THE NUTRITIVE VALUE OF SOME KENYA FEEDSTUFFS AND THE EFFECT OF PROTEIN AND ENERGY RICH CONCENTRATE SUPPLEMENTATION ON THE UTILIZATION OF CHLORIS GAYANA HAY BY WETHER SHEEP.

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DECLARATION

This thesis is my original work and has not been presented for a degree in any other University.

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SUMMARY

1. The need to study the nutritive value of local livestock feeds in the tropics is advocated in section 1. That field of study was felt to be the more important in tropical countries where production from the domiciled livestock is very low as a result of a number of factors, the most important of which was felt to be the poor level of nutrition. It was decided, as a first step, to study *in vivo* digestibility and nutritive value of some improved local pasture grasses, fodders and arable farm by-products and to extend the field of study to include evaluation of the effects of the levels of protein and energy rich concentrate supplementation on the utilization of one of the commonly used pasture grasses, C. gayana. Wether sheep were used in all these studies.

2. Current knowledge on the pasture grasses, fodders and the arable farm by-products studied is reviewed in section 2 together with factors affecting digestibility and the effects of protein and energy supplementation on feed intake, digestibility and on nitrogen excretion, retention and utilization. Methods used in estimating digestibility were also included in that section.

3. Results: Section 3 gives results and discussion of *in vivo* digestibility and nutritive value of the feedstuffs studied. The results and discussion of the effects of the levels of protein and energy rich concentrate supplementation on the utilization of C. gayana hay are given in section 4.

4. Conclusions: Conclusions of the studies carried out in sections 3 and 4 are given in section 5 and are here summarized as follows:-

4.1. <u>Section 3</u>

4.1.1. In all the pasture grasses studied digestibility and nutritive value decreased with maturity although the rate of decrease in a few of the pasture grasses studied was not as fast as in others. There was also a tendency for the voluntary dry matter intake to decrease with maturity when the grasses were considered individually; but there was no correlation between voluntary dry matter intake and either crude protein, digestible energy or digestibility of organic matter when the grasses were considered together. In all the pasture grasses studied crude fibre was more digestible than the nitrogen-free extract.

4.1.2. Phosphorus and sodium levels were low in almost all the pasture grasses and at all the stages of regrowth.

4.1.3. In almost all the pasture grasses studied available digestible crude protein decreased much faster, as the grasses matured, than either available digestible energy or starch equivalent. However, it was apparent from the calculated examples in tables 52, 53 and 54 that available energy from the pastures was the major limiting nutrient for milk production.

4.1.4. D. uncinatum and I. batata vines were considered to be important nutritious fodders and could play an important role in increasing livestock production, especially in small scale farming areas.

4.1.5. Both the arable farm by-products studied were shown to be important sources of supplementary protein and energy but nutritive value of the cottonseed cakes studied flactuated very widely even within the decorticated and the undecorticated grades. At the marketed prices prevailing then both digestible crude protein and starch equivalent were cheapest per unit weight in "wishwa". Starch equivalent was most expensive per unit weight in the maize germ and bran meal. Digestible crude protein was most expensive in the wheat bran but it was cheaper in its starch equivalent than maize germ and bran meal.

4.2. Section 4

4.2.1. With the levels of supplementation to the C. gayana hay, which ranged from 7 percent to 28 percent of the dry matter intake of the hay, both bean meal and maize meal did not significantly increase the voluntary dry matter intake of the hay. Voluntary dry matter intake of the hay was in fact apparently but not significantly decreased as the levels of supplementation by bean meal and maize meal were increased from 50 g to 100 g/wether/day; but levels of hay intake were never lower than in the non-supplemented animals.

4.2.2. Digestibility of all the nutrients in the C. gayana hay (except crude fibre by bean meal and crude protein and crude fibre by maize meal) were linearly, but not significantly, improved by both bean meal and maize meal supplementation.

4.2.3. Nitrogen retention was apparently increased as a result of bean meal and maize meal supplementation.

4.2.4. There were no significant liveweight gains resulting from bean meal and maize meal supplementation to the C. gayana hay; most probably as a result of either lower levels of supplementation used in the experiment or, possibly, as a result of the problems inherent in determination of liveweight. There was, however, an apparent increase in liveweight gain as the levels of maize meal supplementation were increased, even though ingested digestible energy levels were not very much higher than the digestible energy levels attained with bean meal supplementation. It was thought that, possibly, the higher levels of maize meal supplementation increased the efficiency of utilization of the resultant rumen metabolites.

4.2.5. Calculated metabolizability of digestible energy tended to decrease as a result of bean meal and maize meal supplementation but percent metabolizability was apparently least decreased at higher levels of maize meal supplementation.

4.2.6. It was concluded that if higher levels of supplements had been used and/or if the numbers of replicates had been increased, the trends of the parameters studied would, most likely, have been more marked and statistically more clear cut.

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SECTION I Introduction

The importance of increasing the world production of protein of animal origin for human consumption cannot be overstressed. The need to do so is more pressing in the developing countries where, the daily consumption per caput of animal protein is only 11 grammes - an intake which does not reach the minimum level of protein required for growth (FAO, 1972). The daily consumption per caput of milk (including liquid milk equivalent of milk products other than butter) is 850 grammes in North America and 494 grammes in Europe, whereas consumption in the Near East is 214 grammes and in Africa it is 96 grammes only (FAO, 1962). In Kenya the daily consumption per caput of milk is estimated at 170 grammes but it is very unevenly distributed (Mann, 1962).

There are a number of factors involved in these low consumption figures but the major and widely accepted factor is the low production level by the livestock domiciled within these developing countries. Represented in terms of livestock units, 70 percent of livestock resources are domiciled in the developing countries but these produce only 21 percent of the world milk production and 34 percent of the world beef production; working at 2445 kg milk and 1140 kg meat per 100 ha compared to 16350 kg milk and 2747 kg meat per 100 ha for developed countries (FAO, 1972).

High production levels by livestock from the developing countries can be attained in several ways; by improving the genetic production potential of the indigenous livestock breeds, by encouraging, where possible, the keeping of exotic livestock breeds, by improving the environmental conditions such as diseases and management, but most important by improving the plane of nutrition. It is the nutrition of the existing breeds of livestock in Kenya, as in many other tropical countries, that has first to be put on a higher and uniform plane before the geneticist and animal breeder can either select or improve.

In Kenya good progress has been made, and is being made, in the field of animal breeding; and in high potential areas of the country exotic livestock breeds and their crosses are the main species reared. Very good progress has been made in combating disease problems and epidemics. But much still needs to be done in improving the plane of nutrition. It is common knowledge that for a longer period of the year the vast majority of livestock in the lower potential areas of Kenya, as in many other tropical countries, subsist on very poor and uneven supply of pastures without any supplementation. As a consequence of these prolonged periods of malnutrition production levels are very low. Even in the high potential areas of Kenya, however, production levels are not always as high as would be expected from the livestock. Foot (1965) conclude in his extensive survey of dairy production in such areas that there can be little doubt that a major cause of low production parameters in the dairy herds is inadequate feeding and "particularly failure to provide enough energy to meet the requirements for high yielders".

Hamilton (1955) in the U.K. showed that grass when grazed provides the cheapest food for ruminants and when properly conserved it can be cheaper than most livestock feeding stuffs. In Kenya a greater portion of the land is suitable for range farming while in the wetter areas and at high altitude areas of the country an excellent potential for pasture production exists. In fact ley farming is an established system especially in the latter areas. The importance of the full use of grass for livestock production makes it absolutely essential to investigate the nutritive value of such grasses. In the tropics the rate of herbage growth is usually very rapid in the rainy season and the vegetation quickly reaches the flowering and seeding stages resulting in equally fast decline of its nutritive values (Musangi, 1967; Soneji, 1970 and Said, 1971). A substantial amount of work has been done in Kenya on pasture establishment and improvement, but Morrison (1969) observed that more animal production trials were needed to confirm the findings of these agronomic trials.

It was stated by Kleiber (1936) and Blaxter (1962) that the most efficient animals are likely to be those that eat the most per unit body weight. Whereas a number of factors are known to affect dry matter intake per unit body weight (Balch and Campling, 1962), under tropical conditions, the ambient high temperatures and the rapid decline in pasture quality, as already mentioned, are undoubtedly the major factors. It is a matter of simple calculation to show that for a high yielding cow or for a fast growing ruminant the required nutrients cannot be met from the roughage alone, especially if gut fill is restricted by the quality of the roughage on offer. Whereas in tropical areas both protein and energy levels are low and uneven most of the year, it is most likely that energy is more often deficient than protein. It was also reported by Milford and Minson (1963-64) that the level of animal production from tropical pasture is determined largely by the quantity and quality of energy consumed per unit time, and to a lesser extent by the availability of dietary protein. Musangi (1969), and more recently Lawrence (1972) concluded that adequate digestible energy appeared to be one of the important factors affecting the utilization of improved pastures by ruminants in Uganda. The use of supplementary feeding in the form of concentrates to offset a deficiency of nutrients in the roughage diet is not only recommended for dairy farms but may in the very near future find wide use in feedlot beef production in Kenya.

It has already been pointed out that dairy herds in Kenya are not adequately fed (Foot, 1965). The UNDP/FAO Beef Research Station at Lanet, Kenya, has proved that top quality feedlot beef is economically produced from maize silage, maize grain/maize germ and bran meal, cottonseed cake and the locally produced molasses. It is indeed very likely that intensive beef production may find its place in the farming enterprises in Kenya. Already 15 commercial beef feedlot enterprises are operating at profitable margins. Apart from the foreign exchange earnings expected to be accrued from the sale of such top quality beef, there will be a rewarding market for bull calves from dairy farms. Hopefully then there will be an added incentive to produce and grow healtheir calves which could best be produced from better fed dams and better feeding of the young stock. Undoubtedly the demand for locally produced arable farm by-products such as cereal by-products and oil seed cakes will be high and so will be the need to know their nutritive values. Currently the developing countries are exporting nearly 7 million tons of oil seed meals and cakes and 2.5 million tons of fish meal to the developed countries (FAO, 1972). The sale of these high quality feedstuffs to the developed countries when our own livestock are hungry and unproductive seems to have little justification.

As a prerequisite for more productive feeding it is imperative that we study the nutritive value of our pastures and pasture lands, fodders and the locally available arable farm by-products. It is relatively easy and less expensive to determine the chemical composition of feedstuffs on offer to the animal. A considerable amount of chemical analyses has been carried out on some Kenya livestock feeds (Dougall, 1960). But knowledge of such crude composition does not enable scientific feeding practices to be adopted although it has the application of assessing and eliminating certain dietary deficiencies. To get the most valid information from such analyses it would be necessacry, and highly desirable, to determine in vivo digestion coefficients of such feeds and also to determine the effects of supplementary feeding on both voluntary intake and on the utilization of the feed by the animals.

These studies were therefore undertaken to study in vivo digestion coefficients and nutritive values of some improved local pasture grasses, fodders and arable farm by-products and also to evaluate the effect of protein and energy rich concentrate supplementation on the utilization of one of the commonly used pasture grasses; Chloris gayana.

SECTION 2 Review of Literature

2.1. Review of commonly used local pasture grasses, fodders and arable farm by-products.

2.1.1. Pasture grasses and fodders.

2.1.1.1. Pennisetum clandestinum (Kikuyu grass)

P. clandestinum has been reported by Edwards (1935) to be occuring naturally only in East Central Africa between altitudes of 1981 - 3048 m (6,500 - 10,000 ft.), where rainfall is not less than 1016 mm per annum (40 iches). It constitutes one of the most important natural pasture grasses in Kenya. It has been estimated that the potential P. clandestinum country in Kenya is 1,813,00 - 2,072,000 ha. (7,000 - 8,000 square miles). Introduction of the grass into other tropical areas and into the moist regions of the sub-tropics has been very successful and it is now cultivated in these countries as a thriving pasture grass.

Todd (1956) ranked P. clandestinum as more nutritious in protein than C. gayana and Bothriochloa insculpta. Squibb, Gurzman and Scrimshaw (1953) reported that dried P. clandestinum meal compared favourably with alfalfa hay and alfalfa meal. They also showed that P. clandestinum was an excellent source of protein, riboflavin and provitamin A. Sherrod and Ishizaki (1967) showed that digestibilities of organic matter, crude protein and crude fibre in P. clandestinum decreased with each extended regrowth period but digestibility of the energy components was almost constant through 12 weeks period.

Edwards (1940) showed the absolute necessity for intensive management of P. clandestinum. In another experiment Edwards (1943) found that after six years of severe treatment by monthly cutting P. clandestinum growing in its natural habitat had a ground cover of 84 - 98 percent as compared to 52 - 68 percent ground cover by C. gayana (cultivar Nzoia) under similar treatment.

However P. clandestinum is established vegetatively and therefore it is labour intensive and expensive in the initial stages of its establishment. It is therefore a pasture grass most suitable on small scale farms. These observations are of great practical application in the present change of land policy in Kenya. The emergent land policy in many parts in the Kenya Highlands where large units of land are subdivided into smaller units to settle landless people has meant that the pastures in many of these farms is now more intensively grazed. The majority of the new settlers in the Highlands keep dairy cows and, almost exclusively, the only pasture grass available is the natural P. clandestinum. It is supplemented by arable farm by-products such as maize stalks, bean haulms, sweet potato vines and also by P. purpureum. Proprietary concentrate mixtures are also fed to cows by a few settlers.

2.1.1.2. Chloris gayana (Rhodes grass).

C. gayana is a native of Africa, although it has been introduced in many parts of the world. In Africa, the grass is distributed naturally in East and Central Africa, much of South Africa and the Eastern part of West Africa (Bogdan, 1969). In Kenya the grass is widely distributed from the Coast to over 1981 m. altitude. Numerous ecotypes (cultivars) of the grass occur in East Africa such as Mpwapwa, Mbarara, Masaba, Pokot, Nzoia, and Rongai.

C. gayana is adapted to soils from sands to alkaline clays but grows best on fertile soils of medium texture (Wyte, Moir and Cooper, 1959). It is one of the best species for rotation grasslands in the tropics and subtropics. On a world scale C. gayana is cultivated in most of Africa, in South and Central America, in the U.S.A., Australia, South Asia, Japan and in South of U.S.S.R. Seed production is relatively easy and prolific in most ecotypes and percentage germination is very high giving tillers and stolons which cover the ground well. Growth from seed is fast and by 4-6 months the grass can be grazed. C. gayana forms a palatable pasture and withstands grazing and trampling well (Bogdan, 1969).

Digestibility of crude protein, nitrogen-free extract, crude fibre and ether extract of C. gayana cultivar Katambora at 3.8 percent crude protein in dry matter was 1.1, 42, 57 and 28 percent respectively (Elliot and Fokkema, 1960a). Marshall and Long (1967), reported that gross energy and digestible energy of C. gayana was 4.073 - 4.192 kcal/g dry matter and 2.170 - 2.167 kcal/g dry matter when its percentage crude protein contents in the dry matter were 4.3 and 8.5 respectively. Soneji (1970) found that the organic matter digestibilities of C. gayana at boot, head, bloom and seed stages were respectively 63.4, 61.0, 54.6 and 53.5 when the percentage of crude protein in the organic matter at the same stages were respectively 20.4, 18.4, 15.0 and 16.6. In his review on digestibility of tropical grasses Butterworth (1967) compiled data for proximate composition and digestibility of C. gayana at some stages of regrowths as was given by the various workers.

Productivity of C. gayana in terms of liveweight gains in cattle is given as 366 kg/ha in its first year of growth, 217 kg/ha in the second year and 161 kg/ha in the third year of growth (Department of Agriculture, 1961). In grazing trials with lambs, C. gayana in its first year gave a liveweight gain of 283 kg/ha compared to 238-418 kg/ha from other grass species (Department of Agriculture, 1963). Literature on milk production from the grass is scanty (Bogdan, 1969).

2.1.1.3. Cynodon dactylon (Star grass).

C. dactylon is a spreading perennial with long, rapidly growing rooting runners. There are several strains which differ widely in such characters as size, colour (from bright yellowish-green to dull bluish-green), texture of stems and leaves and size of spikes (Edwards and Bogdan, 1951). The grass is widely distributed throughout the world in the tropics and sub-tropics extending into temperate zones along Coasts. It is the most important pasture grass in South East United States and in India and is used as a permanent pasture in Rhodesia (Whyte et al, 1959).

Bogdan (1959) stated that the East African varieties of C. dactylon which are all stoloniferous belong usually to three fairly distinct types.

(i) A large robust type occurring mostly at forest edges. It is particularly common in Western Kenya and in Uganda.

(ii) A fine type with numerous thin and wiry stems and numerous small and short leaves; this type occurs regularly in arid parts of Kenya, usually under water logged conditions, often on saline and alkaline soil.

(iii) A third type which is widely distributed in Kenya is of medium vigour. It is very uniform, and includes numerous varieties, many of which produce high quality herbage. Because most of the varieties of C. dactylon are poor seeders propagation is effected by means of cuttings from the stolons. The grass is very resistant to heavy grazing and trampling and gives large yields of palatable fodder under good management (Whyte et al, 1959). According to Strange (1958) C. dactylon is comparatively drought resistant and does not lose its quality as rapidly as many other grasses.

Digestion coefficients of C. dactylon growing in Trinidad at "young and flowering" stages were given by

Butterworth (1963) as 59.1, 59.9 for dry matter; 68.4, 64.3 for crude protein; 32.9, 41.7 for ether extract; 66.2, 65.8 for crude fibre and 58.7, 60.8 for nitrogen-free extractives, for the two stages respectively. Grieve and Osbourn (1965) found that the apparent digestion coefficients of dry matter and crude protein for C. dactylon growing in Trinidad were respectively 59.4, 75.8 at 3 weeks regrowth; 64.8, 77.1 at 4 weeks regrowth and 55.0, 65.1 at 6 weeks regrowth. Data of proximate composition and digestibility of C. dactylon at some stages of regrowths has been compiled by Butterworth (1967).

2.1.1.4. Setaria sphacelata.

Four cultivars of S. sphacelata are now in commercial production. There are Nandi, Narok, Kazungula and Bua River. The main cultivar used in East Africa is the Nandi whereas Kazungula is mainly grown in South Africa. Cultivars Narok and Bua River are very common in the Australian continent.

The Nandi cultivar is a stout tufted perennial 60 to 180 centimeters high, with or without creeping rhizomes or stolons, (Whyte et al, 1959). In East Africa it is distributed in the Highland Grassland and Scattered Tree Grassland but occurs even at the Coast (Edwards and Bogdan, 1951).

The grass is a widely used ley grass and its importance in Kenya is already established. It originates in Nandi district, Kenya. The attractive features of this grass are its persistence, productivity, high palatability and relatively good seed production. These valuable features outweigh its negative characteristics, viz: its tufted habits and its tendency to go to stem too early. Nandi setaria pasture can last upto four years; this is a long enough period for the ordinary ley (Bogdan, 1959).

Digestion coefficients of the Kazungula cultivar at its mature stage, growing in Trinidad, West Indies, have been given by Butterworth (1963) as 63.3, 51.5, 49.3, 65.1 and 67.9 respectively for dry matter, crude protein, ether extract, crude fibre and for nitrogen-free extractives. Also in Trinidad Grieve and Osbourn (1965) studied three regrowth stages of Nandi cultivar and found that the digestion coefficients for dry matter and for crude protein respectively were 68.2 and 69.4 at 4 weeks; 56.5 and 53.6 at 6 weeks and 56.3 and 44.0 at 8 weeks. In Uganda, Soneji (1971) gave digestion coefficient of dry matter for Nandi cultivar as 61.2, 59.0, 56.0 and 50.4 at boot, head bloom and seed stages.

Recently it was observed in Australia (CSIRO, 1972) that some S. sphacelata varieties had exceptionally high oxalate accumulating characteristics which could cause oxalate poisoning under special conditions of high potassium and nitrogen fertilization. It was reported in the same report that the Bua River and Kazungula cultivars were consistently high in oxalate while the Nandi cultivar was consistently low. The recently released Narok cultivar had intermediate levels.

2.1.1.5. Pennisetum purpureum (Napier grass),

P. purpureum, which is sometimes also called Elephant grass or Napier grass, is a tall perennial grass growing upto 3.5-5.2 m. high. It forms large bamboo - like clumps with stems up to 2.5 cm. in diameter (Edwards and Bogdan, 1951). In East Africa the grass is distributed from sea-level to 1829 m. in varying ecological zones. P. purpureum is also grown in other parts of the tropical and subtropical regions. There are a number of geographical varieties of P. purpureum. The Gold Coast (Ghana) variety, the Cameroons variety, the Uganda hairless variety are the common varieties used locally on many farms (Strange, 1958).

P. purpureum is strongly drought resistant. It is widely used as reserve fodder and as silage, for which purposes it is cut before the stems become hard and woody. It is also well suited to a system of rapid rotational grazing at the younger stages of growth and its regeneration following defoliation is correspondingly rapid. Blaser (1958) reported that more leaves per plant were produced by grazed than by ungrazed grass but that more than 90 percent defoliation killed the plants. Stripping leaves from ungrazed plants or cutting plants down to 58.8 cm. encouraged greater leaf production. In a grazing trial, Strange (1958) found that the Gold Coast and the Cameroons varieties withstood grazing better than the other varieties and that they were the most productive, the former being possibly the more palatable of the two. Ware - Austin (1963) reported that in Kitale, Kenya, P. purpureum (no specific variety quoted) in its second and third seasons gave annual dry matter yields of 10,294 and 9,541 kg/ha respectively as compared to sown pastures in their second and third years. The sown pasture grasses consisted of C. gayana cultivar Endebess grown alone or in mixture with S. sphacelata variety Nandi and/or Kenya White Clover and their respective dry matter yields were 3,513 and 1,758 kg/ha. Ware - Austin (1963) also indicated that one quarter or more of the annual yield of P. purpureum was obtained during the months between January and March, in which months the greater part of Kenya is dry and the sown pastures may not yet have fully emerged from their dormancy. The availability of green fodders at such critical periods will do much to alleviate sub-maintenance levels of the pastures. That is even more important in herds with seasonal calvings, and if calving seasons, for one reason or another, fall at times when the nutritive value of sown pastures and natural grasslands are at their lowest.

Ware - Austin (1963) followed up monthly fluctuations in crude protein content of P. purpureum and some sown pastures. He found that the highest and lowest contents of crude protein for P. purpureum were 19.7 and 9.6 percent in the dry matter for the months of May and February respectively. At the same periods the crude protein contents of the sown pastures were 12.4 and 6.8 percent in the dry matter although the highest crude protein content of the sown pastures was 15.0 percent dry matter in August of the same year. It was also found that the crude protein content of P. purpureum was almost consistently higher than that of the sown pastures throughout the twelve months.

French (1943) reported that the digestion coefficients of P. purpureum at 30.5-45.7 cm. and 76.2-91.5 cm. growing in Tanganyika were, respectively 61.2, 54.4 for crude protein 74.7, 60.5 for crude fibre and 71.8, 62.2 for nitrogen-free extract. Butterworth (1963) in Trinidad West Indies gave digestion coefficients of P. purpureum at its "young" stage of growth as 54.5, 51.6, 19.2, 59.9 and 61.1 for dry matter, crude protein, ether extract, crude fibre and for nitrogen-free extract, respectively.

2.1.1.6. Desmodium Uncinatum (Silver leaf desmodium).

Desmodium species (Desmodium uncinatum and D. intortum) are among the tropical pasture legumes that have come into prominence in recent years. They were unknown in agriculture before 1950, but many countries in the tropics and subtropics have now tested and found them of actual or potential value (Bryan, 1969).

D. uncinatum originates from South America. It was introduced into Kenya from Australia in 1953. It is a plant of warmer areas and grows best at altitudes below 1981 m. and at 762 mm. rainfall (Suttie and Moore, 1966). Naveh and Anderson (1967) reported that D. uncinatum responded well to moist conditions. It is a vigorous fodder plant which mixes well with a wide range of grasses; and is a medium to good seeder under Kenya conditions (Bogdan, 1965). It can be planted from inoculated seeds or vegetatively by planting individual slips or by broadcasting slips and discing them in.

Suttie and Moore (1966) described D. uncinatum as a palatable fodder, persistent and drought tolerant, remaining green well into the dry season. Whiteman (1969) in grazing experiments with sheep reported that close rotation on D. uncinatum/ C. gayana pasture eliminated the legume in four years. However, Bryan (1969) quoting research in New South Wales, Australia, reported that the legume, in a mixed pasture, was thriving after being grazed by cattle for five years and concluded that results of persistency of the legume reflected the management used. Out of several legumes studied by Bryan (1968) D. uncinatum gave the most consistent production throughout the year.

Milford (1967) reported that of the seven tropical legumes tested D. uncinatum was among the better one as regards feeding value. At respective crude protein and crude fibre percentages of 18.2 and 32.5, he found that the corresponding digestion coefficients of dry matter, crude protein and crude fibre were 54.1, 67.5 and 33.3.

2.1.1.7. Ipomea batatas vines (Sweet potato vines).

Many small scale farmers in many parts of East Africa use I. batatas vines to feed to their livestock. The vines are a palatable nutritious fodder. However, because they are very high in water content they are difficult to cure into good hay. They are a good fodder to make silage from and Morrison (1959) reported that I. batatas vines silage was equal to maize silage for fattening cattle and that silage made from a combination of the vines and culled

I. batatas potatoes was equal to maize silage for dairy cows in terms of feeding value. Watson and Nash (1960) reported that in terms of milk and butter fat production silage made from vines and potatoes, was a superior foodstuff to good quality maize silage but in feeding pigs, weight gains were low for the I. batatas silage as compared to a maize ration.

2.1.2. Arable Farm by-products

2.1.2.1. Cottonseed cake/meal

Cottonseed cake is the residue from the extraction of oil from cottonseed. When the hulls of the seeds are sheared before extraction of oil the resultant cake is called decorticated cottonseed cake and is of superior quality than the cake after extraction of oil from wholeseeds, which cake is called undecorticated cottonseed cake (table 1). Sometimes the cake is ground and the product is sold as cottonseed meal. In other countries cottonseed meal is put through pelleting machines to produce pellets or cubes of various sizes.

Table 1 - Chemical composition of cottonseed and cottonseed cakes as given by Bredon and Marshall (1962).

	% Dry matter	Percent dry matter				
		Crude protein	Crude oil	Crude fibre	Ash	N. free extract
Cotton seed	91.0	23.3	20.9	21.8	4.0	29.9
Cottonseed cake (undecorticated)	91.0	19.9	5.9	32.7	3.6	37.8
Cottonseed cake (decorticated)	91.9	35.0	8.1	19.4	6.2	31.3

Used properly cottonseed cake, decorticated or not, is a valuable source of protein for livestock feeding. The way in which it is used is determined by two of its main characteristics, namely its fibre and gossypol contents. The high fibre content of undecorticated cottonseed cake limits its application to the feeding of young ruminants whilst its gossypol content, depending upon the method of extraction, can restrict its free use except to the feeding of mature ruminants. For pigs and poultry some kinds of cottonseed meals should be fed in strictly limited amounts as these classes of livestock are very susceptible to gossypol poisoning. Fortunately, however, much of the gossypol is rendered innocuous by the ordinary milling processes of oil-extraction.

Cottonseed cake is very rich in phosphorus but low in calcium. Like other oil seed products, it lacks vitamin D, and it has also little or no carotene (Morrison, 1959). It is one of the best protein supplements for dairy cows, beef and sheep. Its percentage content, in dry matter varies from 20-42 depending upon whether it is decorticated or not. Abrams, (1961) reported that in the process of oil-extraction, however, the solubility and digestibility of the protein is diminished and there is also loss of thiamine. Several observers have compared cottonseed cake/meals produced by (a) the press method, (b) expeller method and (c) solvent extraction. Solvent extraction, whereby the temperature can be kept down, tends to yield the best product for the nonruminant. Under these conditions it is as good as soya bean meal when tested for the growth of rats and chicks and for freedom from toxicity (Abrams, 1961). Tillman, Woods, Kruse and Gallup (1961) in experiments with chicks found that a cottonseed meal processed by a high-speed screw press was inferior to a prepress solvent-extracted meal. The same authors also reported that digestibility of crude protein in cottonseed meal processed by the high speed screw press was lower than that produced by the prepress solvent extracted meal and that both meals had a lower digestible nitrogen than solvent extracted soya bean meal. Denke, Sherrod, Nelson and Tillman (1966) found that autoclaving between 45 and 75 minutes at 1.05 kg./cm^2 in a cold-hexane extracted cottonseed meal resulted in maximum retention of nitrogen in sheep. Autoclaving from 75 to 90 minutes reduced nitrogen digestibility by 8.2 units. In the same experiment the same authors reported that steaming decorticated cottonseed before oil extraction by cold hexane, decreased nitrogen solubility slightly, but in a linear fashion as heating time increased, however, nitrogen digestibility was highest in the unheated meal. Good growth performance in pigs has been reported by Haines, Wallace and Kroger (1957) when the rations contained as much as 20 percent of cottonseed meal (free gossypol 0.01 percent, nitrogen solubility 89 percent) prepared by solvent extraction. An expeller product, of the same gossypol content, but nitrogen solubility of 42 gave inferior results. Cottonseed/soya bean blends gave the best results. In poultry, good results, though not quite equal to those on soya been meal, have been obtained by feeding de-gossypolized cottonseed meal to growing chicks, using 38 percent of the meal as the main protein source. Press-cake and expeller meal gave somewhat poorer results (Morgan and Willimon, 1954).

Morrison (1959) observed that cottonseed meal tends to produce milk fat of high melting point and hard body fat. It is also slightly constipating and this may be advantageous when considerable amounts of very laxative feeds are used.

Cottonseed as whole seeds may be fed to cattle but too large amounts may cause scour, on account of the large amount of oil. In trials with dairy cows, 77.6 kg. to 93.4 kg. of cottonseed were required to equal 45.4 kg of cottonseed meal in feeding value (Morrison, 1959). For fattening cattle cottonseed may be a substitute for part or all of the cottonseed meal in a ration. Cottonseed hulls are used extensively in the southern states of the U.S.A. chiefly as roughages. Cottonseed hulls are comparable to late cut grass or oat-straw in total digestible nutrients but worth more than maize or sorghum stover or poor hay. The hulls are very low in protein and none of it is digestible (Morrison, 1959).

2.1.2.2. Wheatbran

Wheat is separated into the following main portions by milling.

i) The scaly outer part of the grain, known as <u>bran</u> or <u>wheat offals</u>

ii) <u>Flour</u>

iii) <u>Wheat germ</u>

iv) <u>Pollard</u> - consisting of finer particles of bran and some wheat germ.

Depending upon the thoroughness with which the bran is separated from the rest of the grain, samples of different nutritive value may be obtained. Thus the quality of the bran depends upon the precise milling technique used (table 2). In European countries therefore a variety of grades of wheat bran exists depending upon the milling technique used. In East Africa no such refinements within the wheat bran exist. The by-product is sold just as a wheat bran.

Table 2. Composition of the main groups of wheat-feeds as given by Abrams (1961).

	% Dry matter	Percent dry matter				
		Crude protein	Ether extract	Crude fibre	Ash	N. free extract
Bran, broad	87.0	14.7	4.0	10.3	5.9	52.1
Bran, 4th grade	87.0	15.1	3.8	9.5	5.8	52.8
Fine wheat-feed (Coarse middlings or sharps)	86.0	15.9	4.5	6.0	3.7	55.9
Fine wheat-feed (Fine middlings)	86.7	17.0	4.2	2.3	2.4	60.8

Wheat bran forms a useful feed for all classes of livestock. It is palatable and has a laxative effect which is desirable in some classes of livestock at certain periods. It is being used widely by many farmers whether as plain wheat bran or in home concentrate mixtures for cattle, pigs and poultry. Proprietary feed manufacturers are using it in the production of various forms of livestock feeds.

Judged by its chemical composition wheat bran should be nearly equal to oats in feeding value, but Abrams (1961) states that it takes nearly 0.6804 kg of ordinary bran to equal 0.4536 kg of oats for fattening purposes or as a substitute for oats to yield energy for working horses. Bran is rich in phosphates and magnesium, but poor in lime, and is thus unbalanced in its mineral constituents (French, 1940).

Digestion coefficients of local bran in Tanganyika as reported by French (1943) were 70.6, 45.0, 48.8 and 65.7 for crude protein, ether extract, crude fibre and for nitrogen-free extracts respectively when the percent dry matter chemical composition was 14.3 protein, 4.0 ether extract, 12.7 crude fibre and 64.9 nitrogen free extract.

2.1.2.3. <u>Maize germ and bran meal</u>.

Whereas in European countries maize is used industrially for the preparation of starch, in East African countries a major industrial product of maize is maize meal for human consumption. The main by-product in East Africa is therefore the maize germ and bran meal. Some millers separate bran from germ meal selling it separately as two by-products. For livestock feeding it is the maize germ and bran meal that is widely used. Individual farmers supplement it to their livestock separately or in home mixtures. Proprietary feed manufacturers use maize germ and bran meal to produce a variety of feeds for various species and classes of livestock.

Maize germ and bran meal is very palatable and highly digestible. However, its proteins are of low biological value and must be supplemented with protein concentrates of higher biological value.

2.1.2.4. "Wishwa"

"Wishwa" is a local name for the equivalent of maize germ and bran meal but which is produced locally by a pestle and mortar. It is a very common concentrate to livestock all along the Kenya Coast. Many dairy farms at the Coast use "wishwa" as the only supplement to their cows. Its production is fairly substantial to probably just satisfy local demand of the farmers at their present numbers and level of feeding. Nevertheless its importance to the farmers has prompted interest in determining its nutritive value.

2.2 Some factors affecting digestibility.

Digestibility of a feed is one of the three important parameters determining the nutritive value of a feed, the other two parameters being the level of intake of that feed and the efficiency of its utilization. However digestibility of a feed is affected by various factors. Some of the major factors are:-

2.2.1. Stage of maturity of herbage and seasonal changes.

2.2.2. Effect of fertilizers.

2.2.3. Effect of level of intake.

2.2.4. Effect of feed processing.

2.2.1. Stage of maturity of herbage and seasonal changes.

Published data generally show that digestibility of a forage is primarily dependent upon its physiological and morphological development (Meyer, Weir, Jones and Hull, 1957: Soneji, 1970; Musangi, 1969 and Said, 1971;) Minson, Raymond and Harris (1960) found that a rapid decline in digestibility occurred after forage plants headed. Minson, Harris, Raymond and Milford (1964) observed that in the case of a number of temperate grasses the fall in digestibility was between 0.40 percent to 0.51 percent daily.

Miller (1961) quoted work which showed that the decrease in digestibility was due to an increase in structural constituents (crude fibre, cellulose and lignin) and a decrease in the non-structural constituents (mainly the soluble carbohydrates) and that microscopic examination of the faeces after the animals had been fed *Trifolium pratense* clover established that the size of the undigested particles was correlated to the increase in maturity of the forage and an increase in lignification.

Seasonal changes are also known to affect digestibility. Lower digestibilities have been recorded in Perennial rye grasses growing during the summer when temperatures were high (Raymond, 1969). Smith (1962) reported that organic matter digestibility of Hyparrhenia species during the dry season dropped from 50 percent to 38 percent by mid dry season and crude protein digestibility of the same grass was negative.

2.2.2. Effect of fertilizers.

The ability of the soil to supply the plant with nutrients is also another important factor affecting the nutritive value of a pasture sward. This aspect of agrostology is also intimately bound up with fertilizer treatment.

Richardson, Trumble and Shapter (1931) reported that the levels of soluble ash, calcium, nitrogen, phosphorus and potassium in Italian rye grass were proportional to the levels in the soil and therefore it may also be assumed that under some specific conditions the levels of the minerals in the forage may be proportional to the types and levels of fertilizer application. It was also stated by Tribe, Freer and Combe (1962) that in the case of many elements, such as calcium, nitrogen, phosphorus, potassium, magnesium, copper and sulphur; a low level in the soil is often reflected in a decreased productivity of the sward or of certain of its constituents. Corrections of deficiencies of elemental nutrients have resulted in many cases, in increased productivity of the pasture swards. Increased productivity is likely also to be followed by either decreased structural components of the plants, and hence increased digestibility of certain of its nutrients, or by a change in the composition of the sward. Thus Hilder and Spencer (1954) found that fertilization with sulphur increased the proportion of legumes in the sward with a subsequent increase in the crude protein of the herbage and Reid and Jung (1965) reported increased protein levels in tall fescue from 12.7 percent to a maximum of 23.8 percent at the highest level of nitrogen fertilization. Woelfel and Poulton (1960) reported that both the content and digestibility of the nitrogen-free extract decreased markedly with increased nitrogen fertilization and hypothesized that nitrogen fertilization could possibly have altered the nature of the nitrogen-free extract rendering them less digestible.

In addition to the direct effects by fertilizers on the nutritive value of the sward, there may be interaction in the soil between some of the minerals which may indirectly cause a change in the nutritive value of the sward. Thus, Worden et al,(1962) gave a situation in which for example, the application of lime to the soil can cause effects other than an increase in the calcium content of the herbage, such as an increase in the availability of molybdenum thus resulting in a subsequent rise in the legume content of the pasture which may increase its digestibility.

Raymond (1969) outlined several situations in which nitrogen fertilization is likely to affect forage digestibility:

(a) in a mixed grass/clover sward the use of nitrogen fertilizer may reduce the contribution, in the forage harvested, of the more digestible clover component;

(b) nitrogen fertilizer will increase the proportion of new growth in uneaten herbage left on a sward after stock have grazed. The new growth may increase its digestibility. (c) unfertilized herbage may contain an inadequate level of nitrogen for the growth of rumen microorganisms; thus Smith (1962) found an increased level of digestibility after application of nitrogen to such forage. The crude protein content increased from 3.6 to 6.8 percent and the digestibility of the forage dry matter increased from 51.7 to 59.5 percent.

Woelfel and Poulton (1960) reported that apparent digestibility of crude protein increased significantly with increasing nitrogen fertilization. Similar results were reported by Poulton, McDonald and Vander Noot (1957) and by Chalupa, Cason and Baumgardt (1959). It was also reported by Woelfel and Poulton (1960) that apparent digestibility of the nitrogen-free extract decreased markedly with increasing nitrogen fertilization while ether extract and crude fibre digestion coefficients did not show any significant differences related to the various nitrogen application levels.

Holmes and Lang (1963) reported that at high nitrogen fertilization dry matter digestibility of 2nd year rye-grass-cooks-foot-clover sward was significantly higher than at low nitrogen fertilization. It was also stated by Blaser (1964) that nitrogen fertilization reduced carbohydrates in forages but digestible energy was not appreciably altered by such application. Heineman and Evans (1965) reported that in irrigated grass-legume pastures and nitrogen fertilized pastures, protein digestibility was higher throughout the experiment for nitrogen-fertilization pastures but there were no significant differences in animal daily gain or animal gain per acre due to nitrogen fertilization. Nitrogen fertilizer increased crude protein digestibility but that was associated with lower dry matter and nitrogen-free extract digestibility (Cameron, 1967).

In the experiments of Reid and Jung (1965) the reported increase in crude protein by nitrogen fertilization in both the first and the aftermath cuttings of tall fescue were followed by increased apparent digestibility of crude protein as compared to the control plots and to those fertilized with high levels of potassium or phosphate. However nitrogen fertilization did not increase dry matter or cellulose digestibility in the first cutting but significantly increased dry matter digestibility in the aftermath cutting in contrast to high potassium or phophorus fertilization.

The important role of inorganic minerals in stimulating metabolic activities of rumen microorganisms and similarly animal performance is well recognised and Chappel, Sirny, Whitehair and McVicar (1952) reported increases in digestibility of rations containing large amounts of roughages as a result of addition of minerals. Tillman, Chappel, Sirny and McVicar (1954) reported that neither the addition of a complete mineral mixture nor alfalfa ash increased the digestibility of a prairie hay basal ration by sheep. However Tillman, Sirney and McVicar (1954), reported that the addition of 28 g of alfalfa ash to lamb ration containing 60 percent cottonseed hulls improved the apparent digestibility of each ration constituent. In vitro cellulose digestion by a suspension of washed rumen bacteria was stimulated by sodium, potassium, sulphur, magnesium and calcium (Hubbert, Cheng and Burroughs, 1958; and Martin, Arrington, Moore, Ammerman, Davis and Shirley, 1964). Hubbert, Cheng and Burroughs (1958 b) reported that extremely low levels of copper, cobalt, zinc and boron depressed in vitro cellulose digestion. It may be concluded therefore that in a situation where the application of fertilizers result in changes in the mineral status of the herbage, such changes are likely to be followed by changes in the digestibility of the ration constituents.

2.2.3. Effect of level of intake.

Watson (1947) in a summary of 15 years of experimentation with various feeding levels fed both singly and in combination stated that the level of feeding had no effect upon digestibility or, where differences existed, they were of small magnitude. This conclusion was also confirmed by Bloom, Jacobson, Allen, McGilliard and Homeyer (1957) who showed that feeding levels did not significantly affect digestibility. Blood *et al* (1957) also quoted Hansson who worked with monozygous cattle twins and showed that feeding levels had no effect on digestibility.

However, Raymond, Harris, and Kemp (1955) observed that numerous published data showed that the digestibility of concentrates and mixed rations decreased with increase in level of feeding but no such effect was found with dried roughages. Reid (1961) stated that digestibility decreased with increased consumption of a ration which does not change in compositon. In their review of literature Balch and Campling (1962) concluded that there was a direct relation between the voluntary intake of roughages by ruminants and their digestibility; and Blaxter (1962) stated that with higher levels of intake the rate of passage through the rumen is accelerated and the microbial digestion of the feed particles does not proceed to completion. These conclusions were also confirmed by Brown (1966) who concluded from an extensive review of literature that in most instances reducing the feed intake of ruminants resulted in higher digestion coefficients for all nutrients. Thornton and Yates (1968) found similar increase in digestion coefficients when restricting feed intake and a further increase when water was also restricted. Utley, Bradley and Boling (1970) reported that restricting water intake resulted in a significant reduction in voluntary intake and an increase in apparent digestibility but the higher digestion coefficients values were not significantly different from control digestion coefficients. The increase in digestion coefficient may not be a direct effect of water deprivation but may have resulted indirectly from the reduced feed intake as was extensively reviewed by Payne (1966) and/or by the increased production of saliva with a consequent favourable effect on rumen fermentation as suggested by Balch, Johnson and Turner (1953).

2.2.4. Effect of feed processing.

Forbes, Fries and Braman (1925) in a direct comparison of lucerne hay, coarsely cut in a chaff cutter and finely ground, showed that there were no significant differences in digestion coefficients between the two forms of lucerne although the coarsely cut hay gave slightly higher digestion coefficients (table 3). Meyer, Gaskill, Stocwsand and Weir (1959) showed no significant differences in digestibility between ground and long hay. Watson and Nash (1960) quoted figures which showed that there were no significant differences in digestibilities between hay meal and chopped hay. They concluded that grinding hay fine enough to seriously affect rumination would not alter digestibility.

Table 3. Digestibility coefficients of hay and hay meal determined with sheep (Watson and Nash, 1960)

Nutrients	Chopped hay	Hay meal	Chopped hay	Hay meal
Organic matter	51.1	51.9	62.8	60.2
Crude protein	65.7	72.2	75.0	73.7
Ether extract	31.0	46.0	23.0	22.9
Fibre	50.6	46.4	44.3	39.4
Nitrogen-free extractive	52.7	55.2	72.8	72.2

However, Balch (1950) and Rodrigue and Allen (1960) reported that digestibility in ground hay was depressed and that the finer the hay was ground the greater was the depression in digestibility, which might have been due to the quicker rate of passage of finer ground hay through the alimentary canal. Campling, Freer and Balch (1963) also reported lower digestion of ground hay compared to long hay. Rodgrigue and Allen (1960) and Campling et al (1963) both found that the depression in digestibility caused by grinding was most marked in the crude fibre fraction. Minson (1963) in an extensive review of literature stated that dry matter digestibility was slightly increased by pelleting in five comparisons but depressed in twenty one other experiments and that the mean change was a depression of 3.3 digestibility coefficients units. He quoted other workers who reported that the lower dry matter digestibility of the pellets was attributed to the animals on the long hay being able to select the more digestible parts of the ration. Only minor differences were found in digestion coefficients between baled and wafered lucerne hay and chopped and wafered meadow hay (Minson, 1963).

In his review of the nutritive value of forage crops, Raymond (1969) reported that most workers agreed that (a) the voluntary intake of pelleted ground forages was considerably higher than that of the corresponding long forage, (b) under ad libitum conditions the long forage was more digestible, but (c) that there was usually an increase in the net intake of digestible energy on pelleted forage, (d) the magnitude of those effects differed, however, among forage species and with the stage of maturity of a given forage.

Many experiments have shown that heat-dehydration of forage can reduce the apparent digestibility of the crude protein in the forage but that nitrogen retention was increased under controlled heat-dehydration (Raymond, 1969). Cooking feeds does not help digestibility in mature farm animals except in the case of a few feeds for swine and poultry and Maynard and Loosli (1956) concluded that none of the various processes of fermenting, predigesting and malting of roughages and other fibrous feeds have been found to have any advantage when subjected to critical tests.

Raymond, Harris and Harker (1953) showed that herbage stored at -15°C had negligible effect on dry matter and organic matter digestibility but slightly reduced the digestibility of the crude protein fraction.

There was no significant difference in digestibility between herbage and the corresponding silages nor were there any significant differences in digestibilities by ensiling methods such as addition of molasses and organic acids (Harris and Raymond, 1963). There are reports indicating lower digestibility of silage than of the fresh crop to be ensiled but Raymond (1969) pointed out that losses of volatile constituents during oven drying might lead to underestimation in the amount of silage ingested and in the measured digestibility. Estimation of true dry matter content by toluene could overcome the problem of loss of volatile constituents (Harris and Raymond, 1963).

Grinding grain usually would not increase digestibility in those animals which masticate their feed thoroughly, but seeds which escape mastication may remain largely undigested in passing through the tract. Digestibility in growing swine is only slightly increased by grinding, but the effect is more marked in older animals (Maynard and Loosli, 1956).

Johson, Matsushima and Knox (1968) found that apparent dry matter digestibility of flaked maize ration was an average of 4.7 percent higher than the cracked maize ration. Apparent digestibilities of protein and ether extract were slightly higher in the flaked maize ration but did not reach significance; inspite of a 9 hour faster rate of passage through the alimentary tract by the flaked maize ration compared to the cracked maize ration. However, there was a decrease of energy loss as methane gas and an estimated increase in energy retention of from 6 to 10 percent in the flaked maize than in the cracked maize ration.

2.3. Effect of protein and energy supplementation on feed intake, digestibility and on nitrogen excretion and retention.

2.3.1. Effect on feed intake.

Factors which affect feed intake have been extensively reviewed by many workers. Among them are Blaxter, Wainman and Wilson (1961), Balch and Campling (1962), Murdoch (1964) and Musangi (1969). They fall under three broad categories: the central nervous factors, feed factors and animal factors. In this section only the effects of protein and energy supplementation on feed intake are reviewed.

In farming practice, concentrates are frequently given in restricted amounts to cattle offered roughage ad libitum. Inspite of the common occurence of this practice there appear to be comparatively few reports of experiments examining the effect of giving concentrates on the voluntary intake of roughage. In their review of literature Campling and Murdoch (1966) observed that there is also considerable variation among the results reported from experiments on this subject.

It has been reported by Holmes, Arnold and Provan (1960) that the feeding of concentrates from 1.81 to 2.72 kg per day caused no significant depression in the intake of silage by cows and only a slight depression in the intake of hay. Murdoch (1962) reported that a mixture of barley and 16 percent decorticated groundnut cake was superior to barley alone in increasing the voluntary intake by cows offered, ad libitum, grass silage with a crude protein content of 15.2 percent dry matter. Earlier to that Campling and Freer (1961) showed that the voluntary intake of straw was increased when it was supplemented with urea; an increase of 39 percent by cows was recorded when the straw was supplemented with 150 g urea/day. Blaxter and Wilson (1963) working with sheep observed that voluntary intake of roughage was depressed when restricted amounts of concentrates were given and that the extent of the depression varied inversely with the quality of the roughage; the more digestible the roughage the greater the depression of the roughage intake. Murdoch (1964) showed that concentrates with relatively higher protein content depressed roughage intake to a lesser extent than concentrates with a low protein content. The roughages in the experiment reported consisted of silage and hay having 21.1 and 12.2 crude protein percent dry matter respectively. Table 4 shows the trend of dry matter intake of hays at different levels of protein contents as it is affected by the levels of concentrates supplementation.

Table 4. Mean voluntary consumption of hay by sheep given different amounts of concentrates (Blaxter and Wilson, 1963).

	Voluntary consumption of hay g DM/kg $w^{0.73}$		
Amount of concentrates consumed daily (g)	Hay. Cut 1 8.76 % CP	Hay. Cut 2 6.57 % CP	Hay. Cut 3 5.11 % CP
Nil	70.0	61.8	57.2
200	67.9	64.9	63.0
500	59.1	61.3	64.4
800	49.5	53.8	57.9
1200	34.8	37.6	45.8

In his review on the effects of concentrates on the intake of roughage Campling (1964) stated that although the total intake of dry matter generally increased when restricted amounts of concentrates were given, the intake of roughage often dropped and that the considerable variation in the extent of the decline in the voluntary intake of the roughage portion per unit of concentrates reported in the literature could be due in part to the varying quality of the roughages that had been given.

The observed increases and decreases in the intake of the roughages could be explained by the very wide subject of feed interactions in the ruminal fermentation processes resulting in either accelerated or decreased passage of the roughage out of the rumen. The subject is reviewed in the preceeding section 2.3.2 on the effect of protein and energy supplementation on digestibility.

2.3.2. Effect on digestibility.

Addition of restricted amounts of concentrates to the diet of ruminants, offered roughage ad libitum, often alters the voluntary intake of the roughage. The type and extent of the change in voluntary intake of the roughage seem- to depend largely on the quality of the roughage. It was suggested by Campling and Murdoch (1966) that the increase in voluntary intake of a poor quality roughage when supplemented with concentrates was probably due to an increase in the rate of disappearance of digesta from the gut which was, in turn, due to the nitrogenous constituents stimulating the cellulotytic activity of rumen microorganisms whereas with better quality roughages there is a depression in the rate of disappearance from the reticulo-rumen of digesta derived from the roughage.

The effect of protein supplementation on digestibility of the roughage portion of the diet has been reported by many workers. Thus Swift, Thacker, Blach, Bratzler and James (1947) reported that the addition of casein in a roughage increased the digestibility of the crude fibre and of nitrogen-free extract while urea supplementation to a ration already containing 12.9 percent protein caused a prominent increase in the digestibility of protein. Woods, Thompson and Grainger (1956) reported that increased protein levels in the form of soyabean meal fed together with low quality timothy hay resulted in a highly significant increase in apparent digestibility, by sheep, of dry matter, organic matter, protein, nitrogen-free extract and energy in the total ration. However, they found that the level of protein had no significant effect on crude fibre digestibility.

Bloom et al (1957) reported that from high to low hay rations digestion coefficients of dry matter, crude protein, ether extract and crude fibre were significantly increased but that of nitrogen-free extractives increased significantly only at the lowest hay ration (15:85 hay to concentrate ration). Kane, Jacobson and Moore (1961) found that there was no effect on forage component digestibility by cows with varied hay-grain intakes but significant increases in the component digestibilities of the total ration were observed.

It was reported by Campling, Freer and Balch (1962) that organic matter digestibility was increased from 41 to 50 percent when urea supplement was fed with oat straw containing 3.0 percent crude protein. Campling (1966) reported that the addition of large amounts of concentrates containing 19 to 20 percent crude protein to a roughage diet containing 7.2 to 7.9 percent crude protein decreased the digestibility of the crude fibre of the hay and was followed by an increased ruminating time per kg hay the cows ingested. Recently it has been reported by Campbell, Sherrod and Ishizaki (1969) that supplemental protein on P. clandestinum at crude protein content of 5.1 percent dry matter increased the digestibility of organic matter, crude protein, nitrogen-free extract and gross energy in the total ration. The digestibility of crude fibre in both the total ration and in the grass portion was not uniformly affected by increased protein levels. No significant increase in the digestibility of the grass portion was observed with increased levels of protein supplementation.

Energy supplementation when fed with forage results in a significant decrease in the digestibility of the fibre fraction of the forage, unaccounted for by any change in the composition of the cell wall (Raymond, 1969). El-Shazly, Dehority and Johnson (1961) attributed the decrease of digestibility of forage crude fibre when fed with carbohydrate to preferential digestion of the starch by the rumen microorganisms or alternatively that the amylolytic bacteria compete preferentially for ammonia against the cellulolytic bacteria, so reducing cellulose digestion. However, Tilley, Terry Deriaz and Outen (1964) showed a marked reduction in the rate and extent of digestion of dry matter and cellulose in in vitro when the pH of the in vitro system is reduced. These workers have suggested that the lower rumen pH when a starch supplement is fed may provide a less favourable environment for the cellulolytic and other bacteria that are able to digest plant fibre. And Topps, Reed and Elliot (1965) have shown that when a starch supplement is fed with a forage there is a reduction in the pH of the rumen content compared with when forage is fed alone.

Wood et al (1956) reported that energy supplementation significantly increased the digestibility of nitrogen-free extract in the total ration but that digestion coefficients of dry matter, organic matter, crude fibre and energy were not significantly affected by levels of energy supplementation. Only at high levels of energy supplementation was there a definite tendency for a decrease in crude fibre digestibility of the total ration. Murdoch (1964) showed that barley increased the digestibility of the dry matter in whole ration of barley and hay but dairy cubes slightly decreased the digestibility of the dry matter component in the whole ration consisting of hay + dairy cubes. Campbell et al (1969) reported that digestibility of organic matter, ether extract, nitrogen-free extract and gross energy in the total ration of P. clandestinum and corn were improved with higher corn levels. There was no significant trend for improved digestibility of crude protein in the total ration with additional corn levels.

For the grass portion there was a linear depression of digestibility for crude protein and crude fibre with increased corn levels.

2.3.3. Effect on nitrogen excretion, retention and utilization.

Woods et al (1956) reported that the addition of soyabean meal to mature timothy hay resulted in a highly significant increase in nitrogen retention. It was also reported by Robinson and Forbes (1970) that nitrogen retention increased significantly with increasing nitrogen intake. Crude protein supplementation at 11.2 percent depressed digestibility of energy resulting in a significantly lower net energy value compared to a 16 percent crude protein supplementation, but efficiency of milk synthesis from metabolizable energy was not affected by protein level (Tyrrel and Moe, 1972).

Mitchell, Hamilton and Haines (1940) observed that nitrogen retention was increased in beef calves by adding glucose as a supplement to basal rations containing approximately 15 and 20 percent protein but that glucose supplementation of low protein ration failed to increase nitrogen retention. However, Lofgreen, Loosli and Maynard (1951) found that increasing the energy intake of dairy calves resulted in an increased nitrogen retention when a moderately low protein ration was fed but the increased energy intake was without effect when a high protein ration was fed.

Fontenot, Gallup and Nelson (1955) showed that addition of energy in the form of cerelose produced a significant decrease in nitrogen retention in the 8 percent protein basal ration, a significant increase in nitrogen retention in the 10 percent protein basal ration and a small but insignificant increase in nitrogen retention in the 12 percent protein basal ration. At all levels of cerelose supplementations the increases in faecal nitrogen excretion were roughly proportional to the amount of cerelose added but when faecal nitrogen values were corrected for metabolic nitrogen the differences in faecal nitrogen excretion between the supplemented and the unsupplemented rations disappeared. It was also apparent in the work of Fontenot et al (1955) that the biological value of nitrogen, unlike the nitrogen retention was significantly improved by the cerelose additions, regardless of the protein levels of the basal rations.

Stone and Fontenot (1965) have reported that energy supplementation at three levels to three rations all containing 12.5 percent protein significantly affected nitrogen retention but at medium energy level the biological value of the protein in the diet was highest. Robinson and Forbes (1970) found that when non-pregnant ewes were given three rations, all with a crude protein content of just over 11 percent but varying in the roughage to concentrate ratios, the retention of nitrogen tended to decrease as the ratio of roughage to concentrate increased but did not reach significant levels. There was also a decrease in the efficiency of nitrogen utilization but not at significant levels. Recently Tyrrel and Moe (1972) showed that at a higher gross energy intake, from rations of varying maize silage and varying concentrate ratios, there were greater losses of energy in the form of faeces, urine and methane. As a result of these losses metabolizable energy, as a percentage of gross energy was also significantly reduced but available metabolizable energy per kg dry matter was higher in the high gross energy intake. It was also apparent in their work that substitution of energy by a concentrate source in the silage-concentrate ratio did not result in significant differences in digestible energy, metabolizable energy or in the efficiency of conversion of feed energy into milk energy.

2.4 Methods of estimating digestibility.

The potential value of a feed for supplying a particular nutrient can be determined by chemical analysis, but the actual value of the feed to the animal can be arrived at only after making allowances for the inevitable losses that occur during digestion, absorption and metabolism. The first tax imposed on feeds is that represented by the part of it which is not absorbed and is excreted in the faeces. The part that is not excreted is assumed to be the portion of the feed which has not been digested by the animal. The digestibility of a feed is therefore most accurately defined as the portion which is not excreted in the faeces and which is, therefore, assumed to be absorbed by the animal. It is commonly expressed as a percentage; the digestibility coefficient.

$$\text{Digestibility coefficient} = \left(\frac{\text{Feed ingested} - \text{Feed excreted}}{\text{Feed ingested}} \right) \times 100$$

Coefficients could be calculated in the same way for each constituent in the feed by substituting the word constituent for the feed in the formula given.

The excretion in the faeces of substances not arising directly from the feed leads to underestimation of the proportion of the feed actually digested by the animal. In practice estimation of the substances not arising directly from the feed is difficult and determination of true digestibility is therefore not easy. Until recently no suitable methods were available for the fractionation of faecal nitrogen into undigested dietary nitrogen and non-dietary faecal nitrogen which has its origin from digestive enzymes, abraded intestinal mucosa and from alimentary canal microorganisms. The values obtained in digestibility trials are therefore called "apparent" digestibility coefficients to distinguish them from true digestibility coefficients. Mason (1969) described three reliable methods of estimating undigested dietary nitrogen and reported that estimation of true digestibility of nitrogen were in accord with published estimates derived by extrapolation techniques.

Digestibility of a feed can be determined by the following methods:-

2.4.1. Direct in vivo method

2.4.2. Indirect in vivo methods using reference substances

2.4.3. In vitro laboratory techniques

2.4.4. Prediction from chemical composition

2.4.1. Direct in vivo method.

The measurement of digestion requires a preliminary feeding period during which the experimental animals adapt to the feed under test, followed by a test period during which feed eaten and faecal output are measured. In in vivo method the feed under investigation is given to the animal in known amounts and any left over feed is weighed and recorded. Total output of faeces is measured. Digestibility is then calculated as described.

Male animals are preferred to females because it is easier to collect faeces and urine separately with the male animals. Small animals are confined in metabolism cages and larger animals are usually fitted with harness and faeces collection bags; but digestion stalls have been used in cattle by other workers (Balch, Bartlett and Johnson, 1951; Kane, Jacobson and Moore, 1953; Greenhalgh and Corbett, 1960; and by Bredon, Juko and Marshall, 1961). Sheep, have found preference with many workers as they are easy to handle and need less feed.

Watson, Davidson, Kennedy, Robinson and Muir (1948) in digestibility studies with sheep and steers reported that there were some slight differences in the digestive powers of sheep and steers but they were not of very great magnitude. Lancaster (1950) observed that the digestibility coefficients determined with sheep were 5 percent higher than those found with cows and Jordan and Staples (1951) reported that sheep digest roughages better than cattle. Vander Noot, Cordts and Hunt (1965) in their studies with eight different silages reported that with many nutrients in the silages sheep were superior in their digestion abilities compared to steers. However Cipollini, Schneider, Lucas and Pavleck (1951) in their calculated data indicated that cattle are superior to sheep in digesting all nutrients in dry roughages and silages.

In the comparison on digestion abilities between sheep and cattle Blaxter and Wainman (1961) found no differences of any magnitude in the percentage loss of dietary energy in faeces, in urine, or in methane production between the two species when the comparisons were made at comparable nutritional levels. Previous to that French (1956) indicated no differences between sheep and cattle for overall mean digestion coefficients averages of several hays. Blaxter (1962) concluded that for all practical purposes any differences in the ability of sheep and cattle to digest feed were negligible. This was also confirmed by Landlands, Corbett and McDonald (1963) who compared regression equations relating digestibility to the nitrogen content of faeces in cattle and sheep fed on the same herbage and concluded that the relationships were of similar predictive value for cattle and sheep. It was also reported by Harkers (1963) that no significant differences were found between the digestive efficiencies of wether sheep and dairy cows in three experiments conducted by him.

There has been no unanimous agreement of results in the literature regarding the influence of age of sheep on the efficiency of digestion. Hadjipieris, Jones and Holmes (1965) concluded that it did not seem justifiable to adopt correction for ages.

Grieve and Beacom (1963) found that there was little difference between the performance of the caged and penned sheep and they concluded that data obtained by feeding sheep confined in metabolism stalls or in a pen are equally applicable to practical feeding conditions. It was also reported by Blaxter (1962) and by Hadjipieris and Holmes (1966) that neither pregnancy nor lactation affect the apparent digestibility of a constant ration of feed.

It has been found by Raymond, et al (1953) that digestive abilities of individual animals differ. It is evident, therefore that the larger the number of animals in a group from which a prediction of mean digestibility is required, the more likely they are to be a fair sample of the population, and so the more accurate the prediction. In general the error associated with one animal is more than halved when six sheep are used (Raymond, Kemp, Kemp and Harris, 1954). Bredon, Juko and Marshall (1961) found an increased accuracy in digestibility coefficients proportional to the number of animals used. However, Blaxter, Wainman and Wilson (1961) showed that animal to animal variation in voluntary intake was not significant and Blaxter and Wainman (1964) stated that both in cattle and in sheep individual differences in apparent digestibility of energy were not significant.

The most accurate results in in vivo digestion trials could possibly be obtained by feeding the tested feed of uniform composition throughout the experimental period in order to avoid the problem of day to day variation. With forages this is not possible in its fresh form as this class of feed changes in its composition almost daily. In many studies this day-to-day variation in feed characteristics has been overcome by cutting, at one time, sufficient fresh forage for the complete digestibility experiment, and preserving this forage so that it can be fed over an extended period (Raymond, 1969). Minson (1966) reported that there were no differences in dry matter digestibility and in dry matter intake of tropical pasture when fed to sheep either in the fresh or dried form. Raymond, Harris and Harker (1953) showed that herbage stored at -15^{o} C had negligible effect on dry matter and organic matter digestibility but slightly reduced the digestibility of the crude protein fraction. No significant differences in digestibility were found between the herbage and the corresponding silage (Harris and Raymond, 1963).

For precise measurement preliminary and test periods of at least 10 days are recommended (Raymond, 1969). Bredon, Juko and Marshall (1961) reported that in steers the length of the experimental period necessary for accurate digestibility coefficients results was about 10 days. Reviewing other literature on the subject Raymond (1969) recommended that for precise measurement of digestibility coefficients preliminary and test periods of at least 10 days are recommended.

The most accurate method of determining digestibility coefficients would be to make as frequent collections and analyses of faeces as possible. However, this procedure, although it has many advantages, is both expensive and laborious. Various attempts have been made to reduce the number of chemical determinations and handling of the faeces, either by bulking the faeces or their aliquots, or by reducing the experimental period or the number of animals used (Hodgson and Knott, 1932; Neal, Bekcer and Dix Arnold, 1935; Bechtel, Shaw and Atkeson, 1945). But there has been no consistency or agreement among the various workers on these methods. Bredon, Juko and Marshall (1961) compared digestion coefficients obtained by daily faeces combined and analysed as three day composite samples dried over 12 days, and daily drying and analysis of each collection for 12 days. They found no significant differences in the two methods used. In four experiments conducted over 10 days test period, with four wethers in each experiment, no significant differences were detected in digestion coefficients of dry matter, organic matter, crude protein, ether extract, crude fibre and nitrogen-free extract between one 24 hour collection of faeces composited over the 10 days and analysed as one sample, and one 24 hour collection of faeces separetely dried and analysed as individual daily samples. No were there any significant differences in digestibilities of the nutrients between one daily sampling of faeces composited over 10 days test period and two daily samplings also composited over the ten days period (Said, 1970). However due to the limited number of wethers used in each of the four experiments these results should be interpreted with caution.

2.4.2. Indirect in vivo methods using reference substances.

Indirect methods of determining digestibility have been adapted to overcome the rather laborious and comparatively expensive process used in the direct method. Such methods would also enable indirect measurement of the quantity of pasture herbage consumed by grazing animals provided the indicator used is a normal constituent of the feed.

Indirect methods involve the use of an indicator substance which should be a natural constituent of plant material (internal) or may be added to the ration (external). Reid, Woolfolk, Richards, Kaufmann, Loosli, Turk, Miller and Blaser (1950) stated that for accurate results the indicator substance should posses the following features: a) It should be indigestible and therefore completely recoverable in the faeces and for which chemical analysis is simple, accurate and rapid. b) The recovery of the indicator substance from the faeces must not be influenced by treatment of the feed or by stage of maturity or by irregular passage of the indicator through the gut. Substances which have been used are lignin, methoxyl groups, chromogen, silica, chromium oxide, iron oxide and monastral blue.

Indirect methods can be divided into two main sections:-

2.4.2.1. Ratio technique.

In this method the concentrations of a naturally occurring indigestible indicators in samples of feed and faeces are determined together with the concentrations of nutrients from which the apparent digestibility Y may be calculated as by Miller (1961).

$$Y = 100 - \left(100 \times \frac{\%\ \text{indicator in feed}}{\%\ \text{indicator in faeces}} \times \frac{\%\ \text{nutrient in faeces}}{\%\ \text{nutrient in feed}}\right)$$

There are two naturally occurring reference substance which have been used for this purpose.

2.4.2.1.1. Lignin.

This indigestible fraction of crude fibre of feeds has been successfully used by Forbes and Garrigus (1950) as a predictor of digestibility. There is, however, conflicting evidence about the indigestibility of lignin particularly in young herbage. Forbes and Garrigus (1948) and Richards and Reid (1952) found recoveries of lignin in the faeces greater than 100 percent. Although the latter group of workers ascribed these high recoveries of lignin to interfering substances in the faeces, the problem raises great doubts about the adequacy of the analytical methods at present in use. This is further complicated by the wide range of the methods used for the analysis of lignin and the lack of a definition on this component (Musangi, 1967).

Methoxyl content of lignin and the percentage of the total methoxyl in the plant increases with advancing age of the plant. Methoxyl content of the plants are also more quickly and easily analysed than the lignin (Richards and Reid, 1952). Richards et al (1952) also reported that the digestibility of forage dry matter was correlated negatively (r = - 0.974) with the amounts of methoxyl in the forages consumed. They concluded that methoxyl content of forages and/or faeces might prove to be equal or superior to the lignin content as an index of digestibility of forages.

2.4.2.1.2. Chromogen.

The use of chromogen was first suggested by Reid et al (1950) and was tested by Reid, Woolfolk, Hardison, Martin, Brundage and Kaufmann (1952). The latter group of workers noted that chromogen method was reliable only under conditions in which samples of feed obtained for analysis truly represented the feed consumed by the animal; which conditions exist only when hand feeding is practised.
Reid et al (1952) also reported occasional discrepancies in digestibility results based on chromogen. These discrepancies might have been due to the assumption that chromogen is completely indigestible. Evidence of slight chromogen digestibility was given by Irvin, Wiseman, Shaw and Moore (1953) who stated that chemical degradations of the chromogen which interfere with analysis occur during digestion of the feed. Chromogen recovery of 130 percent when grain was fed

without herbage was reported by Kane, Ely, and Moore (1953). Cook and Harris (1961) found low recoveries of chromogen from sheep feeding on certain range plant - Antiplex contortifolia.

The greatest disadvantage of the ratio techniques, however, is the subjective sampling of the sward grazed when animals are not hand fed. The reference substances are not evenly distributed throughout the plant. Lignin occurs to a greater extent in the stems than in the leafy portions of the plant, while chromogen occurs in higher proportions in the leaves than in the stemmy portions. Depending therefore on what constituent one is analysing and the stage of maturity of the herbage being grazed, one is likely to get a sample for analysis which does not represent the grazed herbage due to the selective behaviour of the animals.

2.4.2.2. Faecal index methods.

In faecal index methods use is made of the relationship between faecal composition and feed digestibility. As the calculation of digestibility by the index methods is not dependent upon a knowledge of the feed composition, the source of error that may arise due to the subjective sampling of feeds, particularly herbage, is eliminated.

The faecal index methods seem more promising than the indicator techniques since the latter make certain precise demands in an indicator whereas the former methods can be studied using a wide range of chemical constituents;

from chromogen, which is largely indigestible, to nitrogen which is highly digestible. Furthermore the faecal index methods require analysis of faeces only instead of faeces and herbage as is the case with the indicator methods used in the ratio techniques. Differences in prediction of digestibility with faecal indices observed by some workers may be attributed to analytical methods used or to types of herbage involved (Raymond, et al 1954). Raymond, Minson and Harris (1956) have reported that a feacal index regression is more precise if restricted in its derivation, and therefore in its application, to herbages differing by only a small degree in composition and digestibility.

The various reference substances which have been used in the faecal index techniques are:-

2.4.2.2.1. Fibre.

Lancaster (1944) and McMeekan (1944) and Forbes and Garrigus (1948) suggested the use of either lignin or crude fibre in feed for the estimation of feed digestibility. Raymond (1949) appreciating the value of the faecal index methods, pointed out that the crude fibre content of faeces could be used for digestibility estimates and he gave the equation:

$$Y = 89.98 - 0.6366 X$$

Where Y is digestible dry matter and X the crude fibre percentage of the faeces.

However, data were published by Raymond, et al (1956) showing that the predictions of herbage digestibility in the field from normal acid fibre or lignin contents of faeces are completely unreliable. This is because of the way in which the concentrations of these two components in the faeces change with the level of feed intake. As the level of feed intake increases, the concentration of normal acid fibre in resulting faeces decreases. This would indicate an increase in digestibility instead of a decrease as actually found.

2.4.2.2.2. Nitrogen.

The relationship between the crude protein of roughage feeds and the digestibility has long been recognised. But the use of herbage nitrogen instead of faecal nitrogen in predicting digestibility was tested by Minson and Kemp (1961) and found not to be related in any significant manner to herbage digestibility; probably because of the difficulty of sampling herbage for analysis which is fairly representative of the grazed herbage. Lancaster (1957), Raymond et al (1954) produced regression equations relating faecal nitrogen to digestibility and prediction of one from the other. Raymond et al (1954) related faecal nitrogen to organic matter digestibility and obtained reliable predictions using the equation:

$$Y = 44.84 + 7.947 \quad X$$

Where Y is percent digestible organic matter,

and X is percent nitrogen in faecal organic matter.

Minson and Raymond (1958) stated that when digestibility of herbage is estimated from the concentration of nitrogen in faeces it is better to use "local" regression equation derived from the same growth of herbage that is being grazed than a more general equation drived from a number of herbages growing at various times of the year. It was reported by Greenhalgh and Corbett (1960) that the relationship between herbage digestibility and faecal nitrogen concentration could not be described satisfactorily by a single equation for all types of herbages. The found that for a given faecal nitrogen concentration herbage digestibility was about five units higher for first-growth than for aftermath herbage. Greenhalgh and Corbett (1960) therefore advised separate equations for different growths as being more precise than general equations.

2.4.2.2.3. Chromogen.

Following initiation by Reid et al (1950) in the use of plant pigments for the ratio technique, Reid et al (1952) reported the possibility of using chromogen as a faecal indicator since the former method necessitated the sampling of herbage with all its possible errors. Chromogen as a faecal indicator proved to be a valid method when used under suitable conditions. The relationship between the chromogen content of the feed and the faeces was found to be:

$$Y = (0.0925\ X + 137.3\ \log\ X) - 242.12$$

Where Y is units of chromogen per gram dry forage
and X is units of chromogen per gram dry faeces.

Using this estimate and applying it in much the same way as for the ratio technique, digestible organic matter is calculated as follows:

% digestible organic matter =

$$100 - \left(100 \times \frac{\text{Units chromogen per gram dry forage}}{\text{Units chromogen per gram dry faeces}}\right)$$

Calculated digestion coefficients by the chromogen faecal index method agreed very closely ($r = 0.985 \pm 0.004$) with those determined conventionally (Elliot and Fokkema, 1960 b). It is also reported by Elliot and Fokkema (1960 b) that the chromogen faecal index method of determining digestibility is probably the most accurate known method under certain grazing conditions. But Greenhalgh and Corbett (1960) reported that as with nitrogen the relationship between herbage digestibility and faecal chromogen concentration could not be adequately described by a single equation for all types of herbages. In most of the trials by Greenhalgh and Corbett (1960) more chromogen was recovered in faeces than was consumed in the herbage and also the proportion recovered in faeces appeared to increase as the season advanced inspite of the very efficient analytical method of recovery.

Greenhalgh, Corbett and McDonald (1960) reported that both season of cutting and nitrogen fertilizer treatment had a significant effect on the faecal index regressions obtained. They concluded that although the "restricted" faecal index regressions by Greenhalgh and Corbett (1960) were found to be more accurate than some published "general" equations, they were not entirely satisfactory but accurate enough for measuring digestibility per se in grazing experiments.

2.4.3. <u>In vitro laboratory techniques</u>.

In order to avoid the delay in obtaining a measure of digestibility by the conventional procedure with animals, in vitro digestion techniques have been developed. These involve digestion of the ground feedstuff, in most cases a herbage, by incubation with fresh rumen liquor. In using in vitro methods it is essential to simulate conditions in the intact rumen as closely as possible. The in vitro digestibility coefficient is determined as the proportion of the feed brought into solution during incubation.

Nearly every laboratory reporting in vitro results employs a sightly different procedure, and a standard method has not evolved which is applicable to all conditions. In an in vitro study in which digestibilities of the dry matter and cellulose in forages were measured in 17 laboratories, Barnes (1967) reported that after 24 hours the mean values for cellulose digestibilities ranged from 40.0 to 63.9 percent, reflecting the use of different techniques in terms of sample size, preparation of the rumen inoculum, pH control, etc. Using identical procedures, Raymond (1969) reports a close agreement between in vitro results from two laboratories.

Initially investigations in in vitro methods were concerned with fibre digestibility and in particular with the digestibility of the cellulose fraction in forages but various other workers have used the techniques in determining digestibilities of dry matter, organic matter, energy and protein contents of forages (Miller, 1961 and Raymond, 1969).

Raymond (1969) reports that in most cases the extent of digestion in in vitro was found to be less than that in in vivo and regression equation were developed to allow prediction of in in vivo values. Tilley and Terry (1963) suggested that these discrepancies might be the result of correlating data from a single digestion with rumen microorganisms with those from digestion with the rumen followed by a mainly enzymatic digestion in the remainder of the digestive tract. Within the rumen, the digestible polysaccharides, carbohydrates and protein in the feed are broken down by the action of the microorganisms there. Some of the products of digestion are absorbed directly through the rumen wall, but a considerable part serves as the substrate for microbial growth, and is resynthesized into protein, polysaccharides and lipids within the proliferating bacterial and protozoal population. These microorganisms, entrained in the residues of undigested fibre and other feed components, then pass from the rumen to the abomasum and duodemim. In these organs the digesta are acidified and further digested by secreted enzymes that hydrolyze much of the bacterial and residual plant proteins to amino acids. These are then absorbed as the main source of amino acids for the metabolism of the host animals. This second stage digestion in the animal is not normally simulated in in vitro techniques, and Tilley and Terry (1963) therefore, proposed that it should be simulated by subjecting the residues from the in vitro bacterial digestion to a second enzymetic digestion. They examined several enzymes and concluded that a second digestion by acid-pepsin gave the closest agreement with in vivo digestibility values for the dry matter and organic matter contents of forages. This method showed a correlation of 0.97 between in vitro and in vivo values when tested on a wide range of forages including grasses fertilized with different levels of nitrogen, and legumes (Raymond, 1969).

It is reported by Raymond (1969) that low nitrogen in the test forage or in the diet of the donor animal gave low in vitro digestibility but that digestibility in in vivo was high as a result of the animals ability to recycle urea via salivary and ruminal secretions. Addition of 6 mg of N, as urea, to the in vitro systems increased sample digestibility to the in vivo level. Engels and Van der Merwe (1969) found that the difference between in vitro and in vivo digestibility values of veldt grasses became greater as the nitrogen content of the test forages decreased. Addition of 20 mg of urea N to each digestion tube gave in vitro values in close agreement with those in in vivo, but a marked depression in digestibility occured when 60 mg of urea N was included in the digestion system.

In his review of in vitro techniques, Raymond (1969) concluded that in vitro technique appears to give a better prediction of in vivo forage digestibility than any of the chemical methods yet investigated. Like in vivo techniques, in vitro technique is integrative and without additional chemical information it can only describe, rather than explain, the differences in digestibility observed among different forage samples.

2.4.4. Prediction from chemical composition

Another means for obtaining digestibility data without recourse to digestibility trials is the use of formulae equating digestibility or digestible constituents with proximate analyses of materials for which digestibility data exist. There have been varying reports on the accuracy of such methods. Raymond (1969) reported that when proximate analyses of Weende crude fibre, crude protein and nitrogen-free extractives are applied to a limited range of forage close relationships between digestibility and the chemical compositions can be established, but that these relationships become less precise as the range of forages included is increased. Schneider and Lucas (1950) showed that 25-45 percent of the total variability in the digestibility of differing samples of the same feed can be traced to one or more proximate constituents. Schneider, Lucas. Pavlech and Cipolloni (1951 and 1952) produced linear regression formulae which enabled the calculation of digestibility coefficient from proximate analyses.

French, Glover and Duthie (1957) and Glover, Duthie and French (1957) derived a curvilinear equation relating the digestibility of crude protein with percentage crude protein for a wide range of feeding-stuffs from different parts of the world. Dougall (1958) produced a similar relationship for the calculation of digestible crude protein from crude protein and crude fibre percentages.

Norman (1935) reported that crude fibre was inadequate as a determinant of nutritive value. Cellulose, holo-cellulose and modified acid detergent fibre were suggested respectively by Crampton and Maynard (1935); Ely and Moore (1955); and by Clancy and Wilson (1966). However, there are considerable difficulties in superseding the crude fibre determination because of the uncertainties of lignin and cellulose determination; and also because the lignin fractions of feed and faeces are not of the same composition (Miller, 1961). The assumption that the extent of fibre fraction digestibility is directly proportional to that fraction is not entirely correct; and it is reported by Raymond, (1969) that there was no decrease in the digestibility of the cellulose in S. 24 rye grass as the cellulose content increased from 14.1 to 19.0 percent of the dry matter. Gailliard (1962) also showed that the cellulose in lucern is much less digestible than that in grasses with the same content of cellulose.

Miller (1961) and Sullivan (1962) concluded that the relationships of fibre components and forage digestibility are more precise than those based on crude fibre but they are still inadequate for predictive purposes.

The conclusion drawn above led to the development of techniques of graded extraction of forage cellulose, of neutral-detergent fibre and of acid-detergent fibre as reviewed extensively by Raymond (1969). As yet prediction of digestibilities by these techniques is restricted to relatively few forages.

SECTION 3 In vivo digestion coefficients and nutritive value of some pasture grasses, fodders and some arable farm by-products.

3.1 Introduction.

It was pointed out earlier that a considerable amount of chemical analyses of grasses and other feedstuffs has been carried out in East Africa; but the main merits of such work are in assessing and eliminating certain dietary deficiencies. Information from such chemical composition does not enable scientific feeding practices to be adopted. It was also observed by Morrison (1969) that more animal production trials are needed to confirm the findings of some agronomic trials already conducted by other workers.

In an effort to fill some of this gap in our knowledge, trials on digestibility and nutritive value were conducted on some of the most commonly used pasture grasses, fodders and some arable farm by-products as reviewed in sections 2.1.1. and 2.1.2.

3.2 Experimental procedure.

Except for the D. uncinatum and I. batatas vines, in which only one stage of regrowth was used, all the pasture grasses tested were three to four stages of regrowth. Where possible representative fresh samples were taken for dry matter estimation. All the samples were fed in the form of hays except for I. batatas vines which were fed in the fresh green form.

All the herbage samples tested were cut with a chaff cutter to lengths of 3-10 cm. They were mixed well and stored for feeding. Three to four representative samples of the cut herbage were taken for proximate, energy and mineral analyses.

Four New Zealand Romney Marsh x Corriedale wethers of approximately the same age and liveweight ranging from 31-55 kg were used to test any one feedstuff. The wethers were from a clean farm in the Kenya Highlands. Routine anthelmintics prophylaxis was enforced. The wethers were kept and fed individually in metabolism cages, untied. The design of the cages except for slight modification, was as that described by Soneji (1970). Water was given *ad libitum*. A comprehensive salt mixture was provided in the feed. In each trial there was a pre-experimental period of 7-10 days, during which time the wethers received the test feed. No samples were collected during that period. Following that was the experimental period of 10 days during which time daily rations offered were weighed. Any left overs were collected 24 hours later, weighed and pooled over the 10 days and analysed for proximate, energy and mineral analyses. Total collections of faeces were done from each wether. They were weighed and representative 10 days samples consisting of 10 percent of each day's output were pooled in plastic bottles for each wether and stored under refrigeration for proximate analyses and energy determinations. Detailed procedure of all the chemical analyses performed on the samples is given in Appendix 1.

All the wethers were weighed between 8.00-9.00 hrs, before feeding, on the day they were put in the cages to start the pre-experimental period. The second weighing was done between 8.00-9.00 hrs brefore feeding, on the last day of the experimental period.

Digestion coefficients were calculated as:

$$\left(\frac{\text{Nutrient ingested} - \text{Nutrient excreted}}{\text{Nutrient ingested}}\right) \times 100$$

Starch equivalent values were calculated using Kellner's net energy values for the various digestible nutrients and by using a correction factor of minus 0.58 SE per 1 percent crude fibre as quoted by McDonald, Edwards and Greenhalgh (1966). Calculated standard errors are presented in the tables as S.e.

3.3 Results.

3.3.1. P. clandestinum (Kikuyu grass).

Four regrowth stages of P. clandestinum were cropped from a farm in Limuru, Kenya; a site within the natural habitat of P. clandestinum. A plot carrying almost a pure stand of the grass and some indigenous white clover (Trifolium johnstoni) was fenced off. All the herbage was mowed down to 8-15 cm. Thereafter three regrowths were cropped from measured sub-plots at 5, 8 and 11 weeks. The herbage cropped originally from the plot before the regrowth was estimated as a 15 weeks regrowth post grazing. It represented typical regrowth of the pasture after the long rains. Total rainfall recorded was 203.5 mm in 19 days, 34.5 mm in 6 days and 10.2 mm in 5 days for the 5 weeks regrowth, 8 weeks regrowth and 11 weeks regrowth respectively.

3.3.1.1. Chemical composition.

Table 5 shows that the percentage moisture of P. clandestinum from 5-11 weeks remained quite high, 87.1 to 81.8 percent. Hence dry matter increased from 12.9 percent to 18.2 percent over the same period of 6 weeks. In the dry matter crude protein decreased from 23.7 percent to 14.8 percent in just 6 weeks, whereas crude fibre and nitrogen-free extract increased by about 4 units and by 7.5 units respectively over the same period of 6 weeks. After 8 weeks ether extract and gross energy tended to decrease with maturity.

Table 5. Chemical composition of four regrowths of P. clandestinum

Stage of regrowth	Percent moisture	Percent dry matter					Gross energy Kcal/g DM
		Crude protein	Ether extract	Crude fibre	Ash	N-free extract	
5 weeks regrowth	87.1	23.7	3.4	26.2	13.0	33.7	4.296
8 " "	83.9	19.1	4.2	29.1	12.4	35.3	4.321
11 " "	81.8	14.8	2.6	30.1	10.8	41.2	4.187
15 " "	-	13.7	1.9	32.2	13.4	38.8	4.088

Calcium and magnesium levels (table 6) were almost the same throughout the four stages of regrowth. Phosphorus levels, which all together appeared high, decreased substantially with maturity; whereas sodium levels were consistently low in all stages. Potassium showed fluctuations within the four regrowth stages but levels were high and approximate those reported for other grasses at about the same time of the year (Howard, Burdin and Lampkin, 1962).

Table 6. Mineral content of four regrowths of P. clandestinum.

Stage of regrowth	Percent dry matter				
	Ca	P	Mg	K	Na
5 weeks regrowth	0.47	0.41	0.26	4.39	0.001
8 " "	0.44	0.37	0.25	3.18	0.007
11 " "	0.46	0.34	0.24	4.38	0.012
15 " "	0.47	0.30	0.25	3.98	0.009

3.3.1.2. Level of intake.

Daily rations of hay ranged from 0.8 - 1.0 kg per wether throughout the four experiments. With the exception of the 15 weeks regrowth all hays offered were taken with relish. Mean dry matter intakes for 5, 8, 11 and 15 weeks regrowth were respectively 0.74, 0.93, 0.90 and 0.61 kg per 16.2, 16.6, 17.0 and 16.9 kg mean metabolic liveweight ($w^{0.75}$). Although mean dry matter intake at 5 weeks was 0.74 kg. it was apparent that the wethers would have taken more if offered but due to shortage of feed at that stage that was not possible.

3.3.1.3. Digestion coefficients.

Apparent mean digestion coefficients are listed in table 7. Digestibility of all nutrients decreased substantially and consistently with increasing age. From 5 weeks to 15 weeks regrowth stage digestion coefficients fell by the following number of units: dry matter 17.3, organic matter 15.9, crude protein 19.9, ether extract 32.3, crude fibre 12.5 and nitrogen-free extract 14.9.

Table 7. Apparent mean digestion coefficients of four regrowths of P. clandestinum.

Stage of regrowth	Dry matter	Organic matter	Crude protein	Ether extract	Crude fibre	N-free extract	Gross energy
5 weeks	71.9	72.6	78.2	68.8	74.2	67.9	69.1
S.e.	±0.63	±0.70	±0.63	±0.68	±0.25	±1.53	±0.66
8 weeks	67.1	67.0	67.9	68.6	69.3	64.3	63.7
S.e.	±0.82	±0.89	±0.72	±1.33	±0.79	±1.18	±1.31
11 weeks	62.6	63.3	62.2	54.7	64.5	63.5	58.4
S.e.	±0.37	±0.35	±0.72	±0.83	±0.85	±0.42	±0.70
15 weeks	54.6	56.7	58.3	36.5	61.7	53.0	54.1
S.e.	±0.46	±0.68	±0.77	±1.45	±0.60	±1.40	±1.19

3.3.1.4. Digestible crude protein, digestible energy and starch equivalent value.

In table 8 both DCP, DE and SE values decreased substantially and consistently with maturity. Within 6 weeks regrowth from 5-11 weeks DCP decreased by 50 percent and SE decreased by 21 percent.

Table 8. Digestible crude protein (DCP) digestible energy (DE) and starch equivalent (SE) values of four regrowths of P. clandestinum.

Stage of regrowth	DCP percent DM	DE Kcal/g DM	SE g/g DM
5 weeks	18.5	2.969	0.502
8 "	12.9	2.750	0.434
11 "	9.2	2.444	0.396
15 "	7.9	2.212	0.306

3.3.1.5. Effect on liveweight.

Table 9 shows mean liveweight changes by each wether in a group of four wethers as they are affected by stage of regrowth and by the resultant available DCP, DE and SE from ingested hays.

There were respective mean liveweight gains of 111.8 g, 44.4 g and 25.0 g/wether/day by 5, 8 and 11 weeks regrowth hay samples and a loss of 55.0 g/wether/day by the 15 weeks regrowth hay.

Table 9. Mean liveweight changes from the four regrowth stages of P. clandestinum.

Stage of regrowth	DM intake g/kg $w^{0.75}$	DCP ingested g/kg $w^{0.75}$	DE ingested Kcal/kg $w^{0.75}$	SE ingested g/kg $w^{0.75}$	Days in cage	Mean Lwt change g/wether/day
5 weeks	45.7*	8.5	135.7	22.9	17	+ 111.8
8 "	56.0	7.2	154.0	24.3	18	+ 44.4
11 "	52.9	4.9	129.3	20.9	20	+ 25.0
15 "	36.1	2.9	79.9	11.0	20	- 55.0

* Hay was not fed ad libitum due to shortage of the sample.

3.3.2. Chloris gayana (Rhodes grass).

Altogether four batches of C. gayana were studied. The first batch was ecotype Mbarara which consisted of the three regrowth stages at 10 weeks, 14 weeks and 18 weeks. This batch was cropped from Muguga, Kenya; altitude 2096 m. Rainfall for the three regrowths was respectively 235.3 mm in 28 days, 14.4 mm in 4 days and 15.9 mm in 4 days. The ley was in its 3rd year and had previously been under C. dactylon.

The second batch of C. gayana, also ecotype Mbarara, was cropped from the National Agricultural Research Station Kitale, Rift Valley, Kenya at an altitude of 1896 m. It consisted of three regrowth stages at 6 weeks, 8 weeks and 10 weeks. Rainfall for the three regrowths was 167.5 mm in 6 days, 14.8 mm in 3 days and 21.3 mm in 8 days. The ley was in its 3rd year.

The third batch of C. gayana, ecotype Pokot, also from the National Agricultural Research Station Kitale consisted of three regrowths at 6 weeks, 9 weeks and 12 weeks. Rainfall for the three regrowths was respectively 32.2 mm in 7 days, 30.7 mm in 14 days and 70.1 mm in 15 days. The ley was 2 years old.

The fourth batch was C. gayana, ecotype, Mbarara, from Dundori Rift Valley, Kenya, altitude 1873 m. There were four samples within this fourth batch. Sample 1 consisted of C. gayana, ecotype Mbarara and a high proportion of Kenya wild white clover (Trifolium johnstoni). The ley was in its

5th year having been undersown to wheat. The pasture was in its early flowering stage when cut. Sample 2 was from the same field as 1 above but was cut 3 months later when the seeds were already shed. Sample 3 consisted of about 50 percent C. gayana, ecotype Mbarara, about 25 percent S. sphacelata, Nandi cultivar, and about 25 percent of Palisade grass (Brachiaria brizantha) and Paspalum grass (unidentified). The ley was in its first year and the sample was cut at early flowering when it was 4 months old. Sample 4 consisted of about 60 percent C. gayana ecotype Mbarara, about 5 percent Nandi cultivar, 1 percent Kenya Wild white clover and about 34 percent Crow foot grass (Dactyloctenium aegyptium). The ley was in its first year and the sample was cut at early flowering when it was 4 months old. Fourth batch hays were not tested in the sequence in which they appear in the table. Rainfall data for the fourth batch was not available.

3.3.2.1. Chemical composition.

Table 10 gives the chemical composition of the four batches of C. gayana used in the experiments. Within each batch crude protein decreased with age whereas crude fibre, except for a few minor cases, increased with maturity. It is not easy to compare the chemical composition of the four batches since they were growing in different climatic areas under different managerial treatments. The fourth batch was under very good management and it is significant that sample 1 in this batch, although cropped from a ley in

Table 10. Chemical composition of the four batches of C. gayana at various stages of regrowth.

Type of pasture and stage of regrowth	% D.M. in hay	Per cent dry matter					Gross energy Kcal/g DM
		Crude protein	Ether extract	Crude fibre	Ash	N-free extract	
First batch (Muguga)							
C. gayana c.v. Mbarara							
8 weeks early flowering	93.2	6.9	3.6	39.4	10.0	40.1	4.038
12 " full flowering	91.0	6.4	2.3	38.9	9.7	42.7	4.197
16 " many seeding	92.5	5.8	2.4	43.2	9.6	39.0	4.084
Second batch (Kitale)							
C. gayana c.v. Mbarara							
6 weeks	91.2	12.7	2.8	41.0	8.1	34.8	4.242
8 "	91.8	8.7	2.2	37.8	10.3	41.0	4.399
10 "	90.5	8.5	1.9	41.3	8.3	40.0	4.054
Third batch (Kitale)							
C. gayana c.v. Pokot							
6 weeks	90.1	7.7	2.0	42.7	9.7	37.9	4.065
9 "	89.1	6.6	1.8	41.8	9.7	39.9	4.054
12 "	91.5	5.1	2.3	47.9	9.5	35.2	4.026
Fourth batch (Dundori)							
C. gayana c.v. Mbarara							
Sample 1. early flowering	92.0	12.4	4.3	34.2	10.9	38.2	4.190
Sample 2. Seeds shed	92.8	4.2	2.1	39.1	10.2	44.4	3.969
Sample 3. Early flowering (16 wks)	91.8	8.9	2.2	37.9	10.9	40.1	3.955
Sample 4. Early flowering (16 wks)	91.3	14.1	4.7	33.9	11.1	36.0	4.013

Table 11. Mineral content of the four batches of *C. gayana* at various stages of regrowth.

Type of pasture and stage of regrowth	Per cent dry matter				
	Ca	P	Mg	K	Na
First batch (Muguga)					
C. gayana c.v. Mbarara					
8 weeks early flowering	0.46	0.19	0.13	1.87	0.004
12 " full flowering	0.48	0.20	0.12	1.99	0.004
16 " some seeding	0.45	0.14	0.10	1.92	0.004
Second batch (Kitale)					
C. gayana c.v. Mbarara					
6 weeks	0.56	0.25	0.17	2.65	0.030
8 "	0.55	0.23	0.16	2.85	0.031
10 "	0.55	0.16	0.16	2.55	0.027
Third batch (Kitale)					
C. gayana c.v. Pokot					
6 weeks	0.34	0.29	0.15	2.30	0.001
9 "	0.32	0.21	0.16	2.00	0.001
12 "	0.24	0.19	0.14	2.44	0.001
Fourth batch (Dundori)					
C. gayana c.v. Mbarara					
Sample 1. Early flowering	0.41	0.25	0.18	3.46	0.004
Sample 2. Seeds shed	0.53	0.18	0.15	3.22	0.003
Sample 3. Early flowering (16 wks)	0.42	0.26	0.20	3.25	0.005
Sample 4. Early flowering (16 ")	0.44	0.27	0.24	4.26	0.007

its 5th year of life, was still high in its crude protein content.

Phosphorus shows a decline with maturity (table 11). Sodium levels were constistently low for all stages and in all the batches except the second batch (C. gayana c.v. Mbarara).

3.3.2.2. Levels of intake.

For the first batch daily mean intakes of hays for 8, 12 and 16 weeks regrowths were respectively 0.97 kg, 0.98 kg and 0.92 kg giving a mean daily dry matter intake of 0.90, 0.89 and 0.85 kg per 16.4, 16.6 and 17.0 kg mean $w^{0.75}$.

For the second batch daily mean intakes of hays were 1.0, 0.99 and 0.95 kg for the 6, 8 and 10 weeks regrowths. Mean daily dry matter intakes were therefore respectively 0.91, 0.91 and 0.86 kg per 17.5, 18.2 and 18.1 kg mean $w^{0.75}$.

Daily mean intakes of hays for the third batch at 6, 9 and 12 weeks regrowth were 0.96, 0.94 and 0.88 kg. Mean daily dry matter intakes were therefore respectively 0.86, 0.84 and 0.77 kg per 17.4, 17.6 and 17.1 kg mean $w^{0.75}$.

Daily mean intake of hays for the fourth batch were 0.72, 0.65, 0.76 and 0.80 kg for samples, 1, 2, 3 and 4. Mean daily dry matter intakes were therefore respectively 0.66, 0.60, 0.70 and 0.73 kg per 13.3, 14.2, 15.4 and 13.6 kg mean $w^{0.75}$. Mean dry matter intakes in g kg $w^{0.75}$ are given in table 14.

3.3.2.3. Digestion coefficients.

Apparent mean digestion coefficients given in

Table 12. Apparent mean digestion coefficients of the four batches of C. gayana.

Type of pasture and stage of	Dry matter	Organic matter	Crude protein	Ether extract	Crude Fibre	N-free extract	Gross energy
First batch (Muguga)							
C. gayana c.v. Mbarara							
8 weeks	60.9	64.2	62.2	72.3	67.3	60.7	61.9
S.e.	±1.05	±0.80	±0.90	±1.13	±1.26	±1.09	±1.37
12 weeks	54.6	57.8	50.9	52.5	60.3	57.0	56.9
S.e.	±0.74	±0.64	±1.41	±2.50	±1.09	±0.81	±0.54
16 weeks	45.9	48.5	34.2	51.0	52.8	42.9	42.9
S.e.	±1.49	±1.33	±1.09	±2.58	±0.79	±0.84	±1.21
Second batch (Kitale)							
C. gayana c.v. Mbarara							
6 weeks	56.4	57.4	56.6	58.8	69.4	43.3	52.1
S.e.	±0.76	±0.73	±1.00	±1.03	±1.80	±1.16	±0.59
8 weeks	55.9	55.8	49.9	38.5	63.7	51.4	53.7
S.e.	±0.76	±0.81	±1.04	±3.23	±1.29	±0.88	±0.72
10 weeks	58.0	58.5	56.3	45.7	64.6	53.9	52.7
S.e.	±0.47	±0.36	±0.93	±1.98	±0.69	±0.60	±0.62
Third batch (Kitale)							
C. gayana c.v. Pokot							
6 weeks	58.4	60.1	53.9	47.5	69.3	53.4	59.1
S.e.	±0.62	±0.69	±0.70	±0.64	±1.05	±0.63	±0.50
9 weeks	62.2	64.3	55.5	51.1	69.4	60.4	56.7
S.e.	±0.55	±0.65	±0.92	±2.35	±0.58	±0.44	±0.63
12 weeks	52.1	54.8	37.7	47.9	62.8	47.6	42.7
S.e.	±0.42	±0.51	±1.16	±1.20	±1.16	±1.89	±1.40
Fourth batch (Dundori)							
C. gayana c.v. Mbarara							
Sample 1. early flowering	62.1	64.9	75.0	72.3	68.2	61.3	57.8
S.e.	±1.29	±1.12	±1.73	±1.40	±1.51	±1.92	±0.57
Sample 2. seed shed	60.8	64.5	50.5	66.5	67.9	64.8	40.6
S.e.	±0.85	±0.90	±0.72	±1.60	±0.79	±1.91	±0.45
Sample 3. early flowering (16 wks.)	63.3	65.0	62.4	36.9	66.4	66.0	53.2
S.e.	±1.39	±1.47	±1.59	±4.11	±1.88	±1.30	±0.47
Sample 4. early flowering (16 wks.)	70.9	72.8	73.2	78.8	76.7	68.3	63.8
S.e.	±1.12	±0.92	±1.41	±2.87	±1.06	±1.90	±0.61

table 12 show that for first batch C. gayana c.v. Mbarara its crude protein digestibility fell from 62.2 to 34.2 percent over 8 weeks regrowth i.e. a fall of 45 percent. Over the 6 weeks regrowth digestion coefficient of crude protein of third batch C. gayana c.v. Pokot fell by 30 percent. Crude protein digestion coefficients in samples 1 and 2 (fourth batch) fell from 75.0 at early flowering to 50.5 three months later when seeds were shed, a fall of 32.6 percent.

Crude fibre digestibility showed a tendency to decrease with maturity but in all the four batches the digestibility of crude fibre was higher than that of the nitrogen-free extractives.

3.3.2.4. Digestible crude protein, digestible energy and starch equivalent value.

DCP and DE in table 13 decreased with maturity in all the four batches. DE was higher in sample four than in sample 3 even though all the two samples were at the same stage of regrowth. SE values in the first, third and fourth batches decreased with maturity. In the second batch SE value decreased by 2.7 percent from 6 to 8 weeks regrowth but in another two weeks regrowth, from 8 to 10 weeks, SE value increased by 5.5 percent.

Table 13. DCP, DE and SE of each of the four batches of C. gayana.

Type of pasture and stage of regrowth	DCP per cent DM	DE Kcal/g DM	SE g/g DM
First batch (Muguga)			
C. gayana c.v. Mbarara			
8 weeks	4.3	2.498	0.368
12 "	3.3	2.386	0.306
16 "	2.0	1.780	0.186
Second batch (Kitale)			
C. gayana c.v. Mbarara			
6 weeks	7.2	2.208	0.297
8 "	4.3	2.360	0.289
10 "	4.8	2.136	0.305
Third batch (Kitale)			
C. gayana c.v. Pokot			
6 weeks	4.2	2.402	0.306
9 "	3.7	2.300	0.341
12 "	1.9	1.719	0.230
Fourth batch (Dundori)			
C. gayana c.v. Mbarara			
Sample 1. early flowering	9.3	2.423	0.408
Sample 2. seeds shed	2.1	1.610	0.371
Sample 3. early flowering (16 wks)	5.6	2.102	0.366
Sample 4. " " (16 ")	10.3	2.560	0.478

3.3.2.5. Effect on liveweight.

Table 14 shows daily mean liveweight changes by each wether in a group of 4 wethers as they were affected by regrowth stages of the four batches of C. gayana and also by the resultant available DCP, DE and SE from the ingested hays.

There was a general trend for the liveweights to increase as the levels of DE and SE intakes increased but their relationships were not proportional in all the cases.

Table 14. Mean liveweight changes by wether sheep feeding on the four batches of C. gayana and by the resultant available DCP, DE and SE.

Type of pasture and stage of regrowth	DM intake g/kg $w^{0.75}$	DCP ingested g/kg $w^{0.75}$	DE ingested Kcal/kg$w^{0.75}$	SE ingested g/kg $w^{0.75}$	Days in cage	Mean Lw: change g/wether/day
First batch (Muguga) C. gayana c.v. Mbarara						
8 weeks	54.9	2.4	137.1	20.2	20	+ 41.5
12 "	53.6	1.8	127.9	16.4	20	+ 35.0
16 "	50.0	1.0	89.0	9.3	20	-105.0
Second batch (Kitale) C. gayana c.v. Mbarara						
6 weeks	52.0	3.7	114.8	15.4	17	+ 82.4
8 "	50.0	2.2	118.0	14.5	17	+ 79.4
10 "	47.5	2.3	101.5	14.5	17	+ 51.8
Third batch (Kitale) C. gayana c.v. Pokot						
6 weeks	49.4	2.1	118.7	15.1	20	+ 70.0
9 "	47.7	1.8	109.7	16.3	20	+ 81.5
12 "	45.0	0.9	77.4	10.4	20	+ 36.5
Fourth batch (Dundori) C. gayana c.v. Mbarara						
Sample 1. early flowering	49.6	4.6	120.2	20.2	17	+ 76.5
Sample 2. seeds shed	42.3	0.9	68.1	15.7	19	- 1.3
Sample 3. early flowering (16 wks)	45.5	2.5	95.6	16.7	19	+ 60.5
Sample 4. early flowering (16 wks)	53.7	5.5	137.5	25.7	19	+102.6

3.3.3. Cynodon dactylon (Star grass).

The grass was cropped from Muguga, Kenya; altitude 2096 m. Three regrowths at 10 weeks, 14 weeks and 18 weeks were cropped. Rainfall recorded for the three regrowths was respectively 256.6 mm in 32 days, 14.4 mm in 4 days and 15.9 mm in 4 days. The ley had been under permanent C. dactylon pasture for 15 years. No fertilizers had been applied except for the manurial effect of the dung and urine from the grazing cattle.

3.3.3.1. Chemical composition.

Table 15 shows that the percentage moisture of C. dactylon regrowth at 10 weeks was 71.0 percent but increased to 88.0 percent 4 weeks later. In another 4 weeks, at 18 weeks regrowth the percentage moisture went down to 55.0 percent giving a dry matter percentage of 45.0.

Crude protein, ranging from 10.2 to 9.1 percent, decreased steadily with maturity. Crude fibre showed a very insignificant variation after a regrowth period of 4 weeks, from 10 to 14 weeks regrowth, but actually decreased by 3.7 units after a regrowth period of 8 weeks, from 10 to 18 weeks. Nitrogen-free extract increased by 2.8 units after a regrowth period of 8 weeks.

Mineral content of the three regrowths of C. dactylon is given in table 16. Calcium ranged from 0.58 to 0.33 percent. It was lowest at 14 weeks regrowth. Phosphorus and Magnesium were highest at 10 weeks regrowth, 0.44 and 0.16 percent respectively. Sodium levels were consistently low in all the three regrowth stages.

Table 15. Chemical composition of three regrowths of C. dactylon.

Stage of regrowth	Moisture percentage in fresh grass	Per cent dry matter					gross energy Kcal/g DM
		Crude protein	Ether extract	Crude fibre	Ash	N-free extract	
10 weeks	71.0	10.2	2.1	37.8	8.7	41.5	4314
14 "	88.0	9.5	2.0	37.4	10.6	40.4	4019
18 "	55.0	9.1	2.6	34.7	9.5	44.3	4077

Table 16. Mineral content of three regrowths of C. dactylon.

Stage of regrowth	Percent dry matter				
	Ca	P	Mg	K	Na
10 weeks	0.44	0.44	0.16	2.22	0.005
14 "	0.33	0.36	0.17	2.10	0.o13
18 "	0.58	0.41	0.41	2.33	0.008

3.3.3.2. Level of intake.

As a result of shortage of hay samples only 0.8 - 0.9 kg hay was offered per wether and no left overs were recorded in any of the three experiments. Dry matter intake at 10 weeks regrowth was 0.57 kg per 16.4 kg mean $w^{0.75}$. At 14 and 18 weeks regrowth mean daily dry matter intakes were respectively 0.8 and 0.5 kg per 16.6 and 17.0 kg mean $w^{0.75}$. It was apparent in these three experiments that the hays were very palatable and all the wethers would probably have taken more than the quantities offered. Mean dry matter intakes in g/kg $w^{0.75}$/day are given in table 19.

3.3.3.3. Digestion coefficients.

Table 17 shows apparent mean digestion coefficients of the three regrowths of C. dactylon. Crude protein digestibility fell from 66.0 percent at 10 weeks regrowth to 53.7 percent after 4 weeks regrowth. From 14 weeks to 18 weeks regrowth digestion coefficient was almost constant increasing by only 0.3 percent. Crude fibre digestibility was constant within 4 weeks regrowth but decreased by 5 units in 8 weeks (from 10 weeks to 18 weeks regrowth). Nitrogen-free extract fell within the first 4 weeks regrowth but increased again from 14 weeks to 18 weeks regrowth.

Table 17. Apparent mean digestion coefficients of three regrowths of C. dactylon.

Stage of regrowth	Dry matter	Organic matter	Crude protein	Ether extract	Crude fibre	N-free extract	Gross energy
10 weeks	55.1	58.2	66.0	37.4	63.7	55.5	55.6
S.e.	±3.68	±3.40	±3.67	±3.20	±3.20	±3.92	±3.10
14 weeks	51.4	54.2	53.7	48.9	63.7	45.6	49.4
S.e.	±0.92	±0.79	±1.15	±2.08	±0.76	±0.89	±1.58
18 weeks	51.1	54.2	54.0	55.9	58.7	50.6	48.9
S.e.	±0.45	±0.43	±0.76	±1.66	±0.69	±0.51	±0.48

3.3.3.4. Digestible crude protein, digestible energy and starch equivalent value.

Table 18 shows that DCP consistently decreased with maturity. DE and SE also decreased with maturity from

10 weeks to 14 weeks regrowth. From 14 to 18 weeks regrowth DE increased insignificantly by only 0.6 percent whereas SE increased by 9 percent.

Table 18. DCP, DE and SE of three regrowths of C. dactylon.

Stage of regrowth	DCP Percent DM	DE Kcal/g DM	SE g/g DM
10 weeks	6.3	2.396	0.329
14 "	4.6	1.983	0.272
18 "	4.4	1.995	0.299

3.3.3.5. Effect on liveweight.

Table 19 shows mean liveweight changes by each wether in a group of four wethers ingesting C. dactylon hay at the three stages of regrowth indicated. Available DCP, DE and SE from the ingested amounts of dry matter are also indicated. There was a mean gain in liveweight of only 5.0 grams per day per wether on 10 weeks regrowth. When intake of hay was 0.9 kg per wether per day of the 14 weeks regrowth, the animals gained a mean daily weight of 95 grams. At 18 weeks regrowth on the same level of intake as in 14 weeks regrowth the animals lost weight by 20.0 grams per wether per day. Such levels of liveweight gains and a loss by the 18 weeks regrowth are probably more a reflection of lower dry matter intake levels than the quality of the hays fed.

Table 19. Daily mean liveweight changes by wether sheep feeding on the three regrowth stages of C. dactylon.

Stage of regrowth	DM intake g/kg $w^{0.75}$	DCP ingested g/kg $w^{0.75}$	DE ingested Kcal/kg $w^{0.75}$	SE ingested g/kg $w^{0.75}$	Days in cages	Mean lwt change g/wether/day
10 weeks	34.8*	2.2	83.4	11.4	19	+ 5.0
14 "	48.2*	2.2	95.6	13.1	20	+ 95.0
18 "	29.4*	1.3	58.7	8.8	20	- 20.0

* Hays were not offered ad libitum due to shortage of samples.

3.3.4. Setaria sphacelata (Nandi cultivar).

Three stages of regrowths of S. sphacelata were cropped from a ley three years old growing at the National Agricultural Research Station Kitale. Phosphate had been applied at a very young stage (date not available). The three regrowths, regrowing from the mowed pasture, were at 4 weeks, young and leafy; at 6 weeks, just after flowering and at 8 weeks, full flowers. Rainfall recorded was 98.9 mm in 17 days for the 4 weeks regrowth, 81.8 mm in 12 days for the 6 weeks regrowth and 28.8 mm in 8 days for the 8 weeks regrowth.

3.3.4.1. Chemical composition.

At 4 weeks regrowth crude protein was 12.2 percent but dropped to 9.1 percent. From 6 weeks to 8 weeks crude protein fell to 6.6 percent. Ether extract decreased by 32.0 percent from 4 to 6 weeks regrowth but increased by 17.6 percent from 6 weeks regrowth to 8 weeks regrowth. Crude fibre increased by 29.8 percent from 4 to 6 weeks regrowth but decreased by 4.0 percent from 6 to 8 weeks regrowth. Nitrogen-free extract at 39.2 percent at 4 weeks regrowth dropped down to 34.8 percent at 6 weeks regrowth, and remained almost steady after 2 weeks regrowth at 8 weeks.

Table 20. Chemical composition of three regrowths of S. sphacelata (Nandi cultivar).

Stage of regrowth	% D.M. in hay	Percent dry matter					Gross energy Kcal/g DM
		Crude protein	Ether extract	Crude fibre	Ash	N-free extract	
4 weeks	87.0	12.2	2.5	32.5	11.5	39.2	4.180
6 "	91.1	9.1	1.7	42.2	12.2	34.8	4.013
8 "	95.5	6.6	2.0	40.5	16.0	34.4	3.990

In both the three regrowths phosphorus levels were low and tended to decrease with maturity. Sodium was also low.

Table 21. Mineral content of the three regrowths of S. sphacelata (Nandi cultivar).

Stage of regrowth	Percent dry matter				
	Ca	P	Mg	K	Na
4 weeks	0.22	0.19	0.17	3.58	0.005
6 "	0.25	0.15	0.15	3.40	0.003
8 "	0.24	0.13	0.15	3.34	0.003

3.3.4.2. Level of intake.

In all the three experiments conducted levels of hays offered were 1.2 kg per wether per day. Between 1.0 and 0.9 kg of the 4 weeks regrowth hay were ingested. Only between 0.8 and 0.9 kg of the 6 weeks regrowth hay and 0.5 and 0.6 kg of the 8 weeks regrowth hay were ingested. Mean daily dry matter intake for the 4 weeks regrowth was 0.83 kg per 18.2 kg mean $w^{0.75}$. For the 6 and 8 weeks regrowths mean daily dry matter intakes were respectively 0.78 kg and 0.53 kg per 18.1 and 17.3 kg mean $w^{0.75}$. Mean dry matter intakes in g/kg $w^{0.75}$/day are given in table 24.

3.3.4.3. Digestion coefficients.

Table 22 shows that apparent mean digestion coefficients of crude protein decreased by 12.9 percent from 4 to 6 weeks regrowth. From 6 to 8 weeks regrowth digestibility of crude protein remained the same at 43.9 percent. Crude fibre and nitrogen-free extract were less digestible by 4.3 and 4.1 units, a decrease of 6.3 and 7.7 percent respectively, after two weeks regrowth from 4 to 6 weeks regrowth. From 6 to 8 weeks, another two weeks regrowth, crude fibre digestibility decreased 15.4 percent, but that of nitrogen-free extract decreased by only 7.9 percent over the same period of regrowth.

Table 22. Apparent mean digestion coefficients of three regrowths of S. sphacelata (Nandi cultivar).

Stage of regrowth	Dry matter	Organic matter	Crude protein	Ether extract	Crude fibre	N-free extract	Gross energy
4 weeks	65.0	62.4	60.4	52.0	68.5	53.2	59.7
S.e.	±0.70	±1.13	±1.09	±2.63	±0.64	±0.49	±0.95
6 weeks	54.5	54.6	43.9	34.7	64.3	49.1	56.0
S.e.	±0.72	±0.71	±1.04	±2.66	±0.52	±0.44	±0.53
8 weeks	54.9	57.6	43.9	52.1	54.4	45.2	53.5
S.e.	±0.77	±2.01	±2.98	±2.79	±0.71	±1.81	±0.65

3.3.4.4. Digestible crude protein, and starch equivalent value.

Table 23 shows the values of DCP, DE and SE in the three regrowths of S. sphacelata (Nandi cultivar). Both the values decreased consistently with maturity.

Table 23. DCP, DE and SE of three regrowths of S. sphacelata (Nandi cultivar).

Stage of regrowth	DCP percent DM	DE Kcal/g DM	SE g/g DM
4 weeks	7.4	2.497	0.337
6 "	4.0	2.247	0.246
8 "	2.8	2.135	0.181

3.3.4.5. Effect on liveweight.

Table 24 shows mean liveweight changes by each wether in a group of four wethers as they are affected by stage of regrowth of the grass and by the resultant available

DCP, DE and SE in the ingested hays. On 4 and 6 weeks regrowth mean liveweight gains per wether per day were 88.0 grams and 59.0 grams respectively. There was a mean daily loss of 94.0 grams liveweight for the 8 weeks regrowth.

Table 24. Mean daily liveweight changes by wether sheep feeding on three regrowths of S. sphacelata (Nandi cultivar).

Stage of regrowth	DM intake g/kg $w^{0.75}$	DCP ingested g/kg $w^{0.75}$	DE ingested Kcal/kg $w^{0.75}$	SE ingested g/kg $w^{0.75}$	Days in cages	Mean lwt change g/wether/day
4 weeks	45.6	3.4	113.9	15.4	17	+ 88.0
6 "	43.1	1.7	96.8	10.6	17	+ 59.0
8 "	30.6	0.9	65.3	5.5	17	- 94.0

3.3.5. Pennisetum purpureum (c.v. French Cameroons).

Three regrowth stages of P. purpureum (c.v. French Cameroons) were cropped from the National Agricultural Research Station Kitale, Kenya. The grass had been established five years back. The three regrowths were cropped at 3, 5 and 7 weeks. Rainfall recorded was 165.7 mm in 6 days, 14.8 mm in 3 days and 21.1 mm in 7 days for the 3, 5 and 7 weeks regrowths respectively.

3.3.5.1. Chemical composition.

Table 25 shows that percentage crude protein of 16.6 at 3 weeks dropped to Lo.1 at 5 weeks regrowth, a percentage fall of 39.2 percent in the two weeks regrowth. At 7 weeks regrowth crude protein dropped to 7.1 percent, a percentage fall of 29.7 percent. Crude fibre of 37.0 percent at 3 weeks regrowth increased by 11.6 and 7.3 percent at 5 weeks and 7 weeks regrowths respectively. Nitrogen-free extract increased from 29.7 percent at 3 weeks regrowth to 33.4 and 34.0 percent at 5 and 7 weeks regrowths respectively giving percentage increases of 12.5 and 1.8.

Table 25. Chemical composition of three regrowths of P. purpureum (c.v. French Cameroons).

Stage of regrowth	Percent dry matter: % DM in hay	Crude protein	Ether extract	Crude fibre	Ash	N-free extract	Gross energy Kcal/g DM
3 weeks	88.9	16.6	2.2	37.0	14.5	29.7	3.912
5 "	89.2	10.1	1.5	41.3	13.8	33.4	3.923
7 "	91.6	7.1	1.6	44.3	13.0	34.0	3.880

Mineral content in table 26 shows that calcium was lower than in the other grasses studied and showed a tendency to decrease with maturity. Phosphorus ranged from 0.25 to 0.21 percent dry matter. Sodium was consistently low in all the regrowths.

Table 26. Mineral content of three regrowth stages of P. purpureum (c.v. French Cameroons).

Stage of regrowth	Percent dry matter: Ca	P	Mg	K	Na
3 weeks	0.27	0.25	0.19	4.50	0.002
5 "	0.23	0.21	0.22	4.82	0.003
7 "	0.20	0.21	0.20	3.50	0.002

3.3.5.2. Level of intake.

Hays offered ranged from 0.7 to 0.8 kg per wether per day. Left overs were recorded from all the regrowths by all the wethers. Mean daily dry matter intakes for the 3, 5 and 7 weeks regrowths were respectively 0.7 kg, 0.6 kg and 0.7 kg per 17.6, 18.0 and 17.3 kg mean $w^{0.75}$. Intakes in g/kg $w^{0.75}$/wether/day are given in table 29.

3.3.5.3. Digestion coefficients.

Table 27 shows apparent mean digestion coefficients of the nutrients indicated. Only three wethers were used for the 3 weeks regrowth as the fourth wether was not feeding well. Crude protein of the 3 weeks regrowth was highly digestible at 73.2 percent; falling to 69.9 and 43.8 percent at 5 and 7 weeks regrowths. From 3 to 5 weeks regrowth crude fibre digestibility was almost the same but decreased slightly to 76.9 percent at 7 weeks regrowth. Digestibility of nitrogen-free extract, at 61.8 percent increased to 75.9 percent at 5 weeks but decreased to 58.1 percent at 7 weeks regrowth. As in all other grasses studied, crude fibre was more digestible than the nitrogen-free extract in all the three regrowths. Gross energy, like dry matter, was most digestible in the 5 weeks regrowth.

Table 27. Apparent mean digestion coefficients of three regrowths of P. purpureum (c.v. French Cameroons).

Stage of regrowth	Dry matter	Organic matter	Crude protein	Ether extract	Crude fibre	N-free extract	Gross energy
3 weeks	70.0	71.1	73.2	48.2	79.0	61.8	67.6
S.e.	±0.78	±0.82	±0.61	±5.14	±0.63	±1.34	±1.13
5 weeks	76.0	77.1	69.9	70.4	80.2	75.9	73.7
S.e.	±3.57	±3.36	±4.67	±5.03	±3.45	±4.67	±3.86
7 weeks	66.1	66.6	43.8	58.5	76.9	58.1	62.3
S.e.	±0.32	±0.38	±0.99	±2.03	±0.87	±0.98	±0.71

3.3.5.4. Digestible crude protein, digestible energy and starch equivalent value.

Table 28 gives DCP, DE and SE value. From 3 to 5 weeks regrowth DCP decreased from 12.2 to 7.1 percent, a percentage fall of 41.8 percent. At 7 weeks regrowth DCP dropped to 3.1 percent, a percentage drop of 56.3 over the 2 weeks regrowth from 5 to 7 weeks. SE at 5 weeks increased by 11.8 percent compared to the SE at 3 weeks but fell by 27.0 percent at 7 weeks regrowth.

Table 28. DCP, DE and SE of three regrowths of P. purpureum (c.v. French Cameroons).

Stage of regrowth	DCP percent DM	DE Kcal/g DM	SE g/g DM
3 weeks	12.2	2.646	0.395
5 "	7.1	2.891	0.448
7 "	3.1	2.417	0.327

3.3.5.5. Effect on liveweight.

Table 29 shows daily mean liveweight changes by each wether is a group of four wethers feeding on the three regrowths of P. purpureum (c.v. French Cameroons). Available DCP, DE and SE from the ingested amounts of dry matter are also indicated. The highest liveweight gain was in the 3 weeks regrowth and the lowest was in the 5 weeks regrowth.

Table 29. Daily mean liveweight changes by wether sheep feeding on the three regrowths of P. purpureum (c.v. French Cameroons).

Stage of regrowth	DM intake g/kg $w^{0.75}$	DCP ingested g/kg $w^{0.75}$	DE ingested Kcal/kg $w^{0.75}$	SE ingested g/kg $w^{0.75}$	Days in cages	Mean lwt change g/wether/day
3 weeks	39.8	4.9	105.3	15.7	17	+ 82.0
5 "	33.3	2.4	96.3	14.9	17	+ 5.0
7 "	40.5	1.3	97.9	13.2	20	+ 35.0

3.3.6. Desmodium uncinatum (Silver leaf desmodium).

The D. uncinatum used in this experiment was cropped at the National Agricultural Research Station, Kitale. It was actively growing and flowering. It was cropped, hayed, and fed after chaffing in a chaff cutter.

3.3.6.1. Chemical composition.

Table 30 shows that crude protein content was quite high as there was minimal of dessication of leaves in the hay. Crude fibre was high contributed mainly by the stalky nature of the hay.

Table 30. Chemical composition of D. uncinatum.

	Percent dry matter					
% D.M. in hay	Crude protein	Ether extract	Crude fibre	Ash	N-free extract	Gross energy Kcal/g DM
90.4	16.8	3.2	40.4	8.0	31.6	4.421

Table 31. Mineral content of D. uncinatum.

Percent dry matter				
Ca	P	Mg	K	Na
1.08	0.25	0.19	2.96	0.04

3.3.6.2. Level of intake.

D. uncinatum hay was offered together with 16 weeks regrowth C. gayana hay c.v. Mbarara (first batch), whose digestion coefficients had already been determined. From 0.40 kg to 0.32 kg of the legume hay were ingested per wether per day. C. gayana hay ingested varied from 0.60 kg to 0.54 kg per wether per day. Total mean dry matter intake was 0.86 kg per 17.3 kg mean $w^{0.75}$ giving a mean dry matter intake of 20.8 g/kg $w^{0.75}$ for the D. uncinatum and a mean total dry matter intake of 53.7 g/kg $w^{0.75}$.

3.3.6.3. Digestion coefficients.

Apparent digestion coefficients of D. uncinatum by the four wethers are given in table 32. Mean dry matter and organic matter digestibilities were 69.8 and 68.8 percent respectively. Crude protein digestibility ranged from 60.8 to 67.4 percent with a mean percentage of 64.3. Unlike all the grasses studied crude fibre digestibility was less than the nitrogen-free extract fraction by all the four wethers. One wether gave a digestion coefficient of nitrogen-free extract of 105.2 percent which could be explained by error involved in working out the digestion coefficients of the D. uncinatum by difference from the digestion coefficient ~~basal diet~~ of C. gayana hay fed as a basal diet.

Table 32. Apparent digestion coefficients of D. uncinatum by four wether sheep (by difference).

	Dry matter	Organic matter	Crude protein	Ether extract	Crude fibre	N-free extract
	68.0	67.9	60.8	88.7	52.8	94.3
	78.7	77.8	67.4	63.4	65.4	105.2
	61.2	60.1	63.6	73.4	50.2	75.0
	71.5	69.7	65.4	75.3	67.8	79.2
Mean	69.8	68.8	64.3	75.2	59.0	88.4
S.e.	±3.65	±3.63	±1.40	±5.20	±4.42	±6.96

3.3.6.4. Digestible crude protein and starch equivalent value.

DCP of D. uncinatum was 9.8 percent dry matter and SE was 0.431 g/g dry matter.

3.3.6.5. Effect on liveweight.

Table 33 gives mean liveweight change by the four wethers feeding on D. uncinatum and the basal diet. Mean available DCP and SE from the ingested amount of dry matter are also indicated. There was a mean liveweight gain of 64.7 grams per wether per day over the 17 days that the wethers were confined in the cages.

Table 33. Daily mean liveweight change by wether sheep feeding on D. uncinatum and the basal diet given.

Feed offered	DM intake g/kg $w^{0.75}$	DCP ingested g/kg $w^{0.75}$	SE ingested g/kg $w^{0.75}$	Days in cages	Mean lwt change g/wether day
C. gayana	32.9	0.7	6.1		
D. uncinatum	20.8	2.0	9.0		
Total	53.7	2.7	15.1	17	+ 64.7

3.3.7. Ipomea batatas vines (Sweet potato vines).

The vines used in this experiment were growing at Kabete, Kenya, altitude 1836 m. and mean annual rainfall of 925 mm. The original crop was propagated by stem cuttings from Western Kenya. The vines were growing actively and some were flowering. Enough vines were cropped from a measured plot every morning to be fed green twice a day. The roots portions were excluded by cutting them off 3-4 cm above the beginning of the root system. The remaining portions of the vines were cut into small pieces 4-2 cm long. They were mixed well. During the pre-experimental period representative samples for laboratory analyses were taken for 2 days. Throughout the 10 days experimental period daily representative samples were taken for dry matter determinations. At the end of the experimental period routine analyses were done on the first day sample, the dry matter content of which had already been determined. The remaining 9 samples, from which dry matter contents had also been determined previously, were bulked to make three representative samples i.e. 2nd to 4th day, 5th to 7th day and 8th to 10th day. Routine analyses were done on the samples.

Throughout the experimental period vines left over were collected every morning. They were weighed straight away and dried for dry matter determinations. Left overs for each wether, after being dried, were composited over the 10 days experimental period and analyses were done on such composited samples.

Table 35. Mineral content of four samples of I. batatas vines.

Samples	Percent dry matter				
	Ca	P	Mg	K	Na
1st day	0.91	0.12	0.39	4.49	0.039
2nd - 4th day	1.12	0.23	0.42	1.85	0.012
5th - 7th "	0.55	0.16	0.35	2.05	0.011
8th -10th "	0.70	0.20	0.40	1.90	0.013
Mean	0.82	0.18	0.39	2.57	0.019
S.e.	±0.13	±0.03	±0.02	±0.64	±0.005

3.3.7.2. Level of intake.

Each wether was offered 9.5 kg of fresh green vines per day. Mean daily intake of fresh green vines was 9.30 kg per wether giving a mean daily dry matter intake of 0.8 kg per 44.2 kg mean liveweight and 46.8 g dry matter per kg $w^{0.75}$/day. It was observed throughout the experiment that one wether was always selecting the leaves first and would later eat the stems. Another wether would always select the stems first and would eat the leaves last. The two remaining wethers were not selective either way and would eat both the leaves and the stems at the same time.

3.3.7.3. Digestion coefficients.

Table 36 gives apparent digestion coefficients of the four wethers over the 10 days experimental period.

3.3.7.1. Chemical composition.

Percentage moisture in the green vines varied from 86.9 to 95.7 giving a mean moisture content of 91.5 percent (table 34). The lowest crude protein content in the four samples was 10.5 and the highest was 17.5 percent. The mean of the four samples was 14.6 percent.

Crude fibre in all the four samples was quite stable with a mean of 19.6 percent. Mean contents of ash, nitrogen-free extract and gross energy were respectively 16.3 percent, 46.4 percent and 3,666 kcal/g dry matter.

Table 34. Chemical composition of four samples of I. batatas vines.

		Percent of dry matter					Gross energy Kcal/g DM
Samples	Moisture percent	Crude protein	Ether extract	Crude fibre	Ash	N-free extract	
1st day	86.9	10.5	3.3	19.9	13.3	53.0	3.807
2nd - 4th day	90.7	13.1	3.2	19.0	17.6	47.1	3.677
5th - 7th day	95.7	17.6	3.0	19.0	17.6	42.8	3.600
8th - 10th day	92.9	17.5	2.9	20.1	16.6	42.9	3.580
Mean	91.5	14.6	3.1	19.6	16.3	46.4	3.666
S.e.	±1.86	±1.77	±0.09	±0.29	±1.02	±2.40	±0.05

Table 35 shows that calcium, potassium and sodium content in the first day sample were higher than in the others. Mean contents of calcium, phosphorus, magnesium, potassium and sodium were respectively 0.82, 0.18, 0.39, 2.57 and 0.019 percent dry matter.

Table 35. Mineral content of four samples of I. batatas vines.

Samples	Percent dry matter				
	Ca	P	Mg	K	Na
1st day	0.91	0.12	0.39	4.49	0.039
2nd - 4th day	1.12	0.23	0.42	1.85	0.012
5th - 7th "	0.55	0.16	0.35	2.05	0.011
8th -10th "	0.70	0.20	0.40	1.90	0.013
Mean	0.82	0.18	0.39	2.57	0.019
S.e.	±0.13	±0.03	±0.02	±0.64	±0.005

3.3.7.2. Level of intake.

Each wether was offered 9.5 kg of fresh green vines per day. Mean daily intake of fresh green vines was 9.30 kg per wether giving a mean daily dry matter intake of 0.8 kg per 44.2 kg mean liveweight and 46.8 g dry matter per kg $w^{0.75}$/day. It was observed throughout the experiment that one wether was always selecting the leaves first and would later eat the stems. Another wether would always select the stems first and would eat the leaves last. The two remaining wethers were not selective either way and would eat both the leaves and the stems at the same time.

3.3.7.3. Digestion coefficients.

Table 36 gives apparent digestion coefficients of the four wethers over the 10 days experimental period.

Dry matter digestibility ranged from 56.3 to 62.3 percent giving a mean digestion coefficient of 58.8 percent. Crude protein digestibility ranged from 51.4 to 56.6 percent with a mean of 53.8 percent. Mean digestion coefficients of crude fibre and nitrogen-free extract were respectively 46.3 and 77.6. Like the D. uncinatum, and unlike all the pasture grasses studied, crude fibre was less digestible than the nitrogen-free extract.

Table 36. Apparent digestion coefficients of I. batatas vines by four wether sheep.

Dry matter	Organic matter	Crude protein	Ether extract	Crude fibre	N-free extract	Gross energy
59.5	66.5	54.2	55.3	46.6	79.1	64.3
56.3	63.5	51.4	55.0	44.5	75.3	60.2
62.3	68.1	56.6	58.4	50.4	79.4	66.1
57.1	64.0	53.3	47.1	43.9	76.7	*
Mean 58.8	65.5	53.8	53.9	46.3	77.6	63.5
S.e. ±1.40	±1.08	±1.08	±2.41	±1.47	±0.99	±1.51

* Digestion coefficients of gross energy not determined as faeces sample were discarded.

3.3.7.4. Digestible crude protein, digestible energy and starch equivalent value.

DCP and DE were 7.9 percent and 2.329 kcal/g dry matter. SE was 0.361 g per g dry matter.

3.3.7.5. Effect on liveweight.

The four wethers were confined in the cages for a total of 20 days; 10 days pre-experimental and 10 days experimental period. One wether had lost an average of 20.0 g per day over the 20 days. The remaining three gained 30.0 g, 25.0 g and 80.0 g per day over the 20 days. In all the four wethers there was a mean daily liveweight gain of 26.0 g (table 37).

It was observed, however, that the wethers feeding on the fresh green vines excreted very high quantities of urine. As a result of this observation, during the pre-experimental period, it was decided to keep comparison records of water intake between this experiment and another digestibility experiment on C. gayana c.v. Pokot (6 weeks regrowth) by another group of 4 wethers which was in progress at the same time and in the same house. Table 37 shows that mean water intake/kg $w^{0.75}$/day during the I. batatas vine experiment was lower than during the C. gayana experiment whereas mean water available/kg $w^{0.75}$/day from the vines was very high than from the C. gayana. Mean total water intake from bucket and feed was 664 ml/kg $w^{0.75}$/day by the vines group and 191 ml/kg $w^{0.75}$/day by the C. gayana. Mean water excreted in the faeces per kg $w^{0.75}$/day was 446 ml and 24 ml for the vines and the C. gayana group respectively. The I. batatas vines group excreted a mean of 451 ml of urine/kg $w^{0.75}$/day whereas the C. gayana group excreted a mean of 68 ml/kg $w^{0.75}$/day.

It is apparent from the figures in table 37 that, excluding other sources of water gain and water loss from the body, the wethers on the I. batatas vines had lost more water than was taken from the bucket and from the vines. Inspite of the fact that the wethers feeding on the vines had higher available DCP and SE/kg $w^{0.75}$ compared to those on the C. gayana hay (table 37), their mean liveweight gains were lower at 26.0 g/day than at 70.0 g/day by the C. gayana hay. This comparatively lower liveweight gain could possible have been due to either the loss of body water as indicated in the table, which will imply that the vines have a possible diuretic effect, or it may have been due to the fact that more energy was used in excreting the high quantity of water in the vines ingested. There was, however, no substantial difference in the intake of water from the buckets as a result of the two diets given.

Table 37. Intake and excretion of water by wether sheep feeding on I. batatas vines and C. gayana and their effect on liveweight.

Parameters	Ipomea batatas vines (fed green)	C. gayana c.v. Pokot (6 weeks) (fed as hay)
Mean liveweight/wether (kg $w^{0.75}$)	17.1	17.4
Water intake/kg $w^{0.75}$/day (offered ad lib)	167 ml	179 ml
Water available from feed/day/ kg $w^{0.75}$	497 ml	6 ml
Total water intake/kg $w^{0.75}$/day	664 ml	185 ml
Excretion of water in faeces/ kg $w^{0.75}$/day	446 ml	24 ml
Water retained/kg $w^{0.75}$ (excluding output in urine)	218 ml	161 ml
Excretion of urine/kg $w^{0.75}$/day	451 ml	68 ml
D.M. intake g/kg $w^{0.75}$/day	46.8	49.4
DCP ingested g/kg $w^{0.75}$/day	3.7	2.1
SE ingested g/kg $w^{0.75}$/day	16.9	15.1
DE ingested kcal/kg $w^{0.75}$/day	108.9	118.6
Mean lwt gain/wether/day	26.0 g	70.0 g

3.3.8. Cottonseed cakes.

Both decorticated and undecorticated cottonseed cakes were used. The cakes were broken into small pieces. Basal diets of known digestibilities consisted of P. clandestinum (11 weeks regrowth) for the decorticated cottonseed cake and C. gayana (sample 3, Dundori) for the undecorticated cottonseed cake. For both the experiments pre-experimental and experimental periods were 10 days each.

3.3.8.1. Chemical composition.

Table 38 shows that dry matter content of the decorticated cottonseed cake was slightly higher than that of the undecorticated cake. Crude protein was lower in the undecorticated cake than in the decorticated cake but crude fibre was higher in the undecorticated compared to the decorticated cake. Nitrogen-free extract was, however, higher in the undecorticated than in the decorticated cake.

Table 38. Chemical composition of decorticated and undecorticated cottonseed cakes used in the experiment.

		Percent dry matter					
Type of cake	% DM	Crude protein	Ether extract	Crude fibre	Ash	N-free extract	Gross energy Kcal/g DM
Decorticated	93.6	39.9	6.8	19.2	6.6	27.2	4.677
Undecorticated	90.3	22.2	9.2	31.0	5.1	32.5	4.565

Table 39 shows that phosphorus, magnesium and sodium was higher in the decorticated cake and that calcium and potassium was higher in the undecorticated cake.

Table 39. Mineral content of decorticated and undecorticated cottonseed cakes used in the experiment.

Type of cake	Percent dry matter				
	Ca	P	Mg	K	Na
Decorticated	0.17	0.89	0.56	0.87	0.009
Undecorticated	0.29	0.20	0.14	2.16	0.002

3.3.8.2. <u>Level of intake</u>.

Only 0.5 kg of each of the cakes were offered per wether per day. No cakes were left over throughout the 10 days experimental period. Mean intake of P. *clandestinum* hay, which was offered as a basal diet (but not *ad libitum*) in the decorticated cake experiment, was 0.60 kg per wether per day. Mean intake of the C. *gayana* hay, which was offered as a basal diet (*ad libitum*) in the decorticated cake experiment, was 0.61 kg per wether per day. Total mean intakes of the cakes and the hays for decorticated and undecorticated cakes experiments were therefore respectively 1.10 kg and 1.11 kg per 17.0 and 17.2 kg mean $w^{0.75}$. Dry matter intake/kg $w^{0.75}$/day for decorticated cake and the P. *clandestinum* hay were 27.5 g and 33.5 g respectively giving a total of 61.0 g. For the undecorticated cake and the C. *gayana* hay dry matter intake/kg $w^{0.75}$/day were respectively 26.3 g and 32.6 g with a total of 58.9 g.

3.3.8.3. Digestion coefficients.

Apparent mean digestion coefficients of crude protein and nitrogen-free extract were higher in the decorticated cake than in the undecorticated cake (table 40). There were apparent negligible differences in the digestibilities of ether extract and crude fibre in the two samples of cakes used. In all the two cakes nitrogen-free extract was more digestible than the crude fibre.

Table 40. Apparent mean digestion coefficients of decorticated and undecorticated cottonseed cakes used in the experiment (by difference).

Type of cake	Dry matter	Organic matter	Crude protein	Ether extract	Crude fibre	N-free extract
Decorticated	69.5	70.7	83.7	93.6	34.5	72.5
S.e.	±3.21	±3.01	±1.21	±2.36	±5.33	±3.93
Undecorticated	54.6	55.3	71.9	94.9	35.0	51.7
S.e.	±2.40	±2.02	±0.25	±1.17	±1.98	±3.40

3.3.8.4. Digestible crude protein and starch equivalent value.

DCP of the decorticated cake was slightly more than twice that of the undecorticated cake while SE was 26 percent higher in the former than in the latter cake.

Table 41. DCP and SE of decorticated and undecorticated cottonseed cakes used in the experiment.

Type of cake	DCP percent DM	SE g/g DM
Decorticated	33.8	0.620
Undecorticated	16.0	0.456

3.3.8.5. Effect on liveweight.

Table 42 gives mean liveweight changes together with the available DCP and SE from both the cottonseed cakes and the basal diets offered.

Table 42. Daily mean liveweight changes by wether sheep feeding on decorticated and undecorticated cottonseed cakes together with the basal diets.

Type of cake	Total DMI g/kg $w^{0.75}$	DCP ingested g/kg $w^{0.75}$	SE ingested g/kg $w^{0.75}$	Days in cages	Mean lwt changes g/wether/day
Decorticated	61.0	12.4	30.4	20	+ 126.0
Undecorticated	58.9	6.0	23.9	20	+ 65.0

3.3.9. Wheat bran, maize germ and bran meal and "wishwa".

The three arable farm by-products were tested in different experiments. Two experiments were conducted on the wheat bran and one experiment each for the other two cereal by-products. Four wethers were used for any one experiment. Basal diets of known digestibilities consisted of C. gayana (sample 3 Dundori) for the wheat bran. For both maize germ and bran meal and "wishwa", a basal diet of C. gayana (sample 4, Dundori) was used; its digestibilities had been estimated in earlier experiments.

The cereal by-products were given as the first feeds in the morning and were followed with the hays about mid day. Except for the wheat bran, for which a preliminary period lasted for 7 days, preliminary and experimental periods lasted for 10 days each in all the other experiments.

3.3.9.1. Chemical composition.

Table 43 shows that crude protein was highest in the wheat bran at 16.7 percent dry matter. "Wishwa" was 1.5 percent higher in crude protein than maize germ and bran meal. Ether extract was comparatively low in the wheat bran compared to maize germ and bran meal and to "wishwa", but crude fibre was highest in the wheat bran. Ash was lowest in the maize germ and bran meal but its nitrogen-free extract content was highest, followed by "wishwa" and wheat bran. Gross energy was also highest in the maize germ and bran meal.

Table 43. Chemical composition of the wheat bran, maize germ and bran meal and "wishwa" used in the experiments.

Type of by-product	% DM	Percent dry matter					Gross energy Kcal/g DM
		Crude protein	Ether extract	Crude fibre	Ash	N-free extract	
Wheat bran	90.2	16.7	5.0	14.2	5.2	58.9	4.369
Maize germ & bran meal	91.1	10.0	12.4	9.9	3.3	64.4	4.603
"Wishwa"	89.4	12.9	10.8	8.0	6.7	61.6	4.400

Maize germ and bran meal was consistently low in all the minerals compared to the wheat bran and "wishwa. In all the three cereal by-products calcium was low compared to phosphorus.

Table 44. Mineral content of wheat bran, maize germ and bran meal and "wishwa" used in the experiments.

Type of by-product	Percent dry matter				
	Ca	P	Mg	K	Na
Wheat bran	0.32	1.36	0.51	1.58	0.057
Maize germ & bran meal	0.04	0.58	0.25	0.88	0.032
"Wishwa"	0.13	1.19	0.38	1.24	0.048

3.3.9.2. Level of intake.

Amounts offered per wether per day were 0.40, 0.30 and 0.40 kg of wheat bran, maize germ and bran meal and "wishwa" respectively. With the exception of a few grammes left over by one wether on "wishwa", no left overs in the other cereal by-products were recorded. Hays, in dry matter, ingested as basal diets for wheat bran (offered ad libitum), maize germ and bran meal and for "wishwa" (not offered ad libitum) were respectively 554, 457 and 311 g per wether per day. Total mean dry matter intakes of both the basal and the experimental diets were 915 g per 44.5 kg mean liveweight for wheat bran, 730 g per 43.8 kg mean liveweight for maize germ and bran meal and 668 g per 45.4 kg mean liveweight for "wishwa". Presented in intake/kg $w^{0.75}$/day levels were 20.9 g and 32.2 g for the wheat bran and its basal diet, 16.1 g and 26.9 g for the maize germ and bran meal and its basal diet and 20.5 g and 17.8 g for the "wishwa" and its basal diet. Total dry matter intakes/kg $w^{0.75}$ for each of the three cereal by-products, together with their basal diets, were respectively 53.1 g, 43.0 g and 38.3 g.

3.3.9.3. Digestion coefficients.

Table 45 shows that digestibilities of organic matter, ether extract, crude fibre and that of nitrogen-free extract were highest in "wishwa" compared to those of wheat bran and maize germ and bran meal but digestion coefficient of crude protein in "wishwa" was lowest at 59.0 percent. Digestion coefficient of crude protein in the wheat bran was comparatively highest at 79.1 percent.

Table 45. Apparent mean digestion coefficients of wheat bran, maize germ and bran meal and of "wishwa" used in the experiments (by difference).

Type of by-product	Dry matter	Organic matter	Crude protein	Ether extract	Crude fibre	N-free extract
Wheat bran	64.2	71.4	79.1	81.7	52.4	76.7
S.e.	±0.65	±1.44	±1.46	±4.42	±1.05	±3.28
Maize germ & bran meal	75.9	79.9	63.7	83.9	27.3	85.7
S.e.	±2.43	±1.24	±2.99	±1.36	±2.82	±4.91
"Wishwa"	75.0	83.1	59.0	89.0	52.9	86.8
S.e.	±2.00	±4.17	±3.25	±2.15	±11.32	±1.10

3.3.9.4. Digestible crude protein and starch equivalent value.

Table 46 shows that DCP of wheat bran was higher than that in the maize germ and bran meal and in "wishwa". However, its SE was lower than the SE values of the other two by-products. The SE value of "wishwa" was highest at 0.840 g/g D.M.

Table 46. DCP and SE of wheat bran, maize germ and bran meal and "wishwa" used in the experiments.

Type of by-product	DCP percent DM	SE g/g DM
Wheat bran	13.2	0.694
Maize germ & bran meal	6.4	0.802
"Wishwa"	7.4	0.840

3.3.9.5. Effect on liveweight

Table 47 shows mean liveweight changes by wether sheep feeding on the three cereal by-products and the basal diets of hays given. Available DCP and SE from the total diets ingested by each group are also indicated in the table. The varying liveweight gains in the table are not entirely related to the cereal by-products given as these were given together with basal diets of varying quantities; and in two of the cereal by-products the basal diets were also of varying quantities.

Table 47. Daily mean liveweight changes by wether sheep feeding on the three cereal by-products together with the basal diets of hays given.

Type of by-product	Total DMI g/kg $w^{0.75}$	DCP ingested g/kg $w^{0.75}$	SE ingested g/kg $w^{0.75}$	Days in cages	Mean lwt change g/wether/day
Wheat bran	53.1	4.6	26.3	17	+ 70.6
Maize germ & bran meal	43.0	3.8	35.8	20	+ 95.0
"Wishwa"	38.3	3.3	25.7	20	+ 75.0

3.4 Discussion of the results of section 3.

3.4.1. Chemical composition.

P. *clandestinum* was superior to many other well established pasture grasses in East Africa as evidenced by the crude protein levels (23.7 and 14.8 percent dry matter at 5 and 11 weeks regrowth - see table 5). However, the percentage moisture in the fresh green grass was generally high and as was stated by Todd (1956) the high water content of the young grass and its tendency to cause bloat could be its main drawbacks. However, many farmers have managed to control the incidence of bloat and severe forms of pasture diarrhoea by feeding hay. It was also shown by Butterworth, Groom and Wilson (1961) that the mean intake of dry matter by milking cows was 3.0 and 3.7 percent of liveweight in the wet and dry seasons, respectively. The herbage available for grazing during the wet season contained 23.4 percent dry matter and that of the dry season contained 39.2 percent. Holmes and Lang (1963), working in a temperate zone, produced forage with a low dry matter content by heavy application of nitrogenous fertilizers and concluded that intake of dry matter by cattle was not affected by high water content in the forage. In his review on nutrition of ruminants in the tropics Payne (1966) dwelt on the inconclusive nature of the experimental evidence, mainly performed in the temperate zones, on the effect of moisture content of forage on its dry matter intake. He concluded that when appetite is already depressed by the direct effect of high ambient temperature and humidity, high water content of the forage or free water on the forage contributes to prevent the animal from eating all the dry matter it requires for high production.

Among the C. gayana grasses studied the highest crude protein content at 14.1 percent dry matter was in the Sample 4 c.v. Mbarara (table 10) in its early flowering stage at 16 weeks. Sample 1, also at early flowering, had a crude protein content of 12.4 percent dry matter and it dropped to 4.2 percent when seeds were shed (table 10 sample 2). However crude fibre increased from 34.2 to 39.1 percent dry matter from early flowering to seeding stage.

Bogdan (1969) noted that C. gayana pastures, generally, though not always, contain slightly less crude protein than most other grass species grown under comparable conditions. He gave the percentage contents of organic compounds for C. gayana as; crude protein 4-13, crude fibre 30-40, ether extract 0.8-1.5 and nitrogen-free extract 42-48. The lower and upper limits given compare favourably for crude protein and crude fibre in the C. gayana grasses studied in this work. The upper limit of the ether extract is lower than that in table 10 and the upper limit of the nitrogen-free extract is slightly higher. It was also reported by Bogdan (1969) that the crude protein contents might vary widely, increasing with increases in available soil nitrogen and decreasing with the age of the plant or its parts. The results in this study conform to that observation.

C. dactylon which was growing under very comparable conditions with the first batch C. gayana had, all through, higher crude protein and lower crude fibre contents compared to the first batch C. gayana. The 10.2 percent crude protein in C. dactylon at 10 weeks regrowth declined to only 9.1 percent after 8 weeks regrowth. The mean weekly decline of crude protein in 8 weeks regrowth by C. dactylon was only 0.14 percent. It is interesting to note that the higher levels of crude protein in the C. dactylon and its slow drop of quality is in agreement with the observation by Strange (1958) and by Grieve and Osbourne (1965).

S. sphacelata c.v. Nandi studied here had constistently higher crude protein contents at all the stages compared to contents reported by Grieve and Osbourne (1965) at similar stages of regrowths. The mean weekly decline of crude protein from 4 to 8 weeks regrowth was 1.4 percent.

The crude protein content of P. purpureum at 3 weeks was 16.6 percent dry matter whereas that of P. clandestinum, at a much older age of 8 weeks, was higher at 19.1 percent dry matter. However, compared to second batch C. gayana (tables 10 and 25) which was cropped at about the same time but at different regrowth stages of 8 and 10 weeks for the C. gayana and 5 and 7 weeks for the P. purpureum the latter grass was lower in crude protein. Like most other pasture grasses the crude fibre content of P. purpureum increased with maturity.

The nutrient contents of the D. uncinatum studied were in some respects slightly different from the figures quoted by

Milford (1967). At the same vegetative form Milford's (1967) figures showed 1.4 percent higher in crude protein, 1.4 percent higher in ether extract, 7.9 percent lower in crude fibre and 10.1 percent higher in nitrogen-free extract. These differences were probably due to differences in maturity even though both of them were cropped at what had been described as "actively growing and flowering stages".

The high moisture content in the I. batatas vines could not only possibly affect dry matter availability when fed green byt may also make it expensive to process the vines into I. batatas vines meal. Crude protein content was quite high and crude fibre, at a mean level of 19.6 percent dry matter, makes the vines a valuable fodder.

Cottonseed cakes, both decorticated and undecorticated, used in the experiments are those that are produced locally in East Africa. As expected, the crude protein content of the decorticated was higher than that of the undecorticated cake. The crude protein content of 39.9 percent dry matter in the decorticated cake and the nitrogen-free extract levels of both the decorticated and the undecorticated cakes agree fairly well with the figures by Bredon and Marshall (1962), Abrams (1961) and McDonald, Edwards and Greenhalgh (1966). The crude fibre content of 31.0 percent dry matter in the undecorticated cake is about 7 units higher than that of 24.8 percent reported by McDonald et al (1966) but agrees very well with the analysis by Bredon et al (1962). The crude fibre content of the decorticated cake at 19.2 percent dry matter is, however, surprisingly high but is just about the same as that by Bredon et al (1962). In the analyses of thirteen other samples of cottonseed cakes, marketed as "decorticated grades", the crude fibre contents showed variations from 15.2 to 20.7 percent dry matter while crude protein varied from 28.4 to 50.0 percent dry matter. It is apparent from these unpublished analyses that the cottonseed cakes marketed locally, under no specific requirements, are very variable indeed.

The chemical composition (table 43) of the three related cereals by-products showed that in terms of crude protein wheat bran was superior compared to the maize germ and bran meal and to "wishwa". But this protein content superiority in the wheat bran was offset by the higher ether and nitrogen-free extract in the maize germ and bran meal, a reflection of the contribution by the percentage germ meal present. Chemical compositionwise "wishwa" was superior to wheat bran in terms of ether and nitrogen-free extracts.

Calcium levels in the pasture grasses and the fodders studied ranged from 1.08 percent dry matter in D. uncinatum to 0.20 percent dry matter in P. purpureum, 7 weeks regrowth. S. sphacelata c.v. Nandi and P. purpureum had lowest levels of calcium. Grieve and Osbourn (1965) gave a mean calcium content in S. sphacelata at 4, 6 and 8 weeks growth as 0.300 percent dry matter. Gupta, Pramanik and Majumdar (1967) gave a calcium content of 0.47 percent dry matter in P. purpureum. There was no clear cut tendency for the calcium to increase with maturity and the pooled correlation coefficient (table 48) between crude protein and calcium content $r = 0.1236$.

Table 48. Crude protein contents as correlated to mineral contents of the pasture grasses tested.

	Percent dry matter					
Type of pasture and stage of regrowth	Crude protein	Ca	P	Mg	K	Na
P. clandestinum (Limuru)						
5 weeks	23.7	0.47	0.41	0.26	4.39	0.001
8 "	19.1	0.44	0.37	0.25	3.18	0.007
11 "	14.8	0.46	0.34	0.24	4.38	0.012
15 "	13.7	0.47	0.30	0.25	3.98	0.009
		-0.0414*	0.9656*	-0.7973*	0.0230*	-0.9229*
C. gayana						
First batch (Muguga)						
c.v. Mbarara						
8 weeks	6.9	0.46	0.19	0.13	1.87	0.004
12 "	6.4	0.48	0.20	0.12	1.99	0.004
16 "	5.8	0.45	0.14	0.10	1.92	0.004
		0.3800*	0.8090*	1.0000*	-0.3665*	0.000*
Second batch (Kitale)						
c.v. Mbarara						
6 weeks	12.7	0.56	0.25	0.17	2.65	0.030
8 "	8.7	0.55	0.23	0.16	2.85	0.031
10 "	8.5	0.55	0.16	0.16	2.55	0.027
		0.6037*	0.7026*	1.0000*	-0.1474*	0.1612*
Third batch (Kitale)						
c.v. Pokot						
6 weeks	7.7	0.34	0.29	0.15	2.30	0.001
9 "	6.6	0.32	0.21	0.16	2.00	0.001
12 "	5.1	0.24	0.19	0.14	2.44	0.001
		0.9701*	0.9122*	0.5762*	-0.3943*	0.000*
Fourth batch (Dundori)						
c.v. Mbarara						
Sample 1 Early flowering	12.4	0.41	0.25	0.18	3.46	0.004
Sample 2 Seeds shed	4.2	0.53	0.18	0.15	3.22	0.003
Sample 3 Early flowering 16 weeks	8.9	0.42	0.26	0.20	3.25	0.005
Sample 4 Early flowering 16 weeks	14.1	0.44	0.27	0.24	4.26	0.007
		-0.7904*	0.8831*	0.8137*	0.7731*	-0.2284*
C. dactylon (Muguga)						
10 weeks	10.2	0.44	0.44	0.16	2.22	0.005
14 "	9.5	0.33	0.36	0.17	2.10	0.013
18 "	9.1	0.58	0.41	0.14	2.33	0.008
		-0.4228*	0.5115*	0.5294*	-0.3357*	-0.3450*
S. sphacelata (Kitale)						
c.v. Nandi						
4 weeks	12.2	0.22	0.19	0.17	3.58	0.005
6 "	9.1	0.25	0.15	0.15	3.40	0.003
8 "	6.6	0.24	0.13	0.15	3.34	0.003
		-0.7001*	0.9918*	0.8151*	0.9761*	-0.2536*
P. purpureum (Kitale)						
c.v. French Cameroon						
3 weeks	16.6	0.27	0.25	0.19	4.50	0.002
5 "	10.1	0.23	0.21	0.22	4.82	0.003
7 "	7.1	0.20	0.21	0.20	3.50	0.002
		0.9919*	0.9511*	-0.5167*	0.5672*	-0.2080*
		0.1236**	0.5939**	0.7929**	0.6129**	0.0498**

Note: ** = pooled *r* values

* = individual *r* values

Considered individually, C. gayana, second and third batches, and P. purpureum had high to very high positive correlation coefficients between crude protein and calcium contents (table 48). P. clandestinum, C. gayana (fourth batch), C. dactylon and S. sphacelata har *r* values of *0.0414*, *-0.7904*, *- 0.4228* and *- 0.7001* respectively. At the recommended calcium levels of 0.16 percent dry matter for gestation and lactation in dairy cattle, and from 0.24 to 0.32 percent dry matter for sheep (NRC, 1958 & 1957) most of the forages would have adequate calcium except, perhaps, S. sphacelata and P. purpureum which would not meet the sheep requirements at the higher calcium levels of 0.32 percent. Calcium deficiency in beef cattle is comparatively rare and mild and the symptoms are inconspicuous (NRC, 1966).

Phosphorus, in all cases, declined with maturity in all the grasses studied. Individual grasses *r* values for crude protein and phosphorus contents were consistently high (table 48) but pooled correlation coefficient between crude protein and phosphorus levels was not very high $r = 0.5939$. Howard, Burdin and Lampkin (1962) correlated crude protein and phosphorus levels in C. gayana, C. dactylon and some other grasses and found an *r* value of *0.718*. Phosphorus levels ranged from 0.44 in C. dactylon to 0.13 percent dry matter in S. sphacelata. Du Toit, Louw and Malan (1940) suggested that 0.140 percent phosphorus was the minimum level required in pasture for normal growth. Based on phosphorus requirements given by McDonald et al (1966), and working on a DMI of 3 kg per 100 kg liveweight, it works out that for maintenance requirements alone by a 350 to 500 kg liveweight cow the level of phosphorus in pastures should range from 0.13 to 0.17 percent dry matter. If production of 10 kg FCM is included then phosphorus in pastures needs to be from 0.25 to 0.29 percent dry matter to maintain and support that milk production. The required levels of phsophorus in pastures, even for that moderate level of production, could be met from only a few of the grasses studied here. At higher levels of production supplementation would have to be practiced. During the dry season it would be very likely that the pastures would not meet the phosphorus requirements even for maintenance and poor production. Howard et al (1962) reported that the average phosphorus content of C. gayana, C. dactylon and some other pastures studied over a period of two years was 0.145 percent with a monthly range of 0.072 to 0.252 percent dry matter. Their finding conform to the observation made here that phosphorus could be a limiting nutrient for animals raised solely on pastures.

Individual grasses r values between crude protein and magnesium levels ranged from *1.0000* to *0.5762*. Only in P. purpureum was there a negative r value of - *0.5167*. Pooled r value was high, *0.7929*. ARC (1965) gives magnesium requirements for a 500 kg liveweight cow, producing from 10-20 kg milk, as ranging from 13.8 to 20.1 g/day. At a DMI of 3 kg per 100 kg liveweight, the quoted requirements would imply that magnesium levels in pastures would have to be from 0.09 to 0.13 percent dry matter. From the analyses in the pastures it would therefore be very unlikely that magnesium would be deficient for the maintenance and production of up to 20 kg milk by a 500 kg cow. Howard et al (1962) reported an average magnesium level of 0.180 percent dry matter and the lowest monthly average of 0.140 percent.

Potassium levels in the pasture grasses studied showed a tendency to vary with maturity. Correlation coefficient between crude protein and potassium content was $r = 0.6129$. Compared to ARC (1965) requirements, potassium levels were more than adequate.

Individual grasses r values between crude protein and sodium were $- 0.9229$ for P. clandestinum and $- 0.2080$, $- 0.2284$, $- 0.2536$ and 0.3450 for P. purpureum, C. gayana fourth batch, S. sphacelata and for C. dactylon respectively. C. gayana, second batch had an r value of 0.1612. Correlation coefficients were nil for C. gayana, first and third batches. Pooled correlation coefficient between crude protein and sodium levels was $r = 0.0498$.

Sodium levels ranged from 0.040 percent as the highest in the D. uncinatum to 0.001 percent as the lowest in the C. gayana third batch. It was also reported by Howard et al (1962) that sodium levels are low in pastures throughout Kenya. Walker (1957) reported that sodium supplementation significantly increased the growth rate of steers grazing sodium deficient pastures on the Rhodesian veldt. Compared to requirements in

ARC (1962) for milk production, all the pastures studied would be grossly inadequate in sodium. French (1957) reported that the dry season shortage of sodium is often most marked, as evidenced by the wide spread seeking for salt by the tropical stock; and that chlorine content, although also usually low in mature herbage in the tropics, is generally not so acutely deficient as sodium.

Phosphorus was higher in the decorticated cottonseed cake than in the undecorticated cake. It was highest in the cereal by-products, especially in the wheat bran. The phosphorus contents of the cottonseed cakes and the cereal by-products could make a fair contribution to the animals' phosphorus requirements. However, sodium contents in all the cereal by-products studied would not likely improve very much the defficiency of the mineral in pastures.

3.4.2. Feed intake.

Table 49 shows voluntary dry matter intake as reported by other investigators. Levels are in general agreement with intake levels reported in this study under the respective tables.

There was an apparent increase in the total dry matter intake of the basal diets of hays and concentrates. When decorticated cottonseed cake was offered with a basal diet of P. clandestinum at 11 weeks regrowth, total dry matter intake was 61.0 g/kg $w^{0.75}$, an increase in the total dry matter intake of 15 percent over the intake of the P. clandestinum fed alone in the previous experiment; inspite of the fact that the hay was not offered ad libitum. Total dry matter intake was 58.9 g/kg $w^{0.75}$ when undecorticated cottonseed cake was fed together with a basal diet of C. gayana, Sample 3; an increase again of 30 percent over the intake of the hay alone when fed in the previous experiment. This higher percentage increase in the total dry matter intake in the undecorticated experiment than in the decorticated cake is most likely due to the fact that the C. gayana hay was fed ad libitum, unlike in the decorticated cake experiment. Feeding levels of both the cottonseed cakes were the same at 0.5 kg/wether/day.

Table 49. DM intake g/kg metabolic body weight (MBW) of some pasture grasses as reported by other investigators.

Investigators	Species of grass	Stage of growth	Crude protein % D.M.	Species of animal used	Voluntary intake g DM/kg MBW
Minson & Milford (1968)	P. clandestinum	52 days	23.1	Sheep	50.3[1]
Elliot (1967)	C. gayana	Mature hay	Low protein	"	50.8[2]
Minson & Milford (1967)	C. gayana	50-188 days			54.1 - 26.5
Milford & Minson (1968)	C. gayana	28-140 days	16.9 - 7.6	"	55.7 - 41.7[1]
Minson & Milford (1968)	S. sphacelata c.v. Nandi	52-102 days	7.5 - 3.6	"	47.6 - 28.5[1]
Soneji (1970)	C. gayana	Boot - seed	20.4⁺ - 16.6⁺	"	57.7* - 47.3*[2]
Soneji (1970)	S. sphacelata c.v. Nandi	Boot - seed	19.1⁺ - 16.6⁺	"	51.0* - 41.7*[2]
Grieve & Osbourn (1965)	S. sphacelata c.v. Nandi	28-56 days	14.8 - 19.0	"	66.0 - 39.8[1]
Grieve & Osbourn (1965)	C. dactylon	21-42 days	13.5 - 8.7	"	69.5 - 77.0[1]
Marshall, Bredon & Juko (1961)	C. dactylon	-	4.7 - 4.4	Steers	85.5 - 76.9[1] (Recalculated from daily intake per steer

Note

[1] MBW = $w^{0.75}$

[2] " = $w^{0.73}$

+percent organic matter

*intake of organic matter

Total dry matter intake for wheat bran, maize germ and bran meal and for "wishwa", including the basal diets given, were respectively 53.1, 43.0 and 38.3 g/kg $w^{0.75}$; indicating an increase in total dry matter intake over the basal diets alone of 17 percent by wheat bran but decreases of 20 and 29 percent over the basal diets alone by the maize germ and bran meal and by "wishwa". However these decreases in total dry matter intake in the latter two cereal by-products experiments are of doubtful significance since hays in both the two experiments were not fed ad libitum and all that was offered was ingested. The cereal by-products were also not fed ad libitum and the maize germ and bran meal was in fact fed at a lower level than the "wishwa". It was in fact apprent in the experiments that the wethers would have taken much more of the cereal by-products tested if they had been offered.

It is significant that both the cottonseed cakes and wheat bran increased the total dry matter intake and the impression obtained while feeding the maize germ and bran meal and "wishwa" ~~were~~ was that they also could have increased the total dry matter intake if both the by-products and the basal diets of hays were offered ad libitum. However, the undecorticated cottonseed cake and the wheat bran apparently decreased the intake of the basal diets of hays.

3.4.3. Feed intake as correlated to pasture quality.

Heaney, Pritchard and Pigden (1968) showed that a maximum of forty eight sheep were required to obtain an eighty percent chance to detect real intake differences at 5 percent level on metabolic weight. Only four wether sheep were, however, used in any of these experiments. The sacrifice on intake precision saved the prohibitive cost of a larger number of animals and yet gave some indications of ad libitum intake trends.

In this study dry matter intake has been expressed per unit metabolic weight, as it has been shown by Grieve and Osbourn (1965) that only 0.2 percent of the variation in daily dry matter intake was associated with differences in metabolic liveweight of the wether but that 13 percent of the variation in dry matter intake was attributable to gravitational weight. Dry matter intake in table 49 (also see figures 1 and 2) was correlated to the percentage crude protein and to the digestibility of organic matter, digestible energy and also to gross energy. P. clandestinum at 5 weeks regrowth, and both regrowth stages of C. dactylon were excluded as they were not fed ad libitum.

When dry matter intake g/kg $w^{0.75}$/day was correlated to the quality of the forages, where quality was scaled by its crude protein content, the pooled *r* value of *0.1810* for all the forages in table 50 showed that there was a poor correlation. However *r* values for individual grass species, at the stages of regrowths indicated, ranged from *0.9991* to *0.7596* for all the grasses except for the P. purpureum which had an *r* value of *0.1210*. Calculated *r* value for the same parameters from the work of Butterworth (1965) on P. purpureum at four stages of regrowth was - *0.0975*. The very

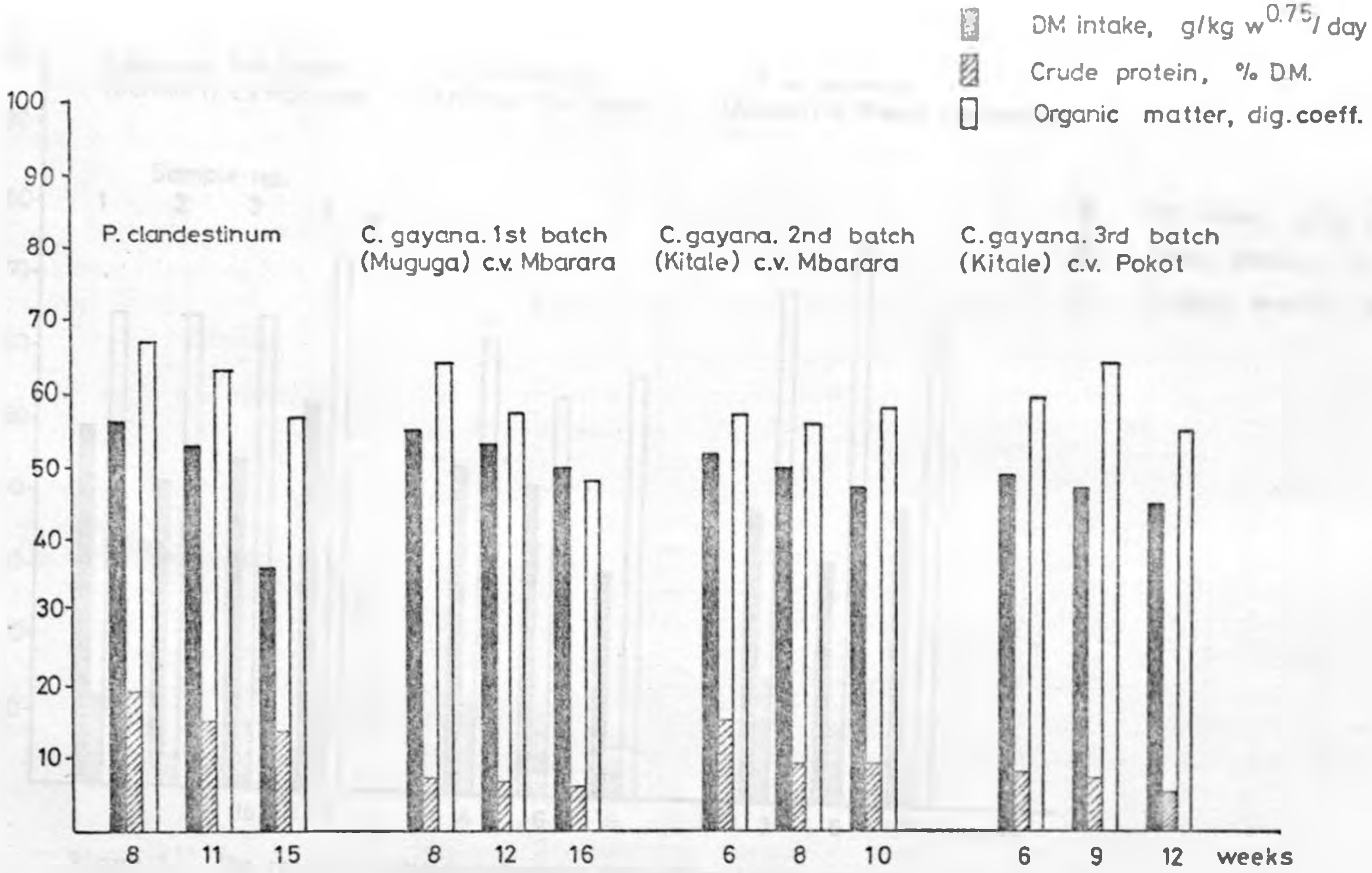

Figure 1. The relation between voluntary dry matter intake and the level of crude protein and organic matter digestibility.

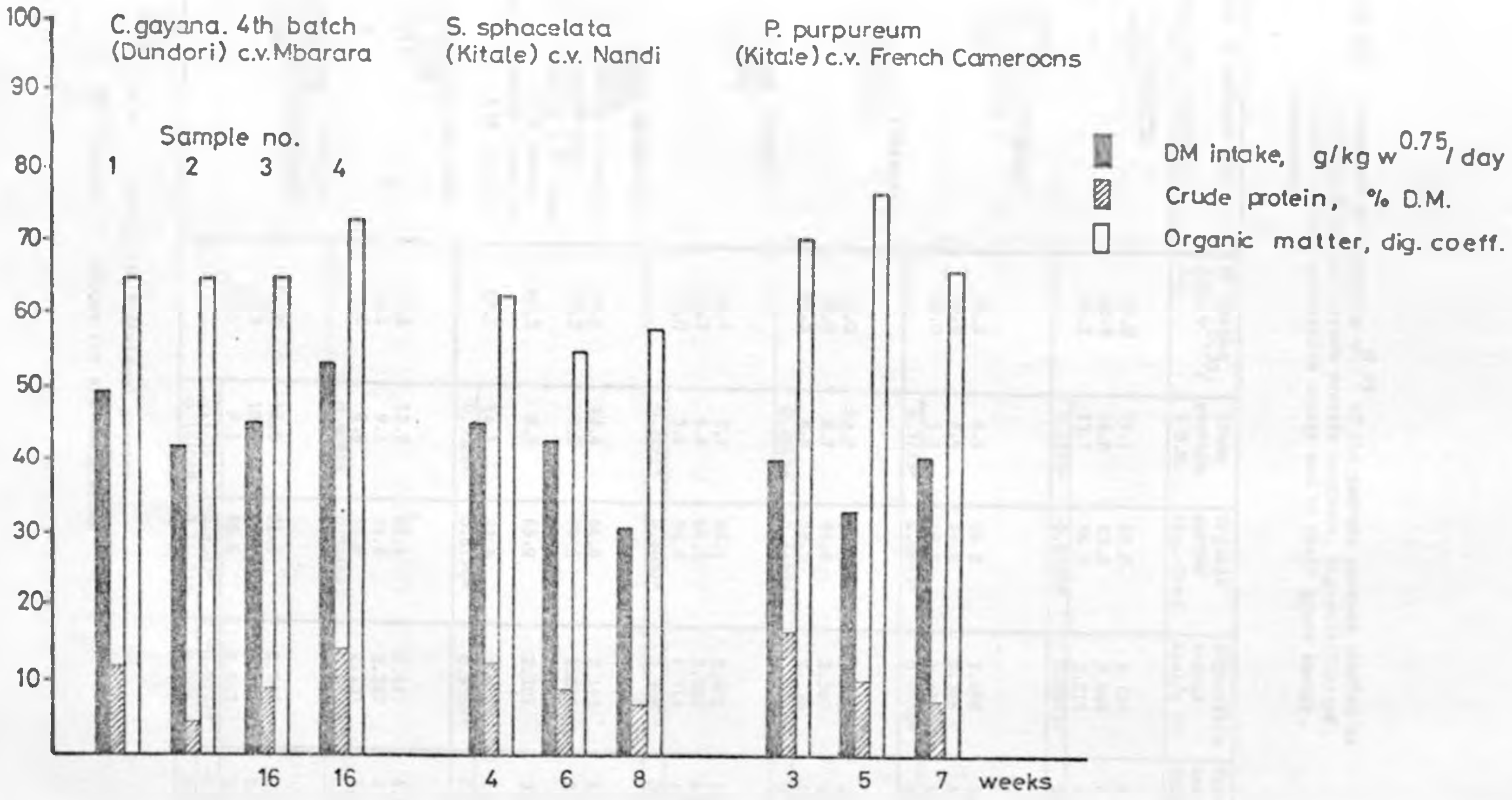

Figure 2. The relation between voluntary dry matter intake and the level of crude protein and organic matter digestibility.

Table 50. Voluntary DM intake/kg $W^{0.75}$ of the pasture grasses studied as correlated to their crude protein contents, digestibility of organic matter, digestible energy and to their gross energy contents.

Type of pasture and stage of regrowth	DM intake g/kg $W^{0.75}$/day	Crude protein % D.M.	Organic matter dig. Coef.	Digestible energy Kcal/g DM	Gross energy Kcal/g DM
P. clandestinum					
8 weeks	56.0	19.1	67.0	2.750	4.321
11 "	52.9	14.8	63.3	2.444	4.187
15 "	36.1	13.7	56.7	2.212	4.098
		0.7596*	0.9765*	0.8973*	0.8947*
C. gayana					
First batch (Muguga)					
c.v. Mbarara					
8 weeks	54.9	6.9	64.2	2.498	4.038
12 "	53.6	6.4	57.8	2.386	4.197
16 "	50.0	5.8	48.5	1.780	4.084
		0.9775*	0.9874*	0.9936*	0.0220*
Second batch (Kitale)					
c.v. Mbarara					
6 weeks	52.0	12.7	57.4	2.208	4.242
8 "	50.0	8.7	55.8	2.360	4.399
10 "	47.5	8.5	58.5	2.136	4.054
		0.8548*	-0.4627*	0.3746*	0.5948*
Third batch (Kitale)					
c.v. Pokot					
6 weeks	49.4	7.7	60.1	2.402	4.065
9 "	47.7	6.6	64.3	2.300	4.054
12 "	45.0	5.1	54.8	1.719	4.026
		0.9991*	0.6600*	0.9678*	0.9910*
Fourth batch (Dundori)					
c.v. Mbarara					
Sample 1 Early flowering	49.6	12.4	64.9	2.423	4.190
Sample 2 Seeds shed	42.3	4.2	64.5	1.610	3.969
Sample 3 Early flowering (16 weeks)	45.5	8.9	65.0	2.102	3.955
Sample 4 Early flowering (16 weeks)	53.7	14.1	72.8	2.560	4.013
		0.9684*	0.5194*	0.9558*	0.4151*
S. sphacelata (Kitale)					
c.v. Nandi					
4 weeks	45.6	12.2	62.4	2.497	4.180
6 "	43.1	9.1	54.6	2.247	4.013
8 "	30.6	6.6	57.6	2.135	3.990
		0.9092*	0.2846*	0.8344*	0.7002*
P. purpureum (Kitale)					
c.v. French Cameroons					
3 weeks	39.8	16.6	71.1	2.646	3.912
5 "	33.3	10.1	77.1	2.891	3.923
7 "	40.5	7.1	66.6	2.417	3.880
		0.1210*	-0.9383*	-0.9147*	-0.7541*
		0.1310**	-0.1118**	0.0961**	0.6367**

NOTE

* = r values for individual grasses

** = pooled r values for all the grasses low pooled *r* value of *0.1810* agrees with the findings of Grieve and Osbourn (1965) who correlated dry matter intake g/kg $w^{0.75}$ with crude protein of seven different tropical pasture species and obtained in fact a small negative *r* value of - *0.20*. Calculated *r* value from the work of Soneji (1970) and Minson (1971) were respectively *0.3784* and - *0.1909*. The former *r* value was for organic matter intake g/kg $w^{0.73}$ correlated to the crude protein contents of three species of grasses at four stages of regrowth; and the latter *r* value was for dry matter intake g/kg $w^{0.75}$ correlated to the crude protein content of six varieties of Panicum grasses. On the other hand the established positive correlation between intake and crude protein content for the individual grasses agrees with the findings of Blaxter, Wainman and Wilson (1961), and also agrees with the *r* value calculated from the work of Soneji (1970), which ranged from *0.5909* to *0.8883* for the three species of grasses studied by him.

Dry matter intake g/kg $w^{0.75}$/day was correlated to digestibility of organic matter as the second criterion of forage quality and gave an *r* value of - *0.1118* for all the forages pooled together but *r* values for individual grasses were high (*0.9874* to *0.6600*) for all the grasses except for second batch C. gayana, S. sphacelata and for P. purpureum which had *r* value of - *0.4627*, *0.2846* and - *0.9383* respectively. The *r* value for the pooled forages does not agree with the findings of Grieve and Osbourn (1965)

(r = *0.57*) and the r values calculated from the work of Soneji (1970) and Minson (1971) which were *0.6094* and *0.8718* respectively. No other explanation could be given for these deviations from those calculated relationship between intake and digestibility of organic matter beside the very important fact that the forages tested in this work were growing under different environmental conditions and the species and varieties were wider than those tested by the workers quoted. However the high positive correlations between dry matter intake and organic matter digestibility for the individual grasses agree with the report of Elliot, Fokkema and French (1961) for Rhodesian veldt pastures and also agrees with the report of Corbett, Langlands and Reid (1963) for mixed grass pastures in Aberdeen. With young highly digestible herbage Harris and Raymond (1963) found no close relationship between intake and its digestibility and Campling (1964) suggested, from a review of literature, that with such herbage intake is probably not limited by its filling effect in the reticulo-rumen but possibly by chemoregulatory or thermo-regulatory mechanisms or by some other less understood factors.

Correlation coefficient between voluntary dry matter intake g/kg $w^{0.75}$/day and digestible energy Kcal/g DM was low (r = *0.0961*) for all the grasses pooled together but for individual grasses r values were high (*0.9936* to *0.8344*) for all the grasses except for the C. gayana, second batch, and P. purpureum which gave r values of *0.3746* and - *0.9147* respectively. The *r* values for the individual grasses agree with the findings of Blaxter et al (1961) who tested hay at three qualities (poor, medium and good) and concluded that the voluntary intake of the fodders by sheep were closely related to digestible energy of those fodders. In addition to correlating voluntary intake to digestible energy, voluntary intake was also correlated to gross energy and gave *r* value of *0.637* for all the grasses pooled together.

Under the conditions in these experiments and with the variety of fodders tested it was apparent that generally both crude protein content, digestibility of organic matter, digestible energy and gross energy content of forages would give an indication of voluntary intake for most grasses only when they are considered individually within their own stages of maturity. However, differences in local environmental effects of season, and differences in stages of maturity and in species and varieties of the grasses studied might make it unreliable to predict comparative voluntary intake of the fodders considered together from the comparison of the nutrients characteristics mentioned. Milford and Minson (1963-64) stated that the voluntary intake of dry matter from pastures under Australian conditions was more closely correlated with intake of digestible nutrients ($r = 0.916$) than was dry matter digestibility ($r = 0.546$) and that there was no close correlation between intake and either leafiness or nitrogen content for most species of grasses studied by them. Nitrogen content was more closely correlated with intake only when crude protein content was less than 6 percent.

3.4.4. Liveweight change.

Liveweight changes for all the pasture grasses studied as indicated in their respective tables showed that only in five cases were sheep gaining weight when the ingested DE was below 98.6 kcal/kg $w^{0.75}$/day; which is the maintainance energy requirement for sheep recalculated from $w^{0.73}$ as given by Blaxter (1962). Ingested DE at levels above 98.6 kcal/kg $w^{0.75}$/day was strongly correlated to mean liveweight gains recorded ($r = 0.8237$) and agrees with the finding of Blaxter et al (1961) and Grieve and Osbourn (1965). However mean liveweight gains were not in all cases proportional to the ingested DE in excess of that required for maintainance as given by Blaxter (1962) and the excess DE levels above maintainance were not consistent with the observed liveweight gains. That and the fact that in five cases sheep gained weight when ingested DE was below maintainance level could possibly be due to the problems inherent in the determination of accurate liveweight records.

3.4.5. Digestion coefficients and nutritive values.

In almost all the pasture grasses studied there was consistently a general trend for digestion coefficients to decrease as the grasses matured. That tendency was obvious even in the P. clandestinum which was growing in rather cooler temperatures and wetter conditions; but as its nutrient contents were much higher than in all the other grasses studied in the work the net available nutrients were equally higher. Table 51 shows falls of digestion coefficients of organic matter, crude protein and crude fibre after the periods of regrowths indicated. Among the C. gayana grasses studied it was apparent that after 2 and 4 weeks regrowth the falls in digestion coefficients ranged from units 1.6 to 6.4 for organic matter, 0.3 to 11.3 for crude protein and units 4.8 to 7.0 for crude fibre. From 4 to 8 weeks regrowth by C. gayana, first batch, drop of digestion coefficients for the three nutrients (organic matter, crude protein and crude fibre) were in general higher and that of crude protein was highest. The small increases in digestion coefficients of organic matter, crude protein and crude fibre by the C. gayana, third batch, even after a 3 weeks regrowth, could probably have resulted from the fact that the 30.7 mm rainfall recorded in that period was more evenly distributed over the 14 days. It was remarkable that after 12 weeks regrowth, the fourth batch C. gayana, sample 2, had comparatively the lowest fall in the digestion coefficient of crude protein and almost negligible falls in organic matter and crude fibre digestibility. The grass was known to have had a good proportion of Kenya wild white clover.

Like its chemical composition, C. dactylon had the lowest fall in digestion coefficients and confirms the finding of Grieve and Osbourn (1965) who also showed that the grass does not lose its quality as rapidly as many other grasses. S. sphacelata c.v. Nandi, however, showed a very high fall in the digestion coefficient of crude fibre after only 4 weeks regrowth; not a surprising feature as the grass tends to throw out stems much faster than many other grasses. It was, however, remarkable that the crude protein digestibility was maintained at the same level from 2 to 4 weeks regrowth. P. purpureum, c.v. French Cameroons, like C. dactylon, had lowest falls in organic matter and crude fibre digestibilities but showed a very drastic fall in crude protein digestibility after a regrowth period of 2 weeks, from 2 to 4 weeks.

Table 51. The fall in digestion coefficients of organic matter, crude protein and crude fibre after the regrowth period indicated.

Type of pasture	Period of regrowth	Fall in digestion coefficient units		
		Organic matter	Crude protein	Crude fibre
P. clandestinum	After 3 wks regrowth	5.6	10.3	4.9
	" 6 " "	9.3	16.0	9.7
C. gayana First batch (Muguga) c.v. Mbarara	After 4 " "	6.4	11.3	7.0
	" 8 " "	15.7	28.0	14.5
Second batch (Kitale) c.v. Mbarara	After 2 " "	1.6	6.7	5.7
	" 4 " "	+1.1	0.3	4.8
Third batch (Kitale) c.v. Pokot	After 3 " "	+4.2	+1.6	+0.1
	" 6 " "	5.3	16.2	6.5
Fourth batch (Dundori) c.v. Mbarara Sample 2	After 12 " "	0.4	24.5	0.3
C. dactylon	After 4 " "	4.0	12.3	0.0
	" 8 " "	4.0	12.0	5.0
S. sphacelata c.v. Nandi	After 2 " "	7.8	16.5	4.2
	" 4 " "	4.8	16.5	14.1
P. Purpureum c.v. French Cameroons	After 2 " "	0.0	3.3	+2.1
	" 4 " "	4.5	29.4	2.1

Note + indicate increase in digestion coefficients.

Crude fibre digestibility in all the pasture grass studied was consistently higher than the nitrogen-free extract fractions. This does not harmonize with the figures for temperate grasses, where such a trend has only occasionally been recorded, but agrees very well with the vast data by other workers for tropical pastures as reviewed by French (1957). At comparable protein levels, Laksesvela and Said (1971) noted that all the few Kenyan grasses that were compared showed that their crude fibre digestibilities were consistently higher than the nitrogen-free extract fractions. A similar trend was found for some North American grasses compared. The few North West European grasses compared by Laksesvela and Said (1973) showed the reverse trend; the crude fibre digestibilities being consistently lower than the digestibilities of the nitrogen-free extract fractions.

The results obtained with the pasture grasses studied indicate that it would have been very interesting to pursue the field further by comparing the growth characteristics and nutritive values under very identical or almost identical environmental conditions and management since it was pointed out by French (1957) that wiltting, which occurs under tropical conditions at any stage of maturity and in various different localities, result in a retarded or ceasation of growth. The absorption of soil nutrients is temporarily halted leading to a re-orientation of herbage constituents within the plants and is accompanied by a partial lignification of the cell walls. The lignification inhibits contact between the digestive enzymes and the cellular constituents resulting in lower digestion coefficients.

The tendency for lower digestion coefficients, as the grasses mature, resulting in an equally lower available nutrients, is of greatest set back especially in the tropics.

Crampton et al (1960) stated that even for animals fed temperate or subtropical perennial forages "the primary output deterents are inadequate digestible energy content and voluntary consumption rates". Holmes and Jones (1965) stated that when the digestibility of herbage is below 70 percent physical limitation of feed digestibility may restrict feed intake. It was also pointed out by Musangi (1966) that the high ambient temperatures and intense solar radiations coupled with high humidity result in lower herbage intake by the grazing animals. The three factors

a) lower nutrient contents and scarcity of herbage

b) lower digestion coefficients resulting in low available nutrients and also increased metabolic heat production by digestion and grazing activity c) and decreased herbage intake brought about by the physical effect of decreased passage of the digesta and by the thermostatic regulation of feed intake; all the three factors together, adversely affect animal nutrition from pastures in the tropics. The Bos taurus cattle breeds which are less tolerant to heat stresses and demand higher levels of nutrients, due to their higher production potentialities, are more adversely affected than their Bos indicus counterparts. However the demand for more animal products necessitates the keeping of the Bos taurus cattle breeds where possible. For the latter breeds to maintain their high production potentialities supplementary feeding, in terms of concentrates, has to be practiced as was pointed out earlier.

In almost all the pasture grasses studied the percentage falls in DCP with maturity were higher than the corresponding falls with maturity in DE and SE. In a few regrowths there were actually small increases instead of falls in DE and SE values. However, inspite of the higher falls in DCP and the comparatively more stable levels of SE, it was apparent from tables 52, 53 and 54 that energy was the limiting factor affecting milk production from the pastures studied; which could be said to represent the majority of the improved pastures used in East Africa. Only in 8 and 12 weeks regrowth C. gayana, first batch, 9 weeks regrowth C. gayana, third batch, sample 2 C. gayana fourth batch and 7 weeks regrowth P. purpureum c.v. French Cameroons (table 52) was energy not limiting for milk production but DCP was. Table 53 shows that when the DMC was lower (10 kg DMI) only four out of the five regrowth stages mentioned had a small excess energy for milk production and that in terms of milk production percentage deficiencies of energy for all the pasture grasses increased at the lower DMC, indicating that steps taken to increase the DMC of ruminants would also reduce levels of energy deficiency. With the slightly smaller cow and lower maintainance requirements (table 54) the same pastures as in table 52 showed some excesses in energy for milk production but percentages of energy deficiencies for milk production increased more compared to percentage deficiencies in table 52. It is also important to realize that as the pasture grasses mature the assessed dry matter

Table 52. Ingested DCP and SE by a 500 kg liveweight cow with a dry matter capacity of 15 kg+ and maintenance requirements of 295 g DCP and 2.90 kg SE*

Type of pasture and stage of regrowth	Ingested		Balance available after maintenance		Milk capable of being produced by the balance	
	DCP g	SE kg	DCP g	SE kg	DCP	SE
					Kg FCM*	Kg FCM*
P. clandestinum						
5 weeks	2775	7.53	2480	4.63	44.3	16.0
8 "	1935	6.51	1640	3.61	29.3	12.4
11 "	1380	5.94	1085	3.04	19.4	10.5
15 "	1185	4.59	890	1.69	15.9	5.8
C. gayana						
First batch (Muguga) c.v. Mbarara						
8 weeks	645	5.52	350	2.62	6.3	9.0
12 "	495	4.59	200	1.69	3.6	5.8
16 "	300	2.79	5	-0.11	0.1	- 0.4
Second batch (Kitale) c.v. Mbarara						
6 weeks	1080	4.46	785	1.56	14.0	5.4
8 "	645	4.34	350	1.44	6.3	5.0
10 "	720	4.58	425	1.68	7.6	5.8
Third batch (Kitale) c.v. Pokot						
6 weeks	630	4.59	335	1.69	6.0	5.8
9 "	555	5.12	260	2.22	4.6	7.7
12 "	285	3.45	- 10	0.55	- 0.2	1.9
Fourth batch (Dundori) c.v. Mbarara						
Sample 1. Early flowering	1395	6.12	1100	3.22	19.6	11.1
Sample 2. Seeds shed	315	5.57	20	2.67	0.4	9.2
Sample 3. Early flowering (16 weeks)	840	5.49	545	2.59	9.7	8.9
Sample 4. Early flowering (16 weeks)	1545	7.17	1250	4.27	22.3	14.7
C. dactylon						
10 weeks	945	4.94	650	2.04	11.6	7.0
14 "	690	4.08	395	1.18	7.1	4.1
18 "	660	4.49	365	1.59	6.5	5.5
S. sphacelata c.v. Nandi						
4 weeks	1110	5.06	815	2.16	14.6	7.4
6 "	600	3.69	305	0.79	5.4	2.7
8 "	420	2.72	125	-0.18	2.2	- 0.6
P. purpureum c.v. French Cameroons						
3 weeks	1830	5.93	1535	3.03	27.4	10.4
5 "	1065	6.72	770	3.82	13.8	13.2
7 "	465	4.91	170	2.01	3.0	6.9

NOTE:

+ As stipulated by Abrams (1961)

* As stipulated by McDonald, Edwards and Greenhalgh (1966)

Table 53. Ingested DCP and SE by a 500 kg+ liveweight cow with dry matter capacity of 10 kg+ and maintenance requirements of 295 g DCP and 2.9 kg SE*

Type of pasture and stage of regrowth	Ingested		Balance available after maintenance		Milk capable of being produced by the balance	
	DCP g	SE kg	DCP g	SE kg	DCP	SE
					Kg FCM*	Kg FCM*
P. clandestinum						
5 weeks	1850	5.02	1555	2.12	27.8	7.3
8 "	1290	4.34	995	1.44	17.8	5.0
11 "	920	3.96	625	1.06	11.2	3.7
15 "	790	3.06	495	0.16	8.8	0.6
C. gayana						
First batch (Muguga)						
c.v. Mbarara						
8 weeks	430	3.68	135	0.78	2.4	2.7
12 "	330	3.06	35	0.16	0.6	0.6
16 "	200	1.86	- 95	-1.04	- 1.7	- 3.6
Second batch (Kitale)						
c.v. Mbarara						
6 weeks	720	2.97	425	0.07	7.6	0.2
8 "	430	2.89	135	-0.01	2.4	- 0.03
10 "	480	3.05	185	0.15	3.3	0.5
Third batch (Kitale)						
c.v. Pokot						
6 weeks	420	3.06	125	0.16	2.2	0.6
9 "	370	3.41	75	0.51	1.3	1.8
12 "	190	2.30	-105	-0.60	- 1.9	- 2.1
Fourth batch (Dundori)						
c.v. Mbarara						
Sample 1. Early flowering	930	4.08	635	1.18	11.3	4.1
Sample 2. Seeds shed	210	3.71	- 85	0.81	- 1.5	2.8
Sample 3. Early flowering (16 weeks)	560	3.66	265	0.76	4.7	2.6
Sample 4. Early flowering (16 weeks)	1030	4.78	735	1.88	13.1	6.5
C. dactylon						
10 weeks	630	3.29	335	0.39	6.0	1.3
14 "	460	2.72	165	-0.18	2.9	- 0.6
18 "	440	2.99	145	0.09	2.6	0.3
S. sphacelata c.v. Nandi						
4 weeks	740	3.37	445	0.47	7.9	1.6
6 "	400	2.46	105	-0.44	1.9	- 1.5
8 "	280	1.81	- 15	-1.09	- 0.3	- 3.8
P. purpureum c.v. French Cameroons						
3 weeks	1220	3.95	925	1.05	16.5	3.6
5 "	710	4.48	415	1.58	7.4	5.4
7 "	310	3.27	15	0.37	0.3	1.3

FOOT NOTE

+ As stipulated by Morrison (1956)

* As stipulated by McDonald, Edwards and Greenhalgh (1966)

Table 54. Ingested DCP and SE by a 450 kg liveweight cow with a dry matter capacity of 10 kg+ and maintenance requirements of 270 g DCP and 2.70 kg SE*

Type of pasture and stage of regrowth	Ingested		Balance available after maintenance		Milk capable of being produced by the balance	
	DCP g	SE kg	DCP g	SE kg	DCP	SE
					Kg FCM*	Kg FCM*
P. clandestinum						
5 weeks	1850	5.02	1580	2.32	28.2	8.0
8 "	1290	4.34	1020	1.64	18.2	5.7
11 "	920	3.96	650	1.26	11.6	4.3
15 "	790	3.06	520	0.36	9.3	1.2
C. gayana						
First batch (Muguga)						
8 weeks	430	3.68	160	0.98	2.9	3.4
12 "	330	3.06	60	0.36	1.1	1.2
16 "	200	1.86	- 70	-0.84	- 1.3	- 2.9
Second batch (Kitale) c.v. Mbarara						
6 weeks	720	2.97	450	0.27	8.0	0.9
8 "	430	2.89	160	0.19	2.9	0.7
10 "	480	3.05	210	0.35	3.8	1.2
Third batch (Kitale) c.v. Pokot						
6 weeks	420	3.06	150	0.36	2.7	1.2
9 "	370	3.41	100	0.71	1.8	2.4
12 "	190	2.30	- 80	-0.40	- 1.4	- 1.4
Fourth batch (Dundori) c.v. Mbarara						
Sample 1. Early flowering	930	4.08	660	1.38	11.8	4.8
Sample 2. Seeds shed	210	3.71	- 60	1.01	- 1.1	3.5
Sample 3. Early flowering (16 weeks)	560	3.66	290	0.96	5.2	3.3
Sample 4. Early flowering (16 weeks)	1030	4.78	760	2.08	13.6	7.2
C. dactylon						
10 weeks	630	3.29	360	0.59	6.4	2.0
14 "	460	2.72	190	0.02	3.4	0.1
18 "	440	2.99	170	0.29	3.0	1.0
S. sphacelata c.v. Nandi						
4 weeks	740	3.37	470	0.67	8.4	2.3
6 "	400	2.46	130	-0.24	2.3	- 0.8
8 "	280	1.81	10	-0.89	0.2	- 3.1
P. purpureum c.v. French Cameroons						
3 weeks	1220	3.95	950	1.25	17.0	4.3
5 "	710	4.48	440	1.78	7.9	6.1
7 "	310	3.27	40	0.57	0.7	2.0

FOOT NOTE

+ As stipulated by Morrison (1959)

* As stipulated by McDonald, Edwards and Greenhalgh (1966)

intake levels in tables 52, 53 and 54 are likely to decrease and that the deficiencies for energy and digestible crude protein for production are therefore likely to be accelerated. These mathematical conclusions as regards degrees of energy deficiencies with the larger and the smaller cows would have varying implications under the varying tropical microclimates. The experimental evidence as reviewed by Payne (1966) suggested that at high ambient temperatures, 21.1^{o} to $37.8^{o}C$, feed intake was reduced more in the larger than in the smaller Bos taurus cattle breeds.

It was apparent from all three tables there was a preponderance of energy deficiency for milk production. It was also pointed out by Musangi (1969) that inadequate digestible energy in pastures was one of the most important factors affecting livestock production in Uganda. However, these conclusions do not entirely agree with the findings of Butterworth (1963) who reported that in 35 forages studied only 10 had DCP values below maintenance requirements for adult cows but that 25 were below DCP requirements for the growth of heifers/steers. He also reported that only 5 of the forages contained inadequate TDN (total digestible nutrients) for the growth of 270 kg heifer/steer and that 13 contained inadequate TDN for the growth of younger heifers/steers at 180 kg.

However, Elliot and Topps (1963), working in Rhodesia, reported that the protein requirements of cattle for maintenance are much lower than what has been accepted (1.3 g DCP/kg $w^{0.73}$/day).

It was also shown by Annison, Chalmers, Marshalls and Synge (1954) that when ruminants were given a lower supply of protein but adequate energy, they excreted very small amounts of urea since in such a case the ruminal production of ammonia, the precursor or urea, was low. In the ruminant the recycling of nitrogen in salivary urea is likely to be quantitatively important when the intake of nitrogen is low (McDonald et al 1966). In his review of nutrition of ruminants in the tropics Payne (1966) also reported that at low nitrogen intake from pasture, output of nitrogen is reduced and the nitrogen recycling mechanism is increased. Whereas protein deficiency in tropical pastures is an important factor to consider, especially as below critical levels it affects dry matter intake (see section 2.3.1.), nevertheless, the general impression from this and other published works is that there is exigency for energy supplementation if high livestock output is to be realized from such pastures.

The digestion coefficients, DCP and SE values of the D. uncinatum and the I. batatas vines show that they could make a very good contribution to the nutrition of the ruminant. It was also very interesting to note that at comparable crude protein contents, the crude protein in the grasses was more digestible than that in the D. uncinatum and I. batatas vines. The nitrogen-free extract digestibilities in both the fodders were comparatively higher than those of the grasses studied. As a result of the stemmy nature of the hay from the D. uncinatum its crude fibre was high and its digestibility was correspondingly low. It is very significant that in both the fodders studied the digestibilities of the crude fibre fractions were lower than those of their nitrogen-free extract fractions, a trend which is opposite in the grasses studied as discussed earlier. Milford (1967) also reported lower digestibility of crude fibre and higher digestibility of the nitrogen-free extract in D. uncinatum.

The higher digestion coefficients of crude protein and that of the nitrogen-free extract in the decorticated cottonseed cake, together with its lower fibre and high crude protein content, account for its higher DCP and SE values. However, it was obvious from this study that the nutritive value of the local cottonseed cakes as they are locally marketed now are of a very unpredictable value due to their very wide ranges in the crude protein and crude fibre contents. Unless there is a guarranteed specified requirements, and until when there is a governmental legislation enforcing marketing on specified guarranteed contents, the presently marketed cottonseed cakes should be considered as of a very variable quality.

Digestion coefficients of organic matter, ether extract and of the nitrogen-free extract in all the cereal by-products studied were consistently high but were highest in the "wishwa". Table 55 shows that DCP and SE values for the wheat bran studied compared well with the figures of McDonald et al (1966) for coarse middlings and of Abrams (1961) for middlings. The SE value of 0.694 g/g DM for the wheat bran tested was much higher than that of 0.591 g/g DM by Morrison (1959) and was higher than 0.498 g/g DM by French (1943). DCP values of the maize glutean feeds in table 55 were about three times higher than the value of 6.4 percent for the maize germ and bran meal studied, but their SE values compared well. For maize bran (table 55) DCP and SE values were slightly lower than those of the maize germ and bran meal studied.

Table 55. DCP and SE value of some wheat and maize by-products.

Type of feed	References	DCP % DM	SE g/g DM
Coarse middlings	McDonald, Edwards and Greenhalgh (1966)	13.5	0.660
Broad wheat bran	Abrams (1961)	11.0	0.426
Middlings	" "	12.6	0.690
Wheat bran	Morrison (1959)	13.3	0.591
Wheat bran	French (1943)	10.3	0.498
Wheat bran	This work	13.2	0.694
Maize glutean feed	Abrams (1961)	20.0	0.756
Maize bran	" "	5.5	0.670
Maize glutean feed	McDonald, Edwards and Greenhalgh (1966)	22.2	0.840
Maize bran	French (1943)	5.6	0.685
Maize bran	Morrison (1959)	5.6	0.639
Maize glutean feed	" "	21.3	0.682
Maize germ & bran meal	This work	6.4	0.802

In the three cereal by-products studied "wishwa' was richest in SE value and took second place to wheat bran in its DCP value. "Wishwa" was cheapest in terms of DCP and SE than wheat bran (See table 56). DCP in maize germ and bran meal was the most expensive of the three feeds but it was cheaper in SE than wheat bran. However, "wishwa" is not in industrial production and whatever is available is probably just enough for use at district level. For a farmer outside the Coast Province a choice between wheat bran and "wishwa" will also be dictated by haulage expenses, as that could easily increase the price per unit of nutrient to equal or even exceed the wheat bran. Where "wishwa" is available locally, as at the Kenya Coast, it is apparently the cheapest of the three concentrates studied. In fact it is being used there by many farmers as the only feed supplement to livestock.

Table 56. Comparative costs per kg DCP and SE of wheat bran, maize germ and bran meal and of "wishwa" in Kenya Shillings (K.Shs.).

Type of feed	Current cost: (K. Shs.)	Cost per kg DCP (K.Shs.)	Cost per kg SE (K.Shs.)
Wheat bran	13.65 per 45 kg bag	2.55	0.48
Maize germ & bran meal	18.00 " 70 kg bag	4.41	0.35
"Wishwa"	10.00 " 70 kg bag	2.16	0.19

SECTION 4: The effects of the levels of protein and energy rich concentrate supplementation on the utilization of Chloris gayana hay by wether sheep.

4.1 Introduction

The need to adequately feed livestock in the developing countries and especially in Kenya, where a substantial number of Bos taurus cattle breeds are kept, has already been advocated in the earlier sections. It was also apparent from the study of the pasture grasses in section 3 of this work that the two major nutrients that are deficient most times of the year are likely to be protein and, most importantly, energy. However supplementation of these feed components into a ration has fundamental effects on both the basal diet and on the total ration and these effects have already been reviewed in section 2.3.

One of the most commonly used pasture grasses in the high potential farming areas in Kenya is C. gayana in its various cultivars. Since hay is also commonly made from the grass it was therefore planned to extend this study to cover the effects of the levels of protein and energy rich concentrate supplementation on the utilization of C. gayana hay.

4.2 Experimental procedure.

The experiment lasted 15 weeks. Eighteen Corriedale cross New Zealand Romney Marsh wethers averaging 45.3 kg liveweight at the beginning of the experiment, were used. They were randomly alloted to nine groups of two wethers per treatment as indicated in table 60. The wethers were confined in individual metabolism cages. After the initial weighing all the wethers were weighed again at the same time of the day at weekly intervals throughout the experimental period. After the weekly weighing they were allowed to rest on a concrete floor for 3-4 hours before they were returned to the cages.

Diets fed consisted of C. gayana hay c.v. Pokot, mixed bean meal (Phaseolus vulgaris) and maize meal, the latter two diets hereafter referred to as BM and MM respectively. The hay, which was bought from the National Agricultural Research Station, Kitale, was from a ley 1½ years old. The grass was at the flowering stage when it was mowed and cured. In the 38 days prior to mowing rainfall recorded was 145.4 mm in 24 days out of the 38 days.

Hay was fed ad libitum to all treatment groups after chopping and mixing enough to last for one week. Sufficient hay was offered so that no less than 10-15 percent of the amount offered was left after 24 hours. Mixed bean meal and maize meal, which were used as protein and energy rich concentrates respectively, were fed in ground forms as the first diets. Enough mixed beans (B) and maize (M) to last for one week were mixed in the ratios of B1 : M0, B0 : M1, B1 : M1, B2 : M1 and B1 : M2. They were ground in a hammer mill and the mixtures were respectively called diet numbers 2, 3, 4, 5 and 6 according to the order of the ratios given and as indicated in table 60. The ground mixtures were mixed again before sampling and feeding. The feeding level is also shown in table 60. All the wethers were given a comprehensive salt mixture.

Table 60. Plan of the experiment and feeding levels of hay, mixed bean meal and maize meal.

Group number	1	2	3	4	5	6	7	8	9
Diet number	1	2	2	3	4	5	3	6	4
Mixing ratio of the diets	Hay alone	B1 : MO	B1 : MO	BO : M1	B1 : M1	B2 : M1	BO : M1	B1 : M2	B1 : M1
Amount of diet offered g/wether/day	Ad lib*	50	100	50	100	150	100	150	200
Actual amount of concentrate diet offered									
BM g/wether/day	0	50	100	0	50	100	0	50	100
MM g/wether/day	0	0	0	50	50	50	100	100	100

* Hay was also offered ad lib to all the other treatment groups.

The first 3 weeks of feeding the above constituted pre-experimental period in which time the wethers became adjusted to their confined environment and to the diet. The experimental period (running from the 4th to the 15th week of feeding) was of 12 weeks duration. During this period representative feed samples were taken at weekly intervals for proximate, mineral and energy analyses. Feeds offered and left over 24 hours ere recorded every morning for each wether from the second to fifth day of feeding to represent feeds offered and ingested for one week. Total faeces output by each wether was also measured and recorded for the corresponding 4 days, assumingly, representing faeces output for feeds ingested in the 4 days. 10 percent aliquot samples of the faeces were taken for each wether and composited over the collection period for analyses as described in the earlier experiments. Total urine output from each wether was measured and recorded every second day of the feeding period of 4 days. Aliquot urine samples were taken for nitrogen determinations.

Analyses of feeds, faeces and urine were performed as described in Appendix 1. Statistical analyses (analysis of variance) were performed on results, the variance being portioned as indicated in Appendices 2 and 3.

4.3 Experimental results.

4.3.1. Chemical composition.

The chemical composition and SE of the diets used in the experiment are given in table 62. Percentage values are means of 12 weeks analyses with 3 replicates in each analyses. Gross energy values were, however, determined only in the last 7 weeks of the experiment. Weekly analyses for the 6 diets are given in Appendices 4.1 to 4.6. Diets 1, 2 and 3 refer respectively to the C. gayana hay, mixed bean meal and maize meal already referred to in table 60. Diets 4, 5 and 6 consisted of mixtures of mixed bean meal and maize meal in the varying ratios also indicated in table 60.

Hay had the highest percent dry matter content followed by bean meal and maize meal in that order. Crude protein content in the hay at 9.3 percent was higher than that in maize meal at 7.5 percent. Bean meal had the highest content of crude protein at 24.1 percent. Crude fibre and ash were highest in the hay followed by bean meal and maize meal in that order. Nitrogen-free extract, however, was highest in maize meal followed by bean meal and hay. Gross energy was again highest in maize meal and least in bean meal. Calcium was very low in maize meal and highest in the hay; while phosphorus was highest in bean meal and lowest in hay. Sodium levels were low in all the three diets.

Table 62. The mean percentage chemical composition of the hay and the concentrate diets used in the experiment.

	Diet number	D.M. %	Percent dry matter									Gross energy kcal/g DM
			Crude protein	Ether extract	Crude fibre	Ash	N-free extract	Ca	P	K	Na	
Hay	1	93.0	9.3	2.2	37.4	9.2	41.7	0.40	0.20	2.42	0.002	4.118
	S.e.	±0.49	±0.15	±0.06	±0.38	±0.15	±0.52	±0.01	±0.01	±0.08	±0.0002	±0.03
Bean meal	2	90.4	24.1	1.7	6.5	5.1	62.6	0.13	0.45	1.41	0.001	4.073
	S.e.	±0.65	±0.55	±0.05	±0.19	±0.10	±0.66	±0.003	±0.006	±0.05	±0.0001	±0.09
Maize meal	3	86.9	7.5	4.5	3.4	2.0	83.5	0.01	0.27	0.32	0.001	4.293
	S.e.	±0.81	±0.09	±0.12	±0.09	±0.21	±0.59	±0.003	±0.01	±0.01	±0.0002	±0.07
B1 : M1	4	89.3	15.7	3.3	4.8	3.2	73.0	0.07	0.37	0.83	0.001	4.184
	S.e	±0.74	±0.25	±0.07	±0.08	±0.07	±0.43	±0.002	±0.009	±0.03	±0.0001	±0.04
B2 : M1	5	89.6	18.0	3.0	5.4	3.9	69.7	0.10	0.39	1.01	0.001	4.196
	S.e.	±0.70	±0.23	±0.10	±0.13	±0.06	±0.37	±0.003	±0.003	±0.02	±0.0001	±0.05
B1 : M2	6	87.8	12.8	3.3	4.5	2.8	76.8	0.06	0.34	0.64	0.001	4.264
	S.e.	±0.68	±0.09	±0.23	±0.14	±0.06	±0.27	±0.006	±0.006	±0.02	±0.0001	±0.17

4.3.2. Dry matter and organic matter intake.

Mean dry matter and organic matter intake in g/kg $w^{0.75}$/day for the C. gayana hay is given in table 63. Levels refer to group means over the 12 weeks experimental period. Levels of intake for individual wethers in 4 days over the 12 weeks experimental period are given in Appendices 5 and 6. Appendices 7.1, 7.2 and 7.3 give the calculated metabolic liveweights in kg $w^{0.75}$, and intakes of DM and OM in g/kg $w^{0.75}$ respectively.

Table 63. Effect of levels of protein and energy rich concentrate supplementation on dry matter and organic matter intake of the C. gayana hay.

Group number	1	2	3	4	5	6	7	8	9
Diet number	1	2	2	3	4	5	3	6	4
BM g/wether/day	0	50	100	0	50	100	0	50	100
MM g/wether/day	0	0	0	50	50	50	100	100	100
H a y	A d l i b i t u m								
DMI from hay g/kg $w^{0.75}$/day	44.8	52.9	48.0	51.1	52.7	49.4	45.2	49.8	46.9
S.e.	±1.52	±0.79	±1.26	±1.10	±1.51	±1.13	±0.83	±0.96	±0.58
OMI from hay g/kg $w^{0.75}$/day	41.0	48.7	45.1	46.4	48.0	44.8	41.0	45.5	42.6
S.e.	±1.41	±0.90	±0.77	±1.03	±1.53	±0.78	±0.81	±0.94	±0.55

Analysis of variance for dry matter intake of the C. gayana hay is given in Appendix 8. Both BM and MM supplementation to the hay resulted in apparent increased dry matter intake of the hay but the increases were not significant. Increasing the levels of supplementation of both BM and MM from 50 g to 100 g/wether/day, however, caused apparent decreases in the dry matter intake of the hay but they were not significant either. However, levels of intake of the hay were never lower than in the unsupplemented hay. The BM x MM interaction was not significant.

4.3.3. Apparent digestion coefficients of the hay and the total diets.

Apparent digestion coefficients of dry matter, organic matter, crude protein, ether extract, crude fibre, nitrogen-free extract and of gross energy are given in table 64. Coefficients and SE refer to group means over the 12 weeks experimental period, with the exception of GE which was determined only in the last seven weeks of the experiment. Individual apparent digestion coefficients are given in Appnedices 9.1 to 9.7. Appendices 10 to 16 give analyses of variance for the digestion coefficients of the nutrients studied.

It will be seen in table 64 that the digestion coefficient of crude fibre in the hay was higher than that of the nitrogen-free extract, a trend which was observed in all the other grasses studied in this work. BM supplementation did not significantly increase the digestibilities of any of the nutrients studied except that of the ether extract. There was a significant linear effect of ether extract digestibility in the total diet ($P < 0.05$) as BM supplementation was increased from 50 g to 100 g/wether/day.

There was a tendency for the digestibility of crude fibre to decrease with increased levels of BM supplementation but this quadratic effect was not significant.

Table 64. Apparent digestion coefficients of the hay in group 1 and the effect of levels of protein and energy rich concentrate supplementation on apparent digestion coefficients of the total diets in group 2 to 9.

Group numbers	1	2	3	4	5	6	7	8	9
Ration numbers	1	2	2	3	4	5	3	6	4
BM g/day/wether	0	50	100	0	50	100	0	50	100
MM g/day/wether	0	0	0	50	50	50	100	100	100
Dig. coeffs. of hay and total diets									
Dry matter	56.8	57.6	58.3	60.2	58.0	60.4	58.5	62.2	64.4
S.E.	±1.33	±1.11	±1.49	±1.14	±1.74	±1.34	±1.67	±1.45	±1.34
Organic matter	58.7	60.2	61.5	62.5	60.1	63.5	62.5	64.7	65.6
S.E.	±1.50	±1.00	±1.17	±1.05	±1.68	±1.29	±1.10	±1.43	±1.48
Crude protein	48.3	51.3	54.2	53.3	50.5	55.5	50.3	55.4	54.9
S.E.	±2.17	±1.20	±1.66	±2.13	±2.38	±1.80	±1.81	±1.58	±2.07
Ether extracts	41.3	48.0	48.1	50.4	49.8	51.6	46.7	51.6	58.3
S.E.	±4.96	±4.80	±4.54	±4.79	±4.21	±3.90	±4.64	±2.81	±3.97
Crude fibre	64.3	67.5	66.3	67.5	64.6	67.4	65.7	68.3	69.9
S.E.	±2.92	±1.58	±1.45	±1.29	±1.93	±3.61	±1.88	±1.70	±2.47
N-free extract	54.3	56.4	59.4	59.7	59.7	62.4	62.3	63.3	64.9
S.E.	±1.92	±1.20	±1.56	±1.50	±1.65	±1.22	±1.29	±1.72	±2.70
Gross energy	51.8	54.6	56.0	57.8	55.6	59.1	58.0	58.7	61.9
S.E.	±1.41	±1.43	±2.51	±1.37	±2.63	±1.24	±1.28	±2.06	±1.52

MM supplementation did not significantly increase the digestibilities of all the nutrients in the total diet except those of ether extract and the nitrogen-free extract. The digestibilities of the ether extract and nitrogen-free extract in the total diet were significantly increased with MM supplemention ($P < 0.05$) as were the linear effects when MM supplementation was increased from 50 g to 100 g/wether/day ($P < 0.05$). Whereas MM supplementation did not significantly increase the digestibilities of dry matter and gross energy in the total diet, the linear effects in the digestibilities of the two nutrients were significant ($P < 0.05$) as MM supplementation was increased from 50 g to 100 g/wether/day.

The effect of BM x MM interaction on the digestibilities of all the studied nutrients in the total diets were not significant. The BM_L x MM_L interactions were not significant for any of the nutrients studied.

4.3.4. Nitrogen excretion and retention.

Table 65 shows nitrogen balance in the 9 groups of animals as affected by levels of protein and energy rich concentrate supplementation. The values quoted for nitrogen intake, excreted in faeces and urine, and for nitrogen retained refer to means of group means over the 12 weeks experimental period. Individual group values are given in Appendices 17.1 to 17.4. Regretably analyses of variance could not be attempted on the figures in those appendices as replicates were erroneously eliminated by pooling urine samples from any one treatment group of two wethers. It is therefore not possible to have any meaningful interpretation of the results in table 65. One can

Table 65. Nitrogen balance in the hay in group 1 and the effect of levels of protein and energy rich concentrate supplementation in nitrogen balance in the total diets in groups 2 to 9.

Group number	1	2	3	4	5	6	7	8	9
Diet number	1	2	2	3	4	5	3	6	4
BM g/wether/day	0	50	100	0	50	100	0	50	100
MM g/wether/day	0	0	0	50	50	50	100	100	100
Hay	Ad libitum								
N-balance g/kg $w^{0.75}$/day									
Ingested N	0.69	0.91	0.95	0.83	0.92	0.97	0.75	0.89	0.96
S.e.	±0.34	±0.37	±0.34	±0.31	±0.45	±0.34	±0.29	±0.35	±0.26
Faecal N	0.35	0.44	0.43	0.38	0.44	0.43	0.37	0.39	0.41
S.e.	±0.19	±0.23	±0.14	±0.20	±0.23	±0.28	±0.15	±0.23	±0.15
Urinary N	0.19	0.22	0.22	0.15	0.25	0.23	0.17	0.23	0.23
S.e.	±0.13	±0.15	±0.18	±0.21	±0.18	±0.38	±0.22	±0.23	±0.22
Retained N	0.15	0.25	0.30	0.30	0.23	0.31	0.21	0.27	0.32
S.e.	±0.39	±0.32	±0.42	±0.46	±0.57	±0.67	±0.71	±0.44	±0.62
Retained N as a % of intake	21.7	27.5	31.6	36.1	25.0	32.0	28.0	30.3	33.3

only cautiously note the trends of nitrogen excretion in the faeces and urine and retained nitrogen with the types and levels of concentrate supplmentations used. Excretion of faecal and urinary nitrogen apparently increased from 0.35 and 0.19 g/kg $w^{0.75}$/day to 0.44 and 0.22 g respectively with 50 g BM supplementation. With 100 g BM supplementation levels of nitrogen excretion in both the faeces and urine were almost the same as at 50 g BM supplementation. There was an apparent linear increase in nitrogen excretion in both faeces and urine as BM supplementation levels increased from 50 g to 100 g/wether/day.

With increased MM supplementation there was also an apparent linear increase in faecal nitrogen excretion. However, urinary nitrogen excretion decreased at 50 g MM supplementation and only increased to a little higher than non-supplemented animals at 100 g MM.

There was an apparent linear increase in nitrogen retention with increase of BM supplementation from 50 g to 100 g/wether/day. Nitrogen retention was also apparently linearly increased by the MM supplementation. With 50 g MM supplementation, retained nitrogen in g/kg $w^{0.75}$ was twice as much as when hay was fed alone and was higher than at 50 g BM supplementation. With 100 g MM supplementation retained nitrogen was apparently higher than when hay was fed alone, but was lower than at 50 g MM.

Retained nitrogen, as a percentage of the total nitrogen intake, also increased in a linear fashion as the levels of BM supplementation increased. Retained nitrogen as a percentage of nitrogen intake was apparently highest with 50 g MM supplementation and second highest with 100 g BM/100 g MM supplementation but total nitrogen retained was highest with the latter levels of supplementation.

4.3.5. Digestible crude protein, digestible energy and starch equivalent value.

Table 66 gives contents and intakes of DCP, DE and SE in the hay by groups 1 to 9. Values refer to the mean intakes of two wethers in the 12 week experimental period.

Appendix 18.1 gives the calculated crude protein ingested in the 12 weeks by the 9 groups. Appendices 18.2 and 18.3 give the calculated DCP content percent dry matter and DCP ingested in g/kg $w^{0.75}$/day by the 9 groups. Ingested gross energy in the hay by group 1 and in the total diets ingested by group 2 to 9 is given in Appendix 19. Appendices 20, 21 and 22 give contents of DE in kcal/g DM, total DMI by the 9 groups in weeks 6 to 12 and ingested DE in kcal/kg $w^{0.75}$/day in the hay by group 1 and in the total diets ingested by groups 2 to 9.

Calculation of SE values in groups 2 to 9 were done after calculating the composite contents of crude protein, ether extract, crude fibre and nitrogen-free extract percent dry matter in the total diets ingested. These calculations are given in Appendices 23.1 to 23.8. Calculated SE values are given in Appendices 24.1 to 24.9. Appendices 25 to 27 give analyses of variance of ingested DCP, ingested DE and ingested SE. DE was determined only over the last 7 weeks of the experiment.

Ingested DCP was 2.1 g/kg $w^{0.75}$/day in the unsupplemented diet of hay. With 50 g and 100 g BM supplementation, total DCP ingested increased to 3.0 and 3.2 g respectively. This linear increase in total DCP ingested was significant ($P < 0.01$).

With 50 g MM supplement total ingested DCP at 2.8 g/kg $w^{0.75}$/day was higher than when hay alone was fed. When MM supplement was increased to 100 g, total DCP

Table 66. Effect of the level of protein and energy-rich concentrate supplementation to C. gayana hay on the content and ingestion of DCP, DE and SE.

Group number	1	2	3	4	5	6	7	8	9
Diet number	1	2	2	3	4	5	3	6	4
BM g/wether/day	0	50	100	0	50	100	0	50	100
MM g/wether/day	0	0	0	50	50	50	100	100	100
H a y	A d l i b i t u m								
DCP % DM in hay and in total diet ingested	4.5	5.2	5.9	4.9	5.0	5.8	4.7	5.4	5.7
S.e.	±0.25	±0.18	±0.22	±0.26	±0.28	±0.23	±0.21	±0.19	±0.25
DCP ingested g/kg $w^{0.75}$/day	2.1	3.0	3.2	2.8	3.0	3.4	2.4	3.1	3.3
S.e.	±0.14	±0.12	±0.16	±0.17	±0.20	±0.16	±0.13	±0.13	±0.15
DE kcal/g DM in hay and in total diet ingested	2.136	2.247	2.309	2.390	2.292	2.438	2.399	2.423	2.492
S.e.	±0.069	±0.045	±0.113	±0.065	±0.112	±0.063	±0.061	±0.087	±0.064
DE ingested kcal/kg $w^{0.75}$/day	100.033	126.142	119.843	126.512	133.408	135.371	118.283	132.339	138.580
S.e.	±7.773	±4.335	±9.038	±4.401	±11.641	±5.607	±4.679	±7.052	±4.751
SE in hay and in total diet ingested g/g/DM	0.506	0.531	0.543	0.550	0.537	0.565	0.554	0.574	0.591
S.e.	±0.016	±0.010	±0.012	±0.009	±0.014	±0.010	±0.012	±0.014	±0.014
SE ingested g/kg $w^{0.75}$/day	22.73	29.31	28.83	29.37	30.92	31.91	27.68	32.39	33.15
S.e.	±1.26	±0.65	±1.18	±1.10	±1.50	±0.91	±0.92	±1.12	±1.05

ingested decreased from 2.8 to 2.4 g/kg $w^{0.75}$/day; this was probably a result of decreased dry matter intake of hay and/or also decreased digestibility of the crude protein in the total diet. The increased intake of DCP from 2.1 g to 2.8 g with 50 g MM supplementation was not significant; neither was the decreasing effect of 100 g MM supplementation on DCP intake significant.

BM x MM interaction on DCP intake for all levels of supplementation was not significant as was BM_L x MM_L interaction.

Total ingested DE in kcal/kg $w^{0.75}$/day (table 66) was not significantly increased by either BM or MM supplementation. The apparent linear effect of BM supplementation in increasing ingested DE was also not significant.

When 50 g MM was supplemented to the hay total ingested DE was apparently higher than when 50 g BM was supplemented. When MM supplementation was increased to 100 g, total DE ingested/kg $w^{0.75}$ was insignificantly decreased; this was lower than with any of the other BM supplemented levels but was higher than with unsupplemented hay diet. Presumably this apparent decrease was a result of lowered dry matter intake of hay. The apparent increase in DE intake as a result of MM supplementation was also not significant. BM x MM and

BM_L x MM_L interactions on DE intake in g/kg $w^{0.75}$ for all levels of supplementation were not significant.

Ingested SE g/kg $w^{0.75}$/day in the unsupplemented hay diet and with the supplemented levels of 50 g and 100 g BM varied in the same pattern as DE. It increased insignificantly with 50 g BM supplementation and decreas as the level of BM supplementation was increased to 100 g but was higher than in the unsupplemented hay. The linear and the quadratic effects of BM supplementation were, however, not significant.

With 50 g MM supplementation total ingested SE was apparently higher than at either levels of BM supplementation. However ingested SE decreased to 27.68 g/kg $w^{0.75}$ when MM supplementation was increased to 100 g. Both the linear and the quadratic effects of MM supplementation were, however, not statistically significant. BM x MM and BM_L x MM_L interactions for all levels were also not significant.

4.3.6. <u>Liveweight changes</u>.

Table 67 gives liveweight gains by the 9 treatment groups. Values refer to daily means for the two wethers in each group. Ingested DE and retained nitrogen are also indicated in table 67. Liveweight gains calculated by linear regression analyses together with their *P* values have been included in table 67. Appendix 28 gives individual liveweights of the wethers throughout the experimental period. Individual observed liveweight changes during the 12 week experimental period are given in Appendix 29. Appendix 30 give analyses of variance for the observed liveweight gains.

Table 67. Effect of the level of protein and energy rich concentrate supplementation to C. gayana hay on liveweight gains of wethers.

Group number	1	2	3	4	5	6	7	8	9
Diet number	1	2	2	3	4	5	3	6	4
BM g/wether/day	0	50	100	0	50	100	0	50	100
MM g/wether/day	0	0	0	50	50	50	100	100	100
Hay	Ad libitum								
Initial mean lwt kg.	39.3	44.3	44.5	45.8	43.8	48.5	43.5	50.5	50.0
Observed mean lwt gain g/wether/12 weeks	0	500	250	500	250	1250	1000	2250	2500
g/wether/day	0	6	3	6	3	15	12	27	30
[1]Calculated mean lwt gain g/wether/day	3	18	19	8	11	22	13	34	36
t value	0.597*	2.611**	2.627**	1.353*	1.334*	2.848**	1.501*	3.688**	3.695***
Ingested DE kcal/kg $W^{0.75}$/wether/day	100.033	126.142	119.843	126.512	133.408	135.371	118.283	132.339	138.580
Retained N g/kg $W^{0.75}$/wether/day	0.15	0.25	0.30	0.30	0.23	0.31	0.21	0.27	0.32

[1]Calculated by linear regression analysis.

* Not significant

** Significant - $P < 0.05$.

*** Significant - $P < 0.01$.

Both BM and MM supplements at the levels given did not have any significant effects on liveweight gains (Appendix 30). Observed small liveweight gains (means of 12 weeks) were closely correlated to GE intake from the BM and MM supplements ($r = 0.846$, $P < 0.01$). When liveweight gains were correlated to ingested DE and to retained nitrogen, r values were 0.632 and 0.503 respectively but both the r values did not reach the 5 percent level of significance.

It is apparent from table 67 that unsupplemented hay by group 1 provided maintenance level of feeding and that the supplemental levels given were possibly too small to elicit any significant effect on liveweight gains. When 50 g BM were supplemented there was a daily gain of only 6 g/wether; this decreased to 3 g when BM supplementation was increased to 100 g; despite a slightly higher nitrogen retention level with 100 g than with 50 g BM supplementation. With 50 g MM supplementation observed liveweight gains were the same as with 50 g BM supplementation but were doubled to only 12 g/day when MM was increased to 100 g/day. Liveweight gain calculated by regression analysis showed a very slight increase when BM supplementation was increased from 50 g to 100 g, but increasing MM supplementation from 50 g to 100 g apparently increased liveweight gain by more than 50 percent.

With 50 g BM/50 g MM observed mean liveweight gain was the same as with 100 g BM supplementation possibly indicating that 50 g levels of supplementation were too small to elicit any difference. When supplemented with 100 g BM/50 g MM the observed liveweight gain was 15 g/day; however, this was approximately half the gain observed when the hay was supplemented with 50 g BM/100 g MM. Liveweight gain by both observed and regression analyses was highest at 100 g BM/100g MM supplementation but it was not statistically significant.

4.4 Discussion of the results of Section 4.

4.4.1. Dry matter and organic matter intake of the hay.

Dry matter intake in section 4 and in the previous experiments in section 3 has been expressed in g/kg $w^{0.75}$ as it was shown by Blaxter et al (1961) that voluntary intake varied with a functional power of body weight close to 0.734. Grieve and Osbourn (1965) also reported that only 0.2 percent of the variation in daily dry matter intake was associated with differences in metabolic liveweight but that 13 percent of the variation in daily dry matter intake was attributable to gravitational weight. Blaxter et al (1961) established that the length of time necessary to establish stable intakes varied from 12-15 days. In this experiment mean dry matter and organic matter intake of the hay indicated in table 63 was for the 84 days that the wethers were on the experiment; it was assumed, therefore, to have incorporated the length of time that it takes sheep to establish stable intakes.

With the levels of supplementation indicated in table 63 both BM and MM did not significantly increase dry matter intake of C. gayana hay. It was also apparent that as the levels of supplementation increased, dry matter intake of the hay showed a tendency to decrease, relative to the supplementation at the lower levels but intake levels were never lower than when no supplements were given. Dry matter intake was apparently but not significantly decreased when MM supplementation was increased from 50 g to 100 g/wether/day and was decreased further when BM and MM supplementation together was 200 g/wether/day; but was again not lower than when no supplements were given. It is probable that if the concentrate supplements were increased to levels beyond 200 g/day there would have been actual decreases in the dry matter intake of the hay as had been shown by other workers quoted previously in the review of literature. It was also observed and reported in section 3 that intake of the basal diets of hays, which were offered *ad libitum*, in the undecorticated cottonseed cake and the wheat bran experiments, were apparelty decreased compared to intake levels of the same hays fed alone in the preceeding experiments using the same wether sheep. Holmes, Arnold and Provan (1960) reported that the feeding of concentrates from 1.81 to 2.72 kg per day caused no significant depression in the intake of silage by cows and only a slight depression in the intake of hay. Murdoch (1962) reported that both barley and cottonseed cake increased the voluntary intake by cows, offered *ad libitum*, grass silage with a crude protein content of 15.2 percent dry matter. Campling and Freer (1961) showed that the voluntary intake of straw was increased when it was supplemented with urea but Blaxter and Wilson (1963) and Murdoch (1964) reported that the voluntary intake of roughage was depressed when restricted amounts of concentrates were given. However, it was concluded by Blaxter et al (1963) that depression or increase in the dry matter intake of the roughage, apart from other factors, depends upon the quality of the roughage being supplemented. Campling and Murdoch (1966) suggested that the increase in voluntary intake of a poor quality roughage when supplemented with concentrates was probably due to an increase in the rate of disappearance of digesta from the gut which was, in turn, due to the nitrogenous constituents stimulating the cellulolytic activity of rumen microorganisms; whereas with better quality roughages there is a depression in the rate of disappearance from the reticulo-rumen of digesta derived from the roughage.

4.4.2. Digestion coefficients of the hay and of the total diet.

Apparent increases in digestibilities of organic matter, crude protein, nitrogen-free extract and of gross energy in the total diet, as a result of protein supplementation, agree with the findings of Woods et al (1956) and that of Campbell et al (1969). It is also likely that if higher levels of protein supplementation had been used in this experiment, the apparent increases would also have been statistically significant. The absence of significant effect by protein supplementation on crude fibre digestibility in the total diet also agrees with the findings of Wood et al (1956), and that of Campbell et al (1969). MM supplementation apparently improved the digestibilities of all the nutrients except for crude protein and crude fibre and this trend agrees with the finding of Campbell et al (1969) with the exception that the observed improved digestibility coefficients were not statistically significant. As was suggested by El-Shazly et al (1961) it is probable that the non-significant increase in the digestibility of the crude fibre in the total diet could have have been due to decreased digestibility of the crude fibre in the hay portion, as a result of either preferential digestion of the starch by the rumen microorganisms, or alternatively that the amylolytic bacteria compete, preferentially, for ammonia against the cellulolytic bacteria. There is also the possibility of reduced rumen pH as a result of MM supplementation which may provide a less favourable environment for the cellulolytic bacteria (Tilley et al, 1964).

4.4.3. Nitrogen excretion and retention.

The apparent increases in faecal nitrogen excretion with increasing levels of MM supplementation agree with the findings of Fontenot et al (1955) who reported a similar trend of increased faecal nitrogen excretion with increased levels of cerelose supplementation. The apparent increased nitrogen retention with increased levels of BM supplementation also agrees with the findings of Woods et al (1956) and that of Robinson and Forbes (1970) who reported that increasing the nitrogen content of the diet resulted in increased nitrogen retention. It is probable also that these apparent increases in faecal nitrogen excretion and statistically significant if the replicates effects were not erroneously eliminated and if higher levels of concentrate supplementations were used than those used in this experiment.

Mitchel et al (1940) reported that nitrogen retention increased with energy supplementation to a diet high in nitrogen content. In this study MM supplementation to the C. gayana hay with 9.3 percent crude protein resulted in apparent increases in nitrogen retention and if those increases were statistically significant they would have agreed with Lofgreen et al (1951) who showed that increased energy intake by dairy calves resulted in increased nitrogen retention when a moderately low protein ration was fed. If statistically significant, the results of this work would also agree with that of Stone et al (1965) who reported that all the three levels of energy supplementation to a ration containing 12.5 percent crude protein, nitrogen retention was significantly increased.

4.4.4. Liveweight changes and energy utilization.

Observed liveweight gains were closely correlated to GE intake from the total diet ($r = 0.734$, $P < 0.005$) and was very closely correlated to GE intake from the BM and MM supplements ($r = 0.846$, $P < 0.01$). When liveweight gains were correlated to ingested DE and to retained nitrogen r values were 0.632 and 0.503 respectively, but both these r values did not quite reach the 5 percent level of significance.

The tendency for higher liveweight gains in table 67 at higher MM levels, even though ingested DE was not very much higher than for lower liveweight gains, could possibly have been due, if they were statistically significant, to higher efficiency of utilization of ruminal metabolites. Armstrong, Blaxter and Graham (1957) observed that the efficiency of utilization of mixtures of volatile fatty acids for maintenance was decreased as the molar proportion of acetic acid was increased. Blaxter and Wainman (1964) showed that rations containing large amounts of flaked maize resulted in a marked reduction in the molar proportions of acetic acid in the steam volatile fatty acids of rumen contents. They also showed that the efficiency with which metabolizable energy was used in fattening was increased as the molar proportion of acetic acid in rumen liquor was decreased. It is probable that with 50 g MM supplementation (observed liveweight gain of 6 g/wether/day and ingested DE 126.512 kcal/kg $w^{0.75}$/day) the expected decrease in molar proportion of acetic acid was insignificant to change the efficiency of utilization of the rumen metabolites; but it was apparent that even at the lower level of 100 g MM supplementation (observed liveweight gain of 12 g/wether/day and ingested DE 118.283 kcal/kg$w^{0.75}$/day), there was a tendency of implied increased efficiency of utilization of metabolizable energy for fattening.

Table 68 and 69 give estimates of metabolizable energy and percent metabolizabilities of the ingested DE by using efficiencies of utilization of ME for maintenance and for fattening as given in ARC (1965) for table 68; and also by using values for estimation of methane and urinary energy losses also given in ARC (1965) for table 69. However, these estimates should be interpreted with caution as figures of liveweight gains used were not statistically significant. It was found in table 68 that percent metabolizability of 73 was highest in the unsupplemented C. gayana hay and decreased when BM and MM was supplemented to the hay, but the apparent decreases were not consistent with the types and levels of concentrate supplementation. Percent metabolizability was apparently least decreased when supplementation levels were 100 g MM, 50 g BM/100 g MM and 100 g BM/100 g MM. This trend, even with the very low levels of supplements used in this experiment, agrees with the results of Blaxter and Wainman (1964) who reported that with diets containing a lot of maize, metabolizable energy was unaffected by an increase in the levels supplementation. Percent metabolizability in table 69 was apparently changed little, possibly because energy loss in form of methane (8 kcal/100 kcal GE) did not take into consideration the type of diets supplying the GE whereas Blaxter and Wainman (1964) had shown that the type of diet affects the level of methane production.

Table 68. Calculation of metabolizable energy (ME) and the resultant metabolizability of the ingested DE as per observed liveweight changes.

Group number	1	2	3	4	5	6	7	8	9
Diet number	1	2	2	3	4	5	3	6	4
BM g/wether/day	0	50	100	0	50	100	0	50	100
MM g/wether/day	0	0	0	50	50	50	100	100	100
H a y	A d	l i b i t u m							
Mean lwt. kg.	39.0	44.8	45.1	46.2	44.8	50.0	44.9	52.3	52.1
Observed mean lwt. gain g/wether/day	0	6	3	6	3	15	12	27	30
NE required for maintenance (kcal) [1]	803	923	929	952	922	1030	925	1077	1073
ME required for maintenance (kcal) [2]	1084	1246	1254	1284	1246	1390	1248	1454	1448
NE required for the observed lwt. gain (kcal) [3]	0	29	14	29	14	72	57	129	143
ME required for the lwt. gain (kcal) [4]	0	71	35	71	35	169	137	306	331
Total ME required for maintenance and for lwt. gain (kcal)	1084	1317	1289	1355	1281	1559	1385	1760	1779
DE ingested/wether/day (kcal)	1488	2146	2133	2259	2296	2584	2097	2667	2706
Metabolizability of DE (%)	73	61	60	60	56	60	66	66	66

Note

1. NE required for maintenance = 63 kcal/kg $W^{0.73}$ (20.58 kcal/kg lwt) (ARC, 1965).
2. Efficiency of utilization of ME for maintenance (*km*) = 74.1 percent (ARC, 1965).
3. NE required for liveweight gain = 4.768 kcal/g liveweight gain (ARC, 1965).
4. Efficiency of utilization of ME for fattening (*kf*) as per formula ($kf = 65.6 - 0.70\ F$) where *F* is the percentage of crude fibre in the feed (ARC, 1965).

Table 69. Calculation of ME and the resultant metabolizability of the ingested DE as per energy losses in methane and in urine given in ARC (1965).

Group number	1	2	3	4	5	6	7	8	9
Diet number	1	2	2	3	4	5	3	6	4
BM g/wether/day	0	50	100	0	50	100	0	50	100
MM g/wether/day	0	0	0	50	50	100	100	100	100
H a y	A d			l i b i t u m					
Methane energy (kcal)	230	315	304	312	330	350	289	364	358
Urinary energy (kcal)	148	218	218	234	235	270	218	278	294
ME = (DE - Methane and Urinary energy) (kcal)	1111	1614	1611	1750	1731	1965	1591	2025	2054
Metabolizability of DE (%)	75	75	76	76	75	76	76	76	76

SECTION 5 Conclusions

5.1. Experiments carried out in section 3.

It was not possible to compare with each other all the pasture grasses studied in section 3 as most of them had either been growing in different areas and/or were cropped at different stages of regrowth and season. However, under the conditions of the experiments reported it was concluded that in terms of chemical composition, P. clandestinum was very nutritious but the high moisture content of the grass in the early stages of regrowth could possibly limit dry matter intake and, unless controlled, might cause pasture diarrhoea and bloat in some animals.

C. dactylon which was growing under very comparable conditions with the first batch C. gayana had, all through, higher crude protein and lower crude fibre contents compared to the first batch C. gayana. The nutritive value of C. dactylon also decreased more slowly through the three stages of regrowth compared to the first batch C. gayana. Crude protein content of S. sphacelata c.v. Nandi declined faster with maturity and crude fibre increased faster from 4 to 6 weeks regrowth but remained steady from 6 to 8 weeks regrowth. Like in the S. sphacelata c.v. Nandi, crude protein in P. purpureum c.v. French Cameroons declined faster with maturity whereas crude fibre content was only increased a little from 5 weeks to 7 weeks regrowth.

In many of the pasture grasses studied gross energy decreased little with maturity and in some cases there were almost no changes. In almost all the pasture grasses studied phosphorus and sodium levels were low and phosphorus intake was likely to be sub-maintenance with increasing maturity of the grasses and during the dry season.

Dry matter intake in most of the grasses studied was decreased with maturity. It was observed that dry matter intake was closely correlated to crude protein, gross energy and digestible energy content and also was closely correlated to the digestibility of organic matter when the correlations were within the individual grass species. Except for gross energy there were no close correlations between dry matter intake and the other nutrients mentioned when the grasses were pooled together.

With the exception of the D. uncinatum and the I. batatas vines, crude fibre in all the pasture grasses studied was more digestible than the nitrogen-free extract. There was a general trend for digestion coefficients to decrease as the grasses matured. That tendency was observed even in the P. clandestinum which was growing in rather cooler temperatures and wetter conditions. Digestibility of the nutrients studied decreased much faster with some grasses than others. This tendency for lower digestible nutrients as pastures matured affect livestock production adversely, especially under tropical conditions where both available quantity to graze on and voluntary dry matter intake are also adversely affected by the pertaining environmental conditions.

Percentage falls in the amounts of digestible crude protein in almost all the pasture grasses studied were higher than the corresponding falls in either the starch equivalent or the digestible energy but it was indicative in the worked examples in tables 52, 53 and 54 that there was a preponderance of energy deficiency for milk production by the pasture grasses studied. At lower dry matter intake capacities percentage deficiencies of energy for milk production were higher, which implied that there was need to increase dry matter intake of cows, or alternatively it might be probable that the rearing of larger dairy breeds under those conditions would be better than the smaller dairy breeds. However, this problem needs to be looked into together with other important factors such as the efficiencies of utilization of food energy by the larger and the smaller breeds of dairy cattle.

Cottonseed cakes produced locally were very variable in their crude protein values even within the decorticated and the undecorticated grades; but in all the cases the decorticated grades were superior, nutritivewise, to the undecorticated grades. In the three cereal by-products studied - wheat bran, maize germ and bran meal and "wishwa" - crude protein was highest in the wheat bran followed by "wishwa" and by maize germ and bran meal. Ether extract and nitrogen-free extract were highest in the maize germ and bran meal. However "wishwa" was richest in starch equivalent value, and was second highest in digestible crude protein. At the prices that they were sold when these calculations were done, "wishwa" was cheapest in terms of both digestible crude protein and starch equivalent. Maize germ and bran meal was the most expensive in terms of starch equivalent but cheaper than wheat bran in terms of digestible crude protein. Starch equivalent was second cheapest in the wheat bran.

Both types of cottonseed cakes and also wheat bran increased total dry matter intake by the sheep. Maize germ and bran meal and "wishwa" were not fed *ad libitum* but it was felt that they also would have increased the total dry matter intake by the sheep if they were fed *ad libitum*. However, there was an apparent decrease in the dry matter intake of the basal diets of hays as a result of feeding undecorticated cottonseed cakes and wheat bran.

5.2. Experiment carried out in section 4.

Under the experimental conditions reported in this section it was concluded that levels of supplementation with bean meal and maize meal, singularly or together, which ranged from 7 percent to 28 percent of the C. gayana hay intake, did not significantly increase the dry matter intake of the hay alone. Dry matter intake of the hay was apparently but not significantly decreased as the levels of supplementation by both bean meal and maize meal supplementation was increased from 50 g to 100 g/wether/day. However, at no levels of supplementation was the dry matter intake of the hay lower than when no supplements were given. It is probable from the observed trend of dry matter intake that if higher levels of supplements had been used, or if the number of replicates were higher than those used in this experiment the decreases in dry matter intake of the hay would have been statistically significant.

Digestion coefficients of most nutrients in the total diets were apparently but not significantly increased by the levels of bean meal and maize meal supplementation. Crude fibre digestibility in the total diet was not significantly increased by bean meal or maize meal supplements. Nitrogen retention was apparently increased by both bean meal and maize meal supplements; but it was considered not proper and fruitful to carry out analysis of variance of the nitrogen figures as, regretably, replicate effects were erroneously eliminated.

Both the levels of bean meal and maize meal supplementation used resulted in apparent but insignificant increases in liveweight gains. There was a very close significant correlation between liveweight gain and gross energy intake from both the total diet and from the supplements alone. Apparent liveweight gains were also closely correlated to retained nitrogen but both these two r values did not quite reach the 5 percent level of significance.

There was a tendency, but statistically insignificant, for comparatively higher liveweight gains at higher maize meal supplementation even though ingested digestible energy levels were not very much higher than those attained at lower liveweight gains with bean meal supplementation. It was suggested that, possibly, the higher levels of maize meal supplementation resulted in increased efficiencies of utilization of rumen metabolites as was indicated by other workers (Armstrong et al, 1957 and Blaxter and Wainman, 1964).

Metabolizability of digestible energy tended to decrease as a result of bean meal and maize meal supplementation to the C. gayana hay. However, percent metabolizability was apparently least decreased at higher levels of maize meal supplementation.

In the final analysis the main conclusion to be drawn from the experiment in section 4 of this work is that the trend of the parameters studied would, most likely, have been more marked and statistically more clear cut if the supplements used were fed at higher levels and, possibly, if the number of replicates were increased beyond those used therein.

5.3 Scope for further work

It is advocated that digestibility studies similar to the ones reported here should be carried out for forages growing in various other parts of Kenya. From the knowledge of such digestibility and/or established local regression equations, nutrient deficiencies may be anticipated which would then be corrected by supplementation with concentrates.

The need to supplement forages with concentrates may be more accentuated as a result of increased scarcity of agriculturally high potential land in some parts of Kenya. Such scarcity of land is already causing utilization of forages to be at a high grazing intensity in order to increase output per hectare. This increased grazing intensity is likely to lead to overstocking on some farms thus reducing productivity per individual animal unless concentrate supplements are fed. However, it is apparent from this work that for high level production from animals, under most grazing conditions, energy is likely to be the more limiting nutrient and that, comparatively, the response to energy-rich concentrate supplementation is likely to be more rewarding than supplementation with protein-rich concentrates. It is, therefore, felt that the work reported in section 4 of this report should be extended to further evaluate responses to higher levels of concentrate supplementation, especially energy, than those used therein.

The supply of many of the ingredients used to formulate common supplementary rations has been uneven and in some cases prices have been prohibitive. Under the circumstances the challenge to research should also be to develop nutritionally adequate feed supplements from ingredients that are cheap and also readily available.

SECTION 6 References

ARC = Agricultural Research Council

CISRO = Commonwealth Industrial Scientific Research Organization

FAO = Food & Agriculture Organization

NRC = National Research Council

WHO = World Health Organization

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Appendix 1. Analytical methods

1.1 Dry matter determination.

Four individually marked aluminium dishes were weighed to 4 points of decimals using a Sartorius analytical balance. About 2 g of the sample were put in each of the 4 aluminium dishes and the dishes together with the samples were weighed again to 4 points of decimals. They were then dried in a Termarks oven at 105°C for 4 hours. At the end of the 4 hours the dishes and the dried samples were cooled for 20-30 minutes in a dessicator. They were then weighed again to 4 points of decimals. The difference between the weights before and after drying was the amount of moisture evaporated. Percentage dry matter of the sample were then calculated for each of the 4 replicates. A mean of the 4 determinations was taken to represent the dry matter content of the sample.

Determinations of dry matter in faeces samples were done in 2 stages. First the representative raw faeces samples were weighed and dried in cabinet shelves for about 24 hours using circulating hot air. The dry faeces samples were then removed from the shelves and left to cool outside at room temperature for about 4 hours before they were weighed again to determine the dry weights (not moisture free). The second stage was as described in the first paragraph above. Final dry matter determinations in faeces samples were then calculated as:

$$\% \text{ dry matter in faeces} = \frac{\text{raw weight} - (A + B)}{\text{raw weight}} \times 100$$

where A = weight of water evaporated by air drying
B = dry weight x % water in air dried sample.

Percentage dry matter was given as a mean of the 4 replicates.

1.2 Crude protein determination (Macro Kjeldahl method).

1.2.1. Digestion Five Kjeldahl flasks were used. About 2 g of the sample measured to 4 points of decimals was put in the 4 flasks. The fifth flask was used as blank and only chemicals were added in it for digestion, distillation and titration. In each of the 5 flasks was added one tablet of Kjeldahl catalyst and 25 ml of concentrated sulphuric acid (H_2SO_4). The flasks were then heated by a Baird and Tatlock thermostatistically controlled heater to complete digestion of the samples. They were then left to cool before distillation.

1.3 Distillation of ammonia.

The digested contents in the 5 flasks were diluted with some distilled water. 4-5 drops of phenolphthalein indicator were added in each flask followed by 50 % Sodium hydroxide (NaOH) to a pink colour. 1 g Zink metal powder was then added and the Kjeldahl flasks were immediately connected to distillation flasks containing 50 mls of 0.1 N hydrochloric acid (HCl), and 150 ml distilled water.

1.3.1. Titration.

The cooled distillate was titrated against 0.1 N NaOH using Congo red as indicator.

1.3.2. Calculation of % N and crude protein in the sample.

$$\% \text{ nitrogen} = \frac{1.4007 \times \text{ml } 0.1 \text{ N NaOH used} \times 100}{\text{weight of sample digested}}$$

$$\% \text{ crude protein} = \frac{1.4007 \times \text{ml } 0.1 \text{ N NaOH used} \times 100 \times 6.25}{\text{weight of sample digested}}$$

Percentage crude protein was given as a mean of the 4 replicates.

1.4 Ether extract (crude fat) determination).

About 2 g of the samples measured to four points of decimals was put in each of the four Soxhlet thimbles used. Some clean cotton wool was used to plug the thimbles to prevent the contents from escaping. The thimbles were then put into Soxhlet extractors which were then connected to clean and dry Quickfit flasks which had been weighed to 4 points of decimal. About 100 mls of diethyl ether was poured over each of the 4 thimbles. The reflux condensers were placed on top of the extractors and connected to cooling water supply. The Quickfit flasks were imersed in water which was then thermostatically maintained at 48^{o} C. Extraction was continued for 18 hours. After the ether was distilled off, the flasks were dried for 2 hours at 105^{o} C in a thermostatically controlled drying oven. The Quickfit flasks were then transferred to a desiccator to cool for about 20-30 minutes. They were then weighed again to 4 points of decimals. The increased weights of the flasks represented the weights of crude fat extracted from the measured samples.

Percentage ether extract was calculated:

$$\%\text{ ether extract} = \frac{\text{(weight of ether extract in the quickfit flask)}}{\text{weight of sample}} \times 100$$

Percentage ether extract in the sample was given as a mean of the 4 replicates.

1.5 Crude fibre determination.

2 g of the sample, measured to 4 points of decimals, were put in four 600 ml graduated beakers, some boiling water was added in each of the beakers, followed by 25 ml of 2.04 N Sulphuric acid (H_2SO_4). More boiling water was added to the 200 ml mark. The mixture in the beakers were boiled on a hot plate for 30 minutes. Using a vacuum pump the mixtures were then filtered through filter tubes packed with glasswool, and washed 3 times with boiling water.

The filter tubes were then disconnected from the vacuum pump, and left in the beaker. Some boiling water was added into the beakers, followed by 25 ml 1.78 N potassium hydroxide (KOH) to each beaker and they were again filled with boiling water to the 200 ml mark. The mixtures were boiled for another 30 minutes and were then filtered and washed 3 times with boiling water as described in the first filtration process. The filter tubes were finally washed with small amounts of ethanol followed by ethyl ether.

The glasswool with the fibre were removed from filter tubes and transferred to 100 ml silica dishes. The dishes and the glasswool were dried in a Termarks oven at 105^{o} C for 2 hours. They were then cooled in a desiccator for 15-20 minutes and weighed to 4 points of decimals. The dishes were then transferred to a Heraeus muffel oven and kept at 600^{o} C for 30 minutes. The furnance was then cooled down to 100^{o} C and the dishes were cooled in a desiccator for 15-20 minutes. Then they were again weighed to 4 points of decimals. The difference in the weights before and after ignition gave the weight of the fibre.

$$\% \text{ crude fibre} = \frac{(A - B) \times 100}{\text{weight of the sample}}$$

where: A = weight of dish and glasswool before ignition

B = weight of dish and glasswool after ignition

Percentage crude fibre of the sample was given as a mean of the 4 replicates.

1.6 Ash determination

Four silica crucibles were weighed to 4 point of decimals. About 2 g of the sample was put in each of the 4 dishes and they were again weighed to 4 points of decimals. The difference between the two weights gave the weights of the samples. The dishes were placed in a Heraeus muffel oven and the temperature kept at 600° C for 3 hours. Complete ashing was ensured by stirring the ash carefully with a small platinum spatula. The furnance was then cooled down to 100° C, and the crucibles transferred to a desiccator and cooled for 15-20 minutes. They were then weighed to 4 points of decimals. The difference in the weights between the crucibles with the ash and the empty crucibles gave the weights of the ashes.

$$\% \text{ ash} = \frac{(\text{weight of the crucible + ash}) - (\text{weight of empty crucible})}{\text{weight of the sample}} \times 100$$

Percentage ash was given as mean of the 4 replicates.

1.7 Nitrogen-free extract (NFE).

Nitrogen-free extract was obtained by subtraction.

NFE = 100 % - summed percentages of moisture, crude protein, ether extract, crude fibre and ash.

1.8 Minerals determination.

Minerals determination were done using a Perkin-Elmer Model 303 atomic absorption spectro photometer. 2.000 g of sample material was taken and digested by heating with 15 ml of concentrated perchloric acid and 5 ml concentrated nitric acid (HNO_3). The solution was left to cool. The digested sample was transferred to a volumetric flask and diluted to 100 ml with demineralized water. This solution, ready for minerals determination was stored in plastic bottles. Standard curves were prepared from standard solutions for every element to be determined. Dilutions of the sample solution were run, and the content of each element was calculated using the standard curves.

1.9 Gross energy determinations.

Energy determinations were done using Gallenkamp adiabatic bomb calorimeter. Using a tableting press, a quantity of the sample to be determined was pressed into a tablet weighing about one gram. It was weighed to 4 places of decimals and placed in a nickle crucible. The crucible was secured in a holder in the bomb assembly. A 5-mp ignition wire 9 cm long was connected across the two terminals and a cotton fuse of similar length tied onto the wire with the ends touching the tablet. 1 ml of distilled water was put in the bomb to dissolve the oxides of sulphur and nitrogen when the tablet was burnt. The bomb was assembled and tested on the instrument for proper electrical connections. The bomb was filled with oxygen to a pressure of 25 atmospheres through a valve in the bomb.

The bomb was placed in the adiabatic calorimeter vessel containing 2.1 kg of distilled water. Adiabatic conditions were obtained by stabilising the calorimeter for 15 minutes. The temperature was then recorded and the bomb was fired. Seven to eight minutes were given for the temperature to rise. The final temperature was read. The rise in temperature was caused by the heat of combustion. The bomb was then removed from the instrument and excess pressure was released. The water in the bomb was washed quantitively into a beaker and diluted to about 100 ml volume. Correction values for the temperature rise due to oxidation of sulphur and nitrogen were obtained by determining the amount of H_2SO_4 and by titrations.

Calculation

1. Nickel wire and cotton fuse correction = 0.075° C

   Sulphur and nitrogen correction = 0.008° C

   Total correction 0.083° C

   The total is subtracted from the temperature rise observed.

2. $^oC \text{ per g dry matter} = \frac{\text{Corrected } ^oC \text{ temperature rise}}{\text{Dry matter mg.}}$

3. Calories per g = (°C per g D.M.) x (instrument factor of 2.586 cal/°C)

Appendix 2. Analysis of variance for dry matter intake, digestibility coefficients of DM, OM, CP, EE, CF, NFE, GE and for intake of DCP and SE

Source			df
Weeks			11
Treatments			8
Levels of supplementation with BM		2	
BM linear effect (BM_L)	1		
BM quadratic effect	1		
Levels of supplementation with MM		2	
MM linear effect (MM_L)	1		
MM quadratic effect	1		
BM x MM		4	
BM_L x MM_L		1	
Treatments x weeks			88
Replicates			1
Treatments x replicates			8
Treatments x replicates x weeks			99
Total			215

Appendix 3. Analysis of variance for ingested digestible energy from week 7 to week 12.

Source			df
Weeks			6
Treatments			8
Levels of supplementation with BM		2	
BM linear effect (BM_L)	1		
BM quadratic effect	1		
Levels of supplementation with MM		2	
MM linear effect (MM_L)	1		
MM quadratic effect	1		
BM x MM		4	
BM_L x MM_L		1	
Treatment x weeks			48
Replicates			1
Treatments x replicates			8
Treatments x replicates x weeks			54
Total			125

The second order interaction "treatment x replicates" was used to test treatments and replicates main effects while the third order interaction "treatments x replicates x weeks" was used to test weeks and treatments x weeks effects.

Appendix 4.1 Chemical composition and mineral content of the *C. gayana* hay sampled every week over the 12 weeks period.

Week No.	% DM	Percent dry matter									Gross energy Kcal/g DM
		Crude protein	Ether extract	Crude fibre	Ash	N-free extract	Ca	P	K	Na	
1	92.6	9.5	2.1	38.3	8.9	41.2	0.42	0.21	2.59	0.003	
2	92.6	9.5	2.1	38.3	8.9	41.2	0.41	0.20	2.20	0.004	
3	88.7	9.4	2.1	39.7	9.9	38.9	0.42	0.21	2.59	0.003	
4	93.7	10.0	2.2	37.5	9.8	40.5	0.45	0.22	3.06	0.002	
5	92.4	9.6	2.4	37.2	9.5	40.3	0.39	0.18	2.25	0.002	
6	94.0	9.4	1.8	34.8	8.8	45.2	0.36	0.18	2.13	0.002	4.193
7	92.5	10.0	2.1	37.8	10.0	40.1	0.40	0.20	2.28	0.002	4.173
8	95.5	8.7	2.7	35.9	9.0	43.7	0.40	0.22	2.20	0.002	3.984
9	94.0	9.4	2.2	37.4	9.6	41.4	0.45	0.18	2.70	0.002	4.071
10	93.9	8.8	2.4	36.0	8.8	44.0	0.28	0.18	2.50	0.002	4.123
11	94.4	8.3	2.2	38.5	8.3	41.9	0.30	0.18	2.36	0.002	4.111
12	92.5	9.5	2.3	37.0	9.3	41.9	0.40	0.19	2.22	0.003	4.169
Mean	93.0	9.3	2.2	37.4	9.2	41.7	0.40	0.20	2.42	0.002	4.118
S.e.	±0.49	±0.15	±0.06	±0.38	±0.15	±0.52	±0.01	±0.01	±0.08	±0.0002	±0.03

Appendix 4.2 Chemical composition and mineral content of diet No. 2 (mixed bean meal with no maize added) sampled every week over the 12 weeks period.

Week No.	% DM	Percent dry matter									Gross energy Kcal/g DM
		Crude protein	Ether extract	Crude fibre	Ash	N-free extract	Ca	P	K	Na	
1	92.3	22.8	1.7	6.1	4.8	64.6	0.13	0.48	1.26	0.001	
2	87.9	28.5	1.8	6.0	4.9	58.8	0.11	0.48	1.35	0.001	
3	87.5	25.9	1.8	6.0	5.0	60.8	0.12	0.40	1.32	0.001	
4	93.6	22.7	1.9	7.8	4.5	63.1	0.12	0.45	1.89	0.001	
5	92.3	22.3	1.6	5.7	4.8	65.0	0.12	0.46	1.31	0.001	
6	91.5	23.3	1.5	5.9	5.2	66.0	0.12	0.47	1.35	0.001	4.313
7	88.4	24.1	1.9	7.1	5.8	61.1	0.12	0.45	1.51	0.001	4.333
8	93.4	23.3	1.6	6.6	4.9	62.7	0.15	0.43	1.35	0.001	4.191
9	91.3	22.2	1.4	6.5	5.2	64.7	0.15	0.43	1.38	0.001	3.627
10	89.5	25.2	1.5	6.7	5.4	61.2	0.15	0.43	1.43	0.001	3.887
11	87.5	25.8	1.9	7.4	5.2	59.7	0.12	0.43	1.35	0.002	4.067
12	90.2	23.2	1.6	6.4	5.4	63.4	0.14	0.44	1.40	0.001	4.095
Mean	90.4	24.1	1.7	6.5	5.1	62.6	0.13	0.45	1.41	0.001	4.073
S.e.	±0.65	±0.55	±0.05	±0.19	±0.10	±0.66	±0.003	±0.006	±0.05	±0.0001	±0.09

Appendix 4.3 Chemical composition and mineral content of diet No. 3 (maize meal with no mixed bean meal added) sampled every week over the 12 weeks period.

Week No.	% DM	Percent dry matter									Gross energy Kcal/g DM
		Crude protein	Ether extract	Crude fibre	Ash	N-free extract	Ca	P	K	Na	
1	89.3	7.7	3.7	3.2	1.6	83.8	0.01	0.30	0.24	0.001	
2	85.2	7.9	4.7	4.0	1.8	79.6	0.01	0.30	0.26	0.001	
3	85.4	7.5	5.1	3.2	1.9	82.3	0.01	0.39	0.33	0.001	
4	89.7	7.5	4.3	3.9	2.3	82.0	0.01	0.31	0.41	0.001	
5	91.0	7.6	5.1	3.2	1.8	82.3	0.01	0.28	0.29	0.001	
6	86.2	8.2	4.3	3.5	4.2	81.3	0.01	0.27	0.33	0.001	4.322
7	99.6	7.0	4.8	3.1	1.7	83.4	0.01	0.28	0.28	0.001	4.399
8	86.9	7.5	4.9	3.1	1.7	85.8	0.01	0.26	0.27	0.001	4.287
9	83.2	7.0	4.2	3.5	2.1	85.8	0.01	0.27	0.33	0.001	4.072
10	89.8	7.2	4.2	3.1	1.5	86.4	0.01	0.28	0.39	0.001	4.338
11	83.7	7.5	4.7	3.6	1.7	84.5	0.01	0.28	0.34	0.001	4.566
12	83.7	7.5	4.3	3.6	1.7	84.5	0.04	0.35	0.34	0.001	4.067
Mean	86.9	7.5	4.5	3.4	2.0	83.5	0.01	0.27	0.32	0.001	4.293
S.e.	±0.81	±0.09	±0.12	±0.09	±0.21	±0.59	±0.003	±0.01	±0.01	±0.0002	±0.07

Appendix 4.4 Chemical composition and mineral content of diet No. 4 (mixed bean meal and maize meal in the ratio of 1:1) sampled every week over the 12 weeks period.

		Percent dry matter									
Week No.	% DM	Crude protein	Ether extract	Crude fibre	Ash	N-free extract	Ca	P	K	Na	Gross energy Kcal/g DM
1	89.7	15.7	3.3	5.3	3.1	72.6	0.08	0.40	0.81	0.002	
2	87.6	16.1	3.3	4.9	3.2	72.5	0.07	0.39	0.86	0.001	
3	86.4	16.5	3.6	4.7	3.4	71.8	0.06	0.42	0.84	0.001	
4	92.4	15.1	3.2	5.0	3.1	73.6	0.07	0.39	1.05	0.001	
5	91.1	15.2	3.5	4.6	3.1	73.1	0.07	0.37	0.72	0.001	
6	90.0	13.7	3.1	4.9	3.2	75.1	0.08	0.37	0.74	0.001	4.307
7	87.3	16.3	3.2	4.5	3.5	71.4	0.07	0.36	0.70	0.001	4.312
8	92.1	15.1	3.8	4.4	2.6	74.1	0.07	0.38	0.80	0.001	4.284
9	86.2	14.1	2.9	5.0	3.5	74.5	0.07	0.36	0.84	0.001	4.080
10	94.0	14.6	3.2	4.4	3.1	74.7	0.06	0.35	0.88	0.001	4.053
11	87.8	15.7	3.3	4.8	3.1	71.5	0.07	0.35	0.87	0.002	4.125
12	87.8	15.7	3.3	4.8	3.1	71.5	0.06	0.35	0.86	0.003	4.125
Mean	89.3	15.3	3.3	4.8	3.2	73.0	0.07	0.37	0.83	0.001	4.184
S.e.	±0.74	±0.25	±0.07	±0.08	±0.07	±0.43	±0.002	±0.001	±0.03	±0.0001	±0.04

Appendix 4.5 Chemical composition and mineral content of diet No. 5 (mixed bean meal and maize meal in the ratio of 2:1) sampled every week over the 12 weeks period.

Week No.	% DM	Crude protein	Ether extract	Crude fibre	Ash	N-free extract	Ca	P	K	Na	Gross energy kcal/g DM
		Percent dry matter									
1	89.5	17.7	2.7	5.8	3.7	70.6	0.09	0.41	1.08	0.001	
2	87.5	18.2	3.0	5.6	3.8	69.4	0.09	0.39	1.03	0.001	
3	85.6	19.2	3.2	5.3	4.0	68.3	0.08	0.38	0.93	0.001	
4	92.6	17.0	2.7	5.6	3.7	71.0	0.09	0.40	0.88	0.001	
5	89.1	17.9	3.6	5.5	3.9	69.1	0.08	0.39	0.98	0.001	
6	89.9	17.1	2.3	6.1	4.3	70.2	0.09	0.41	0.96	0.001	4.340
7	87.3	19.1	3.1	5.6	4.1	67.3	0.10	0.38	0.97	0.001	4.313
8	92.8	18.7	3.1	4.9	3.9	69.4	0.12	0.39	1.10	0.001	3.996
9	90.8	16.8	2.4	4.4	4.0	72.4	0.12	0.38	1.05	0.001	4.100
10	93.6	18.0	3.0	4.9	4.1	70.0	0.11	0.39	1.06	0.001	4.113
11	88.5	18.1	3.2	5.6	3.6	69.5	0.11	0.39	1.00	0.002	4.256
12	88.5	18.1	3.2	5.6	3.6	69.5	0.10	0.39	1.02	0.001	4.256
Mean	89.6	18.0	3.0	5.4	3.9	69.7	0.10	0.39	1.01	0.001	4.196
S.e.	±0.70	±0.23	±0.10	±0.13	±0.06	±0.37	±0.003	±0.003	±0.02	±0.0001	±0.05

Appendix 4.6 Chemical composition and mineral content of diet No. 6 (mixed bean meal and maize meal in the ratio of 1:2) sampled every week over the 12 weeks period.

		Percent dry matter									
Week No.	% DM	Crude protein	Ether extract	Crude fibre	Ash	N-free extract	Ca	P	K	Na	Gross energy kcal/g DM
1	88.6	12.8	3.9	4.0	2.5	76.8	0.05	0.35	0.60	0.002	
2	86.5	12.7	3.8	4.6	2.5	76.4	0.11	0.30	0.63	0.001	
3	86.7	12.9	4.0	3.9	2.8	76.0	0.05	0.35	0.62	0.001	
4	89.2	13.1	4.2	5.2	3.0	74.5	0.05	0.36	0.84	0.001	
5	90.4	12.9	4.1	4.1	2.5	76.4	0.05	0.34	0.56	0.001	
6	89.7	12.4	3.2	4.8	2.7	76.9	0.05	0.36	0.56	0.001	4.350
7	86.2	12.9	2.5	4.7	2.9	77.0	0.04	0.35	0.60	0.001	4.392
8	89.9	12.9	2.3	3.9	2.7	78.2	0.04	0.33	0.56	0.001	4.250
9	82.6	12.9	2.9	5.3	3.2	77.2	0.08	0.33	0.70	0.001	4.011
10	90.6	12.0	3.8	4.3	2.8	77.1	0.06	0.32	0.70	0.001	5.116
11	86.7	13.0	2.3	4.4	2.8	77.5	0.06	0.33	0.68	0.001	3.864
12	86.7	13.0	2.3	4.4	2.8	77.5	0.05	0.31	0.60	0.001	3.864
Mean	87.8	12.8	3.3	4.5	2.8	76.8	0.06	0.34	0.64	0.001	4.264
S.e.	±0.68	±0.09	±0.23	±0.14	±0.06	±0.27	±0.006	±0.006	±0.02	±0.0001	±0.17

Appendix 5. Dry matter intake g/wether/4 days of hay in group 1 and hay and concentrate diets (conc.) in groups 2 to 9.

Group number		1		2		3		4		5		6		7		8		9	
Diet number		1		2		2		3		4		5		3		6		4	
BM g/wether/day		0		50		100		0		50		100		0		50		100	
MM g/wether/day		0		0		0		50		50		50		100		100		100	
Hay		Ad libitum																	
Week number 1	Conc.	–	–	189	189	377	377	179	179	359	359	537	537	357	357	532	532	718	718
	Hay	2370	2739	3354	3924	3164	3427	3378	3102	3172	3792	3816	3746	3268	2797	3674	4038	3438	3589
2		–	–	176	176	352	352	170	170	350	350	525	525	341	341	519	519	701	701
		2760	2780	3196	4066	3418	3285	3935	3593	3371	3287	3867	4052	3299	3211	3987	4058	3731	3668
3		–	–	175	175	350	350	171	171	346	346	514	514	342	342	520	520	691	691
		2694	2456	2273	3983	2851	3794	3947	3195	3564	3888	3501	3530	3503	2426	3869	3959	3335	3516
4		–	–	187	187	374	374	179	179	370	370	556	556	359	359	535	535	739	739
		2935	2626	3051	4305	3402	3853	4189	3962	3831	3891	3765	3863	3580	3254	4245	4164	3612	3803
5		–	–	185	185	369	369	181	181	364	364	535	535	362	362	542	542	705	705
		2415	2698	3156	4209	3309	4035	3337	3980	3725	4015	3800	3917	3453	3045	4216	4050	3820	3731
6		–	–	183	183	366	366	172	172	360	360	539	539	345	345	538	538	720	720
		2519	2822	2869	4073	3378	3953	3728	3420	4061	3935	3728	4095	3339	3140	4114	3755	3730	3423
7		–	–	177	177	354	354	179	179	349	349	524	524	358	358	517	517	698	698
		2322	2920	3116	4291	2715	3525	3007	3861	4059	4106	3806	3864	3121	3000	4093	3964	3977	3453
8		–	–	187	187	374	374	174	174	368	368	557	557	346	348	539	539	737	737
		2390	2737	3283	4312	2893	2669	4049	3340	3683	3544	3825	3497	2834	3577	3984	3507	4134	3158
9		–	–	183	183	365	365	166	166	345	345	545	545	333	333	496	496	690	690
		2407	3093	3528	4185	3139	3657	3409	3342	3429	3693	3830	3694	2960	3547	4024	3931	3821	3598
10		–	–	170	170	340	340	180	180	376	376	562	562	359	359	544	544	752	752
		2933	2700	3202	4094	3141	3666	3789	3257	3482	2521	2908	3636	2879	3158	4007	3317	3647	3579
11		–	–	161	161	323	323	167	167	351	351	531	531	335	335	496	496	702	702
		3574	3649	3717	4142	3637	3659	4331	3715	4238	4189	3612	3694	3327	3533	4198	3961	3975	3811
12		–	–	180	180	361	361	167	167	351	351	531	531	335	335	496	496	702	702
		3011	3576	3713	3752	2202	3541	4045	2909	3681	2666	3421	3412	2419	3132	3191	3032	3281	3500
Individual wether mean	Conc.	–	–	179	179	359	359	174	174	357	357	538	538	349	349	523	523	713	713
	Hay	2694	2900	3205	4103	3104	3589	3762	3473	3691	3626	3673	3750	3165	3152	3967	3811	3708	3570
Group mean	Conc.	–		179		359		174		357		538		349		523		713	
	Hay	2797		3654		3347		3618		3659		3712		3159		3889		3639	
Group S.e.	Hay	±77		±112		±90		±81		±89		±50		±66		±66		±47	

<u>Appendix 6.</u> Organic matter intake g/wether/4 days of hay in group 1 and hay and concentrate diets in groups 2 to 9.

Group number		1		2		3		4		5		6		7		8		9	
Diet number		1		2		2		3		4		5		3		6		4	
BM g/wether/day		0		50		0		50		100		0		0		50		100	
MM g/wether/day		0		0		0		50		50		50		100		100		100	
H a y		A d l i b i t u m																	
Week number	Conc.	–	–	180	180	359	359	176	176	348	348	517	517	351	351	518	518	695	695
1	Hay	2164	2492	3055	3874	2887	3125	3083	2831	2894	3465	3479	3410	2980	2554	3348	3676	3132	3275
2		–	–	167	167	334	334	167	167	339	339	505	505	335	335	506	506	678	678
		2522	2535	2911	3704	3117	2994	3582	3274	3075	3001	3524	3690	3014	2934	4133	3694	3405	3343
3		–	–	166	166	332	332	168	168	334	334	492	492	335	335	506	506	667	667
		2421	2211	2042	3588	2567	3419	3551	2868	3204	3500	3150	3178	3154	2172	3473	3560	2996	3161
4		–	–	179	179	358	358	175	175	358	358	535	535	351	351	519	519	716	716
		2654	2374	2756	3883	3072	3478	3777	3569	3454	3517	3392	3477	3224	2934	3827	3752	3255	3431
5		–	–	176	176	353	352	178	178	353	353	514	514	356	356	529	529	706	706
		2370	2592	2854	3603	2938	3649	3019	3605	3425	3664	3489	3584	3124	2750	3814	3661	3454	3372
6		–	–	173	173	347	347	165	165	348	348	516	516	330	330	524	524	697	697
		2329	2578	2688	3731	3087	3646	3450	3139	3709	3627	3414	3736	3075	2876	3758	3433	3409	3128
7		–	–	167	167	333	333	176	176	337	337	502	502	352	352	503	503	674	674
		2042	2596	2771	3827	2389	3137	2663	3436	3617	3664	3381	3436	2764	2654	3645	3526	3538	3058
8		–	–	178	178	356	356	171	171	359	359	535	535	341	341	525	525	718	718
		2230	2506	3005	3925	2683	3371	3706	3048	3365	3251	3483	3192	2607	3257	3626	3185	3760	2866
9		–	–	173	173	346	346	163	163	333	333	523	523	326	326	480	480	666	666
		2171	2798	3208	3783	2836	3334	3136	3022	3103	3359	3463	3340	2682	3210	3642	3550	3456	3246
10		–	–	161	161	321	321	177	177	364	364	539	539	354	354	529	529	729	729
		2684	2467	2926	3733	2860	3342	3456	2971	3179	2326	2654	3315	2626	2881	3656	3029	3328	3263
11		–	–	153	153	306	306	165	165	340	340	512	512	329	329	482	482	681	681
		3294	3360	3424	3806	3349	3417	3985	3423	3893	3848	3510	3397	3067	3252	3857	3639	3652	3505
12		–	–	171	171	341	341	165	165	340	340	512	512	329	329	482	482	681	681
		2737	3254	3372	3406	2017	3232	3672	2648	3345	2436	3109	3090	2189	2839	2904	2741	2967	3168
Individual	Conc.	–	–	170	170	340	340	171	171	346	346	516	516	340	340	508	508	692	692
wether mean	Hay	2468	2646	2917	3755	2821	3345	3423	3152	3355	3304	3337	3403	2875	2859	3640	3453	3362	3234
Group	Conc.	–	–	170		340		171		346		516		340		508		692	
mean	Hay	2557		3336		3083		3287		3329		3370		2867		3546		3298	
Group S.e.	Hay	± 70		± 103		± 80		± 74		± 80		± 134		± 62		± 64		± 44	

Appendix 7.1. Calculated metabolic liveweights of the wether sheep in the 9 treatment groups over the 12 weeks experimental period.

Group number	1		2		3		4		5		6		7		8		9	
Diet number	1		2		2		3		4		5		3		6		4	
BM g/wether/day	0		50		100		0		50		100		0		50		100	
MM g/wether/day	0		0		0		50		50		50		100		100		100	
Week number																		
1	15.9	15.5	17.1	17.2	16.8	17.7	19.1	16.1	16.1	17.9	19.5	17.2	18.1	15.8	18.7	19.2	18.1	19.5
2	15.8	15.5	16.6	17.4	16.8	17.2	18.8	16.1	16.2	17.8	19.5	17.4	18.2	16.1	18.8	18.9	17.9	19.8
3	15.6	15.5	16.8	17.4	16.6	17.5	19.2	15.8	16.1	17.9	19.6	17.1	18.2	15.6	18.8	19.5	17.9	19.9
4	15.6	15.3	16.8	17.4	16.9	17.5	19.1	15.8	16.1	17.6	19.6	17.5	18.4	16.2	18.7	19.1	17.8	20.2
5	15.6	15.5	16.9	17.7	17.1	17.9	19.5	16.1	16.8	18.4	20.2	17.8	18.5	16.8	19.4	19.9	18.4	20.5
6	15.8	15.6	17.2	18.1	17.4	18.1	19.6	16.0	16.8	18.4	20.1	18.1	18.8	16.8	19.8	19.9	18.8	21.0
7	15.6	15.5	16.8	17.8	17.2	17.9	19.5	16.2	17.1	17.8	20.1	20.6	18.8	16.8	19.4	19.6	18.8	20.5
8	15.6	15.2	17.1	17.7	16.9	17.9	19.4	15.8	16.9	18.4	19.9	17.8	18.4	16.8	19.2	19.6	18.4	20.5
9	15.8	15.5	16.9	17.9	17.1	17.9	19.5	15.8	16.1	17.9	19.9	17.9	18.1	16.8	19.5	19.9	18.1	20.6
10	15.8	15.6	17.1	17.9	17.1	18.1	19.6	15.8	16.8	18.1	20.1	18.1	18.4	16.6	19.5	19.8	18.4	20.7
11	15.6	15.5	16.9	18.1	16.9	18.1	19.4	15.6	16.8	17.9	19.9	17.9	17.9	16.8	19.5	19.8	18.4	20.7
12	15.8	15.6	16.9	17.2	16.9	18.2	19.6	15.8	16.8	18.1	20.2	17.7	18.2	16.8	19.5	19.9	18.8	20.9
Wether mean	15.7	15.5	16.9	17.6	16.9	17.8	19.3	15.9	16.5	18.0	19.8	17.9	18.3	16.4	19.2	19.5	18.3	20.4

Appendix 7.2 Calculated dry matter intake of hay g/kg $w^{0.75}$/wether/day

Group number	1		2		3		4		5		6		7		8		9	
Diet number	1		2		2		3		4		5		3		6		4	
BM g/wether/day	0		50		100		0		50		100		0		50		100	
MM g/wether/day	0		0		0		50		50		50		100		100		100	
Hay	Ad libitum																	
Week number																		
1	37.3	44.2	49.0	57.0	47.1	48.4	44.2	48.2	49.3	53.0	48.9	54.4	45.1	44.3	49.1	51.2	47.5	46.0
2	43.7	44.8	48.1	58.4	50.9	47.8	52.3	55.8	52.0	46.2	49.6	58.2	45.3	49.9	53.0	53.7	52.1	46.3
3	42.3	39.6	33.8	57.2	42.9	54.2	51.4	50.6	55.3	54.3	44.7	51.6	48.1	38.9	51.5	50.8	46.6	44.2
4	47.0	42.9	45.4	61.9	50.3	55.0	54.8	62.7	59.5	54.7	48.0	55.2	48.6	50.2	56.8	54.5	50.7	47.1
5	38.7	43.5	46.7	59.5	48.4	56.4	42.8	61.8	55.4	54.6	47.0	55.0	46.7	45.3	54.3	50.9	51.9	45.5
6	39.9	45.2	41.7	56.3	48.5	54.6	47.6	53.4	60.4	53.5	46.4	56.6	44.4	46.7	51.9	47.2	49.6	40.8
7	37.2	47.1	46.4	60.3	39.5	49.2	38.6	59.6	59.3	57.7	47.3	46.9	41.5	44.6	52.7	50.6	52.9	42.1
8	38.3	45.0	48.0	60.9	42.8	37.3	52.2	52.8	54.5	48.2	48.1	49.1	38.5	53.2	51.9	44.7	56.2	38.5
9	38.1	49.9	52.2	58.5	45.9	51.1	43.7	52.9	53.2	51.6	48.1	51.6	40.9	52.8	51.6	49.4	52.8	43.7
10	46.4	43.3	46.8	57.2	45.9	50.6	48.3	51.5	51.8	34.8	36.2	50.2	39.1	47.6	51.4	41.9	49.6	43.2
11	57.3	58.9	55.0	57.2	53.8	50.5	55.8	59.5	63.1	58.5	47.9	51.6	46.5	52.6	53.8	50.0	54.0	46.0
12	47.6	57.3	54.9	54.5	32.6	48.6	51.6	46.0	54.8	36.8	42.3	48.2	33.2	46.6	40.9	38.1	43.6	41.9
Wether mean	42.9	46.8	47.4	58.2	45.7	50.3	48.6	54.6	55.7	50.3	46.2	52.4	43.2	47.7	51.6	48.6	50.6	43.8
S.e.	±1.72	±1.68	±1.66	±0.60	±1.64	±1.44	±1.53	±1.54	±1.17	±2.20	±1.07	±1.01	±1.32	±1.22	±1.11	±1.39	±1.00	±0.74

Appendix 7.3 Calculated organic matter intake of hay g/kg $W^{0.75}$/wether/day

Group number	1		2		3		4		5		6		7		8		9	
Diet number	1		2		2		3		4		5		3		6		4	
BM g/wether/day	0		50		100		0		50		100		0		50		100	
MM g/wether/day	0		0		0		50		50		50		100		100		100	
H a y	A d l i b i t u m																	
Week number																		
1	34.0	40.1	47.2	58.9	48.3	49.2	42.6	46.6	50.3	53.2	51.2	57.0	46.0	45.9	51.6	54.6	66.6	50.9
2	39.9	40.8	46.3	55.6	51.3	48.3	49.8	53.4	52.6	46.9	51.6	60.2	46.0	50.7	55.0	55.5	57.0	50.7
3	38.7	35.6	32.8	53.9	43.6	53.4	48.4	48.0	54.9	53.5	46.4	53.6	47.9	40.1	52.9	52.1	51.1	48.0
4	42.5	38.7	43.6	58.3	50.7	54.7	51.7	59.2	48.0	54.4	50.0	57.3	48.5	50.6	58.1	55.9	55.7	51.3
5	37.9	41.8	44.8	56,2	48.8	55.8	40.9	58.7	56.2	54.5	49.5	57.5	47.0	46.2	55.9	52.6	56.5	49.7
6	36.8	41.3	41.5	53.9	49.3	55.1	46.1	51.6	60.3	54.0	48.8	58.7	45.2	47.7	54.0	49.7	54.6	45.5
7	31.7	40.7	42.6	55.0	38.5	47.4	35.4	54.6	56.7	55.1	47.3	46.9	40.4	43.6	52.5	50.4	55.0	44.6
8	35.7	41.2	46.5	57.9	44.9	52.0	49.9	50.9	55.0	49.0	50.4	52.3	40.0	53.5	54.0	47.3	60.8	43.7
9	34.3	45.1	50.0	55.2	46.5	51.3	42.2	50.3	53.3	51.5	50.0	53.9	41.5	52.6	52.8	50.6	56.9	47.4
10	42.4	39.5	45.1	54.3	46.5	50.5	46.3	49.8	52.7	37.1	39.7	53.2	40.4	48.7	53.6	44.9	55.1	48.2
11	52.7	54.1	52.9	54.6	54.0	51.4	53.4	57.5	62.9	58.4	50.5	54.5	47.4	53.2	55.6	52.0	58.8	50.5
12	47.4	52.1	52.4	51.9	34.8	49.0	48.9	44.4	54.8	38.3	44.8	50.8	34.5	47.1	43.4	40.5	48.5	46.0
Wether mean	39.5	42.5	45.4	55.4	46.4	51.5	46.3	52.0	54.8	50.4	48.3	54.6	43.7	48.3	53.2	50.5	56.3	48.0
S.e.	±1.74	±1.56	±1.55	±2.05	±3.86	±0.80	±1.49	±1.37	±1.17	±1.92	±0.98	±1.08	±1.24	±1.18	±1.03	±1.30	±1.32	±0.76

Appendix 8. Analysis of variance of dry matter intake of hay by wether sheep as affected by the levels of protein and energy rich concentrate supplementation to C. gayana.

Source			df	ss	Mss	F	P
Weeks			11	1149.65	104.51	6.13	<0.01
Treatments			8	1737.08	217.13	1.05	NS
Levels of supplementation with BM		2		887.02	443.51	2.14	NS
BM linear	1			29.43	29.43	0.14	NS
BM quadratic	1			859.37	859.37	4.16	NS
Levels of supplementation with MM		2		538.08	269.04	1.30	NS
MM linear	1			34.32	34.32	0.17	NS
MM quadratic	1			15.23	15.23	0.07	NS
BM x MM		4		311.98	78.00	0.38	NS
BM_L x MM_L	1			11.83	11.83	0.06	NS
Treatments x weeks			88	1777.83	20.20	1.19	NS
Replicates			1	348.33	348.33	1.68	NS
Treatments x replicates			8	1654.21	206.78		
Treatments x replicates x weeks			99	1687.31	17.04		
Total			215	8354.41			

Appendix 9.1 Individual and mean digestion coefficients of dry matter by wether sheep in the 9 treatment groups.

Group number		1		2		3		4		5		6		7		8		9	
Diet number		1		2		2		3		4		5		3		6		4	
[illegible] g/wether/day		0		50		100		0		50		100		0		50		100	
[illegible] g/wether/day		0		0		0		50		50		50		100		100		100	
Hay		Ad libitum																	
Week number		57.1	63.5	56.6	58.6	52.9	57.4	65.7	51.7	51.8	51.2	59.4	41.0	57.7	56.6	55.9	78.6	59.6	59.6
1	X̄*	60.3		57.6		55.2		58.7		51.5		50.2		57.5		67.3		59.6	
2		55.2	55.6	42.7	67.6	57.6	61.9	70.0	60.6	64.1	64.3	65.2	64.8	50.5	63.4	63.1	54.6	66.4	69.8
	X̄*	55.4		55.2		59.8		65.3		64.2		65.0		57.0		63.9		68.1	
3		56.9	57.4	59.0	67.3	55.6	61.1	62.1	51.2	58.6	56.1	57.8	59.9	72.8	75.9	62.3	63.1	63.3	87.2
	X̄*	57.2		63.2		58.4		56.7		57.4		58.9		74.4		62.7		75.3	
4		65.7	66.2	63.1	67.3	65.8	65.5	74.9	63.7	59.4	65.2	68.0	67.3	64.5	72.4	68.3	67.5	67.3	69.0
	X̄*	66.0		65.2		65.7		69.3		62.3		67.7		68.5		67.9		68.2	
5		56.0	61.5	55.6	64.1	61.2	62.0	64.3	58.8	73.4	62.8	64.4	66.5	65.3	60.2	65.6	68.2	64.8	68.2
	X̄*	58.8		59.9		61.6		61.6		68.1		65.5		62.8		66.9		66.5	
6		52.6	64.0	51.3	55.1	64.3	60.6	59.2	55.5	62.2	57.7	56.6	63.6	61.1	60.0	61.3	61.1	59.6	63.7
	X̄*	58.3		53.2		62.5		57.4		60.0		60.1		60.6		61.2		61.7	
7		40.9	57.2	53.1	63.0	60.2	59.7	62.6	58.5	61.8	57.8	63.1	61.4	58.0	60.7	62.2	45.6	61.6	61.7
	X̄*	49.0		58.1		60.0		60.6		59.8		62.2		59.4		53.9		61.7	
8		43.5	57.2	50.2	60.2	53.0	41.6	60.9	51.0	51.8	61.4	58.4	56.2	53.0	61.1	52.5	58.1	61.9	55.9
	X̄*	50.4		55.2		47.3		56.0		56.6		57.3		57.1		55.3		58.9	
9		45.5	61.6	38.1	66.2	60.0	63.3	61.1	61.3	55.6	61.1	61.9	61.9	60.2	64.0	65.4	66.0	63.2	63.7
	X̄*	53.6		52.2		61.7		61.2		58.4		61.9		62.1		65.7		63.5	
10		51.6	58.2	51.8	59.0	57.3	56.8	58.9	53.5	56.4	39.2	53.8	59.9	58.3	60.2	62.3	58.0	64.8	59.5
	X̄*	54.9		55.4		57.1		56.2		47.8		56.9		59.3		60.2		62.2	
11		58.2	62.7	57.8	61.0	60.5	57.7	63.4	58.1	62.6	58.8	62.3	57.7	59.1	60.6	66.2	65.5	63.4	68.9
	X̄*	60.5		59.4		59.1		60.8		60.7		60.0		59.8		65.9		66.2	
12		53.2	61.1	57.9	55.6	43.5	57.7	65.3	51.7	53.5	44.9	59.4	57.9	47.3	60.1	52.7	57.9	59.6	62.9
	X̄*	57.2		56.8		50.6		58.5		49.2		58.7		53.7		55.3		61.3	
	X̄**	53.0	60.5	53.1	62.1	57.7	58.8	64.0	56.3	59.3	56.7	60.9	59.8	59.0	57.9	61.5	62.9	63.0	65.8
	X̄***	56.8		57.6		58.3		60.2		58.0		60.4		60.0		62.2		64.4	
X̄* S.e.		±1.33		±1.11		±1.49		±1.14		±1.74		±1.34		±1.67		±1.45		±1.34	

Note: X̄* - group mean.

X̄** - individual sheep mean in 12 weeks

X̄*** - mean of group means " " "

Appendix 9.2 Individual and mean digestion coefficients of organic matter by wether sheep in the 9 treatment groups.

Group number		1		2		3		4		5		6		7		8		9	
Diet number		1		2		2		3		4		5		3		6		4	
BM g/wether/day		0		50		100		0		50		100		0		50		100	
MM g/wether/day		0		0		0		50		50		50		100		100		100	
H a y		A d l i b i t u m																	
Week number																			
1		59.1	65.4	59.6	62.0	56.5	60.5	68.5	54.8	55.7	55.0	62.7	46.2	60.2	61.1	59.1	80.2	70.9	63.5
	$\bar{X}$*	62.3		60.8		58.5		61.7		55.4		54.5		60.7		69.7		67.2	
2		57.4	58.3	45.2	68.7	59.6	64.0	71.7	62.1	66.3	66.1	66.9	67.0	52.5	65.4	64.7	66.4	68.4	71.6
	$\bar{X}$*	57.9		57.0		61.8		66.9		66.2		67.0		59.0		65.6		70.0	
3		58.6	59.4	61.1	69.5	57.9	62.6	64.1	52.8	60.1	57.8	59.6	62.1	65.2	54.6	63.9	64.4	63.5	90.9
	$\bar{X}$*	59.0		65.3		60.3		58.5		59.0		60.9		59.9		64.2		77.2	
4		67.4	68.0	65.2	68.6	67.7	67.1	76.2	65.0	52.2	66.7	69.6	69.2	65.9	73.9	69.6	69.0	69.6	71.0
	$\bar{X}$*	67.7		66.9		67.4		70.6		59.5		69.4		69.9		69.3		70.3	
5		60.6	64.9	57.2	67.8	65.5	63.5	65.9	60.0	77.5	64.3	69.9	70.6	69.1	64.0	68.7	71.1	69.2	73.5
	$\bar{X}$*	62.8		62.5		64.5		63.0		70.9		70.3		66.6		69.9		71.4	
6		55.3	65.8	56.0	60.3	69.8	64.6	62.3	58.2	66.4	61.5	61.8	68.3	65.0	65.8	65.2	65.3	64.3	67.8
	$\bar{X}$*	60.6		58.2		67.2		60.3		64.0		65.1		65.4		65.3		66.1	
7		38.9	57.0	54.0	64.6	61.9	61.3	64.0	60.0	63.8	59.8	65.4	64.0	59.6	63.1	63.7	48.0	63.1	63.9
	$\bar{X}$*	48.0		59.3		61.6		62.0		61.8		64.7		61.4		55.9		63.5	
8		47.1	59.5	53.7	63.0	57.2	58.5	63.9	54.1	55.8	55.9	61.3	60.3	56.7	64.5	56.6	61.4	64.8	60.1
	$\bar{X}$*	53.3		58.4		57.9		59.0		55.9		60.8		60.6		59.0		62.5	
9		46.5	62.9	42.1	68.4	63.2	65.4	63.9	64.2	59.3	63.4	64.8	65.4	63.1	66.8	67.8	68.1	66.5	66.6
	$\bar{X}$*	54.7		55.3		64.3		64.1		61.4		65.1		65.0		68.0		66.6	
10		53.1	59.7	54.4	60.5	59.0	58.4	60.5	55.6	58.9	43.5	56.5	62.2	60.5	62.3	64.3	60.5	67.7	62.1
	$\bar{X}$*	56.4		57.5		58.7		58.1		51.2		59.3		61.4		62.4		64.9	
11		60.3	64.8	61.2	63.8	63.7	61.2	66.6	61.5	65.7	62.4	65.5	61.5	62.8	64.4	69.4	68.4	65.5	71.9
	$\bar{X}$*	62.6		62.5		62.5		64.1		64.1		63.5		63.6		68.9		68.7	
12		55.0	62.8	59.9	58.3	46.7	60.2	68.0	54.5	56.0	48.6	61.8	60.4	49.7	62.0	55.2	60.0	62.0	65.0
	$\bar{X}$*	58.9		59.1		53.5		61.3		52.3		61.1		55.9		57.6		63.5	
	$\bar{X}$**	54.9	62.4	55.8	64.6	60.7	62.3	66.3	58.6	61.5	58.8	63.8	63.1	60.9	64.0	64.0	65.2	66.3	69.0
	$\bar{X}$***	58.7		60.2		61.5		62.5		60.1		63.5		62.5		64.7		67.7	
$\bar{X}$* S.e.		±1.49		±1.00		±1.11		±1.05		±1.68		±1.29		±1.10		±1.43		±1.48	

Note: $\bar{X}$* = group mean.

$\bar{X}$** = individual sheep mean in 12 weeks.

$\bar{X}$*** = mean of group means " " "

Appendix 9.3 Individual and mean digestion coefficients of crude protein by wether sheep in the 9 treatment groups

Group number	1		2		3		4		5		6		7		8		9	
Diet number	1		2		2		3		4		5		3		6		4	
BM g/wether/day	0		50		100		0		50		100		0		50		100	
MM g/wether/day	0		0		0		50		50		50		100		100		100	
Hay	Ad libitum																	
Week number 1	51.9	55.8	53.0	52.9	47.8	54.2	59.8	43.8	42.9	43.6	53.2	30.8	47.3	45.1	48.2	75.9	51.0	51.0
X̄*	53.9		53.0		51.0		51.8		43.3		42.0		46.2		62.1		51.0	
2	47.5	41.6	34.5	61.9	53.3	58.9	63.8	53.9	57.1	61.8	60.4	57.4	37.3	50.7	53.4	58.1	57.3	61.8
X̄*	44.6		48.2		56.1		58.9		59.5		58.9		44.0		55.8		59.6	
3	37.9	42.4	41.5	62.8	40.5	56.9	53.1	44.2	52.5	52.4	54.6	55.0	68.5	35.4	52.7	57.0	14.3	58.0
X̄*	40.2		52.2		48.7		48.7		52.5		54.8		52.0		54.9		36.2	
4	61.0	61.3	58.4	63.5	62.7	61.5	71.2	60.7	54.1	60.6	63.9	63.0	56.9	65.1	49.6	63.1	60.1	61.9
X̄*	61.2		61.0		62.1		66.0		57.4		63.5		61.0		56.4		61.0	
5	49.5	64.4	50.9	56.5	62.1	60.5	63.3	59.2	67.1	58.2	61.8	64.4	58.0	51.6	60.7	69.3	60.3	64.7
X̄*	57.0		53.7		61.3		61.3		62.7		63.1		54.8		65.0		62.5	
6	37.2	45.4	44.1	47.0	61.7	55.3	52.5	51.6	32.1	54.4	53.6	60.8	53.4	52.3	57.0	55.9	52.8	56.5
X̄*	41.3		45.6		58.5		52.1		42.3		57.2		52.9		56.5		54.7	
7	40.9	54.9	53.7	57.3	59.5	56.2	62.1	57.5	59.9	56.9	62.6	59.2	56.0	59.0	59.4	42.8	60.7	58.4
X̄*	47.9		55.5		57.9		59.8		58.4		60.9		57.5		51.1		59.6	
8	29.7	44.6	45.6	54.6	51.3	52.1	51.7	42.0	42.6	47.6	53.1	48.8	38.4	50.2	39.6	51.6	52.5	46.5
X̄*	37.2		50.1		51.7		46.9		45.1		51.0		44.8		45.6		49.5	
9	46.1	59.5	34.2	61.9	58.8	58.9	58.1	52.6	50.4	60.1	59.5	57.8	54.4	58.6	58.9	64.0	57.5	56.0
X̄*	52.8		48.1		58.9		55.4		55.3		58.7		56.5		61.5		56.8	
10	40.5	48.7	45.5	52.0	50.8	46.1	49.2	34.2	46.1	26.2	47.7	54.9	47.0	48.2	51.2	50.9	57.1	48.7
X̄*	44.6		48.8		48.5		41.7		36.2		51.3		47.6		51.1		52.9	
11	40.1	47.6	46.0	50.1	49.1	43.5	45.6	41.8	50.2	45.7	50.7	48.5	39.0	45.0	51.7	55.4	52.8	56.5
X̄*	43.9		48.1		46.3		43.7		48.0		49.6		42.0		53.6		54.7	
12	51.1	58.1	54.7	48.6	46.3	52.1	58.8	47.1	47.3	44.1	56.1	53.6	38.3	51.6	46.9	55.8	55.4	64.3
X̄*	54.6		51.7		49.2		53.0		45.7		54.9		45.0		51.4		59.9	
X̄**	44.5	52.0	46.8	55.8	53.7	54.7	57.4	49.1	50.2	51.0	56.4	54.5	49.5	51.1	52.4	58.3	52.7	57.0
X̄***	48.3		51.3		54.2		53.3		50.5		55.5		50.3		55.4		54.9	
X̄* S.e.	±2.17		±1.20		±1.66		±2.13		±2.38		±1.79		±1.81		±1.58		±2.07	

Note:

X̄* = group mean.

X̄** = individual sheep mean in 12 weeks.

X̄*** = mean of group means " " "

Appendix 9.4 Individual and mean digestion coefficients of ether extract by wether sheep in the 9 treatment groups.

Group number	1		2		3		4		5		6		7		8		9	
Diet number	1		2		2		3		4		5		3		6		4	
EM g/wether/day	0		50		100		0		50		100		0		50		100	
NM g/wether/day	0		0		0		50		50		50		100		100		100	
H a y	A d l i b i t u m																	
Week number 1	40.9	56.3	50.6	53.0	41.1	45.2	55.3	41.7	42.5	39.2	52.1	28.2	43.8	47.3	47.4	72.1	59.0	44.0
X̄*	48.6		51.8		43.2		48.5		40.9		40.2		45.6		59.8		51.5	
2	28.7	36.9	26.3	57.9	28.9	43.1	55.4	53.1	57.7	50.7	52.7	53.3	24.0	44.3	55.0	56.4	67.2	59.7
X̄*	32.8		42.1		36.0		54.3		54.2		53.0		34.2		55.7		63.5	
3	31.9	29.3	19.2	36.3	15.1	25.9	24.4	28.9	34.7	28.0	41.4	47.1	49.2	35.4	38.6	36.6	14.9	37.2
X̄*	30.6		27.8		20.5		26.7		31.4		44.3		42.3		37.6		26.1	
4	50.1	54.0	50.5	54.7	48.2	49.1	68.8	53.6	42.0	50.4	50.6	36.0	30.6	41.9	39.1	39.1	57.7	57.0
X̄*	52.1		52.6		48.7		61.2		46.2		43.3		36.3		39.1		57.4	
5	50.7	70.5	66.1	78.1	76.2	74.8	78.2	74.2	84.9	76.1	76.0	79.1	78.8	79.2	57.6	61.8	63.1	68.3
X̄*	60.6		72.1		75.5		76.2		80.9		77.6		79.0		59.7		65.7	
6	38.3	32.7	29.2	23.8	31.8	26.5	9.9	28.9	37.9	43.6	25.4	44.1	14.6	17.0	44.5	50.8	51.5	52.9
X̄*	35.5		26.5		29.2		19.4		40.8		34.8		15.8		47.7		52.2	
7	1.7	34.2	44.6	53.2	50.9	53.3	43.6	29.1	37.1	32.6	49.3	48.1	44.5	62.1	59.4	40.2	69.2	72.0
X̄*	18.0		48.9		52.1		36.4		34.9		48.7		53.3		49.8		70.6	
8	47.7	67.4	51.9	62.1	55.8	56.4	59.8	57.4	52.4	62.2	69.3	73.1	56.4	61.1	53.4	59.8	63.7	52.8
X̄*	57.6		57.0		56.1		58.6		57.3		71.2		58.8		56.6		58.3	
9	17.0	17.0	7.9	30.0	34.7	52.3	51.2	48.2	38.1	39.4	37.4	49.5	30.5	52.9	40.4	33.8	45.2	41.7
X̄*	17.0		19.0		43.5		49.7		38.8		43.5		41.7		37.1		43.5	
10	47.8	51.3	49.3	53.3	54.4	49.3	53.6	49.5	53.6	48.0	38.1	42.1	44.0	32.8	45.7	56.1	63.4	60.9
X̄*	49.6		51.3		51.9		51.6		50.8		40.1		38.4		50.9		62.2	
11	65.1	72.2	68.8	73.2	69.8	72.4	70.5	72.2	73.3	68.0	65.6	62.1	59.9	64.0	65.6	69.2	74.1	75.8
X̄*	68.7		71.0		71.1		71.4		70.7		63.9		62.0		67.4		75.0	
12	16.8	32.9	54.4	56.6	44.0	55.1	58.8	43.8	64.0	36.9	60.6	56.8	49.5	56.0	56.6	58.6	71.5	74.4
X̄*	24.9		55.5		49.6		51.3		50.5		58.7		52.8		57.6		73.0	
X̄**	36.4	46.2	43.2	52.7	45.9	50.3	52.5	48.4	51.5	48.0	51.5	51.6	43.8	49.5	50.3	52.9	58.4	58.1
X̄***	41.3		48.0		48.1		50.4		49.8		51.6		46.7		51.6		58.3	
X̄* S.e.	±4.96		±4.80		±4.54		±4.79		±4.21		±3.89		±4.64		±2.81		±3.97	

Note: X̄* = group mean.

X̄** = individual sheep mean in 12 weeks.

X̄*** = mean of group means " " "

Appendix 9.5 Individual and mean digestion coefficients of crude fibre by wether sheep in the 9 treatment groups.

Group number	1		2		3		4		5		6		7		8		9	
Diet number	1		2		2		3		4		5		3		6		4	
EM g/wether/day	0		50		100		0		50		100		0		50		100	
MM g/wether/day	0		0		0		50		50		50		100		100		100	
Hay	Ad libitum																	
Week number 1	71.0	73.8	66.3	68.7	62.4	65.0	75.4	59.4	60.7	63.3	66.8	52.3	66.5	67.8	64.9	82.4	67.6	70.4
X̄*	72.4		67.5		63.7		67.4		62.0		59.6		67.2		73.7		69.0	
2	65.3	70.3	55.8	74.0	66.1	71.7	78.1	67.2	70.7	68.9	72.1	72.8	59.4	73.0	66.7	67.5	66.9	68.7
X̄*	67.8		64.9		68.9		72.7		69.8		72.5		66.2		67.1		67.8	
3	71.2	71.7	70.0	75.6	66.7	70.3	74.4	62.6	66.1	64.1	63.9	66.7	33.6	65.1	71.7	71.9	73.0	72.3
X̄*	71.5		72.8		68.5		68.5		65.1		65.4		49.4		71.8		72.7	
4	75.3	76.7	84.0	74.8	73.0	72.7	80.5	70.6	68.4	72.6	72.8	72.3	70.4	78.4	75.4	73.3	73.3	76.0
X̄*	76.0		79.4		72.9		75.6		70.5		72.6		74.4		74.4		74.7	
5	69.7	75.1	66.8	73.7	70.8	71.3	73.5	67.5	79.2	69.5	71.5	73.8	73.6	69.6	73.6	75.5	70.9	74.6
X̄*	72.4		70.3		71.1		70.5		74.4		72.7		71.6		74.6		72.8	
6	53.2	66.5	54.1	63.3	68.9	66.6	64.1	55.3	70.4	62.1	58.5	69.9	67.9	64.4	68.1	66.4	66.2	70.2
X̄*	59.9		58.7		67.8		59.7		66.3		64.2		66.2		67.3		68.2	
7	52.6	65.3	62.3	71.8	63.9	69.1	69.0	67.3	68.9	63.2	70.3	67.5	65.4	69.8	68.6	50.3	67.4	71.0
X̄*	59.0		67.1		66.5		68.2		66.1		68.9		67.6		59.5		69.2	
8	53.2	67.0	59.1	69.1	61.9	63.1	70.5	57.5	61.7	56.0	63.7	60.7	55.6	69.4	59.8	60.0	66.0	59.7
X̄*	60.1		64.1		62.5		64.0		58.9		62.2		62.5		59.9		62.9	
9	55.8	71.6	52.3	74.1	67.3	71.3	67.4	62.2	63.3	68.7	69.2	69.8	70.2	72.0	72.8	72.8	72.3	74.4
X̄*	63.7		63.2		69.3		64.8		66.0		69.5		71.1		72.8		73.4	
10	59.3	64.8	60.0	65.2	59.0	62.4	65.0	59.8	59.4	40.7	57.3	64.6	60.7	63.9	67.1	60.8	66.4	65.8
X̄*	62.1		62.6		60.7		62.4		50.1		61.0		62.3		64.0		66.1	
11	70.2	72.9	70.4	71.5	69.3	68.3	74.2	66.6	71.4	67.1	70.8	64.9	68.5	69.6	72.3	70.4	71.0	77.6
X̄*	71.6		71.0		68.8		70.4		69.3		67.9		69.1		71.4		74.3	
12	65.3	73.4	68.6	68.4	45.1	64.9	74.3	57.7	63.0	51.4	68.4	66.8	54.2	67.6	60.3	65.5	65.0	70.3
X̄*	69.4		68.5		55.0		66.0		57.2		67.6		60.9		62.9		67.7	
X̄**	63.5	70.8	64.1	70.9	64.5	68.1	72.2	62.8	66.9	62.3	67.1	66.8	62.2	69.2	68.4	68.1	68.8	70.9
X̄***	64.3		67.5		66.3		67.5		64.6		67.0		65.7		68.3		69.9	
X̄* S.e.	±2.92		±1.58		±1.45		±1.29		±1.93		±3.61		±1.88		±1.70		±2.47	

Note: X̄* = group mean.

X̄** = individual sheep mean in 12 weeks.

X̄*** = mean of group means " " "

Appendix 9.6 Individual and mean digestion coefficients of nitrogen-free extract by wether sheep in the 9 treatment groups.

Group number	1		2		3		4		5		6		7		8		9	
Diet number	1		2		2		3		4		5		3		6		4	
BM g/wether/day	0		50		100		0		50		100		0		50		100	
MM g/wether/day	0		0		0		50		50		50		100		100		100	
H a y	A d l i b i t u m																	
Week number 1	49.3	60.9	56.4	58.7	55.0	59.2	65.3	54.3	55.4	51.6	62.4	46.4	58.9	60.0	57.6	79.9	63.4	62.3
$\bar{X}$*	55.1		57.6		57.1		59.8		53.5		54.4		59.5		68.8		62.9	
2	54.0	52.4	40.4	66.3	57.5	60.2	68.9	60.3	65.3	65.7	65.1	65.4	51.5	63.5	66.2	67.8	71.9	76.5
$\bar{X}$*	53.2		53.4		58.9		64.6		65.5		65.3		57.5		67.0		74.2	
3	52.5	53.5	60.3	64.8	57.0	59.0	59.3	46.8	57.9	55.1	58.5	61.2	72.4	50.7	61.5	61.5	13.5	62.3
$\bar{X}$*	53.0		62.6		58.0		53.1		56.5		59.9		61.6		61.5		37.9	
4	63.4	63.0	61.6	65.2	65.8	65.0	74.1	62.0	58.1	64.3	69.6	70.1	66.3	74.1	69.3	48.2	70.1	70.5
$\bar{X}$*	63.2		63.4		65.4		68.1		61.2		69.9		70.2		58.8		70.3	
5	56.7	56.3	39.6	64.6	61.5	57.1	48.6	52.7	78.0	60.7	52.4	69.1	67.2	61.0	67.6	69.1	70.7	75.3
$\bar{X}$*	56.5		52.1		59.3		50.7		69.4		60.8		64.1		68.4		73.0	
6	60.1	70.9	60.9	62.4	73.3	66.7	65.0	62.7	67.4	63.3	66.7	69.8	66.8	70.4	65.9	67.1	66.1	69.4
$\bar{X}$*	65.5		61.7		70.0		63.9		65.4		68.3		68.6		66.5		67.8	
7	27.1	51.3	47.4	60.7	61.9	57.0	61.6	56.2	62.0	59.2	63.4	60.5	56.4	58.8	61.2	39.7	60.3	60.0
$\bar{X}$*	39.2		54.1		59.5		58.9		60.6		62.0		57.6		50.5		60.2	
8	45.9	56.3	51.9	60.0	55.6	41.1	54.4	54.0	54.6	57.5	60.9	61.7	60.6	63.9	58.0	64.8	66.6	63.8
$\bar{X}$*	51.1		56.0		48.4		54.2		56.1		61.3		62.3		61.4		65.2	
9	40.8	58.0	38.7	66.9	62.4	63.0	63.0	58.7	59.3	61.1	63.9	64.8	61.2	65.1	67.2	67.0	65.5	64.8
$\bar{X}$*	49.4		52.8		62.7		60.9		60.2		64.4		63.2		67.1		65.2	
10	50.8	58.6	44.7	59.0	61.1	59.0	51.7	57.2	61.4	48.0	58.7	63.4	63.6	65.0	66.0	62.1	70.8	62.7
$\bar{X}$*	54.7		51.9		60.1		54.7		54.7		61.1		64.3		64.1		66.8	
11	54.5	60.4	56.2	59.2	62.0	57.5	63.8	59.9	63.7	61.2	64.5	62.0	62.5	64.1	70.7	69.3	66.2	71.6
$\bar{X}$*	57.5		57.7		59.8		61.9		62.5		63.3		63.3		70.0		68.9	
12	49.4	56.3	55.1	52.8	48.0	59.1	65.3	54.6	51.9	48.6	58.3	58.5	49.2	60.6	53.8	57.4	60.7	72.3
$\bar{X}$*	52.9		54.0		53.6		60.0		50.3		58.4		54.9		55.6		66.5	
$\bar{X}$**	50.4	58.2	51.1	61.7	60.1	58.7	61.8	56.6	61.3	58.0	62.0	62.7	61.4	63.1	63.8	62.8	62.2	67.6
$\bar{X}$***	54.3		56.4		59.4		59.7		59.7		62.4		62.3		63.3		64.9	
$\bar{X}$* S.e.	±1.92		±1.20		±1.56		±1.50		±1.65		±1.22		±1.29		±1.72		±2.70	

Note: $\bar{X}$* = group mean.

$\bar{X}$** = individual sheep mean in 12 weeks.

$\bar{X}$*** = mean of group means " " "

Appendix 9.7 Individual and mean digestion coefficients of gross energy by wether sheep in the 7 treatment groups.

Group number		1		2		3		4		5		6		7		8		9	
Diet number		1		2		2		3		4		5		3		6		4	
BM g/wether/day		0		50		100		0		50		100		0		50		100	
MM g/wether/day		0		0		0		50		50		50		100		100		100	
H a y		A d l i b i t u m																	
Week number 6		48.1	61.1	50.9	55.7	66.1	61.6	59.1	56.2	64.3	58.8	58.8	66.1	61.3	62.0	62.1	62.5	61.8	65.4
	$\bar{X}$*	54.6		53.3		63.9		57.7		61.6		62.5		61.7		62.3		53.6	
7		44.0	59.5	57.4	64.4	62.6	61.9	65.7	61.0	64.0	60.2	62.9	61.7	59.4	62.4	61.4	45.6	61.8	62.4
	$\bar{X}$*	51.8		60.9		62.3		63.4		62.1		62.3		60.9		53.5		62.1	
8		39.4	52.9	48.3	59.7	52.0	40.7	59.0	49.4	50.7	61.1	56.3	54.1	49.5	59.1	49.4	55.8	59.8	53.4
	$\bar{X}$*	46.2		54.0		46.4		54.2		55.9		55.2		54.3		52.6		56.6	
9		39.9	58.0	35.2	64.0	57.7	60.5	59.0	59.7	55.7	59.2	60.4	61.3	58.6	63.0	64.2	65.1	62.1	63.2
	$\bar{X}$*	49.0		49.6		59.1		59.4		57.5		60.9		60.8		64.7		62.7	
10		46.7	53.1	47.8	55.1	53.1	53.1	55.3	49.6	52.5	36.9	50.1	58.1	54.1	57.5	60.7	57.2	64.5	57.5
	$\bar{X}$*	49.9		51.5		53.1		52.5		44.7		54.2		55.8		59.0		61.0	
11		54.2	59.5	55.5	59.6	59.0	57.7	62.2	57.4	61.8	58.4	61.2	57.0	58.1	60.0	65.1	64.7	63.4	68.0
	$\bar{X}$*	56.9		57.6		58.4		59.8		60.1		59.1		59.1		64.9		65.7	
12		50.2	58.7	55.3	54.6	41.6	56.8	64.8	51.1	52.1	42.5	60.0	58.7	47.6	59.5	50.7	56.5	59.9	62.9
	$\bar{X}$*	54.5		55.0		49.2		58.0		47.3		59.4		53.6		53.6		61.4	
	$\bar{X}$**	46.1	57.5	50.1	59.0	56.0	56.0	60.7	54.9	57.3	53.9	58.5	59.6	55.5	60.5	59.1	58.2	61.9	61.8
	$\bar{X}$***	51.8		54.6		56.0		57.8		55.6		59.1		58.0		58.7		61.9	
$\bar{X}$*	S.e.	±1.08		±1.09		±1.92		±1.05		±2.01		±0.94		±0.98		±1.57		±1.17	

Note:

$\bar{X}$* = group mean.

$\bar{X}$** = individual sheep mean in 12 weeks.

$\bar{X}$*** = mean of group means " " "

Appendix 10. Analysis of variance of dry matter digestibility of the total diet as affected by the levels of protein and energy rich concentrate supplementation to C. gayana.

Source			df	ss	Mss	F	P
Weeks			11	2395.19	217.74	8.87	<0.01
Treatments			8	1136.62	142.08	0.91	NS
Levels of supplementation with BM		2		140.99	70.55	0.45	NS
BM linear	1			102.35	102.35	0.66	NS
BM quadratic	1			38.64	38.64	0.25	NS
Levels of supplementation with MM		2		906.89	453.45	2.91	NS
MM linear	1			894.01	894.01	5.73	<0.05
MM quadratic	1			12.88	12.88	0.08	NS
BM x MM		4		88.74	22.19	0.14	NS
BM_L x MM_L		1		23.80	23.80	0.15	NS
Treatments x weeks			88	2293.16	26.06	1.06	NS
Replicates			1	140.01	140.01	0.90	NS
Treatments x replicates			8	1247.45	155.93		
Treatments x replicates x weeks			99	2430.35	24.55		
Total			215	9642.78			

Appendix 11. Analysis of variance of organic matter digestibility of the total diet as affected by the levels of protein and energy rich concentrate supplementation to C. gayana.

Source			df	ss	Mss	F	P
Weeks			11	2083.07	189.37	3.93	<0.01
Treatments			8	962.75	120.34	0.71	NS
Levels of supplementation with BM		2		218.72	109.39	0.64	NS
BM linear	1			196.00	196.00	1.15	NS
BM quadratic	1			22.72	22.72	0.13	NS
Levels of supplementation with MM		2		600.28	300.14	1.77	NS
MM linear	1			599.00	599.00	3.53	NS
MM quadratic	1			1.28	1.28	0.01	NS
BM x MM		4		143.69	35.92	0.21	NS
BM_L x MM_L		1		0.51	0.51	0.01	NS
Treatments x weeks			88	2026.53	23.03	0.48	NS
Replicates			1	212.41	212.41	1.25	NS
Treatments x replicates			8	1357.97	169.75		
Treatments x replicates x weeks			99	4772.53	48.21		
Total			215	11415.26			

Appendix 12. Analysis of variance of crude protein digestibility of the total diet as affected by the levels of protein and energy rich concentrate supplementation to C. gayana.

Source			df	ss	Mss	F	P
Weeks			11	4887.72	444.34	9.65	<0.01
Treatments			8	1314.80	164.35	0.98	NS
Levels of supplementation with BM		2		676.14	338.07	2.01	NS
BM linear	1			670.81	670.81	3.99	NS
BM quadratic	1			5.33	5.33	0.03	NS
Levels of supplementation with MM		2		194.81	97.41	0.58	NS
MM linear	1			172.27	172.27	1.02	NS
MM quadratic	1			22.14	22.14	0.13	NS
BM x MM		4		443.85	110.96	0.66	NS
BM_L x MM_L		1		36.38	36.38	0.22	NS
Treatments x weeks			88	3677.53	41.79	0.91	NS
Replicates			1	273.82	273.82	1.63	NS
Treatments x replicates			8	1344.68	168.09		
Treatments x replicates x weeks			99	4556.93	46.03		
Total			215	16055.48			

Appendix 13. Analysis of variance of ether extract digestibility in the total diet as affected by the levels of protein and energy rich concentrate supplementation to C. gayana.

Source			df	ss	Mss	F	P
Weeks			11	31048.98	2822.63	55.31	<0.01
Treatments			8	3961.51	495.19	3.16	NS
Levels of supplementation with BM		2		1529.26	764.63	4.88	<0.05
BM linear	1			1522.30	1522.30	9.72	<0.05
BM quadratic	1			9.96	9.96	0.06	NS
Levels of supplementation with MM		2		1582.68	791.34	5.05	<0.05
MM linear	1			1457.30	1457.30	9.30	<0.05
MM quadratic	1			125.38	125.38	0.80	NS
BM x MM		4		849.57	212.40	1.36	NS
BM_L x MM_L	1			136.57	136.57	0.87	NS
Treatments x weeks			88	13589.30	154.42	3.03	<0.01
Replicates			1	387.21	387.21	2.47	NS
Treatments x replicates			8	1253.16	156.65		
Treatments x replicates x weeks			99	5052.45	51.04		
Total			215	55292.61			

Appendix 14. Analysis of variance of crude fibre digestibility in the total diet as affected by the levels of protein and energy rich concentrate supplementation to C. gayana.

Source			df	ss	Mss	F	P
Weeks			11	3185.05	289.55	12.58	<0.01
Treatments			8	435.99	54.50	0.28	NS
Levels of supplementation with BM		2		41.76	20.88	0.11	NS
BM linear	1			31.73	31.73	0.16	NS
BM quadratic	1			10.03	10.03	0.05	NS
Levels of supplementation with MM		2		90.82	45.41	0.23	NS
MM linear	1			33.54	33.54	0.17	NS
MM quadratic	1			57.28	57.28	0.30	NS
BM x MM		4		303.41	75.86	0.39	NS
BM_L x MM_L	1			27.41	27.41	0.14	NS
Treatments x weeks			88	2594.99	29.49	1.29	NS
Replicates			1	95.20	95.20	0.49	NS
Treatments x replicates			8	1548.29	193.54		
Treatments x replicates x weeks			99	2278.81	23.02		
Total			215	10138.33			

Appendix 15. Analysis of variance of nitrogen-free extract digestibility in the total diet as affected by the levels of protein and energy rich concentrate supplementation to C. gayana.

Source			df	ss	Mss	F	P
Weeks			11	2596.18	236.02	9.88	<0.01
Treatments			8	2209.66	276.21	1.68	NS
Levels of supplementation with BM		2		498.35	249.18	1.51	NS
BM linear	1			480.30	480.30	2.92	NS
BM quadratic	1			18.05	18.05	0.11	NS
Levels of supplementation with MM		2		1664.28	832.14	5.06	<0.05
MM linear	1			1659.20	1659.20	10.08	<0.05
MM quadratic	1			5.08	5.08	0.03	NS
BM x MM		4		47.03	11.76	0.07	NS
BM_L x MM_L	1			36.38	36.38	0.22	NS
Treatments x weeks			88	13797.15	156.79	6.56	<0.01
Replicates			1	161.90	161.90	0.98	NS
Treatments x replicates			8	1316.38	164.55		
Treatments x replicates x weeks			99	2366.43	23.90		
Total			215	14758.28			

Appendix 16 Analysis of variance of gross energy digestibility on the total diet as affected by the levels of protein and energy rich concentrate supplementation.

Source			df	ss	Mss	F	P
Weeks			6	1166.04	194.34	6.64	<0.01
Treatments			8	955.10	119.39	2.00	NS
Levels of supplementation with BM		2		297.04	148.52	2.49	NS
BM linear	1			202.10	202.10	3.39	NS
BM quadratic	1			3.03	3.03	0.05	NS
Levels of supplementation with MM		2		620.68	310.34	5.12	NS
MM linear	1			608.05	608.05	10.20	<0.05
MM quadratic	1			12.62	12.62	0.21	NS
BM x MM		4		37.38	9.35	0.16	NS
BM_L x MM_L	1			0.46	0.46	0.01	NS
Treatments x weeks			48	1151.90	24.00	0.82	NS
Replicates			1	103.15	103.15	1.73	NS
Treatments x replicates			8	476.93	59.62		
Treatments x replicates x weeks			54	1581.80	29.29		
Total			125	5434.92			

Appendix 17.1. Ingestion of nitrogen g/wether/day from hay and concentrate diets (group mean).

Group number	1	2	3	4	5	6	7	8	9
Diet number	1	2	2	3	4	5	3	6	4
BM g/wether/day	0	50	100	0	50	100	0	50	100
MM g/wether/day	0	0	0	50	50	50	100	100	100
H a y	A d l i b i t u m								
Week number 1	10.56	16.28	16.78	13.54	15.76	18.70	12.88	17.66	18.14
2	10.90	16.32	17.30	15.54	15.16	19.08	12.88	17.78	18.62
3	9.36	12.52	15.44	14.54	15.40	17.86	12.20	17.64	18.20
4	11.90	17.04	18.46	17.42	17.96	19.82	15.16	17.94	20.22
5	10.40	16.44	17.78	15.20	17.46	19.24	13.86	18.96	19.66
6	9.90	15.14	17.40	14.72	17.14	18.74	13.48	18.02	18.18
7	10.96	17.02	16.68	14.68	18.48	19.68	13.90	18.70	19.90
8	8.72	15.56	15.36	14.06	15.22	17.70	12.22	16.30	17.94
9	11.74	16.68	16.66	14.38	15.74	18.54	13.76	18.02	18.62
10	9.92	15.10	15.84	13.40	12.62	16.08	11.78	15.68	17.48
11	11.70	14.66	15.06	13.96	16.20	16.38	12.10	16.18	17.56
12	12.94	16.26	14.62	14.46	15.26	17.70	12.28	15.14	18.32
Mean of group means	10.75	15.75	16.45	14.66	16.03	18.29	13.04	17.34	18.57
S.e.	±0.34	±0.37	±0.34	±0.31	±0.45	±0.34	±0.29	±0.35	±0.26

Appendix 17.2. Excretion of nitrogen in faeces g/wether/day (group mean).

Group number	1	2	3	4	5	6	7	8	9
Diet number	1	2	2	3	4	5	3	6	4
BM g/wether/day	0	50	100	0	50	100	0	50	100
MM g/wether/day	0	0	0	50	50	50	100	100	100
H a y	A d l i b i t u m								
Week number									
1	4.86	7.66	8.21	6.50	8.94	10.86	6.72	6.58	8.88
2	6.06	8.29	7.60	6.37	6.16	7.86	7.20	7.86	7.52
3	5.61	5.57	7.70	7.41	7.88	8.08	5.51	7.95	7.75
4	4.63	6.60	7.00	5.92	7.65	7.25	5.94	7.70	7.88
5	4.42	7.57	6.89	5.92	6.56	7.12	6.24	6.68	7.38
6	5.76	8.23	7.25	7.06	7.88	7.99	6.36	7.84	8.25
7	5.62	7.55	7.05	5.94	7.70	7.70	5.92	9.14	8.04
8	5.43	7.71	7.42	7.42	8.36	8.67	6.73	8.90	9.02
9	5.45	8.55	6.85	6.42	7.01	7.66	5.97	6.93	8.05
10	5.50	7.71	8.19	7.72	7.90	7.77	6.17	7.67	8.24
11	6.56	7.60	8.09	7.83	8.43	8.27	7.00	7.51	7.97
12	5.84	7.86	7.36	6.70	8.27	7.99	6.66	7.38	7.34
Mean of group means	5.48	7.58	7.47	6.77	7.73	8.10	6.39	7.68	8.03
S.e.	±0.19	±0.23	±0.14	±0.20	±0.23	±0.28	±0.15	±0.23	±0.15

Appendix 17.3. Excretion of nitrogen in urine g/wether/day (group mean).

Group number	1	2	3	4	5	6	7	8	9
Diet number	1	2	2	3	4	5	3	6	4
EM g/wether/day	0	50	100	0	50	100	0	50	100
MM g/wether/day	0	0	0	50	50	50	100	100	100
Hay	Ad libitum								
Week number									
1	3.97	5.01	5.46	4.51	5.52	6.65	4.42	5.49	6.22
2	3.61	4.23	4.11	2.56	4.39	4.93	3.04	6.25	3.92
3	3.24	3.23	3.92	2.78	4.52	4.79	3.04	4.95	4.79
4	2.97	4.07	3.98	3.17	5.16	4.77	2.52	4.90	4.06
5	3.17	3.70	3.98	3.38	4.31	4.65	2.50	4.45	4.77
6	3.09	3.70	4.41	3.01	4.15	5.11	3.11	4.78	4.81
7	2.69	3.34	3.17	2.36	4.02	1.90	2.86	3.73	5.06
8	2.76	3.81	3.68	2.24	4.18	4.53	3.07	4.67	4.03
9	2.76	3.35	3.83	2.70	3.23	3.98	2.19	3.63	3.62
10	2.75	3.49	3.29	2.21	4.37	3.74	1.83	4.25	3.76
11	2.70	4.28	3.56	2.18	4.50	4.38	2.06	3.78	4.31
12	2.29	3.35	3.20	1.72	3.62	1.92	4.04	4.02	3.49
Mean of group means	3.00	3.80	3.88	2.74	4.33	4.28	2.89	4.58	4.60
S.e.	±0.13	±0.15	±0.18	±0.21	±0.18	±0.38	±0.22	±0.23	±0.22

Appendix 17.4 Retention of nitrogen g/wether/day from hay and concentrate diets (group mean).

Group number	1	2	3	4	5	6	7	8	9
Diet number	1	2	2	3	4	5	3	6	4
BM g/wether/day	0	50	100	0	50	100	0	50	100
MM g/wether/day	0	0	0	50	50	50	100	100	100
H a y	A d		l i b i t u m						
Week number									
1	1.73	3.61	3.11	2.53	1.30	1.19	1.54	5.59	3.04
2	1.23	3.80	5.59	6.61	4.61	6.29	2.64	3.67	7.18
3	0.51	3.72	3.82	4.35	3.00	4.99	3.65	4.74	5.66
4	4.30	6.37	7.48	8.33	5.15	7.80	6.70	5.34	8.28
5	2.81	5.17	6.91	5.90	6.59	7.47	5.12	7.83	7.51
6	1.05	3.21	5.74	4.65	5.11	5.64	4.01	5.40	5.12
7	2.65	6.13	6.46	6.38	6.76	10.08	5.12	5.83	6.80
8	0.53	4.04	4.26	4.40	2.68	4.50	2.42	2.73	4.89
9	3.53	4.78	5.98	5.26	5.50	6.90	5.60	7.46	6.95
10	1.67	3.90	4.36	3.47	0.35	4.57	3.78	3.76	5.48
11	2.44	2.78	3.41	3.95	3.27	3.73	3.04	4.89	5.28
12	4.81	5.05	4.06	6.04	3.37	7.79	1.58	3.74	6.67
Mean of group means	2.27	4.38	5.10	5.16	3.97	5.91	3.76	5.08	6.07
S.e.	±0.39	±0.32	±0.42	±0.46	±0.57	±0.67	±0.71	±0.44	±0.62

Appendix 18.1. Crude protein intake g/wether/4 days from hay in group 1 and hay and concentrate diets in group 2 to 9

Group number	1		2		3		4		5		6		7		8		9	
Diet number	1		2		2		3		4		5		3		6		4	
BM g/wether/day	0		50		100		0		50		100		0		50		100	
MM g/wether/day	0		0		0		50		50		50		100		100		100	
Hay	Ad libitum																	
Week number																		
1	239	289	395	419	411	428	349	328	369	419	464	471	340	304	419	464	455	452
2	267	278	377	439	440	425	402	375	379	379	472	482	320	324	439	450	463	468
3	244	224	215	411	318	454	391	336	340	430	446	447	358	252	433	449	445	465
4	313	282	375	477	441	482	442	429	445	453	485	506	393	365	400	497	496	515
5	238	282	375	447	411	478	348	412	416	457	474	488	362	331	477	471	491	492
6	223	272	334	423	408	462	374	362	430	427	450	487	344	330	460	441	464	445
7	244	304	389	462	383	451	325	409	459	465	488	496	353	342	469	466	514	481
8	198	238	357	421	352	416	374	329	380	381	451	434	271	340	421	394	479	418
9	257	330	398	436	396	437	361	358	379	408	464	463	319	369	452	449	473	458
10	251	245	348	407	374	418	353	317	357	274	368	436	283	306	418	366	436	438
11	284	301	351	382	379	374	373	325	406	404	410	409	288	317	411	398	443	435
12	305	342	411	402	308	423	407	316	410	353	437	448	273	341	381	376	446	470
Wether mean	255	282	360	427	385	437	374	358	397	404	450	463	325	326	431	443	467	461
S.e.	±9.51	±10.15	±14.78	±7.68	±11.93	±8.71	±9.17	±11.56	±10.46	±16.34	±9.78	±8.50	±11.44	±8.93	±8.34	±11.97	±6.99	±7.70

Appendix 18.2. Digestible crude protein percent dry matter in the hay and in the total diet of hay and concentrate ingested

Group number	1		2		3		4		5		6		7		8		9	
Diet number	1		2		2		3		4		5		3		6		4	
BM g/wether/day	0		50		100		0		50		100		0		50		100	
MM g/wether/day	0		0		0		50		50		50		100		100		100	
H a y	A d l i b i t u m																	
Week number																		
1	4.9	5.3	5.4	5.4	5.2	5.9	5.6	4.1	4.3	4.4	5.6	3.2	4.4	4.2	4.8	7.5	5.4	5.4
2	4.5	4.0	3.6	6.4	6.0	6.7	6.0	5.1	5.8	6.2	6.3	6.0	3.5	4.7	5.3	5.8	6.1	6.6
3	3.6	4.0	4.3	6.5	4.5	6.3	4.9	4.1	5.3	5.2	5.8	5.9	6.3	3.3	5.2	5.6	1.5	6.1
4	6.1	6.1	6.2	6.7	7.0	6.9	7.0	6.0	5.6	6.3	7.0	6.9	5.6	6.4	5.2	6.6	6.5	6.7
5	4.8	6.2	5.2	5.8	6.8	6.6	6.0	5.6	6.8	5.9	6.6	6.8	5.5	4.9	6.1	6.9	6.3	6.8
6	3.5	4.3	4.5	4.7	6.6	5.9	4.9	4.8	3.1	5.3	5.5	6.3	5.0	4.9	5.6	5.5	5.3	5.7
7	4.1	5.5	5.7	6.1	6.8	6.4	6.1	5.7	6.3	6.0	6.9	6.6	5.4	5.7	6.1	4.4	6.7	6.4
8	2.6	3.9	4.3	5.1	5.3	5.4	4.4	3.6	4.0	4.4	5.3	4.9	3.3	4.3	3.6	4.7	5.1	4.6
9	4.3	5.6	3.4	6.2	6.2	6.2	5.4	4.9	4.9	5.9	6.1	6.0	5.0	5.4	5.8	6.3	5.8	5.7
10	3.6	4.3	4.3	4.9	5.2	4.7	4.3	3.0	4.3	2.5	4.8	5.5	4.0	4.1	4.7	4.7	5.6	4.8
11	3.3	4.0	4.1	4.5	4.8	4.2	3.8	3,5	4.5	4.1	4.8	4.6	3.2	3.7	4.6	4.9	5.0	5.3
12	4.9	5.5	5.5	4.9	5.2	5.7	5.5	4.4	4.8	4.6	6.0	5.7	3.6	4.8	4.7	5.6	5.9	6.0
Wether mean	4.2	4.9	4.7	5.6	5.8	5.9	5.3	4.6	5.0	5.1	5.9	5.7	4.6	4.7	5.1	5.7	5.4	5.8
S.e.	±0.27	±0.26	±0.25	±0.22	±0.25	±0.23	±0.26	±0.27	±0.30	±0.32	±0.21	±0.30	±0.30	±0.25	±0.21	±0.28	±0.39	±0.21

Appendix 18.3. Ingested DCP g/kg $w^{0.75}$/day from the hay by group 1 and the total diet of hay and concentrate ingested by group 2 to 9.

Group number	1		2		3		4		5		6		7		8		9	
Diet number	1		2		2		3		4		5		3		6		4	
BM g/wether/day	0		50		100		0		50		100		0		50		100	
MM g/wether/day	0		0		0		50		50		50		100		100		100	
Hay	Ad libitum																	
Week numbers 1	1.8	2.3	2.6	3.1	2.4	2.9	2.5	2.0	2.1	2.3	2.7	1.7	2.0	1.9	2.4	3.8	2.6	2.5
2	2.0	1.8	1.7	3.7	3.1	3.2	3.1	2.8	3.0	2.9	3.1	3.5	1.6	2.3	2.8	3.1	3.2	3.1
3	1.6	1.6	1.5	3.7	1.9	3.4	2.5	2.1	2.9	2.8	2.6	3.0	3.0	1.3	2.7	2.8	0.7	2.7
4	2.9	2.6	2.8	4.1	3.5	3.8	3.8	3.8	3.3	3.4	3.4	3.8	2.7	3.2	3.0	3.6	3.3	3.2
5	1.9	2.7	2.4	3.5	3.3	3.7	2.6	3.5	3.8	3.2	3.1	3.7	2.6	2.2	3.3	3.5	3.3	3.1
6	1.4	1.9	1.9	2.6	3.2	3.2	2.3	2.6	1.9	2.8	2.6	3.6	2.2	2.3	2.9	2.6	2,6	2.3
7	1.5	2.6	2.6	3.7	2.7	3.1	2.4	3.4	3.7	3.4	3.3	3.1	2.2	2.5	3.2	2.2	3.5	2.7
8	1.0	1.8	2.1	3.1	2.3	2.0	2.3	1.9	2.2	2.1	2.5	2.4	1.3	2.3	1.9	2.1	2.9	1.8
9	1.6	2.8	1.8	3.6	2.8	3.2	2.4	2.6	2.6	3.0	2.9	3.1	2.0	2.9	3.0	3.1	3.1	2.5
10	1.7	1.9	2.0	2.8	2.4	2.4	2.1	1.5	2.2	0.9	1.7	2.8	1.6	2.0	2.4	2.0	2.8	2.1
11	1.9	2.4	2.3	2.6	2.6	2.4	2.1	2.1	2.8	2.3	2.3	2.4	1.5	1.9	2.5	2.5	2.7	2.4
12	2.3	3.2	3.0	2.7	1.7	2.8	2.8	2.0	2.6	1.7	2.5	2.7	1.2	1.7	1.9	2.1	2.6	2.5
Wether mean	1.8	2.3	2.2	3.3	2.7	3.0	2.6	2.5	2.8	2.6	2.7	3.0	2.0	2.2	2.7	2.8	2.8	2.6
S.e.	±0.13	±0.14	±0.13	±0.14	±0.15	±0.15	±0.13	±0.20	±0.17	±0.21	±0.13	±0.17	±0.16	±0.14	±0.13	±0.18	±0.20	±0.11

Appendix 19 GE intake kcal/g DM by group 1 in hay and by group 2 to 9 in the total diet of hay and concentrate

Group number	1		2		3		4		5		6		7		8		9	
Diet number	1		2		2		3		4		5		3		6		4	
BM g/wether/day	0		50		100		0		50		100		0		50		100	
MM g/wether/day	0		0		0		50		50		50		100		100		100	
H a y	A d l i b i t u m																	
Week number																		
6	4.142	4.204	4.358	4.201	4.193	4.264	4.253	4.241	4.198	4.243	4.224	4.222	4.232	4.220	4.233	4.246	4.236	4.242
7	4.219	4.228	4.269	4.180	4.278	4.250	4.273	4.220	4.225	4.218	4.254	4.241	4.378	4.392	4.227	4.227	4.224	4.310
8	3.967	3.886	4.005	3.983	3.989	4.114	4.021	4.025	4.010	4.037	3.984	3.985	4.035	4.018	4.014	4.029	4.037	4.029
9	4.075	4.097	4.113	4.064	4.048	4.123	4.171	4.121	4.118	4.123	4.097	4.102	4.117	4.088	4.084	4.080	4.096	4.093
10	4.140	4.091	4.127	4.116	4.138	4.134	4.150	4.160	4.125	4.125	4.084	4.126	4.131	4.128	4.240	4.268	4.114	4.114
11	4.059	4.057	4.069	4.097	4.099	4.181	4.127	4.120	4.108	4.117	4.136	4.138	4.122	4.124	4.089	4.095	4.121	4.124
12	4.194	4.168	4.179	4.158	4.187	4.191	4.169	4.185	4.195	4.182	4.216	4.221	4.267	4.206	4.090	4.183	4.231	4.197
Wether mean	4.114	4.104	4.160	4.114	4.133	4.180	4.166	4.153	4.140	4.149	4.142	4.148	4.183	4.168	4.140	4.161	4.151	4.158
S.e.	±0.033	±0.043	±0.045	±0.028	±0.037	±0.023	±0.032	±0.028	±0.028	±0.027	±0.036	±0.034	±0.043	±0.045	±0.035	±0.035	±0.030	±0.037

Appendix 20. DE kcal/g DM in hay and in the total diet in group 2 to 9.

Group number	1		2		3		4		5		6		7		8		9	
Diet number	1		2		2		3		4		5		3		6		4	
BM g/wether/day	0		50		100		0		50		100		0		50		100	
MM g/wether/day	0		0		0		50		50		50		100		100		100	
H a y	A d l i b i t u m																	
Week number																		
6	2.0	2.6	2.2	2.4	2.9	2.7	2.6	2.4	2.8	2.5	2.5	2.9	2.6	2.7	2.7	2.7	2.7	2.8
7	1.8	2.5	2.5	2.8	2.7	2.7	2.9	2.7	2.8	2.6	2.7	2.7	2.6	2.7	2.7	2.0	2.7	2.7
8	1.6	2.1	2.0	2.5	2.2	1.7	2.5	2.1	2.2	2.6	2.3	2.2	2.1	2.5	2.1	2.4	2.6	2.3
9	1.6	2.4	1.3	2.3	2.1	2.2	2.4	2.4	2.3	2.4	2.5	2.5	2.4	2.6	2.6	2.6	2.5	2.6
10	1.9	2.2	1.9	2.1	2.1	2.1	2.4	2.2	2.1	1.5	2.1	2.4	2.3	2.5	3.1	2.9	2.6	2.3
11	2.2	2.4	2.3	2.4	2.4	2.3	2.8	2.6	2.5	2.4	2.6	2.4	2.7	2.7	2.5	2.5	2.6	2.8
12	2.1	2.4	2.3	2.2	1.7	2.3	2.6	2.1	2.1	1.8	2.6	2.5	1.9	2.4	2.0	2.2	2.5	2.6
Wether mean	1.9	2.4	2.1	2.4	2.3	2.3	2.6	2.4	2.4	2.3	2.5	2.5	2.4	2.6	2.5	2.5	2.6	2.6
S.e.	±0.08	±0.06	±0.14	±0.08	±0.15	±0.12	±0.07	±0.08	±0.11	±0.16	±0.07	±0.08	±0.10	±0.04	±0.14	±0.11	±0.03	±0.07

DE = Dig. coeff. of individual wethers x gross energy of the respective diets.

Appendix 21. Total DMI g/kg $w^{0.75}$/day from week 6 to 12.

Group number	1		2		3		4		5		6		7		8		9	
Diet number	1		2		2		3		4		5		3		6		4	
BM g/wether/day	0		50		100		0		50		100		0		50		100	
MM g/wether/day	0		0		0		50		50		50		100		100		100	
Hay	Ad libitum																	
Week number																		
6	39.9	45.2	44.4	58.8	53.8	59.7	49.7	56.1	65.8	58.4	53.1	64.0	49.0	51.8	58.7	53.9	59.2	49.3
7	37.2	47.1	49.0	62.8	44.6	54.2	40.8	62.3	64.4	62.6	53.9	53.3	46.3	50.0	59.4	56.6	62.2	50.6
8	38.3	45.0	50.7	63.5	48.3	42.5	54.4	55.6	59.9	53.2	55.1	56.9	43.2	58.4	58.9	51.6	66.2	47.5
9	38.1	49.9	54.9	61.0	51.2	56.2	45.8	55.5	58.6	56.4	55.0	59.2	45.5	57.7	57.9	55.6	62.3	52.0
10	46.4	43.3	49.3	59.6	50.9	55.3	50.6	54.4	57.4	40.0	43.1	58.0	44.0	53.0	58.3	48.7	59.8	52.3
11	57.3	58.9	57.4	59.4	58.6	55.0	58.0	62.2	68.3	63.4	54.6	59.0	51.1	57.6	60.2	56.3	63.5	54.5
12	47.6	57.3	57.6	57.2	37.9	53.6	53.7	48.7	60.0	41.7	48.9	55.7	37.8	51.6	47.3	44.3	53.0	50.3
Wether mean	43.5	49.5	51.9	60.3	49.3	53.8	50.4	56.4	62.1	53.7	52.0	58.0	45.3	54.3	57.2	52.4	60.9	50.9
S.e.	±2.77	±2.35	±1.85	±0.85	±2.51	±2.02	±2.17	±1.78	±1.55	±3.56	±1.68	±1.26	±1.62	±1.32	±1.68	±1.72	±1.58	±0.85

Appendix 22. Ingested DE kcal/kg $w^{0.75}$/day from hay by group 1 and from the total diet by group 2 to 9.

Group number	1		2		3		4		5		6		7		8		9	
Diet number	1		2		2		3		4		5		3		6		4	
BM g/wether/day	0		50		100		0		50		100		0		50		100	
MM g/wether/day	0		0		0		50		50		50		100		100		100	
Hay	Ad libitum																	
Week number																		
6	79.80	117.52	91.74	135.12	140.65	147.42	123.76	128.16	169.12	133.75	116.00	164.14	115.44	126.09	140.13	127.44	133.92	114.24
7	66.96	117.75	116.00	168.84	106.65	132.84	111.94	160.92	166.04	150.02	127.71	126.63	107.90	120.42	142.29	101.20	142.83	113.67
8	61.28	94.50	96.00	152.25	94.16	63.41	130.50	110.88	119.90	125.32	110.63	108.02	80.85	133.00	108.99	107.28	146.12	88.55
9	60.96	119.76	67.86	134.55	96.39	112.42	104.88	126.96	122.36	123.84	120.25	129.00	98.16	137.28	134.16	128.44	132.00	113.62
10	88.16	95.26	88.92	99.12	96.39	106.26	115.92	113.30	108.78	52.20	76.02	120.48	89.93	119.00	159.34	121.51	128.96	99.36
11	126.06	141.36	126.50	137.28	129.12	116.15	156.24	154.70	157.75	140.40	124.54	123.84	125.55	142.02	134.50	125.00	140.40	128.80
12	99.96	137.52	126.27	119.90	55.42	111.78	134.16	96.60	115.08	66.24	109.98	120.50	63.08	111.84	81.80	83.82	109.00	108.94
Wether mean	83.31	117.66	101.89	135.29	102.68	112.89	125.34	127.36	137.00	113.11	112.16	127.51	97.27	120.09	128.74	113.52	133.31	109.59
S.e.	±9.00	±6.91	±8.27	±8.41	±10.42	±9.89	±6.46	±8.86	±9.88	±14.42	±6.53	±6.62	±8.10	±4.10	±9.65	±6.34	±4.68	±4.81

Appendix 23.1. Calculation of composite contents of crude protein (CP), ether extract (EE), crude fibre (CF) and nitrogen-free extract (NFE) in the total diet ingested by group 2 feeding on hay and on concentrate diet number 2.

Week	Mean DMI/4 days	Mean DMI/4 days	CP		EE		CF		NFE		% DM of mixture of hay and conc.			
number	hay g	conc. g	hay	conc.	hay	conc.	hay	conc.	hay	conc.	CP	EE	CF	NFE
1	3639	189	9.5	22.8	2.1	1.7	38.3	6.1	41.2	64.6	10.2	2.1	36.7	42.4
2	3631	179	9.5	28.5	2.1	1.8	38.3	6.0	41.2	58.8	10.4	2.1	36.8	42.0
3	3128	175	9.4	25.9	2.1	1.8	39.7	6.0	38.9	60.8	10.3	2.1	37.9	40.1
4	3678	187	10.0	22.7	2.2	1.9	37.5	7.8	40.5	63.1	10.6	2.2	36.1	41.6
5	3683	185	9.6	22.3	2.4	1.6	37.2	5.7	40.3	65.0	10.2	2.4	35.7	41.5
6	3563	183	9.4	23.3	1.8	1.5	34.8	5.9	45.2	66.0	10.1	1.8	33.4	46.2
7	3704	177	10.0	24.1	2.1	1.9	37.8	7.1	40.1	61.1	10.6	2.1	36.4	41.1
8	3798	186	8.7	23.3	2.7	1.6	35.9	6.6	43.7	62.7	9.4	2.6	34.5	44.6
9	3857	183	9.4	22.2	2.2	1.4	37.4	6.5	41.4	64.7	10.0	2.2	36.0	42.5
10	3648	170	8.8	25.2	2.4	1.5	36.0	6.7	44.0	61.2	9.5	2.4	34.7	44.8
11	3930	161	8.3	25.8	2.2	1.9	38.5	7.4	41.9	59.7	9.0	2.2	37.3	42.6
12	3733	180	9.5	23.2	2.3	1.6	37.0	6.4	41.9	63.4	10.1	2.3	35.6	42.9
Mean	3666	180	9.3	24.1	2.2	1.7	37.4	6.5	41.7	62.6	10.0	2.2	35.9	42.7
S.e.	±57.2	±2.3	±0.15	±0.55	±0.06	±0.05	±0.38	±0.19	±0.52	±0.66	±0.14	±0.06	±0.36	±0.50

Appendix 23.2. Calculation of composite contents of CP, EE, CF and NFE in the total diet ingested by group 3 feeding on hay and concentrate diet 2.

Week number	Mean DMI/4 days hay g	Mean DMI/4 days conc. g	CP		EE		CF		NFE		% DM of mixture of hay and conc.			
			hay	conc.	hay	conc.	hay	conc.	hay	conc.	CP	EE	CF	NFE
1	3296	377	9.5	22.8	2.1	1.7	38.3	6.1	41.2	64.6	10.9	2.1	35.0	43.6
2	3552	352	9.5	28.5	2.1	1.8	38.3	6.0	41.2	58.8	11.3	2.1	35.2	42.9
3	3323	350	9.4	25.9	2.1	1.8	39.7	6.0	38.9	60.8	11.0	2.1	36.5	41.0
4	3628	374	10.0	22.7	2.2	1.9	37.5	7.8	40.5	63.1	11.2	2.2	34.7	42.6
5	3672	369	9.6	22.3	2.4	1.6	37.2	5.7	40.3	65.0	10.9	2.3	34.3	42.6
6	3666	366	9.4	23.3	1.8	1.5	34.8	5.9	45.2	66.0	10.7	1.8	32.2	47.1
7	3120	354	10.0	24.1	2.1	1.9	37.8	7.1	40.1	61.0	11.4	2.1	34.8	42.2
8	2761	374	8.7	23.3	2.7	1.6	35.9	6.6	43.7	62.7	10.4	2.6	32.4	46.0
9	3398	365	9.4	22.2	2.2	1.4	37.4	6.5	41.4	64.7	10.6	2.1	34.4	43.7
10	3404	340	8.8	25.2	2.4	1.5	36.0	6.7	44.0	61.2	10.3	2.3	33.3	45.6
11	3648	323	8.3	25.8	2.2	1.9	38.5	7.4	41.9	59.7	9.7	2.2	36.0	43.3
12	2872	361	9.5	23.2	2.3	1.6	37.0	6.4	41.9	63.4	11.0	2.2	33.6	44.3
Mean	3347	359	9.3	24.1	2.2	1.7	37.4	6.5	41.7	62.6	10.8	2.2	34.4	43.7
S.e.	±86.3	±4.6	±0.15	±0.55	±0.06	±0.05	±0.38	±0.19	±0.52	±0.66	±0.14	±0.05	±0.38	±0.31

Appendix 23.3. Calculation of composite contents of CP, EE, CF and NFE in the total diet ingested by group 4 feeding hay and concentrate diet 3.

Week	Mean DMI/4 days	Mean DMI/4 days	CP		EE		CF		NFE		% DM of mixture of hay and conc.			
number	hay g	conc. g	hay	conc.	hay	conc.	hay	conc.	hay	conc.	CP	EE	CF	NFE
1	3240	179	9.5	7.7	2.1	3.7	38.3	3.2	41.2	83.8	9.4	2.2	36.5	43.4
2	3764	170	9.5	7.9	2.1	4.7	38.3	4.0	41.2	79.6	9.4	2.2	36.8	42.3
3	3571	171	9.4	7.5	2.1	5.1	39.7	3.2	38.9	82.3	9.3	2.2	38.0	40.9
4	4076	179	10.0	7.5	2.2	4.3	37.5	3.9	40.5	82.0	9.9	2.3	36.1	42.2
5	3658	181	9.6	7.6	2.4	5.1	37.2	3.2	40.3	82.3	9.5	2.5	35.6	42.3
6	3574	172	9.4	8.2	1.8	4.3	34.8	3.5	45.2	81.3	9.3	1.9	33.4	46.9
7	3434	179	10.0	7.0	2.1	4.8	37.8	3.1	40.1	83.4	9.9	2.2	36.1	42.2
8	3695	174	8.7	7.5	2.7	4.9	35.9	3.1	43.7	85.8	8.6	2.8	34.4	45.6
9	3376	166	9.4	7.0	2.2	4.2	37.4	3.5	41.4	85.8	9.3	2.3	35.8	43.5
10	3523	180	8.8	7.2	2.4	4.2	36.0	3.1	44.0	86.4	8.7	2.2	34.4	46.1
11	4023	167	8.3	7.5	2.2	4.7	38.5	3.6	41.9	84.5	8.3	2.3	37.1	43.6
12	3477	167	9.5	7.5	2.3	4.3	37.0	3.6	41.9	84.5	9.4	2.4	35.5	43.9
Mean	3618	174	9.3	7.5	2.2	4.5	37.4	3.4	41.7	83.5	9.3	2.3	35.8	43.6
S.e.	±71.3	±1.63	±0.15	±0.10	±0.06	±0.12	±0.38	±0.09	±0.52	±0.59	±0.15	±0.06	±0.37	±0.52

Appendix 23.4 Calculation of composite contents of CP, EE, CF and NFE in the total diet ingested by group 5 feeding on hay and concentrate diet 4.

Week number	Mean DMI/4 days hay g	Mean DMI/4 days conc. g	CP		EE		CF		NFE		% DM of mixture of hay and conc.			
			hay	conc.	hay	conc.	hay	conc.	hay	conc.	CP	EE	CF	NFE
1	3482	359	9.5	15.7	2.1	3.3	38.3	5.3	41.2	72.6	10.1	2.2	35.2	44.1
2	3329	350	9.5	16.1	2.1	3.3	38.3	4.9	41.2	72.5	10.1	2.2	35.1	44.2
3	3726	346	9.4	16.5	2.1	3.6	39.7	4.7	38.9	71.8	10.0	2.2	36.7	41.7
4	3861	370	10.0	15.1	2.2	3.2	37.5	5.0	40.5	73.6	10.4	2.3	34.7	43.4
5	3870	364	9.6	15.2	2.4	3.5	37.2	4.6	40.3	73.1	10.1	2.5	34.4	43.1
6	3998	360	9.4	13.7	1.8	3.1	34.8	4.9	45.2	75.1	9.8	1.9	32.3	47.7
7	4083	349	10.0	16.3	2.1	3.2	37.8	4.5	40.1	71.4	10.5	2.2	35.2	42.6
8	3614	368	8.7	15.1	2.7	3.8	35.9	4.4	43.7	74.1	9.3	2.8	33.0	46.5
9	3561	345	9.4	14.1	2.2	2.9	37.4	5.0	41.4	74.5	9.8	2.3	34.5	44.3
10	3002	376	8.8	14.6	2.4	3.2	36.0	4.4	44.0	74.7	9.4	2.5	32.5	47.4
11	4214	351	8.3	15.7	2.2	3.3	38.5	4.8	41.9	71.5	8.9	2.3	35.9	44.2
12	3174	351	9.5	15.7	2.3	3.3	37.0	4.8	41.9	71.5	10.1	2.4	33.8	44.8
Mean	3660	357	9.3	15.3	2.2	3.3	37.4	4.8	41.7	73.0	9.9	2.3	34.4	44.5
S.e.	±107.0	±2.97	±0.15	±0.25	±0.06	±0.07	±0.38	±0.08	±0.52	±0.43	±0.14	±0.06	±0.38	±0.53

Appendix 23.5. Calculation of composite contents of CP, EE, CF and NFE in the total diet ingested by group 6 feeding on hay and concentrate diet 5.

Week number	Mean DMI/4 days hay g	Mean DMI/4 days conc. g	CP		EE		CF		NFE		% DM of mixture of hay and conc.			
			hay	conc.	hay	conc.	hay	conc.	hay	conc.	CP	EE	CF	NFE
1	3781	537	9.5	17.7	2.1	2.7	38.3	5.8	41.7	70.6	10.5	2.2	34.3	44.9
2	3960	525	9.5	18.2	2.1	3.0	38.3	5.6	41.2	69.4	10.5	2.2	34.5	44.5
3	3516	514	9.4	19.2	2.1	3.2	39.7	5.3	38.9	68.3	10.7	2.2	35.3	42.7
4	3814	556	10.0	17.0	2.2	2.7	37.5	5.6	40.5	71.0	10.9	2.3	33.4	44.4
5	3859	535	9.6	17.9	2.4	3.6	37.2	5.5	40.3	69.1	10.6	2.5	33.3	43.8
6	3912	539	9.4	17.1	1.8	2.3	34.8	6.1	45.2	70.2	10.3	1.9	31.3	48.2
7	3835	524	10.0	19.1	2.1	3.1	37.8	5.6	40.1	67.3	11.1	2.2	33.9	43.4
8	3661	557	8.7	18.7	2.7	3.1	35.9	4.9	43.7	69.4	10.0	2.8	31.8	47.1
9	3762	545	9.4	16.8	2.2	2.4	37.4	4.4	41.4	72.4	10.3	2.2	33.2	45.3
10	3272	562	8.8	18.0	2.4	3.0	36.0	4.9	44.0	70.0	10.1	2.5	31.4	47.8
11	3753	531	8.3	18.1	2.2	3.2	38.5	5.6	41.9	69.5	9.5	2.3	34.4	45.3
12	3417	531	9.5	18.1	2.3	3.2	37.0	5.6	41.9	69.5	10.7	2.4	32.8	45.6
Mean	3712	538	9.5	18.0	2.2	3.0	37.4	5.4	41.7	69.7	10.4	2.3	33.3	45.3
S.e.	±60.2	±4.2	±0.15	±0.23	±0.06	±0.10	±0.38	±0.13	±0.52	±0.37	±0.12	±0.06	±0.37	±0.49

Appendix 23.6 Calculation of composite contents of CP, EE, CF and NFE in the total diet ingested by <u>group 7</u> feeding on hay and concentrate diet 3.

Week	Mean DMI/4 days	Mean DMI/4 days	CP		EE		CF		NFE		% DM of mixture of hay and conc.			
number	hay g	conc. g	hay	conc.	hay	conc.	hay	conc.	hay	conc.	CP	EE	CF	NFE
1	3033	357	9.5	7.7	2.1	3.7	38.3	3.2	41.2	83.8	9.3	2.3	34.6	45.7
2	3255	341	9.5	7.9	2.1	4.7	38.3	4.0	41.2	79.6	9.3	2.3	35.0	44.8
3	2965	342	9.4	7.5	2.1	5.1	39.7	3.2	38.9	82.3	9.2	2.4	35.9	43.4
4	3417	359	10.0	7.5	2.2	4.3	37.5	3.9	40.5	82.0	9.8	2.4	34.3	44.4
5	3249	362	9.6	7.6	2.4	5.1	37.2	3.2	40.3	82.3	9.4	2.8	33.8	44.5
6	3240	345	9.4	8.2	1.8	4.3	34.8	3.5	45.2	81.3	9.3	2.0	31.8	48.7
7	3061	358	10.0	7.0	2.1	4.8	37.8	3.1	40.1	83.4	9.7	2.4	34.2	44.6
8	3206	348	8.7	7.5	2.7	4.2	35.9	3.1	43.7	85.8	8.6	2.8	32.7	47.8
9	3254	333	9.4	7.0	2.2	4.5	37.4	3.5	41.4	85.8	9.2	2.4	34.3	45.5
10	3019	359	8.8	7.2	2.4	3.8	36.0	3.1	44.0	86.4	8.6	2.5	32.5	48.5
11	3430	335	8.3	7.5	2.2	3.7	38.5	3.6	41.9	84.5	8.2	2.3	35.4	45.7
12	2776	335	9.5	7.5	2.3	4.7	37.0	3.6	41.9	84.5	9.3	2.6	33.4	46.5
Mean	3159	348	9.3	7.5	2.2	4.4	37.4	3.4	41.7	83.5	9.2	2.4	34.0	45.8
S.e.	±62.7	±3.1	±0.15	±0.10	±0.06	±0.12	±0.38	±0.09	±0.52	±0.59	±0.14	±0.07	±0.35	±0.49

Appendix 23.7 Calculation of composite contents of CP, EE, CF and NFE in the total diet ingested by group 8 feeding on hay and concentrate diet 4.

Week number	Mean DMI/4 days hay g	Mean DMI/4 days conc. g	CP		EE		CF		NFE		% DM of mixture of hay and conc.			
			hay	conc.	hay	conc.	hay	conc.	hay	conc.	CP	EE	CF	NFE
1	3856	532	9.5	12.8	2.1	3.9	38.3	4.0	41.2	76.8	9.9	2.3	34.1	45.5
2	4023	519	9.5	12.7	2.1	3.8	38.3	4.6	41.2	76.4	9.9	2.3	34.4	45.2
3	3914	520	9.4	12.9	2.1	4.0	39.7	3.9	38.9	76.0	9.8	2.3	35.5	43.3
4	4205	535	10.0	13.1	2.2	4.2	37.5	5.2	40.5	74.5	10.4	2.4	33.9	44.3
5	4133	542	9.6	12.9	2.4	4.1	37.2	4.1	40.3	76.4	10.0	2.6	33.4	44.5
6	3935	538	9.4	12.4	1.8	3.2	34.8	4.8	45.2	76.9	9.8	2.0	31.2	49.0
7	4029	517	10.0	12.9	2.1	2.5	37.8	4.7	40.1	77.0	10.3	2.1	34.0	44.3
8	3746	539	8.7	12.9	2.7	2.3	35.9	3.9	43.7	78.2	9.2	2.7	31.9	48.0
9	3978	496	9.4	12.9	2.2	2.9	37.4	5.3	41.4	77.2	9.8	2.3	33.8	45.4
10	3662	544	8.8	12.0	2.4	3.8	36.0	4.3	44.0	77.1	9.2	2.6	31.9	48.3
11	4080	496	8.3	13.0	2.2	2.3	38.5	4.4	41.9	77.5	8.8	2.2	32.5	45.7
12	3112	496	9.5	13.0	2.3	2.3	37.0	4.4	41.9	77.5	10.0	2.3	32.5	46.7
Mean	3889	523	9.3	12.8	2.2	3.3	37.4	4.5	41.7	76.8	9.8	2.3	33.5	45.9
S.e.	±83.5	±5.2	±0.15	±0.09	±0.06	±0.23	±0.38	±0.14	±0.52	±0.27	±0.14	±0.06	±0.36	±0.52

Appendix 23.8 Calculation of composite contents of CP, EE, CF and NFE in the total diet ingested by group 9 feeding on hay and concentrate diet 4.

Week	Mean DMI/4 days	Mean DMI/4 days	CP		EE		CF		NFE		% DM of mixture of hay and conc.			
number	hay g	conc. g	hay	conc.	hay	conc.	hay	conc.	hay	conc.	CP	EE	CF	NFE
1	3514	718	9.5	15.7	2.1	3.3	38.3	5.3	41.2	72.6	10.6	2.2	32.7	46.5
2	3700	701	9.5	16.1	2.1	3.3	38.3	4.9	41.2	72.5	10.6	2.3	33.0	46.2
3	3426	691	9.4	16.5	2.1	3.6	39.7	4.7	38.9	71.8	10.6	2.4	33.8	44.4
4	3710	739	10.0	15.1	2.2	3.2	37.5	5.0	40.5	73.6	10.8	2.4	32.1	46.0
5	3775	729	9.6	15.2	2.4	3.5	37.2	4.6	40.3	73.1	10.5	2.6	31.9	45.6
6	3577	720	9.4	13.7	1.8	3.1	34.8	4.9	45.2	75.1	10.1	2.0	29.8	50.2
7	3715	698	10.0	16.3	2.1	3.2	37.8	4.5	40.1	71.4	11.0	2.3	32.5	45.1
8	3646	737	8.7	15.1	2.7	3.8	35.9	4.4	43.7	74.1	9.8	2.9	30.1	48.8
9	3710	690	9.4	14.1	2.2	2.9	37.4	5.0	41.4	74.5	10.1	2.3	32.3	46.6
10	3613	752	8.8	14.6	2.4	3.2	36.0	4.4	44.0	74.7	9.8	2.5	30.6	49.3
11	3893	702	8.3	15.7	2.2	3.3	38.5	4.8	41.9	71.5	9.4	2.4	33.4	46.4
12	3391	702	9.5	15.7	2.3	3.3	37.0	4.8	41.9	71.5	10.6	2.5	31.5	46.9
Mean	3639	715	9.3	15.3	2.2	3.3	37.4	47.8	41.7	73.0	10.3	2.4	32.0	46.8
S.e.	±41.7	±5.9	±0.15	±0.25	±0.06	±0.07	±0.38	±0.08	±0.52	±0.43	±0.14	±0.06	±0.37	±0.50

Appendix 24.1 Calculation of SE and intake of SE g/kgw$^{0.75}$/wether/day in the 12 week period by group 1 feeding on hay alone.

Week number	Chemical composition of hay				Digestion coefficients of hay								g DMI/4 days		Lwt kgw$^{0.75}$		SE g/g DM		SE g/kgw$^{0.75}$/day	
	CP	EE	CF	NFE	CP		EE		CF		NFE									
1	9.5	2.1	38.3	41.2	51.9	55.8	40.9	56.3	71.0	73.8	49.3	60.9	2370	2739	15.9	15.5	0.52	0.59	19.38	26.06
2	9.5	2.1	38.3	41.2	47.5	41.6	28.7	36.9	65.3	70.3	54.0	52.4	2760	2780	15.8	15.5	0.51	0.52	22.27	23.32
3	9.4	2.1	39.7	38.9	37.9	42.4	31.9	29.3	71.2	71.7	52.5	53.5	2694	2456	15.6	15.5	0.51	0.52	22.02	20.60
4	10.0	2.2	37.5	40.5	61.0	61.3	50.1	54.0	75.3	76.7	63.4	63.0	2935	2626	15.6	15.3	0.60	0.60	28.22	25.75
5	9.6	2.4	37.2	40.3	49.5	64.4	50.7	70.5	69.7	75.1	56.7	56.3	2415	2698	15.6	15.5	0.54	0.58	20.90	25.24
6	9.4	1.8	34.8	45.2	37.2	45.4	38.3	32.7	53.2	66.5	60.1	70.9	2519	2822	15.8	15.6	0.48	0.58	19.13	26.23
7	10.0	2.1	37.8	40.1	40.9	54.9	1.7	34.2	52.6	65.3	27.1	51.3	2322	2920	15.6	15.5	0.33	0.50	12.28	23.55
8	8.7	2.7	35.9	43.7	29.7	44.6	47.7	67.4	53.2	67.0	45.9	56.3	2390	2737	15.6	15.2	0.42	0.54	16.09	24.31
9	9.4	2.2	37.4	41.4	46.1	59.5	17.0	17.0	55.8	71.6	40.8	58.0	2407	3093	15.8	15.5	0.41	0.55	15.62	27.44
10	8.8	2.4	36.0	44.0	40.5	48,7	47.8	51.3	59.3	64.8	50.8	58.6	2933	2700	15.8	15.6	0.47	0.53	21.81	22.93
11	8.3	2.2	38.5	41.9	40.1	47.6	65.1	72.2	70.2	72.9	54.5	60.4	3574	3649	15.6	15.5	0.54	0.58	30.93	34.14
12	9.5	2.3	37.0	41.9	51.1	58.1	16.8	32.9	65.3	73.4	49.4	56.3	3011	3576	15.8	15.6	0.48	0.55	22.87	31.52
Mean	9.3	2.2	37.4	41.7	44.5	52.0	36.4	46.2	63.5	70.8	50.4	58.2	2694	2900	15.7	15.5	0.48	0.55	20.96	25.92
S.e.	±0.15	±0.06	±0.38	±0.52	±2.42	±2.28	±5.18	±5.26	±2.39	±1.15	±2.75	±1.54	±107	±106	-	-	±0.02	±0.01	±1.49	±1.08

Appendix 24.2 Calculation of SE and intake of SE g/kgw$^{0.75}$/wether/day in the 12 week period by group 2 feeding on hay and concentrate diet 2.

Week number	Chemical composition of the total diet				Digestion coefficients of hay								g DMI/4 days		Lwt kgw$^{0.75}$		SE g/g DM		SE g/kgw$^{0.75}$/day	
	CP	EE	CF	NFE	CP		EE		CF		NFE									
1	10.2	2.1	36.7	42.4	53.0	52.9	50.6	53.0	66.3	68.7	56.4	58.7	3543	4112	17.1	17.2	0.53	0.55	27.45	32.87
2	10.4	2.1	36.8	42.0	34.5	61.9	26.3	57.9	55.8	74.0	40.4	66.3	3372	4241	16.6	17.4	0.40	0.61	20.31	37.17
3	10.3	2.1	37.9	40.1	41.5	62.8	19.2	36.3	70.0	75.6	60.3	64.8	2448	4158	16.8	17.4	0.54	0.60	19.67	35.84
4	10.6	2.2	36.1	41.6	58.4	63.5	50.6	54.7	84.0	74.8	61.6	65.2	3239	4305	16.8	17.4	0.62	0.61	29.88	37.73
5	10.2	2.4	35.7	41.5	50.9	56.5	66.1	78.1	66.8	73.7	39.6	64.6	3340	4394	16.9	17.7	0.46	0.60	22.73	37.24
6	10.1	1.8	33.4	46.2	44.1	47.0	29.2	23.8	54.1	63.3	60.9	62.4	3052	4256	17.2	18.1	0.49	0.53	21.74	31.16
7	10.6	2.1	36.4	41.1	53.7	57.3	44.6	53.2	62.3	71.8	47.4	60.7	3293	4467	16.8	17.8	0.47	0.57	23.03	35.76
8	9.4	2.6	34.5	44.6	45.6	54.6	51.9	62.1	59.1	69.1	51.9	60.0	3469	4498	17.1	17.7	0.48	0.57	24.34	36.21
9	10.0	2.2	36.0	42.5	34.2	61.9	7.9	30.0	52.3	74.1	38.7	66.9	3710	4367	16.9	17.9	0.37	0.60	20.31	36.59
10	9.5	2.4	34.7	44.8	45.5	52.0	49.3	53.3	60.0	65.2	44.7	59.0	3372	4263	17.1	17.9	0.45	0.54	22.18	32.15
11	9.0	2.2	37.3	42.6	46.0	50.1	68.8	73.2	70.4	71.5	56.2	59.2	3879	4303	16.9	18.1	0.55	0.57	31.55	33.88
12	10.1	2.3	35.6	42.9	54.7	48.6	54.4	56.6	69.6	68.4	55.1	52.8	3893	3933	16.9	17.2	0.54	0.52	31.10	29.73
Mean	10.0	2.2	35.9	42.7	46.8	55.8	43.2	52.7	64.1	70.9	51.1	61.7	3384	4275	16.9	17.6	0.49	0.57	24.52	34.69
S.e.	±0.14	±0.06	±0.36	±0.50	±2.22	±1.68	±5.39	±4.63	±2.56	±1.14	±2.49	±1.18	±112	±45	–	–	±0.02	±0.01	±1.25	±0.77

Appendix 24.3 Calculation of SE and intake of SE g/kg $w^{0.75}$/wether/day in the 12 week period by group 3 feeding on hay and concentrate diet 2.

Week number	Chemical composition of the total diet				Digestion coefficients of the total diet								g DMI/4 days		Lwt $kgw^{0.75}$		SE g/g DM		SE $g/kgw^{0.75}$/day	
	CP	EE	CF	NFE	CP		EE		CF		NFE									
1	10.9	2.1	35.0	43.6	47.8	54.2	41.1	45.2	62.4	65.0	55.0	59.2	3541	3805	16.8	17.7	0.50	0.54	26.35	29.02
2	11.3	2.1	35.2	42.9	53.3	58.9	28.9	43.1	66.1	71.7	57.5	60.2	3769	3637	16.8	17.2	0.53	0.57	29.73	30.13
3	11.0	2.1	36.5	41.0	40.5	56.9	15.1	25.9	66.7	70.3	57.0	59.0	3201	4144	16.6	17.5	0.51	0.55	24.59	32.56
4	11.2	2.2	34.7	42.6	62.7	61.5	48.2	49.1	73.0	72.7	65.8	65.0	3776	4227	16.9	17.5	0.60	0.59	33.51	35.63
5	10.9	2.3	34.3	42.6	62.1	60.5	76.2	74.8	70.8	71.3	61.5	57.1	3678	4404	17.1	17.9	0.58	0.56	31.19	34.44
6	10.7	1.8	32.2	47.1	61.7	55.3	31.8	26.5	68.9	66.6	73.3	66.7	3744	4319	17.4	18.1	0.62	0.57	33.35	34.00
7	11.4	2.1	34.8	42.2	59.5	56.2	50.9	53.3	63.9	69.1	61.9	57.0	3068	3879	17.2	17.9	0.55	0.54	24.53	29.26
8	10.4	2.6	32.4	46.0	51.3	52.1	55.8	56.4	61.9	63.1	55.6	41.1	3267	3043	16.9	17.9	0.51	0.45	24.65	19.13
9	10.6	2.1	34.4	43.7	58.8	58.9	34.7	52.3	67.3	71.3	62.4	63.0	3504	4022	17.1	17.9	0.56	0.58	28.69	32.58
10	10.3	2.3	33.3	45.6	50.8	46.1	54.4	49.3	59.0	62.4	61.1	59.0	3480	4006	17.1	18.1	0.53	0.52	26.96	28.77
11	9.7	2.2	36.0	43.3	49.1	43.5	69.8	72.4	69.3	68.3	62.0	57.5	3959	3982	16.9	18.1	0.57	0.55	33.38	30.25
12	11.0	2.2	33.6	44.3	46.3	52.1	44.0	55.1	45.1	64.9	48.0	59.1	2563	3902	16.9	18.2	0.41	0.54	15.54	28.94
Mean	10.8	2.2	34.4	43.7	53.7	54.7	45.9	50.3	64.5	68.1	60.1	58.7	3462	3947	16.9	17.8	0.54	0.55	27.71	30.39
S.e.	±0.14	±0.05	±0.38	±0.51	±2.09	±1.60	±4.99	±4.27	±2.11	±1.03	±1.81	±1.83	±112	±104	-	-	±0.01	±0.01	±1.48	±1.24

Appendix 24.4 Calculation of SE and intake of SE g/kgw$^{0.75}$/wether/day in the 12 week period by group 4 feeding on hay and concentrate diet 3.

Week number	Chemical composition of the total diet				Digestion coefficients of the total diet								g DMI/4 days		Lwt kgw$^{0.75}$		SE g/g DM		SE g/kgw$^{0.75}$/day	
	CP	EE	CF	NFE	CP		EE		CF		NFE									
1	9.4	2.2	36.5	43.4	59.8	43.8	59.3	41.7	75.4	59.4	65.3	54.3	3557	3280	19.1	16.1	0.61	0.49	28.40	24.96
2	9.4	2.2	36.8	42.3	63.8	53.9	55.4	53.1	78.1	67.2	68.9	60.3	4106	3764	18.8	16.1	0.64	0.55	34.94	32.15
3	9.3	2.2	38.0	40.9	53.1	44.2	24.4	28.9	74.4	62.6	59.3	46.8	4118	3366	19.2	15.8	0.56	0.46	30.03	24.50
4	9.9	2.3	36.1	42.2	71.2	60.7	68.8	53.6	80.5	70.6	74.1	62.0	4368	4142	19.1	15.8	0.68	0.58	38.88	38.01
5	9.5	2.5	35.6	42.3	63.3	59.2	78.2	74.2	73.5	67.5	48.6	52.7	3518	4161	19.5	16.1	0.54	0.53	24.36	34.24
6	9.3	1.9	33.4	46.9	52.5	51.6	9.9	28.9	64.1	55.3	65.0	62.7	3900	3593	19.6	16.0	0.55	0.51	27.36	28.63
7	9.9	2.2	36.1	42.2	62.1	57.5	43.6	29.1	69.0	67.3	61.6	56.2	3186	4040	19.5	16.2	0.57	0.53	23.28	33.04
8	8.6	2.8	34.4	45.6	51.7	42.0	59.8	57.4	70.5	57.5	54.4	54.0	4223	3514	19.4	15.8	0.54	0.49	29.39	27.24
9	9.3	2.3	35.8	43.5	58.1	52.6	51.2	48.2	67.4	62.2	63.0	58.7	3575	3508	19.5	15.8	0.57	0.53	26.13	29.42
10	8.7	2.5	34.4	46.1	49.2	34.2	53.6	49.5	65.0	59.8	51.7	57.2	3963	3436	19.6	15.8	0.51	0.50	25.78	27.18
11	8.3	2.3	37.1	43.6	45.6	41.8	70.5	72.2	74.2	66.6	63.8	59.9	4498	3883	19.4	15.6	0.60	0.55	34.78	34.23
12	9.4	2.4	35.5	43.9	58.8	47.1	58.8	43.8	74.3	57.7	65.3	54.6	4213	3076	19.6	15.8	0.61	0.49	32.78	23.85
Wether mean	9.3	2.3	35.8	43.6	57.4	49.1	52.5	48.4	72.2	62.8	61.8	56.6	3935	3647	19.3	15.9	0.58	0.52	29.68	29.79
S.e.	±0.15	±0.06	±0.37	±0.52	±2.10	±2.36	±5.57	±4.41	±1.47	±1.43	±2.10	±1.30	±115	±102	-	-	±0.01	±0.01	±1.38	±1.30

Appendix 24.5 Calculation of SE and intake of SE g/kg $w^{0.75}$/wether/day in the 12 week period by <u>group 5</u> feeding on hay and concentrate diet 4.

Week	Chemical composition of the total diet				Digestion coefficients of the total diet								g DMI/4 days		Lwt $kgw^{0.75}$		SE g/g DM		SE $g/kgw^{0.75}$/day	
number	CP	EE	CF	NFE	CP		EE		CF		NFE									
1	10.1	2.2	35.2	44.1	42.9	43.6	42.5	39.2	60.7	63.3	55.4	51.6	3531	4151	16.1	17.9	0.50	0.49	27.41	28.41
2	10.1	2.2	35.1	44.2	57.1	61.8	57.7	50.7	70.7	68.9	65.3	65.7	3721	3637	16.2	17.8	0.60	0.59	34.45	30.14
3	10.0	2.2	36.7	41.7	52.5	52.4	34.7	28.0	66.1	64.1	57.9	55.1	3909	4233	16.1	17.9	0.53	0.51	32.17	30.15
4	10.4	2.3	34.7	43.4	54.1	60.6	42.0	50.4	68.4	72.6	58.1	64.3	4201	4261	16.1	17.8	0.54	0.59	35.23	35.31
5	10.1	2.5	34.4	43.1	67.1	58.2	84.9	76.1	79.2	69.5	78.0	60.7	4089	4380	16.8	18.4	0.69	0.57	41.99	33.92
6	9.8	1.9	32.3	47.7	32.1	54.4	37.9	43.6	70.4	62.1	67.4	63.3	4421	4295	16.8	18.4	0.57	0.55	37.50	32.10
7	10.5	2.2	35.2	42.6	59.9	56.9	37.1	32.6	68.9	63.2	62.0	59.2	4408	4455	17.1	17.8	0.56	0.52	36.09	32.54
8	9.3	2.8	33.0	46.5	42.6	47.6	52.4	62.2	61.7	56.0	54.6	51.5	4051	3913	16.9	18.4	0.50	0.51	29.96	27.11
9	9.8	2.3	34.5	44.3	50.4	60.1	38.1	39.4	63.3	68.7	59.3	61.1	3774	4038	16.1	17.9	0.52	0.56	30.47	31.58
10	9.4	2.5	32.5	47.4	46.1	26.2	53.6	48.0	59.4	40.7	61.4	48.0	3858	2897	16.8	18.1	0.53	0.39	30.43	15.61
11	8.9	2.3	35.9	44.2	50.2	45.7	73.3	68.0	71.4	67.1	63.7	61.2	4589	4540	16.8	17.9	0.59	0.56	40.29	35.51
12	10.1	2.4	33.8	44.8	47.3	44.1	64.0	36.9	63.0	51.4	51.9	48.6	4032	3017	16.8	18.1	0.50	0.43	30.00	17.92
Wether mean	9.9	2.3	34.4	44.5	50.2	51.0	51.5	48.0	66.9	62.3	61.3	58.0	4049	3985	16.5	18.0	0.55	0.52	33.83	29.19
S.e.	±0.14	±0.06	±0.38	±0.53	±2.63	±2.95	±4.58	±4.21	±1.64	±2.61	±2.01	±1.81	±91	±156	-	-	±0.02	±0.02	±1.31	±1.84

Appendix 24.6 Calculation of SE and intake of SE g/kg $W^{0.75}$/wether/day in the 12 week period by group 6 feeding on hay and concentrate diet 5.

Week number	Chemical composition of the total diet				Digestion coefficients of the total diet								g DMI/4 days		Lwt $kgw^{0.75}$		SE g/g DM		SE $g/kgw^{0.75}$/day	
	CP	EE	CF	NFE	CP		EE		CP		NFE									
1	10.5	2.2	34.3	44.9	53.2	30.8	52.1	28.2	66.8	52.3	62.4	46.4	4353	4283	19.5	17.2	0.56	0.41	31.25	25.52
2	10.5	2.2	34.5	44.5	60.4	57.4	52.7	53.3	72.1	72.8	65.1	65.4	4392	4577	19.5	17.4	0.60	0.60	33.78	39.46
3	10.7	2.2	35.3	42.7	54.6	55.0	41.4	47.1	63.9	66.7	58.5	61.2	4014	4044	19.6	17.1	0.53	0.55	27.14	32.52
4	10.9	2.3	33.4	44.4	63.9	63.0	50.6	36.0	72.8	72.3	69.6	70.1	4321	4419	19.6	17.5	0.62	0.61	34.17	38.51
5	10.6	2.5	33.3	43.8	61.8	64.4	76.0	79.1	71.5	73.8	52.4	69.1	4452	4452	20.2	17.8	0.55	0.63	29.51	39.39
6	10.3	1.9	31.3	48.2	53.6	60.8	25.4	44.1	58.5	69.9	66.7	69.8	4267	4635	20.1	18.1	0.55	0.61	29.19	39.05
7	11.1	2.2	33.9	43.4	62.6	59.2	49.3	48.1	70.3	67.5	63.4	60.5	4330	4389	20.1	20.6	0.58	0.55	31.24	29.30
8	10.0	2.8	31.8	47.1	53.1	48.8	69.3	73.1	63.7	60.7	60.9	61.7	4382	4054	19.9	17.8	0.56	0.55	30.83	31.32
9	10.3	2.2	33.2	45.3	59.5	57.8	37.4	49.5	69.2	69.8	63.9	64.8	4375	4239	19.9	17.9	0.57	0.58	31.33	34.34
10	10.1	2.5	31.4	47.8	47.7	54.9	38.1	42.1	57.3	64.6	58.7	63.4	3469	4197	20.1	18.1	0.50	0.56	21.57	32.46
11	9.5	2.3	34.4	45.3	50.7	48.5	65.6	62.1	70.8	64.9	64.5	62.0	4343	4225	19.9	17.9	0.59	0.55	32.19	32.45
12	10.7	2.4	32.8	45.6	56.1	53.6	60.6	56.8	68.4	66.8	58.3	58.5	3952	3943	20.2	17.7	0.55	0.55	26.90	30.63
Wether mean	10.4	2.3	33.3	45.3	56.4	54.5	51.5	51.6	67.1	66.8	62.0	62.7	4211	4288	19.8	17.9	0.56	0.56	29.93	33.75
S.e.	±0.12	±0.37	±0.37	±0.49	±1.48	±2.59	±4.24	±4.21	±1.51	±1.72	±1.33	±1.85	±79	±62	-	-	±0.01	±0.02	±1.00	±1.30

Appendix 24.7 Calculation of SE and intake of SE g/kg $w^{0.75}$/wether/day in the 12 week period feeding on hay and concentrate diet 3

Week	Chemical composition of the total diet				Digestion coefficients of the total diet								g DMI/4 days		Lwt kg$w^{0.75}$		SE g/g DM		SE g/kg$w^{0.75}$/day	
number	CP	EE	CF	NFE	CP		EE		CF		NFE									
1	9.3	2.3	34.6	45.7	47.3	45.1	43.8	47.3	66.5	67.8	58.9	60.0	3625	3154	18.1	15.8	0.54	0.55	27.04	27.45
2	9.3	2.3	35.0	44.8	37.3	50.7	24.0	44.3	59.4	73.0	51.5	63.5	3639	3552	18.2	16.1	0.46	0.58	22.99	31.99
3	9.2	2.4	35.9	43.4	68.5	35.4	49.2	35.4	33.6	65.1	72.4	50.7	3844	2768	18.2	15.6	0.50	0.48	26.40	21.29
4	9.8	2.4	34.3	44.4	56.9	65.1	30.6	41.9	70.4	78.4	66.3	74.1	3939	3613	18.4	16.2	0.58	0.66	31.04	36.80
5	9.4	2.8	33.8	44.5	58.0	51.6	78.8	79.2	73.6	69.6	67.2	61.0	3815	3407	18.5	16.8	0.62	0.57	31.96	28.90
6	9.3	2.0	31.8	48.7	53.4	52.3	14.6	17.0	67.9	64.4	66.8	70.4	3683	3484	18.8	16.8	0.57	0.58	27.92	30.07
7	9.7	2.4	34.2	44.6	56.0	59.0	44.5	62.1	65.4	69.8	56.4	58.8	3479	3358	18.8	16.8	0.53	0.56	24.52	27.98
8	8.6	2.8	32.7	47.8	38.4	50.2	56.4	61.1	55.6	69.4	60.6	63.9	3182	3925	18.4	16.8	0.51	0.59	22.05	34.46
9	9.2	2.6	34.3	45.5	54.4	58.6	30.5	52.9	70.2	72.0	61.2	65.1	3293	3880	18.1	16.8	0.56	0.60	25.47	34.64
10	8.6	2.5	32.5	48.5	47.0	48.2	44.0	32.8	60.7	63.9	63.6	65.0	3239	3517	18.4	16.6	0.54	0.56	23.76	29.66
11	8.2	2.3	35.4	45.7	39.0	45.0	59.9	64.0	68.5	69.6	62.5	64.1	3662	3868	17.9	16.8	0.56	0.58	28.64	33.38
12	9.3	2.6	33.4	46.5	38.3	51.6	49.5	56.0	54.2	67.6	49.2	60.6	2753	3467	18.2	16.8	0.45	0.56	17.02	28.89
Wether mean	9.2	2.4	34.0	45.8	49.5	51.1	43.8	49.5	62.2	69.2	61.4	63.1	3513	3499	18.3	16.4	0.54	0.57	25.72	30.46
S.e.	±0.14	±0.07	±0.35	±0.49	±2.88	±2.21	±5.01	±4.82	±3.14	±1.17	±1.93	±1.69	±98	±94	-	-	±0.01	±0.01	±1.17	±1.20

Appendix 24.8 Calculation of SE and intake of SE g/kg $w^{0.75}$/wether/day in the 12 week period by <u>group 8</u> feeding on hay and concentrate diet 6

Week number	Chemical composition of the total diet				Digestion coefficients of the total diet								g DMI/4 days		SE Lwt $kgw^{0.75}$		g/g DM		SE $g/kgw^{0.75}$/day	
	CP	EE	CF	NFE	CP		EE		CF		NFE									
1	9.9	2.3	34.1	45.5	48.2	75.9	47.4	72.1	64.9	82.4	57.6	79.9	4205	4569	18.7	19.2	0.53	0.73	29.79	43.43
2	9.9	2.3	34.4	45.2	53.4	58.1	55.0	56.4	66.7	67.5	66.2	67.8	4506	4577	18.8	18.9	0.58	0.60	34.75	36.33
3	9.8	2.3	35.5	43.3	52.7	57.0	38.6	36.6	71.7	71.9	61.5	61.5	4389	4479	18.8	19.5	0.57	0.57	33.27	32.73
4	10.4	2.4	33.9	44.3	49.6	63.1	39.1	39.1	75.4	73.3	69.3	48.2	4780	4699	18.7	19.1	0.61	0.52	38.98	31.98
5	10.0	2.6	33.4	44.5	60.7	69.3	57.6	61.8	73.6	75.5	67.6	69.1	4758	4593	19.4	19.9	0.61	0.64	37.40	36.93
6	9.8	2.0	31.2	49.0	57.0	55.9	44.5	50.8	68.1	66.4	65.9	67.1	4652	4293	19.8	19.9	0.58	0.59	34.07	31.92
7	10.3	2.1	34.0	44.3	59.4	42.8	59.4	40.2	68.6	50.3	61.2	39.7	4611	4481	19.4	19.6	0.57	0.38	33.87	21.72
8	9.2	2.7	31.9	48.0	39.6	51.6	53.4	59.8	59.8	60.0	58.0	64.8	4523	4047	19.2	19.6	0.51	0.56	30.04	28.91
9	9.8	2.3	33.8	45.4	58.9	64.0	40.4	33.8	72.8	72.8	67.2	67.0	4520	4427	19.5	19.9	0.60	0.60	34.77	33.37
10	9.2	2.6	31.9	48.3	51.2	50.9	45.7	56.1	67.1	60.8	66.0	62.1	4551	3860	19.5	19.8	0.58	0.55	33.84	26.81
11	8.8	2.2	34.8	45.7	51.7	55.4	65.6	69.2	72.3	70.4	70.7	69.3	4694	4458	19.5	19.8	0.63	0.62	37.91	34.90
12	10.0	2.3	32.5	46.7	46.9	55.8	56.6	58.6	60.3	65.5	53.8	57.4	3688	3528	19.5	19.9	0.50	0.54	23.64	23.93
Wether mean	9.8	2.3	33.5	45.9	52.4	58.3	50.3	52.9	68.4	68.1	63.8	62.8	4490	4334	19.2	19.5	0.57	0.58	33.53	31.91
S.e.	±0.14	±0.06	±0.36	±0.52	±1.75	±2.54	±2.56	±3.70	±1.45	±2.42	±1.52	±3.04	±86	±101	-	-	±0.01	±0.02	±1.21	±1.73

Appendix 24.9 Calculation of SE and intake of SE g/kg $w^{0.75}$/wether/day in the 12 week period by group 9 feeding on hay and concentrate diet 4.

Week number	Chemical composition of the total diet CP	EE	CF	NFE	Digestion coefficients of the total diet CP		EE		CF		NFE		g DMI/4 days		Lwt $kgw^{0.75}$		SE g/g DM		SE $g/kgw^{0.75}$/day	
1	10.6	2.3	32.7	46.5	51.0	51.0	59.0	44.0	67.6	70.4	63.4	62.3	4156	4306	18.1	19.5	0.57	0.57	32.72	31.47
2	10.6	2.3	33.0	46.2	57.3	61.8	67.2	59.7	66.9	68.7	71.9	76.5	4432	4369	17.9	19.8	0.62	0.65	38.38	35.86
3	10.6	2.4	33.8	44.4	14.3	58.0	14.9	37.2	73.0	72.3	13.5	62.3	4026	4207	17.9	19.9	0.31	0.58	17.43	30.65
4	10.8	2.4	32.1	46.0	60.1	61.9	57.7	57.0	73.3	76.0	70.1	70.5	4351	4547	17.8	20.2	0.63	0.64	38.50	36.02
5	10.5	2.6	31.9	45.6	60.3	64.7	63.1	68.3	70.9	74.6	70.7	75.3	4549	4459	18.4	20.5	0.62	0.66	38.32	35.89
6	10.1	2.0	29.8	50.2	52.8	56.5	51.5	52.9	66.2	70.2	66.1	69.4	4450	4143	18.8	21.0	0.58	0.61	34.32	30.09
7	11.0	2.3	32.5	45.1	60.7	58.4	69.2	72.0	67.4	71.0	60.3	60.0	4676	4151	18.8	20.5	0.56	0.57	34.82	28.85
8	9.8	2.9	30.1	48.8	52.5	46.5	63.7	52.8	66.0	59.7	66.6	63.8	4871	3894	18.4	20.5	0.59	0.54	39.05	25.64
9	10.1	2.3	32.3	46.6	57.5	56.0	45.2	41.7	72.3	74.4	65.5	64.8	4511	4288	18.1	20.6	0.59	0.59	36.76	30.70
10	9.8	2.5	30.6	49.3	57.1	48.7	63.4	60.9	66.4	65.8	70.8	62.7	4399	4331	18.4	20.7	0.62	0.56	37.06	29.29
11	9.4	2.4	33.4	46.4	52.8	56.5	74.1	75.8	71.0	77.6	66.2	71.6	4677	4513	18.4	20.7	0.61	0.66	38.76	35.97
12	10.6	2.5	31.5	46.9	55.4	64.3	71.5	74.4	65.0	70.3	60.7	72.3	3983	4203	18.8	20.9	0.56	0.64	29.66	32.18
Wether mean	10.3	2.4	32.0	46.8	52.7	57.0	58.4	58.1	68.8	70.9	62.2	67.6	4423	4284	18.3	20.4	0.57	0.61	34.65	31.88
S.e.	±0.14	±0.06	±0.37	±0.50	±3.62	±1.68	±4.61	±3.75	±0.88	±1.39	±4.56	±1.63	±77	±53	-	-	±0.03	±0.01	±1.77	±0.98

Appendix 25. Analysis of variance of ingested DCP as affected by the levels of protein and energy rich concentrate supplementation to C. *gayana*.

Source			df	*ss*	*Mss*	*F*	*P*
Weeks			11	29.90	2.72	14.32	<0.01
Treatments			8	17.18	2.15	2.39	NS
Levels of supplementation with BM		2		12.99	6.50	7.22	<0.05
BM linear	1			11.06	11.06	12.29	<0.01
BM quadratic	1			1.93	1.93	2.14	NS
Levels of supplementation with MM		2		1.41	0.71	0.79	NS
MM linear	1			0.07	0.07	0.08	NS
MM quadratic	1			1.34	1.34	1.49	NS
BM x MM		4		2.78	0.70	0.78	NS
BM_L x MM_L	1			0.26	0.26	0.29	NS
Treatments x weeks			88	14.53	0.17	0.89	NS
Replicates			1	2.78	2.78	3.09	NS
Treatments x replicates			8	7.20	0.90		
Treatments x replicates x weeks			99	18.97	0.19		
Total			215	90.56			

Appendix 26. Analysis of variance of ingested DE as affected by the levels of protein and energy rich concentrate supplementation to C. gayana.

Source			df	ss	Mss	F	P
Weeks			6	17965.58	2994.26	11.60	<0.01
Treatments			8	8128.13	1016.02	0.52	NS
Levels of supplementation with BM		2		1573.77	786.89	0.40	NS
BM linear	1			236.28	236.28	0.12	NS
BM quadratic	1			1337.49	1337.49	0.69	NS
Levels of supplementation with MM		2		4695.53	2347.77	1.20	NS
MM linear	1			1816.38	1816.38	0.93	NS
MM quadratic	1			2879.15	2879.15	1.47	NS
BM x MM		4		1858.83	464.71	0.24	NS
$BM_L \times MM_L$	1			13.64	13.64	0.01	NS
Treatments x weeks			48	20328.07	423.50	1.64	<0.05
Replicates			1	1510.56	1510.56	0.77	NS
Treatments x replicates			8	15619.07	1952.38		
Treatments x replicates x weeks			54	13937.37	258.10		
Total			125	77488.78			

Appendix 27. Analysis of variance of ingested SE as affected by the levels of protein and energy rich concentrate supplementation to C. *gayana*.

Source	df			ss	Mss	F	P
Weeks			11	1519.27	138.12	9.22	<0.01
Treatments			8	1710.11	213.76	1.67	NS
Levels of supplementation with BM		2		871.27	435.64	3.41	NS
BM linear	1			674.53	674.53	5.28	NS
BM quadratic	1			196.74	196.74	1.54	NS
Levels of supplementation with MM		2		694.67	347.34	2.72	NS
MM linear	1			564.30	564.30	4.41	NS
MM quadratic	1			130.37	130.37	1.02	NS
BM x MM		4		144.17	36.04	0.28	NS
BM_L x MM_L	1			1.77	1.77	0.01	NS
Treatments x weeks			88	1229.24	13.97	0.93	NS
Replicates			1	207.95	207.95	1.63	NS
Treatments x replicates			8	1222.89	127.86		
Treatments x replicates x weeks			99	1483.10	14.98		
Total			215	7172.56			

Appendix 28. Weekly liveweights (kg) of wether sheep throughout the experimental period.

Group number	1		2		3		4		5		6		7		8		9	
Diet number	1		2		2		3		4		5		3		6		4	
BM g/wether/day	0		50		100		0		50		100		0		50		100	
NM g/wether/day	0		0		0		50		50		50		100		100		100	
H a y	A d l i b i t u m																	
Week number																		
1	40.0	38.5	44.0	44.5	43.0	46.0	51.0	40.5	40.5	47.0	52.5	44.5	47.5	39.5	49.5	51.5	47.5	52.5
$\bar{X}$*	39.3		44.3		44.5		45.8		43.8		48.5		43.5		50.5		50.0	
2	39.5	38.5	42.5	45.0	43.0	44.5	50.0	40.5	41.0	46.5	52.5	45.0	48.0	40.5	50.0	50.5	47.0	53.5
$\bar{X}$*	39.0		43.8		43.8		45.3		43.5		48.8		44.3		50.3		50.3	
3	39.0	38.5	42.0	45.0	42.5	45.5	51.5	40.0	41.5	47.0	53.0	44.0	46.0	39.0	50.0	52.5	47.0	54.0
$\bar{X}$*	38.8		43.5		44.0		45.8		44.3		48.5		43.5		51.3		50.5	
4	39.0	38.0	42.0	45.0	43.5	45.5	51.0	40.0	41.5	46.5	53.0	45.5	48.5	41.0	49.5	51.0	46.5	55.0
$\bar{X}$*	38.5		43.5		44.5		45.5		44.0		49.3		44.8		50.3		50.8	
5	39.0	38.5	43.5	46.0	44.0	47.0	52.5	41.5	42.0	48.5	55.0	46.5	49.0	42.0	52.0	54.0	48.5	56.0
$\bar{X}$*	38.8		44.8		45.5		47.0		45.3		50.8		45.5		53.0		52.3	
6	40.0	39.5	44.5	47.5	45.0	47.5	53.0	40.5	43.0	48.5	54.5	47.5	50.0	42.0	53.5	54.0	50.0	58.0
$\bar{X}$*	39.8		46.0		46.3		46.8		45.8		51.0		46.0		53.8		54.0	
7	39.0	38.5	43.0	46.5	44.5	47.0	52.5	41.0	44.0	46.5	54.5	56.5	50.0	42.0	52.0	53.0	50.0	56.0
$\bar{X}$*	38.8		44.8		45.8		46.8		45.3		50.5		46.0		52.5		53.0	
8	39.0	37.5	44.0	46.0	43.5	47.0	52.0	39.5	43.5	48.5	54.0	46.5	48.5	42.0	51.5	53.0	48.5	56.0
$\bar{X}$*	38.3		45.0		45.3		45.8		46.0		50.3		45.3		52.3		52.3	
9	39.5	38.5	43.5	47.0	44.0	47.0	52.5	40.0	41.5	47.0	54.0	47.0	47.5	42.0	52.5	54.0	47.5	56.5
$\bar{X}$*	39.0		45.3		45.5		46.3		44.3		50.5		44.8		53.3		52.0	
10	40.0	39.0	44.0	47.0	44.0	47.5	53.0	39.5	43.0	47.5	54.5	47.5	48.5	42.5	52.5	53.5	48.5	57.0
$\bar{X}$*	39.5		45.5		45.8		46.3		45.3		51.0		45.5		53.0		52.8	
11	39.0	38.5	43.5	47.5	43.5	47.5	52.0	39.0	43.0	47.0	54.0	47.0	47.0	42.0	52.5	53.5	48.5	57.0
$\bar{X}$*	38.8		45.5		45.5		45.5		45.0		50.5		44.5		53.0		52.8	
12	39.5	39.0	43.5	44.5	43.5	48.0	53.0	40.0	43.0	47.5	55.0	46.0	48.0	43.0	52.5	54.0	50.0	57.5
$\bar{X}$*	39.3		44.0		45.8		46.5		45.3		50.5		45.5		53.3		53.8	
13	39.5	39.0	43.0	44.5	44.0	45.5	53.5	39.0	42.0	46.0	54.0	45.5	47.0	42.0	52.5	53.0	49.0	56.0
$\bar{X}$*	39.3		43.8		44.8		46.3		44.0		49.8		44.5		52.8		52.5	
$\bar{X}$**	39.0		44.8		45.1		46.2		44.8		50.0		44.9		52.3		52.1	

Note

$\bar{X}$* - group mean.

$\bar{X}$** - mean of group means.

Appendix 29. Effect of levels of protein and energy rich concentrate supplementation on liveweight changes kg/wether/week.

Group number	1		2		3		4		5		6		7		8		9	
Diet number	1		2		2		3		4		5		3		6		4	
DM g/wether/day	0		50		100		0		50		100		0		50		100	
NM g/wether/day	0		0		0		50		50		50		100		100		100	
Hay	Ad libitum																	
Week number 1	-0.5	0	-1.5	0.5	0	-1.5	-1.0	0	0.5	-0.5	0	0.5	0.5	1.0	0.5	-1.0	-0.5	1.0
$\bar{X}^*$	-0.25		-0.5		-0.75		-0.5		0		0.25		0.75		-0.25		0.25	
2	-0.5	0	-0.5	0	-0.5	1.0	1.5	-0.5	0.5	0.5	0.5	-1.0	0	-1.5	0	2.0	0	0.5
$\bar{X}^*$	-0.25		-0.25		0.25		0.5		0.5		-0.25		-0.75		1.0		0.25	
3	0	-0.5	0	0	1.0	0	-0.5	0	0	-0.5	0	1.5	0.5	2.0	-0.5	-1.5	-0.5	1.0
$\bar{X}^*$	-0.25		0		0.5		-0.25		-0.25		0.75		1.25		-1.0		0.25	
4	0	0.5	1.5	1.0	0.5	1.5	1.5	1.5	0.5	2.0	2.0	1.0	0.5	1.0	2.5	3.0	2.0	1.0
$\bar{X}^*$	0.25		1.25		1.0		1.5		1.25		1.5		0.75		2.75		1.5	
5	1.0	1.0	1.0	1.5	1.0	0.5	0.5	-1.0	1.0	0	-0.5	1.0	1.0	0	1.5	0	1.5	2.0
$\bar{X}^*$	1.0		1.25		0.75		-0.25		0.5		0.25		0.5		0.75		1.75	
6	-1.0	-1.0	-1.5	-1.0	-0.5	-0.5	-0.5	0.5	1.0	-2.0	0	-1.0	0	0	-1.5	-1.0	0	-2.0
$\bar{X}^*$	-1.0		-1.25		-0.5		0		-0.5		-0.50		0		-1.25		-1.0	
7	0	-1.0	1.0	-0.5	-1.0	0	-0.5	-1.5	-0.5	2.0	-0.5	0	-1.5	0	-0.5	0	-1.5	0
$\bar{X}^*$	-0.5		0.25		-0.5		-1.0		0.75		-0.25		-0.75		-0.25		-0.75	
8	0.5	1.0	-0.5	1.0	0.5	0	0.5	0.5	-2.0	-1.5	0	0.5	-1.0	0	1.0	1.0	-1.0	0.5
$\bar{X}^*$	0.75		0.25		0.25		0.5		-1.75		0.25		-0.5		1.0		-0.25	
9	0.5	0.5	0.5	0	0	0.5	0.5	-0.5	1.5	0.5	0.5	0.5	1.0	0.5	0	-0.5	1.0	0.5
$\bar{X}^*$	0.5		0.25		0.25		0		1.0		0.5		0.75		-0.25		0.75	
10	-1.0	-0.5	-0.5	0.5	-0.5	0	-1.0	-0.5	0	-0.5	-0.5	-0.5	-1.5	-0.5	0	0	0	0
$\bar{X}^*$	-0.75		0		-0.25		-0.75		-0.25		-0.5		-1.0		0		0	
11	0.5	0.5	0	-3.0	0	0.5	1.0	1.0	0	0.5	1.0	-1.0	1.0	1.0	0	0.5	1.5	0.5
$\bar{X}^*$	0.5		-1.5		0.25		1.0		0.25		0		1.0		0.25		1.0	
12	0	0	-0.5	2.0	0.5	-2.5	0.5	-1.0	-1.0	-1.5	-1.0	-0.5	-1.0	-1.0	0	-1.0	-1.0	-1.5
$\bar{X}^*$	0		0.75		-1.0		-0.25		-0.75		-0.25		-1.0		-0.5		-1.25	
Total for 12 weeks	-0.5	0.5	-1.0	2.0	1.0	-0.5	2.5	-1.5	1.5	-1.0	1.5	1.0	-0.5	2.5	3.0	1.5	1.5	3.5
$\bar{X}^{**}$	0		0.50		0.25		0.50		0.25		1.25		1.0		2.25		2.50	

Note

$\bar{X}^*$ = group mean

$\bar{X}^{**}$ = mean of group means in the 12 weeks.

Appendix 30. *Analysis of variance of liveweight changes by the 9 treatment groups as affected by the levels of protein and energy rich concentrate supplementation to C. *gayana*.

Source			df	ss	Mss	F	P
Weeks			11	63.10	5.74	10.44	<0.01
Treatments			8	1.08	0.14	0.54	NS
Levels of supplementation with BM		2		0.17	0.09	0.35	NS
BM linear	1			0.16	0.16	0.62	NS
BM quadratic	1			0.01	0.01	0.04	NS
Levels of supplementation with MM		2		0.75	0.38	1.46	NS
MM linear	1			0.69	0.69	2.65	NS
MM quadratic	1			0.06	0.06	0.23	NS
BM x MM		4		0.16	0.08	0.31	NS
BM_L x MM_L	1			0.07	0.07	0.27	NS
Treatments x weeks			88	77.4769	0.88	1.60	<0.01
Replicates			1	0.01	0.01	0.04	NS
Treatments x replicates			8	2.07	0.26		
Treatments x replicates x weeks			99	54.42	0.55		
Total			215	198.16			

Note

* A figure 5 was added to all the observations in Appendix 30 for analysis of variance.