POTENTIAL OF WATER HYACINTH (*EICCHORNIA CRASSIPES*) IN RUMINANT NUTRITION IN TANZANIA

BY

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ABSTRACT

A study was conducted to investigate the potentials of water hyacinth (*E. crassipes*) in ruminant nutrition in Tanzania. In experiment 1 Potential yield, chemical composition, *in vitro* digestibility and degradability of water hyacinth were studied. In experiment 2 water hyacinth was ensiled using 10% and 20% molasses as an additive. Samples without molasses were ensiled as controls. Chemical composition, *in vitro* DM and OM digestibilities, pH changes, effective degradability, 48 hours DM degradability fermentation products were studied. Experiment 3 examined the acceptability of water hyacinth silage by livestock.

Degradability of botanical parts of water hyacinth was carried out using three fistulated steers. Four heifers ranging in weight from 163-227 kg were used to test acceptability of water hyacinth silage over 18 days period.

In experiment 1 the biomass yield of water hyacinth during sampling was estimated at 298.61 kg DM/ha. Whole plant showed significantly ($p<0.001$) lower DM digestibility as compared to leaves and shoots. There was no significant ($p>0.05$) difference observed between leaves and shoots. Mean digestibility values obtained for leaves, shoots and whole plant were 58.15%, 57.03% and 42.32% respectively for the two stage *In vitro* digestibility. For one stage *In vitro* whole plant showed significantly ($p<0.001$) lower dry matter digestibilities at both hours of incubation. No significant ($p>0.05$) difference was observed between leaves and

shoots except at 12, 96, and 120 hours where leaves had significantly ($p<0.001$) higher digestibility. Water hyacinth leaves showed the highest DM degradability followed by shoots, while whole plant had the lowest. Potential degradability was 68.09%, 60.82% and 52.91% for leaves, shoots, and whole plant. Rumen degradable fraction was lower in the whole plant (44.2±3.11) and higher (58.71±6.29) (52.41±1.38) in leaves and shoots respectively.

In experiment 2 molasses treated water hyacinth silages had significantly ($p<0.001$) higher DM, WSC, IVDMD%, IVOMD% compared to unmolassed silages. The CP content was significantly ($p<0.001$) lower for molasses treated silages compared to controls. No significant ($p>0.05$) difference in IVDMD%, IVOMD% and CP content was observed by changing the level of molasses from 10% to 20%. In experiment 3 significantly ($p<0.001$) higher DMI g/min and DMI expressed as % of live body weight was obtained for molasses treated silages compared to controls. Intake rate for the 20% molasses terated silage was slightly higher (30.78 g/min) than that of 10% molasses silage (28.05 g/min). 48 hour DM degradability(%) was found to be significantly ($p<0.001$) higher for molasses treated silages compared to controls.

It was concluded that potential yield of water hyacinth is low when compared to other tropical forages. Addition of molasses at higher levels improved the nutritive value of water hyacinth silages. Ruminants readily consumed molasses treated water hyacinth silages compared to unmolassed silage. Nutritionally water hyacinth can be compared to other high quality tropical

forages for livestock feeding.

DECLARATION

I JOHANNES OKONG'O OSARYA, do hereby declare to the senate of Sokoine University of Agriculture that this dissertation is my own original work and that it has not been submitted for a degree award in any other university.

Signature _____

Date 3/9/99

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DEDICATION

To my children Millicent Akinyi and Abraham Osarya.

To my mother Damaris Ayany.

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ABBREVIATIONS

ADF = Acid detergent fibre

°C = Degrees centigrade

CP = Crude protein

cm = centimetre

DM = Dry matter

DMDIG = Dry matter digestibility

DMI = Dry matter intake

E = East

EE = Ether extractive

GLM = General linear models

gm = gram(s)

h = hour

ha = hectare

IVDMD = *In vitro* dry matter digestibility

IVOMD = *In vitro* organic matter digestibility

kg = Kilogramme(s)

km = Kilometre

m = metre

ml = millilitres

mm = millimetre

N = North

N_2 = Nitrogen

NH_3N = Ammonia nitrogen

NDF = Neutral detergent fibre

OM = Organic matter

OMDIG = Organic matter digestibility

S = south

VFA = Volatile fatty acids

WH = Water hyacinth

WHE = Water hyacinth entire

WHL = Water hyacinth leaves

WHS = Water hyacinth shoots

WSC = water soluble carbohydrates

CHAPTER ONE

1.0 INTRODUCTION

Water Hyacinth (*Eicchornia crassipes*) is one of the most prominent aquatic plants found throughout tropical and sub-tropical areas. The plant occurs in nutrient rich aquatic environments such as lakes, reservoirs and fresh water streams. Pollution from urban, industrial and agricultural activities provide essential nutrients for the growth of this aquatic macrophyte. In Tanzania the plant grows in rivers Pangani and Sisi, lake Victoria and the Mtera hydro-power water reservoir (Johanson, 1976).

Despite the detrimental effects of water hyacinth infestation, the plant is treated as a resource with a wide range of applications in China, India and Vietnam. The applications include as a source of biogas, an animal feed and a biofertilizer (Bagnal *et al*,1974; Shiralipour and Smith,1984). In Vietnam water hyacinth flowers are used as vegetable for humans (Nguyen, 1996).

In many parts of the tropics the provision of year-round feed is a major constraint to livestock production. The declining average farm size as the rural population rise results in a decreasing availability of natural grasses and legumes for grazing. As a consequence availability of feed resources become one of the main constraints in livestock

production. In many areas, there is inadequate and inconsistent supply of good quality pasture and fodder crops. This problem is more marked during the dry season which in most areas has been recorded to last for over 6 months per year (Mbwile and Madata,1984). Consequently, the amount of essential nutrients found in pastures can not meet both maintenance and production requirements of livestock. The amount of crude protein may decline below the critical level (7%) required for maintenance. (Crowder and Chheda,1982).

This situation can be more serious among the small-holder dairy farmers, particularly those who practice zero grazing systems in Ukara and Ukerewe islands. Under this farming system most of the land is utilised for cultivation of food and cash crops setting aside small areas of land for pastures and fodder production. As a result production falls and condition of the animals deteriorates. These small plots cannot produce sufficient and good quality pastures for feeding livestock during the dry season. Seasonal shortage of feed is usually experienced and farmers do not practice conservation or supplementation. To reduce this shortage, and to enable more productive and sustainable feed utilisation the incorporation of water hyacinth in the feeding systems is important.

Water hyacinth present great opportunities for increased feed supply to livestock in areas around lake Victoria. The use of this plant could support sustainable production in the medium and long term strategies. However, this alternative has not been considered seriously in livestock feeding in these regions. The fast growth rate of water hyacinth make it a potential resource for livestock feeding. Gaffer (1981) explained that vigorous growth of water hyacinth can guarantee five harvests in a year, giving a year round supply of green fodder.

Instead of considering the water hyacinth as an ecological menace, farmers should also look into the possibility of using it as a renewable resource with economic benefits. Practical information on on how farmers can utilize this plant for livestock feeding in Tanzania is not enough. As a result there was a need to conduct a study on the potentiality of this plant in livestock feeding in areas around lake Victoria.

The main objective of this study was to investigate the potential of water hyacinth in ruminant feeding around the lake Victoria area of Tanzania.

The specific objectives were:

1. To study the chemical composition and biomass yield of water hyacinth.

2. To study the degradability of water hyacinth by *in vitro* and *in sacco* techniques.

3. To assess the chemical composition of silage made from water hyacinth, and test the acceptability of this silage by cattle.

CHAPTER TWO

2.0 LITERATURE REVIEW

2.1 Availability and utilisation of non cultivated plants

Water hyacinth is provided as vegetable for humans and mixture of *Sesbania sesban* and water hyacinth flowers serve as food for people in the flooding periods in Vietnam (Nguyen, 1996). Boiled water hyacinth is used in South-East Asia as a feed for pigs. The plants are chopped and sometimes mixed with other vegetable wastes such as banana stems and boiled slowly for a few hours until the ingredients turn into a paste. To this liquid, paste oil-cake, rice bran and sometimes maize and salt are added (Göhl, 1984). The cooked mixture is good for only three days, after which it will turn sour. The CP content in the plant is about 12% (Göhl, 1984). Pigs prefer the young leaves and refuse the stems. Comparing the CP in the stems and leaves the range was 7 to 19%, respectively (Nguyen, 1996). Water hyacinth flowers are used as a pig feed in many places in the Mekong delta in Vietnam (Nguyen, 1996).

Studies on *Eichhornia crassipes* by Bagnal *et al.*, (1974), showed that it could also be used to remove pollution, purify water, recover silver from waste material, provide cellulose, medicine, methane production, as a fertilizer and as food for both animal and humans.

Table 2.1. The protein content of some aquatic water plants

Name of plant	Crude protein as % of DM	
Azolla pinnata	19.1	Sun - dried
Eicchornia crassipes		
Leaf blade	31.4	"
Petiole	14.5	"
Root	14.8	"
Lemna trisulaca	20.3	Sun - dried
Pistia stratiotes	13.3	"
Salvinia natans		
Leaf	10.7	"
Root	8.8	"
Chlorella vulgaris	32.5	Oven - dried
Lyngba sp.	11.1	"
Rhizoclonium sp.	28.3	"
Spirogyra sp.	10.2	"

Source: Majid and Akhter,1979.

According to Ravindran and Blair (1992) common physical characteristics of all aquatic plants is high water and ash contents. Fresh water hyacinth contains prickly crystals (probably oxalic acid) which makes it unpalatable (Nguyen, 1996). After harvesting, water hyacinth contains 6% to 10% dry matter. In respect of nutrient components water hyacinth can favourably be compared to any other conventional forage and its nutritive value can be improved by mixing straw and some concentrate (Reza and Khan, 1981).

2.2 Nutritive value of water hyacinth and its utilisation as livestock feed

Most aquatic plants including water hyacinth and *Hydrilla spp,* have nutritive value similar to that of high quality forages. Some major minerals (eg sodium, iron, potassium and calcium) ranges are 3 to 100 times higher in aquatic forages than terrestrial forages (Easley and Shirley., 1974). Generally aquatic species are characterized by low dry matter content (3-15%) compared to terrestrial plants with 8-31% (Nguyen,1996).

Reza and Khan (1981) reported that water hyacinth contained high protein, especially in the leaves with low fibre, and good amount of ether extract and calcium and phosphorus. The percentage of the DM in the leaves was higher than in other parts of the plant. They also explained that CP

content of the plant varied greatly from type to type and parts to parts. In each type, leaves contained the highest and stem contained the lowest amount of CP. Boyd (1968) cited by Reza and Khan also observed a high percentage of protein content in water hyacinth. Linn *et al*,(1975) cited by Reza and Khan (1981) found that crude fibre content differ in the plant. In all the types, whole plant and stems contained more fibre than other parts. Sodium content of all types of water hyacinth is fairly high, which may hamper the assimilation of other nutrients especially magnesium. Banerjee (1970) explained that the dietary excess of potassium is normally rapidly excreted through urine, and that its high concentration has less possibility to make any trouble in animals

2.2.1 Utilisation of water hyacinth as livestock feed

Water hyacinth is successfully utilized by ruminants as silage (Hentges *et al.*,1972; Baldwin *et al.*,1975), or sun dried and included in meals (Reddy and Reddy,1979), or sun dried chopped (El-Serafy *et al.*,1979). The plant has been used as animal feed in rations for swine (Pathak *et al.*,1979), laying hens (Handy *et al.*,1978), sheep (Baldwin *et al.*,1975, El-Serafy *et al*,1979). It has also been used as feed for buffaloes (El-Serafy *et al.*,1981) and cattle (Reddy and Reddy 1979, Reddy and Mohan Reo 1979, Reza and Khan 1981). Surat and Singh,(1985), in their study of

utilisation of diets containing untreated rice straw, urea-ammonia treated rice straw and water hyacinth found that inclusion of water hyacinth in urea-ammonia treated rice straw rations may increase the content of readily available carbohydrate and protein. Therefore the cattle fed on these ensilages could at least maintain body weight. Surat and Singh (1980) also reported that fresh water hyacinth could meet nutrients requirements in rams.

Wanapat *et al*, (1985) reported that inclusion of water hyacinth in the ensilages enhanced CP digestibility, and that the digestibilities of DM and ADF were only improved at the higher level of inclusion of water hyacinth. They also explained that inclusion of water hyacinth in these rations may act as a catalytic supplement to stimulate feed intake and or productivity. El-Serafy *et al*, (1981) explained that water hyacinth silage, could meet at least the maintenance requirement of energy and digestible protein for growing buffalo steers. Reza and Khan, (1981) revealed that better utilisation of water hyacinth was found when it was incorporated with straw at a 1:1 ratio.

The incorporation of water hyacinth into diets based on rice straw markedly improved the nutritive value of the rations Wanapat *et al*, 1988. In a situation where basal roughage is relatively limited, water hyacinth can

substitute for the roughage with satisfactory results. This was demonstrated by El-Serafy *et al*, (1979) where berseem hay was replaced by water hyacinth hay up to 70% and by Juul-Nielsen *et al* (1982) where rice straw was replaced by water hyacinth up to 40%.

2.3 Acceptability of water hyacinth by livestock

Some research has been done on the intake of water hyacinth by livestock, especially ruminants (Table 2.2). In Thailand Wanapat *et al*,(1985) recorded a DMI of 3.03-3.49 kg/d with native cattle and 4.21-5.05 kg/d with water buffaloes for rice-straw and water hyacinth mixed diets. In Bangladesh Reza and Khan (1981), feeding diets containing water hyacinth alone, water hyacinth and rice straw, and water hyacinth and rice straw and sesame cake mixture obtained a higher DMI for diet containing water hyacinth, rice straw plus sesame cake. El-Serafy *et al*,(1981) feeding water hyacinth hay and silage to buffalo steers in Egypt found that animals readily consumed the feed and gained between 4.5 and 6.5 kg during the 152 day experimental period and DMI increased by 70.38, 63.03, 54.14 g/day/$W^{0.75}$ with the increase in DM content of the feeds. Wanapat *et al*, (1985) feeding growing cross-bredcalves diets containing wilted water hyacinth mixed with urea-molasses resulted in DMI of 131.78 and 129.93 kg,and a gain in weight of 25.63 and 26.25 kg.

Table 2.2 Voluntary dry matter intake and weight change in cattle and buffaloes fed diets containing water hyacinth

Country	Animals	Diets	Response		Source
			DMI kg/d	Weight gain g/d	
Bangladesh	Cattle	Urea-ammonia treated straw:WH (3:1,DM basis)	3.30	133	Wanapat et al., 1985
	Cattle	Urea-ammonia treated straw:WH (1:1,DM basis)	3.49	23	"
	Water buffaloes	Urea-ammonia treated straw:WH (3:1,DM basis)	6.24	232	"
		Urea-ammonia treated straw:WH (1:1,DM basis)	5.05	329	"
Bangladesh	Cattle	100% Water hyacinth	-	-1.30	Reza & Khan., 1981
		Water hyacinth+rice straw (1:1 ratio)	-	4.17.	"
		WH+rice straw+227 g Sesame-cake	-	5.90	"
Egypt	Buffalo	Water hyacinth hay (90% DM)	5.2	4.5	El-serafy et al., 1981
		Water hyacinth haylage (50% DM)	4.6	3.5	"
		Water hyacinth silage (80% DM)	4.00	3.5	"

2.4 Hay and Silage from water hyacinth

The physical structure of the plant is not suitable for hay and silage making in the normal ways. The neck between petiole and lamina is very brittle. The lamina shrinks and breaks off with handling, leaving the petiole which remains round and full of air (Göhl, 1984). The hay is therefore very bulky. Göhl (1984) reported that inclusion of 20% molasses increased the palatability of hay for cattle. Urea may be included to increase the content of crude protein. High moisture content of water hyacinth requires it to be wilted in the shade for 48 hours and lacerated before ensiling. Molasses should be added and sodium chloride and urea are reported to increase the nutritive value and quality of the silage (Göhl, 1984). Water hyacinth has also been ensiled in a mixture with rice straw in the proportion of 4:1 in favour of water hyacinth with good results. Silages made in these ways were palatable when gradually included in the ration (Göhl, 1984).

2.5 Feeding systems around lake Victoria

Majority of the farmers sorrounding lake Victoria are agropastoralists. The animals are grazed on natural pastures and the grazing time range from 6-11 hours (Laswai *et al*,1995). The animals are herded out early in the morning and brought in late in the evening. The shortest

time for grazing animals coincides with the peak of other agricultural work, when the farmer has to work in the fields first before herding the animals. During the wet season the animals are taken far away from the cultivated lands. Grazing normally take place in the open areas or uncultivated fields such as hilltops and deep ravines. After harvest the animals are allowed to feed on the crop residues in the cultivated areas (Laswai *et al*, 1995). The only time with reliable feed supply is during the wet season from February to June of each year. After this period there is an unreliable feed supply for a period of about seven months. During this period most of the farmers are forced to sell their livestock (personal observation).

2.6 Utilisation of water hyacinth in Tanzania

Water hyacinth belongs to the family Pontederiaceae. It is a floating biomass with long round spongy stems. Leaves are extremely green, large and erect. Roots are long (10 to 90 cm) Reza and Khan (1981). The rhizomes are generally 1 to 25 cm long, occasionally producing internodes. The plant is luxuriant in growth and multiplies very rapidly. The average height of the plant is about 45 cm in mature stage but generally ranges from 30 to 70 cm (Reza and Khan,1981). The plant is characterized by formation of large floating mats which normally covers the water surface.

In Tanzania water hyacinth has not attracted the attention

of farmers as a feed for livestock. Currently, there is no local use for this plant apart from few farmers raising pigs who include the fresh shoots in the diet of these pigs (Kivaisi and Mtilla,1995). This has been contributed by the lack of information on this plant and the fact that it was non-existent in lake Victoria until recently. At the moment the weed is harvested by mechanical means and dumped by the local people whose activities have been hampered by its infestation (Kivaisi and Mtilla., 1995).

During this study only one farmer at Mwaloni beach was observed cutting shoots of water hyacinth and mixing with fresh grasses and feeding to dairy cattle. Many farmers do not feed water hyacinth believing that the plant is poisonous (personal communication with farmers).

2.7 Problems associated with water hyacinth infestation

Water hyacinth has been a major ecological and economic problem both in the tropics and sub tropics. Under suitable conditions of temperature (between 28-30°C) and pH (4.0-8.0), water hyacinth can double its population every seven days to yield 930-2900 tons/ha annually (Lareo and Bressani,1982). In lake Victoria the infestation has become very serious and almost no shore has been spared. The infestation is characterised by formation of large floating mats which cause a number of problems. The major problems

include obstruction of navigation, interference with fishing areas, and reducing the recreational value of inland waters. Other harmful effects are clogging of drainage ditches, irrigation canals and run-off streams, thus causing back waters and flooding conditions. The plant is also chocking the biota and resulting into detrimental ecological effects (Kivaisi and Mtilla,1995). Water hyacinth biomasses are utilised by mosquitoes as breeding grounds and provide a good shelter for snakes and crocodiles. The incidence of malaria is said to be high around heavily infested beaches (personal communication with residents living near infested areas).

There have been several Government statements on the need for regional cooperation to deal with water hyacinth infestation. However there has been no permanent solution worked out to combat water hyacinth. Mechanical or chemical control of the plant is difficult and expensive bearing in mind its multiplication rate. Agencies in Florida spent an estimated $ 3.5 million per year to control aquatic weeds for navigational improvement, drainage, fishing, water conservation and insect control (Bagnall *et al*,1977).

Since water hyacinth has been utilised successfully as an animal feed in many countries, the same can be applied to Tanzania. In Vietnam, China and India the plant is easily

harvested using nets for animal feeding, and in Bangladesh Water hyacinth is termed the cheapest source of roughage for livestock feed. Because of the all year round availability of water hyacinth and the fact that it is not affected by seasonal fluctuations of rainfall, the plant presents potential opportunities for livestock feeding in areas surrounding lake Victoria.

CHAPTER THREE

3.0 MATERIALS AND METHODS

3.1 Site Description

The samples for the different analyses were collected from lake Victoria. The lake lies between the western and eastern rift valley highlands in east - central Africa at an altitude of 1130 m. It covers an area of 69485 km^2. It is about 400 km long and 240 km wide. The greatest recorded depth is 80 m. Ensiling was carried out at Kamanga ferry point in Mwanza where a farmer provided a place for wilting and storage of water hyacinth silage.

Water hyacinth being a floating biomass sampling site selection was done to enable samples to be collected from areas not exposed to direct surf beating, since it is possible to find large concentrations of water hyacinth biomass in such places.

3.2 Sampling procedure

A boat was used to reach the sampling sites. Water hyacinth was pulled out of the water using a hook, and piled in the boat. After harvesting the samples were mixed together on a plastic sheet and sorting was done to remove dirt and mud. After sorting, samples were divided into three parts to enable determination of nutrient content of the plants as a whole and of the different botanical parts of the plant i.e. water hyacinth leaves (WHL), leaf and stem

without roots (WHS), and leaf, stem, and roots i.e whole plant (WHE). These were then dried under the sun for six days after which they were stored in a tightly tied plastic bags for chemical analysis.

3.3 Chemical analyses

The chemical analyses were carried out at the laboratory of the Department of Animal Science and Production of Sokoine University of Agriculture. Analysis of volatile fatty acids and lactic acid were carried out at the Department of Botany of the University of Dar-Es-Salaam.

Prior to analysis, the samples were dried in the oven at 60°C for 48 hours. The dried samples were then ground to pass through a 2 mm sieve for degradability studies and 1 mm sieve for chemical analysis. The dried and ground samples were allowed to equilibrate at room temperature for 24 hours after which they were stored in glass bottles with tight covers.

3.3.1 Chemical analysis of plant parts and silages

Duplicate ground samples of water hyacinth parts and silage were subjected to chemical analysis. Dry matter, ash, crude protein and ether extractive were determined using the A.O.A.C (1990) procedure. The neutral detergent fibre (NDF), and acid detergent fibre (ADF) were determined according to the procedure described by Goering and Van

Soest (1970).

3.3.2 Potential yield estimation

Potential yield was estimated using a floating wooden square of 0.25 m^2 at three different locations . Using a small boat the square was tossed ten times and each time plants falling in it were harvested using a knife. After harvesting the samples were weighed and dried under the sun for six days. After this period the samples were weighed again and the weights recorded and used for estimation of biomass yield. The average fresh and dry weights of the three quadrats were calculated. Dry weights were then used for biomass yield estimation by equating area of quadrats to 1 hectare (10,000 m^2).

3.4 *In vitro* digestibility

Digestion of feeds start in the mouth of an animal and continues in the gut. The digestibility trials are carried in the digestion tubes that do not resemble the conditions in the stomach and mouth, for this reason it is important that conditions in the mouth and gut of an animal be replicated in the digestion tubes. This necessitates the addition of rumen liquor and artificial saliva.

3.4.1 Preparation of artificial saliva

Artificial saliva of the composition shown in Table 3.1 was prepared, and the solution was saturated with carbon dioxide gas and the pH was adjusted to 6.8-6.9.

Table 3.1: Composition of the prepared artificial saliva

$Na_2HPO_4.2H_2O$	29.96g
$NaHCO_3$	49.00g
Nacl	2.35g
Kcl	2.85g
$CaCl_2.2H_2O$	0.26g
$MgCl_2.6H_2O$	0.64g
H_2O	3000g

3.4.2 Collection of rumen liquor

Rumen liquor was obtained from fistulated steers fed on hay and concentrates. It was drawn through the stomach canula using a plastic tube connected to a conical flask which, in turn, was fitted with a vacuum pump at its arm. The rumen fluid obtained was put into a thermos flask before use.In the laboratory the rumen fluid was pressed and strained through a double layer of muslin and put into a bottle which was closed with a rubber stopper and kept in a water bath maintained at 38°C. It was kept in the water bath for

30 minutes before being used.

3.4.3 (a): One stage *in vitro* method

Dry matter digestibility was carried out according to the procedures of Tilley and Terry (1963). Samples were weighed at 0.5g. The samples were then transferred into 100 ml centrifuge tubes. In addition, blanks were also run containing no feed samples but only the same amount of rumen liquor and buffer solution as the other tubes. 10 mls of rumen liquor and 40 mls buffer solution were added to each incubation tube, and were closed under anaerobic conditions with a rubber-stopper fitted with a valve. The tubes were placed in the incubator at 38°C. Each feed was incubated in duplicate for 6, 12, 24, 48, 72, 96, and 120 hours, respectively. After incubation periods samples were kept in a deep freezer for analysis at later date.

Dry matter digestibility was calculated using the following formula:-

$$\%\text{DM digestibility} = \frac{\text{DM of sample} - (\text{DM of residue} - \text{DM of blank}) \times 100}{\text{DM of sample}}$$

3.4.4 (b): Conventional two stage *in vitro* method

In vitro dry matter digestibility determination of the samples with pepsin-hydrochloric acid digestion was carried out separately at 48 hours incubation with another set of duplicate tubes. Dry matter digestibility was calculated in the same way as in part (a) above. Both one stage and two

stage in vitro experiments were carried out to enable comparison of digestibility trends over different hours even after 96 hours in one stage *in vitro*.In two stage *in vitro* bacteria were killed by adding pepsin hydrochloride solution at the second stage. Digestion then continued for another 48 hours without rumen microbes, giving a difference with one stage *in vitro* method in terms of digestibility.

3.4.5 *In sacco* degradability method

Degradability of water hyacinth parts and silage was done using the nylon bag technique described by Ørskov *et al* (1980). The nylon bags used had a pore size of 40 μM. For each sample 3 gm were weighed and the incubation periods were 6, 12, 24, 48, 72, 96, and 120 hours. Dry matter disappearance was calculated as follows.

$$\%\text{DM disappearance} = \frac{(\text{DM into bag} - \text{DM in bag after incubation}) \times 100}{\text{DM into bag}}$$

The data obtained were fitted to the equation below to obtain the degradation characteristics.

The percentage of material degraded (p) after time (t) was obtained by the equation described below (Ørskov and McDonald, 1979).

$P = a + b(1-e^{-ct})$

where P = percentages of material degraded after time t in hours,

a = intercept of the degradation curve,

b = potential degradability,

c = rate of degradation,

t = time in hours.

The values for the equation above were calculated by a computer using a NAWAY program developed by Ørskov *et al* (1980) and Ørskov (1982).

Effective degradability of the samples were calculated by using SUPERCAL computer package at a passage rate of 0.01 using the formula below.

$Y = a+bc/(c+k)$

Where,

Y = effective degradability

a = water soluble component

b = insoluble but potentially rumen degradable part

c = rate of degradability of insoluble material

k = passage rate

3.4.6 Silage preparation

After harvesting, plant shoots were lacerated and separated from the roots. After lacerating samples were chopped using knives and spread on polythene sheet 6 to 8 metres long and wilted under shade for 48 hours. Two levels of molasses 10% and 20% were used in making the silage. Samples with no molasses were also ensiled as controls. These were replicated six times in a completely randomized design.

3.4.6.1 Experimental silos

Plastic buckets of 20 litres capacity were used as silos. During the ensiling process a layer of dry grass was laid at the bottom of each bucket to act as absorbent to any effluent generated. Nature of the plastic buckets used did not allow effluent to drain out, so a layer of grass acted as an absorbent for effluent generated. This was followed by a piece of newspaper to separate grass and silage. Small holes were made on the newspaper to ensure that effluent seeped through it. After ensiling 1 kg of sand was poured into a polythene shopping bag and tightly tied, and it was then spread on top of the silage to prevent air penetration. The bucket covers were then replaced and tightly closed, for the fermentation process to take place.

3.4.6.2 Addition of molasses

Due to the high viscosity of molasses it was difficult to mix it uniformly with the sample. For this reason, molasses was mixed with water at the ratio of 1:1 to reduce viscosity and to facilitate uniform mixing. Then it was sprinkled using a cup and thoroughly mixed using hand until uniform mixture was obtained. Mixing was done on a polythene sheet to ensure that no molasses was lost through leakage. After addition of molasses, ensiling was done immediately, and reasonable compaction was achieved in all of the buckets.

3.4.6.3 pH determination

Portions of molasses treated and untreated samples were ensiled in 5 litre containers for pH monitoring during the fermentation process. pH changes were monitored at a weekly interval until it was considered that the stable pH was reached. At opening, for each container 100 gm of silage was taken for pH determination. The subsample was soaked into 500 mls of distilled water (ratio 1:5) for 12 hours after which it was filtered using a filter paper. The resulting solution was divided into six parts from which their pH was read using a pH meter. pH at the time of ensiling was taken as initial pH of the material ensiled.

3.5 Sampling for chemical analysis

3.5.1 Pre-ensiling sampling

Subsamples (400 gm of each treatment) were deep frozen for the DM determination and analysis of volatile fatty acids, and butyric acid. Subsamples were also air-dried for determination of crude protein (CP), Ash, neutral detergent fiber (NDF), acid detergent fiber (ADF), water soluble carbohydrates (WSC), dry matter (DM) and organic matter (OM) digestibilities. The frozen samples were transported in a cool box from Mwanza to the Department of Animal Science and Production of Sokoine University of Agriculture where they were stored in a deep freezer awaiting analysis.

3.5.2 Silage sampling

Immediately after opening each bucket 400 gm of silage were taken and stored in a deep freezer for analysis as in section 3.4.1. Samples were taken from different depths of the bucket and mixed together to ensure that uniform material was sampled. Subsamples were air dried for dry matter calculation, *In vitro* DM and OM digestibility determinations.

3.6 Acceptability study

Acceptability study was conducted at Magadu dairy farm of Sokoine University of Agriculture. A total of four heifers ranging in weight from 163 - 227 kg were used for studying

the acceptability of the silage by livestock for an eighteen (18) day period. 2 kg of silage were weighed after opening each bucket and offered to each heifer, making a total of 8 kg.

The silage was offered in the morning at 8.00 am for ten minutes after which the refusals were collected and weighed to obtain the amount eaten by an animal. At the start of the feeding experiment four men held the buckets containing the silage. This was poured at once in the feeding trough. After ten minutes the heifers were prevented from consuming more silage by leading them away to allow the remains of the silage to be collected and weighed. This experiment was repeated daily up to the end of 18 days period. From the data obtained intake rate was calculated as follows.

Amount (in grams) of silage eaten/Ten minutes

3.7 Determination of water soluble carbohydrates

Water soluble carbohydrates was determined Spectrophotometrically by an automated procedure for the determination of water soluble carbohydrates in herbage according to Thomas, (1977).

Equation of the straight line $Y = mx + c$ was used for calculating the results.

Where,

Y = Absorbance,

m = Gradient,

x = Intercept on x axis = milligrams of glucose corresponding with absorbance Y,

c = Absorbance corresponding to 0 mg of glucose from the standard graph.

From the equation the number of mg of glucose equivalent to absorbances of the sample and the blank determination was calculated. The difference after correcting for the blank was multiplied by 500. The result gave g/kg of soluble carbohydrates, calculated as glucose in the sample.

3.8 Determination of ammonia nitrogen concentration

The ammonia nitrogen (expressed as % of total N) of silage samples was determined by routine Kjeldahl method described by (A.O.A.C, 1990).

3.9 Determination of Lactic acid by gas chromatography

Because lactic acid is not volatile, methylation was done. Centrifuged sample (0.5ml) was pipetted into a test tube followed by 0.5ml of 10mM malonic acid (internal standard), 0.4ml of 50% sulphuric acid(H_2SO_4) AND 2.0ml of ethanol. Contents were then mixed by stirring and incubated in a water bath at 50°c for 30 minutes. After incubation, 1ml of

distilled water and 1ml of chloroform were added before meticulous mixing. Then 2μL of the mixed content was injected into GC equipment using a wipe syringe for determination of lactic acid.The GC was operated isothermally at 125°c (column oven), 125°c (injection or inlet) and 170°c (detection).

The percentage lactic acid produced was obtained by the equation;

$$\% \text{ Lactic acid yield} = \frac{\text{Grams lactic acid produced X 100}}{\text{Grams of sugar consumed}}$$

3.9.1 Analysis of Fatty Acid using gas - liquid chromatography

This analysis was based on the separation of various fatty acid components which are present in a liquid. Separation was done by selective division of the components in a stationary and a running phase. Stationary phase carrier is 10% S - 1000 /1% H_3PO_4. The stationary phase are in a column, through which the running phase (N_2) is flowing. Depending on the properties of the fatty acid, it will leave the column sooner or later. After leaving the column , fatty acids was detected using a flame - ionisation detector. The organic matter was ionised in the flame. The ionisation was expressed in an electrical current, which was visualised using a recorder. Volatile fatty acids

(acetate, propionate, butyrate) were distinguished from non - volatile fatty acids (lactate, succinate). Non - volatile fatty acids were first made volatile by methylation.

3.9.2 Statistical analysis

Descriptive statistics were calculated for chemical composition and potential yield estimation. The degradability of the different plant parts at each incubation period were analyzed using NAWAY computer package. The SAS GLM procedure (SAS 1988) was used for analysis of *in vitro* digestibility of plant parts and the silage data according to the statistical models below.

3.9.3 In- vitro dry matter digestibility

$Y_{ij} = \mu + V_i + e_{ij}$

Where.

Y_{ij} = The DM digestibility of the j^{th} sample from i^{th} part.

μ = general mean.

V_i = The digestibility value of the i^{th} part.

e_{ij} = error term.

3.9.4 Model for silage experiment

$Y_{ij} = \mu + T_i + ei_j$

Where.

Y_{ij} = Quality attributes of ensiled and pre-ensiled treatments of water hyacinth DM, CP, Ash, EE, NDF, and ADF,.

μ = the overall mean value.

T_i = effect of i^{th} treatment level (10%, 20% molasses).

eij = random error.

CHAPTER FOUR

4.0 RESULTS

4.1 Chemical composition of water hyacinth parts

Table 4.1 shows the chemical composition of water hyacinth and its parts. Both water hyacinth leaves, shoots and entire plant had low dry matter content. Water hyacinth leaves contained low ash content, followed by shoots and the entire plant had the highest amount. Leaves had low content of acid detergent fibre, followed by shoots, while the entire plant had the highest amount of acid detergent fibre. Entire plant had the lowest ether extract while shoots and leaves contained nearly 2% of DM as ether extract. Crude protein content of the leaves was higher, followed by that of shoots and the entire plant had the lowest CP content.

Table 4.1: Chemical composition of water hyacinth and its parts

		As % of dry matter				
Sample	%DM	Ash	EE	CP	NDF	ADF
Leaves	10.72±0.03	12.27±0.02	1.82±0.007	18.03±0.26	50.07±0.99	21.09±0.07
Shoot	9.86±0.13	18.32±0.02	1.79±0.07	18.04±0.75	54.32±0.54	30.78±0.65
Whole plant	9.42±0.03	20.12±0.12	1.42±0.007	8.53±0.43	64.90±0.74	34.34±0.02

4.2 Potential yield estimation

Table 4.2 shows the biomass of water hyacinth at the time of sampling expressed in grams. After harvesting the shoots of the plant contained a dry matter in the range of 6-10 %.

Table 4.2: Weight of water hyacinth after harvesting in (gm)

Quadrant	Location 1	Location 2	Location 3
1	9.17	6.42	6.58
2	6.98	6.98	6.37
3	6.37	10.74	7.36
4	8.29	7.62	7.85
5	6.73	6.47	6.58
6	6.98	9.20	10.52
7	7.21	7.85	7.85
8	5.79	7.69	6.27
9	7.19	6.98	9.44
10	6.37	7.69	6.42
Mean	7.10	7.76	7.52

The total biomass of water hyacinth was estimated at 298.61 kgDM/ha.

4.3 Comparison of dry matter digestibility of water hyacinth parts by two-stage *in vitro* incubation in rumen liquor

The mean DM digestibility values of water hyacinth parts obtained by two stage *in vitro* incubation is shown in Table 4.3. Significantly lower ($P<0.001$) digestibility value were obtained for whole plant. No significant ($p>0.05$) difference in digestibility was obtained between leaves and shoots. In both water hyacinth parts, shoots and leaves showed higher digestibilities and the whole plant had the lowest digestibility.

Table 4.3: Comparison of the DM digestibility values of the water hyacinth parts using two stage *in vitro* method

Parts	% DM digestibility
Leaves	58.15^{a}
Shoots	57.03^{a}
Whole plant	42.32^{b}
SEM	0.62

^{a,b,c} within column means with different superscripts differ significantly ($p<0.05$)

4.4 Comparison of the DM digestibility of the water hyacinth parts over different durations of incubation

Figure 2 shows that percentage DM digestibility of all water hyacinth parts increased with time. In all water hyacinth parts, leaves and shoots had the highest *in vitro* DM digestibilities and whole plant had the lowest. Significantly ($p<0.05$) lower DM digestibilities were obtained for whole plant compared with other water hyacinth parts. Comparing the DM digestibility values obtained after 48 and 120 hours, the dry matter digestibility at 48 hours were significantly ($P<0.05$) lower than those obtained at 120 hours for both water hyacinth parts. The DM digestibility values for the water hyacinth parts over time showed a higher correlation coefficients 0.99 for leaves and 0.98. This kind of association indicates that higher digestibility values were attained as time increases.

Table 4.4: Comparison of the DM digestibility of water hyacinth parts using one stage *in vitro* method over different periods of incubation

Incubation time(h)	Parts			
	Leaves	Shoots	Whole plant	SEM
6	14.36^{a}	13.96^{a}	10.25^{b}	0.417
12	19.63^{a}	18.46^{b}	15.33^{c}	0.345
24	26.88^{a}	25.93^{a}	21.67^{b}	0.419
48	38.26^{a}	37.34^{a}	29^{b}	0.62
72	39.35^{a}	39.96^{a}	32.94^{b}	0.385
96	43.89^{a}	41.56^{b}	36.53^{c}	0.482
120	45.75^{a}	44.16^{b}	38.30^{c}	0.514

^{a,b,c} within rows means with different superscripts denote statistical significance ($p<0.05$)

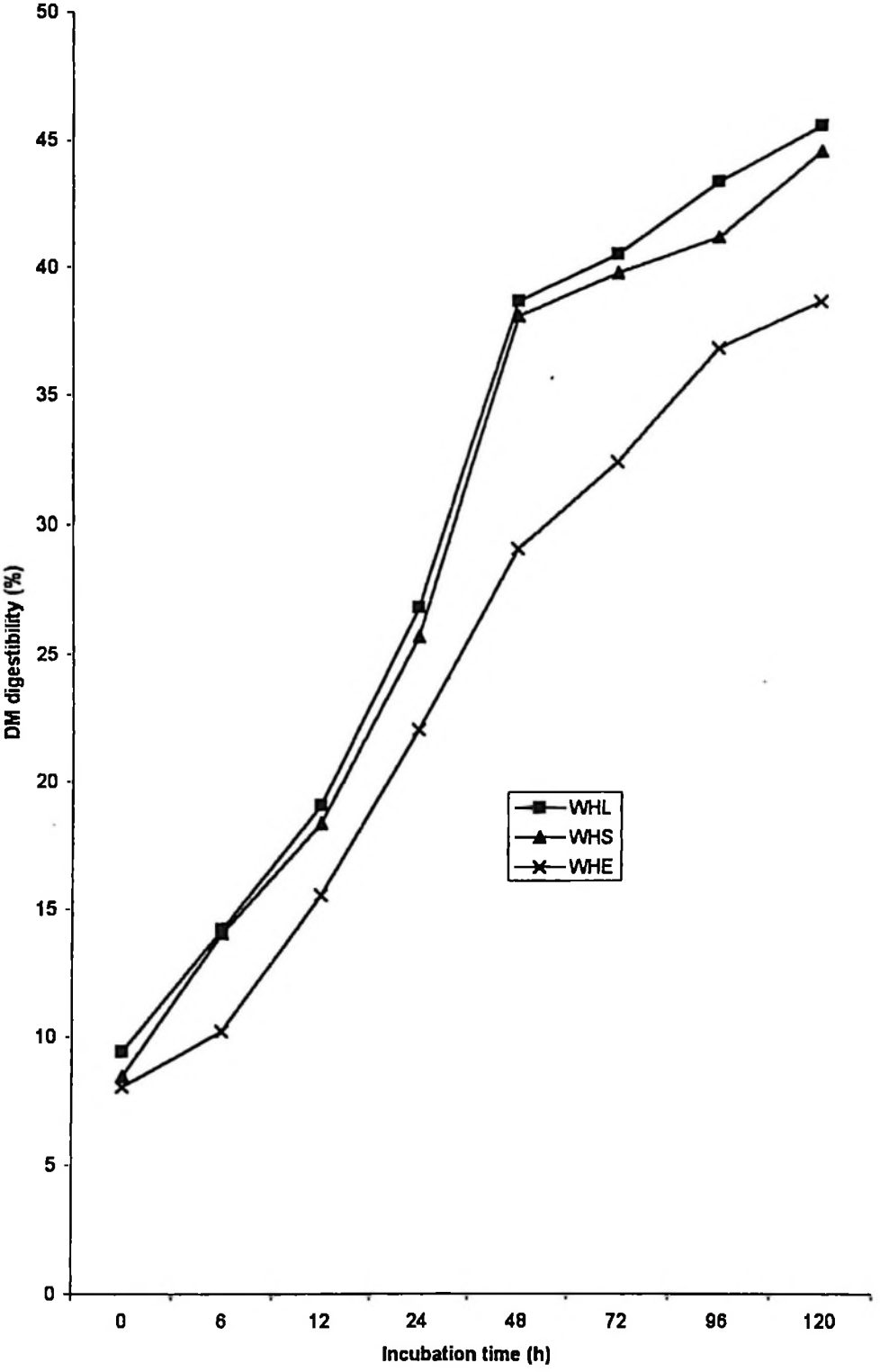

Figure 1: Comparison of DM digestibility using one stage *in vitro* method

4.5 Dry matter degradability of plant parts by *in sacco* method

The percentage DM degradability of the parts is shown in Figure 3. In all samples the percentage DM disappearance increased with time. As a normal trend, the leaves showed the highest DM degradability followed by shoots, and whole plant had the lowest. Degradability characteristics of the parts is shown in Table 4.5. Potential degradability (a+b) was highest in leaves and shoots and lowest in entire plant. The insoluble but potentially degradable fraction (b) in the entire plant was lower compared to that of leaves and shoots. Not much difference was observed in the immediately soluble fraction (a). The leaves had the highest immediately soluble fraction followed by the entire plant and shoots had the lowest. Figure 3 indicates that the constants (c) for the parts and whole plant were most rapid between 12 and 48 hours of incubation. Mean DM degradability after 48 hours of incubation was 53.57%, 49.54%, and 44.25% for leaves, shoots, and whole plant respectively.

Table 4.5: Estimates of DM degradability of the WH parts by *in sacco* method

Sample	Degradability characteristics				
	a	b	c	a+b	RSD
WHL	9.38±1.45	58.71±6.26	0.030±0.007	68.09±3.85	3.96±0.74
WHS	8.41±2.28	52.41±1.38	0.032±0.005	60.82±1.83	4.06±0.69
WHE	8.71±1.16	44.2±3.11	0.034±0.006	52.91±2.13	2.87±1.48

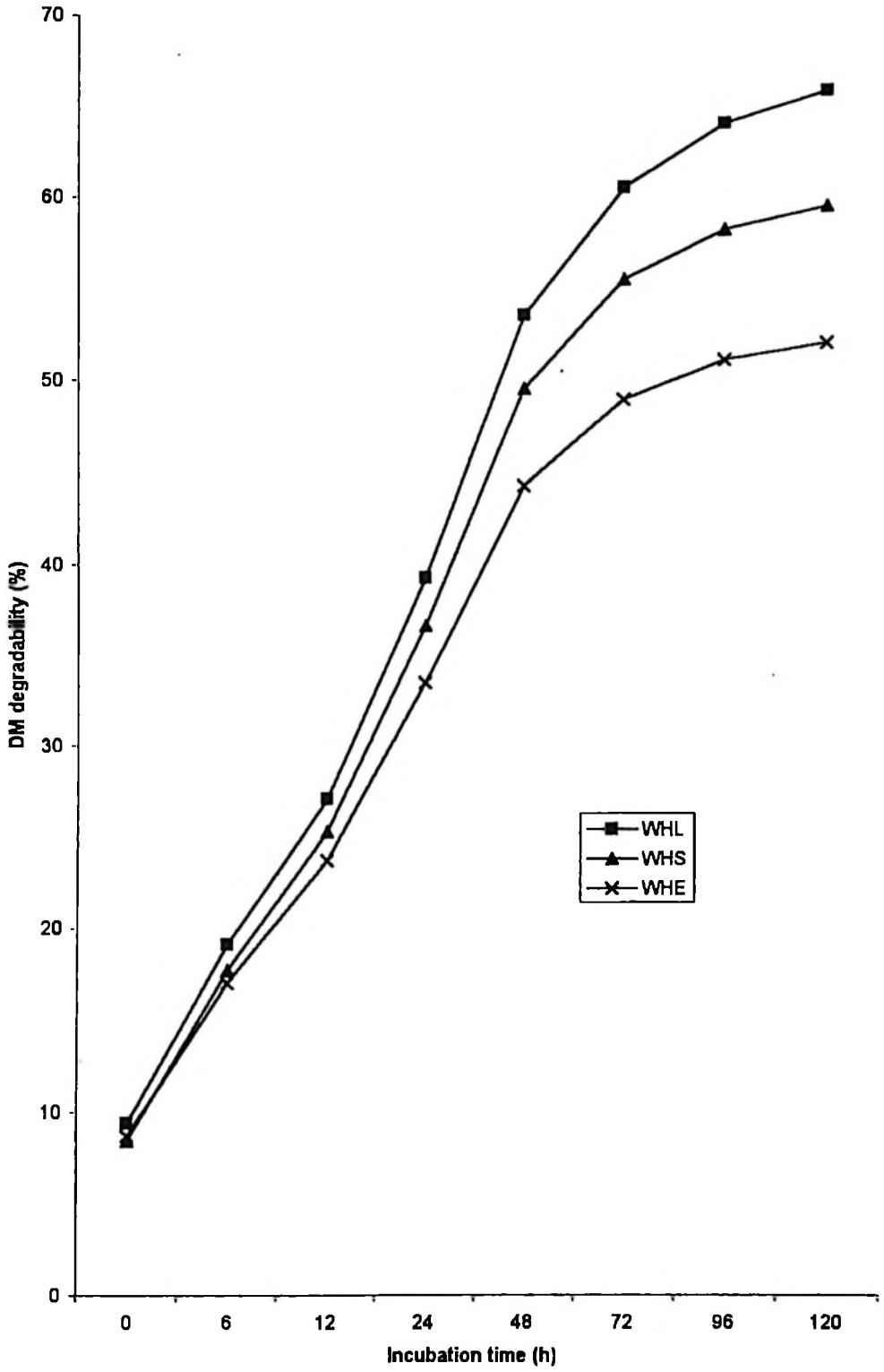

Figure 2: DM degradability of water hyacinth parts

4.6 Chemical composition, *in vitro* DM and OM digestibility of water hyacinth treatments before ensiling

Mean chemical composition of water hyacinth before ensiling is shown in Table 4.6. DM content of molasses treated water hyacinth were significantly ($p<0.001$) higher than that of unmolassed treatment. The CP content of unmolassed water hyacinth was significantly ($p<0.001$) higher than that of molassed treatments. Significantly ($p<0.001$) higher values of, IVDMD and IVOMD were obtained for the molassed treatments compared to unmolassed.

Table 4.6: Mean chemical composition, in vitro DM and OM digestibility of water hyacinth treatments before ensiling

Forage	DM	CP	EE	Ash	IVDMD	IVOMD
	(%)		$gkg^{-1}DM$		(%)	(%)
No molasses	15.39[a]	110.18	16.82	160.09	40.61[b]	42.30[a]
+10% molasses	21.51[b]	82.21	22.98	161.47	51.99[a]	55.47[b]
+20% molasses	25.35[c]	80.75	23.61	160.96	52.26[a]	54.33[b]
SEM	0.27	0.178	0.109	0.182	0.346	1.226

[a,b,c] within column means with different superscripts differ significantly ($p<0.05$)

4.7: Effect of ensiling water hyacinth on NDF, ADF and WSC

Effects of ensiling water hyacinth on NDF, ADF and WSC is shown in table 4.7. Pre-ensiled water hyacinth had lower NDF and ADF values than in the silages. Significantly ($p<0.001$) higher values of WSC were obtained for water hyacinth pre-ensiled material compared to silages. The values for NDF and ADF were higher for the pre-ensiled material than in the silages.

Table 4.7: Effect of ensiling water hyacinth on NDF, ADF and WSC

	Before ensiling			After ensiling		
	NDF	ADF	WSC	NDF	ADF	WSC
No molasses	581.81	335.33	210.99[b]	675.89[a]	346.52[a]	172.67[c]
+10% molasses	394.75	229.22	283.25[a]	437.4[b]	247.94[b]	215.24[b]
+20% molasses	379.25	214.35	319.14[a]	393.96[c]	213.58[c]	285.02[a]
SEM	0.808	0.215	1.437	0.571	0.152	1.016

[a,b,c] within column means with different superscripts differ significantly ($p<0.05$)

4.8 Effect of addition of molasses in chemical composition of silage

Addition of molasses showed significant effects on chemical composition of water hyacinth silage (Table 4.7). Significantly ($p<0.001$) higher dry matter, and ether extract values were observed for the molasses treated water hyacinth silage. WSC content was also significantly ($p<0.01$) increased by the addition of molasses. The crude protein content of molasses treated water hyacinth silage was significantly ($p<0.001$) lower than that of untreated water hyacinth silage. Significantly ($p<0.001$) lower values of NDF and ADF were obtained for molasses treated silage compared to that without molasses. Ash content was slightly lower for the molasses treated silage compared to untreated silage. Significantly higher ($p<0.001$) DM and OM digestibilities were obtained for the molasses treated water hyacinth silage compared with untreated silage.

In general molasses treated silages had higher dry matter, ether extract and WSC contents. Changing the level of molasses from 10% to 20% significantly ($p<0.001$) increased the dry matter content and WSC of the silages, while ether extract, ash, OM and DM digestibility contents were not significantly ($p>0.05$) changed by the increase in molasses level. Similarly, no significant ($p>0.05$) difference in crude protein, DM and OM digestibilities was obtained by

changing the level of molasses from 10% to 20%. 20% molasses treated silage showed a significantly lower NDF and ADF as compared to the 10% molasses treated silage.

Table 4.8: Effects of additive (molasses) on chemical composition of water hyacinth silage

Parameter	0% molasses	10% molasses	20% molasses	SEM
DM	14.03^{c}	20.67^{b}	24.26^{a}	0.191
g kg-1 DM				
CP	97.61^{a}	80.75^{b}	77.68^{b}	0.126
EE	18.26^{b}	28^{a}	28.23^{a}	0.077
Ash	171^{a}	162.53^{b}	165.22^{b}	0.128
WSC	172.67^{c}	215.24^{b}	285.02^{a}	1.016
NDF	675.89^{a}	437.40^{b}	393.96^{c}	0.571
ADF	346.52^{a}	247.94^{b}	213.58^{c}	0.152
DMDIG%	39.54^{b}	51.79^{a}	51.87^{a}	0.245
OMDIG%	42.15^{b}	54.60^{a}	52.76^{a}	0.867

^{a,b,c} within rows means with different superscripts differ significantly ($p<0.05$)

4.9 Acceptability of silage

Results for the acceptability of silage are summarised in Table 4.8. The DMI g/min was significantly ($P<0.001$) increased by the addition of molasses. However, changing the molasses level from 10% to 20% did not significantly ($P>0.05$) increase the intake rate of silage. Intake rate of 20% molasses treated silage was slightly higher (30.78 g/min) than that of 10% molasses treated silage (28.05 g/min). Significant ($P<0.001$) difference was also observed in the DMI expressed as % of live body weight between

molasses treated and untreated silage. No significant ($P>0.05$) difference was observed in increasing the molasses level from 10% to 20%. A highly significant ($P<0.001$) difference in DMI (per unit metabolic body weight) was also observed between molasses treated and untreated silage. Increasing the level of molasses from 10% to 20% did not have a significant ($P>0.05$) effect on the $DMI/W^{0.75}$. The average DMI g/min for molassed and unmolassed silage was 30.78 ± 11, 28.05 ± 7, and 3.15 ± 1.8 for 20%, 10%, and 0% molasses levels respectively.

4.9.1 Degradability of water hyacinth silage

Degradability characteristics of water hyacinth silage is shown in Table 4.8. Significant differences were observed in the degradation characteristics of the silages. Significant difference ($p<0.001$) was observed in the water soluble fraction A, rumen degradable portion B, potentially degradable fraction A+B, effective degradability %, 48 hours DM degradability, and rate of passage C.

Molasses treated silage had a significantly ($p<0.001$) higher water soluble fraction A, rumen degradable portion B, potential degradability A+B, effective degradability %, and rate of passage C. Significantly ($p<0.001$) lower effective degradability was obtained for the molasses treated silage compared to untreated silage. Increasing the level of molasses from 10% to 20% significantly ($p<0.001$)

increased the effective degradability, while there was no significant ($p>0.05$) difference in 48 hours degradability between 10% and 20% molasses treated silage.

Figure 4, shows that 20% molasses treated water hyacinth silage had slightly higher degradability compared to 10% molasses treated silage from 0 to 48 hours, but from 72 to 120 hours there seems to be no difference in the degradability of molasses treated silages. However, unmolassed silage had lower degradability at both hours of incubation (Figure 4).

Table 4.9a: Effect of addition of molasses on silage DMI rate and DM degradation of silages at 48 hours

Parameter	0% molasses	10% molasses	20% molasses	SEM
DMI g/min	3.15^{b}	28.05^{a}	30.78^{a}	1.64
DMI % BW	0.16^{b}	1.47^{a}	1.59^{a}	0.09
$DMI/W^{0.75}$	0.61^{b}	5.49^{a}	5.94^{a}	1.86
A	13.62^{c}	16.54^{b}	18.7^{a}	0.129
B	47.50^{b}	49.51^{a}	45.25^{c}	0.274
A+B	61.13^{c}	66.06^{a}	63.96^{b}	0.27
C	0.028^{c}	0.043^{a}	0.033^{b}	0.0002
Effective DEG%	48.29^{a}	31.9^{c}	33.91^{b}	0.11
48 h DM DEG%	48.53^{b}	54.76^{a}	54.55^{a}	0.141

Note: A=water soluble fraction, B= rumen degradable portion, C= rate of passage.

^{a,b,c} within rows means with different superscripts differs significantly ($p<0.05$)

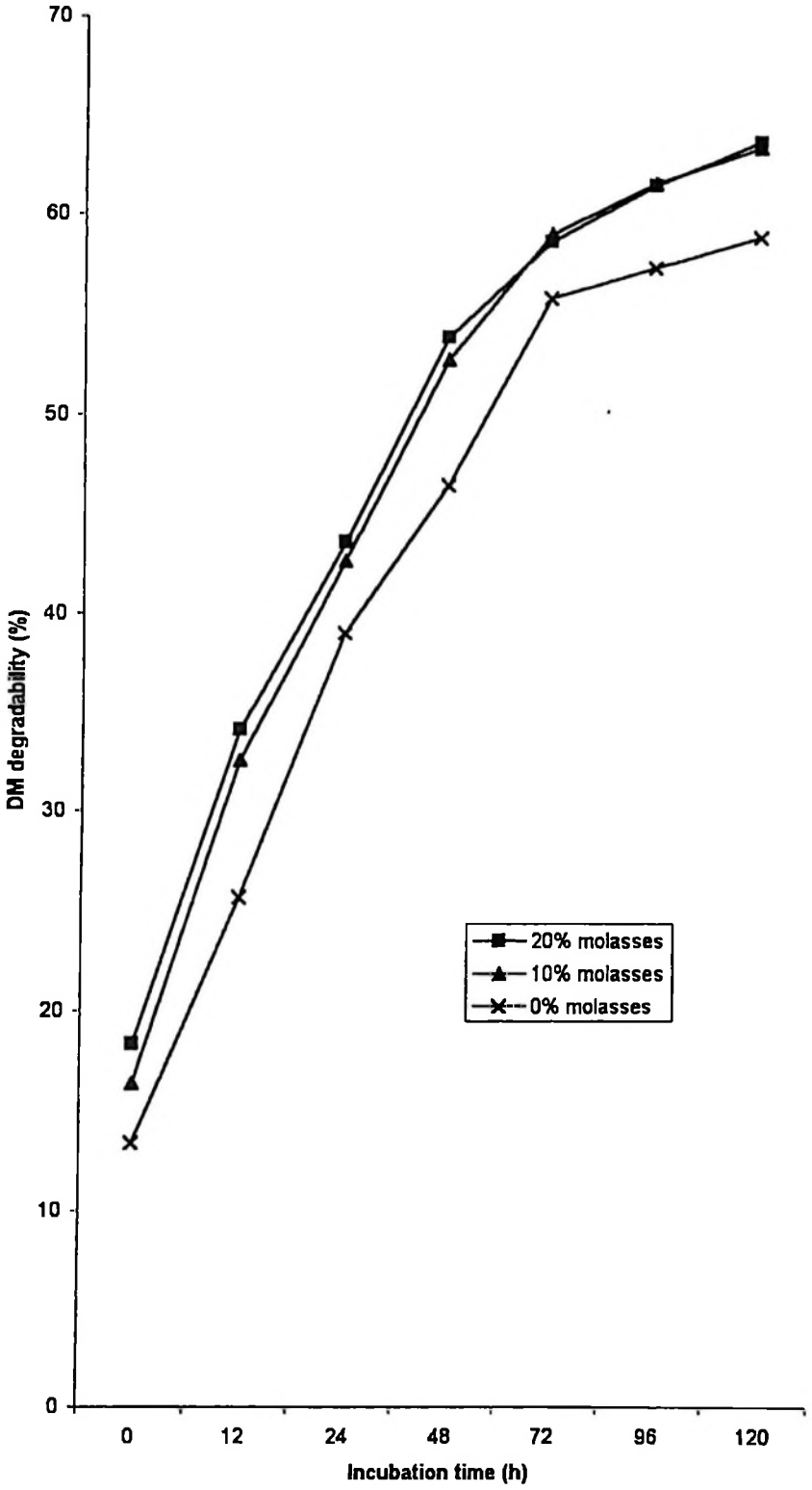

Figure 3: *In sacco* degradability of water hyacinth silage

4.9.2 pH changes during ensiling of water hyacinth

Results for the effects of addition of molasses on the fermentation products of WH silage are summarised in Table 4.9. Level of molasses had a significant ($P<0.001$) effect on pH. Increasing the molasses level from 10% to 20% significantly ($P<0.001$) lowered the pH value of the silage. Figure 5 shows the course of change in pH over different fermentation periods. The pH of 20% and 10% molasses treated silage was almost at the same level (4.24 and 4.32) after one week, while untreated silage had a pH of 4.78. Rapid decline in pH occurred from second week for molassed silage reaching minimum of 3.48, and 3.08 after four weeks for 20% and 10% molasses treated silage respectively, then rising and becoming constant from fifth week onwards. 10% molasses treated silage maintained a lower pH values of 3.71 and 3.68 in the fifth and sixth week while 20% molasses treated silage had a pH of 3.78 and 3.89 during the fifth and sixth week respectively. Untreated silage had its pH rise, (Figure 5) reaching a maximum of 5.31 in the third week, then decreasing to 4.75 in the fourth week and finally maintaining a pH of 5.22 after the sixth week.

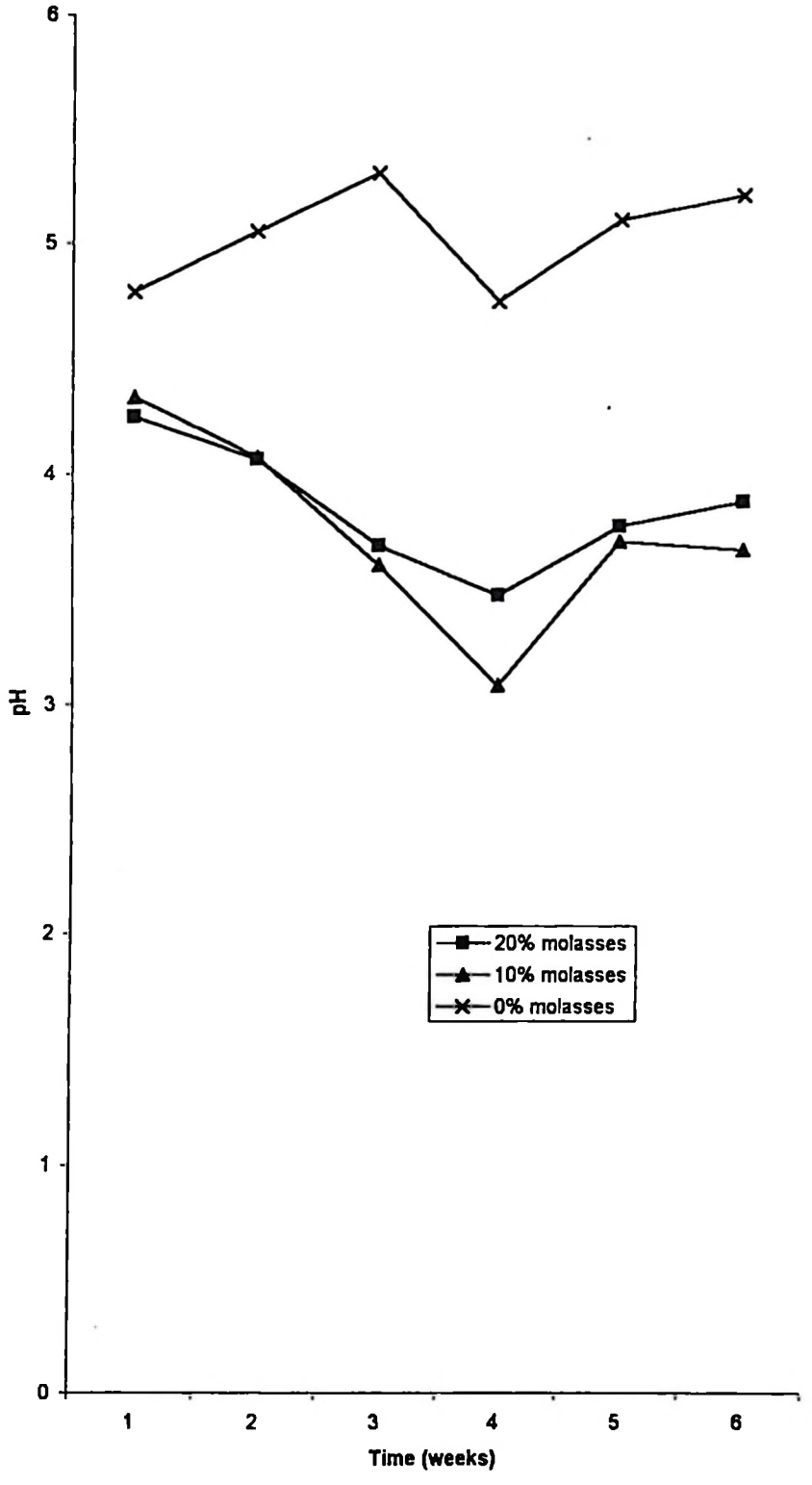

Figure 4: Silage weekly pH changes

4.9.3 Effect of addition of molasses on the fermentation products of water hyacinth silage

Table 4.9 shows the effect of addition of molasses on the quality of fermentation products of water hyacinth silage. Addition of molasses showed significant effects on the quality of fermentation products of water hyacinth silage. Significantly ($p< 0.001$) higher values of lactic and acetic acid were observed for the molasses treated water hyacinth silage compared with untreated. While, 10% molasses treated silage had a significantly ($p<0.001$) higher values of propionic acid, 20% molasses treated silage showed a significantly ($p<0.001$) lower propionic acid values. There was no significant ($p>0.05$) difference in butyric acid between 10% molasses treated silage and untreated while 20% molasses treated silage had a significantly ($p<0.05$) lower butyric acid content. Changing the level of molasses from 10% to 20% significantly ($p<0.05$) lowered the butyric acid content, while propionic acid content was significantly ($p<0.001$) lowered by increasing the level of molasses. The content of acetic acid was significantly ($p<0.001$) increased by increasing the level of molasses while lactic acid content was not significantly affected by changing the level of molasses ($p>0.05$). There was a highly significant ($P<0.001$) difference in NH_3N (%) between untreated and molasses treated silage. Increasing the level of molasses from 10% to 20% did not significantly ($P>0.05$) change the

NH_3N (%). However, 20% molasses treated silage had a slightly lower concentration of NH_3N (%) compared to that of 10 % molasses treated silage

Table 4.9.b: Effects of addition of molasses on the fermentation products of WH silage

Parameter	0% molasses	10% molasses	20% molasses	SEM
pH	5.04^a	3.88^b	3.75^c	0.014
NH_3N (%)	7.23^a	4.11^b	3.31^b	0.477
Lactic acid	0.22^b	26.41^a	25.07^a	1.952
Acetic acid	4.05^c	11.88^b	16.38^a	0.878
Propionic acid	0.31^b	0.55^a	0.04^c	0.044
Butyric acid	0.26^a	0.26^a	0.01^b	0.074

^{a,b,c} within rows means with different superscripts denote statistical significance ($p<0.05$)

CHAPTER FIVE

5.0 DISCUSSION

5.1 Chemical composition of water hyacinth

The chemical composition of water hyacinth parts fall within the ranges reported in the literature. The crude protein content of both the leaves and shoots is consistent with that reported by Nguyen (1996). The CP content of leaves and shoots must be considered as favourable for feeding to ruminants as it is higher than most crop by-products (Shem *et al.* (1993) and comparable to browse plants (Shayo 1992). The DM of water hyacinth was low. This may affect intake negatively but on the other hand it can be advantageous if drinking water is in short supply.

Similar findings have been reported by Reza and Khan, (1981) and El-serafy *et al.*, (1981). Whole plant had the highest content of NDF and ADF followed by shoots, while leaves had the lowest content of NDF and ADF. Ash content of the whole plant was high which is a characteristic of aquatic plants, but that of the leaves and shoots does not differ much from that of most tropical forages. Ether extract values fall also within the ranges reported by Nguyen, (1996) and Göhl, (1981). Table 4.1 indicate that water hyacinth parts differ in nutritive value. In conformity with the classification of crop residues, in crude protein content, according to Schiere and De wit

(1995) the leaves and shoots of water hyacinth contain crude protein in the class of good and the entire plant falls in the medium class. The CP content of both leaves and shoots is equivalent to that of wheat bran. Therefore one can say that leaves and shoots of water hyacinth are superior to many tropical grasses in terms of CP content.

5.2 Biomass yield of water hyacinth

The vegetation cover of water hyacinth obtained in this study of 298.61 kgDM/ha is low when compared to that of other tropical grasses and legumes such as *P purpureum* (130t DM/ha), and *P maximum* (54t DM/ha) Crowder and Ccheda, (1982). However, this is a yield at the sampling time only water hyacinth multiply continously. Under suitable conditions of temperature (between 28-30°c) and pH (4.0-8.0), WH can double its population every seven days to yield 930-2900t DM/ha annually (Lareo and Bressani, 1982). This is a superior yield that can guarantee a year round supply of green fodder if harvesting is not carried out in such a way that no single plant remains in the water to multiply.

Penfound and Earle.(1948) cited by Joyce.(1990), also demonstrated the fast multiplication of water hyacinth to yield large quantities of DM. They found that ten water hyacinth plants can produce over 655,000 plants and cover

0.4 hectare in eight months. This fast multiplication rate also show that the use of this plant is not confined to lakes or big rivers only. A farmer owning a 0.4 hectare of pond water may produce water hyacinth for feeding cattle, and can be assured of five harvests in a year, giving year round supply of green fodder.

McVea (1979) reported that the presence of 5 percent cover by water hyacinth on the water surface of a fish pond did not significantly affect fish production. This show that water hyacinth can be introduced in such places for fodder production provided that the plant is confined to areas intended for its culture to prevent it becoming a pest.

5.3 DM digestibility of water hyacinth and its parts

5.3.1 Two stage *in vitro* method

Table 4.3 shows that whole plant had the lowest digestibility. The differences in DM digestibilities obtained between whole plant and other plant parts may be attributed to the low CP content of whole plant. Both leaves and shoots have almost the same content of CP (18.03% and 18.04%) respectively which is higher and may be the main reason for lack of significant differences in terms of digestibility shown by these parts. The CP content of the entire plant of 8% was half the content in shoots and leaves and is near the minimum required for proper

functioning of rumen microbes. This may be the reason for low digestibilities shown by this part as nitrogen content may have been a limiting factor for rumen microbes in whole plant than in the other parts. The values obtained for leaves and shoots were above 50%. The neutral detergent fibre fraction (NDF) and ADF was also low in leaves and shoots which might be another reason for high digestibility by these parts.

5.3.2 One stage *in vitro* method

DM digestibility of both water hyacinth parts and entire plant increased with time at both incubation periods. This is supported by the linear relationships plant parts have shown over different incubation hours (Appendix 5). The highly significant values of 'b' (Appendix 5) shows that differences existed in the digestibility of water hyacinth parts with time.

Leaves maintained a higher DM digestibility and whole plant the lowest. As a general trend whole plant showed lower digestibilities which further suggests that the lower digestibility of this fraction may be due to limited nitrogen available to the fermenting micro-organisms. The higher fibre content of this fraction may also be another reason for the low DM digestibilities obtained with whole plant. The level of fibre in forages has been reported to have a depressive effect on digestibility and it is

normally given a negative index in feed evaluation (Van Soest, 1982).

The DM digestibility values obtained with whole plant and parts even after 120 hours of incubation are low when compared to digestibilities of other tropical grasses and legumes, such as *Chloris gayana*, *Cenchrus ciliaris*, and *Medicago sativa* which have digestibilities of 70-80% (Reid *et al*,1973). In the case of leaves and shoots the CP content was high enough for nitrogen not to be a limiting factor for the rumen micro organisms. It is therefore obvious that the low DM digestibility values obtained in this study for whole plant and parts is purely a result of the limitation of the *in vitro* method itself as the low digestibility values obtained after six hours suggest that rumen microbes required time to adjust to the conditions in the digestion tubes. The digestibility trend showed that it was fast during the first 48 hours and slowed down after this period. This digestibility trend reflects the nature of substrates where easily digestible components are digested fast, and inaccessible and recalcitrant material such as lignin and crystalline cellulose are digested slowly by rumen microbes. The fact that after 48 hours more than 70% of the material digested after 120 hours was already digested showed that the plant is suitable as a ruminant feed since this is the period that is spent by

feed inside the ruminant's digestive system

5.3.3 In sacco DM degradability of water hyacinth

The whole plant had low degradabilities as compared to the other water hyacinth parts. A similar trend was reported by Kivaisi and Mtilla (1995). Consequently this could be due to the higher NDF content of this part. A tendency of feeds higher in NDF content to resist degradation by rumen micro-organisms has been reported (Smith *et al*, 1972; Ørskov *et al*,1974). Degradation rates of water hyacinth parts was slow as indicated in Figure 3. This may imply increased retention time of the digesta in the rumen, hence decreased feed intake (Ørskov *et al*,1974; Kimambo *et al*,1992; Shem *et al*,1993). Increased retention time is also evident from Figure 3, showing that with increased time the degradability of water hyacinth parts was still increasing though at a decreasing rate. The leaves and shoots of water hyacinth contained low levels of NDF and ADF, and had higher degradabilities. According to Van Soest (1965) the critical level of NDF content, which limit intake is 55% (this was for mid west grasses). Leaves and shoots were above this value by 1% and whole plant by 10%. Ørskov, *et al*. (1989) and Shem, *et al*., (1993) in their study of degradation for prediction of intake and growth rate of cattle found that at 48 hours of incubation the degradability of straw and banana leaf was 32-47%, of

stover and *Chloris gayana* hay 50-54%, and of green *Chloris gayana*, setaria grass, elephant grass and guatemala grass 60%. From the results of this study, one can say that the degradability of WHL and WHS at 48 hours of incubation is better than that of straw and banana leaf, and is similar to that of stover and *Chloris gayana* hay, while, degradability of WHE is equivalent to that of straw and banana leaf.

5.4 Chemical composition, *in vitro* DM and OM digestibility of water hyacinth treatments before ensiling

Lower DM values obtained for unmolassed water hyacinth at the time of ensiling reflects the characteristic of aquatic plants.

Addition of molasses at 10 and 20 percent improved the DM by 6.12 and 9.98 percent respectively. This was expected since molasses itself had a DM content of 714.7 gkg^{-1} (Appendix 2), which mainly comprised of soluble sugars. Low levels of CP obtained for water hyacinth treatments to be ensiled when compared to water hyacinth shoots (Table 4.1) can largely be attributed to field losses occurring during wilting and chopping of water hyacinth. Such losses are reported to account for 10 to 20 percent or more during ensiling of tropical forages (Crowder and Ccheda, 1982). Another reason for the low CP values may be due to proteolysis taking place in the water hyacinth pre-ensiled

treatments. The CP content of molasses added was very low, (3 percent) (Appendix 2) which might have a dilution effect on the CP content of water hyacinth treatments before ensiling thus lowering the CP content.

Lower content of WSC was observed for the unmolassed water hyacinth. Addition of 10 and 20 percent molasses improved the WSC in 10 and 20 percent molassed water hyacinth by 72.26 and 108.15 $gkg^{-1}DM$ respectively above the untreated water hyacinth. This can be explained by the fact that the molasses used had high content of WSC (Appendix 2). The *in vitro* DMDIG and OMDIG values in the pre ensiled water hyacinth was improved by addition of molasses. This is due to the fact that soluble sugars present in molasses are a good source of energy that is a useful substrate for survival and multiplication of rumen cellulolytic microbes responsible for degradation of fibrous forages eaten by ruminants (McDonald *et al.*, 1973). This phenomena was likely to occur in silages treated with molasses.

5.5 Effect of ensiling on chemical composition of water hyacinth

Ensiling showed a significant effect on the chemical composition of water hyacinth. There was a decrease in DM, CP, WSC, and DM digestibility of silages compared to that of the original ensiled material. This decline in the

content of some parameters can be mainly attributed to the proteolytic changes that took place during ensiling process. However, the reasons for high NDF and ADF values in the silages compared to original ensiled material could not be established. The DM loss obtained in this study was 1.36, 0.84 and 1.11 percent for 0, 10 and 20 percent molasses treated silages. This loss is within the acceptable limits of 15 percent accepted as the maximum DM loss for silages (Barnett, 1954). An increase in the fibre fraction (NDF and ADF) of the silages compared to the material ensiled is another evidence of loss of cell contents during ensiling. Losses in DM and nutritive value of silage normally range from 10 to 20 percent and even higher, and that they occur from field spoilage, type of fermentation, seepage or effluent, and spoilage or wastage during storage Crowder and Ccheda (1982). The lower values of CP may also be due to overheating, since silage was transported in train wagons from Mwanza to Morogoro. Sample *et al.*(1966) as cited by Sarwatt *et al* (1989) reported a decrease of 3.9% when Pangola grass was ensiled, and that the decrease of CP was attributed to overheating during the ensiling process.

5.6 Effects of additive molasses on quality of water hyacinth silage

Addition of molasses to water hyacinth at ensiling was

generally noticed to have improved fermentation, hence the quality of water hyacinth silage obtained in this study

5.7 Effects of addition of molasses on chemical composition of water hyacinth silage

In the present study, water hyacinth silage with molasses showed a higher DM content of about 6% and 10% for 10% and 20% molasses treated silages respectively above that found in unmolassed water hyacinth silage. This was possibly contributed by some soluble sugars and trace minerals from the molasses added as molasses was found to contain 322.5, and 86.1 g kg^{-1} DM of WSC and ash respectively (Appendix 2).

However, the values obtained in this study were lower when compared to those obtained by El- Serafy *et al* (1981). They obtained a DM content of 31.72% for sugar cane molasses treated silage. Significantly ($p<0.001$) lower crude protein values observed in the molasses treated silage and untreated water hyacinth silage as compared to that of water hyacinth shoots may largely be attributed to field losses during the ensiling process. McDonald *et al.*(1991) showed that field losses resulting from increased proteolysis in high moisture crops may reduce more than 50% of the total nitrogen present in herbage. Most studies on chemical composition of water hyacinth silage did not take into consideration the protein values between pre-ensiled

water hyacinth and the silage itself.

Apart from losses of nitrogen due to proteolysis, the lower crude protein values observed in the molasses treated silage compared with unmolassed silage might be attributed to some effluent losses occurring during fermentation inside the buckets. Molasses treated silages might have produced more effluent resulting from molasses and water added leading to more nutrient losses . The crude protein values obtained in the present study were lower than those obtained by El-Serafy *et al* (1981) of 13% for water hyacinth silage treated with sugar cane molasses. However, it should be taken into consideration that crude protein values obtained for silage can not give a clear picture of the true protein contents since it is the combination of both protein nitrogen and non protein nitrogen. But, one is tempted to conclude that molasses treated water hyacinth silage has more protein since Van Soest (1982) suggested that chances of recovery of amino acids especially methionine, cystine and tyrosine in silages decline as the pH rise above 4.2. Molassed silages had pH lower than 4.2. However, the reason for significantly ($p<0.001$) lower values of ash contents between molassses treated and untreated water hyacinth silage could not be established. The WSC content of molasses treated water hyacinth silage was significantly ($p<0.05$) higher than that of untreated

silage. This might be due to additional soluble sugars from molasses.

Higher ether extract values obtained on molasses treated compared with untreated water hyacinth silage reflects the higher concentration of total organic acids not recovered by petroleum ether. Molasses treated silage had concentrations of 28 and 28.23 g kg^{-1} DM for 10% and 20% molasses treated silage compared with 18.26 g kg^{-1} DM for untreated silage. This must be expected since excess soluble sugars from molasses might have induced homolactic and heterolactic fermentation ending up in large amounts of lactic and acetic acids in the silage. Slightly higher NDF and ADF in unmolassed water hyacinth silage compared to molasses treated silage was likely a result of seepage losses of the cell contents of forage in untreated silage, leaving behind higher percentage of cell wall contents in the total dry matter. Another reason for this may be due to lower pH exhibited by the molasses treated silage which might have stimulated further hydrolysis of linked sugar molecules in the cell wall, resulting into further breakdown of hemicellulose. McDonald *et al.*(1991) have documented a breakdown of up to 50% of hemicellulose during the silage fermentation process. The values obtained in this study were slightly lower compared to those of El-Serafy *et al.* (1981) they found values of 354.1 and 551.0

g kg^{-1} DM for ADF and NDF respectively for molasses treated water hyacinth silages.

Changing the level of molasses from 10% to 20% did not result in changes in some of the chemical components of the silages except for DM, CP, NDF, and ADF. However the fermentation process was improved by increasing the level of molasses as this was supported by the WSC content that significantly ($p<0.001$) improved with changing molasses levels. The result was improved quality of the fermentation products (pH and volatile fatty acids). Higher DM and OM digestibility values obtained for molasses treated silages compared to untreated silage can be due to the molasses added, since molasses is known to be a good source of energy. This might have supplied the necessary energy required by rumen micro-organisms to digest the water hyacinth silages. Lower fibre fraction, (NDF and ADF) values for molasses treated silages could be another reason for the increased digestibility in molasses treated silages compared to the untreated silage.

5.8 Effect of additive (molasses) on silage intake rate

The DM intake rate was significantly improved by the addition of molasses . Since addition of molasses at the time of ensiling produced a well fermented silage with possibly an acceptable aroma and texture which might have

aroused the appetite of the test animals thus increasing acceptance of the test diets. This was also supported by the fact that some of the fermentation products such as butyric acid which indicate the extent of spoilage of silage by secondary fermentation bacteria were present in negligible quantities in water hyacinth treated silage compared to the untreated silage.

Improved fermentation in molasses treated silages results into high levels of organic acids, (Carpintero *et al*.1969). These acids were also noted to induce negative effects on intake (Rogers *et al*., 1979; Forbes,1986). This is likely where higher levels of organic acids are produced in the silage. However, with this study addition of molasses at the time of ensiling had a greater positive effect on acceptability which masked the negative effect of concentration of organic acids. DMI (g/min and $kgW^{0.75}$) increased ($p<0.01$) with the addition of molasses. since the dry matter content of silages also increased with the addition of molasses it can be speculated that DMI of silage increased with increasing dry matter. DMI as percent of live body weight was also significantly increased with the addition of molasses. Comparable DMI (per unit metabolic body weight and per cent body weight) was reported by El-Serafy *et al*. (1979) for water hyacinth silage fed to sheep and Hentges *et al*. (1972) for water hyacinth silage fed to cattle. Changing the level of

molasses from 10% to 20% did not result in a change in DMI. This showed that there was no difference between changing the molasses level from 10% to 20% and that at least 10% level of molasses could produce silage with good qualities.

Degradability of molasses treated water hyacinth silages was higher than that of untreated silage. 10% and 20% molasses treated silages had low NDF and ADF, and had higher degradabilities. Van Soest (1965) found that the critical level of NDF which limits intake is 55% (for mid west grasses). All molasses treated water hyacinth silages had NDF content below this value. The degradability of molasses treated water hyacinth silages at 48 hours was better than that of straw and banana leaf, and similar to that of stover and *Chloris gayana* hay (Ørskov *et al.* 1989). Molasses being a good source of energy might also have supplied the necessary energy required by rumen micro organisms finally resulting into high degradability values.

5.9 Effects of addition of molasses on fermentation quality of water hyacinth silage

Quality of fermentation products of water hyacinth silage obtained in the present study was also improved by the addition of molasses at the time of ensiling. Molasses supplied WSC, without which the high moisture content of

water hyacinth would counteract the preservative action of the primary fermentation acids and allow extensive microbial degradation of proteins to yield large quantities of ammonia. This in turn allows secondary fermentation of lactic acid to butyric acid which in turn reduce the lactic and acetic acid concentration in the resulting silage as observed in untreated water hyacinth silage. The extent of spoilage of silages by secondary fermentation bacteria is denoted by the butyric acid concentration. The maximum level for most well preserved tropical silages is 0.3% DM of the silage DM. The levels obtained in this study however, were below this value. This possibly was caused by additional WSC content in the herbage from the molasses added, which in turn was fermented by the lactic acid bacteria ending up with large quantities of lactic and acetic acid in the total acidity. This acidity stabilized the silage at lower pH values thereby inhibiting the wasteful activities of clostridial bacteria which was indicated by lower level of ammonia-N and butyric acid (4.1, 3.3 and 0.26, 0.01) for 10 and 20% molasses treated silages and higher concentration of lactic and acetic acids (26.41, 25.07 and 11.88, 16.38) for 10 and 20% molasses respectively, the fermentation qualities which were contrary from those observed for untreated water hyacinth silage. The pH and lactate values of the silage indicated clearly that addition of molasses was beneficial in

preservation of water hyacinth silage. However, pH values obtained in this experiment of 3.48 and 3.08 for 20% and 10% molasses level after four weeks were low for wilted silages expected to have a pH of about 4.4 (McDonald *et al*, 1995).

Whittenbury *et al*. (1967) stated that in silos with a high moisture content, the pH level should be lower than usual, and this may be the reason for low pH values since the plastic buckets used for ensiling had no outlet to allow effluent seepage. Both 20 and 10% molasses treated silages had a pH of 3.48, 3.78 and 3.08, 3.71 in the fourth and fifth weeks indicating that they preserved well.

The higher pH values of 5.31, 4.75, and 5.22 maintained by untreated silage in the third, fourth, and fifth weeks are indicators of poor preservation, since these values fall in the ranges of pH for badly preserved silage for the forages (McDonald *et al*, 1995). The evidence of poor preservation was also observed when opening the buckets containing untreated silage, as there was a mouldy growth on the surface that was not observed in the 20% and 10% molasses treated silages. Statistical analysis (Appendix 3) show that level of molasses significantly ($P<0.001$) affected the pH of the silage. Comparison of means (Table 4.9) show that there was a significant ($P<0.001$) difference in pH between 20%, 10%, and 0% molasses treated silages.

CHAPTER SIX

6.0 CONCLUSIONS AND RECOMMENDATIONS

6.1 Conclusion

It is evident that, the shoots and leaves of WH were high in N content and can match the ruminant animals requirements (i.e. the rumen micro-organisms require about 7% CP for their normal physiological functioning). Under practical conditions, the shoot is normally fed to livestock and the animal may get about 15% CP in the diet which will probably be more than adequate in relation to intake.

The entire plant had low CP content which was close to the minimum 7% CP required for the proper functioning of rumen micro-organisms. However under practical conditions farmers do not feed the entire plant since roots are normally heavily contaminated with mud and debris.

The silage especially molasses treated silages had low CP content, but were still above the minimum required for the proper functioning of rumen micro-organisms. This

indicates that feeding of water hyacinth silage to ruminants may not require supplementation with N source in order to satisfy their requirements and assure a high intake.

Acceptability study indicated that ruminants can readily consume the silages made from water hyacinth. This fact was demonstrated by the amount of molasses treated silage consumed when offered to heifers. However, it should be noted that the present study could not present the nutritive value of water hyacinth in the broad sense, because of the parameters this study was limited to.

6.2 Recommendations

1. There is a need to conduct more, comparative studies to assess the nutritional adequacy of various forms in which water hyacinth can be offered to ruminants.

2. Research is required to investigate on an appropriate type of supplement and an optimum level of supplementation to match livestock requirements when fed water hyacinth.

REFERENCES

AOAC,1990. Official methods of Analysis 12th edition. Association of Analytical Chemists,Arlington,VA, USA. pp 957.

Bagnal, L.O, Baldwin, J.A, and Hentges, J.F., 1974. Processing and storage of water hyacinth silage. *Hyacinth Control Journal* 12: 73-78.

Bagnal, L.C, Hentges, J.F, and Baldwin, J.A., 1977. Hay and silage from water hyacinth. Hyacinth Control Journal 37: 126-129

Baldwin, J.A., Hentges, J.F., Bagnall,L.C., and Shirley, R.L. 1975. Comparison of Pangola grass and water hyacinth silages as diets for sheep. *Journal of Animal Science*. 40: 968-71

Barnerjee, G.C., 1970. A textbook of animal husbandry. 3rd edition: pp 231. Oxford and IBH publishing company., New Delhi, Bombay, Calcutta.

Barnett, A.J.G., 1954. *Silage fermentation*. Academic Press, New York: pp 4-77.

Blakeney, E.W, Rusoff,L.L, and Culley, D.D., 1994. Duckweeds: A potential source of protein and amino acids. *Journal of Agricultural and Chemistry* **28**: 848-850.

Boyd, C.E.,1978. *Chemical composition of wetland plants.* In *fresh water wetlands.* **22**: Academic press, New York. pp 395-468.

Carpintero, M.C., Holding, A.J., and McDonald, P., 1969. Fermentation studies on lucerne. *Journal of the Science of Food and Agriculture.* **20**: 677-681

Crowder, L.V and Chheda,H.R.(1982). *Tropical grassland husbandry.* London. UK. Longman Group Limited. pp 316-325.

Easley, J.F. and Shirley, R.L.,1974. Nutrient elements for livestock in aquatic plants. *Hyacinth Control Journal* **12**: 82-85.

El-Serafy, A.M, Allam S.M, El-Ashry M.A, Khattab H.M, Soliman H.S, and Dinius D.A., 1979. The nutritive value of water hyacinth hay as roughage for sheep. *Journal of Animal Science* **49**: 263.

El-Serafy, A.M., Soliman, H.S.H., Khattab, H.M., El-Ashry, M.A., and Swidan, F.Z., 1981. Dry matter intake and nutrients digestibility of water hyacinth hay, haylage and silage by buffalo steers. *Indian Journal of Animal Science*. 57 : 698-701.

Forbes, J.M. 1986. *The voluntary feed intake of farm animals*. Butterworths and Co. Ltd. London. pp 129-142.

Goering, H.K. and Van Soest P.J.,1970. *Forage fibre analysis*. Agriculture Handbook NO 379. Agriculture research services, US Department of Agriculture, Washington, D.C. pp 1-20.

Gohl, B.,1984. *Tropical feeds*. FAO animal production and health series. pp 249.

Göhl, B., 1981. *Tropical feeds*. FAO publication. Rome, Italy. pp 95-96.

Gonsalves, J.F.,1995. Resource protective agriculture for food and nutrition security. San News. SIBAT. 1-11.

Gopal,B.,1990. Aquatic weeds. *The ecology and management of nuisance aquatic vegetation*. Oxford University press. pp 22-27.

Handy, S. Khalifan M.M, Khalil A.Z, and Kosba M.A., 1978. Effect of corn and bean replacement by dried water hyacinth on the performance of laying hens. *Alexandria Journal of Agricultural Research* 26: 515.

Hentges, J.F., Salveson, R.E., Shirley, R.L., and Moore, J.E., 1972. Processed aquatic plants in cattle diets. *Journal of Animal Science*. 34:360.

Joyce, J.C., 1990. *Aquatic weeds*. The ecology and management of nuisance aquatic vegetation. Oxford University press. pp 11.

Juul-Nielsen, J. Thomsen L. and Vibe E., 1982. Evaluation of nutritional potential of fibrous residues in Bangladesh. Maximum energy value of cattle fed rations with different amounts of rice straw and water hyacinth. Paper presented at the Third Annual Meeting on "Maximum Livestock Production on Minimum Land". Joydepus Bangladesh Feb 15-18.

Kimambo, A.E., Mkiwa, A.M., Shem, M.N. 1992. The use of *Leucaena leucocephala* supplementation to improve the utilisation of maize stover by sheep. Joint Feed Resources Network workshop on the Complimentary of Feed Resources for Animal Production in Africa, Gaborone Botswana. 4-8 March

Kivaisi. A.K and Mtila.M., 1995. Chemical composition and *in vitro* degradability of whole plants and shoots of the water hyacinth (*E.crassipes*) by rumen micro-organisms. *Tanzania Veterinary Journal*. **15**: 121-129.

Lareo, L. and Bressani R., 1982. Possible utilisation of the water hyacinth in nutrition and industry. *Food and Nutrition Bulletin.*, **40**: 60.

Laswai, G.H., Mutayoba, S.K., Maeda-Machangu, A.D., Kurwijila, R.V. and Kimambo, E.S., 1995. Local knowledge and gender roles in animal husbandry in different livestock production systems.In: *Proceedings of The Tanzania Society of Animal Production.*, **22**: 249-259.

Majid, F.Z., and Akhter, N., 1979. Use of aquatic algae and aquatic weeds as livestock feed. A paper presented at

the seminar "Maximum livestock production on minimum land" held at Bangladesh Agriculture University, Mymensingh 16th-17th January, 1980

Mbwile, R.P and Madata, G.S., 1984. Research on dry season feeds at Uyole Agriculture centre. In: *Proceedings of a seminar held at LPRI*. 20-22 september 1994, Mpwapwa, Tanzania.

MCDonald, P., Henderson, A.R and Heron, S.J.E., 1991. *The biochemistry of silage*. London, UK. Chalcombe publications. pp 340.

McDonald, P., Henderson, A.R. and Ralton, I., 1973. Energy changes during ensilage. *Journal of the Science of Food and Agriculture* 24: 827-834.

Mc Vea, 1979. Effect of water hyacinth cover on water chemistry, phytoplankton and fish in ponds. ADAB News., 6: 12.

Nguyen, N.X.D., Le, N.M., 1993. Nutrient composition of some feedstuffs in the Mekong delta. Cantho University, Mimeograph report. pp 34-42.

Nguyen, N.X.D., 1996. Identification and evaluation of non cultivated plants used for livestock feed in the Mekong delta of Vietnam. M.Sc. Thesis. Paper 1 and 2 pp 2-11 & pp 2-8

Ogle, R.B, Bui X. M, Preston, T.R.,1995. Use of duckweed (*Lemna* spp) as a replacement for soya bean meal in broken rice based diets for fattening ducks in the Mekong delta of Vietnam. National Seminar Workshop on sustainable livestock production on Local Feed Resources. pp 11-13.

Ørskov, E.R., Kay, M. and Reid, G.W., 1989. Prediction of intake of straw and performance by cattle from chemical analysis, biological measurements and degradation characteristics. In: *M. Chenost and P. Reiniger (eds)*. Evaluation of straw in ruminant feeding. Elsevier Science Publishing Co., Inc. pp 155-162.

Ørskov, E.R., Fraser, C. and Gordon, J.G., 1974. Effect of processing of cereals on rumen fermentation, digestibility, rumination time and firmness of subcutaneous fat in lambs. *British Journal of Nutrition* 2: 59-69.

Pathak, N.N, Srivastrava S.K, and Ranjhan S.K., 1979. Note on growth response and feed conversion efficiency of weaned Landrace pigs fed ad lib water hyacinth and limited conventional feeds during growing-finishing periods. *Indian Journal of Animal Science* **49**: 1108.

Pieterse, A.H.,1990. *Aquatic weeds the ecology and management of nuisance aquatic vegetation*. Oxford University press. pp 21-25.

Ravindran, V. and Blair., 1992. Feed resources for poultry production in Asia and the Pacific region. Plant protein source. *Worlds Poultry Science Journal*, **48**. 207-234.

Reddy, P.V.S, and Reddy M.R., 1979. Utilisation of water hyacinth in the concentrate feeds of cross-bred calves. *Indian Journal of Dairy science* **44**: 174.

Reddy, M.R, and Mohan,R.A.V., 1979. Studies on supplementation of water hyacinth hay to paddy straw for improved utilisation by growing cross-bred calves. *Indian Journal of Animal Science* **49**: 618.

Reid, R.L., Post, A.J., Olsen, F.J. and Mugerwa, J.S., 1973. Studies on the nutritional quality of grasses and legumes in Uganda. Application of *in vitro* digestibility techniques to species and stage of growth effects. *Tropical Agriculture* 50: 1-15.

Reza, A. and Khan,J., 1981. Water hyacinth as cattle feed. *Indian Journal of Animal Science* 51: 702.

Rogers, G.L., Bryant, A.M., Jury, K.E. and Hutton, J.B. 1979. *New Zealand Journal of Agriculture Research*. 22: 511-522.

Saha, R.C., Singh, R.B, Banerjee, G.C., 1995. Water hyacinth. In handbook for straw feeding systems. Principles and applications with emphasis on Indian livestock production. Indo-Dutch project on Bioconversion of crop residue. pp 407-420.

Sarwatt, S.V., Mussa, M.A. and Kategile, J.A., 1989. Nutritive value of ensiled forages cut at three stages of growth. *Journal of Animal Feed Science and Technology* 22: 237-245.

Schiere, J.B. and DeWit, J., 1995. Livestock and farming systems research. III: Different ways of feeding crop

residues. In: *J.B. Schiere (eds). cattle, Straw and System control*. A study of straw feeding systems. pp 63-75.

Sculthorpe, C.D., 1967. The biology of aquatic vascular plants, cited by Joyce, 1990.In: *Aquatic weeds. The ecology and management of nuisance aquatic vegetation*. Oxford University. 11.

Shayo, C.M., 1992. Evaluation of water melons as a source of water, and water melon seeds and acacia pods as a protein supplement for dairy cows in central Tanzania. MSc dissertation. Swedish University of Agricultural Sciences, Uppsala, Sweden. pp. 56-89.

Shem, M.N., Ørskov, E.R., and Kimambo, A.E., 1993. Prediction of voluntary intake feed intake and growth rate of cattle fed on crop residues and forages on smallholder farms using the nylon bag technique. In: *Proceedings of the IFS scientific workshop for East African Grantees (Animal production)*.pp 21-37.

Shiralipour, A. and Smith, P.H., 1984. Conversion of biomass to methane gas. *Biomass* **6**: 85-94.

Smith, L.W., Goering, H.K. and Gordon, C.H., 1972. Relationships of forage composition with rate of cell wall digestion and indigestibility of cell walls. *Journal of Dairy Science* **55**: 1140-1147.

Snedecor, G.W, and Cochran, W.G., 1989. *Statistical Methods*. 8th Edition, Iowa university Press, U.S.A.

Statistical Analysis System. 1988. SAS Institute Inc. *SAS/STAT™ Users Guide, Release 6.03 Edition*. Cary, NC, SAS Institute Inc.

Surat R, and Singh G.S., 1980. Chemical composition and nutritive value of water hyacinth. *Indian Journal of Dairy Science* **34**: 282.

Tilley, J.M.A and Terry, R.A.1963. A two stage technique for the in vitro digestion of forage crops. *Journal of The British Grassland Society* **18**: 104-111.

Van Soest, P.J., 1981. *Nutritional ecology of the ruminant. Ruminant metabolism nutritional strategies, the cellulolytic fermentation and the chemistry of forages and plant fibres*. COMSTOCK publishers. pp 141-151.

Van Soest, P.J., 1965. Symposium of factors influencing the voluntary intake in relation to chemical composition and digestibility. *Journal of Animal Science*. **24**: 834.

Wanapat, M. Sriwattanasombat S. and Chantai S., 1985. The utilisation of diets containing untreated rice straw, urea-ammonia treated rice straw and water hyacinth. *Tropical Animal Production* **10**: 50-57.

Whittenbury, R., McDonald, P. and Bryan-Jones, D.G., 1967. A short review of some biochemical and microbiological aspects of ensilage. *Journal of Science of Food and Agriculture.*, **18**: 441-444.

APPENDICES

Appendix 1. Silage intake in grams of fresh silage

TREATMENT	Animal 1 wt 193 kg	Animal 2 wt 227 kg	Animal 3 wt 163 kg	Animal 4 wt 192 kg
20%molasses	384.8	1316	1093.30	358.6
	1437.4	1650.6	1830.8	1279
	1334.5	1558.9	1818.5	657.7
	1735	1869.5	1697	1338.4
	1677	1905.3	555	973
	1524.2	1779.1	1625.2	582.6
10%molasses	1913.5	1684.8	1855.2	922
	1604	1684.8	1618.1	1260.1
	1321.6	967.3	1722.5	862.3
	1561.9	1534.2	1831.7	634.7
	1342.1	1664.3	1442.6	1020.2
	1766.8	1728.6	1644.7	496.1
0%molasses	265.8	168.8	702.8	202.1
	146.3	216.6	189.3	112.5
	138.7	322.6	406	104.5
	206.3	446.3	218.1	96.3
	103.7	236.1	229.7	220.8
	347.1	413.5	304.6	213.1

Appendix 1 continues.....
Silage refusal in grams

Treatment	Animal 1 wt 193kg	Animal 2 wt 227kg	Animal 3 wt 163 kg	Animal 4 wt 192 kg
20% molasses	1615.2	684	906.7	1641.4
	562.6	349.4	169.2	721
	665.5	441.1	181.5	1344.3
	265	130.5	303	661.6
	323	94.7	1445	1027
	475.8	220.9	374.8	1417.4
10% molasses	86.5	315.2	144.8	1078
	396	315.2	381.9	739.9
	678.4	1032.7	277.5	1137.7
	438.1	465.8	168.3	1365.3
	657.9	335.7	557.4	979.8
	233.2	271.4	355.3	1503.9
0% molasses	1734.2	1831.2	1297.2	1797.9
	1853.7	1783.4	1810.7	1887.5
	1861.3	1677.4	1594	1895.5
	1793.7	1553.7	1781.9	1903.7
	1896.3	1763.9	1770.3	1779.2
	1652.9	1586.5	1695.4	1786.9

Appendix 2 (a) DM digestibility of water hyacinth parts by one stage *in vitro* method

			Incubation time (h)						
Part	Animal	Rep	6	12	24	48	72	96	120
WHL	1	1	13.99	19.96	25.10	37.91	39.06	43.39	45.26
		2	14.93	19.9	26.88	36.45	38.71	44.32	46.32
	2	1	15.92	20.89	27.97	39.78	38.98	45.74	47.82
		2	14.7	18.36	27.77	37.17	38.12	44.13	45.22
	3	1	13.86	19.45	26.51	39.10	41.23	43.63	45.01
		2	12.76	19.23	27.10	39.16	40	42.16	44.91
WHS	1	1	12.92	18.71	25.81	36.67	39.71	43.76	45.9
		2	13.11	17.22	25.10	35.21	39.92	41.39	44.7
	2	1	13.23	19.82	26.17	37.13	39.33	41.22	43.41
		2	14.02	18.3	25.8	37.7	40.9	42.67	43.1
	3	1	15.72	18.41	27.15	39.01	40.01	40.7	43.16
		2	14.8	18.34	25.6	38.33	39.91	39.62	44.7
WHE	1	1	10.72	15.12	22.99	31.07	34.71	37.06	39.26
		2	9.63	15.62	21.33	31.33	33.39	37.32	39.32
	2	1	11.03	16.82	20.72	29.23	33.32	36.9	39.96
		2	11.2	15.11	23.3	27.28	32.2	36.88	38.13
	3	1	9.01	15.13	21.66	27.12	31.7	35.33	37.01
		2	9.93	14.22	20.02	27.99	32.36	35.72	36.13

Appendix 2b DM digestibility of WH parts by two stage *in vitro* method

Animal	Rep	WHL	WHS	WHE
1	1	56.11	60.44	43.21
	2	57.26	58.06	44.9
2	1	55.8	57.11	40.43
	2	56.12	56.14	41.2
3	1	59.21	59.17	43.17
	2	57.73	58.01	41.01

Appendix 2c: DM degradability of WH parts at different hours of incubation

		Incubation time (h)							
Sample	Animal no	0	6	12	24	48	72	96	120
WHL	1	10.41	17.9	31.76	45.81	54.36	57.29	61.27	73.81
		9.18	14.74	33.17	47.6	58.29	56.31	62.7	69.76
	2	11.08	15.14	33.68	36.27	51.72	64.87	73.16	72.24
		9.79	18.11	33.11	38.06	53.14	66.65	68.51	71.18
	3	10.26	12.08	29.34	37.12	45.07	51.75	60.47	61.08
		9.54	10.82	26.41	37.52	47.91	55.41	58.73	60.38
		10.04	14.79	31.24	40.39	51.74	58.71	64.14	68.07
WHS	1	9.89	18.06	33.72	38.79	38.98	60.72	60.29	62
		9.76	16.78	33.74	40.18	49.62	60.49	61.31	60.31
	2	7.66	12.93	31.21	41.14	49.7	59.94	60.72	61.2
		8.12	11.9	35.04	36.57	47.65	56.72	60.13	59.7
	3	8.83	10.28	22.13	36.40	41.57	49.09	53.62	59.12
		7.72	9.87	27.86	33.49	43.55	51.73	57.7	57.93
		8.66	13.3	30.61	37.76	45.17	56.44	58.96	60.04
WHE	1	7.92	13.9	27.99	35.44	46.11	49.38	53.67	59.22
		8.31	14.09	24.87	37.52	46.85	46.26	51.52	57.86
	2	8.46	13.64	29.71	39.3	40.98	46.11	49.3	55.4
		9.63	11.72	30.76	33.86	43.34	45.14	51.23	54.37
	3	9.92	12.54	25.18	31.12	39.84	43.96	48.52	50.38
		8.67	9.67	22.52	29.43	41.85	45.14	51.66	51.55
		8.81	12.59	26.83	34.44	43.16	45.99	50.98	54.79

Appendix 2d: DM degradability of water hyacinth silages

		Incubation time (h)						
Treatment	Animal no	0	12	24	48	72	96	120
20% molasses	1	19.29	36.58	46.35	55.18	61.18	63.48	65.12
		19.04	35.64	45.28	53.71	59.2	61.38	63.28
	2	17.81	30.72	40.16	51.5	57.04	61.1	63.5
		16.59	31.60	39.99	52.58	57.3	59.79	62.17
	3	19.32	34.24	45.30	56.6	60.8	62	63.61
		18.14	35.66	44.66	54.05	57.17	61.7	65.1
		18.36	34.07	43.62	53.93	58.78	61.57	63.79
10% molasses	1	17.3	31.2	43.12	54.4	60.33	61.6	64.58
		15.69	32.63	42.55	53.12	61.71	62.17	65.01
	2	15.58	30.30	41.37	50.3	56.72	61.8	62.06
		14.13	31.83	38.6	53.92	58.2	59.17	62.12
	3	17.27	33.17	53.92	55.24	63.8	61.78	63.24
		18.33	36.18	46.49	55.73	54.18	62.58	64.11
		16.38	32.55	42.67	53.78	59.15	61.68	63.52
0% molasses	1	13.5	23.34	41.71	42.92	57.72	59	60.51
		14.3	30.06	38.8	51.12	50.1	60.7	61.4
	2	11.26	21.65	39.8	43.01	53.06	57.72	59.3
		12.92	21.77	37.29	41.38	54.12	59.26	60.66
	3	14.58	27.41	35.37	49.33	53.9	54.05	57.2
		14.05	29.58	41.29	51.29	60.73	54.31	55.12
		13.43	25.63	39.04	46.30	54.93	57.5	59.03

Appendix 2e:Chemical composition of molasses used in the study

DM	gkg^{-1} DM		
(%)	CP	Ash	WSC
71.47	34.8	120.51	451.25

Appendix 3a:Class level information on Silage DMI in g/min, % body weight and g/min/$W^{0.75}$

General Linear Models Procedure
Class Level Information

Class	Levels	Values
LEVEL	3	0 10 20

Number of observations in data set = 72

Dependent Variable: DMIGM

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	2	11125.31034	5562.65517	85.65	0.0001
Error	69	4481.32009	64.94667		
Corrected Total	71	15606.63043			

R-Square	C.V.	Root MSE	DMIGM Mean
0.712858	39.00095	8.058950	20.6634722

Dependent Variable: DMIGM

Source	DF	Type III SS	Mean Square	F Value	Pr > F
LEVEL	2	11125.31034	5562.65517	85.65	0.0001

Dependent Variable: DMIPBW

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	2	30.27775833	15.13887917	71.58	0.0001
Error	69	14.59292917	0.21149173		
Corrected Total	71	44.87068750			

R-Square	C.V.	Root MSE	DMIPBW Mean
0.674778	42.73006	0.459882	1.07625000

Dependent Variable: DMIPBW

Source	DF	Type III SS	Mean Square	F Value	Pr > F
LEVEL	2	30.27775833	15.13887917	71.58	0.0001

Dependent Variable: DMIMBW

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	2	420.3508861	210.1754431	79.60	0.0001
Error	69	182.1967792	2.6405330		
Corrected Total	71	602.5476653			

R-Square	C.V.	Root MSE	DMIMBW Mean
0.697623	40.42917	1.624972	4.01930556

Dependent Variable: DMIMBW

Source	DF	Type III SS	Mean Square	F Value	Pr > F
LEVEL	2	420.3508861	210.1754431	79.60	0.0001

Appendix 3b: Class level information for two stage *in vitro* method

General Linear Models Procedure
Class Level Information

Class	Levels	Values
PART	3	WHE WHL WHS

Number of observations in data set = 18

Dependent Variable: DMDIG

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	2	937.2470111	468.6235056	202.99	0.0001
Error	15	34.6296333	2.3086422		
Corrected Total	17	971.8766444			

R-Square	C.V.	Root MSE	DMDIG Mean
0.964368	2.893892	1.519422	52.5044444

Dependent Variable: DMDIG

Source	DF	Type I SS	Mean Square	F Value	Pr > F
PART	2	937.2470111	468.6235056	202.99	0.0001

Source	DF	Type III SS	Mean Square	F Value	Pr > F
PART	2	937.2470111	468.6235056	202.99	0.0001

Least Squares Means

PART	DMDIG LSMEAN	Std Err LSMEAN	Pr > |T| H0:LSMEAN=0	LSMEAN Number
WHE	42.3200000	0.6203013	0.0001	1
WHL	57.0383333	0.6203013	0.0001	2
WHS	58.1550000	0.6203013	0.0001	3

Pr > |T| H0: LSMEAN(i)=LSMEAN(j)

i/j	1	2	3
1	.	0.0001	0.0001
2	0.0001	.	0.2224
3	0.0001	0.2224	.

Appendix 3c: Class level information for one stage *in vitro* method

General Linear Models Procedure
Class Level Information

Class	Levels	Values
PART	3	WHE WHL WHS

Number of observations in data set = 18

Dependent Variable: DMD at 6 hours

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	2	61.61653333	30.80826667	29.40	0.0001
Error	15	15.72066667	1.04804444		
Corrected Total	17	77.33720000			

R-Square	C.V.	Root MSE	DMDIG6 Mean
0.796726	7.960656	1.023740	12.8600000

Dependent Variable: DMD at 6 hours

Source	DF	Type I SS	Mean Square	F Value	Pr > F
PART	2	61.61653333	30.80826667	29.40	0.0001

Dependent Variable: DMD at 12 hours

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	2	59.20230000	29.60115000	41.36	0.0001
Error	15	10.73515000	0.71567667		
Corrected Total	17	69.93745000			

R-Square	C.V.	Root MSE	DMDIG12 Mean
0.846504	4.749565	0.845977	17.8116667

Dependent Variable: DMD at 12 hours

Source	DF	Type I SS	Mean Square	F Value	Pr > F
PART	2	59.20230000	29.60115000	41.36	0.0001

Dependent Variable: DMD at 24 hours

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	2	92.70434444	46.35217222	43.87	0.0001
Error	15	15.84816667	1.05654444		
Corrected Total	17	108.55251111			

R-Square	C.V.	Root MSE	DMDIG24 Mean
0.854005	4.139313	1.027883	24.8322222

Dependent Variable: DMD at 24 hours

Source	DF	Type I SS	Mean Square	F Value	Pr > F
PART	2	92.70434444	46.35217222	43.87	0.0001

Dependent Variable: DMD at 48 hours

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	2	312.1818778	156.0909389	67.63	0.0001
Error	15	34.6207000	2.3080467		

Corrected Total	17	346.8025778			
	R-Square	C.V.	Root MSE		DMDIG48 Mean
	0.900172	4.356966	1.519226		34.8688889

Dependent Variable: DMD at 48 hours

Source	DF	Type I SS	Mean Square	F Value	Pr > F
PART	2	312.1818778	156.0909389	67.63	0.0001

Dependent Variable: DMD at 72 hours

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	2	181.2249333	90.6124667	101.80	0.0001
Error	15	13.3510667	0.8900711		
Corrected Total	17	194.5760000			
	R-Square	C.V.	Root MSE		DMDIG72 Mean
	0.931384	2.521207	0.943436		37.4200000

Dependent Variable: DMD at 72 hours

Source	DF	Type I SS	Mean Square	F Value	Pr > F
PART	2	181.2249333	90.6124667	101.80	0.0001

Dependent Variable: DMD at 96 hours

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	2	169.7449000	84.8724500	60.75	0.0001
Error	15	20.9555000	1.3970333		
Corrected Total	17	190.7004000			
	R-Square	C.V.	Root MSE		DMDIG96 Mean
	0.890113	2.906701	1.181962		40.6633333

Dependent Variable: DMD at 96 hours

Source	DF	Type I SS	Mean Square	F Value	Pr > F
PART	2	169.7449000	84.8724500	60.75	0.0001

Dependent Variable: DMD at 120 hours

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	2	184.9213000	92.4606500	58.27	0.0001
Error	15	23.8001000	1.5866733		
Corrected Total	17	208.7214000			
	R-Square	C.V.	Root MSE		DMDIG120 Mean
	0.885972	2.947198	1.259632		42.7400000

Dependent Variable: DMD at 120 hours

Source	DF	Type I SS	Mean Square	F Value	Pr > F
PART	2	184.9213000	92.4606500	58.27	0.0001

Appendix 4a: Degradability characteristics of water hyacinth parts

WHL ANIMAL1

A=	8.71	B=	57.16	C=	.0390	RSD=	4.82	
Times		0.	6.	12.	24.	48.	72.	96.	120.
Measurements		9.79	16.32	32.46	46.70	56.35	56.80	61.98	71.78
Fitted values		8.71	20.63	30.06	43.43	57.07	62.42	64.52	65.34
K		.01	.02	.03	.04	.05	.06		
A+BC/(C+K)		54.2	46.5	41.0	36.9	33.7	31.2		
K		.07	.08	.09	.10	.11	.12		
A+BC/(C+K)		29.2	27.4	26.0	24.7	23.7	22.7		

WHL ANIMAL2

A=	11.06	B=	65.60	C=	.0232	RSD=	3.61	
Times		0.	6.	12.	24.	48.	72.	96.	120.
Measurements		10.43	16.62	33.39	37.16	52.43	65.76	70.83	71.71
Fitted values		11.06	19.59	27.00	39.07	55.11	64.31	69.58	72.60
K		.01	.02	.03	.04	.05	.06		
A+BC/(C+K)		56.9	46.3	39.7	35.1	31.9	29.4		
K		.07	.08	.09	.10	.11	.12		
A+BC/(C+K)		27.4	25.8	24.5	23.4	22.5	21.7		

WHL ANIMAL3

A=	8.39	B=	53.37	C=	.0291	RSD=	3.45	
Times		0.	6.	12.	24.	48.	72.	96.	120.
Measurements		9.90	11.45	27.87	37.32	46.49	53.58	59.60	60.73
Fitted values		8.39	16.93	24.11	35.19	48.53	55.17	58.48	60.13
K		.01	.02	.03	.04	.05	.06		
A+BC/(C+K)		48.1	40.0	34.7	30.9	28.0	25.8		
K		.07	.08	.09	.10	.11	.12		
A+BC/(C+K)		24.0	22.6	21.4	20.4	19.5	18.8		

WHS ANIMAL1

A=	11.05	B=	51.25	C=	.0323	RSD=	4.69	
Times		0.	6.	12.	24.	48.	72.	96.	120.
Measurements		9.82	17.42	33.73	39.48	44.30	60.60	60.80	61.15
Fitted values		11.05	20.08	27.52	38.70	51.43	57.29	59.99	61.24
K		.01	.02	.03	.04	.05	.06		
A+BC/(C+K)		50.2	42.7	37.6	33.9	31.2	29.0		
K		.07	.08	.09	.10	.11	.12		
A+BC/(C+K)		27.2	25.8	24.6	23.6	22.7	21.9		

WHS ANIMAL2

A=	7.01	B=	53.95	C=	.0377	RSD=	4.17	

Times 0. 6. 12. 24. 48. 72. 96. 120.

Measurements 7.89 12.41 33.12 38.85 48.67 58.33 60.42 60.45

Fitted values 7.01 17.93 26.64 39.13 52.13 57.39 59.52 60.38

K .01 .02 .03 .04 .05 .06

A+BC/(C+K) 49.7 42.3 37.1 33.2 30.2 27.8

K .07 .08 .09 .10 .11 .12

A+BC/(C+K) 25.9 24.3 22.9 21.8 20.8 19.9

WHS ANIMAL3

A= 7.17 B= 52.04 C= .0272 RSD= 3.32

Times 0. 6. 12. 24. 48. 72. 96. 120.

Measurements 8.27 10.07 24.99 34.94 42.56 50.41 55.66 58.52

Fitted values 7.17 14.99 21.64 32.09 45.08 51.85 55.38 57.21

K .01 .02 .03 .04 .05 .06

A+BC/(C+K) 45.2 37.1 31.9 28.2 25.5 23.4

K .07 .08 .09 .10 .11 .12

A+BC/(C+K) 21.7 20.4 19.2 18.3 17.5 16.8

WHE ANIMAL1

A= 7.72 B= 47.77 C= .0351 RSD= 3.04

Times 0. 6. 12. 24. 48. 72. 96. 120.

Measurements 8.11 13.99 26.43 36.48 46.48 47.82 52.59 58.54

Fitted values 7.72 16.78 24.13 34.90 46.62 51.67 53.84 54.78

K .01 .02 .03 .04 .05 .06

A+BC/(C+K) 44.9 38.1 33.5 30.0 27.4 25.3

K .07 .08 .09 .10 .11 .12

A+BC/(C+K) 23.7 22.3 21.1 20.1 19.3 18.5

WHE ANIMAL2

A= 8.43 B= 42.86 C= .0404 RSD= 4.27

Times 0. 6. 12. 24. 48. 72. 96. 120.

Measurements 9.04 12.68 30.23 36.58 42.16 45.62 50.26 54.88

Fitted values 8.43 17.65 24.89 35.03 45.12 48.95 50.41 50.96

K .01 .02 .03 .04 .05 .06

A+BC/(C+K) 42.8 37.1 33.0 30.0 27.6 25.7

K .07 .08 .09 .10 .11 .12

A+BC/(C+K) 24.1 22.8 21.7 20.8 19.9 19.2

WHE ANIMAL3

A= 9.99 B= 41.99 C= .0279 RSD= 1.32

Times 0. 6. 12. 24. 48. 72. 96. 120.

Measurements 9.29 16.10 23.85 30.27 40.84 44.55 50.09 50.96

Fitted values 9.99 16.48 21.96 30.51 41.01 46.37 49.11 50.52

K .01 .02 .03 .04 .05 .06

Appendix 5. Regression and Correlation analysis

	Parameter estimates			
	a	b	r	R-square
WHL	32.5919	0.9316	0.9904	0.9808
WHS	31.5919	0.9225	0.9812	0.9627
WHE	26.2969	0.9456	0.9862	0.9726