EFFECTS OF SUPPLEMENTS OF WATER HYACINTH AND CASSAVA HAY ON THE PERFORMANCE OF LOCAL “YELLOW” CATTLE FED A BASAL DIET OF RICE STRAW

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ISBN 978-91-86197-97-1

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Dedication

To

My wife Hourt Sereyromny
My daughter Phal Arunvatei
My son Phal Duongpisedth

My families

And

My country

Effects of supplements of water hyacinth and cassava hay on the performance of local "Yellow" cattle fed a basal diet of rice straw

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Abstract

Eighteen male local "Yellow" cattle with average weight of 101±14.5 kg were allocated in a randomized complete block design (RCB) to a 3*2 factorial combination of 6 treatments, with three replicates of each treatment. The factors were: 3 sources of rumen supplement (water hyacinth leaves, water hyacinth leaves+stems and urea-mineral mixture), and supplementation or not with cassava hay. The basal diet was untreated rice straw fed *ad libitum*. The rumen supplements were offered at levels to provide 100 g crude protein (CP) per 100 kg live weight. The cassava hay was offered at levels equivalent to 200 g CP per 100 kg live weight.

Live weight gain was increased dramatically when cassava hay was fed. However, there was a significant interaction between the effect of the cassava hay and the rumen supplements. When cassava hay was fed growth rates were higher when the leaves of water hyacinth were given as the rumen supplement with no difference between water hyacinth leaves plus stem and the urea-mineral mixture. In the absence of cassava hay, the cattle fed either leaves or leaves plus stem of water hyacinth lost body weight while those fed the urea-mineral mixture gained in weight. It is concluded: (i) that water hyacinth leaves can be used effectively as a source of rumen nutrients for growing cattle on a basal diet of rice straw provided a source of bypass protein (in this case cassava hay) is also fed; and (ii) that the limiting factors in water hyacinth foliage are the presence of anti-nutritional factors the negative effects of which are exacerbated at low levels of dietary crude protein.

Key words: *Anti-nutritional factors, bypass protein, protozoa, rumen ammonia, rumen supplements, urea-mineral*

Table of contents

Abbreviation

ADF	Acid detergent fibre
ANOVA	Analysis of variance
AOAC	Association of Official Analytical Chemists
CH	Cassava hay
CP	Crude protein
DM	Dry matter
FCR	Feed conversion ratio
FMD	Foot and mouth disease
HCN	Hydrogen cyanide
LW	Live weight
Mekarn	Mekong basin animal research network
N	Nitrogen
NDF	Neutral detergent fibre
NH_3	Ammonia
OM	Organic matter
Pb	Lead
pH	Power of/potential Hydrogen
Prob/P	Probability
RCB	Randomized complete block design
RUA	Royal university of agriculture
SE Asia	South East Asia
SEM	Standard error of the mean
Sida-SAREC	Swedish international development cooperation agency-Department for research cooperation
UM	Urea-mineral mixture
UTA	University of tropical agriculture
WHL	Water hyacinth leaves
WHLS	Water hyacinth leaves+stems

1. Introduction

Cattle and buffaloes in developed and developing countries provide meat, milk, traction power and manure to the beneficial integration of agricultural and livestock farming. To achieve a good performance of those animals, correct feeding methods need to be applied, by understanding first the factors governing rumen function and secondly the role of bypass nutrients (Preston and Leng 2009).

2. Literature review

2.1. Feed resources for cattle production in Cambodia

Ruminants are able to use nutrients arising from poor quality forage or cellulosic biomass, especially forages of low digestibility, such as crop residues, agro-industrial by-products, weeds, grasses from rangeland, foliage of trees and shrubs. These are the basal feed resources of ruminants in developing countries (Preston and Leng 2009). Thus rice straw is the roughage that is usually fed to cattle as the main diet during the dry season in many Asian countries, particularly in Cambodia. It has low content of essential nutrients and low digestibility, which results in low performance and poor health.

The ruminant derives essential nutrients for metabolism from the combination of the products of rumen microbial fermentation and unfermented feed that bypasses the rumen. Poor-quality diets (hay and crop residues) are followed by poor animal productivity, resulting from the lack of one or more essential nutrients required for rumen microbial activity, typically nitrogen and minerals and nutrients required for efficient metabolism of the absorbed nutrients which also must meet the requirement for production (tissues, milk and hair). Supplements are required to correct these deficiencies.

2.2 Supplements that enhance rumen function

Supplementation with urea and minerals has been shown to markedly improve rumen function and hence the utilization of rice straw (Perdok and Leng 1985). However, urea has increased in price as it is made from natural gas, which is a declining resource (Leng 2008). It is therefore important to evaluate locally available feeds which could replace the urea.

Protein-rich foliages that are rapidly degraded in the rumen could be a source of ammonia for rumen micro-organisms. If the foliages are also rich in minerals this could be an added advantage in correcting any mineral deficiencies. Water hyacinth is an aquatic plant that grows profusely on water in all tropical countries. It is an easily accessible feed resource for livestock while at the same time by harvesting it there would be environmental benefits. The leaves are relatively rich in crude protein and also contain a high level of minerals.

There are many studies on the nutritive value of water hyacinth but the results are confusing. On the basis of proximal analysis the leaves of water hyacinth appear to have a relatively high nutritive value. The DM digestibility is reported to be close to 60% (Abdelhamid and Gabr 1991) while the crude protein approaches 20% in DM (Paper I). Despite what appears to be a relatively high nutritive value, the results of feeding it to cattle have been poor, with reports of low feed intake which was insufficient to support maintenance when the leaves were the sole diet of cattle (Hentges 1970). Khan (1977) also found that when fed a diet solely based on only fresh water hyacinth, the cattle lost body weight. However, when rice straw was given together with the water hyacinth (1:1 ratio) the cattle increased their DM intake by 67% and gained 68g/day of live weight. It would appear from these results that the beneficial effect of the rice straw was to dilute a compound in the water hyacinth that was depressing intake since, both in digestibility and protein content, rice straw is much inferior to water hyacinth.

The presence of anti-nutritional compounds in water hyacinth could thus be the explanation of the poor performance when this plant was the sole feed. Yet here also the reports in the literature are variable. Gohl (1994) reported that fresh water hyacinth contained prickly crystals (supposedly oxalate salts), which reduced its palatability. However, according to Lareo and Bressani (1991) the levels of oxalate and other anti-physiological factors present in the plant were either very low or non-existent. They reported that the level of tannins was less than 1 per cent of the DM in the whole plant and only 2 per cent in the leaves. The plant had no trypsin inhibitors and the tests for saponins and alkaloids were negative. The level of oxalates was only 0.8 per cent in DM. Low levels of tannins in water hyacinth were also reported by El-Serafy et al (1981), Mishra et al (1987) and Dutta et al (1984).

The findings from the experiment reported in Paper I, would appear to confirm the presence of some anti-nutritional factor in the water hyacinth leaves, since the cattle lost weight when fed only rice straw and water hyacinth leaves, but gained in weight when the rice straw was supplemented with a urea-mineral mixture.

2.3. Toxic elements in feed resources (water hyacinth)

Lead is highly toxic to humans, plants and animals. Lead poisoning (plumbism) causes plant and animal death as well as mental deficiency, anemia, brain damage, kidney dysfunction, and behavioral problems in humans (Mo et al 1988). Varying degrees of lead (Pb) poisoning were recorded in cows and buffaloes near a primary lead-zinc smelter in India; affected animals had history of clinical signs characterized by blindness, head pressing, violent movement and salivation (Dwivedi et al 2001).

In another study of lead poisoning in animals grazing near a lead smelter, Hammond and Aronson (1964) reported that a dose of 6 mg lead/kg live weight for 60 days was toxic to young growing cattle. This equates to a daily concentration in feed DM of about 200 mg/kg. In the UK the maximum acceptable limit of lead in feeds is set at 10 mg/kg DM (Statutory Instrument 1995), while in the USA it is 30 mg/kg DM (NRC 1980).

Abdelhamid and Gabr (1991) reported that the lead (Pb) content in water hyacinth leaves and stems was in the range from 90 to 100ppm and 120 to 146 ppm (DM basis), respectively. These values are intermediate between generally accepted limits of 10 to 30 mg/kg DM) and levels causing toxicity (about 200 mg/kg). Thus it appears likely that the concentrations of lead in water hyacinth leaves (about 100 mg/kg DM) could be close to the toxic levels of this element.

Toxicity in goats consuming water hyacinth as the sole feed was reported by Dutta et al (1984) and Mishra et al (1987). The symptoms were stiff legs and cardionephrotic failure. Most of the animals died. Sheep fed on water-hyacinth alone lost live weight and suffered from hepatic failure followed by death in a study reported by Singh et al (1988). In the study reported by Abdelhamid and Gabr (1991), one of the sheep fed only water hyacinth died after a week of tetany and "stiffy" legs without response to Ca-injection.

2.4. Sources of bypass protein

Cassava (*Manihot esculenta*) is an annual root crop which grows well on low quality soil, in regions with low rainfall and high temperature. Therefore, it is a cash crop cultivated by small-holder farmers within the existing farming systems in most SE Asian countries. The main purpose of growing cassava is for root production. However, after harvesting the roots the aerial part of the plant remains, which can be used for animal feed. Cassava leaves have relatively high levels of crude protein, some of which can apparently by-pass the rumen because of the formation of a tannin-protein complex (Wanapat 1995). Beside tannins that are found in cassava foliage, there are other substances which can be toxic, namely the cyanogenic glucosides, which can give rise to hydrocyanic acid (HCN). However, both sun-drying and ensiling are effective ways of reducing HCN to safe levels (Bui Huy Nhu Phuc et al 2001).

The roots as energy sources and leaves as protein sources have been used successfully in ruminant rations (Wanapat 2008). Thus supplementation of urea-treated rice straw with cassava hay at 1-2 kg/head/day to dairy cattle markedly decreased the requirements for concentrate and improved the yield and composition of milk. Studies with fresh cassava leaves in diets for fattening cattle based on minerals showed that it supported the same high growth rate as a supplement of soybean meal (Ffoulkes and Preston 1978). When used as a supplement to untreated rice straw, the growth rates in local "Yellow" cattle (in Cambodia) were increased threefold by supplementing them with fresh cassava foliage (Seng Mom et al 2001). Similar findings for positive effects of cassava foliage on growth rates of cattle fed untreated rice straw were reported by Keo Sath et al (2008) and Ho Thanh Tham et al (2008), the former using sun-dried foliage and the latter the sun-dried leaves in the form of meal.

In the experiment reported in Paper I, supplementation with sun-dried cassava foliage had a dramatic positive effect on animal performance. Cattle, which lost body weight when the only supplement to rice straw was water hyacinth leaves or leaves + stems, gained weight when sun-dried cassava foliage was also fed. Furthermore, better results were obtained when the water hyacinth leaves (or leaves + stems) were the source of rumen nutrients compared with the urea-mineral mixture. In the absence of the cassava foliage the contrary was the case: cattle gained weight with the urea-mineral supplement but lost weight with water hyacinth.

The effect of feeding cassava foliage to cattle on a rice straw diet is to enhance the protein status of the animal, since it is believed that much of the protein in the cassava leaves escape from the rumen fermentation for enzymic digestion in the small intestine (Wanapat 2008).

3. Conclusions

- It appears that the constraint to the use of water hyacinth as livestock feed may be related to sub-clinical concentrations of heavy metals, especially lead. It should not therefore be fed as the sole feed but complemented with other feeds with known low concentrations of "heavy metals" so as to dilute the overall concentrations of these toxic elements in the diet.
- The other approach is to improve the protein status of animals fed water hyacinth in view of the known beneficial effects of an increased supply of amino acids when the immune system is challenged as part of the host's defence processes against, for example, the ingestion of toxic compounds (Leng 2005).
- The feeding of cassava foliage could therefore be especially important as a means of neutralizing the presumed presence of anti-nutritional compounds in water hyacinth.

4. Acknowledgements

The research was conducted at Royal University of Agriculture (RUA), Phnom Penh, Kingdom of Cambodia, with support from Mekong Basin Animal Research Network (MEKARN) project, financed by the Swedish International Development Cooperation Agency (Sida).

I would like to express my thanks to the MEKARN project, financed by Sida, for the financial support of this research, and especially express my sincere gratitude to my supervisors, Prof. Dr. T R Preston and Dr. Khieu Borin for their valuable guidance and advice to achieve this research.

My sincere thanks to Prof. Brian Ogle, International Coordinator, MEKARN project; Dr. Ngo Van Man, MEKARN regional coordinator and Mr. Nguyen Van Cong, MEKARN program officer for their facilitation, help and support to the whole course.

I am also very grateful to all lecturers for in the MSc course 2008-2010 who provided and shared their useful lectures and experiences to the whole course.

The Royal University of Agriculture (RUA) is acknowledged for provision of research facilities.

Warm thanks are extended to my father CHUN Hour, my mother SIEM Khim, my father-in-law HOURT Nakri, my mother-in-law TAING Kuylim, my young sister HOUR Pheng, my young brother HOUR Try and my brothers-in-law for their support and encouragement; to my wife HOURT Sereyromny, my daughter PHAL Arunvatei and my son PHAL Duongpisedth for their love; and to all the people who have contributed to this research.

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Abstract

Eighteen male local "Yellow" cattle with average weight of 101±14.5 kg were allocated in a randomized complete block design (RCB) to a 3*2 factorial combination of 6 treatments, with three replicates of each treatment. The factors were: 3 sources of rumen supplement (water hyacinth leaves, water hyacinth leaves+stems and urea-mineral mixture), and supplementation or not with cassava hay. The basal diet was untreated rice straw fed *ad libitum*. The rumen supplements were offered at levels to provide 100 g crude protein (CP) per 100 kg live weight. The cassava hay was offered at levels equivalent to 200 g CP per 100 kg live weight.

Live weight gain was increased dramatically when cassava hay was fed. However, there was a significant interaction between the effect of the cassava hay and the rumen supplements. When cassava hay was fed growth rates were higher when the leaves of water hyacinth were given as the rumen supplement with no difference between water hyacinth leaves plus stem and the urea-mineral mixture. In the absence of cassava hay, the cattle fed either leaves or leaves plus stem of water hyacinth lost body weight while those fed the urea-mineral mixture gained in weight. It is concluded: (i) that water hyacinth leaves can be used effectively as a source of rumen nutrients for growing cattle on a basal diet of rice straw provided a source of bypass protein (in this case cassava hay) is also fed; and (ii) that the limiting factors in water hyacinth foliage are the presence of anti-nutritional factors the negative effects of which are exacerbated at low levels of dietary crude protein.

Key words: *Anti-nutritional factors, bypass protein, protozoa, rumen ammonia, rumen supplements, urea-mineral*

1. Introduction

Livestock are very important for the livelihood of the majority of people in developing countries, and also as a source of renewable energy for draft purposes and as a source of organic fertilizer for their crops (Steinfeld 2006).

Cambodian farmers, like those in other developing countries in SE Asia, have various sources of livelihood, which range from rice farming, vegetable and fruit cultivation in home gardens, other non-rice crop cultivation in upland areas, animal husbandry and fishing (Yang Saing Koma 2001). In the farming system, livestock play a crucial function. Cattle and buffaloes provide most of the draught power and the manure is used to fertilize crops. Moreover, they are an important social asset and prestige for the rural farmers.

The total number of cattle and buffaloes in Cambodia was reported to be around 3 and 0.7 million heads, respectively (MAFF 2004). The numbers of cattle were fluctuating, while buffaloes were declining slightly during the period of 1994-2004. The feeding system of cattle and buffaloes mainly relies on grazing on common areas, but at present this has been significantly declining. Among the constraints for cattle development appears to be a lack of fodder supply, particularly in the dry season, which affects the performance and the production of cattle and buffalo. Due to fodder shortage, rice straw plays as an important role, albeit as a feed source of low nutritional value. Still, in the rainy season, the feed supply remains poor because the dry season grazing area is used for rice production to fulfill the demand for annual population growth. As a result of poor management, community land is heavily overgrazed and degraded (Yang Saing Koma 2001).

Poor-quality feed and fluctuating feed supplies are the biggest constraints to increasing livestock productivity in many tropical countries (ILRI 2009). In order to improve this situation, there is a need to look at ways of extending the availability and quality of the available feed resources.

Water hyacinth (*Eichhronia crassipes*) is a water plant that can be collected locally from rivers, lakes and ponds in Cambodia, as in other tropical countries. It is one of the fastest growing plants, which is known to double its biomass in two weeks (Upadhyay et al 2007). The plant impacts dramatically on water flow, blocks sunlight from reaching native aquatic plants, starves the water of oxygen, and often kills fish. Based on these reasons, it has been recommended that water hyacinths should be removed from water surfaces to limit the disadvantages attributed to this plant (Skinner 2007). This process would be facilitated if it could be used as a feed for animals.

Utilization of water hyacinth as an animal feed has been reported by Hentges (1970), Salveson (1971) and Stephens (1972). When land forages were limited, cattle have been noticed grazing floating water hyacinths (Little 1968). Hentges (1970) reported that the amount of water hyacinth voluntarily consumed by cattle was less than the requirement for maintenance. In order for water hyacinth to be fed as the basis of the diet it therefore needs to be complemented with other nutrient-rich feeds. Water hyacinth foliage is rich in protein and minerals (Abdelhamid and Gabr 1991), thus the other approach to the use of this plant is to consider it as a rumen supplement to complement crop residues such as rice straw which are deficient in such nutrients. For this purpose it needs to supply readily fermentable nitrogen and minerals as well the "unknown" factors often associated with green feeds (Preston and Leng 2009). However, even when the needs of rumen micro-organisms are met, basal diets such as rice straw must also be supplemented with sources of "bypass" or "escape" protein (Preston and Leng 2009) in order to meet the requirements for production. In this respect cassava foliage has proved to be a valuable supplement in diets that otherwise supply only "rumen" nutrients (Ffoulkes and Preston 1978). These authors showed that fresh cassava foliage supported the same growth rate as soybean meal for fattening cattle fed a basal diet includng minerals-urea. On diets of rice straw fed to growing cattle, rates of live weight gain were increased by supplements of fresh cassava foliage (Seng Mom et al 2001), cassava leaf meal (Ho Thanh Tham 2008) and sun-dried cassava hay (Keo Sath et al 2007).

For the above reasons it was decided to evaluate the potential advantages of combining fresh water hyacinth and sun-dried cassava foliage (hay) as respective sources of rumen nutrients and bypass protein in a basal diet of rice straw fed to growing cattle of the local "Yellow" breed.

Hypotheses

The hypotheses to be tested were:

- Giving water hyacinth foliage as a supplement to rice straw fed to local "Yellow" cattle will have a similar effect as a "rumen" supplement containing urea and minerals
- Water hyacinth leaves will have a better feeding value than the whole aerial part containing stems as well as leaves
- Cassava hay will supply bypass protein and therefore, because all diets are devoid of bypass protein, will enhance performance on all the diets

2. Materials and methods

2. 1. Location

The experiment was carried out at the Animal Research Station of the Faculty of Animal Science and Veterinary Medicine, Royal University of Agriculture (RUA), Phnom Penh, Kingdom of Cambodia, for 70 days from November 08, 2009 to January 17, 2010.

2. 2. Experimental design

The experiment was designed as a randomized complete block (RCB) with 3 replicates per treatment. The treatments were arranged as a 3*2 factorial, in which the factors were:

Rumen supplement:

- Water hyacinth leaf (WHL)
- Water hyacinth leaf and stem (WHLS) and
- Urea-mineral mixture (UM)

Bypass protein supplement

- With cassava hay (CH)
- Without cassava hay

Table 1 The 3*2 factorial treatment of 3 supplements and with or without cassava hay

	WH leaf	**WH leaf + stem**	**Urea-mineral mixture**
With cassava hay	WHL-CH	WHLS-CH	UM-CH
Without cassava hay	WHL	WHLS	UM

2. 3. Experimental feeds

All animals received a basal diet of untreated rice straw *ad libitum* and either supplements of WHL, WHLS or UM (Table 2), each of which was provided at a level to supply 100g of crude protein (N*6 25) per 100kg LW.

Table 2 Composition of the urea-mineral mixture for cattle

Ingredient	**%, fresh basis**
Sugar palm syrup	27
Water	13
Rice bran	33.5
Urea	13
Diammonium phosphate (DAP)	3
Salt	5
Lime	5
Sulfur	0.5

Adapted from Seng Mom et al (2001)

Animals on three of the six treatments (WHL-CH, WHLS-CH and UM-CH) received an additional supplement of cassava hay at 1% of DM of live weight. This was planned to provide approximately 200g/day of additional crude protein to a 100 kg live weight animal.

Ingredients for making the urea-mineral mixture were bought from a local market nearby the experimental site, while fresh cassava foliage was obtained from plants that were three months old from farm households in Kampong Cham province. Cassava leaves and petioles were separated from the hard stem and sun dried for about 5 to 7 days on a plastic sheet placed on the ground until the leaves became crisp (>85% DM) (Photo 1). Rice straw of the same variety was bought from farmers at the harvest time. The rice straw was chopped into 15-20 cm lengths for feeding. Water hyacinth (Photo 2) was collected daily from the lagoon located close to RUA.

2. 4. Animals and management

One to one and half-year old local male "Yellow" cattle (Photo 3) with mean live weight of 101±14.5 kg were housed in individual pens (Photo 4) where they could have free access to the rice straw and water. Before starting the experiment, the cattle were de-wormed by injection with Ivomectin (1% of Ivomectin concentration) and vaccinated against foot and mouth disease (FMD) and Pasteurellosis (Heamorraghic Septicaemia). The water hyacinth and urea-mineral mixture were given as the first feed in the morning at 07:00h. At 09:00h and 16:00h the cattle were offered the cassava hay and rice straw.

Photo 1 Sun-dried cassava (hay)

Photo 2 Water hyacinth collecting from lagoon

Photo 3 Experimental local "Yellow" cattle

Photo 4 Experimental cattle kept in individual pens

Photo 5 The stomach tube

Photo 6 The method for taking rumen fluid

2. 5. Data collection

Feeds offered were weighed before giving them to the cattle. Feed refusals were collected each morning prior to offering fresh feed and weighed to measure the feed intake. Representative samples of feeds offered and refusals were collected for chemical analysis. The live weights of the cattle were taken at the beginning, every 2 weeks and at the end of the experiment. Samples of rumen fluid were taken by a stomach tube (Photo 5 and Photo 6) 2 hours post feeding in the morning at 4, 8 and 10 weeks for counting of protozoa and determining rumen ammonia and pH. The samples for counting protozoa were stabilized by adding formaldehyde saline solution (10% formaldehyde and 0.9% NaCl) at the rate of 1ml per 10 ml of rumen fluid and kept in a refrigerator at -20^oC for later counting. For rumen ammonia analysis, 0.3 ml of 50% H_2SO_4 was added to 15.0 ml of rumen fluid (Korhonen et al 2002).

2. 6. Chemical analyses

Water hyacinth leaves plus stems, water hyacinth leaves, cassava hay and rice straw and the urea-mineral mixture and feed refusals were analyzed for dry matter (DM), nitrogen (N) and ash following the methods of AOAC (1990). Acid detergent fiber (ADF), and neutral detergent fiber (NDF) were determined by the methods of Van Soest et al (1991). The numbers of rumen protozoa were counted using a Whitlock universal (worm egg counting) chamber under a microscope at 10x magnification. Rumen pH was measured immediately after taking rumen fluid from the animal with a digital pH meter.

2. 7. Data analyses

Data for feed intake, growth and feed conversion were analyzed with the Generalized Linear Model option of the ANOVA program in the MINITAB software (Version 13.31) (Minitab 2000). Sources of variation were rumen supplements, with or without cassava hay (bypass protein supplement), interaction between rumen supplement and with or without cassava hay and error. When there was a significant difference at P<0 05, then means were compared by using Tukey's procedure of the same MINITAB software. When there were trends in animal responses, linear regression was calculated using the same MINITAB software.

3. Results and discussion

3. 1. Chemical composition of the feeds

The DM and crude protein (CP = N*6 25) contents of water hyacinth leaves+stems (whole aerial part) were higher than reported by Aboud et al (2005) but values for ADF, NDF and ash were lower (Table 3). Leaves of water hyacinth had higher DM, CP and lower ADF and NDF than the combined leaves+stems. On an "as fed"basis the water hyacinth aerial part was only 35% leaf (Table 4). In cassava hay the proportion of leaf was 71%.

Table 3 Chemical composition of the feeds

	DM	CP	Ash	OM	ADF	NDF
	%	-----------------------% of DM-----------------------				
Water hyacinth leaves+stems	14.5	16.2	15.7	84.3	30.0	54.2
Water hyacinth leaves	18.3	19.5	12.2	87.8	28.2	49.9
Cassava hay	86.1	25.9	10.9	89.1	35.8	57.7
Urea-mineral mixture	64.7	64.1	20.5	79.5	-	-
Rice straw	89.3	3.9	13.7	86.3	51.9	69.7

DM = dry matter, CP = crude protein, N = nitrogen, OM = organic matter, ADF = acid detergent fiber, NDF = neutral detergent fiber

Table 4 Proportion of leaf and stem of water hyacinth and leaf and stem + petiole of cassava hay (as fed basis)

	Leaf	Stem/petiole
Water hyacinth	35.3	64.7
Cassava hay,	70.6	29.4

The chemical composition of water hyacinth varies considerably, according to where it grows and when it is harvested. The comparisons made here are with water hyacinth growing in Tanzania and in Thailand. The high CP content of the leaves can be considered as favorable for feeding to ruminants, and thus the leaves may be regarded as a valuable fermentable N supplement for animals fed on low protein crop residues. For cassava hay, the ash, ADF and NDF contents were higher, but CP content was comparable to that reported by Wanapat et al (1997).

3. 2. Feed intake

Total DM intakes were increased by feeding cassava hay and by feeding water hyacinth leaves compared with leaves+stems (Tables 5 and 6; Figures 2 and 3). Dry matter intake on the UM rumen supplement treatment was lower than when water hyacinth was fed in the presence of cassava hay. The opposite was observed in the absence of cassava hay, when rice straw intake and total DM intakes were higher for the UM treatment than for treatments with water hyacinth. The CP content of the diets was lower in the absence of cassava hay and was only marginally above the minimum level needed for efficient rumen function (Preston and Leng 2009). In this situation the water hyacinth treatments were inferior to the urea-mineral treatment, because of the lower total DM intake of the former compared with that of the UM treatment group.

Table 5 Mean values (main effects) for daily feed and crude protein intake for "Yellow" cattle fed rice straw supplemented with water hyacinth leaves, water hyacinth leaves+stems or urea-mineral mixture, in each case with or without cassava hay

Item	Cassava hay		SEM	Prob	Rumen supplement			SEM	Prob
	With	Without			WHL	WHLS	UM		
DM intake, g/day									
WHLS	205^{b}	235^{a}	4.24	0.001		661			
WHL	201	205	2.78	0.321	610				
CH	689				404^{a}	362^{b}	268^{c}	9.29	0.001
UM	23^{b}	48^{a}	1.09	0.001			107		
Rice straw	1497^{b}	1735^{a}	19.8	0.001	1552^{b}	1383^{c}	1913^{a}	24.2	0.001
Total	2616^{a}	2223^{b}	23.3	0.001	2566^{a}	2405^{b}	2287^{c}	28.5	0.001
DM intake, %LW	2.41^{a}	2.15^{b}	0.052	0.005	2.37	2.3	2.17	0.063	0.111
CP intake, g/day									
WHLS	33^{b}	38^{a}	0.69	0.001		107			
WHL	39	40	0.54	0.321	119				
CH	178				105^{a}	94^{b}	69^{c}	2.41	0.001
UM	15^{b}	31^{a}	0.70	0.001			69		
Rice straw	58^{b}	68^{a}	0.77	0.001	60.5^{b}	54^{c}	75^{a}	0.94	0.001
Total	324^{a}	176^{b}	2.64	0.001	284^{a}	255^{b}	213^{c}	3.23	0.001
CP in DM	0.13^{a}	0.09^{b}	0.005	0.001	0.11	0.10	0.11	0.006	0.53

DM = dry matter, CP = crude protein, WHLS = water hyacinth leaves+stems, WHL = water hyacinth leaves, UM = urea-mineral mixture, CH = cassava hay, SEM = standard error of the mean

-^{a,b,c} *mean values with different superscripts within the same row and main effect are different at P<0.05*

Table 6 Mean values for daily feed and crude protein intake for "Yellow" cattle fed rice straw supplemented with water hyacinth leaves, water hyacinth leaves+stems or urea-mineral mixture, in each case with or without cassava hay

Item	Cassava hay			No cassava hay			SEM	Prob
	WHL	WHLS	UM	WHL	WHLS	UM		
DM intake, g/day								
WHLS		616			705			
WHL	604			616				
CH	809	723	535					
UM			70			144		
Rice straw	1582^{b}	1343^{b}	1565^{b}	1522^{b}	1422^{b}	2260^{a}	34.2	0.001
Total	2994^{a}	2682^{b}	2171de	2137de	2127^{e}	2403^{c}	40.3	0.001
DM intake, %LW	2.64^{ab}	2.5^{ac}	2.08^{c}	2.11^{ac}	2.09^{c}	2.26^{abc}	0.089	0.004
CP intake, g/day								
WHLS		100			114			
WHL	118			120				
CH	209	187	139					
UM			45			92		
Rice straw	62^{b}	52^{b}	61^{b}	59^{b}	56^{b}	88^{a}	1.34	0.001
Total	389^{a}	340^{ab}	245^{b}	179^{b}	170^{b}	180^{b}	4.57	0.001
CP in DM	0.13	0.13	0.11	0.09	0.08	0.10	0.008	0.738

$^{a-e}$ *mean values with different superscripts within the same row are different at P<0.05*

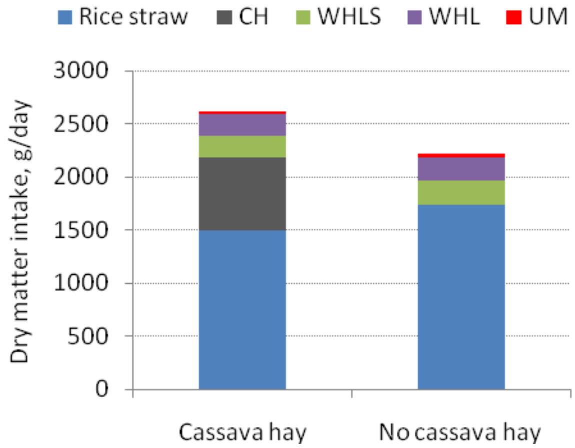

Figure 1 Dry matter intake of dietary ingredients for "Yellow" cattle fed rice straw supplemented with water hyacinth leaves, water hyacinth leaves+stems or urea-mineral mixture, in each case with or without cassava hay

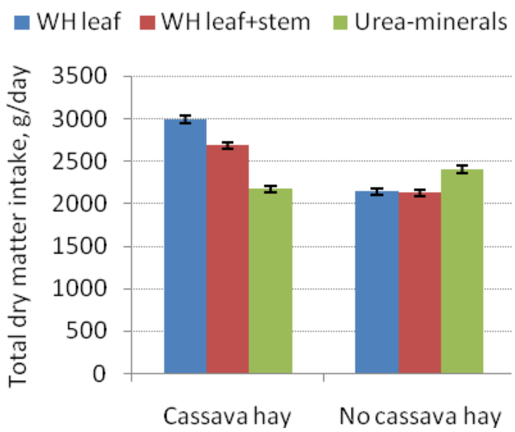

Figure 2 Total DM intake for "Yellow" cattle fed rice straw supplemented with water hyacinth leaves, water hyacinth leaves+stems or urea-mineral mixture, in each case with or without cassava hay

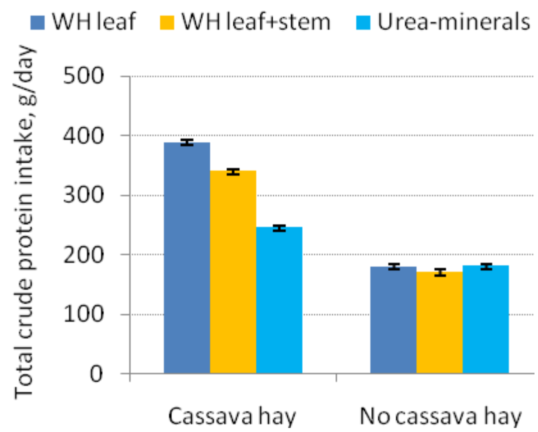

Figure 3 CP intake for "Yellow" cattle fed rice straw supplemented with water hyacinth leaves, water hyacinth leaves+stems or urea-mineral mixture, in each case with or without cassava hay

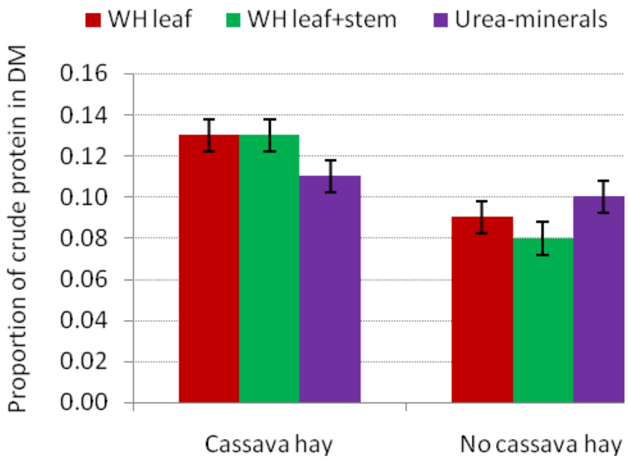

Figure 4 Proportion of CP in DM for "Yellow" cattle fed rice straw supplemented with water hyacinth leaves, water hyacinth leaves+stems or urea-mineral mixture, in each case with or without cassava hay

3. 3. Rumen parameters

The concentration of rumen ammonia was increased by feeding cassava hay and was higher when urea-mineral was the rumen supplement rather than water hyacinth (Tables 7 and 8; Figure 5). The pH values varied only slightly among treatments and all were within the normal range for adequate rumen function (Preston and Leng 2009). Protozoal populations were not affected by dietary treatment, but were lower by a factor of 10 compared to data reported by Seng Mom et al (2001) (populations of protozoa 3-4*10^4/ml).

Table 7 Mean values (main effects) for rumen pH, ammonia and protozoal population in "Yellow" cattle fed rice straw supplemented with water hyacinth leaves, water hyacinth leaves+stems or urea-mineral mixture, in each case with or without cassava hay

Item	Cassava hay		SEM	Prob	Rumen supplement			SEM	Prob
	With	Without			WHL	WHLS	UM		
pH	6.92	6.98	0.023	0.061	6.98[a]	6.98[a]	6.88[b]	0.028	0.018
NH_3, mg/litre	190[a]	144[b]	10.2	0.003	150[b]	141[b]	210[a]	12.7	0.001
Protozoa, *10^{-4}/ml	0.194	0.277	0.044	0.19	0.209	0.274	0.223	0.054	0.67

[a,b] *mean values with different superscripts within the same row and main effect are different at P<0.05*

Table 8 Mean values for rumen pH, ammonia and protozoal population in "Yellow" cattle fed rice straw supplemented with water hyacinth leaves, water hyacinth leaves+stems or urea-mineral mixture, in each case with or without cassava hay

Item	Cassava hay			No cassava hay			SEM	Prob
	WHL	WHLS	UM	WHL	WHLS	UM		
pH	6.96[a]	7.03[a]	6.78[b]	7.01[a]	6.94[a]	6.99[a]	0.04	0.003
NH_3, mg/litre	186[a]	176[ab]	208[a]	113[b]	106[b]	212[a]	17.7	0.057
Protozoa, *10^{-4}/ml	0.095	0.268	0.219	0.324	0.280	0.226	0.076	0.25

[a ,b] *mean values with different superscripts within the same row are different at P<0.05*

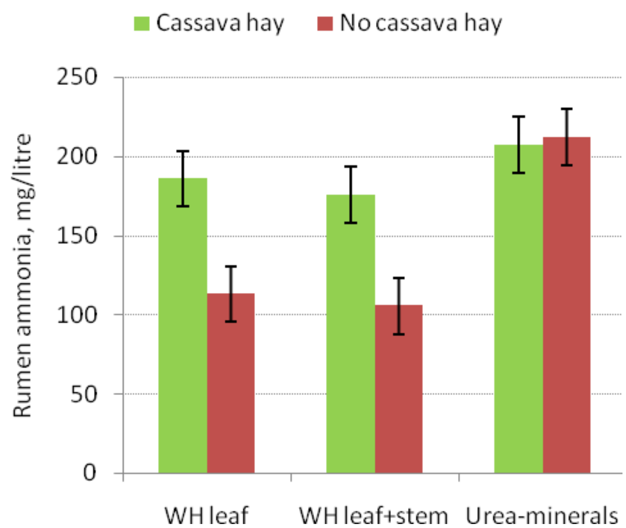

Figure 5 Mean values of rumen ammonia for "Yellow" cattle fed rice straw supplemented with water hyacinth leaves, water hyacinth leaves+stems or urea-mineral mixture, in each case with or without cassava hay

3. 4. Growth rate

Live weight gain was higher when cassava hay was fed (Table 9). However, there was a significant interaction between the main treatments (Figure 6). When cassava hay was fed growth rates were higher when the leaves of water hyacinth were given as the rumen supplement with no difference between water hyacinth leaves plus stems and the urea-mineral mixture (Table 10). In the absence of cassava hay, the cattle fed either leaves or leaves plus stems of water hyacinth lost body weight, while those fed the urea-mineral mixture gained in weight (Table 10; Figure 6). The growth rate on the best treatment, cassava hay and water hyacinth leaves (243 g/day), was similar to that (250 g/day) reported by Seng Mom et al (2001) for "Yellow" cattle fed rice straw supplemented with urea minerals and cassava foliage, and is probably close to the genetic potential of this "small" breed.

The differences in rate of live weight gain (or loss) reflected the differences in DM intake (Figures 8) and the crude protein intake (Figure 9).

Table 9 Mean values (main effects) for total DM intake and live weight in "Yellow" cattle fed rice straw supplemented with water hyacinth leaves, water hyacinth leaves+stems or urea-mineral mixture, in each case with or without cassava hay

Item	Cassava hay		SEM	Prob	Rumen supplement			SEM	Prob
	With	Without			WHL	WHLS	UM		
Total DM intake, g/day	2616[a]	2223[b]	23.3	0.001	2566[a]	2405[b]	2287[c]	28.5	0.001
Live weight, kg									
Initial	102	102	6.2	0.98	103	101	102	7.6	0.98
Final	115	104	6.5	0.25	111	107	111	7.9	0.90
Daily gain, g/day	177[a]	18[b]	15	0.001	113	67	114	18	0.16

[a,b,c] mean values with different superscripts within the same row and main effect are different at P<0.05

Table 10 Mean values for total DM intake, live weight and feed conversion for "Yellow" cattle fed rice straw supplemented with water hyacinth leaves, water hyacinth leaves+stems or urea-mineral mixture, in each case with or without cassava hay

Item	Cassava hay			No cassava hay			SEM	Prob
	WHL	WHLS	UM	WHL	WHLS	UM		
Total DM intake, g/day	2994[a]	2682[b]	2171[de]	2137[de]	2127[e]	2403[c]	40.3	0.001
Live weight, kg								
Initial	103	101	101	102	100	103	10.7	0.99
Final	121	113	113	102	101	109	11.2	0.81
Weight change, g/day	243[a]	147[a]	141[ac]	-17[b]	-13[b]	86[bc]	25	0.009
FCR	12.3±6.6	20.8±6.6	16.8±8.0	#	#	34.5±6.6		

[a ,b] mean values with different superscripts within the same row are different at P<0.05)
 # FCR cannot be calculated as the animals lost live weight during the experiment

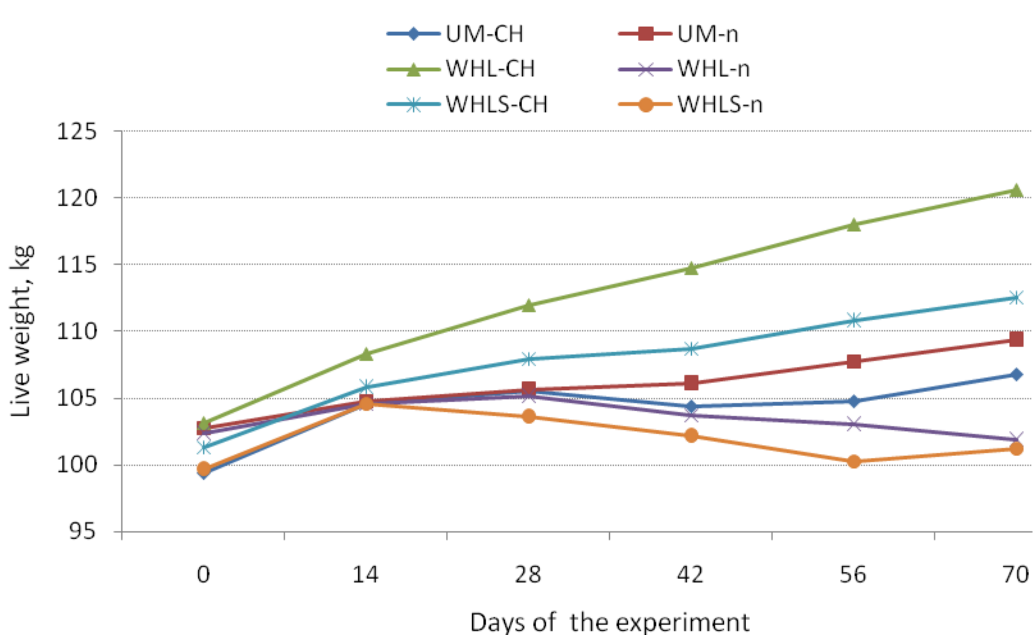

Figure 6 Growth curves for "Yellow" cattle fed rice straw supplemented with water hyacinth leaves, water hyacinth leaves+stems or urea-mineral mixture, in each case with or without cassava hay

The positive growth response to the cassava hay supplement is in agreement with a wide body of recent reports in which cassava foliage was supplemented to rice straw as the basal diet (Seng Mom et al 2001, Ho Thanh Tham 2008; Keo Sath et al 2007). The better growth on water hyacinth leaves compared with leaves+stems may in part be due to the greater concentration of cell wall compounds in the stems, resulting in a lower digestibility. The interesting result, however, is the interaction between cassava hay and the rumen supplements (Figure 7).

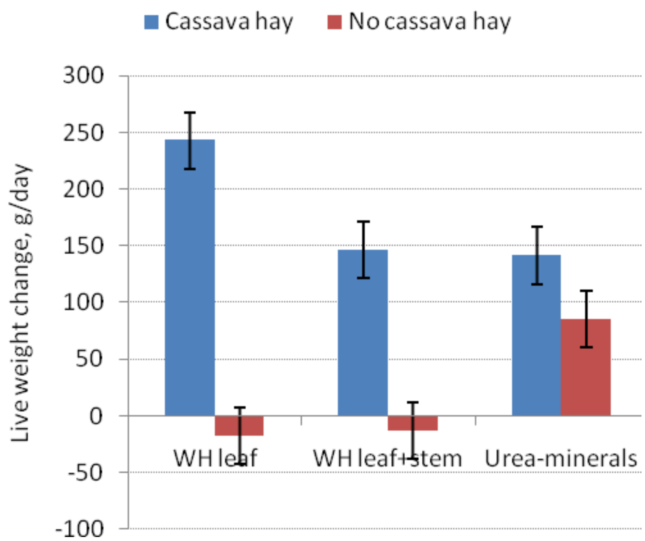

Figure 7 Mean values of live weight change for "Yellow" cattle fed rice straw supplemented with water hyacinth leaves, water hyacinth leaves+stems or urea-mineral mixture, in each case with or without cassava hay

When cassava hay was fed, there were no differences between the rumen supplements of water hyacinth leaves+stems and urea-minerals mixture. However, in the absence of cassava hay, growth was positive with the urea-mineral mixture and negative with water hyacinth leaves and leaves+stems. The implication for these findings is there may be anti-nutritional compounds in the water hyacinth which exerted negative effects on animal metabolism when the protein status of the animal was low (ie: in the absence of cassava hay supplementation). That these negative effects were not evident when cassava hay was fed can be explained by the known positive effects of higher dietary protein levels in animals subjected to disease stress, including that induced by intake of toxic compounds (Leng 2005).

The critical role of the protein supply is evident from the positive relationships between the crude protein consumed and the DM intake and the live weight gain (Figures 8, 9 and 10). The positive relationship between rumen ammonia concentration and live weight gain (figure 11), supports the idea that the N supply to rumen micro-organisms, as well as the protein supply to the animal, were important factors determining animal growth responses.

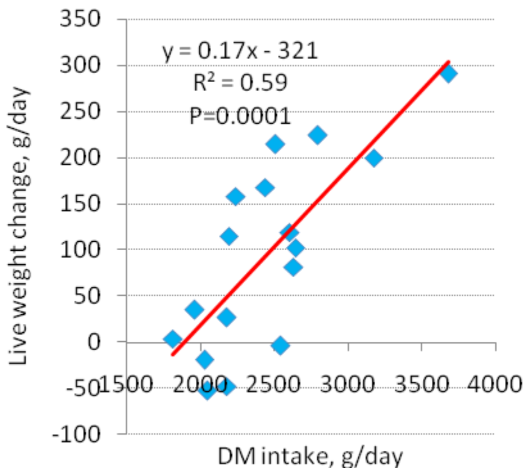

Figure 8 Relationship between dry matter intake and live weight change of "Yellow" cattle fed rice straw supplemented with water hyacinth leaves, water hyacinth leaves+stems or urea-mineral mixture, in each case with or without cassava hay

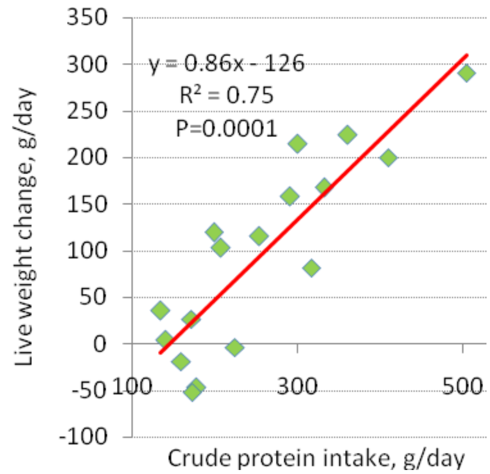

Figure 9 Relationship between crude protein intake and live weight change of "Yellow" cattle fed rice straw supplemented with water hyacinth leaves, water hyacinth leaves+stems or urea-mineral mixture, in each case with or without cassava hay

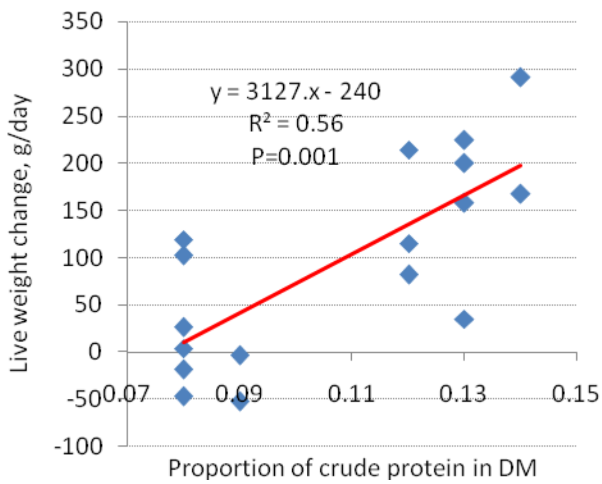

Figure 10 Relationship between proportion of crude protein in dry matter and live weight change of "Yellow" cattle fed rice straw supplemented with water hyacinth leaves, water hyacinth leaves+stems or urea-mineral mixture, in each case with or without cassava hay

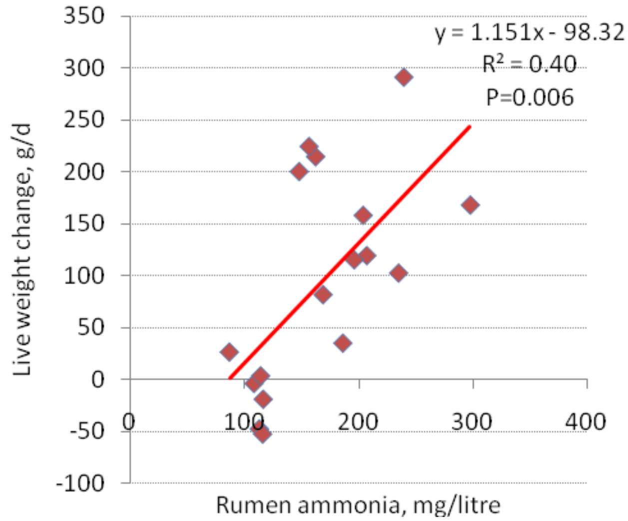

Figure 11 Relationship between rumen ammonia and live weight change of "Yellow" cattle fed rice straw supplemented with water hyacinth leaves, water hyacinth leaves+stems or urea-mineral mixture, in each case with or without cassava hay

Support for the concept of the presence of anti-nutritional compounds in water hyacinth can be found in the report of Hentges (1970) that cattle could not eat enough fresh water hyacinth to cover their maintenance requirement. Khan (1977) also found that green water hyacinth alone was insufficient for the maintenance of bullocks, as the animals lost 23 g/day of live weight during a period of 60 days. However, when rice straw was given together with the water hyacinth (1:1 ratio) the bullocks increased their DM intake by 67% and gained 68g/day of live weight. On the basis of proximal analysis, rice straw has a much lower nutritive value (less crude protein and more cell wall compounds) than water hyacinth. In this case, the positive effects from adding a feed of lower nutritional value could be due to the diluting effect of the rice straw on the anti-nutritional compounds in water hyacinth.

There is confusing evidence on the presence of anti-nutritional compounds in water hyacinth. Lareo and Bressani (1982) stated: "that the levels of anti-physiological factors present in the plant are either very low or non-existent". We found tannins in amounts of only about 1 per cent of the dry matter from the whole plant and 2 per cent in the leaves. The plant as a whole does not have trypsin inhibitors. The tests for saponins and alkaloids were negative, and the level of oxalates was only 0.8 per cent". Abdelhamid and Gabr (1991) also reported low levels of total tannins of only 0.13% in the DM of water hyacinth leaves. In marked contrast, Dutta et al (1984) reported total tannins of 2% in DM in the leaves of water hyacinth. No information was given on the condensed tannin fraction, which can combine with protein to make it insoluble. In any event, even 2% of tannins is not likely to be a problem, as the safe upper level of condensed tannins was indicated to be of the order 5 to 6% in DM by Reed (1995), while levels of 4% were considered by Barry (1987) to be advantageous in enhancing the “bypass” characteristics of the protein.

The presence of toxic heavy metals – lead and mercury – in water hyacinth was reported to be a risk factor by Skinner (2007). However, there seems to be no evidence linking these elements with ruminant animal responses to feeding water hyacinth. What appears to be consistent is the depression in animal growth responses when water hyacinth leaves are fed in increasing amounts up to the point of being the sole diet. Thus Abdelhamid and Gabr (1991) fed sheep on diets of rice straw and concentrates, with increasing proportions of fresh water hyacinth leaves until the sole diet was water hyacinth. Dry matter intake decreased linearly with increasing proportions of water hyacinth in the diet, being only 420 g DM/day with 100% water hyacinth compared with 1290 g/day on the control diet of 30% concentrates and 70% rice straw. They showed that these responses were not related to the apparent nutritive value of the diets as apparent DM digestibility (56-58%) was similar on the control and 100% water hyacinth diets, while the DCP was 13% for water hyacinth compared with 5% for the control diet. These same authors also quoted reports from farmers who used water hyacinth as a green fodder, that all rabbits and geese died shortly after eating water hyacinth. The toxicity for rabbits of water hyacinth as the sole diet was recently reported in Vietnam (Bui Phan Thu Hang 2010, personal communication). There were no problems when the water hyacinth was diluted with 50% of its weight as water spinach. Osman et al (1975) came to the same conclusion, that feeding the fresh plant alone is not possible. The physiological problems caused by the biochemical components of the water hyacinth remained the same after drying the plants according to Becker et al (1987). This would seem to rule out calcium oxalate as a factor limiting intake, since drying Taro (*Colocacia esculenta*) leaves eliminates the limitations to intake caused by the high levels of calcium oxalate in the leaves of this plant (Pheng Buntha et al 2008). At the same time many authors did not find health problems from feeding water hyacinth (Moursi 1976 and El-Serafy et al 1981) but they, along with other authors (Hathout et al 1980; Tagel-Din et al 1989; Zahran et al 1989) recommended its use with appreciable amounts of concentrates.

4. Conclusions

- Supplementation of a rice straw diet with water hyacinth leaves and cassava hay supported normal growth in local “Yellow” cattle
- In the absence of cassava hay, the cattle lost weight when the rumen supplement was water hyacinth leaves or leaves+stems, while those given the urea-mineral supplement gained weight
- It is postulated that there are anti-nutritional compounds present in water hyacinth leaves which at low overall protein intakes lead to reduced feed intake and loss of body weight
- Water hyacinth foliage should never be fed as the sole diet of ruminants but may be fed at up to 25% of the diet DM along with protein-rich supplements
-

5. Acknowledgements

The authors are very grateful to the MEKARN project, financed by Sida-SAREC, Sweden, for the support for this research. The Royal University of Agriculture, Phnom Penh, Kingdom of Cambodia is acknowledged for provision of research facilities.

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