KWAME NKRUMAH UNIVERSITY OF SCIENCE AND
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DEPARTMENT OF ANIMAL SCIENCE

HERBAGE YIELD AND NUTRITIVE VALUE OF TEN VARIETIES OF ELEPHANT GRASS, *PENNISETUM PURPUREUM*, IN ASHANTI REGION OF GHANA

A THESIS SUBMITTED TO THE SCHOOL OF POSTGRADUATE STUDIES KWAME NKRUMAH UNIVERSITY OF SCIENCE AND TECHNOLOGY, KUMASI, IN PARTIAL FULFILMENT OF THE REQUIREMENTS FOR THE M.Sc. (ANIMAL SCIENCE) DEGREE

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CERTIFICATION

I certify that this thesis is the candidate's own account of his research.

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PROJECT SUPERVISOR

DECLARATION

I do hereby declare that the work presented in this thesis is the result of my own effort and that in no previous application for a degree in this University or elsewhere has such work been presented.

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ABSTRACT

Six experiments were conducted to evaluate the nutritive value of nine hybrid *Pennisetum* and a local *Pennisetum purpureum* grown in the Ashanti Region of Ghana. The hybrid varieties were: 15743, 16786, 16791, 16798, 16834, 16835, 16837, 16838 and 16840 obtained from International Livestock Research Institute (ILRI.), Ethiopia.

In the first experiment, agronomic characteristics of these varieties were measured at 56 days of regrowth. Parameters measured were plant height, bunch diameter, leafiness, stem diameter, tiller number, herbage yield and persistence.

In the second experiment (intake studies), one hundred West African Dwarf Sheep (WADS) weighing between 9kg – 20kg were randomly allocated to ten treatments balancing for weight and sex. Grasses harvested each morning and chopped into short lengths were fed to each animal and feed refusals weighed back the following morning to determine intake. Adaptation period of 14 days was followed by 22 days of data collection for each animal.

In the third trial (metabolism studies), eight WADS weighing 12 – 19 kg were used in a change over experiment. Feed intake, faecal output and urine volume was measured to determine apparent digestibility coefficient and nitrogen balance. Ten days adaptation was allowed followed by seven days collection period for each round.

Degradability studies were conducted in the fourth experiment. Four rumen-fistulated rams were used in a completely randomised design. Grass samples collected during intake and metabolism studies were used for incubation at 3, 6, 12, 24, 48, 72, 96 and 120 hrs.

In the fifth experiment grass samples collected during intake and metabolism studies were used for gas production. About 200 mg of each sample and 30 ml of rumen fluid media mixture was injected into syringes (incubation tubes) and incubated in lots of four in water-bath. Gas produced was recorded at 3, 6, 12, 24, 48, 72, 96 and 120 hrs respectively.

Each of the Pennisetum varieties and their fractions were anyalysed for

their content of crude protein (CP), neutral detergent fibre (NDF), acid detergent fibre (ADF) and acid detergent lignin (ADL). Urine and faecal nitrogen were also determined

Measurements of agronomic characteristics indicated that the DM yield was significantly ($P<0.05$) higher in variety 16840 had 1948.55kgha^{-1} while variety 15743 had the lowest, 496.06 kg/ha. The bunch diameter was significantly ($P<0.05$) greater for the local variety than the rest, which ranged from 20.3 to 50.7 cm. Tiller numbers ranged from 12 to 25 and variety 16838 was significantly ($P<0.05$) higher in tiller number than the local. Varieties 16791 and 16835 were significantly ($P<0.05$) taller than both the local and variety 16840. The plant height ranged from 57.57 cm for variety 15743 to 189.98 cm for variety, 16791 which were significantly ($P<0.05$) different. The leaf fractions were significantly ($P<0.05$) greater in varieties 15743, local, 16837 and 16786 than the rest. There were significant differences with respect to persistence. The local variety ranked highest and was significantly ($P<0.05$) better than 16840 and the rest.

The chemical composition of the grasses showed that the CP levels in the whole plant ranged from a low of 7.7% in variety 16791 to a maximum of 13.2% in variety 15743. The NDF concentrations were between 64.3% for variety 15743 to 73% for variety 16786, while ADF concentrations did not show wide variations. The values ranged from 37.3% to 45.3% for varieties 16798 and local respectively. The ADL concentrations in the whole plant were least in varieties 16838, 15743 and 16837 (0.85, 0.87 and 0.87%) respectively. ADL concentrations in the leaf and stem fractions also varied.

The dry matter intake per metabolic body size ranged from 62.78 to 80.41g kg^{-1} per day. Dry matter intake of varieties 16838 and 16786 were significantly ($P<0.05$) higher than varieties 16840, local, 16837 and 16798 while variety 16791 was least consumed. The apparent DM digestibilities of the local variety and varieties 15743, 16840 and 16838 (69.53%) were also significantly ($P<0.05$) higher than the rest.

Rumen degradation of ten varieties using samples from intake studies did not differ significantly ($P>0.05$) between the varieties at 48 and 72 hours of

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Rumen degradation of ten varieties using samples from intake studies did not differ significantly ($P>0.05$) between the varieties at 48 and 72 hours of

incubation. Differences, however, existed among the treatments during the rest of the incubation periods. There were no significant ($P>0.05$) differences between degradation constants for samples used during intake studies. Dry matter loss from 3 hours to 120 hours ranged from 181g kg^{-1} to 600g kg^{-1}. Rumen dry matter degradation using digestibility samples ranged from 90g kg^{-1} (3 hrs) to 736g kg^{-1} (120 hrs) for varieties 16798 and 15743 respectively. Dry matter losses were significantly ($P<0.05$) affected by incubation time periods, except at 48 and 72 hrs for digestibility and intake samples. Significant ($P<0.05$) differences were obtained for degradation constants (a, b, (a+b)) for samples used during digestibility studies.

In vitro gas produced at 3, 6, 12 and 48 hrs was not significantly ($P>0.05$) different using samples from digestibility studies. The volume of gas produced did not differ significantly ($P>0.05$) for each of the incubation periods when samples of intake studies were used. Similar non-significant relationship was obtained for samples used during intake studies except for the potential gas production ($P<0.05$).

In the metabolism studies, dry matter in take per metabolic body size was significantly ($P<0.05$) affected by the type of grass fed to the sheep. Varieties 16837 and 16786 were significantly ($P<0.05$) higher in dry matter intake than the rest. The least consumed were varieties 16791, 15743 and 16835. The nitrogen intake ranged from 3.89g kg^{-1} for variety 16835 to 10.57g kg^{-1} for variety 16837. Faecal nitrogen excreted ranged from 1.79g kg^{-1} for variety 15743 to 3.14g kg^{-1} for variety 16837 while urinary-N ranged from 1.18g kg^{-1} for variety 16791 to 3.34g kg^{-1} for variety 16786. The nitrogen balance was positive for all the varieties with the lowest from 0.60 for variety 16835 to 5.29 for variety 16837.

The relationship between feed intake and apparent digestibility coefficient of dry matter was not significant ($r = 0.292$). The correlation between feed intake and dry matter degradability from 3 to 120h incubation were not significant ($P>0.05$) at all incubation hours except at 6h ($r= -0.320$; $P>0.05$). However, the correlation between apparent digestibility coefficient of dry matter and dry matter degradability was significant at 96 and 120h ($r = 0.371$; $r = 0.440$; $P<0.05$) but not the rest. At 3h of incubation, significant ($P<0.05$) relationship was obtained

between apparent digestibility coefficient of dry matter and *in vitro* gas production but not the rest of incubation hours. There was significant correlation between *in vitro gas* production and dry matter degradation using intake samples at 24h ($r = 0.321$; $P<0.05$). Significant relationship ($P<0.05$) was obtained between yield and other agronomic characteristics measured. Relationship between feed intake and chemical composition were not significant ($P>0.05$) while apparent digestibility and ADF were related ($r = -0.660$).

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CHAPTER ONE

1.0 INTRODUCTION

In many developing countries and Ghana in particular, one of the problems facing the population is poor nutrition with respect to animal protein intake. In order to increase the intake of animal protein, production of animals like poultry, pigs and ruminants should be increased. Even though, there has been a steady increase in the production of poultry and pigs, their cost of production is high. These animals also compete with humans for grains and high protein feed ingredients. Thus, an alternative to this scenario is the improvement of production of ruminant livestock, which do not compete with humans for food. However, the productivity of ruminants is low due mainly to severe malnutrition of grazing animals, especially during the dry season. The problem of lack of good quality pasturelands has also contributed to the poor performance of these animals. In order to reverse this trend, there is need to introduce and develop new feed resources which possess some good attributes. To select pasture crops for an area, it is important to know the nutritive value in addition to other criteria such as agronomic characteristics and yield.

In order to assess the nutritive value of forage, the performance of the animal is the best parameter to be considered. However, feeding trials are quite expensive, laborious and time consuming. Alternatively, there are simpler but reliable methods that can be used in assessing the nutritive value of forages. These include intake, apparent digestibility coefficients of some fractions, *in sacco* degradability, *in vitro* gas production, *in vitro* digestibility and chemical composition. Of these, intake of forage is very important, in that, it greatly influences the performance of the animal since high intake generally leads to high productivity. The level of intake of a feed is influenced by a number of factors. Some of these are the capacity of the digestive tract, the digestibility of the feed, palatability, chemical composition, microbial activity and the rate of passage of undigested residues through the alimentary tract (Van Soest, 1975, Poppi *et al*. 1981). Ørskov *et al.* (1988) had also predicted intake and growth from degradation characteristics of straw. Measurement of the degradability of roughages incubated in a nylon bag in the rumen (*in sacco*) is now widely used

and reported to be generally well correlated with animal performance (Ørskov, 1989). Similarly, the amount of gas produced from gas test is indicative of the extent of degradation and digestibility of the feed which relate to intake (Ørskov, 1989). Menke and Steingass (1988) developed the gas production techniques (*in vitro* gas production) to evaluate the nutritive value of feedstuffs. Blummel and Ørskov (1993) described the kinetics of fermentation by determining the increase in gas production at a series of chosen time intervals (gas test) and then used the exponential equation $P=a+b\ (1-e^{-ct})$: (McDonald, 1981). They reported that total gas production (a + b) from ten straws correlated (r=0.88) with dry matter intake, digestible dry matter intake and growth rate. They reported that chemical composition especially nitrogen, acid detergent fibre (ADF) and neutral detergent fibre (NDF) of the forage affected its rate of digestion which in turn influenced the rate of passage and ultimately the amount of forage the animal can consume in a given period of time. Therefore a combination of these methods can provide a useful system of assessing the nutritive value of the forage species under investigation. This experiment, therefore, was designed to assess the nutritive value of nine interspecific hybrid varieties of *Pennisetum* and a local napier grass using intake, *in vivo* digestibility, *in sacco* degradability, *in vitro* gas production and chemical composition. The hybrids were developed at and provided by the International Livestock Research Institute (ILRI) in Ethiopia.

The objectives of this study were to determine:

(a) the agronomic characteristics.

(b) the chemical composition.

(c) intake, apparent dry matter digestibility, *in sacco* degradability and *in vitro* gas production

and to relate:

(d) intake to *in sacco* dry matter degradability, chemical composition, *in vitro* gas production and apparent dry matter digestibility.

(e) *in vivo* digestibility to *in sacco* dry matter degradability, and also *in vivo* digestibility to *in vitro* gas production and chemical composition.

(f) *in sacco* dry matter degradability to *in vitro* gas production,

in ten cultivars of *P. purpureum* harvested at 56 days regrowth.

CHAPTER TWO

2.0 LITERATURE REVIEW

2.1 Characteristics and nutritive value of tropical grasses

Roughages are classified as being of high or low quality depending on their nutritive value. The low quality roughages (especially straws or stovers) form substantial proportions of the diets of ruminants in the tropics.

According to Jones (1979) and FAO (1982) low quality roughages contain a crude protein of less than 70g/kg or less than 550g/kg digestible cell contents. Fibre, which forms the bulk of roughages is considered as the sum of cellulose, hemicellulose (xylans, mannans, glucomannans, arabinogalactans) and pectic substances. Fibre is normally referred to as non-starch polysaccharides (Englyst, 1989). In straws, the digestible cell contents constitute usually less than 250g/kg of the total dry matter (FAO, 1982) and therefore, make a minor contribution to nutritive value. The cell wall constituents of straws form the bulk of the feed but may have low nutritive value which could be attributed to the structural carbohydrate composition and the cross-linking of this with lignin and the physical arrangement of the cellular and vascular tissues of the plant. However, when fed to ruminants, under a conducive rumen environment, the stovers could make substantial contributions to their nutrition. Stover is the major source of energy, not only for the animal itself, but the numerous species of rumen microbes inhabiting its forestomach and large intestines (Tamminga, 1993). In addition, fibre enhances stratification in the rumen, stimulates contraction and provides adhering surface for the rumen microbes thus preventing them from being washed out of the rumen (Tamminga, 1993).

Most tropical forages differ physiologically from their temperate counterparts. Whereas they have a Carbon-4 (C4) pathway of photosynthesis (Hatch and Slack, 1970). Most temperate zone species have the C3 pathway which fix CO_2 with ribulose 1,5 – diphosphate to form two molecules of 3-phosphoglyceric acid, a 3-carbon acid via the Calvin Cycle of photosynthesis. This reaction is catalyzed by the enzyme ribulose diphosphate carboxylase.

Plants with the C_4 pathway on the other hand, fix CO_2 during photosynthesis by reacting CO_2 with phosphoenol pyruvic acid (PEP) in the presence of enzyme phosphoenol pyruvic acid carboxylase to produce oxaloacetic acid (a 4-carbon acid) via Hatch-Slack pathway. Tropical C_4 plants are photosynthetically more efficient than C3 plants because they tend to exhibit high dry matter content that is often of low nutritive value. These plants have only a few mesophyll cells between vascular bundles as compared with 10 to 15 in C3 plants. Mesophyll cells are unlignified in temperate grasses and therefore their proportion influences quality in terms of digestibility. This and other conditions, such as climatic factors, transpiration and distribution of vascular bundles affect the characteristics of these feeds. The high resistance offered to both mechanical and microbial degradation by the specialized anatomy of tropical grasses may partly explain the longer retention time of these in the rumen compared to temperate grasses. The consequence of this is higher rumen fill and depressed feed intake (Thornton and Minson, 1993).

The low protein and sulphur contents (Egan, 1986) of tropical grasses are inherent characteristics of Carbon-4 (C_4) plant metabolism. C_4 plants use more nitrogen (N) for dry matter (DM) accumulation than C_3 plants which, however, have higher tissue nitrogen than C_4 plants (Coleman and Lazenby, 1970). The percentage of intercellular air spaces in C_3 grasses (10 - 35%) and legumes (41 - 51%) is higher than in C_4 grasses (3 - 12%). This enables a more rapid penetration of bacteria into the leaf and hence quicker digestion of C_3 plants than C_4 plants (Hanna *et al.*, 1973).

Other physical factors that determine roughage quality include the presence of cuticle, waxes, suberin, hairs, lignin found in grasses for example, *Andropogon gayanus, P. purpureun, and Panicum maximum*. The plant cell wall has been found to be the primary restrictive determinant of forage intake, (Van Soest, 1982). Phenolics, acetyl terpenoids, flavonoids and alkaloids are some chemical compounds that limit digestion. Apart from protecting the roughages against insects and other predators, they alter palatability, intake and digestibility of rouphages.

2.2.0 Nutritive value of tropical grasses

The nutritive value of tropical forages is determined mostly by chemical composition, digestibility and intake, which in turn are affected by a number of factors (Schneider and Flatt, 1975). The chemical constituents especially contents of crude protein, acid detergent fibre, neutral detergent fibre, ether extract, hemicellulose, cellulose, organic matter, dry matter and ash affect nutritive value. Feedstuffs with high crude protein, high cell contents and lower fibre levels have higher digestibility and higher intake and hence give better animal performance. The whole plant can be separated into stem, leaves, leaf sheaths and inflorescence, when it is in flower. The leaf sheaths are mostly added to the leaf portion.

Leaf to stem ratio of forages affects nutritive value. It is a measure of proportions of leaf and stem fractions constituting the whole plant. Leaves compared to stems are known to have more nitrogen than stem and are generally more easily digestible due to the low levels of structural carbohydrates. Young stems have about the same percentage digestibility as leaves, so that the leaf: stem ratio is less critical in immature plants than in older plants with elongated flowering stems (Taerum, 1970; Fianu and Winch, 1984). With age, leaf digestibility declines slowly but that of the stem declines rapidly (Schneider and Flatt, 1975) .

Raymond (1969) reported that the leaf and stem fractions of a young forage plant are equally highly digestible because of the high level of cell contents and high digestibility of the cell wall fractions at young stage of growth. With advancing maturity, however, considerable differences in the digestibility between two fractions arise. As the stem matures the cell contents decrease and the cell wall fractions become less digestible because of increased lignification.

The cell contents of leaves remain at higher levels as the rate of lignification is much slower with increase in age than stems.

Samples of leaf plus sheath and stem of *Panicum* species did not differ in digestibility until the 16th week of sampling and thereafter showed a marked decrease *in vitro* digestibility (Reid, *et al* 1973). After stems elongate and side

branches develop in grasses, the stem fraction exceeds the leaf fraction of the whole plant. The time at which the stem weight exceeds leaf weight varies with species and with the season. Haggar (1970) indicated that *Andropogon gayanus* remains leafy until rather late in the season in West Africa, where growth begins with the rains in May and continues into November. *Cenchrus ciliaris* shows a different pattern of development. The stems rapidly surpass the weight of the leaves because of early stem elongation, which becomes more pronounced as the season progresses (Burt, 1968).

It is generally known that tropical forages mature quickly as compared to temperate species. Crude protein content decreases fast with rapid increase in plant structure. The rapid fall in quality of tropical forages may be due to the rapid growth rate. Tropical forages are known to be lower in crude protein and higher in structural carbohydrates than their temperate counterparts
(Minson 1971).

2.3.0 Voluntary feed intake

Voluntary feed intake is the maximum amount of feed eaten by an animal when feed is offered *ad libitum* (McDonald *et al*., 1988). Many theories have been postulated to explain the mechanisms of control of voluntary intake of feeds by ruminants. Balch and Campling (1962) reported that voluntary feed intake is controlled by the central nervous system (CNS). They named two main centres in the central nervous system which have control on feed intake in animals. These are the ventromedial nuclei of the hypothalamus known as the satiety centre and the lateral hypothalamus, the feeding centre. Other centres have been found in the central nervous system and other parts of the body (Anderson and Larsson, 1961). For instance, with the removal of the orbitofrontal lobes of the cerebral cortex, rumination cycles continue but with irregularity. The existence of a reticulo-ruminal centre in the medula oblongata, which may co-ordinate the chain of reflexes associated with rumination, has been reported. The hepatic portal vein and some centres in the liver may control feed intake (Anil and Forbes, 1980). These centres in the

central nervous system and other parts of the body must receive messages before they can register satiety or hunger. Several theories and hypotheses have been put up as to the location of receptors and nature of the stimuli and the signal for satiety in the ruminant. Two main factors that have been identified for controlling feed intake are physical and physiological factors.

2.3.1 Physiological factors affecting feed intake

Ruminants increase their feed intake in response to an increase in demand for energy, for exercise and for counteracting extreme cold stress (Forbes, 1986) According to Preston and Leng (1987), feed intake is high in young growing animals and older animals that need to restore depleted body tissues and in lactating animals. Control of feed intake can also be considered as a component of the homeostatic regulation of energy balance.

Hormonal changes are known to affect feed intake (Lofgren and Warner, 1972). Insulin is a significant component of the satiety signal since it is known to enhance cellular absorption and utilization of glucose and leads to increase glycogen synthesis (Frandson, 1986). Thyroxine is also known to be responsible for metabolism and affects intake (Forbes and France, 1993).

Bines (1968) reported that chemostatic mechanism may also be functioning in the control of feed intake; however, the problem was to determine which metabolites or groups of metabolites provided the signal for cessation of eating. Infusion of propionic and acetic acids depressed intake of lucerne, but glucose, sodium, hexanoic and lactic acid had no effect (Forbes, 1980). Some products of fermentation such as acetic acid, and propionic acid may limit intake by acting on the epithelium of the reticulum and on the liver respectively (Forbes, 1980).

Bines (1971) observed that the fatter an adult animal becomes, the smaller will be its voluntary feed intake possibly due to the excessive amounts of fat deposited within the abdominal cavity which may reduce the effective capacity of the reticulo-rumen. It was also reported that fat animals may have low intake of feed because they have less appetite. Arnold (1977) also reported that animals in poor body condition ate faster and increased their

feed intake both absolutely and per unit metabolic body size than fatter animals.

The composition of a diet determines an animal's voluntary intake. An increase in the levels of deficient nutrients especially protein in the rumen or essential amino acids at tissue level in the animal may increase feed intake. In dairy cows, an increase in the levels of amino acids in the blood increases milk synthesis and hence cause increase demand for nutrients and subsequently increase in feed intake if energy levels are right (Ørskov, 1982).

2.3.2 Physical factors affecting voluntary feed intake

The main physical factors affecting feed intake are rumen distension, gut size, rate of passage, rate and extent of digestion.

Preston and Leng (1987) reported that the size of the reticulo-rumen affects the quantity of roughage consumed. It is known that there are certain stretch factors in the gut which send signals to the satiety centre when the gut is filled. The filling of the gut is affected by its size and the rate of passage of digesta. Tropical animals have larger gut size relative to the body size than temperate animals and so they eat more per metabolic body size.

The gut fill also depends on the rate of passage through the rumen of both soluble and insoluble particulate digesta. This might be controlled by gut hormones, such as, cholecystokinin and secretin. What is not digested accumulates and cause decrease in feed intake (McDonald *et al*., 1988).

Stretch factors stimulating satiety are also affected by the extent of digestion and the rate of digestion. The higher the rate of digestion, the higher the rate of emptying the gut and, therefore, the higher the feed intake (Forbes, 1995).

A decrease in the rate of digestion can cause a reduction in the intake of forages. In many instances when the rate of digestion is decreased, digestibility may also be decreased as the undigested feed has been reduced in size enough to come out of the reticulo-rumen.

McDonald *et al*. (1988) reported that there was a relationship between the digestibility of feed, rate of passage of the digesta and voluntary intake.

Thus the higher the digestibility of the feed, the faster the rate of passage and the higher the feed intake. The rate of passage of the undigested feed residue from the rumen which is dependent on the feed particles being reduced into sizes small enough to pass through the reticulo-omasal orifice, is known to affect the rate of passage of the digesta from the reticulo-rumen and thus voluntary intake of feed (Bines, 1971).

Church (1975) reported that the rate of decrease of particle size and hence rate of passage of indigestible particles is affected by the nature of fibre. For example, sisal pulp contains a large amount of easily digestible material but a small fraction about 5-10% consist of unextractable fibre from which rope is made. This accumulates in the rumen and is not easily broken into small particles to traverse the reticulo-omasal orifice causing a decrease in feed intake because the rumen is filled.

The intake of legumes is generally higher than intake of grasses because legumes are known to be broken down cuboidally while grasses are broken down longitudinally. Thus particles of grasses do not pass through the reticulo-omasal orifice as fast as particles of legumes (Aitchison *et al., 1986*).

2.3.3 Change over from Physiological to Physical Determinants of Intake

There is no clearly defined area of operation of physiological and physical factors in regulating feed intake. However, at higher levels of digestibility (670-800g/kg), intake appears to be controlled by physiological factors while at lower digestibilities (<670g/kg) physical factors predominantly regulate intake (Baumgardt, 1970).

2.3.4 Other factors affecting voluntary feed intake

2.3.4.1 Palatability

The effects of palatability on intake have been contested. Greenhalgh and Reid (1971) proposed that low palatability could affect intake adversely while Gheradi, *et al*, (1991) observed the contrary. They however, found that rumen digesta load and apparent fractional outflow rate were associated more with intake than palatability.

2.3.4.2 Differences among species of animals

Goats were found to have higher voluntary dry matter intake and digest the fibre component of the diet better than sheep (Howe *et al.*, 1988). Dominque *et al.* (1991) made similar observations when they fed a low quality roughage to goats and sheep. They attributed the higher intake and digestibilities to larger rumen pool size and lower rumen fractional outflow rate of the goats used. Comparing cattle with sheep, Amaning-Kwarteng *et al.* (1986) observed higher intake in cattle. The high liquid passage rate and larger rumen pool sizes recorded were factors offered to explain this trend.

2.3.4.3 Intake during pregnancy and lactation

Feed intake in monogastrics generally increases during pregnancy to meet the higher nutrient demand; however, with cattle and sheep no consistent pattern has emerged and at times, a decline is shown during late pregnancy (Weston, 1988). The upward displacement of the ventral wall of the rumen in late pregnancy has been associated with a reduction in rumen digesta volume and voluntary feed consumption (Forbes, 1971). It was suggested that pressure on the rumen, or abdominal wall distension (Forbes, 1980) might modulate voluntary feed consumption. Feed intake increases rapidly after parturition and then remains fairly steady or declines slowly (Weston, 1980). It has been reported by several workers that voluntary intake declines during the last month of pregnancy in cows (Owens *et al.*, 1968; Campling, 1966). This decrease in intake has been ascribed to the compression of the rumen by the growing foetus and also by abdominal fat. The displacement of the rumen by the growing conceptus was illustrated by Forbes (1968). There was negative relationship between the volume of rumen contents at slaughter and the volume of 'incompressible abdominal contents' (uterus plus abdominal fat) in ewes which had been fed on hay (Forbes, 1969). The decline in intake was proportionately less than that of rumen volume probably as a result of the increase in the rate of passage (Graham and Williams, 1962).

2.4.0 Voluntary intake and digestibility of feeds

Larbi *et al.* (1991) did a comparative study on feed intake and digestibility by sheep and goats fed leaf, stem and whole plant fractions of Napier grass (*Pennisetum purpureum*) cut at six weeks of regrowth. Results of the study showed that sheep and goats consumed more leaf than whole plant and stem fractions (67, 46 and 30 $gkg^{-1} W^{0.75} d^{-1}$) for sheep (54, 32 and 20 $gkg^{-1}d^{-1}$) for goats respectively. It was observed that the leaf fractions were digested faster than the whole plant and stem hence higher leaf dry matter intake. Similarly, dry matter intake by sheep fed leaf fractions (67 $gkg^{-1} W^{0.75} d^{-1}$) and whole plant (46g $gkg^{-1} W^{0.75} d^{-1}$) were significantly higher ($P<0.05$) than stem (30g $gkg^{-1} W^{0.75} d^{-1}$) apparently because of shorter retention time for leaf than whole plant and stem in the reticulo-rumen and also shorter retention time for whole plant than stem. Poppi *et al.*, (1981) reported similar findings and they attributed higher intake of (28 $gkg^{-1} W^{0.75} d^{-1}$) leaf fractions to higher crude protein (9.9%) content of the leaf compared to intake of stem (21$gkg^{-1} W^{0.75} d^{-1}$) with 4.1% crude protein. One factor known to be related to feed intake is the percentage of leaf in the pasture (Minson, 1971). The relationship between voluntary intake (g/kg $W^{0.75}$) and dry matter digestibility for three cultivars of the genus Panicum was reported to be positively correlated ($r=0.76$, $P<0.01$). Voluntary intake increased from 62.8 to 68.9 g/kg $W^{0.75}$ with increasing leaf percentage from 44 to 51 respectively. In field grazing studies, cattle were reported to have selectively grazed the leaf fraction in preference to stem and the intake per bite and time spent grazing were related to yield of green leaf in the pasture (Minson, 1971).

2.5.0 Feed intake and apparent digestibility of cell wall Components

With the exception of NDF which was related to intake ($r = 0.68$; $P< 0.05$), ADF, ADL, lignin and N were not found to be related to voluntary intake (θrskov *et al.*, 1988). Church (1975) reported that apparent digestibility of feedstuffs decreased as the percentage of ADF, ADL and Lignin increased. This is because the content of lignin, a substance resistant to chemical

degradation and enzymatic digestion in feedstuffs, is highly correlated with fibre content (McDonald *et al.*, 1988).

2.6.0 Prediction of feed intake and apparent digestibility from the measurements of gas production or DM degradation

Khazaal *et al.* (1993), conducted a study to compare *in vitro* gas production and *in sacco* degradability as predictors of *in vivo* apparent digestibility and voluntary intake of hays harvested at different stages of growth. The results showed that between 12 and 96h incubation, intake and *in vivo* dry matter digestibility were related to dry matter degradation (r = 0.79 to 0.83; r = 0.61 and 0.77) and also to gas production (r = 0.73 to 0.80; r = 0.58 to 0.78) respectively.

Volume of gas production was significantly related (P<0.05; r = 0.73 and 0.80) to intake at all incubation periods. Potential gas production (a+b) values were related with intake and *in vivo* dry matter digestibility (r = 0.74; r = 0.76; P<0.05).

2.7.0 Microbial fermentation in the rumen

The overall function of the digestive process is to reduce feed nutrients to molecular sizes that will allow for their absorption and the absorbed nutrients subsequently used for maintenance and production by the animals. The digestive tract of the ruminant is dominated by the reticulo-rumen sac, functioning basically as a buffered anaerobic fermentation vat in which feed is exposed to and broken down by micro-organisms. About 65% of the digestible organic matter intake (DOMI) is apparently digested in the rumen (ARC, 1980). Ørskov and Ryle (1990) reported that the rumen provides an environment of constant conditions, made up of a stable anaerobic state with a constant temperature and limited pH fluctuations, essential for the growth and efficient functioning of the resident micro-organisms.

Three main groups of micro-organisms have been identified in the rumen; these are bacteria, protozoa and anaerobic fungi (phycomycetes). The rumen fluid contents of bacteria and protozoa are 10^{10} - 10^{11}/ml and 10^{5} -

10^6/ml respectively, while the anaerobic fungi may constitute up to 8% of the intra-ruminal biomass (Ørskov and Ryle, 1990). The rumen bacteria are located in the rumen fluid, found adherent to the feed particles or rumen epithelium or attached to protozoa, mainly in the case of methanogenic bacteria, (Cheng and Costerton, 1980). These micro-organisms are involved in the fermentation of feeds in the reticulo-rumen. Ørskov (1982) reported that most of the fermentation of roughages is accomplished by micro-organisms adhering to the feed particles. The anaerobic fermentation of dietary carbohydrates such as cellulose, hemicellulose, pectin, starch or sugar yields a mixture of volatile fatty acids (mainly acetic, propionic and butyric acids) and carbon dioxide and methane. The energy released in this fermentation reaction is used by the micro-organisms to build their cells (McDonald *et al.*, 1981). About 4 to 5 moles of adenosine triphosphate (ATP) have been reported to be generated per mole of carbohydrate fermented (Ørskov, 1982). The volatile fatty acids (VFAs) also provide most of the energy of the ruminant. The type of substrate fermented affects the proportions of volatile fatty acids in the rumen. According to McDonald *et al.* (1981) the predominant VFA is acetic acid, and roughage diets high in cellulose, give rise to acid mixtures particularly high in acetic acid. As the proportion of concentrate in the diet is increased, the proportion of acetic acid falls and that of propionic acid rises. Bacteria in the rumen especially the cellulolytic types (the most important being *Ruminococcus albus*, *Ruminococcus flavesfasciens* and *Bacteroides succinogens)* are the principal agents for fermenting plant cell wall carbohydrates but the anaerobic phycomycetous fungi may be extremely important in playing a critical role in the rate and total digestion of fibre (Akin *et al.*, 1993). They appear to be the first organisms to invade and commence digestion of the structural plant components. They reduce the tensile strength of these particles resulting in increased breakdown of particles in the rumen (Akin *et al.*, 1993). The damage to digestible particles by the fungi allow bacteria to colonize these materials.

McDonald *et al.* (1981) reported that dietary proteins are hydrolysed by the rumen micro-organisms to peptides and amino acids and are degraded further to organic acids (VFAs), ammonia and carbon dioxide. The ammonia

produced is the main nitrogen source for the rumen micro-organism and together with carbon skeletons are utilized to synthesise amino acids and subsequently microbial proteins. The carbon skeletons may be synthesised by the microbes or the microbes may use carbon skeletons of amino acids especially from the breakdown of proteins. Micro-organisms and by-pass protein entering the lower digestive tract are digested in the small intestines by the animal's enzymes to yield amino acids which are absorbed and used to synthesise protein (Leng, 1992). Lipids are hydrolysed in the rumen to fatty acids and glycerol. The glycerol derived from the hydrolysed fat is converted to volatile fatty acids thus providing an energy source to the ruminants. A large proportion of free fatty acids, however, cannot be utilised in the anaerobic conditions prevailing in the rumen. High levels of these free fatty acids tend to inhibit fibre digestion (Ørskov and Ryle, 1990). Based on the above observation, Ørskov and Ryle (1990) suggested that only low levels of lipids (up to 7%) are acceptable in ruminant diets and that if high levels of fats are to be used, they must be protected from hydrolysis in the rumen.

2.7.1 Factors affecting rumen microbial fermentation.

A number of factors are known to affect the activities of the micro-organisms in the rumen and these include the pH of the rumen fluid, the type of substrate being fermented, nitrogen availability to the micro-organisms, rumen osmolarity, dilution rate, and supply of minerals to the microbes.

2.7.2 The effect of pH and type of substrate on rumen fermentation

The pH of the rumen fluid and the substrate available for fermentation are two of the factors which affect the types of micro-organisms predominating as well as the type of fermentation which occurs in the rumen ecosystem (Ørskov and Ryle (1990). Saliva, containing bicarbonate and phosphate, which is secreted into the rumen provides a buffered medium for the micro-organisms (McDonald *et al* 1981). The buffering capacity of the rumen fluid is important since large quantities of VFAs are produced and bacteria,

particularly the cellulolytic bacteria, survive in a medium with pH between 6.2 and 7.0. On forage based diets, this optimum range for cellulose fermentation is achieved through the secretion of copious amounts of saliva, which provide effective pH stabilization. With high concentrate feeding, salivary flow does not only decrease, but there is also a rapid rate of fermentation of the concentrate with greater amount of VFAs being produced per unit weight of feed resulting in lowered pH that interferes with cellulolysis (Ørskov and Ryle, 1990).

Mould *et al.* (1984) reported that reduction of the rumen pH below a threshold of 6.0 in sheep fed roughages led to the total inhibition of cellulolysis and a depression in dry matter intake. This observation was attributed to the gradual destruction of the microflora normally associated with roughage degradation. The length of time and extent to which rumen pH remained below the critical pH of 6.0 have been reported to be important determinants of bacteria growth (Murphy *et al.*, 1983). Amylolytic bacteria are less sensitive to lowered pH and are capable of fermenting starch over a much wider pH range of 5.0 - 7.0 (Mould and Ørskov, 1984). Ciliate protozoa (the holotrichs and oligotrichs) have been reported to be readily destroyed under acid conditions and that acidity of the rumen was probably the most important factor governing changes in fungal populations (Ørskov and Ryle, 1990). They were found not to survive at low rumen pH and also to be absent in ruminants fed high concentrate diets.

2.7.3 The effect of nitrogen concentration on rumen fermentation

Rumen micro-organisms require nitrogen for growth. Mathison and Miligan (1971) reported that ammonia is the most abundant nitrogen compound available in the rumen. Ammonia in the rumen liquor is the key intermediate compound in the microbial degradation and synthesis of protein (McDonald *et al*, 1981). The concentration of ammonia in the rumen fluid as well as the availability of energy in the form of ATP have been cited as the primary factors which can limit the growth of rumen micro-organisms especially on most diets based on agro-industrial by-products and forage with low digestibility (Preston and Leng, 1987). For maximal efficiency of microbial

growth to occur, nitrogen and energy availability in the rumen must be synchronized (Stern and Hover, 1979)

Critical levels of ammonia required vary from 50 to 250mg/l of rumen fluid (Preston and Leng, 1987). Many reasons have been suggested for the wide range in values of optimum levels of ruminal ammonia. Some of these are different substrate and different types of micro-organisms which may require different concentration of ammonia to maximise microbial yield (Ørskov, 1982). Secondly, the rate of utilization of ammonia is dependent on availability of energy. The concentration required for maximum ruminal degradation of feedstuffs appear to be higher than the concentration required for maximum microbial protein yield (Song and Kennedy, 1990) and pure cultures *in vitro* generally require only very low concentrations of ammonia for growth (Owens *et al*, 1984).

2.7.4 The effect of rumen osmolarity on fermentation

In general osmolarity in the rumen is relatively constant, 200 - 280 mOsmol/kg; (Mackie and Therion, 1984). However, it can increase to between 350 and 450 mOsmol/kg after feeding concentrates or lucerne pellets or feeds containing high levels of salts. Digestion in the rumen can be impaired by high osmolarity. For example, *in vitro* cellulose digestibility has been reported to decrease when osmotic pressure was higher than 400mOsmol/kg and a reduction in voluntary intake was observed at this osmotic pressure (Mackie and Therion, 1984). The inhibitory effect on rumen fermentation by high osmolarity may be due to lysis of micro-organisms (Slyter, 1976). Protozoa appear to be more sensitive to high osmolarity than bacteria (Mackie and Therion, 1984).

2.7.5 The effect of rumen dilution rate and particle fractional outflow rate on fermentation

Rumen dilution rate is defined as the proportion of total rumen volume leaving the rumen per hour (Harrison *et al.*, 1975). Rumen fluid dilution rates

for sheep have been observed to range from 0.04 to 0.15/h (Mackie and Therion, 1984). A number of studies have demonstrated a positive correlation between increased dilution rate and increased microbial growth (Cole *et al.*, 1976). They observed an increase in protein synthesis (from 7.5 to 11.8/100gDM) with an increase in rumen dilution rate (from 0.03 to 0.05/h) when steers were switched from an all concentrate diet to one containing 14% roughage. Intra-ruminal infusion of artificial saliva in sheep was found to increase dilution rate from 0.03 to 0.08/h. Concurrently, there was an increase in total amino acids synthesised per mole of hexose fermented from 25.4 to 29.8g (Harrison *et al.*, 1976).

The fractional outflow rate of feed particles refers to the fraction of rumen particle content leaving the rumen per hour (Ørskov and Ryle 1990). Increased dilution rate tends to increase microbial growth, whilst the rapid rate of passage of feed through the reticulo-rumen (low retention in the rumen) tends to reduce the digestibility of feed by reducing the time for microbial fermentation (McDonald *et al.*, 1981).

Physical characteristics of feed such as particle size and functional specific gravity (the particle specific gravity in the rumen fluid which are selectively discriminated against for onward passage through the recticulo-omasal orifice) may restrict passage from the rumen (Wattiaux *et al.*, 1992). Small particles have been observed to pass faster through the reticulo-omasal orifice compared to larger particles. Poppi *et al.* (1980), reviewing literature on particle sizes, concluded that particles must be reduced in size to less than that passing a 1.18mm sieve in order to escape from the rumen of sheep. Ørskov *et al.*(1988) observed that small particles of fishmeal with higher functional specific gravity had faster outflow rate than the small fibrous particles of straw (0.0697 vs 0.0310/h). This was partly attributed to the trapping of the fibrous straw particles in the floating mat of the rumen as a result of their large surface-to-volume ratio.

The outflow rate of feed particles has been observed to increase with feeding level (Elimam and Ørskov, 1984). They reported that increasing the feeding level of chopped dry grass from 0.5 to 2.0 maintenance level increased fractional outflow rate of chromium treated protein in sheep from

0.010 to 0.039/h.

The composition and particle size of the basal diet can influence the rate at which particles of feed supplements flow out of the rumen. Elimam and Ørskov (1984) reported that increasing the proportion of hay (roughage) in the basal diet increased the fractional outflow rate of chromium-treated fishmeal from the rumen of lactating dairy cows. They also observed greater outflow rate of chromium-treated fishmeal from the rumen when included in a basal diet of larger particles. This was suggested to be due to the dietary structure possibly mediated through increased liquid flow through the rumen or differences in rumen motility. The structure of the diet is known to affect rumination time and saliva secretion (Wilson and Tribe, 1963), and a large inflow of saliva leads to a large outflow of liquid through the reticulo-omasal-orifice (Ørskov and Ryle, 1990).

Temperature is another factor which can alter outflow rates. Kennedy and Milligan (1978) reported that low temperatures could increase outflow rate of particles because of increased gut motility associated with increased thyroid hormone secretions.

2.7.6 The effect of minerals on rumen fermentation

Rumen micro-organisms require both macro and trace minerals for their normal cell function and metabolism (Ørskov, 1982). Sulphur is required by rumen micro-organisms for the synthesis of sulphur-containing amino acids, methionine, cystine and cysteine (Preston and Leng, 1987). The sulphur-containing amino acids constitute a constant proportion of microbial amino acids and, therefore, the requirement for sulphur by the rumen micro-organisms is related to the requirement for nitrogen (Ørskov, 1982). The ratio of nitrogen to sulphur for efficient microbial growth has been reported to range from 10 to 14:1 for sheep (ARC, 1980). The sulphur for the micro-organisms generally comes from the degradation of dietary protein and therefore a deficiency in sulphur is likely to occur if there is also a deficiency in protein (Ørskov, 1982), although inorganic sulphur such as sodium sulphate (Na_2SO_4) can be utilised.

Phosphorus is a constituent of nucleoctides and co-enzymes such as flavin phosphates and pyridoxal phosphates. Phosphorus forms an essential part of the structure of DNA and RNA, helping to build the nucleic acid into the helix. Phosphorus is also essential for all energy transactions within microbial cells in the formation of adenosine di- and tri-phosphates (ADP and ATP) and guanine triphosphate (GTP); (Ørskov, 1982).

Cobalt is required by micro-organisms in the rumen for synthesis of vitamin B_{12} (Maynard *et al.,* 1979). McDonald *et al.* (1981) reported that if cobalt is deficient in the diet, then vitamin B_{12} cannot be produced in the rumen in amounts sufficient to satisfy the animal's requirements and symptoms of 'pining' (emaciation, anaemia and listlessness) occur.

In addition to the requirement of some minerals by the rumen micro-organisms for their growth, the macro-minerals contribute to the regulation of some physico-chemical characteristics of the rumen which have an important and direct influence on fermentation (Ørskov and Ryle, 1990). The bicarbonates and phosphates of sodium and potassium contained in saliva serve as the main buffering components in the rumen under normal feeding conditions (Ørskov and Ryle, 1990). According to Mackie and Therion (1984) the provision of diets containing a high amount of mineral salt such as sodium and potassium can result in hypertonic rumen fluid causing increasing osmolarity which may have an inhibitory effect on rumen fermentation and consequently bring about a reduction in feed intake.

2.8.0 Digestibility of feed and its measurement

According to McDonald *et al*. (1988) digestibility of feed is defined as that portion of ingested feed, which is not excreted in the faeces and is therefore assumed to be absorbed by the animal. It is commonly expressed as a co-efficient or percentage (e.g. percent digestibility of dry matter or a nutrient). In measuring digestibility, feed consumed and faeces excreted are measured. In trials with mammals, male animals are preferred to females because it is easier to collect faeces and urine separately with the male. There is an adjustment period of at least one week to enable the animal to get

accustomed to the test diet and also clear the residues of previous feed from the tract. The period of faeces and urine collection usually lasts from 5 to 14 days (McDonald *et al.*, 1988). The excretion of indigenous substances not arising directly from the feed leads to underestimation of the proportion of the feed actually absorbed by the animals. The values obtained in digestibility trials are therefore referred to as apparent digestibility coefficients (McDonald *et al.*, 1988).

2.8.1 Factors affecting the digestibility of feed

There are various factors that affect the digestibility of feed consumed by ruminants. These include the ration composition (associative effect), the chemical composition of the feed, the amount or level of feed intake, form of preparation or processing, animal factors and water intake.

The digestibility of an ingredient in a diet is not only influenced by its own chemical composition but also by the chemical composition of other ingredients in the diet which is termed associative effect (McDonald *et al.*, 1988). This is because while some of the essential nutrients required for the growth of rumen micro-organisms may be deficient in one ingredient, the others fed with it may supply these nutrients. Mehrez and Ørskov (1980) observed that dietary nitrogen inadequacies cause reduction in feed intake due to a depressed fermentation rate and reduction in digestibility of dry matter and reduction in carbohydrate fermentation in the rumen.

According to McDonald *et al.* (1988) variability in digestibility of feeds is partly due to variations in the contents of crude protein, fibre, ether extract and readily fermentable carbohydrates.

Ørskov (1982) observed that higher levels of protein may increase the digestibility of the dietary fibre of feeds by supplying the nutrients essential for proper growth and activity of micro-organisms in the rumen. Johnson *et al.* (1967) reported that low levels of crude protein in forage diets resulted in low crude protein digestibility, while high crude protein levels increased protein digestibility mainly because of the effects of endogenous protein secreted into the gastro-intestinal tract.

Tuah and Tetteh (1979) observed a decline in CP levels of whole forage, leaf and stem portions with advancing stages of maturity of giant star and guinea grasses at 6, 8 and 10 weeks. Crude Fibre contents, however, increased with increasing age of the grasses. It was shown that the apparent digestibility coefficient of DM was significantly higher at 6th week stage of growth than the other stages. However, the mean daily DM intake per unit of metabolic body size of the forage was not affected significantly by the stage of growth.

McDonald *et al.* (1988) noted that fibre has the greatest influence on the digestibility of feed. Generally, the digestibility of feedstuffs decreased as the percentage of fibre increased (Church, 1975). This is because as the lignin content of the feed increases its digestibility also decreases. The content of lignin, a substance resistant to chemical degradation and enzymatic digestion is highly correlated with fibre content (McDonald *et al.*, 1988). High levels of fibre in diets result in the depression of digestibility of the feed constituents.

Although higher levels of fat in rations increased the digestibility of fat, it appeared to decrease the digestibility of carbohydrates especially fibre, because the fat decreases microbial activity in the rumen (Schneider and Flatt, 1975; Ørskov, 1982).

Schneider and Flatt (1975) reported that generally there was very slight influence of various mineral supplements on digestibility unless there was deficiency of elements essential to the life or activity of rumen microbes. θrskov (1982) observed that the absence of sulphur from the diet of ruminants leads to decrease in digestibility and utilization of cellulose since sulphur containing amino acids are necessary for optimal growth of rumen cellulolytic microbes.

Roberts and Van Soest (1975) observed that a high feed intake resulted in reduced digestibility of nutrients. It was explained that as feed intake increased, the rate of passage of the digesta through the gastro-intestinal tract also increased, resulting in less time for rumen micro-organisms to ferment the feed (McDonald *et al.*,1988).

The commonest treatments applied to feeds are chaffing, crushing or

grinding, cooking, pelleting and flaking. McDonald *et al.* (1988) reported that digestibility is high when cereal grains are crushed for cattle and ground for pigs but grinding of roughages reduces the digestibility of fibre since it increases the rate of passage of the roughage/straw. Heat treatments are most effective in improving digestibility when used for the specific purpose of inactivating the digestive enzyme inhibitors that are present in some feeds such as soybean and groundnut meal (e.g. trypsin inhibitors).

McDonald *et al.*(1988) observed that generally age of the animal has little or no effect on the digestibility of feed once the animal had acquired the normal rumen microflora. Cole and Garrette (1980) reported that within species, variation may occur in digestibility since some individual animals may have more or less efficient digestive system than the average of the species. Blaxter *et al.* (1966) observed that cattle digested dry roughage to a greater extent than sheep whereas sheep were more efficient digesters of concentrates.

2.9.0 *In sacco* methods for estimating the extent of digestion in the rumen

Among the many proposed methods for determining extent of digestion, the nylon bag method is probably the best way to study the rumen environment for any given diet. The nylon bag technique has been used for many years to predict the dietary value of feeds and to evaluate their digestibility (Michalet-Doreau, 1990). The nylon bag method measures the disappearance of feed components from the bag containing the test diet after incubation, for a variable period, in the rumen of an animal fitted with a rumen cannula (Mehrez and Ørskov, 1977). The method is currently used to describe dry matter loss from nylon bag in which substrates are incubated in rumen of fistulated animals by withdrawing bags at chosen time intervals from the rumen and measuring dry matter loss from the bag. Ørskov and McDonald, (1979) described the process by the exponential equation $P=a+b\ (1-e^{-ct})$, where P is the dry matter loss at time t and where a, b and c are constants. The extent of fermentation is entirely based on dry matter loss, assuming that

all the loss occurred by fermentation. If fermentation proceeds without delay the intercept a can be considered as consisting of immediately soluble material, b the insoluble but fermentable and c the rate constant.

Although this method is widely used it is not without criticism (Mehrez and Ørskov, 1977). The strongest criticism is its low repeatability as indicated by diversity of values obtained by different researchers for similar feed samples.

2.9.1 Bag characteristics and influx of microbial population

Bag porosity is an important factor in the measurement of the kinetics of rumen degradation of feed. The pore size has a direct influence on the influx into the bag of agents responsible for feed degradation and the influx of undegraded feed particles.

Bag porosity must be large enough for the entry of micro-organisms into the bag so that ruminal microbial populations may circulate freely through the bag and to prevent clogging of the pores by feed components. Bag pores must also be sufficiently small to limit losses of undegraded feed particles. The choice of bag porosity must be a compromise between these two parameters, and the porosity presently adopted almost universally, is between 40 and 60μm. For this porosity, particle loss is not great and its impact on degradability of feed is low (Uden and Van Soest, 1984).

2.9.2 Sample characteristics

The choice of bag porosity is also affected by the processing of the sample particularly by the fineness of grinding. Grinding iscarried out in order to obtain a homogeneous sample (Mehrez and Ørskov, 1977). They observed that feed degradation increases with the fineness of grinding, but variations in fermentation rate depend on rumen incubation time and feed. The influence of finess of grinding increases fermentation rates (Freer and Dove, 1984). The lag time which is the time between the introduction of the bag into the rumen and the beginning of degradation, significantly increased with an increase in

particle size. During the lag time, only solubilized fractions are lost. Changes in feed degradation due to grinding are probably related to variations in the percentage of fine particles, which are immediately soluble or rapidly degradable (Emmanuele and Staples, 1988). Sample size introduced into the bag, affects degradability. The sample size/surface area ratio influences degradation of forages in that the quantity of sample introduced in the bag with constant surface area could result in an increase or decrease in the proportion of dry matter disappearance. Smaller sample size would allow greater exposure to microbial attack. The substrate attack by micro-organisms increased with the decrease of the sample size. Mehrez and Ørskov, (1977) reported that with a pore size of over 50μm, increasing the bag size and then decreasing the sample size resulted in an increase in the proportion of dry matter disappearance, after 24h of incubation, from 37.5 to 85%.

2.9.3 Bag incubation procedure

Bag incubation sequence can also influence degradability. Results from the systems of placing all bags in the rumen at once and removing them at designated time intervals compared with introduction of bags in reverse sequence and removing them all at once were not the same. Nocek (1985) compared the two methods. The former procedure resulted in lower variation and slower degradability, probably because the degradation process was interrupted when bags not intended for termination of digestion were retrieved and then reinserted into the rumen. Nocek (1985) recommends the second procedure, that is, the introduction of bags at different times and removing all at the same time.

The relative locations of nylon bags suspended within the rumen can affect degradability. The length of string along which bags are fastened is an important factor because it determines the location of bags in the rumen. Dry matter disappearance after 48hr intraruminal incubation varies from four to five percentage points according to the position of the bags in the rumen (Hawley, 1981). A 25cm string would be a sufficient length to allow free movement of the bag in the rumen of sheep (Mehrez and Ørskov, 1977). These variations

can be attributed to stratifications of digesta, the physico-chemical characteristics and the microbe concentration, which vary with the positions of the bags in the rumen. The dorsal sac gives better results than the ventral sac since higher concentration of microbes is associated with the dorsal sac (Yang and Varga, 1989).

2.9.4 Microbial colonization of feed residue in the bag

Since it is necessary for micro-organisms to enter the bag for feed degradation to take place, it is also essential that they be eliminated from the bag after incubation to avoid underestimation of dry matter and protein degradation. The washing of bags after rumen incubation has two main objectives; the first is to stop microbial activity and the second is to separate feed residue from rumen liquid, particularly rumen micro-organisms without increasing the loss of feed particles through bag pores (Mehrez and Ørskov, 1977). The colonization of bag residues by rumen bacteria varies with the method of measurement used to evaluate the microbial fraction and with incubation time and the type of substrate. Bacterial N contamination, expressed in percent of total residual N, increases rapidly in the first hours of incubation. (Ould-Bah, 1989). The length of time necessary before the appearance of the peak of contamination can vary greatly from one feed to another, between 6 and 96hr for forages and between 10 and 20hr for concentrates (Kennedy *et al*., 1984). It was hypothesized that variations in microbial colonization of bag residues may be related to the cell wall content (Gershon *et al*., 1988).

2.9.5 In vitro gas production system in evaluating nutritive value of forages

In vitro gas production from a feed sample with a rumen fluid inoculum has been successfully used to predict the nutritive value of the substrate fermented (Menke *et al*., 1979). In their feed evaluation system the amount of gas produced is measured in series of time intervals. The test is basically similar to the system devised by Tilley and Terry (1963) in which a substrate is incubated with rumen liquor, the difference being that gas production rather than dry matter loss describes the amount of substrate fermented. In the system reported by Menke *et al* (1979) the substrate is incubated in a gas-tight glass syringe fitted with a plunger. The gas produced per hour is recorded. The device, however, may be adapted to reflect the extent and rate of fermentation by reading increase in gas production at a series of chosen time intervals as indicated by the rise of the plunger. The adaptation of the gas production test for longer incubation periods may help to overcome disadvantages associated with other *in vitro* systems. All the kinetic observations can be done on the same sample and insoluble and non-fermentable fractions will not contribute to the gas production. On the other hand other in vitro systems terminate fermentation at any time by measuring the residue. Each observation also results in loss of substrate. This limits the number of samples, which can be analysed. Furthermore, the extent and rate of fermentation are entirely based on dry matter loss assuming that all the losses occurred by fermentation. (Pearce *et al*, 1987). In the method of Menke *et al*. (1979) feed samples are normally incubated for periods of 24 hours or longer. They observed that the longer incubations of rumen inoculum *in vitro* reduced net growth of micro-organisms even though gas production continued to increase. This is probably attributable to an increased lysis as a consequence of substrate exhaustion (Van Nevel and Demeyer, 1977).

2.10.0 Agronomic characteristics and yield of grasses

Yields of tropical grasses vary enormously and under optimum growth conditions can be very high. Yields for individual species vary depending on climate, weather conditions, water supply, soil fertility, the fertilizers applied and the management. Even under seemingly similar conditions, yields of the same species may differ in different parts of the same country (Bogdan, 1977). Cooper (1970) reported that yields of 85.2 tonnes dry matter (tDM) per hectare per year from 6 cuttings can be obtained from elephant grass (*Pennisetum purpureum*) well supplied with nitrogen and other nutrients and receiving adequate amounts of water. Under normal circumstances average yields of dry matter in well fertilized experimental plots could be expected to fluctuate between 20 and 40 tonnes per hectare per year for high yielding grasses, *(Pennisetum purpureum, Andropogon gayanus, Brachiaria spp.)* 10-25 tonnes/ha/year for medium yielding grasses *(Cenchrus ciliaris, Chloris gayanus)* and 3- 10 tonnes/ha/year for low yielding grasses (*Cynodon dactylon, Cynodon plectostachyus)* from 3 to 5 cuttings (Crowder and Chheda, 1982).

Onifade and Agishi (1990) reported that, on average, grasses produced higher dry matter yields than legumes. Yields of grass/legume mixtures were reported to be higher than yields of legumes alone but were within the same range as sole grasses. Agishi (1982) reported that nitrogen and phosphorus were the main factors that affect dry matter yields of grasses and legumes respectively. Phosphorus tended to depress dry matter yields of grasses whilst nitrogen had the same effect on legumes (Agishi, 1982). Dry matter yields obtained in grass pasture under rainfed conditions were generally lower than those from the fertilised irrigated grass pasture (Agishi, 1984). These yields were in the range of 5 – 20 t/ha with grasses generally out yielding legumes. The yields of the grasses; *Panicum maximum* (Guinea grass) were 8-14 t/ha, *Andropogon gayanus* (Gamba grass), 7-10 t/ha, *Brachiara decumbens* (Signal grass): 10-16 t/ha, *Cenchrus ciliaris* (Buffel grass): 8-15 t/ha, *Cynodon plectostachyus* (Giant star grass): 5-8 t/ha. With the legumes,

Centrosema pubescens (centro) had 2-3 t/ha, *Lablab purpureus* (Lablab): 5-10 t/ha and *Stylosanthes guianensis* (stylo): 7-11 t/ha. Grass canopy structure also makes for more efficient light interception for photosynthesis.

Napier grass was reported to yield up to 10 tons DM/ha after 8 months of growth and harvested 4 times in Kenya (KARI, 1985). Hopkinson, (1970) reported yields of 14.35 t/ha without fertilizer for *P. purpureum* from six harvests in Tanzania.

Chheda *et al.* (1973) reported that a collection of *Pennisetum purpureum* varieties from Southern Nigeria had dry matter yields of between 8-12 t/ha per annum from 3 cuttings under low fertility conditions. With adequate fertilization and good management DM yields of 15 to 20 t/ha/annum are common under humid/derived savanna conditions, compared with yields of 3-4 t/ha/annum for local *Cynodon* cultivars from 3 harvest (Mathewman, 1997). Adegbola (1964) also reported dry matter production for some selected grass species grown at Agege, Western Nigeria in 1960-1961. *Andropogon gayanus* gave 17.74 t/ha, *Pennisetum purpureum:* 8.35 t/ha, *Panicum maximum:* 6.65 t/ha, *Cynodon dactylon:* 3.76 t/ha, *Digitaria decumbens:* 3.41 and *Melinis minutiflora,* 4.30 t/ha, from 3 or 4 harvests.

2.10.1.1 The effect of plant height on yield

Ocumpaugh and Rouquette (1985) reported plant height of 1.5-2.5m for dwarf 'Mott' elephantgrass while tall variety of elephant grass ranged from 2 to 6m. Burns *et al.* (1978) reported that plant height had a significant influence on yield.

2.10.1.2 The effect of tillering on yield of grasses

The tiller is the basic unit of the grass plant from which the development and growth of the plant and the sward could be assessed. Within the grass tiller, assimilates are initially preferentially deployed to maintain the production of leaves (Garwood, 1969). The tillers arising on the main stem of the seedling are known as primary tillers. These produce secondary tillers and tertiary tillers

respectively. The rate of tillering is most markedly affected by light energy, which determines the supply of plant assimilates. Species and varieties differ in their rate of tiller production. Tiller production proceeds continuously subject to the environmental conditions while the vegetative growth is only seriously retarded at the onset of stem elongation prior to flowering. Under sward conditions the number of tillers per unit area were at their maximum at the end of the vegetative period. Such annual fluctuations are evident irrespective of frequency of cutting or grazing or harvesting for seed. Differences will occur in any year as a result of differences in weather and growing conditions. Greater fluctuations in tiller numbers per unit area have been observed in perennial ryegrass than in cocksfoot or timothy grass (Garwood, 1969).

Changes in tiller numbers in a sward depend on changes in the rate of production of new tillers, on their longevity and on the death rate of tillers. Cuomo *et al* (1996) reported that the number of fillers per m^2 produced by Pearl Millet Napiergrass hybrid (PMN) increased from 36 to 48 when harvest frequency reduced from 5 to 3 within two years. For Napiergrass the number of tillers increased from 21 to 67 when harvest frequency was reduced from 5 to 3 within two years respectively. According to Beaty *et al*. (1977), leaf production on mature vegetative tillers was highly predictable but lack of correlation between tiller numbers and yield was possibly related to the large numbers of young tillers that initiated growth but died before they could produce leaves. In the case of Bahiagrass it is probable that certain tillers were effective in producing more leaves than others (Beaty *et al*., 1977).

Redfearn *et al*. (1997) observed that tiller densities, the size of the tiller and developmental status of tillers within the sward of switch grass (*Panicum virgatum L*.) population influenced the quantity of forage harvested. Tan *et al*. (1977) concluded that, leaf area per tiller and tiller densities were two fundamental factors that affected yield of smooth bromegrass *(Bromus inermis Leyss)*. Increased yields (2.16 kg m^{-2}) have resulted from selection of plants with larger tillers and leaf blades in reed canary grass (*Phalaris arundinacea L.)* and tall fescue (*Festuca arundinacea Schreb;* Carlson *et al*., (1983). Nelson and Sleper (1983) reported that high yielding forage species (2.41 kg m^{-2}) are favoured by accumulation of a large number of reproductive tillers. Nelson et

al. (1985) and Sleeper and Drolsom (1974) reported that genotypes of Bromegrass selected for high tiller dry weight increased dry matter yields of vegetative and reproductive swards of tall Fescue and Smooth Bromegrass (3.62 kg m^{-2}).

2.10.1.3 Leafiness (Leaf: Stem Ratio)

In the early stages of growth, the herbage consists mainly of leaves. As grasses age stems comprise a greater percentage of bulk of the forage. In non-defoliated grasses such as *Chloris gayana* and *Panicum maximum*, leaf to stem ratio for the grasses at 2½ weeks were 1.06:1.0 and 1.22:1.0 but dropped to 0.61:1 and 0.94:1.0 at 5 weeks and later to less than 0.25:1 and 0.21:1 at 7½ weeks respectively (Taerum, 1970)

Under sward conditions of closely spaced plants with constant rate of tiller appearance, the ratio changes less drastically. As the dry season progresses however, it is difficult to maintain a ratio greater than 0.5:1 even under close grazing.

The aging of forage is frequently associated with a decrease in leafiness. Moore *et al*. (1991) reported that changes in plant morphology during growth determine the potential productivity in perennial forage grasses. To determine total dry matter yield, Moore *et al*. (1991) partitioned switchgrass into leaf blade, leaf sheath and stem components and inflorescence to determine contributions to dry matter yield from these components. In some varieties of *Bromegrass* greater total yields were obtained due to major contributions from total stem dry weight.

Redfearn, *et al*, (1997) observed that generally, leaf blade and leaf sheath fractions accounted for virtually all the dry matter yield in vegetative swards. In elongating and reproductive swards, leaf blade and sheath dry weight per tiller remained constant, whereas stem dry weight per tiller tended to increase as elongating swards progressed to reproductive sward maturity. In elongating swards, the inflorescence at early reproduction, tillers contributed towards total stem weight.

2.10.1.4 Persistence

Persistence involves continuous growth of original plants and/or regeneration from seed. It also involves resistance or tolerance to grazing and cutting, competition from other plants, drought, water logging, shade, low or high temperatures, diseases, insects and nutrient deficiencies. Measuring herbage yields over the period indirectly measures persistence. The influence of harvest schedules and fertilization on persistence and productivity of four warm and six cool season grass species were reported by Jung *et al*. (1974). The grasses were harvested three, five or eight times per year. Persistence of Kentucky bluegrass (*Poa pratensis L.*), tall Fescue (*Festuca arundinacea*), Orchardgrass (*Dactylis glomerata* L.), and timothy (*Phleum pratense L.*) improved as harvesting frequency was increased from three to eight cuts per year from 16 to 32 %, especially at a high rate of nitrogen fertilizer application.

On the other hand Reed Canarygrass (*Phalaris arundinacea* L.) and smooth Bromegrass (*Bromus inermis Leyss.*) stands were better if harvesting was less frequent. The number of tillers m^2 for plots harvested five, four and three times per year increased from 36, 49 and 53 respectively when averaged over two years. Stands of Bermudagrass (*Cynodon dactylon L.*), Indiangrass (*Sorghastrum nutans* L), Big Bluestem (*Andropogan gerardi vitman*) and Switchgrass (*Panicum virgatum L.*) had deteriorated badly after two years. Two yields were lowered by 17 and 34% as harvesting frequency increased from three to five and from three to eight cuts respectively. Anderson and Matches (1983) reported that harvest frequency had large influence on stand persistence. Harvesting two or three times yearly decreased Switchgrass stands by 58%, but a single harvest during the active growing period decreased stands by only 39% (Newell and Keim, 1947). Knettle *et al*. (1991) reported reduced Napiergrass stands as harvest frequency increased. As harvest frequency increased from three, four and five per year, persistence also reduced by 19, 26 and 32% respectively. Cuomo *et al*. (1996) however did not observe a reduction in Napiergrass stands after two years of harvesting 5, 4, and 3 times per year gave 36, 47, and 48 tillers per stand.

CHAPTER THREE

3.0 MATERIALS AND METHODS

3.1 Location and period of study

The study was conducted at the Animal Science Department of the Kwame Nkrumah University of Science and Technology, Kumasi between October 1996 and September 1998.

3.2 Climatic conditions

The trial site falls within the moist semi-deciduous forest belt of Ghana with a bimodal pattern of rainfall. The annual rainfall averages about 1193.6mm (Table 1). The major wet season extends from late March to July with peak rainfall in April and May. After a relatively short dry spell in August, the minor wet season begins in September and tails off in November. This is followed by the major dry season in December through January to February (Osafo, 1976).

Temperatures are generally high throughout the year (Table 2). The mean maximum temperature of about 34.0 °C occurs in February and March whilst the mean minimum monthly temperature of about 21.4 °C is recorded in August (Osafo, 1976).

Morning relative humidities are high throughout the year (Table 3). The monthly figures range between 89 and 97 per cent at 0600 hours and 45 and 74 per cent at 1500 hours (Osafo, 1976).

3.3 Soil description

The experimental site covered an area of 1350m^2. The soils of the trial site at the Livestock Section of the Department of Animal Science consist mainly of Asuansi Series, belonging to the Kumasi-Asuansi/Nta-Ofin Compound Association developed over Cape Coast granite under moist semi-deciduous forest.

The soils of Asuansi Series (Ferric Acrisol - FAO/UNESCO or Oxic Haplustult - S.T./USDA) consist of yellowish red moderately sandy loams and clays and occur on gentle to moderately steep upper to middle slopes. The diagnostic properties include ustic moisture regime, ochric A horizon, low base saturation and low cation exchange capacity. The soil reaction is extremely acid. The soil analysis of the site is shown in Table 4.

Agronomically, Asuansi soils are moderately deep with fairly good physical conditions for plant growth and medium moisture supplying capacity. The soils are, however, susceptible to erosion when bare.

Table 1 Average Monthly and Annual Rainfall for Kumasi, (1988-1998): mm.

STATION KUMASI	MAJOR DRY SEASON			MAJOR WET SEASON					MINOR DRY SEASON	MINOR WET SEASON			YEARLY AVERAGE
Annual Average for 10 years	Dec.	Jan.	Feb.	Mar.	Apr.	May	Jun	July	Aug.	Sept.	Oct.	Nov.	
	29.1	30.8	50.2	88.7	195	178.9	173.1	119.7	80.2	97.8	111.9	23.2	1193.6
1996	51.9	3.7	80.2	72.2	111.8	145.7	106.0	202.7	109.6	72.5	81.8	2.9	1040.9
1997	11.3	53.7	33.0	138.0	276.7	218.8	250.2	73.4	59.0	96.3	162.2	11.1	1403.7
1998	31.7	51.8	26.6	35.9	267.4	183.3	188.7	56.5	75.6	74.7	76.5	23.5	1092.2

Source: Ghana Meteorological Services. (1999)

Table 2 Mean Maximum and Minimum Temperatures for Kumasi (1988-1998): °C

STATION KUMASI	MEAN	Jan.	Feb.	Mar.	Apr.	May	Jun	Jul	Aug	Sept	Oct	Nov.	Dec.	Annual Average
Annual Average for 10 years	MEAN MAXIMUM	32.1	34.0	34.0	32.7	31.8	29.9	28.7	28.1	29.4	30.7	32.6	31.5	31.3
	MEAN MINIMUM	22.0	22.8	23.7	23.0	23.1	22.3	21.8	21.4	21.9	22.2	22.8	22.7	22.5
	MEAN	27.1	28.4	28.9	27.9	27.5	26.1	22.3	24.8	25.7	26.5	27.7	27.1	26.7
1996	MEAN MAXIMUM	31.2	33.1	32.5	32.4	31.9	29.7	29.0	28.3	28.7	29.9	32.8	30.7	30.85
	MEAN MINIMUM	22.2	22.7	23.1	23.2	23.1	22.4	21.8	21.8	21.6	21.8	22.7	22.7	22.43
1997	MEAN MAXIMUM	31.7	34.5	33.9	31.5	31.3	29.5	28.2	28.1	29.9	31.4	32.0	32.0	31.16
	MEAN MINIMUM	22.3	22.6	23.2	23.4	22.7	22.1	21.4	21.9	21. 9	22.5	22.7	22.7	22.30
1998	MEAN MAXIMUM	33.3	34.5	35.7	34.1	32.1	30.5	28.9	27.9	29.5	30.7	32. 9	31.9	31.83
	MEAN MINIMUM	21.5	23.1	24.7	23.4	23.5	22.5	22.1	21.3	22.1	22.4	22.9	22. 8	22.69

Source: Ghana Meteorological Services (1999)

TABLE 3 **Mean Monthly and Annual Relative Humidity at 0600 and 1500 Hours for Kumasi, Compiled from (1988-1998): %**

STATION KUMASI	TIME HRS.	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov. Dec.	Annual Average
Annual Average for 10 years	0600	89	89	92	94	95	96	95	97	96	96	94 93	94
	1500	52	45	50	62	65	72	71	74	70	66	54 59	62
1996	0600	97	94	94	95	96	96	96	97	96	96	94 96	96
	1500	61	55	61	63	63	72	70	75	71	67	47 67	64
1997	0600	90	85	91	95	95	97	95	97	96	96	95 90	94
	1500	57	33	46	65	65	73	73	74	69	65	59 54	61
1998	0600	80	89	91	93	95	96	95	96	96	96	93 94	93
	1500	38	47	43	58	67	70	72	74	71	66	55 57	60

Source: Ghana Meteorological Services. (1999)

Table 4 Properties of Soils (Asuansi series) at the Experimental Site

	0-15 cm	15-30cm
PH (1:2.5 H_20) C (%)	4.4	4.2
Organic Matter	1.50	0.86
Total N (%)	0.12	0.07
Avail. P (mg kg^{-1})	15.1	12.3
Exch. Cations (cmol kg^{-1})		
Ca	2.00	1.20
Mg	0.40	0.40
K	0.27	0.18
Na	0.42	0.96
Al	1.20	0.80
H	2.40	2.80
ECEC (cmol kg^{-1})	6.69	6.34
Particle size (%)		
Sand	67.6	63.6
Silt	21.0	21.0
Clay	11.4	15.4

3.3.0 Planting materials and cultivation

Nine interspecific hybrids of Pennisetum (*P. purpureum x P. typhoides*) grass developed at the International Livestock Research Institute (ILRI) Addis Ababa and one local variety of elephant grass (*P. purpureum)* were cultivated on two fields. Field A was divided into four blocks while B was divided into three blocks. Each of the nine (9) varieties of the *Pennisetum* hybrids (with accession numbers 15743, 16786, 16791, 16798, 16834, 16735, 16837, 16838 and 16840) and local *P. purpureum* variety was planted in each block with three replications.

The selection of the plots in each block for each variety was random. The plots measured 6m x 6m with inter-row planting distance being 0.75m and intra-row planting distance being 0.40m. The plots were planted in December 1994.

3.3.1 Slashing of regrowth

The plots were slashed once at a height of 15cm from ground level in sequential order from 12th November 1996 so that new regrowths could be harvested for a feeding trial at 56-day stage of growth. N.P.K. fertilizer application at the rate of 40kg/ha was carried out after each harvest to stimulate regrowth.

3.4.0 Field measurements

3.4.1 Plant height

For each variety, ten plants (one per stand) were randomly selected from each plot and the height measured from soil level to terminal leaf/inflorescence with a metal tape measure.

3.4.2 Tiller number

For each variety, ten stands per plot were randomly selected and individual tillers counted from each stand.

3.4.3 Leafiness (leaf: stem ratio)

For each variety, about 1.5kg of plant sample was taken from each plot and separated into leaves, stem and inflorescence and weighed separately. They were then dried for dry matter calculation. Leafiness was calculated as weight of leaf DM to DM of whole plant.

3.4.4 Bunch diameter

For each variety, the diameter of ten bunches from each plot was randomly selected and measured with metal tape measure across the cut surface area.

3.4.5 Stem Diameter

For each variety ten primary stems were randomly selected and the diameter was measured with metal tape measure across the cut surface of the stem.

3.4.6 Herbage yield

For each variety, the total cut per plot of fresh forage was weighed and sub samples taken of each variety and chopped into short lengths (2 - 5cm) for dry matter (DM) determination using the procedure of AOAC (1984). This involved drying in an oven at 100°C for 24 hours. Sub samples were dried at 60°C for chemical analysis. Dry matter yield of each variety was calculated on dry matter basis by multiplying weight of fresh forage by DM in samples taken of each variety per plot and calculated on hectare basis.

3.4.7 Persistence

Persistence was determined at the end of the experimental period for each variety by counting the stands that were alive in each plot per total number of stands originally established.

$$P = \frac{A_1}{A} \times 100$$

Where A_1 = Number of stands alive

A = Total number of stands
P = Persistence

3.5.0 Intake studies

Forty West African Dwarf Sheep (WADS) were randomly allocated to ten treatments (four per treatment) and the animals were rotated after each cycle until each variety was consumed by ten animals. The experimental sheep were weighed after feed and water had been withdrawn for 18 hours. They were also dipped in a solution of acaricide, Amitrix 12.5%EC (CHIPRA CO. AMER GIRONA, Spain), and dewormed with Albendazol 2.5% - Polizol (Polichem, S. A) prior to data collection. Sheep were housed in individual pens with slatted wooden floor, which has been described by Tuah *et al.* (1985) during both the adaptation and data collection periods. Each pen was equipped with plastic buckets for water and wooden feed trough designed to minimize spillage.

Grasses were harvested each morning, chopped into short lengths (5 - 10cm) with cutlass, weighed and fed to each animal individually. The feed refusals were weighed back the following morning for each animal and the difference between quantity offered and quantity not eaten was the amount of feed eaten. Sheep were offered enough grass to ensure about 20% refusal rate. Adaptation period of 14 days was allowed followed by 22 days of data collection for each animal. Samples of feed offered and the refusals were taken and dried in an oven for DM and for chemical analysis. These were pooled together on variety basis. Medication was given when necessary.

3.6.0 Metabolism studies

Metabolism crates described by Tuah *et al* (1985) fitted with urine and faecal collection units as well as feeding troughs were used for the studies. The metabolism crates measured 55 cm x 100 cm x 130 cm. The floor of the cages was provided with iron grids. At the middle of the floor, the iron grids were covered with a fine mesh nylon net, which sieves any faeces or hair from the urine as it collects in a plastic container placed on the floor underneath. There were wooden drawer containers under the iron grids to collect daily faecal output of each animal. The head of the animal was held in a stanchion made of two yokes. The animal could lie down and get up but was confined in its position so that the faeces are collected in a drawer at its rear end and feeding trough put in front of the animal (in front of the stanchion). The feeding trough was made of wood and constructed in such a way that the feed could be removed and the animal given water. The sheep were weighed at the beginning and end of each period after an 18hour fast. The animals were rotated after each round.

Sheep were fed *ad libitum* each morning. Chopped grasses were weighed each morning and offered to the animal. Refusals were collected each morning and weighed to estimate feed intake. This was done for 7 days after 10 days of adaptation. Water was provided for 30 minutes, three times a day (morning, afternoon and evening).

About 10% of the faeces voided was sampled then dried in a forced air oven for 48 hours at 60°C. Samples were ground (1mm mesh) and stored in plastic containers at room temperature prior to analysis. Feed samples were also taken and pooled together for each animal during collection period dried in a forced air oven for 48 hours at 60°C and ground (2mm mesh), stored and used for the nylon bag study and for chemical analysis.

Urine voided each day was collected in plastic containers over (20 - 100ml) concentrated hydrochloric acid to ensure that pH was less than 3. This was to avoid loss of nitrogen. The volume of urine voided was measured daily and 10% subsampled and also pooled together for each animal for each period and stored in a freezer prior to urine nitrogen determination.

3.7.0 Degradability studies

Four rumen-fistulated rams were used for these studies. The sheep were housed in individual pens with slatted floor. All the animals were fed local *P. purpureum* during the degradability studies. Samples of each of the ten varieties collected during intake and digestibility studies, were dried and pooled together for each variety for this experiment. Samples were milled through a 2mm screen and stored for the degradability studies. The disappearance of DM from dacron bags was determined in the rumen following the nylon bag technique described by Mehrez and Ørskov (1977). About 3.0gm of milled dry samples were weighed into nylon bags (6.5 x 14cm and 41µm pore size) and introduced into the rumen (via the rumen fistula) after tying bags on a short perforated plastic tube with rubber bands to hold the bags in place. The ten (10) feeds were incubated in two batches so that the first batch made up of 5 feed samples including the local, were introduced into the rumen at the same time and withdrawn. While the second batch was made up of another set of 5 samples plus the local Napier, were also introduced into the rumen at the same time and all withdrawn. Each of these sets were incubated for 3, 6, 12, 24, 48, 72, 96 and 120 hrs respectively. On removal of the bags at the end of each incubation time, the bags were washed under tap water until the water was clear. Samples were dried in an oven at 60°C for 48 hours. A set of bags not incubated (0 hour) but containing each of the feed samples were also washed and dried under similar conditions. The equation of Ørskov and McDonald (1979) below was used to describe the course of degradation of dry matter loss from nylon bags at specific time intervals.

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

Where P is the potential disappearance of DM at time t;

a, the rapidly soluble fraction

b, the potentially degradable fraction and the

c, rate of degradation of b fraction.

t, time.

3.8.0 Gas production

Grass samples collected during intake and digestibility studies were used for this experiment. Dry samples of the ten varieties were milled through 1mm screen and kept in polythene bags before use. About 200mg of each sample was weighed into incubation tubes (syringes) which were lubricated with Vaseline (pure petroleum jelly) to ease the sliding of plunger and prevent the escape of gas. The plungers were pre-warmed (39°C) in a water bath prior to the injection of 30ml of rumen fluid and media mixture (Appendix) (1:2 v/v), and subsequent incubation in a water bath (39 ± 0.5°C). Readings were recorded at 3, 6, 12, 24, 48, 72, 96 and 120 hours and the syringes were gently shaken at each reading time. If the gas production exceeded 60ml for a syringe, it was taken out of the bath and the gas released by opening the clip on the rubber tube to allow the gas out by pushing the plunger gently until it was back to the 30ml mark. Four replicates of each sample were incubated in each period. Parallel syringes, containing no substrate but rumen fluid and media mixture, served as blanks.

For gas production, the equation below was used to describe the course of fermentation after corrections for the blanks: $GP = b(1-e^{-ct})$. Where b is the potential gas production; c the rate of gas production; GP the gas produced at time t (Siaw, *et al.*, 1993).

3.9.0 Chemical analysis

Dry matter in feed, faeces, nylon bag residues and grass samples obtained from intake and digestibility studies were determined by the official methods of Analysis of the Association of Official Analytical Chemists (AOAC, 1984). The nitrogen content of the grass samples, from intake and digestibility studies feed, faeces and urine during digestibility studies were determined by micro-Kjeldahl method (AOAC, 1984). Neutral detergent fibre (NDF), acid detergent fibre (ADF) and acid detergent lignin (ADL) of samples obtained from intake studies were determined following the method described

by Van Soest (1991). Hemicellulose was estimated by the difference between neutral detergent fibre and acid detergent fibre.

The soil was analysed for organic matter, total nitrogen (%) available phosphorus, Exchangeable cations (Ca, Mg. K, Na, Al, H), particle size distribution and pH. Total nitrogen was determined in soils using the micro – Kjeldahl method while organic matter was determined from carbon content of soils using the method of Walkley and Black (1948). The soil reaction (pH) was determined using the pH meter. Mechanical analysis was used for particle size distribution and exchangeable cations was anyalysed using the Flame photometer.

3.9.1 Experimental design and statistical analysis

A completely randomised design (CRD) was used in the degradability and gas production studies. A completely randomised design with a change over design was used in intake and metabolism studies. The randomised complete block design (RCBD) was used for all the agronomic measurements.

The data for intake, metabolism studies and agronomic characteristic measurement were statistically analysed using the general linear models procedure of Statistical Analysis Systems (SAS, 1987).

The data for degradability and gas production tests were analysed using the MSTAT package. Tukey's least significant test (Steel and Torrie, 1980) was used to compare the treatment means.

The relationship between intake and *in sacco* dry matter degradability, chemical composition, *in vitro* gas production and *in vivo* digestibility were estimated by linear regression analysis using MSTAT package.

CHAPTER FOUR

RESULTS

4.1 Agronomic characteristics of ten varieties of *Pennisetum purpureum* at 56 days of regrowth

The plant height, tiller number, bunch diameter, leaf/stem ratio, stem diameter, persistence and yield values are shown in Table 5.

Varieties 16791, 16835, local, 16840, 16798, 16834 and 16786 were not significantly ($P>0.05$) different from each other in plant height. However, they were all significantly ($P<0.05$) taller than varieties 16837, 16838 and 15743. Variety 15743 was significantly ($P<0.05$) shorter than the rest. The plant height ranged from 57.57cm to 189.98 cm.

Tiller number of variety 16838 was significantly ($P<0.05$) higher than the rest of the varieties, which were not significantly different from each other.

Bunch diameter was significantly ($P<0.05$) greater for local variety than the rest. Bunch diameter for varieties 16840, 16786 and 16798 were not significantly ($P>0.05$) different from each other, but were significantly greater than varieties 16834, 16837, 16838, 15743, 16791 and 16835. Similarly, bunch diameter for varieties 16834 and 16837 were not significantly ($P>0.05$) different but was significantly ($P<0.05$) greater than varieties 16838, 15743, 16791 and 16835. The bunch diameter for all the grasses were in the range of 20.3 cm to 50.7 cm.

Leaf: stem ratio was significantly ($P<0.05$) greater for variety 15743 than the rest. Variety 16837 had significantly ($P<0.05$) higher leaf: stem ratio than the others except variety 15743. Varieties 16786, 16798 and local were not significantly ($P>0.05$) different from each other but they had significantly ($P<0.05$) higher leaf: stem ratio than varieties 16838, 16840, 16835, 16834 and 16791. Leafiness values were not significantly ($P>0.05$) different for varieties 16838 and 16840 but were significantly ($P<0.05$) higher than varieties 16834, 16835 and 16791. Varieties 16835 and 16791 were not significantly ($P>0.05$) different.

Table 5 **Agronomic characteristics of ten varieties of *Pennisetum purpureum* at 56 days of regrowth**

VARIETIES	PLANT HEIGHT (cm)	TILLER NUMBER	BUNCH DIAMETER (cm)	% LEAFINESS (leaf: stem ratio)	STEM DIAMETER (cm)	PERSISTENCE (%)	HERBAGE DM YIELD/CUTTING (kg/Ha)	DM (%)
Local	171.50^{b}	12^{a}	50.7^{d}	48.6 (1.03:1.09)	1.78^{c}	75.90^{d}	1547.43^{e}	19.34
HYBRIDS				69.4 (1.59:0.70)				
15743	57.57^{a}	18^{a}	33.7^{b}		1.25^{b}	10.55^{a}	469.06^{a}	15.38
16786	153.82^{b}	17^{a}	45.7^{cd}	41.3 (0.88:1.25)	1.51^{bc}	46.76^{c}	1051.16^{d}	21.04
16791	189.98^{b}	14^{a}	20.3^{a}	13.6 (0.42:2.67)	0.62^{a}	11.33^{a}	623.37^{b}	22.66
16798	161.05^{b}	12^{a}	43.2^{cd}	45.0 (0.94:1.15)	1.73^{c}	35.98^{b}	953.48^{d}	19.08
16834	151.85^{b}	17^{a}	41.0^{c}	26.2 (0.64:1.80)	0.83^{a}	24.88^{b}	642.82^{b}	19.15
16835	182.67^{b}	21^{a}	23.4^{a}	20.5 (0.53:2.06)	0.68^{a}	10.93^{a}	640.17^{b}	20.46
16837	123.37^{ab}	17^{a}	41.5^{c}	48.8 (1.04:1.12)	1.21^{b}	38.19^{c}	827.72^{c}	18.99
16838	122.82^{ab}	25^{b}	38.6^{b}	40.8 (0.86:1.25)	1.0^{a}	19.93^{a}	807.79^{c}	19.56
16840	171.53^{b}	18^{a}	46.2^{cd}	35.5 (0.77:1.40)	1.59^{c}	63.52^{d}	1948.55^{f}	19.69
SED (n=3)	22.57	4.61	2.33	0.26	0.159	9.775	501.06	
SIGNIFICANCE	*	*	*	*	*	*	*	

Footnotes: Leafiness = Leaf DM yield / herbage DM yield. SIGNIFICANCE: $P < 0.05$, *

SED: Standard Error of the Difference.

* Means with different superscripts (a, b, c, d, e and f) in the same column are significantly different.

Stem diameter for varieties 16798, 16840 and local were not significantly ($P>0.05$) different from each other but was significantly ($P<0.05$) bigger than the rest. Varieties 15743 and 16837 were not significantly ($P>0.05$) different but they had significantly ($P<0.05$) bigger stems than varieties 16791, 16834, 16835 and 16838 respectively. Varieties 16791, 16834, 16835 and 16838 were not significantly ($P>0.05$) different from each other.

The local and 16840 varieties were significantly ($P<0.05$) higher with respect to persistence than the rest. Varieties 16786 and 16837 were also significantly ($P<0.05$) more persistent than varieties 16798, 16838, 16835, 16834 16791 and 15743. Varieties 16838, 16835, 16834,16791 and 15743 were significantly ($P<0.05$) less persistent than the others but are not significantly different ($P>0.05$) from each other. Persistence values ranged from 10.55 to 75.90%.

The yields were significantly ($P<0.05$) higher for variety 16840 than the local and the others. The local variety ranked second in yield and was also significantly ($P<0.05$) higher than the rest. Yields of varieties 16786 and 16798 were significantly ($P<0.05$) greater than yields of varieties 16837, 16838, 16834, 16835, 16791 and 15743. Varieties 16837 and 16838 were not significantly different from each other but had significantly ($P<0.05$) greater yield than varieties 16834, 16835, 16791 and 15743. Yields of varieties 16834, 16835 and 16791 were not significantly ($P>0.05$) different from each other. The yield ranged from 469.06 to 1948.55 kg DM/ha.

4.2 Relationship between yield of *P. purpureum* varieties and plant height, tiller number, bunch diameter, stem diameter, leafiness and persistence

The relationships between yield and agronomic characteristics are shown in Table 6. Significant relationship existed between yield and plant height ($r=0.218$; $P<0.05$), between yield and tiller number ($r=-0.194$; $P<0.05$), between yield and bunch diameter ($r=0.488$; $P<0.05$), between yield and leafiness ($r=-0.232$; $P<0.05$), between yield and stem diameter ($r=0.360$; $P<0.05$), and between yield and persistence ($r=0.603$; $P<0.05$), respectively.

Table 6 Relationship between yield (Y) and plant height (x), Tiller number (x), bunch diameter (x), Stem diameter (x), Leafiness (x), and Persistence (x) in *P. purpureum.*

Parameter	Equation	r	LS	SE
Plant height	Y = 133.55 + 0.931x	0.218	P<0.05	0.313
Tiller number	Y = 19.55 – 0.136x	-0.194	P<0.05	0.051
Bunch diameter	Y = 30.47 + 0.575x	0.488	P<0.05	0.077
Stem diameter	Y = 0.91 + 0.018x	0.360	P<0.05	0.004
Leafiness	Y = 0.98 – 0.010x	-0.232	P<0.05	0.003
Persistence	Y = 12.90 + 1.547x	0.603	P<0.05	0.153

Footnotes: r = correlation co-efficient
LS = level of significance
SE = standard error

4.3 Chemical composition of ten varieties of *Pennisetum purpureum* at 56 days of regrowth. (samples used during intake studies)

The crude protein (CP), neutral detergent fibre (NDF) and acid detergent fibre (ADF) hemicellulose, acid detergent lignin contents of leaf, stem and the whole plant are shown in Table 7. The chemical composition of the forages was not subjected to statistical analysis because the values were means of two determinations. Generally, the leaf fractions (7.8 to 13.5%) were higher in crude protein than either stem (5.3 to 12.6%) or whole plant (7.7 to 13.2%). The crude protein content of the whole plant was highest for variety 15743 followed by 16838, local and 16798, respectively. The rest of the varieties were similar with variety 16791 having the lowest value of 7.7%. The neutral detergent fibre content of the varieties were higher than acid detergent fibre contents. Higher contents of NDF were recorded for varieties 16838, 16840, 16837, 16834, 16798, 16791, 16786 and the local for the whole plant. The leaf fractions were all similar in NDF concentrations but not varieties 16840, 16798, 16786 and local which were above 70%. The lowest value was recorded for variety 16835. The NDF concentrations in the whole plant were generally the same except varieties 15743 and 16835 which were less than 70%.

Hemicellulose concentrations in the leaf fractions were generally higher than the stem and whole plant fractions. The hemicellulose contents of the leaf ranged from 27.5% in the local variety to 31.8% in variety 16840. The stem fractions showed hemicellulose

Table 7 **Chemical composition of ten varieties of *Pennisetum purpureum* at 56 days of regrowth (samples obtained from intake studies)**

VARIETIES	% CRUDE PROTEIN			% NDF			% ADF			HEMICELLULOSE (%)			ADL (%)		
	Leaf	Stem	Whole Plant	Leaf	Stem	Whole Plant	Leaf	Stem	Whole Plant	Leaf	Stem	Whole Plant	Leaf	Stem	Whole Plant
Local	10.3	6.7	9.6	72.6	67.1	70.1	45.1	42.1	45.3	27.5	25.0	24.8	1.82	7.38	3.96
HYBRID 15743	13.5	12.6	13.2	66.4	65.2	64.3	36.3	38.1	37.9	30.1	27.1	26.4	0.43	0.87	0.87
16786	9.6	6.9	8.5	72.9	71.7	73.0	42.6	42.9	42.5	30.3	28.8	30.5	3.08	3.46	3.86
16791	11.2	5.3	7.7	68.9	71.5	70.1	39.3	51.2	44.5	29.6	20.3	25.6	3.49	4.34	3.91
16798	10.4	9.2	9.3	74.4	66.9	71.7	43.1	37.9	37.3	31.3	29.9	34.4	2.99	6.33	1.91
16834	7.8	6.6	8.7	69.6	71.6	71.0	39.3	45.5	43.6	30.3	26.1	27.4	2.63	6.99	3.34
16835	13.3	5.8	8.2	65.1	71.9	69.8	36.5	48.1	44.9	28.6	23.8	24.9	1.74	1.73	1.73
16837	11.3	7.1	8.6	69.2	69.8	70.1	41.3	45.9	42.7	27.9	23.9	27.4	0.87	2.15	0.87
16838	11.6	7.3	9.8	69.9	72.5	71.2	39.6	43.2	42.6	30.3	29.3	28.6	0.87	0.86	0.85
16840	9.9	8.9	9.0	72.2	67.6	73.2	40.4	39.0	41.8	31.8	28.6	31.4	1.31	6.83	1.31

Footnotes: NDF = Neutral Detergent Fibre ADF = Acid Detergent Fibre

ADL = Acid Detergent Lignin Values are means of two determinations

concentrations ranging from 20.3% in variety 16791 to 29.4% in variety 16838, while the whole plant ranged from 24.8% for local variety to 34.4% for variety 16798. On the other hand, the ADL concentrations in the leaf fractions was 0.43% for variety 15743 to 3.49% for variety 16791. The ADL concentrations of stem ranged from 0.86 to 7.38% while the whole plant contents ranged from 0.85 to 3.96%.

4.4 Apparent dry matter digestibility, intake and nitrogen balance during metabolism studies

Dry matter intake, apparent digestibility coefficient of dry matter and nitrogen balance values are presented in Table 8. Dry matter intake were significantly ($P<0.05$) affected by the type of grass fed to the sheep. Varieties 16837 and 16786 were significantly ($P<0.05$) greater in dry matter intake per metabolic body size than the local and the others. The intake of local and varieties 16798 and 16840 were also significantly ($P<0.05$) higher than 16834 and 16838. However, dry matter intake of 16791, 15743 and 16835 were the least. The dry matter intake per metabolic body size ranged from 39.02 to 80.18g/kg^{-1}W$^{0.75}$ for all the varieties. Fresh matter intake (g/day) was significantly ($P<0.05$) higher for variety 16837 than the rest. Intake of varieties local, 16786 and 16798 were not significantly ($P>0.05$) different from each other but were significantly ($P<0.05$) higher than varieties 15743, 16791, 16834, 16838 and 16840. However, intake of varieties 15743, 16834, 16838 and 16840 were not significantly ($P>0.05$) different. Variety 16835 was least consumed.

Fresh matter intake (g/day W$^{0.75}$) was significantly ($P<0.05$) higher for the local variety than the rest. On the other hand variety 16835 was significantly ($P<0.05$) least consumed. The rest were however not significantly ($P>0.05$) different.

Intake (g/day DM) was significantly ($P<0.05$) higher for varieties 16786 and 16837 than the rest. Intake for varieties 16798 and local were also significantly ($P<0.05$) higher than the others. However, varieties 16840, 16834, 16838 and 16791 were not significantly ($P>0.05$) different but were higher than varieties 15743 and 16840.

The apparent digestibility coefficient of dry matter values range from 56.01 to 73.31% for the varieties. The local variety, and varieties 15743, 16838 and

16840 were significantly (P<0.05) higher than the rest. Varieties 16798, 16837 and 16786 were not significantly (P>0.05) different from each other but were also significantly (P<0.05) higher than varieties 16834, 16791 and 16835.

The nitrogen intake during the trial range from 3.89 g/day for animals fed variety 16835 to 10.57g/day for those fed variety 16837. Faecal nitrogen values range from 1.79 g/day to 3.04 g/day for animals on varieties 15743 and 16798 respectively. The nitrogen excreted in urine was 1.18 g/day for variety 16791 and 3.34 g/day for animals fed variety 16786 for the lowest and highest respectively. The nitrogen balance were positive for all the varieties fed to the animals and the least value was 0.60 g/day while the highest was 5.29 g/day for varieties 16835 and 16837 respectively. The balance did not show any significant (P>0.05) difference among the varieties.

Table 8 **Intake, apparent dry matter digestibility and nitrogen balance of WAD Sheep on *Pennisetum purpureum* (during metabolism studies).**

VARIETIES	INTAKE OF DM g/KG $W^{0.75}$/DAY	INTAKE OF DM g/DAY	INTAKE OF FRESH MATTER g/DAY $W^{0.75}$)	INTAKE g/DAY FRESH MATTER	APPARENT DIGESTIBILITY CO-EFFICIENT OF DM %	NITROGEN INTAKE g/DAY	NITROGEN VOIDED IN FAECES g/DAY	NITROGEN EXCRETED IN URINE g/DAY	NITROGEN RETAINED g/DAY
LOCAL	68.99^{b}	539.5^{ab}	346.3^{a}	2746^{ab}	69.94^{a}	8.63	2.5	2.95	3.18
15743	43.14^{cd}	349.1^{bc}	269.7^{ab}	2101^{abc}	73.31^{a}	7.34	1.79	2.21	3.34
16786	76.74^{a}	623.3^{a}	341.2^{ab}	2771^{ab}	65.03^{ab}	8.93	3.02	3.34	2.57
16791	47.73^{cd}	392.0^{abc}	192.2^{ab}	1522^{bc}	61.99^{bc}	5.37	2.16	1.18	2.03
16798	68.94^{ab}	557.9^{ab}	336.6^{ab}	2723^{ab}	68.80^{ab}	9.52	3.04	2.00	4.48
16834	56.25^{c}	441.5^{abc}	272.2^{ab}	2074^{abc}	62.23^{bc}	8.00	2.51	2.29	3.20
16835	39.02^{d}	268.2^{c}	174.9^{b}	1348^{c}	56.07^{d}	3.89	1.94	1.35	0.60
16837	80.18^{a}	612.6^{a}	311.1^{ab}	2965^{a}	67.72^{ab}	10.57	3.14	2.14	5.29
16838	49.89^{c}	396.4^{abc}	251.6^{ab}	2000^{abc}	71.14^{a}	5.72	1.95	2.35	1.42
16840	64.31^{b}	447.4^{abc}	318.4^{ab}	2216^{abc}	69.53^{a}	7.10	2.43	2.55	2.12
SED (n =4)	7.396	71.113	48.669	388.199	4.111	-	-	-	1.281
SIGNIFICANCE	*	*	*	*	*	NS	NS	NS	NS

Means with different superscripts (a, b, c, d) in the same column are significantly different at ($P < 0.05$)

SED = Standard error of difference
NS = Not significant ($P>0.05$).

4.5 Intake of ten varieties of *P. purpureum* by West African Dwarf Sheep during intake studies

Intake of dry matter, fresh matter (g/kg) per metabolic body size per day and intake on fresh weight basis (g/day) are shown in Table 9. Intake of dry matter and fresh weight were significantly ($P<0.05$) affected by the treatments. Dry matter intake ranged from 56.17 to 80.41$gkg^{-1}W^{0.75-1}day$. Intake of varieties 16838 and 16786 were significantly ($P<0.05$) higher than the rest. Varieties 16840, local, 16798, 16837, 15743 and 16834 were not significantly ($P>0.05$) different from each other for quantity of varieties consumed. The varieties least consumed were 16835 and 16791 and were not significantly ($P>0.05$) different from each other.

Feed intake of fresh matter (g/kg) per metabolic body size ranged from 267.32 to 362.97 per day. Intake was significantly ($P<0.05$) higher for varieties 15743, 16798, local and 16786 than the rest. Varieties 16838, 16840, 16837 were significantly ($P<0.05$) consumed more than varieties 16834, 16791 and 16835. There were no significant ($P>0.05$) differences in intake of varieties, 16838, 16840 and 16837 but these were significantly ($P<0.05$) higher than varieties 16834, 16791 and 16835. Feed intake was significantly ($P<0.05$) higher for variety 16834 than varieties 16791 and 16835. Variety 16791 was not significantly ($P>0.05$) higher than variety 16835.

Feed intake on fresh weight basis (g/day) ranged from 1962.13 to 2813.04 for varieties 16835 and 15743 respectively. Intake was significantly ($P<0.05$) higher for variety 15743 than the rest. Variety 16798 was significantly ($P<0.05$) higher than varieties 16786, local, 16840, 16837, 16838, 16834, 16791 and 16835 respectively. Varieties 16786, local and 16840 were not significantly ($P>0.05$) different when feed intake was compared on fresh weight basis. Variety 16837 did not differ significantly ($P>0.05$) from variety 16838 but both were significantly ($P<0.05$) higher than varieties 16791 and 16835.

Table 9 **Intake of ten varieties of *P. purpureum* by West African Dwarf sheep during intake studies**

VARIETIES	INTAKE OF DM g/kg $W^{0.75}$/DAY	DM INTAKE g/DAY	INTAKE OF FRESH *P. PURPUREUM* g /DAY	INTAKE OF FRESH *P. PURPUREUM* g/kg $W^{0.75}$/DAY
LOCAL	73.02^{bc}	528.66	2565.3^{c}	354.32^{d}
HYBRIDS				
15743	69.56^{bc}	539.09	2813.04^{d}	362.97^{d}
16786	79.68^{c}	573.70	2596.69^{c}	360.65^{d}
16791	62.78^{ab}	452.64	2038.95^{ab}	282.79^{a}
16798	72.01^{bc}	519.91	2609.69^{cd}	361.45^{d}
16834	67.89^{bc}	490.17	2183.18^{b}	302.38^{b}
16835	56.17^{a}	412.29	1962.13^{a}	267.32^{a}
16837	70.34^{bc}	503.63	2356.20^{bc}	329.08^{c}
16838	80.41^{c}	572.52	2392.76^{bc}	336.06^{c}
16840	73.17^{bc}	537.80	2442.02^{c}	332.25^{c}
SED (n=10)	4.51	43.56	210.21	28.87
SIGNIFICANCE	*	*	*	*

Footnotes:

SED: Standard Error of the Difference
Means with different superscripts in the same column are significantly different (P<.05).

Table 10: Relationship Between Intake (Y) and Chemical Composition (X) of *P. purpureum* (samples used during intake studies)

Parameter	EQUATION	r	LS	SE
CP	Y=5.71+0.050 x	0.239	NS	0.072
NDF	Y=62.12+0.118x	0.345	NS	0.114
ADF	Y=49.81-0.106x	-0.282	NS	0.128
ADL	Y=2.81-0.009x	-0.055	NS	0.060

Table 11 Relationship Between Apparent DM Digestibility (Y) and Chemical Composition (X) of *P. purpureum*

Parameter	EQUATION	r	LS	SE
CP	Y=12.22+0.299x	0.574	NS	0.151
NDF	Y=83.37-0.180x	0.212	NS	0.292
ADF	Y=86.63-0.617x	-0.660	P<0.05	0.248
ADL	Y=7.96-0.081x	-0.192	NS	0.148

CP	=	Crude protein	NS	=	Not significant
NDF	=	Neutral detergent fibre	SE	=	Standard error
ADF	=	Acid detergent fibre	ADL	=	Acid detergent lignin
r	=	Correlation co-efficient	LS	=	Level of significance

The relationship between feed intake and chemical composition (Table 10) were all not significant, CP, r = 0.239, NDF, r = 0.345, ADF, r = -0.282 and ADL, r = 0.055. The relationship between apparent digestibility and chemical composition (Table 11) was significant for only ADF (r = -0.66; P<0.05). The rest were not significant. The relationship between apparent digestibility and crude protein was fairly strong (r = 0.574; P>0.05) but not significant.

4.6 Rumen Degradation Characteristics of Samples from Intake Studies

The data for the rumen degradation of nine interspecific hybrid varieties of *P. purpureum* and a local Napiergrass incubated in rams are indicated in Table 12. Significant differences were observed among the varieties during incubations of 3, 6, 12, 24, 96 and 120h respectively but at 48 and 72h there were no significant differences. At 3h of incubation variety 15743 was significantly ($P<0.05$) more degraded than the rest. Similarly, variety 16834 was also significantly ($P<0.05$) more degraded than the others. Varieties 16835 and 16837 were not significantly different. The local variety was not significantly ($P>0.05$) different in degradability from varieties 16798 and 16838. Dry matter degradation was significantly ($P<0.05$) higher for variety 16798 than varieties 16838, 16786, 16840 and 16791. Variety 16838 was significantly ($P<0.05$) higher than variety 16840 which was significantly ($P<0.05$) more degraded than variety 16791.

At 6h of incubation, dry matter degradation was significantly higher for varieties 15743 and 16840 than the rest. Variety 16838 was significantly ($P<0.05$) more degraded than varieties 16837, 16834, 16798, 16835 and 16791 while varieties 16786 and the local did not differ significantly. Variety 16834 was also significantly (<0.05) more degraded than varieties 16798, 16835 and 16791. There were no significant ($P>0.05$) differences between varieties 16798 and 16835 while variety 16791 was significantly ($P<0.05$) least degraded.

At 12h incubation period variety 16840 ranked first and was significantly ($P<0.05$) better degraded than the rest while varieties 15743 and 16838 were significantly ($P<0.05$) higher than others. The local variety and varieties 16798, 16837 were not significantly ($P>0.05$) different but were significantly ($P<0.05$) higher than varieties 16834, 16786, 16835 and 16791. DM degradability was significantly ($P<0.05$) higher for variety 16834 than varieties 16786, 16835 and 16791. Similarly, variety 16786 was significantly more degraded than varieties 16835 and 16791. Variety 16791 was significantly ($P<0.05$) least degraded.

At 24h period of incubation, variety 15743 was significantly ($P<0.05$) more degraded than the rest. Variety 16786 ranked second and was also significantly ($P<0.05$) more degraded than the others. Dry matter loss from varieties 16798, 16840 and local were not significantly ($P>0.05$) different but were significantly ($P<0.05$) higher than varieties 16834, 16791, 16835, 16838 and 16838 were also not significantly ($P>0.05$) different from each other but were higher than variety 16837.

Dry matter degradation values did not show significant differences at 48 and 72h incubation for all the varieties.

At 96h incubation period, dry matter degradation for variety 16840 was significantly ($P<0.05$) higher than varieties 16798, 15743, 16838, local, 16791, 16834, 16835, 16837 and 16786. Variety 16786 was significantly ($P<0.05$) higher than the others, while variety 15743 and 16798 were not significantly ($P>0.05$) different. Variety 16838 was significantly greater in DM degradation than varieties local, 16791, 16834, 16835 and 16837. Varieties local and 16791 were significantly ($P<0.05$) better degraded than varieties 16835 and 16837. There were no significant ($P>0.05$) differences between varieties 16835 and 16837.

At 120h of incubation, variety 16840 was significantly ($P<0.05$) higher in DM degradation than the rest. Varieties 16786 and 16798 were significantly ($P<0.05$) higher than the others in DM degradability. DM degradation for varieties 15743 and 16838 were not significantly ($P>0.05$) different but was significantly higher than varieties local, 16791, 16834, 16835 and 16837. The local variety was significantly higher in DM degradation than varieties 16791, 16834, 16835 and 16837. Varieties 16834, 16835 and 16837 were significantly least degraded and were not significantly ($P>0.05$) different from each other.

The Pennisetum hybrid varieties and the local *P. purpureum* did not significantly ($P>0.05$) influence the degradation constants estimated for all the varieties. The readily soluble component (a) ranged from 15.58 to 19.23. Slowly degradable fraction (b) varies between 49.71 to 55.95 for varieties local and 16840 respectively. The potential degradable fraction also ranged from 62.33 to 73.86 for varieties 16835 to 15743 respectively. The rate of degradation ranged from 0.0233 to 0.0436 for varieties 16834 and 16786 respectively.

4.7 Rumen degradation studies (samples from digestibility Studies)

Dry matter degradability of samples used during digestibility studies are also shown in Table 13. Rumen dry matter loss values were significantly affected by time of incubation. At 3hr of incubation, variety 15743 was most significantly ($P<0.05$) degraded than the rest. Dry matter degradability values for varieties 16835 and 16837 were not significantly ($P>0.05$) different but were both higher than varieties 16786, 16791, 16798, 16834, 16838, 16840 and local. Varieties 16786, 16834, 16838 and 16840 were also not significantly ($P>0.05$) different from each other but were higher than varieties

local, 16791 and 16798. Significantly least degraded were varieties local and 16798.

At 6hr period of incubation, significant differences were observed for all the varieties. Variety 15743 was most highly degraded and significantly ($P<0.05$) higher than the rest. Variety 16835 was significantly more degraded than varieties 16838, 16837, 16791, 16786, 16834, 16798 and the local respectively. Variety 16838 was also significantly ($P<0.05$) higher in DM degradation than the others. Similarly, dry matter degradation was significantly ($P<0.05$) higher for variety 16837 than varieties 16791, 16786, 16849, 16834, 16798 and local in that order. However, varieties 16786 and 16791 were not significantly different. Variety 16840 was significantly ($P<0.05$) more degraded than varieties 16834, 16798 and local while variety 16834 was significantly ($P<0.05$) more degraded than varieties 16798 and local. The least degraded was variety local.

At 12hr of incubation, variety 15743 ranked significantly ($P<0.05$) highest comparing the degradability values. Dry matter degradability was significantly higher for variety 16837 than varieties 16840, 1638, 16835, local, 16786, 16791, 16798 and 16834. Variety 16840 was significantly greater than varieties 16838, 16835, local, 16786, 16791, 16798 and 16834 respectively. Varieties 16835, 16786 and local were not significantly ($P>0.05$) different from each other but were significantly ($P<0.05$) higher than varieties 16791, 16798 and 16834. Varieties 16791, 16798 and 16834 were not significantly ($P>0.05$) different.

At 24hr period of incubation dry matter degradability was significantly ($P<0.05$) greater for variety 15743 than the rest. Varieties 16834 and 16840 were not significantly ($P>0.05$) different but were significantly ($P<0.05$) higher in degradation than varieties 16791, 16838, local, 16786, 16798, 16835 and 16837. Varieties 16798, 16791 and 16838 were not significantly ($P>0.05$) different but were significantly higher than varieties 16786, local, 16835 and 16837. Varieties local, 16786, 16835 and 16837 were not significantly ($P>0.05$) different.

At 48hr and 72hr periods of incubation, no significant differences were observed for all the varieties.

At 96hr of incubation, dry matter degradation was significantly (P<0.05) higher for variety 15743 compared with the rest. Variety 16840 had significantly (P<0.05) higher dry matter degradation values than varieties 16786, 16798, 16838, 16837, 16834, local, 16835 and 16791 respectively. Variety 16786 was also significantly higher than the rest of the varieties. Variety 16798 was significantly (P<0.05) higher than varieties 16838, 16837, 16834, local, 16835 and 16791. Variety 16838 was also significantly (P<0.05) greater than 16834, local, 16835 and 16791. There were no significant differences between varieties 16834 and local but were significantly higher than varieties 16835 and 16791. Variety 16835 was significantly (P<0.05) higher than variety 16791.

At 120hr of incubation, variety 15743 was significantly (P<0.05) higher in DM degradation than the rest. Varieties 16838 and 16840 were not significantly (P<0.05) than varieties but were higher significantly (P<0.05) than varieties local, 16786, 16791, 16798, 16834, 16835 and 16837 respectively. Variety 16786 was significantly (P<0.05) higher in dry matter degradation than varieties 16791, 16798, 16834, 16835 and 16837. Variety 16798 was also significantly (P<0.05) higher in dry matter loss (DMD) than the varieties 16834, 16835, local and a 16837. While varieties local, 16834 and 16837 were not significantly (P>0.05) different, they were significantly greater than varieties 16835 and 16791. Variety 16835 was significantly (P<0.05) higher than variety 16791.

The degradation constants; readily soluble component (a), slowly degradable component (b), potential degradability (PD) differed significantly (P<0.05) between varieties while the rate of degradation (c) did not differ significantly (P>0.05). The readily soluble component (a) of varieties 15743, 16835, 16837, 16838 and 16840 did not differ significantly (P>0.05) but were all significantly (P<0.05) greater than varieties local, 16786, 16798, 16834 and 16791. The slowly degradable fraction (b) was significantly (P<0.05) higher for varieties local, 15743, 16786, 16798, 16834, 16838 and 16840 than varieties 16791, 16835 and 16837. Varieties 15743, local, 16786, 16798, 16834, 16838 and 16840 were not significantly (P>0.05) different from each other.

Potentially degradable fraction were significantly (P<0.05) higher for varieties 15743, 16786, 16798, 16838, local and 16840 than the rest but varieties 15743, local, 16786, 16798, 16838 and 16840 were not significantly (P>0.05) different. The rate of degradation (c) did not differ significantly for all the varieties.

TABLE 12 Rumen dry matter degradation of ten varieties of *P. purpureum* (samples obtained for intake studies) (g/kg)

VARIETIES	INCUBATION TIME (HOURS)								DEGRADATION CHARACTERISTICS			
	3	6	12	24	48	72	96	120	a	b	PD(a+b)	C(/h)
LOCAL	214^{cd}	214^{de}	325^{e}	427^{c}	559	546	530^{cd}	550^{c}	15.58	49.71	65.20	0.0323
15743	278^{g}	256^{f}	349^{f}	548^{e}	638	640	550^{de}	570^{d}	19.23	54.62	73.86	0.0351
16786	210^{bc}	216^{de}	294^{c}	468^{d}	601	617	565^{ef}	585^{e}	11.56	52.58	64.15	0.0436
16791	181^{a}	160^{a}	252^{a}	396^{b}	497	506	520^{c}	543^{b}	12.92	53.14	66.01	0.0426
16798	216^{d}	179^{b}	316^{e}	433^{c}	598	576	560^{de}	580^{e}	12.69	56.87	69.56	0.0331
16834	246^{f}	199^{c}	303^{d}	418^{bc}	611	557	485^{b}	500^{a}	18.22	52.91	71.13	0.0233
16835	223^{e}	183^{b}	266^{b}	393^{b}	476	531	473^{a}	498^{a}	16.78	45.54	62.33	0.0305
16837	219^{de}	208^{cd}	326^{e}	367^{a}	606	477	478^{a}	500^{a}	17.12	51.52	68.64	0.0254
16838	213^{c}	218^{e}	357^{f}	408^{b}	540	538	540^{d}	568^{d}	18.47	54.82	73.29	0.0262
16840	205^{b}	263^{f}	397^{g}	429^{c}	605	612	575^{f}	600^{f}	17.70	55.95	73.65	0.0295
SED (n=4)	16.8	29.0	30.2	40.4	52.0	76.9	39.6	36.9	2.903	3.863	4.876	0.010
SIGNIFICANCE	*	*	*	*	NS	NS	*	*	NS	NS	NS	NS

Footnotes:

a	-	readily soluble component
b	-	slowly degradable fraction
PD(a+b)	-	potential degradability
c	-	rate of degradation
*	-	significant at $P<0.05$ level
NS	-	not significant
SED	-	standard error of difference

4.8 *In vitro* gas production characteristics of samples used in intake studies

Data relating to *in vitro* gas production values are indicated in Table 14. The values of gas produced for samples used during intake studies did not reveal any significant differences (P>0.05) between treatments for each of the incubation time periods.

There were no significant (P>0.05) differences among the gas production characteristics except the potential gas production (B), which was significant (P<0.05). Variety 16791 had the highest potential gas production (60.318 ml/200 mg DM) and the least potential gas produced was for variety 16837 with 47.685 ml/200mg DM. Rate of gas production per hour was greatest for variety 15743 and lowest for variety 16791.

4.9 *In vitro* gas production studies using samples from Digestibility studies

The *in vitro* gas production values recorded during incubation of ten varieties *of P. purpureum* are shown in Table 15. The values of gas produced during the incubation periods 3, 6, 12, 24, 48 hours were not significantly (P>0.05) different for the ten varieties. At 72 hrs, varieties 16840, 16798, 16786 were significantly (P<0.05) higher in gas produced (ml/200 mg DM) than the rest, while varieties 16838, 16791 and local were also significantly (P<0.05) higher than varieties 15743, 16834, 16835 and 16837. The hybrid varieties 16840, 16838, 15743, 16786 and 16791 were significantly (P<0.05) higher in amount of gas produced than the rest.

At 120hr of incubation varieties 16798 and 16840 were significantly (P<0.05) greater in gas production than the rest. Varieties 15743 and 16838 were significantly (P<0.05) higher in amount of gas produced than the local variety and varieties 16786, 16791, 16834, 16835 and 16838. The local variety as well as varieties 16791, 16834 were not significantly different in gas production but were significantly higher than varieties 16791, 16835 and 16837. Varieties 16791 and 16837 were not significantly (P>0.05) but were significantly (P<0.05) higher than variety 16835

The potential gas production (B), rate of gas production (C) and gas produced within the first hour (BC) were not significantly (P>0.05) different. Similarly, residual standard deviation (RSD) and lag time were also not significantly

(P>0.05) different. The potential gas production recorded for variety 16834 (53.51) was the lowest while variety 16838 was the highest (68.57 ml/200 mg DM). The highest rate of gas produced within the first hour was for variety 16840 followed by varieties 16786 and local. The rate of gas production per hour for all the varieties was not significantly different.

4.10. Relationship Between Intake and Apparent DM Digestibility (During Digestibility studies)

The relationship between feed intake and dry matter degradability, DMD and apparent digestibility co-efficient of dry matter, feed intake and in vitro gas production are shown in Tables 16, 17 and 18.

The relationship between feed intake and apparent digestibility coefficient of dry matter was not significant (Y = 57.26 + 0.143X; P>0.05) (Table 16). The relationship between feed intake and dry matter degradability was significant at 6h (r = -0.20), while the rest were however not significant and poorly related (Table 17).

The relationship between feed intake and *in vitro* gas production were not significant at all the incubation periods (Table 19). The relationship between apparent digestibility co-efficient of dry matter and dry matter degradability (Table 18) did not show significant relationship from3h to 72h, but significant relationships were obtained at 96h (r = 0.371) and 120h (r = 0.440; P<0.05) respectively.

The relationship for apparent digestibility co-efficient of dry matter and *in vitro* gas production (Table 20) was significantly correlated at 3h (r = 0.373); P<0.05). The rest of the incubation periods did not show any significance.

The relationship between dry matter degradability and *in vitro* gas production using intake samples (Table 21) at all incubation periods did not show significance except at 24h (r = 0.321; P<0.05). The overall relationship between dry matter degradability and *in vitro* gas production (Table 22) using digestibility samples was not significant at all incubation periods. The relationship between DMD and *in vitro* gas production constants for both a+b and c were not significant when intake and digestibility samples were used (Table 23).

TABLE 13 Rumen dry matter degradation of ten varieties of *P. purpureum* using rams (samples used in digestibility studies) gkg⁻¹

VARIETIES	INCUBATION TIME (HOURS)								DEGRADATION CHARACTERISTICS			
	3	6	12	24	48	72	96	120	a	b	PD	C(/h)
LOCAL	98a	138^{a}	260^{ab}	328^{a}	514	552	615^{c}	638^{c}	5.63^{a}	60.10^{ab}	65.73^{a}	0.0282
15743	169^{e}	228^{I}	335^{f}	412^{d}	632	610	702^{I}	736^{g}	12.44^{ab}	62.11^{ab}	74.55^{ab}	0.0301
16786	122^{c}	180^{e}	266^{ab}	331^{a}	578	539	664^{g}	674^{e}	7.74^{a}	62.79^{ab}	70.52^{ab}	0.0265
16791	109^{b}	177^{e}	256^{a}	340^{ab}	453	433	558^{a}	566^{a}	9.65^{a}	46.78^{a}	56.42^{a}	0.0289
16798	90^{a}	158^{b}	247^{a}	348^{b}	543	517	654^{f}	652^{d}	5.31^{a}	63.51^{ab}	68.82^{ab}	0.0292
16834	123^{c}	164^{c}	251^{a}	375^{c}	552	567	610^{c}	640^{c}	8.69^{a}	57.57^{ab}	66.26^{a}	0.0271
16835	136^{d}	206^{h}	269^{b}	331^{a}	503	480	571^{b}	586^{b}	11.92^{ab}	48.83^{a}	60.75^{a}	0.0274
16837	139^{d}	193^{f}	327^{e}	327^{a}	534	532	630^{d}	642^{c}	11.81^{ab}	53.75^{a}	65.56^{a}	0.0285
16838	128^{c}	199^{g}	298^{c}	343^{ab}	558	542	643^{e}	686^{f}	11.34^{ab}	59.90^{ab}	71.23^{ab}	0.0240
16840	126^{c}	171^{d}	305^{d}	384^{c}	584	563	683^{h}	683^{f}	9.09^{ab}	63.22^{ab}	71.56^{ab}	0.0284
SED (n=4)	28.04	14.6	29.01	36.92	27.35	63.1	18.24	26.41	1.497	2.913	3.344	-
SIGNIFICANCE	*	*	*	*	NS	NS	*	*	*	*	*	NS

Footnotes:

	a	-	readily soluble component
	b	-	slowly degradable fraction
	PD(a+b)	-	potential degradability
	c	-	rate of degradation
	*	-	significant at P<0.05 level
	NS	-	not significant
	SED	-	standard error of difference

Table 14 ***In vitro*** **gas production (ml/200mg) of ten varieties of** ***Pennisetum purpureum*** **(samples used during intake studies)**

VARIETIES	INCUBATION TIME (HOURS)-ml 200mg^{-1} DM								GAS PRODUCTION CHARACTERISTICS (ml/200mg)				
	3	6	12	24	48	72	96	120	B	C(/h)	BC	RSD	LAG TIME
LOCAL	1.92	3.50	9.00	20.08	30.33	36.75	44.75	42.83	50.847	0.271	12.958	1.405	2.225
15743	2.33	4.50	11.42	24.00	36.42	41.83	48.92	46.92	47.895	0.350	16.766	1.142	2.700
16786	2.08	4.17	11.92	24.98	40.00	46.00	42.42	50.67	51.922	0.295	15.325	0.850	2.725
16791	1.75	4.00	9.83	19.75	31.15	38.33	4358	45.42	60.318	0.265	14.801	1.675	2.950
16798	1.75	3.58	9.08	20.33	32.67	39.33	45.75	46.17	52.445	0.299	15.698	0.955	2.475
16834	2.50	4.75	12.25	24.33	36.92	43.17	42.75	48.33	47.815	0.301	14.367	0.905	2.475
16835	1.67	3.50	9.25	20.08	31.75	38.75	39.33	46.25	50.852	0.291	14.795	1.045	2.775
16837	1.58	3.50	9.17	19.42	29.50	35.67	51.00	41.75	47.685	0.313	14.926	0.723	2.350
16838	2.08	4.42	12.75	26.50	40.75	47.42	46.08	53.17	54.240	0.307	16.658	0.942	2.525
16840	1.92	3.83	9.75	23.60	38.42	43.00	57.50	48.05	54.420	0.300	16.323	1.192	2.925
SED (n=4)	0.482	0.897	2.322	5.032	6.124	5.722	5.311	5.029	3.5001	0.0447	2.0294	0.3612	0.4832
SIGNIFICANCE	NS	NS	NS	NS	NS	NS	NS	NS	*	NS	NS	NS	NS

Footnotes:

B - Potential Gas Production

C - Rate of Gas Production per hour

RSD - Residual Standard deviation

BC - Gas produced within the first hour.

Table 15 ***In vitro*** **gas production (ml/200mg) of ten varieties of** ***P. purpureum*** **(samples used during digestibility studies)**

VARIETIES	INCUBATION TIME (HOURS)-ml 200mg^{-1} DM								GAS PRODUCTION CHARACTERISTICS (ml/200mg)				
	3	6	12	24	48	72	96	120	B	C(/h)	BC	RSD	LAG TIME
LOCAL	1.75	3.25	8.0	26.00	43.75	50.25^{c}	61.90	66.58^{c}	57.76	0.288	16.612	2.608	3.725
15743	1.50	2.50	4.75	15.25	29.50	40.25^{a}	67.20	68.00^{cd}	58.99	0.202	11.763	3.090	4.400
16786	1.25	2.75	7.25	25.00	46.00	53.75^{cd}	56.43	67.45^{c}	62.65	0.267	16.734	2.978	4.200
16791	1.75	3.75	8.25	22.00	40.00	48.00^{bc}	51.23	63.65^{b}	59.77	0.235	13.950	2.010	3.250
16798	1.50	2.75	5.50	20.50	22.00	52.25^{cd}	59.03	70.63^{cde}	66.56	0.229	14.984	4.127	4.600
16834	1.50	2.75	7.25	22.00	38.25	45.25^{b}	61.93	66.93^{c}	53.51	0.261	13.965	2.038	3.675
16835	1.00	2.50	6.50	16.75	33.75	42.75^{ab}	57.38	55.40^{a}	65.69	0.220	13.446	2.313	5.225
16837	1.25	2.50	5.25	16.00	32.75	44.00^{ab}	58.45	61.15^{b}	61.40	0.236	13.824	5.060	3.800
16838	1.50	2.75	5.75	16.25	37.75	48.50^{bc}	69.18	68.38^{cd}	68.57	0.219	14.787	3.587	4.325
16840	1.50	3.0	8.00	26.00	47.75	55.50^{cd}	68.00	71.45^{cde}	63.95	0.276	17.616	3.140	4.100
SED (n=4)	0.447	0.622	1.605	5.227	7.157	4.680	7.284	2.742	4.425	0.0447	2.1481	1.1232	0.7483
SIGNIFICANCE	NS	NS	NS	NS	NS	*	NS	*	NS	NS	NS	NS	NS

Footnotes B - Potential Gas Production C - Rate of Gas Production per hour

RSD - Residual Standard deviation BC - Gas produced within the first hour.

NS - Not significant

* - Means with different superscripts in the same column are significantly different.

Table 16: Relationship between Intake and Apparent digestibility of DM (Digestibility Samples)

Equation	r	LS	SE
Y = 57.26 + 0.143x	0.292	NS	0.67

Table 17: Relationship Between Intake and Dry Matter Degradability at various periods (intake samples)

HRS	EQUATION	r	LS	SE
3	Y=137.09-0.265x	0.116	NS	0.366
6	Y=215.61-0.571x	-0.320	P<0.05	0.274
12	Y=299.02-0.272x	-0.102	NS	0.429
24	Y=352.46-0.071x	-0.026	NS	0.441
48	Y=541.30+0.101x	0.030	NS	0.544
72	Y=473.40+1.033x	-0.549	NS	0.625
96	Y=611.27+0.407x	0.145	NS	0.450
120	Y=659.46-0.135x	-0.042	NS	0.527

Footnotes: r = Correlation co-efficient LS = Level of significance

SE = Standard error NS = Not significant

P<0.05 = significant at 5%

Table 18: Relationship Between Dry Matter Degradability at various periods and Apparent DM Digestibility of P. purpureum (Digestibility samples)

HRS	EQUATION	r	LS	SE
3	Y=209.90-1.345x	-0.291	NS	0.718
6	Y=190.28-0.126x	-0.035	NS	0.587
12	Y=284.55-0.024x	-0.004	NS	0.877
24	Y=365.67-0.265x	-0.048	NS	0.877
48	Y=453.37+1.429x	0.205	NS	1.105
72	Y=522.70+0.176x	0.017	NS	1.696
96	Y=496.15+2.117x	0.371	P<0.05	0.859
120	Y=460.52+2.906x	0.440	P<0.05	0.963

Footnotes:

r = Correlation co-efficient
LS = Level of significance
SE = Standard error
NS = Not significant
P<0.05 = significant at 5%

Table 19 Relationship Between Intake (Y) and *In vitro* Gas Production (X) at various periods of *P. purpureum* (intake samples)

HRS	EQUATION	r	LS	SE
3	Y=1.08+0.006x	0.188	NS	0.005
6	Y=2.60+0.004x	0.080	NS	0.008
12	Y=5.85+0.014x	0.104	NS	0.021
24	Y=15.16+0.092x	0.215	NS	0.068
48	Y=30.44+0.148x	0.249	NS	0.093
72	Y=41.23+0.116x	0.277	NS	0.065
96	Y=46.32+0.092x	0.256	NS	0.056
120	Y=49.01+0.083x	0.239	NS	0.055

Footnotes:

r = Correlation co-efficient
LS = Level of significance
SE = Standard error
NS = Not significant

Table 20 Relationship Between *in vitro* Gas Production and Apparent DM Digestibility (Y) of *P. purpureum* (Digestibility samples)

HRS	EQUATION	r	LS	SE
3	Y=-0.21+0.025x	0.373	P<0.05	0.010
6	Y=7.44-0.068x	0.692	NS	0.050
12	Y=8.49-0.028x	-0.106	NS	0.043
24	Y=18.14+0.037x	0.043	NS	0.141
48	Y=36.36+0.042x	0.035	NS	0.196
72	Y=41.69+0.097x	0.114	NS	0.137
96	Y=45.87+0.090x	0.122	NS	0.118
120	Y=48.89+0.077x	0.108	NS	0.114

Footnotes:

r = Correlation co-efficient
LS = Level of significance
SE = Standard error
NS = Not significant
P<0.05 = significant at 5%

Table 21 Relationship Between *in vitro* Gas Production and Dry Matter Degradability of *P. purpureum* (Intake samples)

HRS	EQUATION	r	LS	SE
3	Y=22.63-0.40x	-0.073	NS	0.892
6	Y=22.70-0.405x	-0.095	NS	0.691
12	Y=26.46+0.472x	0.203	NS	0.369
24	Y=30.97+0.491x	0.321	P<0.05	0.235
48	Y=66.0-0.229x	-0.115	NS	0.321
72	Y=73+0.816x	0.293	NS	0.432
96	Y=34.93+0.553x	0.179	NS	0.494
120	Y=54.11+0.260x	-0.405	NS	1.047

Footnotes:

r = Correlation co-efficient
LS = Level of significance
SE = Standard error
NS = Not significant
P<0.05 = significant at 5%

Table 22 Relationship between gas production and dry matter degradability of *P. purpureum* (digestibility samples)

Hrs	Equation	r	LS	SE
3	Y = 1.62 – 0.001x	-0.096	NS	0.002
6	Y = 3.26 – 0.002x	-0.088	NS	0.004
12	Y = 6.21 + 0.002x	0.032	NS	0.008
24	Y = 28.70 – 0.023x	-0.149	NS	0.025
48	Y = 49.22 – 0.018x	-0.106	NS	0.028
72	Y = 46.24 + 0.003x	0.042	NS	0.013
96	Y = 50.26 + 0.002 x	0.018	NS	0.021
120	Y = 53.81 + 0.000x	0.002	NS	0.017

Footnotes

r = correlation co-efficient
LS = level of significance
SE = standard error
NS = not significance

Table 23 Relationship between dry matter degradability (Y) and *in vitro* gas production (X) constants in *P. purpureum*

1. Intake samples				
	Equation	r	LS	SE
A +b	Y = 60.03 – 0.119x	-0.129	NS	0.323
C	Y = 0.33 – 0.965x	-0.282	NS	1.158
2. Digestibility samples				
	Equation	r	LS	SE
A + b	Y = 52.37 + 0.142x	0.170	NS	0.291
C	Y = 0.28 – 1.269x	-0.077	NS	5.802

Footnotes:
r = correlation coefficient
LS = level of significance
SE = standard error
NS = not significant
a+b = potential degradability
c = rate of degradation

CHAPTER FIVE

DISCUSSION

5.1 Agronomic characteristics of ten varieties of *P. purpureum* at 56 days of regrowth

The plant height of nine interspecific hybrids and a local *P. purpureum* harvested at 56 days of regrowth ranged from 0.57 to 1.9m (Table 5). Rose Innes (1977) reported plant height of mature tall varieties of local *P. purpureum* to range between 4m and 8m while Ocumpaugh and Rouquette (1985) reported plant height of 1.5 to 2.5m for 'Mott' elephant grass a dwarf type and 2 to 6m for tall varieties. The dwarf variety 15743 (0.57m) in this study has a peculiar morphology, which is tussocky and shorter than those reported above. However, the height of the other varieties which ranged from 1.22 to 1.9m compares with the height reported for 'Mott' elephant grass but shorter than the tall varieties. The height recorded in this study was measured at 56 days of regrowth while those reported by Rose Innes (1977), Ocumpaugh and Rouquette (1985) were at full maturity.

Tiller number of *P. purpureum* varieties recorded in this study ranged from 12 to 25 per stand. Cuomo *et al*. (1996) reported 21 tillers per stand for Napier grass. Variety 16838 had significantly higher tiller number than the rest. It was found that tiller number was negatively related to yield. ($r = -0.194$; $P<0.05$). Nelson and Moser (1994) suggested that as plant densities increased, tiller size usually decreased which implied that plants with higher tiller numbers tended to have thinner stems. Varieties 16838 and 16835 that had thinner stems produced greater number of tillers, which agrees with that reported by Nelson and Moser (1994).

Bunch diameter for the grasses reported in this study showed that the values of 0.203 to 0.507m were close to those reported by Ocumpaugh and Rouquette (1985) who indicated that 'Mott' elephant grass produced basal bunch diameter of 0.5m or more.

The stem of elephant grass (*P. purpurem*) was reported to be canelike with thickness from 0.5 up to 3-4cm (Ocumpaugh and Rouquette, 1985. The stem diameter of the hybrids and the local *P. purpureum* (0.62 to 1.78cm) falls within lower range of 0.5 to 4cm reported by Ocumpaugh and Rouquette (1985).

Persistence of the varieties studied ranged between 10.55 to 75.9% with the varieties that are highly persistent producing more herbage. Knettle et al. (1991) reported reduced Napiergrass stand by 19, 26 and 32% as harvest frequency increased from 3, 4, and 5 times per year. Persistence is also known to be affected by grazing pressure, cutting and competition from other plants.

Leafiness for the varieties studied showed that only variety 15743 had more than 50% leaf at harvest. Varieties 16791 and 16835 on the other hand had less than 21% of leaf forage mass. These varieties were the tallest indicating greater contributions from stem. These varieties also reached reproductive stage with the inflorescence also contributing to the stem.

The size, architecture and physiological age of tiller populations within the sward determine the yield of forage. According to Redfearn (1997), canopy architecture as well as leaf angle which includes plant and tiller densities, leaf area index, length of leaf blade and width and internode length influenced the productivity of forage. The environmental factors such as soil nutrients, water, light, temperature and disease also affect the development and maturity of the forage (Van Soest, 1982). There were significant relationship between yield of *P. purpureum* varieties and other agronomic characteristics, such as plant height, tiller number, bunch diameter, leafiness and persistence. Plant height is an important factor which influences herbage yield. Tall plant varieties compared to shorter ones possess longer internodes, bigger stems, greater number of leaves per plant and higher leaf area consequently yielding more herbage. Tiller number could also affect yield since more tillers have greater capacity of producing more herbage. Nelson and Sleper (1983) reported that high yielding forage species are favoured by accumulation of large number of tillers.Leafiness (leaf: stem ratio) is also known to influence yield. Moore et al. (1991) indicated that in some varieties of Bromegrass, greater total yield were obtained due to major contributions from total stem dry weight. On the other hand Redfearn et al. (1997) observed that generally leaf blade and leaf sheath fractions accounted for

virtually all dry matter yield in vegetative swards. Bunch diameter indicates the size of the plant stand hence bigger bunch diameter could produce more tillers and leaf blades thus contributing to yield.Tiller diameter is a measure of stem size. Bigger tillers produces larger proportions of yield.

Grasses with high percentage persistence have greater ground coverage of vegetative materials that produce yield components. Hence the higher the persistence the greater the yield.

In this study, significant relationship was obtained between plant height and yield ($r=0.218$; $P<0.05$). Varieties 16791 and 16835 though very tall produced very low yield probably because of their characteristic thin stem and small narrow leaves. However, varieties 16840, local, 16786, 16798, 16837, 16834 and 16838 which were shorter had higher yield than varieties 16791 and 16835. The dwarf variety 15743 had corresponding low yield since this variety had very short stem and short leaf blades. The yield results indicated that the highest yielding variety 16840 (1948.55kg DM/ha) was about four times the yield of variety 15743 (469.06kg DM/ha). Rose Innes (1977) described elephantgrass (*P. purpureum*) as a tall branching (tufted) grass which can grow up to a height of about 4-8m. Ocumpaugh and Rouquette (1985) reported plant height of 2 to 6m for tall varieties for *P. purpureum* and 1.5 to 2.5m for 'Mott' elephant grass. The varied morphological characteristics of elephantgrass and its hybrids could lead to wide range of differences in yield. The influence of tiller number on yield was not clear cut as the higher yielding varieties (16840, local, 16786 and 16798) produce 18,12,17 and 12 respectively while lower yielding varieties 16838 and 16835 had more tiller numbers. The trend might be due to characteristic thinner stem diameter of the low yielding ones.

With bunch diameter the best four varieties (local 16840, 16786 and 16798) ranked the same with respect to yield. Varieties with bigger bunch diameter therefore yielded more herbage. Leafiness (leaf: stem ratio) of the varieties did not follow the order for yield values probably because of differences between leaf and stem fractions and other morphological characteristics. Varieties with higher stem fraction with the exception of varieties 16791, 16835, and 16834 consequently performed better in terms of yield. Similarly, varieties (local 16840, 16786, 16837 and 16798) with higher percentage persistence also

ranked similar to varieties 16840, local, 16786, 16798, 16837 with more herbage yield. These agronomic factors could play important role in influencing herbage yield.

Stem diameter tended to influence yield since the varieties with higher proportion of stem gave higher herbage yield.

Chheda *et al.* (1973) reported dry matter yields of between 8 to 12 t/ha per annum under low fertility conditions while with adequate fertilization and good management DM yields of 15 to 20 t/ha per annum were common under humid and savanna conditions for P. *purpureum*. KARI (1985) reported that Napiergrass grown in Kenya yielded up to 10 tons dry matter per hectare for one harvest after 8 months of growth. Similarly, Hopkinson (1970) reported yields of 14.35 tons/ha without application of fertilizer for *P. purpureum* from six cuts in Tanzania. This was about 2.3 t/ha per cut, which was higher than the yield figure of 1.95 tons/ha for the best variety 16840 reported in this study. The relatively lower values recorded for these hybrids and the local might be attributed to the different environmental conditions under which these varieties were grown compared to yields reported in Tanzania. The best five varieties in terms of yield are 16840, local, 16786, 16798 and 16837.

A significant relationship was observed between yield and bunch diameter ($r=0.488$; $P<0.05$) (table 6). Increased yields from plants with larger tillers and leaf blades indicating greater bunch diameter in reed canarygrass (*Phalaris arundinacea L.)* were reported by Carlson *et al.* (1983). Varieties 16840, local, 16786 and 16798 produced bigger bunch diameter and consequently contributed to higher yield compared with the rest. The larger bunch diameter of these varieties could be due to the production of new tillers with high leaf forage mass.

Stem diameter was found to correlate with the yield ($r=0.360$; $P<0.05$) (table 6.) in this study. The local variety and hybrid varieties 16786, 16798 and 16840 with stem diameter of 1.78, 1.51, 1.73 and 1.59cm produced corresponding yields of 1.547, 1.051, 0.953 and 1.948 t/ha respectively. The varieties with smaller stem diameter gave lower yield because a greater proportion of the yield was contributed by the stem and hence thin stemmed varieties gave lower yields.

The leafiness of forage is an important indicator of the pasture quality. Leafiness decreases as the plant ages. Variety 15743 that had the highest leaf

portions (69%) recorded the least yield probably due to its tussocky and shorter height. While variety 16840 with the highest yield produced about 36% of leaf forage mass, varieties local, 16786, 16798, 16837 and 16838 produced between 41 and 48% of leaf forage. It was observed that varieties 16791, 16835 and 16834 which produced 14, 21 and 26% of leaf forage mass gave lower yields. This might have resulted in the negative correlation between leafiness and yield. Redfearn *et al.* (1997) observed that generally, leaf blade and leaf sheath fractions accounted for virtually all the dry matter accumulation in vegetative swards while stem dry weight per tiller tended to increase as swards progressed to reproductive stage. Cuomo *et al.* (1996) reported that leaf percentage of regrowth was greater for Napiergrass (88%) than for Pearl Millet x Napiergrass hybrid (PMN) (58%) which resulted in 2.7 and 2.5 t/ha of leaf forage mass respectively.

Persistence measured showed that there were wide variations among the hybrid Pennisetum and the local Napiergrass (Table 5). Some factors that tend to affect persistence include intensity of grazing, cutting frequency, competition from other plants, drought, shading and nutrient deficiencies. Hence measuring herbage yield over a period indirectly measures persistence. Calhoum and Prine (1985) and Knettle *et al.* (1991) reported reduced Napiergrass stands as harvest frequency increased. Varieties with very high percent persistence were the local (75.9) and 16840 (63.5), consequently recorded the highest yield of 1547.4 and 1948.6 kg DM/ha respectively. On the other hand varieties 15743, 16791 and 16835 had very low percent persistence (10, 11, 10) with yields of 469, 623 and 640kg DM ha respectively. Some workers reported that harvest frequency affected stand persistence. Newell and Kein (1947) reported that harvesting two or three times yearly decreased switchgrass stands by 58% but a single harvest during the active growing period decreased stands by only 39%. Persistence was related to yield ($r=0.603$; $P<0.05$). Garwood (1969) reported fluctuations in perennial Ryegrass and Timothy grass and attributed the changes in tiller numbers in a sward to changes in the rate of production of new tillers, their longevity or death rate of tillers.

There were significant relationship between yield and plant height, tiller number, bunch diameter, stem diameter, leafiness and persistence. The result showed that all the agronomic characteristics might have effect on herbage yield.

However, there were negative relationship between yield and tiller number as well as leafiness. This trend could be attributed to the fact that the varieties with more tiller numbers had very thin stem, which led to lower yield. There were greater contributions from stem fractions to yield than leaf hence the trend. The rest had significant positive relationship.

5.2 Chemical composition of ten varieties of *P. purpureum* at 56 days of regrowth (Samples for intake studies)

The crude protein content of the leaf fractions was higher in all the varieties than the stem and whole plant fractions. Similar findings reported by Larbi *et al.* (1991) showed that CP content of leaf, stem and whole plant fractions of *P. purpureum* were 10.3, 5.2 and 8.4%. The values obtained for leaf, stem and whole plant in this study range from 5.3 to 13.5% and are comparable to 8.6 – 14% for that reported in Kenya for 'bana' (Napier grass) (KARI, 1985). The neutral detergent fibre, acid detergent fibre and lignin contents of the *P. purpureum* for the leaf, stem and whole plant fractions were in the range reported by Van Eys *et al.* (1986) (NDF, 73.3; ADF, 44.1; Lignin, 6.9) for Napier grass harvested after 6-8 weeks regrowth. On the other hand, acid detergent lignin and hemicellulose concentrations of *P. Purpureum* were generally lower than those reported for *P. purpureum* 61.8% NDF, 36.7% ADF and 6.7% Lignin on DM basis (Sharma and Orgra, 1990).

5.3 Rumen degradation of ten varieties of *P. purpureum* (samples used during intake studies)

Rumen degradability values at 48h and 72h were not significantly different ($P>0.05$) but the rest differ. Degradation values at 48h were above 550gkg^{-1} for the local variety and hybrid varieties 15743, 16786, 16798, 16834, 16837 and 16840. This suggests that these varieties are highly degradable since a degradability value above 550gkg^{-1} at 48hr was reported to be a good indicator of high animal performance (Preston and Leng,1987). Potential degradability (PD) and rate of dry matter degradability (c) were not significant ($P>0.05$) but the values of PD were comparable to the result of Khazaal *et al.*, (1993). PD values were between 47.1 to 75.6 for different stages of growth of Lucerne,

sweet clover, Persian clover and Italian ryegrass.

5.4 Rumen dry matter degradability of ten varieties of *P. purpureum* (samples used during digestibility studies)

Rumen degradability of samples used during digestibility studies (Table 13) revealed that varieties 15743, 16786, 16834, 16838 and 16840 were more than 550gkg^{-1}DM degradable after 48h of incubation. The potential of these varieties to contribute to animal performance was high as reported by Preston & Leng (1987) who reported that degradability values above 550gkg^{-1}DM at 48h was a good indication for high animal performance. After 96h of incubation however, all the varieties recorded more than this figure which implied that the feed could remain in the rumen for quite a longer period before fully degraded hence feed intake could be adversely affected. Higher potential degradability may have positive influence on digestibility and intake hence better nutritive value of such feeds (McDonald *et al*. 1988). The readily soluble components were high for varieties 15743, 16837, 16838 and 16835, 16837 and 16791 were comparatively lower which contributed to the low values for PD. In any case the rate of degradation did not affect potential degradability because there was no significant relationship between the rate of degradation and potential degradability for digestibility samples used.

5.5 In vitro gas production (ml/200mg) of ten varieties of *P. purpureum* (samples used during digestibility and intake studies)

The volume of gas produced throughout the incubation period from 3h to 120h, were not significant for all the varieties except at 72 and 120h respectively for samples from digestibility studies; whereas there were no significant (P>0.05) differences among varieties when samples used during intake studies were incubated. For the samples used during digestibility studies, gas production constants (b), (c) and (b x c) were all not significant. The non-significant differences observed in the volume of gas produced for samples from digestibility studies may result from the fact that the rate constants did not differ significantly. The volume of gas production at 48 hours for Pennisetum varieties using intake and digestibility samples were higher (29.5 to 47.75 ml/200 mg DM) than those reported by Khazaal et al. (1993) for Lucerne, Sweet Clover, Persian clover and Italian ryegrass (32.2 to 41.2 ml / 200 mgDM). Potential gas production (b) was also higher for Pennisetum varieties (47.69 to 60.32 ml/200mgDM) using intake and (53.51 to 68.57 ml/200mgDM) for digestibility samples compared to those reported by Khazaal et al. (1993) for Lucerne Sweet clover, Persian clover and Italian ryegrass (34.9 to 45.0 ml/200mgDM). In general potential gas production determines the extent of fermentation which also indicate the level of intake. Factors such as chemical composition (NDF, hemicellulose and lignin) or cell wall constituents, plant morphology and leaf - stem ratio have great effect on digestibility and level of intake.

5.6 Intake of ten cultivars of *P.purpureum* and apparent dry matter digestibility of *P. purpureum* fed to West African Dwarf Sheep (WADS) (During intake and metabolism studies)

Dry matter intake per metabolic body size of the ten varieties during metabolism studies ranged from 39.02gkg^{-1} to 80.18 (gkg^{-1}W$^{0.075}$) per day (Table 9). Both physical and physiological factors have been identified for controlling feed intake (Preston and Leng, 1987). The main physical factors include rumen distension, gut size, and rate of digestion, rate of passage and extent of digestion while physiological factors include hormonal changes, chemicals, and

composition of diet, fat deposits and age of the animal (Lofgren and Warner, 1972). The intake values obtained in this study could be influenced by higher proportion of leaf than stem fractions which differ for varieties 16837, 16786, local, 16798, 16840 and 16834 with higher intake. Differences in digestibility for varieties 16835 and 16791 with lower digestibility coefficient could have accounted for their lower dry matter intake. Leaf fraction was known to have more nitrogen than stem and easily digestible due to the low levels of structural carbohydrates (Schneider and Flatt.1975). Voluntary intake is said to increase with increasing leaf percentage, which point to the importance of leafiness (leaf to stem ratio) of the varieties with higher DM intake.

The results of apparent digestibility coefficient of dry matter obtained in this study compares well with those reported by Larbi *et al.* (1993). The relatively higher apparent digestibility values recorded for variety 15743 confirms the lower NDF and lignin concentrations of the leaf, stem and whole plant fractions compared with varieties 16840 and 16786. This confirms the report that neutral detergent fibre concentrations are negatively associated with the time spent ruminating (Mertens and Loften, 1980), hence its effect on digestibility and consequently on intake. The overall relationship between feed intake and apparent digestibility was poor ($r = 0.292$) and not significantly related in this study.

The nitrogen intake for all animals ranged from 3.89 to 10.57g/day which were higher than the critical level of 1.6g N/100g of dry feed required for proper rumen function (Elliot and Topps, 1963). The results reflected the positive nitrogen balance for all the varieties. Even though there were no significant differences, it was observed that varieties with higher nitrogen intake gave higher nitrogen balance and vice versa.

The mean daily dry matter intake per unit of metabolic body size of ten varieties of *Pennisetum* during intake studies ranged from 56.1 to 80.41g/kg DM. The values obtained were higher than 46.0g kg^{-1} $W^{0.75}$ d^{-1} obtained for *P. purpureum* reported by Larbi *et al.* (1991). Sharma and Ogra (1990) also reported dry matter intake of *P. purpureum* (55.9 kg^{-1} $W^{0.75}$) fed to Barbari goats. Physical and physiological factors that regulate intake depended on the digestibility of the feed (Conard *et al.*, 1964). The digestibility of a feed also

depends on several other factors including chemical composition and the rate at which the forages were digested. From the results (Table 9) obtained, the best six varieties which were consumed more were 16838, 16786, 16840, local, 16798 and 16837. It was observed that the apparent digestibility coefficient values were high for these varieties and this might have contributed to the high intake figures since highly digestible forage material would be passed out from the reticulo-rumen faster thus increasing feed intake (Balch and Campling, 1962). Lower dry matter intake of varieties 16835 and 16791 might be due to slow rate of digestion leading to longer rumen retention time (Van Soest, 1982). The rate constant (b) was lowest (45.54 and 53.14) for the two varieties respectively while (a+b) values were equally lowest for varieties 16835 and 16791 (62.33 and 66.01). It was found that these varieties had high NDF and ADF concentration and these are known to influence the intake of dry matter since an inverse relationship has been reported between dry matter intake and fibre content of feed. It appears voluntary intake is related to the percentage of leaf in forages as voluntary intake is reported to increase with increasing leaf percentage (Minson, 1971). Varieties that were consumed more had higher leaf fractions than stem.

Fresh forage intake per unit metabolic body size ($gkg^{-1}W^{0.75}d^{-1}$) and fresh forage intake ($gkg^{-1}d^{-1}$) showed that variety 15743 was consumed most in both cases compared with the rest. However, because of the high moisture content of the grass the dry matter intake tended to be low. Varieties 16798, 16786, local, 16838, 16840 and 16837 were consumed in that order when they were compared on fresh matter basis. It was observed that variety 15743 had the highest apparent digestibility co-efficient of dry matter of 73%. Since it was highly digestible rate of passage was higher and hence there was an increase in feed intake. Values on dry matter basis however showed that less was consumed compared with the others. This could be explained by the presence of high moisture content of the fresh forage hence low DM value (Table 5). For the animal to meet its daily requirement when fed variety 15743, more of it should be eaten. Another attribute of this variety is the lower ADF and lignin contents that contributed to higher degradability consequently higher intake values. Though it appeared the apparent digestibility values were high for varieties 16798, 16786, local, 16838,

16840 and 16837, no significant relationship was obtained between feed intake and apparent digestibility (r=0.292; P>0.05).

However, significant relationship was obtained between feed intake and dry matter degradability at 6h only (r=0.320; P<0.05) while the rest were not. On the other hand, feed intake for fresh forage more consistently low for varieties 16834, 16791 and 16835 respectively. This could be attributed to higher contents of ADF, ADL and lignin in these grasses which depressed digestibility hence intake (Church, 1975, McDonald *et al*., 1988).

5.7 Relationship between feed intake and apparent dry matter digestibility, *in sacco* dry matter degradability (DMD), *in vitro* gas production and chemical composition of ten varieties of *P. purpureum*

The relationship between feed intake and apparent digestibility coefficient of dry matter for all the varieties were not significant (Table 16). Hovell *et al.* (1986) reported that dry matter intake of hays were better related to dry matter degradability at 12, 24, 48, 72h than *in vivo* digestibility. The findings in Table 17) showed significant relationship at 6h only between feed intake and dry matter degradability. This result was not consistent with Hovel *et al*. (1985). Nandra *et al*. (1993) also reported that voluntary intake was closely related to in sacco degradability at 24h (r^2= 0.88).

Poor relationship between feed intake and chemical composition of straw were reported by Ørskov *et al.* (1988) which agrees with poor and non-significant relationship between feed intake and chemical composition (Table 10) in this present study. Significant negative relationship established between digestibility and ADF (Acid detergent fibre) was reported by Van Soest (1975) who described highly significant (P<0.05) negative relationship (r = -0.858) between ADF content and digestibility for Ochard grass, timothy, alfalfa and tall fescue. This may have a useful implication of fibre content on digestibility since high fibre content depresses digestibility (Church, 1988).

The relationship between feed intake and *in vitro* gas production shown in Table 19 indicated no significant relationship during all the incubation periods. Blummel and Ørskov (1993) reported high correlation between dry matter intake,

and gas production (r=0.87).

A weak relationship was obtained at 96 and 120h (r=0.371; r=0.440) between apparent digestibility coefficient of dry matter and dry matter degradability (Table 18). Khazaal *et al.* (1993) found a strong and stable relationship between DMD and *in vivo* digestibility (r=0.79; P<0.05). This relationship implied that the nutritive value of these grasses were affected by cell wall constituents thus leading to longer period taken by the microbes to degrade the feed in the rumen. A weak significant relationship between apparent digestibility and *in vitro* gas production at 3h, showed that (Table 20) only the easily digestible fraction of the fibrous feed may have been fermented and similar observation was reported by Khazaal *et al.* (1993). He established poor relationship between static values of gas production and *in vivo* dry matter digestibility. In Table 21 the relationship between dry matter degradability and in vitro gas production was however weak at 24h (r = 0.321; P<0.05). This could also be due to the more easily digestible components of the grasses being fermented by the rumen microbes.

The overall relationship of all parameters indicated generally weak correlation with a few being significant. The relationship did not follow a definite pattern since it was expected that DMD and *in vitro* gas production should show high correlation as reported by Ørskov *et al.* (1988).

CHAPTER SIX

CONCLUSION

Based on the results of this study, it could be concluded that the yield of the varieties studied was comparable to similar varieties reported by Hopkinson (1970). The local variety ranked best in persistence and tiller number. The leafiness and tiller number was highest in varieties 15743,16837 and 16838. Generally, crude protein concentration in the leaf, stem and whole plant fractions were consistently higher in variety 15743 while other varieties were similar to the local. The NDF, ADF and ADL concentrations were lower in varieties 15743 and 16838 while the rest were also similar to the local. However, agronomic characteristics showed poor significant relationship ($P<0.05$) between yield and plant height, Tiller number, Tiller diameter, Leaf Stem ratio and Persistence

Feed intake per metabolic body size and apparent digestibility co-efficient of dry matter of all the varieties was also similar to or higher than other grasses reported by Larbi et al. (1993). Varieties 16838, 16786, 16840, 16798 and 16837 were higher than the local in apparent digestibility and intake. Varieties 16791 and 16835 were least consumed and digested. Rumen dry matter degradability values for intake and digestibility samples were comparable to intake and digestibility results. *In vitro* gas production results revealed that all the varieties were similar for samples used in intake studies while 72 and 120 hrs of incubation differed for samples used during digestibility studies. The nitrogen balance values were positive for all the varieties fed to the sheep.

There was no significant relationship between feed intake and apparent digestibility coefficient of dry matter for all the varieties fed to sheep while relationship between feed intake and dry matter degradation was significant ($P<0.05$) at 6h only. Similarly, non-significant relationship between feed intake and gas production was established at all the incubation periods. On the other hand, significant relationship ($P<0.05$) existed between apparent digestibility coefficient of dry matter and dry matter degradability at 96 and 120h indicating that DM digestibility could be predicted from rumen DM degradability values at 96 and 120h incubation periods. Significant relationship between apparent digestibility of DM and *in vitro* gas production was obtained at 3h only while significant relationship between *in vitro* gas production and dry matter degradation was

obtained only at 24h of incubation which indicated that as degradability increased, apparent digestibility was also increased.

RECOMMENDATIONS

It is recommended that:

1. Yield assessment should be done over one year period of cutting at 56 days intervals. Locational trials should be carried out within the savanna agro-ecological zones to assess the productivity of the grasses.

2. Further work may be carried out on the cost of establishment and maintenance.

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APPENDIX

ANALYSIS OF VARIANCE (ANOVA) AGRONOMIC CHARACTERISTICS

PARAMETER	SOURCE OF VARIATION	DF	SUM OF SQUARES	MEAN SQUARE	F. VAL.	Pr>F
Plant Height	Block	6	43064.09	7177.35	9.39	0.0001
	Rep	2	991.87	495.94	0.65	0.5232
	Trt	9	449250.47	49916.72	65.34	0.0001
	Error	309	236062.31	763.96		
	Total	326	726901.06			
Yield	Block	6	43073159.18	7178859.86	19.06	0.0001
	Rep	2	5386504.06	1793252.03	4.76	0.0092
	Trt	9	61476761.98	6830751.33	18.14	0.0001
	Error	309	116368702.22	376597.74		
	Total	326	224151588.02			
Tiller Number	Block	6	1391.16	231.86	7.27	0.0001
	Rep	2	206.94	103.47	3.24	0.0403
	Trt	9	4490.23	498.91	15.65	0.0001
	Error	309	9852.69	31.89		
	Total	326	16010.98			
Leafiness	Block	6	0.933	0.187	1.79	0.1151
	Rep	2	0.923	0.461	4.43	0.0129
	Trt	9	24.19	2.687	25.82	0.0001
	Error	232	24.14	0.104		
	Total	248	50.34			
Stem Diameter	Block	6	3.11	0.518	13.68	0.0001
	Rep	2	0.007	0.004	0.10	0.9002
	Trt	9	53.72	5.969	157.55	0.0001
	Error	309	11.70	0.0379		
	Total	326	68.48			
Bunch Diameter	Block	6	11291.62	627.312	23.13	0.0001
	Rep	9	2496.01	277.334	10.23	0.0001
	Trt	9	8795.61	977.290	36.03	0.0001
	Error	81	2196.89	27.122		
	Total	99	13488.51			
Persistence	Block	6	2999.07	499.846	3.487	0.003
	Rep	2	508.27	254.137	0.397	0.673
	Trt	9	81089.2	9009.911	62.85	0.001
	Error	110	15766.8	143.335		
	Total	179	307181.0			

FEED INTAKE DURING INTAKE STUDIES

PARAMETER	SOURCE OF VARIATION	DF	SS	MSQ	F.VAL	Pr>F
(1) Feed Intake	Trt	9	4708.76	523.196	5.2	0.0001
	Rep	9	5901.21	655.69	6.46	0.0001
	Error	81	8227.09	101.569		
	Total	99	18837.06			
Apparent Digestibility	Trt	9	312.29	34.69	0.81	0.6120
	Rep	3	546.43	182.14	4.25	0.0140
	Error	27	1157.77	42.88		
	Total	39	2016.51			

FEED INTAKE AND APPARENT DIGESTIBILITY DURING DIGESTIBILITY STUDIES

(2) Feed Intake $W^{=o.75}$/day	Trt	3	1754.83	584.94	5.35	0.0051
	Rep	9	7400.35	822.26	7.52	0.0001
	Error	27	2953.61	109.39		
	Total	39	12108.79			
Apparent Digestibility Coefficient of DM	Trt	3	276.34	92.12	2.72	0.0638
	Rep	9	952.37	105.82	3.13	0.0103
	Error	27	912.76	33.81		
	Total	39	2141.48			

DRY MATTER DEGRADABILITY (INTAKE SAMPLES)

INCUBAT.	SOURCE	DF	SS	MSQ	F.VAL.	Pr>F
3h	Trt	9	237.76	26.41	46.687	0.0006
	Error	30	169.09	5.63		
	Total	39	406.85			
6h	Trt	9	372.68	41.41	2.46	0.0310
	Error	30	504.77	16.82		
	Total	39	877.45			
12h	Trt	9	667.55	74.17	4.07	0.0017
	Error	30	546.56	18.21		
	Total	39	1214.11			
24h	Trt	9	898.99	99.88	3.06	0.0101
	Error	30	979.42	32.64		
	Total	39	1878.41			
48h	Trt	9	1021.15	111.46	2.095	0.0624
	Error	30	1624.58	54.15		
	Total	39	2645.74			
72h	Trt	9	959.11	106.56	0.900	
	Error	30	3551.81	118.39		
	Total	39	4510.92			
96h	Trt	9	691.0	76.77	2.44	0.0320
	Error	30	942.5	31.41		
	Total	39	1633.5			
120h	Trt	9	719.52	79.94	2.93	0.0127
	Error	30	817.25	27.24		
	Total	39	1536.77			

DRY MATTER DEGRADABILITY (USING DIGESTIBILITY SAMPLES)

INCUBAT.	SOURCE	DF	SS	MSQ	F.VAL.	Pr>F
3h	Trt	9	178.36	19.82	1.26	0.298
	Error	30	471.73	15.72		
	Total	39	650.09			
6h	Trt	9	243.38	27.04	6.323	0.000
	Error	30	128.31	4.27		
	Total	39	371.69			
12h	Trt	9	376.91	41.87	2.48	0.029
	Error	30	504.98	16.83		
	Total	39	881.89			
24h	Trt	9	297.80	33.08	1.214	0.323
	Error	30	817.81	27.26		
	Total	39	1115.62			
48h	Trt	9	870.26	96.69	6.46	0.000
	Error	30	448.87	14.96		
	Total	39	1319.13			
72h	Trt	9	861.59	95.73	1.179	0.343
	Error	30	2435.49	81.18		
	Total	39	3297.08			
96h	Trt	9	758.06	84.22	12.66	0.000
	Error	30	199.58	6.65		
	Total	39	957.64			
120h	Trt	9	874.03	97.11	6.96	0.000
	Error	30	418.36	13.94		
	Total	39	1292.39			

IN VITRO GAS PRODUCTION (DIGESTIBILITY SAMPLES)

INCUBAT.	SOURCE	DF	SS	MSQ	F.VAL.	Pr>F
3h	Trt	9	1.9	0.211	0.528	0.669
	Error	30	12.0	0.40		
	Total	39	13.9			
6h	Trt	9	6.525	0.725	0.935	0.000
	Error	30	23.25	0.775		
	Total	39	29.77			
12h	Trt	9	58.6	6.51	1.264	0.296
	Error	30	154.5	5.15		
	Total	39	213.1			
24h	Trt	9	660.52	73.39	1.343	0.2572
	Error	30	1639.25	54.64		
	Total	39	2299.77			
48h	Trt	9	1367.6	151.95	1.483	0.1993
	Error	30	3073.5	102.45		
	Total	39	4441.1			
72h	Trt	9	895.4	99.48	2.271	0.0446
	Error	30	1314.5	43.81		
	Total	39	2209.9			
96h	Trt	9	1183.64	131.51	1.24	0.3091
	Error	30	3183.03	106.10		
	Total	39	4366.68			
120h		9	1346.32	149.59	9.94	0.000
		30	451.19	15.04		
		39	1797.51			

IN VITRO GAS PRODUCTION (USING INTAKE SAMPLES)

INCUBAT.	SOURCE	DF	SS	MSQ	F.VAL.	Pr>F
3h	Trt	9	9.375	1.042	0.747	0.000
	Error	110	153.417	1.395		
	Total	119	162.792			
6h	Trt	9	23.508	2.612	0.541	0.000
	Error	110	531.417	4.831		
	Total	119	554.925			
12h	Trt	9	234.508	26.056	0.806	0.000
	Error	110	3557.083	32.337		
	Total	119	3791.592			
24h	Trt	9	742.675	82.519	0.543	0.000
	Error	110	16722.917	152.027		
	Total	119	17465.592			
48h	Trt	9	1858.167	206.463	0.914	0.000
	Error	110	24838.50	225.805		
	Total	119	26696.66			
72h	Trt	9	1644.17	182.68	0.93	0.000
	Error	110	21606.75	196.42		
	Total	119	23250.92			
96h	Trt	9	1235.03	137.22	0.904	0.000
	Error	110	16688.66	151.71		
	Total	119	17923.7			
120h	Trt	9	1452.70	161.41	0.954	0.000
	Error	110	18613.08	169.21		
	Total	119	20065.79			

DM LOSS (DMD) USING DIGESTIBILITY SAMPLES – DEGRADATION CONSTANTS

CONSTANTS	SOURCE	DF	SS	MSQ	F.VAL.	Pr>F
A	Rep	3	91.05	30.35	6.77	.001
	Trt	9	237.95	26.43	5.90	.000
	Error	27	120.97	4.48		
	Total	39	449.98			
B	Rep	3	79.97	26.65	1.57	.219
	Trt	9	1333.53	148.17	8.73	.000
	Error	27	458.26	16.97		
	Total	39	1871.76			
A + B	Rep	3	4.52	1.505	0.07	.000
	Trt	9	1066.05	118.45	5.30	.000
	Error	27	603.76	22.36		
	Total	39	1674.32			
	Rep	3	0.00	0.00	1.33	.286
	Trt	9	0.00	0.00	0.26	
	Error	27	0.00			
	Total	39	0.00			

DM LOSS – USING INTAKE SAMPLES – DEGRADATION CONSTANTS

CONSTANTS	SOURCE	DF	SS	MSQ	F.VAL.	Pr>F
A	Rep	3	31.39	10.46	0.66	.102
	Trt	9	266.01	29.55	1.88	
	Error	27	428.31	15.86		
	Total	39	725.70			
B	Rep	3	174.53	58.17	1.95	.145
	Trt	9	391.65	43.51	1.46	.213
	Error	27	805.72	29.84		
	Total	39	1371.90			
A + B	Rep	3	147.59	49.19	1.03	.392
	Trt	9	635.72	70.63	1.43	.203
	Error	27	1283.88	47.55		
	Total	39	2067.18			
C	Rep	3	0.00	0.00	0.24	.00
	Trt	9	0.00	0.00	0.80	.00
	Error	27	0.01	0.00		
	Total	39	0.01			

IN VITRO GAS PRODUCTION (DIGESTIBILITY SAMPLES)– DEGRADATION CONSTANTS

CONSTANTS	SOURCE	DF	SS	MSQ	F.VAL.	Pr>F
B	Trt	9	744.96	82.77	2.11	0.0643
	Rep	3	107.79	35.93	0.92	0.4456
	Error	27	1057.42	39.16		
	Total	39	1910.17			
C	Trt	9	0.30	0.003	0.86	0.5733
	Rep	3	0.01	0.004	1.12	0.3598
	Error	27	0.10	0.004		
	Total	39	0.14			
B x C	Trt	9	111.61	12.62	1.37	0.2508
	Rep	3	38.34	12.78	1.38	0.2687
	Error	27	249.20	9.22		
	Total	39	401.15			

IN VITRO GAS PRODUCTION (INTAKE SAMPLES) – DEGRADATION CONSTANTS

CONSTANTS	SOURCE	DF	SS	MSQ	F.VAL.	Pr>F
B	Trt	9	542.58	60.28	2.46	0.0341
	Rep	3	59.09	19.69	0.80	0.5029
	Error	27	661.84	24.51		
	Total	39	1263.51			
C	Trt	9	0.02	0.002	0.55	0.8263
	Rep	3	0.02	0.008	2.06	0.1292
	Error	27	0.11	0.004		
	Total	39	0.15			
BxC	Trt	9	48.73	5.41	0.66	0.7389
	Rep	3	59.47	19.82	2.41	0.0892
	Error	27	222.40	8.23		
	Total	39	330.59			