FEED INTAKE AND UTILIZATION OF SODUIM HYDROXIDE-TREATED RICE STRAW AS AFFECTED BY SUPPLEMENTS OF CASSAVA PEELS AND TREATED WATER HYACINTH

BY

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DECLARATION

I hereby declare that, except for references which have been fully acknowledged, this thesis is the result of my original research work and contains no material which has been accepted as part of the requirements for any degree in any university or any material published or written.

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ABSTRACT

Several strategies such as chemical treatment and supplementation have been used in an attempt to improve the quality of rice straw as a feed for livestock. Protein and energy supplementation has been shown to improve the nutritive value of straw. Three experiments were conducted on the hypothesis that ensiled water hyacinth, with or without cassava peels, will enhance the utilization of the basal diet of NaOH-treated rice straw and addition of dried cassava peels to ensiled water hyacinth will supply readily available energy and thus improve growth of sheep when fed as a supplement to a basal diet of NaOH- treated rice straw.

Experiment one compared the nutrient digestibility and nitrogen retention of NaOH- treated rice straw supplemented with: ensiled water hyacinth leave (WHL) diet 1, ensiled water hyacinth whole plant (WHLS) diet 2, ensiled water hyacinth leave + cassava peels (WHL-CP) diet 3, ensiled water hyacinth whole plant + cassava peels (WHLS-CP) diet 4 and sodium hydroxide-treated rice straw alone (ENS) diet 5, in 5x5 Latin square design. The difference between nutrient digestibility of dry matter, neutral detergent fiber and organic matter for WHL-CP and WHLS-CP was both significant ($p<0.05$) and both where superior to WHLS, WHL and ENS. For the crude protein digestibility the difference between WHLS and WHL were both significant ($p<0.05$) and where both superior to WHLS-CP, WHL-CP and ENS. The mean nitrogen retained were also significantly different ($p<0.05$), the values were1.32±1.5, 2.15±0.8, 3.28±1.5, 2.52±1.6, -4.3±1.9 for WHL, WHLS, WHL-CP, WHLS-CP and ENS respectively.

Experiment two compared the effect of WHL, WHLS, WHL-CP and WHLS-CP on voluntary feed intake, digestible organic matter in dry matter, and metabolized energy intake and growth rate of djallonke sheep. Significant differences ($p<0.05$) were observed in all these measurement. The mean feed intake values were 689.59g/d, 6.59.94g/d, 596.77g/d and 527g/d for WHLS-CP, WHL-CP, WHLS and WHL respectively. The mean values for the metabolized energy (MJ/KgD) intake were 7.6±3.9, 7.3±3.1, 6.6±2.0 and 6.6±1.2 for WHLS-CP, WHL-CP, WHLS and WHL respectively. Similar trend was observed for the digestible organic matter digestibility in dry matter. Significant differences were also observed with growth rate, with WHLS and WHL, having a negative growth rate.

The studies in experiment three shows that effective degradability of dry matter and crude protein with take into account the flow rate were higher with WHLS-CP and WHL-CP compared with WHLS and WHL. The various diets did have significant difference ($p>0.05$) on rumen pH. Significant differences ($p<0.05$) were however observed with the mean rumen ammonia values. The values observed were 4.26±2.5mg/dl, 5.31±0.46mg/dl, 2.23±0.13mg/dl, and 3.31±0.22mg/dl for WHL, WHLS, WHL-CP and WHLS-CP respectively.

The result from this study shows that although water hyacinth is high in protein and could be fed as a supplement to poor quality straw, for effective influence on animal performance it should not be fed alone as a supplement but together with rumen un-degradable protein or energy such as cassava peels.

DEDICATION

To my childrenHezekiah Nimpah Darkwah, Othniel Nhyirah Okyere Yeboah and Heidi-Lois Nkunim Kusiwaa Darkwah Yeboah. Mummy loves you so much.

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CHAPTER ONE

1.0 INTRODUCTION

1.1 Background

Mixed farming occurs throughout the developing countries where farmers crop the land and use the residues to feed animals. Increasing pressure on cropping land to meet the rising demand for human food reduces the natural grazing land available for livestock as feed. This compounds the shortage of grazing material in the dry season and also results in lessening the animal's ability to withstand exposure to pathogenic organisms (Yousuf and Adeloye, 2010). Tarawali *et al*. (1989) observed that many animals die of starvation during the dry season due to limited availability of feed resources and high cost of conventional feeds. In general, this has resulted in a decline in animal productivity.

However, the increase in cropping land has led to increase in the availability of crop residues for animal usage in the dry season. According to Adjorlolo *et al*. (2001), in Ghana large amounts of crop residues are available as potential feed for ruminants with most of it being cereal crop residues. However, animals fed solely on cereal crop residues usually lose weight due to inadequate nutrient content and poor digestibility of such materials.

Most works done on crop residues have revealed that physical and chemical treatment of such materials help break up the ligno-cellulose bonds, and increase the digestibility of such materials (Quarshie, 1992, and Chaudhry and Miller, 1996).

Although crop residues are high in energy, the utilization of the energy component of such materials by ruminants is highly dependent on the ammonia concentration in the rumen (Preston and Leng, 2009). With most cereal crop residues such as rice straw having low nitrogen content, feeding only cereal residue will lead to low ammonia concentration in the rumen and as a result poor microbial growth. Poor microbial growth leads to poor degradability of feed. Supplementing crop residue with a source of nitrogen, (non-protein nitrogen or protein nitrogen) helps improve the ammonia content in the rumen, increase microbial growth, and enhance better feed degradation (Preston and Leng, 2009).

Water hyacinth (*Eicchornia crassipes*) is one of the prominent fresh water plants found throughout the tropical and subtropical regions can serve as a source of protein nitrogen (El-Serafy *et al*., 1981). The plant is found in rivers, lakes, reservoirs and streams (Lareo and Bressani, 1982). It is one of the fastest growing plants known and capable of doubling its biomass in two weeks (Upadhyay *et al*., 2007) causing a lot of problems in water bodies. Some of the negative effects of water hyacinth include the loss of fishing ground, provision of habitat for mosquitoes, occlusion of water ways for navigation, interference with hydroelectric power generation and suppression of other useful aquatic life (El-Serafy *et al*., 1981). These reasons justify the need to remove water hyacinth from water surfaces to limit the disadvantages attributed it (Skinner, 2007).

One of the ways to dispose of this plant is to use the plant as feed for animals. It is reported to have a high crude protein content ranging from 20-23% (Abdelhamid and Gabr, 1991, Gohl, 1994, Nutsugah, 2011). The protein in water hyacinth is rumen degradable and as a result provides a better rumen environment for effective degradability by rumen microbes (Mako and Akinwande, 2012). The usage of water hyacinth also helps in the reduction of feed cost and this would bring about improvement in ruminant production in the resource poor communities (Mako and Akinwande, 2012). Water hyacinth, being an aquatic plant, will not be scarce during the dry season, meaning all year round feed availability.

However, fresh water hyacinth is unpalatable because it contains prickly crystals which irritate the mouth of livestock (Gohl, 1994). This problem is resolved by ensiling the water hyacinth (Joyce, 1990). According to Aboud *et al*., (2005) ensiled water hyacinth is readily accepted as feed by ruminants, but there is low feed intake when water hyacinth is taken as the sole diet because of it high moisture content. However, there is an increased intake and live weight gain when water hyacinth is used in combination with other feed resource such as rice straw (Khal, 1977 and Nguyen, 2010).

Cassava peel is a by-product from cassava and constitutes about 20-25% of the root tuber (Hahn and Chukwuma, 1986). This abundant crop residue can be harvested as cheap sources of energy for ruminants (Fleischer and Timpong, 1996) because it is easy to digest (Larsen and Amaning-Kwarteng, 1976). Its crude protein content ranges from 1.4%-2.6% (Larsen and Amaning-Kwarteng, 1976 and Akpabio *et al.,* 2012). Due to its low crude protein content Wanapat, (2003) and Wanapat *et al.* (1997) suggested that cassava peels should not be fed alone but be feed in addition to other protein source.

Feeding of fresh cassava peels is limited due to the presence of anti-nutritional substance such as cyanide. This toxic substance can be reduced or completely eliminated through the use of various detoxification methods such as drying and fermentation (Wanapat, 2003).

Considering the protein and energy value of water hyacinth and cassava peels respectively, one can hypothesize that the combined effect of these feeds will enhance rumen microbial activities. Improved microbial activity in the rumen will enhance fermentation processes which eventually will lead to a better feed intake and enhance growth rate.

1.2 Hypotheses

The hypotheses to be tested will be:

A. Both water hyacinth leaves and whole plant will enhance the utilization of the basal diet of sodium hydroxide-treated rice straw when fed as supplement.

B. Dried cassava peels will supply readily available energy and thus improve growth of sheep when fed as a supplement to a basal diet of sodium hydroxide-treated rice straw.

1.3 General Objective

To examine the influence of supplementation with water hyacinth and a combination of water hyacinth plus cassava peels on the performance of sheep fed a basal diet of sodium hydroxide-treated rice straw.

1.3.1 Specific objectives

The specific objectives are to determine the effect of supplements on:

a) Nutrient digestibility and nitrogen retention

b) Feed intake and weight gain

c) Dry matter and crude protein degradability

d) Rumen pH and ammonia levels

CHAPTER TWO

2.0 LITERATURE REVIEW

2.1 The Rumen Ecosystem

The rumen is a fermentation chamber, inhabited by microorganisms that digest complex components of feedstuffs and generate mainly volatile fatty acids (VFAs), methane and carbon dioxide. The process provides substrate (the feed) and ATP (energy) for the growth of micro-organisms (Gregg, 1995). In young animals the rumen forms 25% of the total stomach whiles in adult animals it forms 80% of the total stomach. The rumen is the dominant feature of the digestive tract of ruminants with its medium supporting a dense and varied population of microorganisms. The outcome of the digestion is absorbed by the host through the rumen wall. Microbes in the rumen include bacteria, protozoa and fungi, and are affected by factors such as rumen pH, rumen ammonia concentration and minerals (McDonald *et al*., 1993).

2.1.1 Bacteria

Rumen content of bacteria ranges from 10^{10} to 10^{11}per ml (Krause *et al.,* 2003). They are the most important microbes involved in ruminant digestion (Prescott *et al.,* 2005). Bacteria are involved in the bio transformation of complex polysaccharides into simple sugars. This is achieved by bacteria adhering closely to the substrate during digestion. Some common bacteria found in the rumen include; *Fibrobacter succinogens and Ruminococcus albus,* (McDonald *et al*., 1993)

2.1.2 Protozoa

Protozoa found in the rumen are mostly ciliate (tail-like structures). Protozoa are large in size compared to bacteria (William, 1988). *Holotrichs* and the *spirotrichs* are the two main types of protozoa. *Holotrichs* convert soluble sugars into starch and *spirotrichs* consume starch and cellulose (Prescott, *et al*., 2005).

Protozoa ingest and digest bacteria resulting in a reduction of bacterial biomass in the rumen. It results in a reduction of the supply of microbial protein to the host animal (Coleman, 1992). The presence of protozoa in the rumen may also reduce the rate at which colonization and degradation of ingested feed particles take place in the rumen. In studies with sheep fed straw-based diets, it has been found that the apparent digestibility of dry matter was increased by 18% after protozoa had been removed from the rumen (Bird and Leng, 1984). These authors further indicated that productivity can be increased if animals on fibrous diet have their protozoa removed.

Protozoa are now recognized as having an overall negative effect in the rumen, particularly where ruminants are fed forage diets low in true-protein (Bird and Leng, 1984). The net result of the presence of protozoa is an increased requirement for dietary bypass protein and on low protein diets a decreased efficiency of utilization of feed for growth and milk production (Bird and Leng, 1978).

2.1.3 Rumen Ammonia Concentration and effect on Rumen Microbes

Ammonia in the rumen is derived from degradation of dietary protein, non-protein nitrogen, from the hydrolysis of urea recycled to the rumen, and from the degradation of microbial crude protein (Ørskov, 1982). Rumen ammonia being the major source of nitrogen for microbial protein synthesis (Erdman *et al*., 1986) is absorbed by rumen microbes through the rumen wall (NRC, 1996). Due to the variation in rumen microbial species, the specific ammonia requirement for maximum microbial protein synthesis and fermentation of a given diet varies (Jones *et al*., 1998). The optimum rumen ammonia nitrogen concentration has been defined as the minimum concentration of ammonia nitrogen necessary to support maximum synthesis of microbial protein and degradability of feed (Satter and Slyter, 1974). Perdok and Leng (1989), Wanapat and Pimpa (1999) and Boucher *et al.* (2007) reported that ammonia concentrations should be between 15 to 30mg/dl. However, several other authors have reported varying rumen ammonia concentrations. Kang-Meznarich and Broderick (1981) fed corn based diet and observed rumen ammonia nitrogen concentrations between 1.3-28.9mg/dl, with no difference in their respective rumen mean dry matter digestibility values. They therefore concluded that it is quite difficult to determine the actual ammonia concentration needed for optimum dry matter digestibility. According to Leng *et al.* (1993) and Perdok and Leng (1989) for forage diet, ammonia level ranged from 100- 200mg/dl. Increasing rumen ammonia concentration as a result of increasing protein supply to the rumen microbes increased cellulolytic and fibrolytic bacterial populations whilst total protozoa count is reduced (Chanjula et *al.,* 2004).

2.1.4 Effect of Rumen pH on Rumen Ecosystem

Rumen pH is the most important factor affecting rumen microbial population in the rumen (Lana *et al.,* 1998). For instance in feeding sheep, pH drops few hours after feeding, then it reaches its peak and slowly moves down to the initial pH level before feeding. The effect of pH on microbial population depends on the magnitude of reduction, duration of optimal and suboptimal pH. It has been observed that at low pH most protozoa and fungi died, and fiber digestion is reduced. According to Khafipour *et al.* (2011) cellulose digestion is prevented at a pH of 5.3. Cherney *et al.* (1990) and Mourino *et al.* (2001) also reported that when rumen pH falls below 6.0, fiber digestion in the rumen begins to decline and most rumen microbial activity drops. At pH of 6 there is decrease in the production of obligate amino acids fermenting bacteria and as a result reduced rumen ammonia concentration (Lana *et al*., 1998).

Russel and Willson (1996) stated that the effect of rumen pH on cellulose digestibility often is influenced by the concentration of fiber in the diet or by changes in feed intake. When high levels of concentrates are included in a diet, rumen pH may go below optimum but with high fiber diet more saliva will be produced resulting in increased release of bicarbonates to help maintain the rumen pH. Wet feeds can reduce rumen pH because less saliva is needed to lubricate the feed for swallowing also rumen pH can also be adversely affected with very dry diets because of low intake levels (NRC, 1996).

According to Orskov and Fraser (1975) higher feed intakes mean more material available for bacterial fermentation and higher levels of VFA production. According to Owens (1993), volatile fatty acids (VFA) produced as results of fiber digestion have an effect on rumen pH. High acetate production, leads to more stable fermentation as a result stable rumen pH but high propionate production means faster rate of fermentation and a result reduced rumen pH and depressed fiber digestion.

2.2 Agricultural Waste as Feed for Ruminants

Agricultural waste is the residue left after harvesting and processing of agricultural produce. It can be grouped into crop residues and agro-industrial by-products (Tripathi *et al.,* 1998). Crop residues are the remains on the field after the main crop has been harvested. The by-products after processing the crop into finished products are the agro-industrial by-product. Crop residues and agro-industrial by-product once considered as wastes have become main feed ingredients in the livestock industry. There are large amounts of crop residues available in developing countries. A total of 136 million metric tons of crop residues are produced in the West African Sub Region (Fleischer and Timpong, 1996).

One major cereal crop residue is rice straw, between 0.41kg and 3.96kg of rice straw can be collected from each kilogram of harvested paddy (Koopmans and Koppejan, 1997). Rice straw can be recycled and used as animal feed because it contains high amounts of energy. However, its utilization as an energy source is low due to its fibrous nature, low nitrogen and mineral content (Predok and Leng, 1989). Low nitrogen content of the straw limits microbial fermentation in the rumen. Theander and Anan, (1984) and Smith *et al.* (1983) observed that rice straw had a crude protein ranging from 3-9% but this could not support maintenance of animals. As a result animals fed sole rice straws are not able to maintain their weight (Adjorlolo *et al*., 2001). Attempts to improve the utilization of straw have led to several treatments techniques and nutrient supplementation strategies all aimed at increasing intake and digestion.

2.2.1 Strategies for Improvement in Straw Utilization

The two main approaches in the improvement of rice straw are delignification and nutrient supplementation. Delignification methods include physical, chemical and biological treatments.

2.2.1.1Physical Treatment

This approach aims at minimizing the straw particle size to create a larger surface area for microbial activity and consequently improving intake. Some of these treatments include chopping and grinding.

Chopping reduces particle size and therefore facilitates intake (Kononoff and Heinrichs, 2003). Beauchemin *et al.* (2004) observed that dry matter intake increased by reducing particle size when high fiber diets are fed. Grinding of straw reduce time of passage in the rumen and improve feed intake (Doyle *et al.,* 1986).

2.2.1.2 Chemical Treatment

This aims at increasing the digestibility of crop residues. It does this by hydrolyzing the linkages between cellulose, hemicelluloses and lignin or to modify the compact nature of these tissues, so that lignified tissue would separate from non-lignified once (Chenost and Kayouli, 1997) thus weakening the cell wall and increasing the swelling capacity of the cell wall (Lam *et al*., 2001).

These allow easy access of rumen microorganism to the substrate and as a result increase degradation. The chemicals used in the treatment of straw include alkaline, acidic or oxidative agents. Among these, alkalis have been widely used and the most common alkaline regents used are lime, urea and sodium hydroxide (NaOH).

Lime treated straw adds calcium to the straw (Nath *et al.,* 1969), however, excess calcium residues remaining in the treated straw, cause serious health problems such as creating calcium phosphorus imbalance in animal and the environment. According to Chaudhry and Miller (1996) lime treatment increases the degradability of straw, but reduced dry matter intake, due to reduced acceptability of the treated straw by animals.

Sodium hydroxide (NaOH) treatment of rice straw is known to be the more effective in terms of its degradability and palatability compared to all the other alkaline treatments (Ye *et al.,* 1999). Hadjipanayiotou (1984) reported that NaOH-treated straw has high neutral detergent fiber (NDF) digestibility and also cause increased rate of rumen degradation. Jackson (1977) observed dry matter intake of straw increased from 59% (untreated straw) to 70% when rice straw was treated with NaOH and digestibility was increased from 46.8% (untreated) to 55.9%.Ye *et al.,* (1999) also reported that feeding dairy cows with NaOH-treated rice straw led to production of 7.9% more milk per day than those on untreated-straw diets.

Urea treatment of crop residue is less effective in terms of degradability when compared to sodium Hydroxide treatment, it however adds ammonia to the crop residues and as a result improves their nutritional content (Dias-da-Silva and Guedes, 1990 and Nguyen, 2010). Hussein *et al*. (1991) treated rice straw with urea and observed that the crude protein content of the straw increased from 3.3% to 8.10%. Urea is a cheap commodity and readily available in developing countries.

2.2.1.3 Biological Treatment

This involves use of fungi and their enzymes to breakdown the lignin bonds. Fungi are able to secrete enzymes that break down the lignin in straw. Some groups of fungi include the white rot, brown rot and soft rot fungi (Steffen, 2003). Among these the commonest used are the white rot fungi because it causes high degradability of straw (Hatakka, 2001). Fungal treatment of rice straw leads to an increase in the crude protein, ether extract and ash contents of the straw resulting in an increased in intake compared with untreated straw (El-Ashry *et al.,* 2002 and Hatakka, 2001).

2.3 Supplementation

As a result of nutrient deficiencies in the straw, rumen microbes are unable to utilize all the energy in the straw after delignification of the straw. This has been the cause of low productivity in animals. This problem can be resolved through specific nutrient supplementation without changing the basal diet (Smith *et al.,* 1983).

Supplements can be in the form of fermentable nitrogen or energy to help the rumen microbes in the degradation of feed (Osuji, 1994). An active rumen environment means increase in the rumen microbial protein synthesis and therefore increased supply of microbial protein to the host animal

(Van Soest, 1994). However, depending on the level of supplementation it can result in substitution of the basal diet (Adegbola *et al*., 1988, Lakpini, 1997 and Pham and Preston, 2009).

2.3.1Energy supplementation

Crop residues such as straw are high in mature plant cell wall carbohydrates but too low in soluble carbohydrates (Van Soest, 1994). Because they are low in soluble carbohydrate they are not able to provide all the energy needs of the rumen microbes. Microbes on straw-based diets may therefore die out of starvation (Van Soest, 1982). Hespel (1979) observed that 60% of the rumen microbial populations die out within two hours due to starvation in the absence of fermentable energy supplementation. For effective utilization of nitrogen and better growth of rumen microbes, energy supplementation is important (Henning *et al*., 1991). Increasing the supply of readily fermentable carbohydrate decreased ammonia-nitrogen concentrations due to improved nitrogen uptake by rumen microbes (Sanson *et al*., 1990). This is supported by Pathokmalansy and Preston (2008) they observed an increase in both intake and nitrogen retention when *Tithonia* forage was used together with cassava chips compared to when *Tithonia* forage was fed alone. Caton and Dhuyvetter, (1997) also observed that fermentable carbohydrates such as wheat middling and beet pulp usually increase forage intake more than nonstructural carbohydrate such as cereal grain.

Ballard *et al*. (2001) supplemented grass silage-based diets with sugars and reported an increase in the flow of microbial protein and non-protein nitrogen into the small intestine. Anderson *et al*. (1988) observed that grazing heifers supplemented with corn or whole soya hulls grow faster than those not supplemented.

However, excessive intakes of rapidly fermentable carbohydrate causes low rumen pH, concentrations of peptides and amino acids in the rumen, this limits microbial growth in the rumen and impede cellulose digestion (Fahey and Beryer, 1988 and Demeyer and Fievez, 2004).

2.3.2 Protein supplementation

Protein supplementation can be done with non-protein nitrogen (NPN) or true protein sources. Rumen micro-flora are able to convert non-protein nitrogen into true protein. The non-protein nitrogen can be used as a supplement alone or ensiled with straw. When urea is ensiled in addition to straw it adds nitrogen to the straw as well as breaks down lignin in the straw (Quarshie, 1992). The improvements in voluntary intake and dry matter digestibility as a result of ammonia and urea treatment have been documented (Quarshie, 1992, Egyir, 1994).

Although rumen microbes are able to synthesis non-protein nitrogen to produce ammonia and amino-acids which can be used by the microbes for synthesis of microbial protein, there is the need to provide an additional by-pass protein to the host animal. True protein or by-pass protein supplement provide amino acids to some rumen microbes and the host animal due to their slow degradability by rumen microbes (Archibeque *et al*., 2002). The supply of amino acids to the rumen microbes is important since some species of organisms commonly found in the rumen require peptides or amino acids for development (Mould and Orskov, 1984). Providing low concentration of amino acids in diet may therefore cause disappearance or changes in the species of microbes in the rumen. According to Atasoglu *et al*. (2004) lysine was the potential amino acid limiting growth of rumen bacteria. Kernick (1991) suggested that the addition of amino acids and peptides (dietary protein) will improve growth in cellulolytic and amyolytic bacteria and also increase fiber digestion. Atasoglu *et al.* (2001) concluded that cellulolytic bacteria prefer amino acids to nitrogen from ammonia. Marshall *et al.* (2006) therefore concluded that for maximum microbial protein synthesis some amount of rumen non-degradable protein must be incorporated in the diet.

Even when nutrients are not limiting in the rumen, the rumen system may not supply sufficient microbial protein to meet the needs of animals for maximum production. Under these conditions, high production depends on an additional exogenous amino acid supply to the duodenum. Although escape protein improved the performance of animals it is often too expensive to be afforded by the poor farmer. Therefore there is the need to find cheaper ways of providing these escape protein supplements in other to enhance ruminant production. The usage of forages is of particular interest because they are high in readily degradable nitrogen (NRC, 2000) and some by-pass protein (Archibeque *et al*., 2001).

2.4 Nutritive Value of Forage

The quality of a forage depends on it crude protein content. Different forages have different crude protein content ranging from 29.6% for *leuceana leucocephala* (Dalzell and Kireven, 1998), 18.83% for *Delonis regia* observed by Sottie (1997), 22.10% observed by Fianu, *et al,* (1994) for *Pueraria*. Ndimele *et al.* (2011) reported a crude protein range 25-35% for water hyacinth forage. Variation within crude protein content of forage exists with the plant part used as feed with the leaves of most forages having more crude protein than the other plant parts. For instance Adjorlolo (1999) observed a crude protein level of 25% for mucuna leaves and 16.6% for mucuna whole plant. Solotu and Sule (2011), observed a crude protein of 28.2% water hyacinth leaves and 24.1% for the water hyacinth whole plant without the root. Although leaves are high in crude protein, it intakes may be limited due to its high anti-nutritional factors compared with the other plant part. Lowry *et al.* (1996) observed that leaves of most forage are high anti nutritional factors such as tannins, phenol and saponins.

2.5 History and Biology of Water hyacinth

Water hyacinth is an aquatic plant that can float on water unattached to the bottom (Langeland and Burks, 1998). It can be found in tropical and sub-tropical areas of the world. It was originally native to the Amazon Basin of Brazil in South America (Parsons and Cuthbertson, 2001). Since the nineteenth century, water hyacinth has infested many water bodies due to its usage as an ornamental plant. Navarro and Phiri, (2000) reported an infestation of 12000 ha in Lake Victoria. They also reported of infestations in Lake Malawi, the River Zambezi in Southern Africa, the River Niger in Nigeria and the river Volta in Ghana.

The plant reproduces by both sexual and asexual means (Reza and Khan, 1981). The rate of reproduction depends on the climatic condition in which the plant is found. According to Langeland and Burks (1998), in a mild climatic condition, the plant produces lots of seeds because it produces flowers all year round. In the tropics, as a result of activities of pollinating insects, the plant is reported to produce twice as much seeds as it does in the temperate regions (Barrett, 1980). The plant doubles its biomass every two weeks (Joyce, 1990). Water hyacinth is therefore described as a nuisance wherever it is found. Table 1.1 shows the amount of water hyacinth that can be harvested depending on the medium in which it grows.

Table 2.1 Productivity of water hyacinths under different aquatic environments

Aquatic environment	Yield (tonnes/ha/year)
Fertile ponds	15-200
Artificially fertilized ponds	76.6-191.1
Fertilized pond	70.8
Fertilized pond with sewage effluent	212-657
Irrigation canals in China	400-750
Nutrient non-limiting water of florida, USA	106
Man-made lakes of central Java	255

Source: Little and Muir (1987)

Due to its ability to multiply so rapidly, the plant can have several negative effects on the environment. These include:

- Destruction of sub-marine vegetation; water hyacinth spreads on surfaces of water bodies like a mat. These mat-like sheets formed on the surfaces of water bodies, prevent sunlight from reaching submerged vegetation (Gopal and Goel, 1993). Growth of native species is impaired because they do not get enough sunlight for photosynthesis (Lareo and Bressani, 1982). The submerged vegetation eventually dies and decay, leading to a reduction in oxygen availability needed to support growth of other marine species such as fish (Lareo and Bressani, 1982).

- Water hyacinth chokes water ways when the mat-like sheet becomes dense, leading to the blockage of waterways and preventing free flow of water. They prevent the flow of water supply for hydro-electrical power generation (Hill and Coetzee, 2008), interfere with irrigation and water treatment (Opande *et al.,* 2004).

- In situations where water is stagnant, these aquatic weeds grow massively on it and create a habitat for disease vectors. According to Kushwaha (2012) water hyacinth as a weed creates a favorable environment for the multiplication of disease vectors such as schistosomosis and mosquitoes larvae that cause malaria as well as parasitic flatworms (Lareo and Bressani, 1982).

2.5.1 Agricultural Importance of Water Hyacinth

Water hyacinth produces a lot of green leaves due to its ability to increase its biomass so rapidly. It is also high in nitrogen, phosphorus and easy to degrade (Reddy *et al.,* 1990).With such a high biomass and nutrient content it can be harvested and used as an organic fertilizer when incorporated into the soil (Ahmed, *et al*., 1992). Water hyacinth as a green manure would therefore help to increase the nutrient content of the soil.

2.5.1.1 The use of Water Hyacinth in Animal Feeding

Due to the high nitrogen absorption rate of the plant (Reddy *et al*., 1990), it is known to have high crude protein content (Ndimele *et al*., 2011, Nutsugah, 2011) and could therefore be used as feed for livestock. In Egypt, trials by El-Serafy *et al,* (1981) have clearly shown that water hyacinth can be successfully incorporated in ruminant's diets. Nguyen (1996) reported the usage of fresh and ensiled water hyacinth as a supplement for fattening pigs in Vietnam. Inclusions of up to 20% water hyacinth in the diet resulted in weight gain of fish (Konyeme *et al.,* 2006). Khal, (1977) observed increase in weight of cattle when water hyacinth was fed in a ratio of 1:1 with rice straw.

Water hyacinth is therefore considered as a plant for hunger and poverty alleviation in several developing countries (Nguyen, 1996). The proximate composition of water hyacinth is shown in table 2.1

Table 2.2 chemical composition of water hyacinth

Chemical composition (%)	Water hyacinth leaves	Water hyacinth leaves + stems	Source
Dry matter	12.3	8.10	1
	10.72		3
Crude protein	21.8	18.4	1
	20.8		2
	18.3		3
Ash	13.9	15.9	1
	13.4		2
Neutral detergent fiber	55.5	61.8	2
	50.1		3
Acid detergent fiber	25.4	27.8	3

Source: *Thu et al, (2011)* - (1); *Hira et al (2002)* - (2); *Aboud* et al. *(2005)* - (3)

2.5.1.2 Effect of water hyacinth forage supplementation on voluntary intake and weight gain

Voluntary intake in ruminants is determined by two main factors, the ingestion of the forage and the intake capacity of the animal (Dulphy and Dermarquilly, 1994). The intake of water hyacinth forage as a feed or supplement depends on the form in which it is presented. In the dry season when there is poor availability of forages on land, buffalos and cattle have been observed feeding on fresh water hyacinth in streams and lakes (Aboud *et al.,* 2005).

However, fresh water hyacinth as a sole diet is not enough to support maintenance due to its high moisture content (Abdelhamid and Gabr, 1991, Khan *et al*., 2002). Feeding fresh water hyacinth to cattle at different supplementation levels have been observed to cause abnormal rumen distension as intake increased (Ho, 2012). Although the cause of this was not established, Ho

(2012) recommended that the inclusion rate above 30% in the diet of cattle be avoided since it resulted in rumen distention. Aboud *et al.,* (2005) reported that in addition to the high moisture content of fresh water hyacinth, the presence of anti-nutritional factors such as oxalate leads to low feed intake because it causes irritation in the mouth when it is ingested fresh. This limitation can be resolved by ensiling (Ho, 2012). Various authors have given ensiled water hyacinth as a supplement with rice straw or other feedstuff and it has given good results in terms of feed intake. According to Thanh (2008), ensiled water hyacinth improved dry matte intake when fed to local cattle as a supplement to rice straw. According to Nyugen (2010) and Thu (2011) levels of supplementation of ensiled water hyacinth has no effect on dry matter intake. However, where water hyacinth was used as the basal diet Thu *et al.* (2011) observed an increased in intake when the basal diet was water hyacinth leaf rather than with water hyacinth whole plant. This difference in intake was attributed to high crude protein content of the leaf compared to the leaf plus stem.

Since water hyacinth supplies more of rumen degradable protein, other authors have suggested that when offering water hyacinth as a supplement, there is the need to provide by-pass protein or energy sources to the host so as to increase productivity of the animal (Gohl, 1982 and Sophia *et al.,* 2010).

As a result of poor feed intake of fresh water hyacinth weight gain has been observed to be poor (Khal 1977 and Ahmed *et al.,* 1992). Aregheore and Cawa (2000) also reported that wilted water hyacinth when given as a sole feed to goats resulted in poor growth. However, when given as a supplement to rice straw showed a positive effect on intake and growth of beef cattle (Islam *et al.,* 2009). Daily live weight gain of approximately 500g was gained by cattle when 30% wilted water hyacinth was as a supplement to a basal diet of wheat straw (Parashar *et al.*, 1999).

According to Thanh (2008) and Aboud *et al.* (2005) feeding ensiling water hyacinth as a supplement to rice straw leads to improvement in the growth rate in ruminants. Nguyen (2010) observed no difference in weight gain when ensiled water hyacinth was used to replace Para grass compared with when Para grass was fed alone. Sophia *et al.* (2010) fed rice straw and supplemented it with water hyacinth leaves and leaves plus stem and by-pass cassava hay. It was realized that, there was an increase in weight gain when the water hyacinth leaf and cassava hay were the supplement compared to when leaves plus stem and cassava hay were the supplement. However, when only water hyacinth leaf or water hyacinth whole plant was the supplement, weight gain was poor.

2.5.1.3 Effect of Water Hyacinth Supplementation on Nutrient Digestibility

According to Van Soest (1994) the primary component of the feed regulating intake is the plant cell wall content or neutral detergent fiber (NDF); When the cell wall content of forage increases digestion rate decreases (this is so because mastication increases per unit bit leading to reduction in intake) (Dulphy and Demarquilly 1994). Feed digestion also depends on the lignin content of feed. Feed with high lignin content tend to have low digestibility and vice- versa. Water hyacinth is known to have low lignin content and as a result high digestibility (Aboud *et al.,* 2005). However, depending on the processing method there could be differences in the digestibility. For instance, El-Serafy *et al.* (1980) observed that fresh water hyacinth has a digestibility within the range of 47-58% while that of the ensiled was within 64-67%. Digestibility also depends on the plant part that was used as feed, the leaf of water hyacinth has a dry matter digestibility ranging between 58 - 72% and that of the whole plant is 42% (Khal, 1977; Hira *et al.,* 2002; Aboud *et al.,* 2005).

Although several authors have reported a reduction in intake of basal diet when water hyacinth silage is given as a supplement to low quality crop resides, their digestible organic matter and dry matter do not change (Abdelhamid and Gabr,1991 and Nyugen, 2010**).** This might be due to the fact that intake offered does not always appear to be positively related to digestibility and that digestibility depends on both cell wall content and its availability to digestion (Van Soest, 1994).

Water hyacinth is known to have high crude protein content and as a result high digestible crude protein. However the amount of crude protein digested depends on the quantity of water hyacinth in the diet (Abdelhamid and Gabr, 1991, Islam *et al.,* 2009 and Tham and Udem, 2013) these authors' observed that the higher quantity of water hyacinth supplied in a given diet the higher the crude protein digested.

2.5.1.4 Effect of Water Hyacinth Supplementation on Rumen pH and Ammonia

The rumen pH shows how acidic or alkaline the rumen fluid is. A pH of 7 is considered neutral, where the amount of acid and base are equal. Maintaining effective rumen pH is critical to maintaining a healthy rumen microorganism. This is so because a fall in rumen pH below 6.0-6.2, fiber digestion in the rumen begins to decline because fibrolytic bacteria in the rumen become less active (Thomas and Hall, 1984). At pH of 5.8-5.9, the rumen is mildly acidic and fiber digestion in the rumen ceases completely (Kincaid *et al.,* 1981).

Rumen pH is reduced when there is insufficient fiber or fiber is chopped too fine, under this condition chewing time is reduced and as result less saliva production. This is so because saliva is rich in, bicarbonate, phosphate and urea, these serves as a buffer and helps maintain the rumen pH. This has been confirmed by Nguyen (2010) and Sophal *et al.* (2010). These authors observed no changed rumen pH after supplementing rice straw with water hyacinth. This might be attributed to the fact both feed were fibrous as a result there was increased saliva production to help maintain the rumen pH.

Volatile fatty acids (VFA) produced as a result of fermentation in the rumen also helps reduce rumen pH. According to McDonald et al. (1993) VFA are capable of reducing rumen liquor by a range of 2.5-3.5 and this has effect on the rumen pH. VFA production depends on the rate of fermentation in the rumen; highly fermentable feed will produce more volatile fatty acids and therefore lowers the rumen pH. This is in agreement with observation by Egyir (1994) and Ye *et al*. (1999) both authors observed a reduction in pH when they supplemented straw with molasses. Water hyacinth being rumen degradable is known to increase the ammonia concentration in the rumen when given as feed or supplement. Thanh (2008) reported an ammonia concentration of 11.6-11.9mg/100ml before feeding cattle with rice straw and supplemented with ensiled water hyacinth. It increased to 17.5-18.0 mg/100ml three hours after feeding.

Sophal *et al.,*(2010) observed no significant difference in rumen ammonia concentration when rice straw was supplemented with water hyacinth leaves or water hyacinth leaves and stem. However when a source of protein (cassava hay) was added to the water hyacinth leaf and leaf plus stem there was a significant difference in the pH.

2.5.1.5 Anti- nutritional factors in water hyacinth

Anti-nutritional factors are chemical substances found in plant that inhibit their usage at higher levels because of their harmful effect on the animals (Tacon et al, 1985; Banerjee and Matai, 1990). Some of these include: tannis, nitrate and oxalate.

Tannis are phenolic compounds that interfered with protein digestion. According to Mcleod, 1974, a tannis content of 6% reduces feed value by precipitating protein. Nitrates are also known to accumulate in forage plant.

A nitrate level of 1.5% have been considered safe for animal consumption (Banerjee and Matai, 1990).

Oxalate is one of the anti-nutritional factors found in almost all plant species. It plays a major role in plant such as calcium regulation, plant protection, tissue support, ion balances and heavy metals detoxification (Libert and Fraceschi, 1987). Their quantities in plant species can be as low as 1-2% as in rice straw (Libert and Franchi, 1987) and as high as 3-6% depending on the plant part used (Ji and Peng, 2005).

They are mostly found in leaf tissues followed by stem tissues (Jones and ford 1972, Maries *et al.* 1997, and Rahman *et al*., 2006). In water hyacinth the leaves have more oxalate (2%) compares with the stem (1%) (Khal, 1977). Oxalate ingested in high quantities forms complexes with dietary calcium and disturbances the calcium phosphorus metabolism invoking excessive mobilization of bone mineral. The demineralized bone becomes fibrotic and deformed causing lameness (Mckenzie *et al*., 1981). It also causes irritation in the month when plants are taken in the fresh state (Aboud *et al*., 2005).

According to Aboud *et al.*, 2005, ensiling water hyacinth before feeding reduce it irritation and improved intake.

2.6 Origin and History of Cassava

Cassava originated from Brazil about 10,000 BC (Allem, 2002). In the sixteenth century, the plant was introduced to the African continent and has become a staple food (Sadik, 1988) with Nigeria being the world's largest producer (FAO, 2002). It is the third highest source of carbohydrate in West Africa (Burns *et al,* 2012). Cassava has three main edible parts that is; the leaves, the roots and the peels. Cassava leaves and root tuber are eaten by both humans and animals but its peels are not consumed by human and so normally fed to animals. According to Man and Wiktorsson (2001) 1.75 tonnes/ha of cassava peels are obtained in root harvesting. Cassava peels represent 5 to 25% of the root tuber (Hahn and Chukwuma, 1986; Nwokoro *et al.,* 2005). It is the commonest by-product of cassava used in the ruminant industry (Tuah *et al.,* 1994) as energy feed in ruminant diets (Smith, 1989). Due to its high degradability in the rumen, it is able to provide readily available energy to the rumen microbes to facilitate the effective utilization of available nitrogen.

2.6.1 Effect of Cyanide and Chemical Composition of Cassava Peels

The utilization of fresh cassava peels may be constrained by their high cyanide content especially when taken in large quantities (Cereda and Mattos, 1996). Kumar (1992) observed that feeding levels of 2-4mg hydrogen cyanide per kilo body weight could be lethal to cattle. Oboh *et al.,* (2002), Hill and Coetzee (2008) also observed that the high cyanide content leads to a reduction in feed intake, sometimes causing death particularly in non-ruminants. Treating cassava peels before feeding is known to reduce the effect of the cyanide in the cassava peels to acceptable levels (Smith, 1989). Adegbola *et al*., (1988) reported that sun drying reduced the cyanide content of the cassava peels by 60% whiles ensiling reduced it by 83%. Table 1.1 shows the chemical composition of sun dried cassava peels.

Table 2.3 Chemical composition of dried cassava peels

Fraction (% of DM)	Content	Source
Crude Protein	3.96	1
	5.72	2
Crude Fiber	19.6	1
	9.82	2
Ash	8.4	1
	2.2	2
Ether extract	0.98	1
	9.37	2
Metabolized energy (MJ/kgDM)	17.83	1

Source Adegun (2012)*-1, Anaeto et al.* (2013*)-2*

Considering the low protein content of cassava peels, it is usually better to supplement it with readily fermentable protein and by-pass protein, as well as micronutrients including sulphur, phosphorus, and vitamin B for optimum production (Smith, 1989, Otukoya and Babayemi, 2008).

2.6.2 Effect of Cassava Peels Supplementation on Voluntary Intake and Weight Gain

Cassava peels has been used by small ruminant famers for ages. However, feeding peels alone as a sole diet has been discouraged due to its low crude protein content and the bulky nature of the peels resulting in low dry matter intake. This is confirmed by Baah *et al*., (2011) they observed an increase in dry matter intake from 44 to 58 g $W^{0.75}$/d when cassava peels was supplemented with *Ficus.* Supplementation has therefore been documented by several authors as increasing the total dry matter intake. However, depending on the level of supplementation it can result in substitution of the basal diet. This has been confirmed by Pham and Preston, (2009) Lakpini *et al*. (1997), Adegbola *et al*. (1988). These authors observed a reduction intake of the basal diet (grass) as intake of cassava peels increased, however there was an overall increase in total dry matter intake.

The increase in dry matter and organic matter intake when cassava peels were given as a supplement was due to the readily fermentable carbohydrates supplied by the peels. These fermentable carbohydrates help in the utilization of rumen nitrogen and as a result stimulated microbial activity (Fahey and Beryer, 1988).

The increase in intake as a result of using cassava peels as a supplement is reflected in the overall weight gain of animals (Ifut, 1987). This is supported by the work of Adegbola (1982) when he fed sheep with diets consisting of 100% *Gliricidia*, 20% *Gliricidia*, and 80% dried cassava peels then observed that animals on the dried cassava peels based diet plus *Gliricidia* had high weight gain compared to those on sole *Gliricidia* diet. Larsen and Amaning-Kwarteng (1976) fed grazing cross-bred cattle a supplement made up of molasses and dried cassava peels at 0.7 percent of body weight, for about six months. Weight gains recorded were 0.07 kg/day for control (cattle grazed with no supplement), 0.29 kg/day for test (cattle grazed and supplemented with dried cassava peel).

Weight gain as a result of supplementation with cassava peels depends on the level of supplementation. According to Fomunyan and Maffeja, (1987) the higher the level of intake the higher the weight gains

2.6.3 Effect of Cassava Peels Supplementation on Nutrient Digestibility

Fomunyan and Maffeja (1987) observed an increase in dry matter and crude protein digestibility when cassava peels were used to supplement elephant grass in the diets for sheep with cotton seed as the main source of nitrogen. According to Ifut (1987) supplementing *Gliricidia* with cassava peels leads to higher organic matter and dry matter digestibility compared to feeding *Gliricidia* as a sole diet. However, Gliricidia as a sole diet observed a high crude protein digestibility and increase nitrogen intake but when it was supplemented with cassava peels in a ratio of 70% *Gliricidia* to 30% cassava peels he observed the highest nitrogen retention and neutral detergent fiber digestibility (NDF). This difference might be attributed to the readily available carbohydrate supply by the cassava peels to the rumen microbes to active them. Activated rumen microbes mean better degradability of fiber hence the high NDF digestibility.

2.6.3 Effect of cassava peels supplementation on rumen pH and ammonia concentration

Pham and Preston, (2009) supplemented grass with different levels of sun dried cassava peels to bulls and observed that supplementation had no effect on pH. For ammonia concentration Pham and Preston (2009) reported that ammonia concentration decreases as cassava peels supplementation increases in a diet. This is so because cassava peels has been shown to ferment more rapidly in the rumen and as such stimulating rumen microbial synthesis (Fernandez and Hovell, 1978) for the production of VFA. According to McDonald, (1993) volatile fatty acids are capable of reducing rumen ammonia concentration and this has effect on the rumen pH.

CHAPTER THREE

3.0 GENERAL MATERIALS AND METHODS

3.1 Study Location

The study was conducted at the Livestock and Poultry Research Centre, University of Ghana Legon, in the coastal savanna ecosystem. Chemical analyses were carried out at the Livestock and Poultry Research Centre and the Department of Animal Science, University of Ghana, Legon.

3.2 Collection and Treatment of Feed Ingredients

3.2.1 Water Hyacinth

Water hyacinth was collected from the Volta River at Saikope near Adidome in the Volta Region of Ghana (approximately 120 km from Accra).

Water hyacinth plants were divided into two groups: the first group (L) used only the leaves whiles the second group (LS) used whole plant without the root. These portions were wilted separately under shade for 48 hours. Wilted samples were further chopped using an electric forage chopper (CeCoCO forage SFC1400, Chou Boeki Goshi Kaisha, Central Commercial Company, Ibaraki- shi, OSAKA JAPAN) to 3cm in length. Each portion was ensiled in a concrete culvert lined with polythene sheets for three weeks (Quarshie, 1992).

3.2.2 Cassava Peels

Cassava peels were collected from Akrade in the Eastern Region of Ghana. Fresh cassava peels were chopped into smaller units and sun-dried to a moisture content of 25%. Dried peels were stored in jute sacks until ready for use.

3.2.3 Rice Straw

Rice straw was obtained from the Small Scale Irrigation Agricultural Project at Ashaiman in the Greater Accra Region. Straw was chopped to approximately 3cm length using a forage chopper. For treatment of straw 200g of NaOH was mixed with one liter of water. This was used to mix 4kg of straw. The treated straw was ensiled in a concrete culvert lined with polythene sheets for a minimum of 21 days (Nour, 1986, Adjorlolo, 1999).

3.3 Experimental Diets

All animals received a basal diet of NaOH-treated rice straw at a feed allowance of 5% of body weight on dry matter basis (Adjorlolo, 1999).Water hyacinth was given at 7g crude protein per 10kg body weight of the animal and cassava peels offered at 10% of feed intake. Experimental diets were:

Diet 1- Ensiled NaOH- treated rice straw + ensiled water hyacinth leaf (WHL)

Diet 2- Ensiled NaOH- treated rice straw + ensiled water hyacinth whole plant (WHLS)

Diet3- Ensiled NaOH- treated rice straw + ensiled water hyacinth leaf + dried cassava peels (WHL+DCP)

Diet 4- Ensiled NaOH- treated rice straw + water hyacinth whole plant plus cassava peels (WHLS+DCP)

Diet 5-Ensiled NaOH-treated rice straw (ENS)

3.3.1 Chemical Composition of Feedstuff

Samples of the ensiled NaOH rice straw, water hyacinth leaves and water hyacinth whole plant and dried cassava peels were oven dried separately at 55°C to a constant weight. The samples were ground separately through a 1mm sieve using a hammer mill and put in polythene bags packed in envelopes until ready for analysis. Chemical analyses carried-out were: Acid detergent fiber (ADF), neutral detergent fiber (NDF) using methods suggested by Van Soest (1994).

Hemicelluloses were calculated as the difference between NDF and ADF. The difference between ADF weight and residue after the 72% H_2SO_4 wash was used to calculate the cellulose. Lignin was calculated using weight difference between the residue acid wash and the ash ADF (Van-Soest, 1994).

Crude protein was determined by the micro-Kjedahl technique (AOAC, 1995). Total ash was determined by combusting the weighed sample in a ceramic crucible in a furnace at 500°C for 3 hours (AOAC, 1995). Organic matter was determined as dry matter less residual ash obtained after ashing (AOAC, 1995).

Table 3.1: Chemical composition of NaOH-treated rice straw (ENS), ensiled water hyacinth leave (L), ensiled water hyacinth leaf+ stem (LS) and dried cassava peels (DCP)

Chemical composition	ENS	L	LS	DCP
Dry matter content (%)	85.69	36.0	40.32	95.05
Composition (%DM)				
Ash	25.26	30.04	25.25	14.98
Crude protein	4.22	28.03	21.17	1.48
NDF	54.36	63.16	67.51	35.39
ADF	50.93	45.29	50.57	26.66
Hemicelluloses	3.43	17.87	16.94	8.73
Cellulose	32.67	28.13	28.29	6.54
Lignin	5.58	11.07	11.58	10.4
Silica	12.37	6.08	10.7	10.08

CHAPTER FOUR

4.0 EXPERIMENT ONE

Influence of Water Hyacinth and Dry Cassava Peels Supplementation on Nutrient Digestibility and Nitrogen Balance of Sheep Fed Sodium Hydroxide-Treated Rice Straw

Abstract

The objective of the study was to determine the influence of supplementation of ensiled water hyacinth and dried cassava peels on nutrient digestibility and nitrogen balance of sheep fed a basal diet of sodium hydroxide- treated rice straw.

This was determined using 5 rams (mean weight between 26±3kg) in a 5x5 Latin square design using metabolic crates. Each measurement lasted for 21days with 14 days for adjustment and 7 days for data collection. Fecal bags and urine tubes were fitted to the animals.

Animals were fed treated rice straw supplemented with water hyacinth leaves (WHL) as diet 1, treated straw supplemented with water hyacinth whole plant (WHLS) as diet 2, treated straw supplemented with water hyacinth leaves + dried cassava peels (WHL-DCP) as diet 3, treated straw supplemented with water hyacinth whole plant + dry cassava peels (WHLS-DCP) as diet 4 and NaOH- treated rice (ENS) straw alone as diet 5.

Significant difference ($P<0.05$) was observed in the dry matter digestibility; the highest was observed when the supplement was WHLS-DCP followed by WHL-DCP, WHLS having, WHL supplementation had whilst ENS had the lowest dry matter digestibility. There were significant differences ($P<0.05$) in neutral detergent fiber digestibility among the various treatment values

obtained. These were 76.78, 74.71, 69.78, 63.62 and 54.38 for WHLS-DCP, WHL-DCP, WHLS, WHL, and ENS respectively. Significant differences ($P< 0.05$) were observed in the crude protein digestibility (CPD). The highest CPD was observed when the supplement was WHLS, followed by WHL, WHLS-DCP, WHL-DCP with ENS having the lowest CPD. The highest organic matter digestibility observed was observed in WHLS-DCP whiles the least was observed in ENS respectively. For nitrogen retained significant difference ($p<0.05$) were observed among the various treatment mean values with ENS given negative nitrogen retention.

It can be concluded from the study that supplementing NaOH-treated rice straw with water hyacinth led to an improvement in nutrient digestibility. However, the addition of cassava peels to water hyacinth gave a better improvement in nutrient digestibility compared to when water hyacinth was the sole supplement. Although there was an improvement in the nitrogen balance when WHL and WHLS were used to supplement NaOH- treated rice straw, the addition of cassava peels to water hyacinth leaf (WHL-DCP) or water hyacinth whole plant (WHLS-DCP) led to a better improvement in the nitrogen retained .

4.1 Introduction

In the West African sub–region most of our economies are predominately agricultural base (Amaning- Kwarteng, 1991; MacMillan, 1996) with most of our ruminants fed mainly poor quality natural grass and agricultural by-products such as rice straw (Fleischer and Timpong, 1996). Although rice straw is available all year round and in large quantities (Adjorlolo *et al.,* 2001) its usage is limited due to its low digestibility and protein content (Van-Soest, 1994). However with feed accounting for the main cost of production, even if household labour is been cost (Bagyaraj and Rangswami, 2001) there is the need to improve available feed resources. One of such intervention is chemical treatment of straw, urea and NaOH treatments of straw have been found to break down lignocelluloses linkage in straw (Adjorlolo, 1999, Sottie,1997) making available the potential fermentable dry matter.

Cassava peels like most root crops is said to have high crude protein compared with the edible portion (Adjorlolo *et al.,* 2001; Mettle *et al.*, 2010) and high gross energy (Oyebimpe *et al.,* 2006). Although the protein in cassava peels by-pass rumen degradation (Gohl, 1981) they are not enough to support growth in ruminant; however it provides readily available energy for rumen microbial degradation. There is therefore the need to provide additional protein source if production is to be sustained.

Water hyacinth, an invasive aquatic weed, is known to have high biomass (Joyce, 1990) and is rich in crude protein content. Crude protein is content between 20-35% has been observed by Ndimele *et al.* (2011) and Thu (2011). According to Nguyen et al. (2000) water hyacinth leaf or stem can replace 40-60% of para grass in rabbit diet. The use of water hyacinth leaf or stem to improve digestibility in goat have been observed by Bui *et al.* (1992a).

Considering the high protein content of water hyacinth and the energy and by pass nature of cassava peels one could speculate that the combination of these will improve the digestibility and nitrogen needs of sheep. The objective of the study was therefore to find out the effect of water hyacinth and cassava peels supplementation on the digestibility and nitrogen retention of sheep fed a basal diet of NaOH-treated rice straw.

Specific objectives

- To determine the effect of the diets (WHL, WHLS, WHL-DCP, WHLS-DCP and ENS) on nutrient digestibility of sheep.
- To determine the effect of the various diet (WHL, WHLS, WHL-DCP, WHLS-DCP and ENS) on nitrogen retention in sheep.

4.2 Experimental procedure

4.2.1 *In-vivo* Nutrient Digestibility and Nitrogen balance

Five intact djallonke sheep with mean 27±0.1 kg were randomly assigned to five treatments in a 5 x 5 Latin square design and put in wooden metabolic crates. Drinking water was provided *ad libitum* to the animals. Daily feed offer and refusal were weighed. Each trial lasted for 21 days each; comprising of 14days of adjustment and 7days of data collection. Faeces were collected in the morning before feeding. Fresh weight of the fecal samples was taken; ten percent of each collected fecal sample was oven dried at 55^0C, than milled and stored in polythene bags packed in envelopes for chemical analysis. The fecal sample remaining after the 10% was collected for each day per treatment was oven dried at 105^0C for 24 hours to determine the gross fecal dry matter

Urine was collected using funnels attached to the genital region of the animals and connected to rubber tubes which led to a plastic bottle containing 20ml of 10% H_2SO_4. Ten percent of total urine sample was bulk per treatment per animal and frozen. These were thawed before analyzing them.

$$\text{Nutrient Digestibility (\%)} = \frac{\text{nutrient in feed – nutrient Faeces}}{\text{nutrient in Feed}} \times 100$$

Nitrogen balance (%) = nitrogen intake-(fecal + urine nitrogen)

Statistical Analysis

Data for digestibility and nitrogen retention were subjected to analysis of variance using GenStat (2009) and mean separation was done using least significant difference (LSD).

4.3 RESULTS

4.3.1 Chemical Composition

The chemical composition of NaOH-treated rice straw (ENS), ensiled water hyacinth leaf (L), ensiled water hyacinth whole plant (LS) and dried cassava peels (DCP) as presented in Table 3.1. There were differences among the various feed ingredient used in the experiment on dry matter basis. Cassava peels had the highest DM content (95%) and the lowest was ensiled water hyacinth leaf (36.05%). The levels of CP fractions observed in the water hyacinth leave (28.03%) and water hyacinth whole plant (21.17%) were high. The lowest CP fractions were observed in rice straw (4.22%) and cassava peels (1.48%).

The least NDF value was observed in cassava peels (35.39%) followed by NaOH-treated rice straw (54.57%). The highest neutral detergent fiber value was observed in water hyacinth whole plant (67.51%) followed by the water hyacinth leaf (63.16%). There was no difference in the ADF values observed in water hyacinth leaf (50.57%) and NaOH-treated straw (50.93%). The ADF value observed in the dried cassava peels was (26.6%), whereas that of water hyacinth leaf was 45.29%. The highest percent cellulose content was observed in rice straw (32.67%). There was no difference in the mean percent cellulose value for ensiled water hyacinth leaves (28.13%) and ensiled water hyacinth whole plant (28.29%). The highest lignin values were observed in water hyacinth whole plant (11.58%) and water hyacinth leaf (11.07%) followed by dried cassava peels (10.4%) with NaOH-treated rice straw having the least. There was however, no difference in the silica content of cassava peels 10.8% and water hyacinth whole plant (10.7%). The highest silica content was (12.37%) observed in the treated rice straw and the least was (6.08%) for water hyacinth leaf.

4.3.2 *In-vivo* Digestibility for NaOH Treated-Rice Straw Supplemented with Water Hyacinth dried Cassava Peels

Table 4.2 presented below shows the mean *in-vivo* digestibility of WHL, WHLS and WHL-DCP and WHLS-DCP diets. There were significant differences ($P<0.05$) in the nutrient digestibility for the various treatments. The highest mean value ($P<0.05$) for the dry matter digestibility was WHLS-CP this was followed by WHL-CP, WHLS, WHL with ENS having the least. The mean NDF digestibility values observed were 63.62%, 67.78%, 74.71%, 76.78% and 54.38% for WHL, WHLS, WHL-CP, WHLS-CP and ENS respectively. The highest mean CP digestibility value was observed when the diet was WHLS (92.5%), followed by WHL (78.57), WHLS-DCP (75.35%), WHL-DCP (63.81%) and ENS (55.87%). The highest mean organic matter digestibility value was observed when the diet was WHLS-DCP and the least was observed in ENS diet.

4.3.3 Nitrogen Retained of NaOH Treated-Rice Straw Supplemented with Water Hyacinth and dried Cassava Peels

Table 4.3 shows the mean values for nitrogen retained observed in the study. The highest significant differences ($P<0.05$) for the mean nitrogen intake was observed in WHL and lowest intake was observed in ENS. The highest ($P<0.05$) mean fecal nitrogen value was observed in

WHL-CP and the lowest in WHLS. Significant differences ($P<0.05$) were observed in the mean urine nitrogen values; with WHLS having the highest urine nitrogen and the lowest observed when ENS was fed alone. There were significant differences ($P<0.05$) among the various treatment in terms of nitrogen retained with ENS given a negative nitrogen retention.

Table 4.1 Mean *in-vivo* digestibility values of WHL, WHLS, WHL-DCP, WHLS-DCP and ENS

Treatment	WHL	WHLS	WHL-CP	WHLS-CP	ENS	SD
DMD (%)	65.68^{d}	68.30^{c}	75.64^{b}	77.20^{a}	52.20^{e}	1.06
NDF-D (%)	63.62^{d}	67.78^{c}	74.71^{b}	76.78^{a}	54.38^{e}	1.2
CP-D (%)	78.57^{b}	92.50^{a}	63.80^{d}	75.35^{c}	55.87^{e}	1.09
OMD (%)	67.38^{d}	69.41^{c}	80.71^{b}	83.03^{a}	55.10^{e}	1.01

Figures bearing the same superscript within column are not significantly different ($P>0.05$)

Table 4.2 Effect of water hyacinth and dried cassava peels supplementation on nitrogen intake (N-I), fecal nitrogen (F-N), urine nitrogen (U-N) and nitrogen retained (N-R)

Treatment	WHL	WHLS	WHL-CP	WHLS-CP	ENS	SD
N-I (%)	42.99^{a}	40.26^{c}	41.99^{b}	39.34^{d}	20.82^{e}	0.22
F-N (%)	9.8^{b}	3.12^{e}	15.6^{a}	8.47^{c}	6.0^{d}	0.34
U-N (%)	31.87^{b}	34.99^{a}	23.11^{d}	28.35^{c}	19.12^{e}	1.65
N-R (%)	1.32^{d}	2.15^{c}	3.28^{a}	2.52^{b}	-4.30^{e}	1.46

Note: means in the same row with different superscript are significantly different ($P<0.05$)

4.4 DISCUSSION

4.4.1 Chemicals Composition of Feed Ingredients

The low dry matter content of the water hyacinth compared to the other feeds was because of the high moisture content of the plant. According to Crowder and Chheda, (1982) when moisture content is above 60% there is a low nutrient intake and as a result poor animal performance. This low dry matter content might be one of the reasons why it has been suggested that water hyacinth should not be fed as a sole diet but be used as a supplement or fed in combination with other crop residues (Khal, 1977). The dry matter content of the leaves 35.95% and whole plant 40.03% observed in this study is higher than 15.33% for non-ensiled water hyacinth leaves observed by (Hira *et al.,* 2002) the differences might be due to ensiling done in current study. It is however, comparable to what was reported by Nutsugah (2011) who observed a dry matter of 30.05% for ensiled leaf and for whole plant 28.16±2.6. These higher values obtained in this study, might be as a result of the wilting before ensiling. Wilting usually increases the dry matter value of feed. This practice result in improve dry matter intake and animal performance.

The dry matter content of the NaOH-treated straw (85.69%) was comparable to what was observed by Adjorlolo (1999). He observed a dry matter of 88.3% for NaOH treated rice straw. It is however, higher than the range of 72% - 79% observed by Nour (1986) and Fleischer *et al.,* (2000) for NaOH treated straw. The difference might be due to the post-harvest handling of the straw used. For the cassava peels, the dry matter content was very high compared to the other ingredients used in the study. The dry matter content of 95% observed for the dried cassava peels is closer to the dry matter range of 88.9%-87.39 observed by Baiden *et al.* (2007) and Akpabio *et al.* (2012) for both the bitter and sweet varieties of cassava peels respectively. The difference in the dry matter content might be attributed to differences in post harvesting handing processes.

The observed crude protein level for leaves and whole plant was high compared with the other feed ingredients. A crude protein level of 28% and 21.17% (from Table 4.1) for leaves and whole plant respectively observed in this study was comparable to 11-21% crude protein reported by the ARC (1980), as a minimum levels adequate for moderate level of production for ruminants. It is also within the range of 25-35% observed by Ndimele *et al.,* (2011) for water hyacinth. They concluded that, the variation is due to the plant part that is used. It is however in agreement with what was observed by Sotulo and Sulu (2011) and Thu (2011); both authors observed a crude protein range of 21.8% - 28.2% for water hyacinth leaves and 18.41% - 24.17% for whole plant. This study further supports the fact that water hyacinth leaves and whole plant can be used as a supplement to low quality crop residues. The crude protein of water hyacinth is dependent on the age, location, climatic condition and level of nutrients in the water in which it grows. The younger the plant the more protein there is and the higher the nutrients in the plant protein fraction (Taylor *et al.,* 1971).

The crude protein of 4.22% for the NaOH treated rice straw was lower than the range of 5.52% - 8.82% observed by Nour (1986) and Adjorlolo (1999) for NaOH treated rice straw. The difference in the protein level might be as a result of nutrient level of the soil in which the plant was grown and post-harvesting handling of straw that was used for this study. The lowest crude protein was observed with Cassava peels, this is so because cassava peels naturally is known to be high in energy and poor in protein. However, the crude protein content of cassava peels depends on the variety used and the processing technique employed before peels are collected (in this study cassava peels were collected from a gari processing factory) also the rate of drying may have led to the low crude protein level. The crude protein level, however, is within the range of 1.4%–1.63% for bitter variety and 2.63% for sweet variety as observed by NRCRI (2005) and Akpabio *et al*. (2012).

The ash content of water hyacinth observed in this study is in agreement with an earlier report by Nguyen, (1996) who observed an ash content of 30% for the aerial part of the plant. Abdelhamid and Gabr (1991) and Lata and Dubey (2010) also recorded an ash content of 12-

25% for the water hyacinth plant. This is usual of the plant because it is an aquatic plant and like all aquatic plants, it is known to have high mineral content and therefore low organic matter content. There was no difference between the ash content of NaOH-treated rice straw and water hyacinth whole plant. The high ash content of the treated straw might be as a result of NaOH-treatment of straw (Nour, 1986). Sun drying is known to increase nutrient content of cassava peels. This is reflected in the current study with cassava peels having an ash content of 14.98% although it seems to be the least among the diets in the study. This value is in agreement with earlier reports by Adegbola and Asaolu (1986), Calvosa and Amorigi (2010) both recording an ash of 7% for fresh cassava peels and 15.5% for sun dried cassava peels.

The lower NDF and ADF values observed in the current study for water hyacinth leaf are comparable with the finding by Aboud *et al.* (2005). The leaf NDF of (63.17%) observed in the current study were higher than a ranged of 53-55.16% NDF for water hyacinth leaf (Nutsugah, 2011; Bui *et al.* (1992b) and the ADF of 45.29% in the current study is lower than a range of 49.95-53.38% for water hyacinth whole plant (Sornvoraweat and Kongkiattikajorn, 2010 and Nutsugah, 2011).The high values observed in the current study might be due to the wilting of water hyacinth before ensiling.

The NDF of the NaOH-treated rice straw (54.36%) observed in the current study is lower than NDF ranged of 66.8-73.05% (Adjorlolo, 1999 and Fleischer *et al.,* 2000). These authors also observed an ADF range of 54.55-55.1%. The difference might be attributed to post handling treatment of the straw before ensiling. The NDF and ADF for cassava peels were the least among the ingredients. This means cassava peels will have an increased digestibility when given as a feed. Norton (1994) observed that feed with low NDF values (20-35%) are usually high in digestibility. The NDF value of the cassava peels (35.39%) and ADF of (26.66%) is comparable to NDF of 34% and ADF of 24.6% (Bawala *et al*., 2007; and Ifut, 1987)

The cellulose content (28.13% and 28.29%) of the L and LS respectively within the range of 17-31% observed by Gunnarson and Peterson (2007). It is however lower than a range of 30-35% observed by Anjanabha and Kumar (2010). The difference might be due to treatment given in the current study. The cellulose in the NaOH-treated rice straw (32.67%) is comparable to 33.4% observed by Fleischer *et al.* (2000) but however lower than 36.7% reported by Adjorlolo (1999).

There was no observable mean difference in the lignin content of L and LS. The lignin content of the straw is within the range of 5.98- 9.02 (Adjorlolo, 1999 and Fleischer *et al*., 2000). Lignin is known to have effect on the digestibility of feed, plants with low lignin content known to have high digestibility compared to those with high lignin content.

There was no difference in the silica content of cassava peels and LS. The percent silica of the treated rice straw (12.37%) was comparable to what was recorded by Adjorlolo, (1999) thus (13.1%) for NaOH treated rice straw. Silica is part of the indigestible component of the plant so the higher it is the lower the digestibility.

4.4.2 Effect of WHL, WHLS, WHL-DCP and WHLS-DCP diets on *In-vivo* Nutrient Digestibility

From Table 4.2, the dry matter digestibility (DMD) of the NaOH treated-rice straw (52.2%) observed in this current study is within the range of 50–59% observed by Adjorlolo (1999), and Fleischer *et al*. (2000) for NaOH-treated straw. The dry matter digestibility (65.68%) observed when the supplement was WHL is in agreement with what has been observed by other authors (Hira *et al.,* 2002; Nguyen, 2010). The dry matter digestibility when the supplement was WHL is also comparable to the dry matter digestibility of 64% observed by Adegbola, (2002) when rice straw was supplemented with groundnut hay. It could be observed from the study that the addition of a supplement to NaOH-treated rice straw resulted in an increased in dry matter digestibility with WHLS-DCP having the highest dry matter digestibility.

The organic matter digestibility of any feed is of great important for the manufacture and the end users (animals) because it gives information on the energy value in that feed when it is given to the animals (Thomas and Hall, 1984). It could be observed from the study that the entire supplement lead to an improvement in the organic matter digestibility contrary to the observation by Haddad *et al.* (2001) and Dabiri and Thonny (2004). These authors observed that protein source has no effect on organic and dry matter digestibility. However, the addition of an energy source to water hyacinth (WHL-DCP, WHLS-DCP), gave better organic matter digestibility meaning animals on such diets were effective in converting their feed into an energy source for usage. The high dry matter digestibility and organic matter digestibility observed with WHLS-DCP and WHL-DCP might also be attributed to the supply of degradable nitrogen in the rumen synchronizing with the supply of fermentable carbohydrate. Similar observation was made by McCarthy, *et al.* (1989) when they added a source of carbohydrate (molasses) to star-grass compared to when star-grass was fed alone, and also Egyir (1994) when he compared Urea–molasses with ammoniated rice straw. Although the ENS gave low organic matter digestibility compared with the other diets, its organic matter digestibility of 55.10% is higher compared to 48.25% observed by Egyir (1994) for untreated rice straw. NaOH treatment is known to weaken the cell wall component of plants and increase the swelling capacity of the cell wall (Smith, 1989) and as result feeding such diet leads to high dry matter digestible and organic matter digestibly.

Since crude protein of feed have effect on feed intake and digestibility of feed, it was expected WHL supplement which have a crude protein of 28.2% will facilitate the intake of the basal diet and therefore have high dry matter and organic matter digestibility compared with those on WHLS which has a crude protein of 21.17% but the reverse happened in this study. The difference might be due to the part of the forage being used and the availability of the nutrient to the animal. According to Lowry *et al.* (1996), leaves of most fodder forage are high in tannins, saponins and non-protein amino acids. Water hyacinth leaves have been observed by Khal (1977) to have a tannins level of 2% compared to the 1% for the whole plant. Although this is not significant to for it to be lethal the animal it might be the cause of the low dry matter and organic matter digestibility observed for WHL diet compared with WHLS diet. Sophia et al. (2010) also observed low nutrient digestibility with water hyacinth leave supplement compared to water hyacinth whole plant supplement to rice straw.

From the study there was a high crude protein digestibility for animals on diet without cassava peels (WHL, WHLS) compared to those on diet with cassava peels (WHL-DCP, WLS-DCP). The high crude protein digestibility might be due to better rumen environment created by WHL and WHLS diets for microbial degradations. However the low crude protein digestibility with the animals on WHL-DCP and WHLS-DCP diets might be due to an increase in quantity of water soluble nitrogen of microbial and endogenous origin ending up in feaces instead of the feed. This will lead to an over estimation of crude protein in feaces which should have been part of the feed. Similar observation was made by Egyir (1994) when he compared Urea–molasses with ammoniated rice straw.

The crude protein digestibility (63.8%) observed for WHL-DCP is comparable to the range of 64.5-70.93% observed by Aye and Adegun (2010) and Okoruwa *et al.* (2012) when they supplemented grass with cassava peels and fed to sheep.

The crude protein digestibility for WHL (78.57%) was comparable to the range 78.3-78.8% observed by Nguyen (2010) and Ho (2012) when they used water hyacinth leaf as a supplement to rice straw. It is however, higher than 55% observed by Adjorlolo (1999) when he supplemented NaOH treated rice straw with mucuna leaves suggesting that NaOH- treated rice straw supplemented with water hyacinth leaves is of better quality in terms of crude protein digestibility compared with using mucuna leaves. The high crude protein digestibility (92.5% and 78.57%) observed when the diet were WHLS and WHL respectively might be due to the favorable rumen environment such as higher rumen ammonia levels. The crude protein digestibility observed for NaOH treated rice straw (55.87%) was higher when compared to 44.3% observed by Adjorlolo (1999) for NaOH-treated straw. The difference might be attributed to the post-harvest treatment of straw and the difference in the animal condition at the time of the study.

Comparing the NDF of ENS to the other diets, it was observed that supplement led to an improved NDF digestibility. The highest NDF digestibility was observed with diets that have cassava peels inclusion (WHLS-DCP and WHL-DCP). High NDF digestibility has been associated with high passage rate and as a result high intake of such diets. This might have resulted in high dry matter and organic matter digestibility observed with WHL-DCP and WHLS-DCP. The low NDF digestibility of WHL-DCP compared with WHLS-DCP might be been associated with low rumen pH. It is further explained by the observation by Van Soest (1982), Mould *et al.* (1983), and Egyir (1994).These authors' explained that lower values of

NDF digestion observed when sheep are fed readily fermentable carbohydrates are due to a decline in rumen pH. In the current study the lowest mean rumen pH was observed when the diet was WHL-CP (see Table 6.5).

The highest NDF digestibility values were observed when the diets were WHLS-DCP and WHL-DCP, might be also be attributed better to rumen environment created. Hence, microbial degradation of fiber was quite rapid (Sanson *et al*. 1990)

4.4.3 The Effect of the various Diets on the Nitrogen Retention of Djallonke Sheep

From Table 4.3 it was observed that the addition of cassava peels to water hyacinth resulted in an increased fecal nitrogen for both WHL-DCP and WHLS-DCP diet. However, WHL-DCP diet was observed to have high fecal nitrogen. Soluble nitrogen in Faeces is mostly from microbial degradation and endogenous sources more than dietary. This means these diets provided a better rumen environment for microbial growth and therefore more microbes escaping from the rumen to the intestines for usage by the host. This might also be the result of the low crude protein digestibility when the diet was WHL-DCP.

It could also be seen that as the fecal nitrogen increases urine nitrogen reduces, with the least urine nitrogen observed when the diet was WHL-CP (Table 4.3). These low urine nitrogen observed might be attributed to the presence of condensed tannins. Condensed tannins binds protein and other macro-molecules in the rumen, and reduce the availability of nutrients to microbial degradation (Kumar and D'Mello, 1995; McAllister *et al.,* 2005). They mainly reduce excessive ammonia production in the rumen (as observed in WHL-CP see Table 6.5) and decreasing urinary nitrogen losses (Barry, 1985 and Bengaly *et al.,* 2007). This usually leads to increase nitrogen retention for ruminants fed tannin-rich plants (Kaitho *et al.,* 1998). The high nitrogen retention observed when cassava peels was added to the water hyacinth (WHL-CP and

WHLS-CP) means more nitrogen was retained by animals on those diets and may contribute to the better growth rate of animals on that diet. High nitrogen retention was observed by Pathokmmalansy and Pretson (2008) when they fed Tithonia forage together with cassava chips as a fermentable carbohydrate and Egyir (1994) when he compared urea- ammoniated straw with urea- molasses block as feed to livestock.

The low fecal and high urine nitrogen observed for WHL and WHLS might be due to increase dietary protein intake without increased in energy intake. This also means the full benefit for the metabolism of protein was not achieved as there were high protein metabolism to ammonia in the rumen, as a result a reduction in the quantity of protein digested in the small intestine and an increased in urinary nitrogen excretion.

4.5 Conclusion

From the study it was observed that both water hyacinth leave and whole plant are rich in crude protein and could be used as a supplement. It was observed that all the supplements lead to an improvement in the nutrient digestibility and nitrogen retained when compared with the basal diet alone.

However ranking the supplement it was observed that WHLS-DCP and WHL-DCP gave better nutrient digestibility and nitrogen retention than WHL and WHLS diets. The negative nitrogen retained observed when ENS was feed alone confirm the need to add nitrogen supplement to crop residue when given as feed to animal.

As a result of the poor nitrogen retention observed in ENS diet alone it was concluded that it could not support animal survivor for long time so was not used in the growth experiment.

4.6 Recommendation

From the study WHLS-DCP and WHL-DCP is recommend to small ruminant farms as a protein and energy supplement feed. This would help solve environmental problems created by water hyacinth on water bodies. Also with establishment of starch and gari factories and also the use of cassava in the brewery industry the collections cassava peels will be easy and can therefore be collected and utilized.

CHAPTER FIVE

5.0 EXPERIMENT TWO

Influence of ensiled water hyacinth and cassava peel supplementation on voluntary intake and growth of sheep fed sodium hydroxide-treated-rice straw

Abstract

A study was conducted to determine the effect of supplementation of ensiled water hyacinth with or without dried cassava peels on voluntary intake and growth of djallonke sheep fed a basal diet of NaOH-treated rice straw. Sixteen animals with an average weight of 16.5±0.5kg were randomly allocated to four dietary treatments with four animals per treatment in completely randomized design experiment. The diets were WHL, WHLS, WHL-CP and WHLS-CP as used in experiment 1. Feed offered and refusals were weighed each day to determine voluntary feed intake. Digestible organic matter digestibility (DOMD) in dry matter and metabolized energy intake (MEI) were also calculated. Animals were weighed every two weeks to determine growth rate.

In terms of mean voluntary feed intake of straw animals on WHLS-CP diet had the highest ($P<0.05$) (644.3g/d) straw dry matter intake, followed by those on WHL-CP (546.6g/d), with those on WHL (498.8g/d) and WHLS (467.95g/d) having the lower straw dry matter intake. There were significant differences ($P<0.05$) in the mean total dry matter intakes. These were 689.59g/d, 659.94g/d, 596.77g/d and 527.53g/d for WHLS-CP, WHL-CP, WHLS and WHL respectively.

Significant differences ($P<0.05$) were observed in the mean digestible organic matter in dry matter (DOMD) and the metabolized energy intake (MEI). WHLS-CP diet had the highest DOMD and MEI but the lowest was observed in WHL diet. The highest growth rate was observed when the diet was WHLS-CP; this was followed by WHL-CP, WHLS and WHL respectively. The mean growth rates were -0.020g/d, -0.0015g/d, 0.0568g/d, and 0.0684g/d for WHL, WHLS, WHL-CP, and WHLS-CP respectively.

The results indicate that the observed improvement in dry matter intake and live weight gain could be attributed to the improved energy intake resulting from the addition of cassava peels.

5.1 Introduction

In Ghana most of our ruminants rely on natural pasture (Adjorlolo *et al.,* 2001) which are mostly nutritious and productive during the raining season but become more fibrous in the dry season (Teye e*t al.,* 2010). Feeding animals with high fiber diet usually leads to loss of weight and sometimes death (Teye *at al.,* 2010). In order to prevent such occurrence animal feed need to be supplemented. Supplementing with agro- industrial by product such as urea molasses, wheat bran and mineral lick have been found to improve the growth in ruminants (Amaning-Kwarteng *et al*, 2010; Addo, 2005), but these usually come with an additional cost to the local farmer. One other supplements which is cheap but potentially effective that can be exploited for ruminant use in Ghana is cassava peels.

Cassava peels, a kitchen/ industrial waste from cassava tuberous root processing, is high in crude protein compared to the tuber and it also provide readily available energy for ruminant. However it's usage as a sole diet is not encouraged since it is low in protein (Mettle *et al.,* 2010) hence the need for an additional protein source if it is to be used in feeding animals.

Water hyacinth an aggressive aquatic weed found in lakes, rivers and stream, block water ways, impedes electricity generation and kills living things in water bodies by blocking oxygen supply (Joyce, 1990). It is however high in protein (20-30%) according to Nguyen (2010), Sotolu and Sule, (2011) and can grow all year round. In the dry season animals such as buffalo and cattle are found grazing on it. Information on its chemical and anti-nutritional properties have been well documented by (Nutsugah, 2011; Pham, 2008).

With high crude protein content, using it in addition to energy source such as cassava peels will lead to growth of sheep. However information on it usage together is rare. This study therefore seeks to find out the effect of supplementing NaOH-treated rice straw with water hyacinth and dry cassava peels. The specific objective include: the effect of the supplement on:

- Voluntary intake of feed
- Digestible organic matter digestibility in dry matter
- Metabolized energy intake
- Growth rate

5.2 Experimental Procedure

5.2.1Voluntary Intakes and Growth Rate of Sheep feed NaOH-Treated Rice Straw Supplement with Water Hyacinth with or without Cassava Peels

Sixteen rams with average live weights of 16.5±0.5kg were housed in individual pens with concrete floors. Four animals were assigned to each of the four experimental diets as used in experiment one: Diet 1 (WHL), diet 2 (WHLS), diet 3 (WHL-DCP) and diet 4 (WHLS-DCP) in a completely randomized deigns.

The supplemental diets were offered to the animals one hour before the basal diet of sodium hydroxide-treated rice straw was given. Animals were conditioned for two weeks for them to get used to the experimental diet.

The water hyacinths were offered at 7g crude protein per 10kg live weight; and the dried cassava peels were offered at 10% of intake. Rice straw was given at 5% of body weight. Feed offered and refusals were collected to determined voluntary feed intake. Animals were weighed every two weeks to determine their growth rate. These data together with digestible organic matter (obtained from experiment one) were used to calculate digestible organic matter digestibility (DOMD) in dry matter and metabolized energy intake using the formula according to Ministry of Agriculture, Food and Fishery (1975).

Experimental Design and Statistical Analysis

Completely randomized design with four replicate was used. Analysis of variance was carried out on the data collected to determine the mean intake values and means separation was done using LSD. Analysis was done using GenStat (2009)

For the growth rate analysis of variance for simple linear regression were used to established relationships between the weights grained over time for WHL, WHLS, WHLS-DCP and WHLS-DCP. Regression models were shown with their coefficient of determinant (r^2) this was done with gen- statistics model (2009).

Calculations

$$\text{Growth rate} = \frac{\text{final } (W_2) - \text{initial } (W_1)}{\text{Finial } (T_2) \text{- initial time } (T_1)}$$

Metabolized energy intake (MEI) = DOMD*0.15*DMI (MAFF, 1975)

Where DOMD (%) =digestible organic matter digestibility in dry matter

W_2 =Finial weight gain

W_1= Initial weight

T_2=Final time

T_1= Initial time

$$\text{DOMD} = \frac{\text{organic matter intake} - \text{organic matter output x 100}}{\text{Dry matter intake}}$$ (Amaning-Kwarteng *et al.*, 2010)

5.3 RESULTS

5. 3. 1 Intakes and Weight Gain of Sheep fed NaOH- Treated Rice Straw Supplemented with either Ensiled Water Hyacinth or Ensiled Water Hyacinth combined with Dried Cassava Peels

Table 5.1 shows the mean intakes; digestible organic matter digestibility in dry matter and metabolized energy intake of sheep fed a basal diet of NaOH-treated rice straw. There were significant differences ($P<0.05$) among the various diets in terms of intake. The highest total crude protein intake per day was observed in WHLS-DCP, followed by WHL-DCP, WHLS and WHLS respectively. Although the mean straw crude protein intake was high with WHL diet compared to WHLS, the total crude protein intake was high when the diet was WHLS compared to WHL. For the straw, dry matter intake was high when the diet was WHLS-DCP. The lowest straw dry matter intake was observed in WHL. The total dry matter intake per day was observed to be high when the diet was WHLS-DCP followed by WHL-DCP with WHL having lowest total dry matter intake. Significant differences ($P<0.05$) were observed with the mean digestible organic matter digestibility and the mean metabolized energy intake.

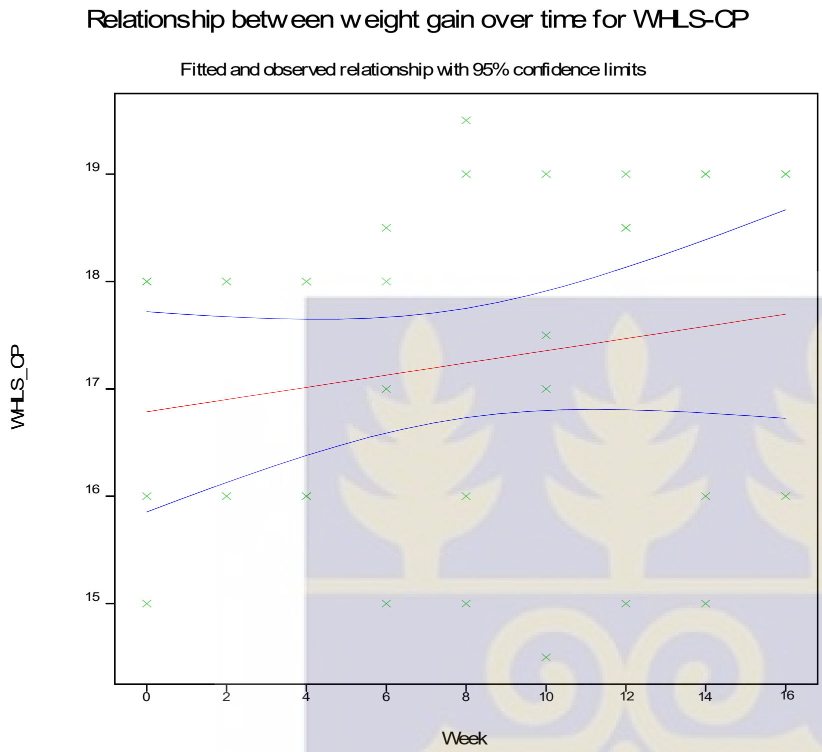
From figure 5.1, it was observed that diets with cassava peels inclusion had the highest growth rate compared with negative growth rate observed in diets without cassava peels (WHLS and WHL).

Table 5.1 Mean Intakes and weight gain in sheep fed a basal diet of NaOH- treated rice straw and supplement with water hyacinth leave, water hyacinth whole plant, water hyacinth leave plus cassava peels and water hyacinth whole plant plus cassava peels

INTAKES	WHL	WHLS	WHL-CP	WHLS-CP	SD
Straw CP (g/d)	21.05^{c}	19.75^{d}	23.07^{b}	27.19^{a}	0.34
Total CPI (g/d)	25.03^{c}	28.45^{d}	33.85^{b}	36.78^{a}	0.48
CPI/total DM (%)	4.8^{d}	5.03^{c}	5.24^{b}	5.40^{a}	0.12
Straw DM (g/d)	498.8^{c}	467.95^{d}	546.6^{b}	644.3^{a}	3.02
Total DMI (g/d)	527.53^{d}	569.77^{c}	659.94^{b}	689.59^{a}	8.02
DOMD (%)	55.74^{d}	56.41^{c}	63.58^{b}	65.30^{a}	6.60
MEI (MJ/KgD)	6.0^{d}	6.6^{c}	7.30^{b}	7.6^{a}	2.55
Growth rate (g/d)	-0.0204	-0.0015	0.0568	0.0684	0.01

Figures bearing the same superscript within rows are not significantly different (P>0.05)

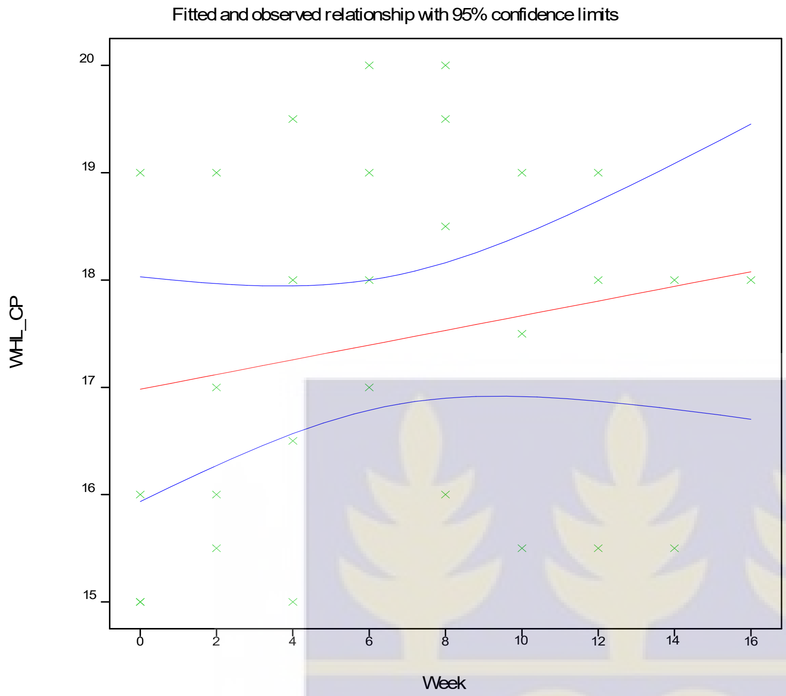
Fig 5.1 Growth rates for animals feed WHLS-CP, WHL-CP, WHLS and WHL respectively



$$y = 16.787 + 0.0568\boldsymbol{x}$$

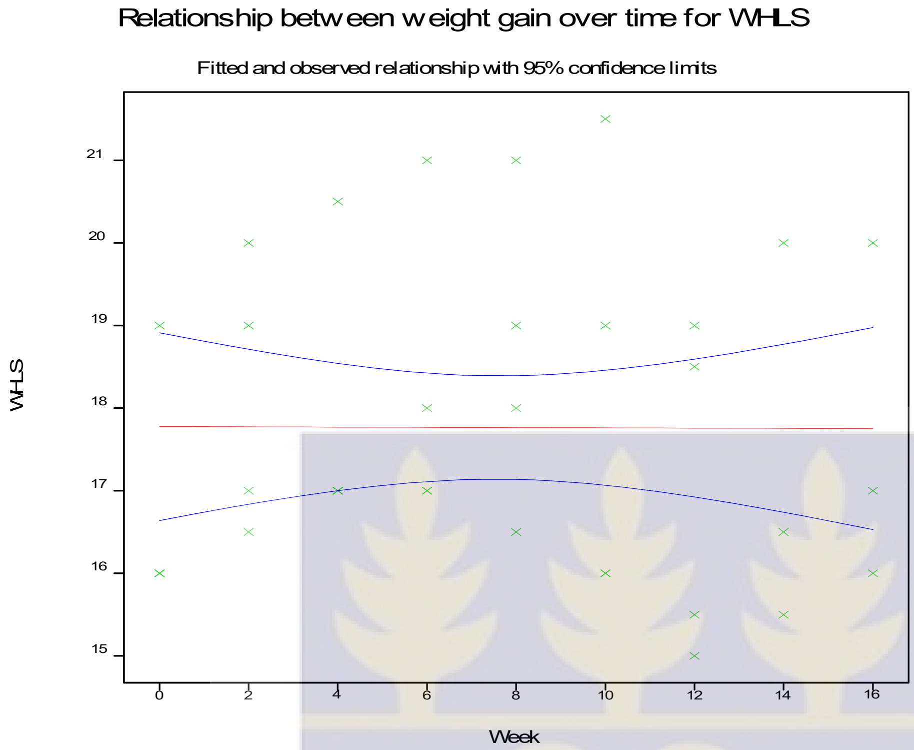
$$r^2 = 3.58\%$$

Relationship between weight gain over time for WHL-CP



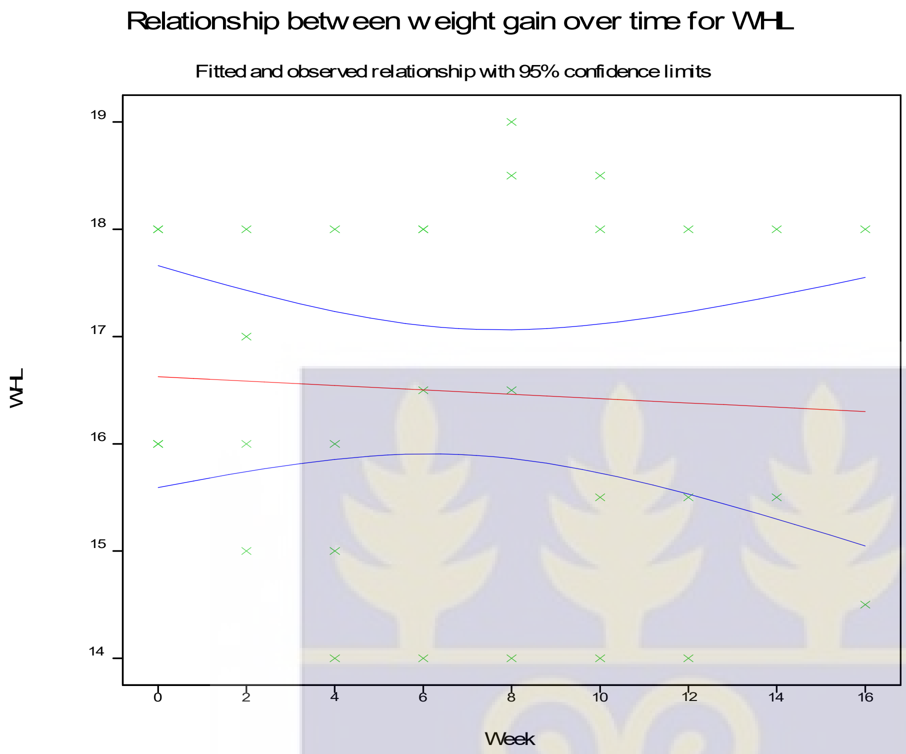
$$y = 16.983 + 0.0684x$$

$$r^2 = 3.75\%$$



$$y = 17.776 - 0.0015x$$

$$r^2 = 0.013\%$$



$$y = 16.626 - 0.0204x$$

$$r^2 = 0.37\%$$

5.4 DISCUSSION

5.4.1 Intake and Growth Rate of Sheep fed Experimental Diets

Significant differences (P<0.05) were seen in the various diets in terms of intake. However diets with cassava peels inclusion (WHL-DCP and WHLS-DCP) were observed to have high crude protein intake compared with those without (WHL, WHLS). This might have stimulated high intake of the basal straw and as a result high total dry matter intake in WHL-DCP and WHLS-DCP diets. Apori *et al*. (2005) and Adejoke (2013), also observed that high intake of crude protein are associated with high intake of straw. The addition of an energy source might have provided available carbohydrate for rumen microbes to use. An activated rumen microbes enhance better straw degradation (Egyri, 1994). The low dry matter intake for the diets without cassava peels (WHLS and WHL) might be attributed to low crude protein intake and low NDF digestibility observed in experiment one. Sophia *et al.* (2010) also observed low dry matter intake when water hyacinth leave and water hyacinth whole plant was used as a supplement to rice straw.

Although all diets led to an improvement in the digestible organic matter digestibility in dry matter, diets with cassava peels were observed to have high digestible organic matter digestibility in dry matter (DOMD) and metabolized energy intake (MEI). The higher MEI value the higher the amount energy retained by the animal for growth and other products such as milk and eggs. This might have resulted in the high growth rate for animals on WHLS-DCP and WHL-DCP diets compared to WHLS and WHL diets. The high growth rate might also be attributed to the high dry matter intake and nitrogen retention observed when the diets were WHLS-DCP and WHLS-DCP. Although WHL and WHLS diets have low growth rate it was better when compared with 56g/d weight loss observed by Adjorlolo *et al.* (2001), when they feed NaOH-treated straw alone. It was observed from the study that, there was an initial weight gain for animals on all the various diets until the 10week when weight started to drop. At this point animals on WHLS-CP and WHL-CP diets were observed to maintain their weight whiles WHLS and WHL diet had their animals losing weight. This also suggests that WHL and WHLS supplement could be served to animals to help solved dry seasonal feed shortage for a short period of time. However for efficient performance an energy source such as cassava peels could be added to water hyacinth.

5.5 Conclusion Voluntary Intake and Growth Rate

The addition of dried cassava peels to water hyacinth resulted in higher intake of crude protein and dry matter of the straw compared with when water hyacinth was fed without cassava peels. Among the various diets, treatment with cassava peels inclusion was observed to have high growth rate whiles those without cassava had a negative growth rate.

5.6 Recommendation

The present study suggest the need to add nitrogen and an energy source as a supplement to animal feed for better growth and development.

CHAPTER SIX

6.0 EXPERIMENT THREE

Effect of Water Hyacinth and Dried Cassava Peels Supplementation on *In-Sacco* Degradation and Rumen Parameters in sheep fed NaOH-treated rice straw

Abstract

A study was conducted to determine the effect of supplementation of ensiled water hyacinth with or without cassava peels on rumen degradation of treated rice straw and rumen parameters

Latin square design (4x4) was used for the study, with four rumen-fistulated sheep with weight of 20±2.1kg. All the animals were on a basal diet of NaOH-treated rice straw. Diet 1 was WHL, diet 2 WHLS, diet 3 was WHL-DCP, and diet 4 WHLS-DCP as used in experiment 1. Animals were given 14days to adjust to the basal diet.

At the end of adjustment period, rumen liquor was sampled from each animal at time 0 (before feeding), 2, 6, 8, 12, 24 hours after feeding. Collected samples were strained through cheese nylon cloth after which the pH meter was used to determine the rumen pH. Equal quantities of each sample were put in test tube for the determination of rumen ammonia. Liquor was preserved with sulphuric acid to prevent nitrogen from escaping.

Treated straw was milled to pass through a 2mm sieve at the start of the experiment and stored for use throughout the experiment. For each treatment 5g of the milled sample was weighted into Dacron bags (135mm x 75mm) and tied. Four bags were tied to a drop line consisting of nylon cords (200mm x 2mm) and weighed with a 20g steel bolt at one end. These were removed at: 3, 6, 9, 12, 24, 36, 48, 72, and 96 hours interval. At the end of each incubation time two bags were

removed from the rumen using a forceps and detached from the nylon thread. The bags were rinsed under running water until no colour was seen in the water. Acetone was used to rinse the bags again to prevent further microbial activity outside the rumen.

Significant differences (P<0.05) were observed among the various treatments in terms of rumen ammonia. The mean rumen ammonia was 4.26mg/dl, 5.31mg/dl, 2.23mg/dl, and 3.31mg/dl for WHL, WHLS, WHL-DCP, WHLS-DCP supplement respectively. No significant difference (P>0.05) was observed with the rumen pH. The mean rumen pH observed was 6.98, 6.99, 6.68, and 6.97 for WHL, WHLS, WHL-DCP, and WHLS-DCP respectively.

No significant differences (P>0.05) were observed for the soluble and insoluble fractions. However there were significant differences (P<0.05) with the rate and effective degradation of dry matter and crude protein of straw. The mean effective dry matter degradation observed were 52.83%, 54.57%, 59.95%, and 69.32% for WHL, WHLS, WHL-DCP, and WHLS-DCP respectively. The mean effective nitrogen degradation observed were 59.70%, 60.46%, 62.91%, 75.29% for WHL, WHLS, WHL-DCP and WHLS-DCP respectively.

It can be observed from the study that although WHL and WHLS had high rumen ammonia their effective nitrogen degradation was low compared with WHL-DCP and WHLS-DCP. These confirm that fact in addition to nitrogen there is the need to add an energy source for an effective degradability of straw by the rumen microbes.

6.1 INTRODUCTION

The worth of any forage as a protein supplement is determined by its ability to supply enough nitrogen and as a result increase the ammonia concentration in the rumen for microbial usage. Higher ammonia concentration also means better growth of rumen microbes and effective degradation of fiber in the rumen.

Several methods have been used to determine the rate of degradation of feed in the rumen, out of these the nylon bag technique has been found to be most reliable, cheap and easy to perform. It gives information as to extent of degradation and the rate at which it occurred (Orskov *et al.,* 1980). It involves suspension within the rumen of porous synthetic bags containing samples of test feed.

Objective

- To determine the effect of the supplements on the *In-Sacco* degradation of straw dry matter (DM) and crude protein (CP).
- To determine the effect of the various supplement on rumen ammonia, and rumen pH

6.2 Animal Management

Four rumen-fistulated sheep weighing 20± 2.0kg were used for degradation studies. All animals were dewormed and put in individual cages with feed and water supplied provided ad-lib. Animals were allowed 14 days to adjust to the feed and the cage environment. Diets given and feeding methods were as described in (chapter 5 see 5.2.1).

6.3 Collection of rumen fluid

After the 14 day adjustment period rumen fluid collection was made on the 15th day. Rumen fluid was collected at 0 (before feeding), 3, 6, 9, 12 and 24 hours after feeding. Rumen fluid was collected using a stomach tube with the aid of a vacuum pump. The fluid was quickly filtered through 3 layers cheese cloth, stirred and the pH immediately read with a pH meter (corning 250). The rumen fluid was then acidified with a few drops of concentrated sulphuric acid and stored in freezer (-5^{0}C) for subsequent analysis of ammonia.

The stored liquor was subsequently thawed, centrifuged and the supernatant analyzed for ammonia using the spectrophotometer.

6.4 Degradability Studies

Degradability studies started on the 16th day. Treated straw was grounded (1mm screen) and degradability of dry matter and nitrogen were studied. Five grams of each sample were weighed into a

nylon bags (8cm x12cm; pore size 25µ).A maximum of six bags at a time were tied to a drop line consisting of nylon cords and weighted with a 20g steel bolt at one end. One drop line was incubated at a time in the rumen of each sheep. Samples were incubated 3, 6, 9, 12, 24, 36, 48, 72 and 96 hours interval. Zero hour bags were not incubated but soak in water and then washed. At the end of each incubation time two bags were removed from the rumen using a forceps and detached from the nylon thread. The bags were rinsed under running water until no colour was seen in the water. Acetone was used to rinse the bags again to prevent further microbial activity outside the rumen. Samples were oven dry dried at 60°C for 48 hours after which it was re-weighed to determine the dry matter disappearance. Content of the bags were also analyzed for nitrogen (AOAC, 1995).

6.5. Statistical analysis

The nitrogen (N) and dry matter (DM) percent disappearance (P) was calculated as the difference between the values of the original sample weight and the dried sample weight divided by the original sample weight multiply by 100.

For each sample percent disappearance N and DM was plotted against incubation time. The values of percent solubility ‘a’ (intercept of the graph on the y-axis). The steepest section of the curves indicating maximum rate of degradation were identified and the percentage degradability (P) and incubation time (t) corresponding to the mid-point of this section were read off; this enable the degradation rate to be calculated from the exponential equation (Ørskov *et al.,* 1980).

$$P=a+b\,(1-\exp^{-ct})$$

$$PD=a+b$$

PD= potential degradation, Effective degradability (ED) values were estimated using the particle outflow rate constants (k_p) of 0.02 and 0.03 as suggested Rooke and Armstrong (1983) and cited by Amaning-Kwarteng *et al.* (1986) and Adjorlolo (1999) in the formula:

$$ED = a + \frac{b \times c}{c + k}$$

Where:

ED = effective degradability, a = water soluble component, b = insoluble but potentially rumen degradable portion, c = rate of degradability of insoluble material k = rumen fractional flow rate.

Analysis of variance and mean separation was done using Genstat (2009) package.

Analysis of variance and the least significance difference was conducted on the data collected for the rumen ammonia (6.3) using the GenStat (2009) package.

6.3 RESULTS

6.3.1 In- Sacco Dry Matter Degradation of NaOH-Treated Rice Straw

The extent of degradation of straw dry matter and nitrogen as affected by the various diets are shown in table 6.1 and 6.2 respectively. Degradation characteristic are shown in Table 6.3 and 6.4 for dry matter and nitrogen respectively. There were no significant difference ($P>0.05$) among diets in terms of soluble and insoluble fraction. Significant differences were observed with the rate of degradation for both the dry matter and nitrogen. The highest mean potential degradability was observed with WHLS-DCP and WHL-DCP diets. Significant differences ($P<0.05$) were also observed with effective degradability of both the dry matter and crude protein.

Table 6.1 Effect of experimental diets on percent Dry matter disappearance (%)

Time (hours)	WHL	WHLS	WHL-DCP	WHLS-DCP
3	28	33.14	33.62	31.33
6	29.22	34.47	36.19	33.23
9	30.30	36.02	36.17	36.21
12	35.62	38.07	39.87	39.25
24	40.02	43.80	47.16	48.86
36	48.60	50.90	51.95	53.58
48	56.76	55.18	60.91	63.02
72	66.16	66.84	73.11	76.25
96	67.20	68.55	74.35	77.58

Table 6.2 Effect of experimental diets on percent nitrogen disappearance

Time	WHL	WHLS	WHL-DCP	WHLS-DCP
3	27.29	35.48	27.15	24.72
6	29.90	39.92	29.20	27.20
9	34.82	43.30	30.62	33.83
12	39.52	45.41	38.51	39.54
24	50.75	51.94	44.46	48.44
36	59.48	57.04	50.43	55.56
48	66.29	55.91	55.91	64.35
72	72.06	71.53	69.18	73.44
96	70.15	69.05	80.55	77.76

Table 6.3 Parameter estimate (PE) for dry matter degradability of NaOH- treated rice straw

PE	WHL	WHLS	WHL-DCP	WHLS-DCP
a	19.98	23.28	20.12	25.20
b	48.4	45.20	54.31	58.38
c	0.043^c	0.045^c	0.055^b	0.072^a
a+b	68.20	68.48	74.43	83.58
$ED_{0.02}$	52.83^d	54.57^c	59.95^b	69.32^a
$ED_{0.03}$	48.31^d	50.42^c	55.42^b	63.54^a

Means bearing the same superscript within rows are not significantly different (P>0.05)

Table 6.4 Parameter estimate (PE) for nitrogen degradability of NaOH- treated rice straw

PE	WHL	WHLS	WHL-DCP	WHLS-DCP
A	18.29	30.01	15.44	13.76
b	53.77	41.52	65.11	64.00
c	0.067^a	0.055^b	0.053^c	0.050^d
a+b	72.09	71.53	80.55	77.76
$ED_{0.02}$	59.70^d	60.46^c	62.91^b	75.29^a
$ED_{0.03}$	55.43^d	56.88^c	57.02^b	74.13^a

Means bearing the same superscript within rows are not significantly different (P>0.05)
a- Soluble fraction(%), b-Insoluble fraction(%),c- The rate of degradation ((h), a+b- potential degradability(%) , ED- effective degradability.

6.3.2 Rumen pH and Ammonia studies

Table 6.5 shows mean rumen pH and ammonia values observed in the study. There were no significant differences (P>0.05) observed among the mean pH for the various diets. However, low mean pH was observed with diet 3 (WHL-DCP) compared with the other treatment.

Significant difference (P<0.05) existed among the various diets in terms of rumen ammonia concentration. The highest mean ammonia concentration was observed in diet 2 (WHLS) with WHL-CP and WHLS-CP having low ammonia concentration.

Table 6.5Mean rumen pH and ammonia of sheep fed NaOH-treated straw supplemented with hyacinth and dried cassava peels

Parameter	WHL	WHLS	WHLS-DCP	WHLS-DCP	SD
Ph	6.98^b	6.99^b	6.68^b	6.97^b	0.01
Ammonia (mg/dl)	4.26^b	5.31^a	2.23^d	3.31^c	0.27

Means bearing the same superscript within rows are not significantly different (P>0.05)

6.4 Discussion

6.4.1 *In–Sacco* Dry Matter and Nitrogen Degradability of NaOH-Treated Rice Straw Supplemented with Water Hyacinth and Water Hyacinth plus Cassava Peels

Supplementation had no effect on solubility of dry matter for all the diets; this confirms the fact solubility of the material is attributed to its chemical composition (Bonsi *et al.,* 1996) rather than the rumen environment. The dry matter solubility value in this study was similar to what was observed by Adjorlolo (1999) for NaOH-treated rice straw. It is however higher than solubility range of 4.4-10 observed by Attoh-Kotoku (2005) for incubation of untreated rice straw. This difference might be attributed to the chemical treatment given to the straw before incubation. Chemical treatment of straw is known to break down lignin content and increased the absorption potential of the straw.

The rate of degradation is an important factor in assessing fermentation activities in the rumen (Van Soest, 1994). The high mean rate of dry matter degradation observed when the diet was WHL-CP and WHLS-CP shows that soluble carbohydrates are prerequisite for rapid microbial growth and colonization. This also means animals on WHL-CP and WHLS-CP diets will empty their gut early and as a result have high intake of feed compared to those on WHL and WHLS diets. Egyir (1994) also observed that the addition of an energy source to nitrogen increased the rate of microbial degradation of fiber. These authors concluded that for optimum degradation of fiber there should be synchronization in the release of nitrogen and soluble carbohydrates.

The high effective degradability means of dry matter for WHL-CP and WHLS-CP diets is in agreement with the observation by Wanapat *et al.* (2012) and Bui *et al*. (1992b). Both authors report of positive effects on rumen degradability of fibrous substrates with addition of readily fermentable carbohydrate.

The low rate of nitrogen degradation observed for WHL-CP and WHLS-CP means ammonia will be retained in the rumen for longer periods and this will help improve degradation of straw and as a result better straw intake. Ammonia in the rumen has been attributed by many authors (Nsahlai and Umurna, 1996 and Choi *et al.* 1998) to provide amino acid, peptides, or proteins which are important for the growth of cellulolytic microbes. Better growth of cellulolytic microbes will imply better degradation since these microbes facilitate fiber degradation.

6.4.2 Rumen Ammonia Concentration and Rumen pH of Sheep fed a basal diet of NaOH-Treated Rice Straw Supplemented with Water Hyacinth and Water Hyacinth plus Cassava Peels

From the study a high ammonia concentration was observed when the diets were WHL and WHLS compared to when the supplements were WHLS-CP and WHL-CP. These results together with the high rate of degradation (Table 6.4) suggest that WHL and WHLS diets supply more of rumen degradable protein to the rumen microbes. However the low rumen ammonia concentration observed with WHL-CP and WHLS-CP may be due to ammonia losses through the rumen epithelium. Studies by Sanson *et al.* (1990) have shown that the supply of increasing amounts of readily fermentable carbohydrate decreased ammonia nitrogen concentrations due to improved nitrogen uptake by rumen microbes. This low ammonia concentration observed as a result of addition of cassava peels is in agreement with what was observed by Pham and Preston (2009) when they used cassava peels as a supplement to natural grass and Egyir (1994) when rice straw was supplemented with urea molasses blocks. The ammonia range observed in this study 2.2-5.3mg/dl (Table 6.5) is within the range of 2-9mg/100 ml observed as the minimum ammonia-nitrogen level suggesting maximizing rumen microbial synthesis (Satter and Styter 1974, Pisulewski *et al.,* 1981). The mean ammonia observed is similar to early observations by other authors Gelaye *et al.* (1990) and Gelaye and Amoah, (1991) when they fed peanut hay to goats. When Ndlovu and Howell, (1995) fed mature veld hay and deep litter poultry manure to sheep, observed an ammonia range of 2.6- 6.06mg/dl.

The various dietary supplements did not have on effect (P>0.05) on rumen pH. Similar observation made by Fleischer *et al. (*2000) and Nguyen (2010). However the low mean pH observed when the diet was WHL-CP might have accounted for the low ammonia concentration on that diet. This might be attributed to the supply of more fermentable carbohydrate to the rumen and as such stimulating rumen microbial synthesis (Fernandez and Hovell 1978) for the production of VFA. According to McDonald et al. (1993) the more VFA are produced the more acidic the rumen fluid becomes and the lower the rumen pH. This was demonstrated by Bloomfield *et al.* (1963) when they observed that at a pH of 6.2 rumen ammonia absorption was 11mg/dl and at a pH of 7.55 ammonia absorption was 26mg/dl

6.5 Conclusion

From the study it has been observed that the various supplements have effect on dry matter and nitrogen degradability. The high mean rate of dry matter degradation for WHL-CP and WHLS-CP means there will be high intake feed by animals on those diets. The low mean rate of nitrogen degradation for animals on WHL-CP and WHLS-CP means rumen ammonia will be released slowly compared to animals on WHL and WHLS diets. The mean rumen ammonia concentration observed in this study is within the minimal rumen ammonia concentration needed for the growth and development of rumen microbes.

6.6 Recommendation

From all the diets studied, water hyacinth plus cassava peels has been recommended for use as a supplement because it provide a better rumen environment for rumen microbial usage and as a result better utilization of the basal diet

CHAPTER SEVEN

7.0 GENERAL DISCUSSION

The parameters used to assess the nutritive value of sodium hydroxide-treated rice straw (ENS) supplemented with water hyacinth leave (WHL), water hyacinth whole plant (WHLS), water hyacinth leave plus cassava peels (WHL-CP) and water hyacinth whole plant plus cassava peels (WHLS-CP) were nutrient digestibility, dry matter intake, weight gain and rumen degradation and rumen dynamics.

From the study it was observed that ENS diet although improved nutrient digestibility compared to untreated rice straw, it gave negative nitrogen retention value explaining the need to add a source of nitrogen to it if it is to be in feeding animals. However, comparing ENS to ENS with supplements, it was observed that all the supplement lead to an improvement in nutrient digestibility with WHLS-CP having the highest nutrient digestibility. However the low CP digestibility observed when the diets were WHL-CP and WHLS-CP might be due to increase in quantity of water soluble nitrogen for microbial and endogenous origin ending up in Faeces instead of the feed (Marshell *et al.,* 2006). This was further explained by the high fecal and low urine nitrogen observed when the diets were WHL-CP and WHLS-CP. The low fecal and high nitrogen observed when the diets were WHL and WHLS might be due to increase in protein intake without increase in energy intake (Kaitho *et al*., 1998). This means the full benefit of metabolism of protein was not achieved as there were high protein metabolism to ammonia in the rumen (Table 6.2) and as a result reduction of protein digestion in the small intestine and an increase in urinary nitrogen excursion (see Table 4.3).

This result is further explained by the observation in Table 6.2 where animals on WHL and WHLS diet were observed to have high rumen ammonia levels and Table 6.0 where they had high crude protein degradation. These suggest that water hyacinth supply more rumen degradable protein to the microbes. The low ammonia concentration observed when the diet were WHL-CP and WHLS-CP may be due to ammonia loss through the rumen epithelium. Also the supply of readily available carbohydrate has been observed to decrease ammonia nitrogen concentration due to improve nitrogen uptake by rumen microbes (Henning *et al*., 1991).

Diets not having effect on rumen pH has been observed by Fleischer *et a*l. (2000). However Bloomfield *et al*. (1963) observed that the pH of a diet has effect on rumen ammonia concentration. With the explanation that at a pH of 6.2 the ammonia concentration was 11mg/dl and at a pH of 7.55 the ammonia concentration was 26mg/dl. This is comparable to the result in this current study when at a pH of 6.68 the ammonia concentration was 2.23mg/dl and at a pH of 6.99 the ammonia concentration was 5.31mg/dl. From the table 5.1 it was observed that WHL-CP and WHLS-CP had the highest dry matter intake. The high dry matter intake might be associated with high NDF digestibility (see Table 4.2) observed under these diets. According to Mould *et al*. (1983), diets with high NDF digestibility have been associated with high passage rate. The current study diets with cassava peels inclusion were observed to have the high passage rate (see Table 6.1.1). It might also be due slow rate at which crude protein was degraded (see Table 6.1.2) given enough time for rumen microbes to act on the straw and as result increased in the dry matter degradation. The high crude protein intakes have also been observed to stimulate high intake (Nguyen, 2010).

The high average daily gain observed when the supplement was WHL-CP and WHLS-CP was as a result of higher voluntary feed intakes, nutrient digestibility, nitrogen retention and better rumen environment observed under this supplement. This was again reflected in the high feed convention ration observed under these diets. The high feed convention in WHL-CP and WHLS-CP compared with WHLS and WHLS further concluded the fact in addition to nitrogen source there is the need to add and energy source for effective utilization of protein.

From the study it was observed that all the supplements lead to an improvement in the intake of the basal diet and the average weight gain of sheep with diet of cassava peels inclusion having high intake and average weight again. It can also be observed that although water hyacinth is high in crude protein and have high crude protein digestibility, the addition an energy source to water hyacinth lead to improvement in the rumen environment and as result better performance of animals on those diet compared with those without cassava peels.

CHAPTER EIGHT

8.0 CONCLUSIONS AND RECOMMENDATION

The abundant straw produces within the country signify significant quantities of feed accessible to small ruminant farmers, however these are of low quality due to it high lignin and poor nitrogen content.

From the study it has been affirmed that treating rice straw with sodium hydroxide lead to improvement in digestibility. However, the negative nitrogen retention observed means it cannot support growth for a long period therefore the need to be supplemented.

Supplementations with water hyacinth have shown to improve nutrient digestibility, nitrogen retention and intake. However, with the addition of cassava peels (energy source) to water hyacinth there was an effective utilization of protein and therefore better improvement in nutrient digestibility, nitrogen retention, better rumen environment and as a result high growth of animals.

From the study, it can be recommend that water hyacinth should be harvested and given to ruminants since it is high in crude protein and also rumen degradable. In doing these the pollution cause by water hyacinth to water bodies could be resolved. However, it is bulky and transportation is difficult and so the need to research into more effective ways of processing and handing it.

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