set-up. This VFCW consisted 06 units of 50-litre capacity and 0.78 m² size each. To cope with the clogging situations generally faced by the systems, 06 pilot-scale units of VFCW were divided into two groups: flooded or saturated and non-flooded or free drainage. A completely randomised design with three replicates was used for the experiments. The units were equipped with a drainage pipe connected to a tap allowing vertical drainage of the percolate through the media.

Plant growth and harvest

Young shoots of *E. pyramidalis* were collected in the surrounding natural wetlands and transplanted the same day in the 06 VFCW units. Seven plants, each with about 20-cm long rhizomes and stems, were planted in each bed. After planting, the beds were flooded with raw wastewater to about 5 cm above the gravel layer and the plants were allowed to establish themselves in raw wastewater. After eight weeks of acclimatisation, the faecal sludge supernatant (FSS) replaced the raw wastewater as the influent to the pilot-scale units of VFCWs. Each VFCW unit was fed twice a week with 15-L of FSS regularly analyzed before (Table 1). In all the experiments, the plants were harvested at two different periods (45 and 100 days) after the start of sludge treatments. At each harvest, the plants were cut 20 cm above the sand level and divided into leaves and stems.

TABLE 1: Physicochemical compositions of the faecal sludge supernatant used in the VFCW units as influent

Parameters	pH	T (°C)	Eh (mV)	EC (µS/cm)	TDS	Ca ²⁺	Mg ²⁺	Na ⁺	(mg/l)			Total N	PT	
									K ⁺	Cl ⁻	NO ₃ ⁻			
Means	6.9	26.3	9.9	3000	1522.5	133.6	86	0.01	0.2	47.8	381	991	979.2	490.7
S.D.	1.2	2.9	69.4	0	28.5	173.8	156.4	0.01	0.6	51.9	11.6	89.1	177.1	35.3

Chemical analyses

For chemical analysis, the leaf and stem samples of *E. pyramidalis* harvested in the experimental units and in the natural wetlands were dried in a forced draft oven at 65 °C for 48 hours. The dried samples were ground to fit through a 1-mm sieve. The dry matter (DM) content was measured by placing 1g of sample in a pre-weighed porcelain crucible in an oven set at 105 °C overnight. The ash was determined after eight hours at 550 °C. Total N was measured by the Kjeldahl method (AOAC, 2000) and crude protein (CP) was calculated as N×6.25. Acid detergent fibre (ADF) including residual ash were analysed according to the AOAC standard methods (1990). Neutral detergent fibre (NDF), including residual ash and sulphuric acid detergent lignin (ADL), were determined by the Van Soest et al. (1991) methods. The lignin content was measured by solubilisation of cellulose with sulphuric acid.

Statistical analysis

The general linear model (GLM) procedures of SPSS (statistical programme) 12.0 for Windows were used for data analysis. All the collected data was tested for normal distribution and variance in homogeneity, and the group means of the homogeneous subsets were compared using Duncan's New Multiple range test. The level of significance was determined at P≤0.05.

RESULTS AND DISCUSSION

Forage quality

Tables 2 and 3 contain details on the mean concentration of cell wall constituents respectively in the leaves and stems of *E. pyramidalis* for two different growing periods (45 and 100 days) under free drainage and flooding conditions.

TABLE 2: Cell wall composition of *E. pyramidalis* leaves grown in faecal sludge wetlands treatment under flooding and free drainage

Treatment condition	Treatment period	DM (%)	Ash	CP	ADF	NDF	ADL(sa)	Lipids
(% DM)								
Ctrl (NW)	Ctrl1	92.5±0.8 ^a	9.7± 1.6 ^c	15.6±1.2 ^b	29.2±3.2 ^a	57.0±1.1 ^a	9.0±0.5 ^a	2.4±0.2 ^a
	Ctrl2	92.1±0.6 ^a	8.6±1.4 ^{bc}	12.9±2.0 ^a	37.6±1.6 ^c	65.2±1.3 ^c	12.9±0.8 ^c	3.9±1.2 ^b
Flooding	45 days	93.5±0.7 ^{bc}	9.6± 1.2 ^c	18.4±0.2 ^c	32.6±0.4 ^b	60.0±3.5 ^{ab}	12.1±2.2 ^c	6.5±0.7 ^c
	100 days	94.6±0.0 ^d	7.4±0.5 ^{ab}	12.0±0.5 ^a	36.5±0.3 ^c	64.0±5.9 ^c	12.2±0.1 ^c	6.8±0.1 ^c
Free drainage	45 days	93.8±1.0 ^c	6.6±0.3 ^a	18.4±0.1 ^c	30.6±0.8 ^b	59.2±1.4 ^a	10.6±0.4 ^b	4.4±0.6 ^b
	100 days	92.8±0.4 ^{ab}	9.8±0.5 ^c	12.2±0.3 ^a	34.4±1.1 ^c	63.3±1.7 ^{bc}	12.5±1.0 ^c	4.2±0.2 ^b

Ctrl (NW): Control, plant grown in the natural wetlands surrounding the experimental site

TABLE 3: Cell wall composition of *E. pyramidalis* stems grown in faecal sludge wetlands treatment under flooding and free drainage

Treatment condition	Treatment period	DM (%)	Ash	CP	ADF	NDF	ADL(sa)	Lipids
(% DM)								
Ctrl (NW)	Ctrl1	94.9±1.7 ^d	10.5±1.0 ^c	11.9±1.5 ^e	39.6±2.7 ^b	68.9±1.5 ^c	13.1±0.8 ^a	2.4±0.2 ^a
	Ctrl2	94.1±1.6 ^{cd}	10.9±1.5 ^c	8.0±0.8 ^{bc}	45.7±0.7 ^d	74.5±0.9 ^d	16.8±0.1 ^c	3.9±1.2 ^b
Flooding	45 days	92.0±0.5 ^a	7.3±0.2 ^b	7.5±0.4 ^b	43.1±1.6 ^c	65.6±1.5 ^{abc}	13.3±1.2 ^a	4.2±0.6 ^b
	100 days	94.9±0.4 ^d	7.1±0.7 ^{ab}	4.5±0.7 ^a	45.4±0.8 ^d	70.5±7.0 ^{abc}	15.4±0.1 ^b	2.6±0.1 ^a
Free drainage	45 days	92.4±0.4 ^{ab}	8.3±1.1 ^a	10.6± 0.3 ^d	35.2±0.5 ^a	73.6±2.9 ^{abc}	15.4±0.1 ^b	2.1±0.1 ^a
	100 days	93.3±0.7 ^{bc}	11.0±0.5 ^c	8.8±0.1 ^c	43.4±0.4 ^c	73.8±1.7 ^{abc}	19.0±0.9 ^d	2.8±0.4 ^a

Ctrl (NW): Control, plant grown in the natural wetlands surrounding the experimental site

After 45 days cultivation of *E. pyramidalis*, the dry matter content varied from 92.5 to 93.8% DM and 92 to 94.9% DM respectively for leaves and stems. As shown in tables 2 and 3, the leaf dry matters were markedly higher than that of the control ($P \leq 0.05$). The ash content ranged around 6.6–9.8% DM and 7.1–11% DM respectively for leaves and stems. The crude protein (CP) concentrations in leaves and stems ranged from 15.6 to 18.4% DM and 7.5 to 11.9 % DM, respectively. The highest crude protein (CP) contents was in the leaves (18.4% DM) while the lowest concentration was in the stems (7.5% DM). In leaves, the CP contents were consistently higher ($P \leq 0.05$) than those of the control and there were no significant difference between the leaf concentrations of the plant grown in flooding and free drainage conditions. Although the cell wall contents (NDF, ADL (sa) and ADF) in leaves were generally in the same trend, ADF, NDF and ADL contents in leaves were respectively ranged from 29.2 to 32.6% DM, 57 to 60%DM and 9 to 12.1% DM (Table 2) and in stems from 35.2 to 43.1% DM, 65.6 to 73.6%DM and 13.3 to 15.4% DM (Table 3). However, the lipid contents in leaves ranging from 4.4 to 6.5% DM were noticeably higher than those in the control experiment (2.4% DM) with those of the stems ranged from 2.1–4.2% DM (Table 3). In general, the same trend of leaf contents reported under the flooding conditions was also observed under the free drainage treatment as illustrated in Table 2.

After 100 days cultivation, the dry matter content of *E. pyramidalis* ranged from 92.8–94.6% DM and 93.3–94.9% DM respectively for leaves and stems. The ash contents varied

between 7.4 to 9.8% DM in leaves and 7.1 to 11%DM in the stems. The CP content around 12% DM in leaves and from 4.5 to 8.8 %DM in stems while the ADF, ADL, NDF contents were quite similar to those of the control experiment.

Similar to the 45-day treatment, the flooding condition did not noticeably influence *E. pyramidalis* leaf constituents after 100 days cultivation (Table 2). These experiments thus reveal that cultivation period (up to 100 days) and flooding conditions did not have any interactive effects on salinity and hence on the nutritive potential of the antelope grass grown in faecal sludge supernatant. The CP levels in the current study were mostly above minimum critical levels (6–8% DM) required for maintenance and growth of small ruminants and proper rumen-bacteria functioning (Van Soest, 1994). As lipids are a concentrated source of energy from forages, their high contents in *E. pyramidalis* can help in satisfying the energy requirements of animals in critical season such as dry season when other sources are limited. The cell wall composition remained close to the critical admissible limit (55–60% DM) for animal feed (Van Soest 1994). However, the high concentrations of cell-wall components could be attributed to the stage of maturity of plants at harvest, as maturity is one of the major factors influencing forage quality. Many studies have shown that fibre concentrations increased as plants matured (Buxton and Redfearn 1997). The highest fibre concentrations in stems could be explained in part by their anatomical features containing more structural and conducting tissues than leaves compared to the thin-walled mesophyll cells in the leaves. ADF representing about 50% NDF is an indication of high levels of hemi cellulose. However, high values of ADF have been reported for *E. pyramidalis* at different stages of growth in natural environments (Adebowale 1988). Moreover, the stage of maturity induces lignification of the plant organs. Like all tropical and C4 photosynthetic pathway forage, *E. pyramidalis* has thinner leaves, more bundle sheaths and smaller interveinal distance with higher hemicelluloses and lignin content. Lignification of plant cell wall at forage maturity has long been discussed in numerous studies (Buxton and Russel 1988).

CONCLUSIONS

The aim of this study was to evaluate the influence of the wetlands treatment processes on the nutritional potential of *E. pyramidalis* grown for 45 and 100 days under flooded and free drainage conditions. The results have shown that the quality of cell-wall constituents of *E. pyramidalis* were affected by the faecal sludge treatment processes. This study showed the suitability of *E. pyramidalis* as a good candidate as forage for the economic utilization in sanitation management and reuse potential. Hence, *E. pyramidalis*-based treatment wetlands for domestic wastewater and faecal sludge could be used as an alternative source of forage production for livestock feeding, in tropical regions where animal feed is of poor quality. Further investigations are necessary to evaluate forage intake, digestibility and hygienic quality.

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