CHAPTER 1

INTRODUCTION AND LITERATURE REVIEW

1.1 Indices of nutritive value and nutritive value of experimental forages

The nutritive value of feeds is conventionally classified under three general components: digestibility, feed consumption (voluntary intake) and the efficiency with which feed energy is utilized (Raymond, 1969). Voluntary intake and the rate and extent of digestion are in turn influenced by the animal consuming the forage, physical characteristics of the forage like the morphological and anatomical characteristics and the chemical properties of the forage. A further component of the nutritive value of feed for ruminants is the degradation of proteins in the rumen. Chalmers and Synge (1954) noted that the nutritive value of feed proteins for ruminants varies inversely with the extent of degradation of the proteins in the rumen.

The extent of dietary protein degradation in the rumen has been related to its solubility (Sherrod & Tillman, 1962; Evans & Biddle, 1971; Peter et al., 1973; Wohlt et al., 1973; Aitchison et al., 1976; Aii & Stobbs, 1980). Protein degradation has led to considerable interest in the concept of by-pass proteins which are thought to leave the rumen intact and escape degradation. By-pass protein fed as a

supplement or forage with by-pass protein characteristics would have the following advantages:

a) it would supply dietary amino acids for absorption.

b) supply glucogenic precursors at tissue level and therefore act as an energy supplement (Lindsay & Armstrong, 1982). This role seems vital when one considers the poor response to energy supplements on high quality pastures due to extensive interaction between energy supplements and pasture digestion (Langlands, 1969).

c) prevent bloat due to reduced plant protein degradation in the rumen (Barry, 1984).

Thus sainfoin or any other forage with by-pass protein characteristics could be used as a sole pasture or in combination with pasture herbs like sheep's burnet which has some feeding potential. Forages with by-pass protein characteristics could also be used in combination with low quality grasses, as by-pass protein has been demonstrated to increase feed intake in sheep (Egan, 1965) and milk production by 20% when formaldehyde treated casein was given to dairy cows feeding on tropical grass (Stobbs et al., 1977). Further evidence was provided by Flores et al. (1979) who showed that a supplement of the tropical legume Leucaena leucocephala increased milk yield in a manner similar to formaldehyde treated casein. They deduced from this observation that L. leucocephala may be more resistant to

deamination in the rumen than the protein in grasses.

The few references to sainfoin in the literature indicate a fodder crop of modest soil requirements and many desirable characteristics, and which has always been prized as a hay for livestock especially brood mares in racing stables (Baker,1952). Work done has shown that the availability to the animal of sainfoin protein appears to be exceptionally high due to low degradation in the rumen (Shedrick & Thomson, 1982). Thomson (1976) noted that sainfoin is a safe food since it does not cause bloat and is more digestible and has a higher voluntary intake than lucerne, red clover or S24 and S22 ryegrass. However there have been contradictory reports on its digestibility (Wilman & Asiedu, 1983; Meissner et al., 1989).

There is virtually no reference to sheep's burnet in the literature. Information gleaned from farmer information leaflets especially in New Zealand, however, indicate a palatable forage that does well even under demanding conditions and provides grazing over a wide range of lower fertility and harsh environmental conditions. Its bloat-free properties have also been noted by farmers in New Zealand Bulletins.

The importance and wide use of lucerne (alfalfa) in many parts of the world, its high digestibility (Wilman et al.,

1977; Wilman & Asiedu, 1983) and nitrogen content (Joyce et al., 1973; Wilman et al., 1983) and its bloat inducing properties makes it an ideal forage for comparison with sainfoin and sheep's burnet.

1.2 Evaluating pastures for yield and quality or nutritive value.

The yield of animal products from pastures depends on a number of associated factors. These factors must be measured, or at least estimated, in order to improve the utilization of forages. Van Soest (1982) summarized these factors or components in the form of a table (Table 1.1). Earlier work in this regard had been done by Raymond (1969), Streeter (1969), Langlands (1975) and Cordova et al. (1978).

Table 1.1 Methods of pasture evaluation.

Aspect	Factor	Method
Forage yield		Cages, clipping
Forage quality	Composition	Chemical analysis
	Digestibility	Oesophageal fistulae, in vitro rumen, faecal bag or grab sampling, markers
	Intake	
Animal yield	Carrying capacity	Stocking rate, put and take, yield/ha
	Efficiency	Portable respiration apparatus

In addition to the factors listed, the rate and extent of degradation of feed protein in the rumen (as discussed before), has been long recognized by several researchers as an important determinant of the nutritive value of feed for ruminants (Chalmers & Synge, 1954; Sherrod & Tillman, 1962; Little et al., 1963; Whitelaw & Preston, 1963; Sharma et al., 1972; Peter et al., 1973; Aitchison et al., 1976). Thus, protein degradation in the rumen is a factor that cannot be ignored in any comprehensive evaluation of pasture for quality or nutritive value.

1.2.1 Dry matter yield as an index of nutritive value and its estimation.

The importance of dry matter yield data in any comprehensive system of pasture evaluation does not lie only in the fact that it ultimately determines the amount of plant material and therefore nutrients available to the grazing animal, but also due to the fact that there is a relationship between forage quality and forage yield. Both experimental and practical evidence suggests that as a forage crop grows to maturity its nutritive value generally tends to decrease (partly due to changes in the ratio of plant parts). Thus, the practical exploitation of any crop involves a compromise between yield and nutritive value. Data on yields at different stages of maturity and digestibilities obtained by in vitro techniques can be used to compile yield-digestibility relationships for different forages and

a comparison in terms of their yields at the given levels effected. Raymond (1969) reported work done by Green at the Grassland Research Institute, Hurley, in the form of graphs for S24 ryegrass during its first growth in spring (Figure 1) and also the yields of different grass varieties at an organic matter digestibility of 65% (Figure 2).

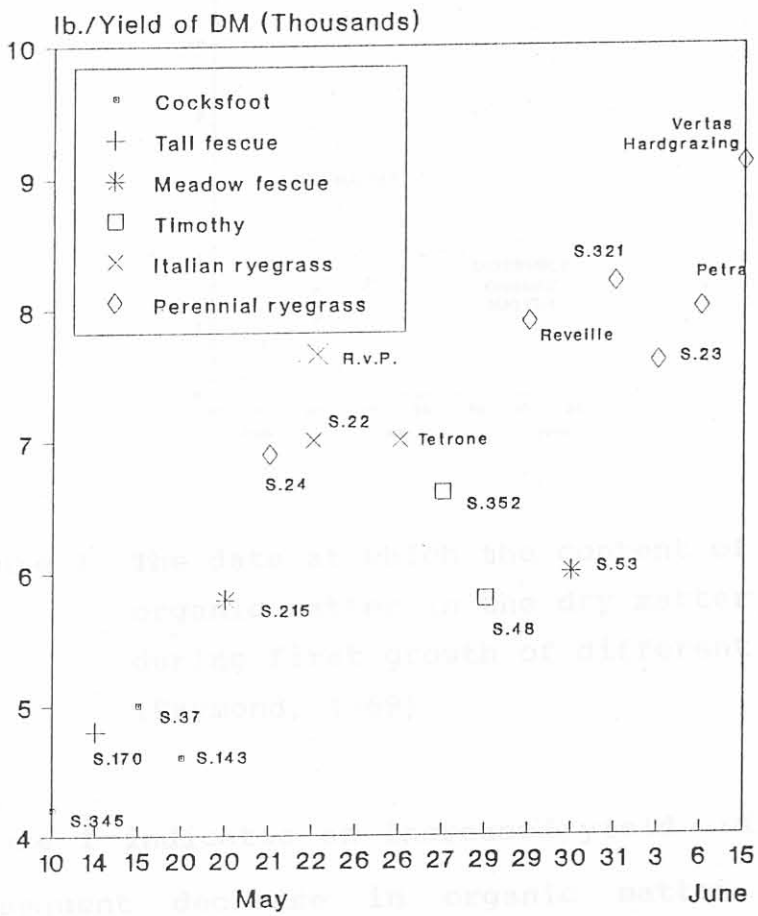

Figure 1. The changes in yield and digestibility of the first growth of S.24 ryegrass during first growth in spring (Raymond, 1969).

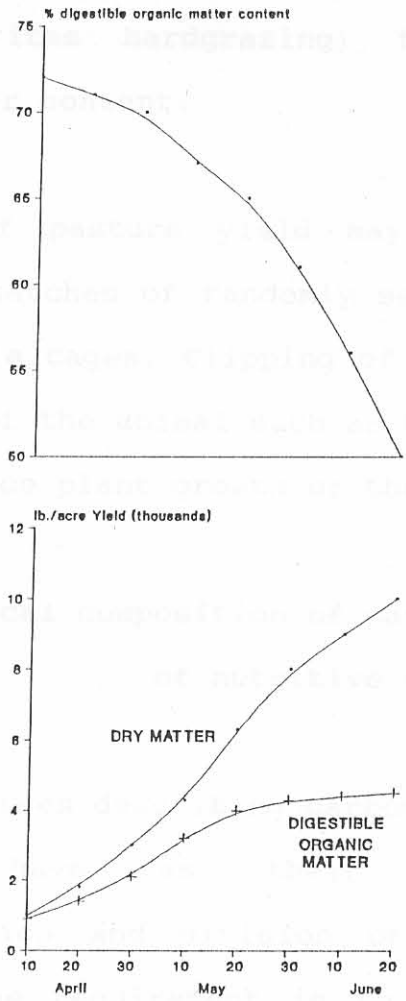

Figure 2. The date at which the content of digestible organic matter in the dry matter falls to 65% during first growth of different grass varieties (Raymond, 1969).

Figure 1 indicates an increased yield with maturity, but a consequent decrease in organic matter digestibility. A compromise therefore has to be sought between digestibility and yield. Figure 2 indicates the higher yields of ryegrass than other grass species harvested at the same digestibility and the interval of 23 days between the dates at which the digestibility of the earliest (S24) and the latest ryegrass

variety (Veritas hardgrazing) falls to 65% digestible organic matter content.

Estimation of pasture yield may be accomplished by the clipping of patches of randomly selected areas protected by use of movable cages. Clipping of protected area eliminates the effects of the animal such as trampling and manure spots which influence plant growth or the plant (Van Soest, 1982).

1.2.2 Chemical composition of pasture as an index of nutritive value.

Chemical analyses describing carbohydrate, protein and fiber fractions, have as their first objective the characterization and division of the dry matter of the feedstuff. The requirement is to establish a relationship between these fractions and a nutritional parameter (eg. digestibility) of forages measured in controlled in vivo experiments from which the nutritive values of other forages can be predicted.

The Weende system of proximate analysis has been generally used for chemical evaluation of feedstuffs in both ruminant and non-ruminant nutrition for more than a century. However criticism of the crude fibre method and the calculation of the nitrogen free extract (NFE) led to serious efforts to find a replacement. Norman (1935) established the inadequacy

of crude fibre as a determinant of nutritive value. Other fibre methods were subsequently proposed including cellulose (Crampton & Maynard, 1938), holocellulose (Ely & Moore, 1955) and eventually the detergent systems (Van Soest, 1963; Van Soest & Wine, 1967) which are in widespread use today. Table 1.2 shows the fractionation of forage organic matter by the system of analysis using detergents.

Table 1.2 Division of forage organic matter by the system of analysis using detergents (Van Soest, 1965).

Fraction	Components
Cell contents (soluble in neutral detergent)	Lipids Sugars, organic acids and water soluble matter Pectin Starch Non-protein nitrogenous compounds Soluble proteins
Cell wall constituents (fiber insoluble in neutral detergent) 1) Soluble in acid detergent 2) Acid-detergent fiber	 Fiber-bound protein Hemicellulose Cellulose Lignin Lignified nitrogenous substances

1.2.2.1 Correlations between chemical composition and nutritive value.

Summarizing work done with a total of 121 forages from different locations in the United States, Van Soest (1965) deduced that in terms of chemical composition and nutritive value the only consistent effect that could be observed for all forages is that of the total fibrous fraction or cell wall constituents. Van Soest (1984) and Allen (1990) reported work done by Mertens with 187 forages (126 grasses and 61 legumes) from 15 experimental sites in the United States and fed at different stages of growth. Table 1.3 and 1.4 indicate correlations of chemical and fermentation parameters with voluntary intake and digestibility.

Table 1.3 Correlations of forage components with voluntary intake and digestibility (Van Soest, 1984).

Component	Intake	Digestibility (in vitro)
Digestibility (in vivo)	+0,61	+0,80
Digestibility (in vitro)	+0,47	
Lignin	-0,08	-0,75
ADF	-0,61	-0,44
Crude protein	+0,56	+0,56
Cellulose	-0,75	-0,45
Cell wall	-0,76	-0,45
Hemicellulose	-0,58	-0,12
Rate of digestion	+0,53	+0,44

Table 1.4 Correlations of ad libitum dry matter intake (kg/$LW^{0.75}$*) with chemical and in vitro fermentation parameters of 126 grasses and 61 legumes (Allen, 1990).

	Grasses	Legumes	Combined
NDF	-0,74	-0,69	-0,76
ADF	-0,69	-0,77	-0,64
Rate of NDF digestibility	+0,66	+0,26	+0,55
Lag	-0,47	-0,45	-0,48
In vitro digestibility			
0h	0,75	0,67	0,75
6h	0,79	0,68	0,79
12h	0,77	0,68	0,74
24h	0,76	0,71	0,64
48h	0,72	0,69	0,46
96h	0,70	0,67	0,36

* LW - livemass

The two tables indicate a high correlation between NDF and intake whilst ADF and lignin are more related to digestibility. It is also evident from the tables the errors that are likely to be made when attempts are made to predict intake from digestibility since the two parameters do not show a consistent relationship.

1.2.3 Voluntary intake and digestibility as indices of nutritive value and their estimation.

Measurements of voluntary intake and total gut tract digestibility are among the most critical estimates required to evaluate the nutritional status of forages for ruminants (Gaylean et al., 1986). Van Soest (1982) noted that intake and efficiency indicate more inter-animal variation (Table

1.5) than digestibility and that it is more difficult to establish feed values for intake and efficiency.

Table 1.5 The approximate relative variation contributed by animal and diet (forage) (Van Soest, 1982).

	Coefficient of variation %	
	Diet	Animal
Digestibility	30	3
Intake	50	30
Efficiency[a]	50	20

a - Use of energy for productive purposes

Thus digestibilities are commonly measured and exclusively used though intake and efficiency are more responsible for total animal responses. Ingalls et al. (1965) concluded that 70% of the variation in production potential between forages can be accounted for in terms of differences in voluntary intake and 30% by differences in digestibility. Gaylean et al. (1986) noted that estimates of nutrient intake in grazing ruminants are typically derived by coupling faecal output data with nutrient indigestibility and that methods that provide accurate and precise estimates of faecal output and digestibility are paramount to a critical evaluation of nutrient intake and digestive physiology in grazing ruminants. Thus, the methods for estimating faecal output, digestibility and intake of grazing ruminants are not mutually exclusive.

1.2.3.1 Methods for estimating faecal output, digestibility and intake of grazing ruminants.

1.2.3.1.1 Total collection of faeces.

This is known as the "standard", "conventional" or direct method. Faecal collection bags have been used in many grazing and confinement trials to determine intake in cattle and sheep. Male animals have generally been used because the separation of urine and faeces is satisfactory. However, when intake and digestibility information particularly relating to nutrition of female physiological processes is required, a female animal must be used and a faeces-urine separator employed (Kartchner & Rittenhouse, 1979).

Problems associated with the method include the fact that it is labour intensive, requires selection of animals with appropriate temperament for harnessing and behavioral modifications due to harnessing and inconsistency of faecal output (Gaylean et al., 1986). However random errors resulting from inconsistency of faecal excretion decrease as the length of the collection period increases. Gaylean et al. (1986) suggested four days as the minimum with seven or more being more appropriate.

Digestibility may be estimated in vitro from samples collected by oesophageally fistulated animals and intake determined from faecal output and digestibility (Langlands,

1975). Digestibility may also be estimated from ratio or index techniques.

1.2.3.1.2 Ratio techniques.

These involve the calculation of digestibility and faecal output through their ratio to an "indigestible" indicator or marker (Cordova et al., 1978). Intake may be calculated once the digestibility and faecal output have been determined from the simple equation:

$$\text{Organic matter intake} = \frac{\text{faecal organic matter output}}{\%\ \text{organic matter indigestibility}}$$

1.2.3.1.2.1 Internal markers or indicators

With internal indicator methods indigestibility is computed by dividing the concentration of a naturally occurring substance in the diet by the concentration of the same substance in the faeces. Digestibility is then calculated by subtracting indigestibility from unity (Streeter, 1969). Internal marker methods that have been used include: chromogen ratio (Reid et al., 1950; Cook & Harris, 1951), lignin ratio (Connor et al., 1963; Wallace & Van Dyne, 1970; Cordova et al., 1978), silica (Jones & Handreck, 1965; McManus et al., 1967), acid insoluble ash (Penning & Johnson, 1983a), potentially indigestible cellulose (Wilkins, 1969; Penning & Johnson, 1983a), indigestible acid detergent fibre (Penning & Johnson, 1983b), indigestible neutral detergent fibre (Lippke et al., 1986), long chain

fatty acids (Body & Hansen, 1978) and long chain n-alkanes (Mayes & Lamb, 1984; Mayes et al., 1986; Dove, Foot & Freer, 1989; Dove, Mayes, Freer, Coombe & Foot, 1989).

1.2.3.1.2.2 External markers or indicators

An external indicator is one which is administered in known amounts. Faichney (1975) summarized the properties of an ideal marker as follows:

1. It must be strictly non-absorbable.
2. It must not affect or be affected by the gastro-intestinal tract or its microbial population.
3. It must be physically similar to or ultimately associated with the material it is to mark.
4. Its method of estimation in digesta samples must be specific and sensitive and it must not interfere with other analyses.

The last point emphasizes the use of markers not only in determining faecal output and feed intake but in the partitioning of digestion within the gastro-intestinal tract, by measuring the quantity and composition of digesta flowing past either re-entrant cannulae (MacRae, 1975) or simple T-shaped cannulae. Digesta flow from the rumen, however, is a discontinuous process, with the fluid and particulate phases flowing at different rates. Therefore the use of a single marker with spot sampling from re-entrant cannulae or simple T-shaped cannulae may give erroneous

estimates of flow due to unrepresentative sampling of the digesta in terms of a preferential selection of the two phases (Siddons et al., 1985). Faichney (1975) demonstrated that this problem could be solved by using two markers in a dual phase system: one to mark the fluid (liquid) phase and the other the particulate phase of digesta.

A comprehensive review of markers and their applications in nutrition has been given by Kotb & Luckey (1972). However, some markers that have been used in recent times in digestibility and intake determinations and the measurement of digesta flow along the alimentary tract include: chromium sesquioxide (Cr_2O_3) (Drennan et al., 1970; Faichney, 1972; Langlands, 1975; Gaylean et al., 1986), the ^{51}Cr complex of ethylenediaminetetraacetic acid (Cr-EDTA) (Downes & McDonald, 1964; Weston & Hogan, 1967; Faichney, 1975), chromium mordant (Uden at al., 1980), the Li or Na salt of Co(III) EDTA (Uden et al., 1980), polyethylene glycol (PEG) (Kay, 1968), Ytterbium (Yb) labelled feedstuffs (Gaylean et al., 1986), Yb acetate (Downes & McDonald, 1964; Drennan et al., 1970; Faichney & Weston, 1971; Hogan & Weston, 1971; Beever et al., 1978; Siddons et al., 1985) and cerium (Uden et al., 1980).

1.2.3.1.3 Index techniques.

These methods generally relate level of intake or digestibility to some component in the faeces through a regression equation. The motivation for the technique arose due to the difficulty in obtaining a representative dietary sample by handclipping of forages (Raymond, 1954). The most common faecal component that has been used is faecal nitrogen. Faecal chromogen has also been used. The faecal nitrogen method entails harvesting herbage for conventional digestion trials to establish a regression between digestibility and percent nitrogen in the faeces. The assumptions behind the faecal index method are:

1) The herbage fed to the animal is similar to that grazed by the animal, and
2) the penned and grazing animals digest herbage to the same degree (Wallace & Van Dyne, 1970).

An advantage of the method is that it does not require sampling of the grazed forage. Weaknesses of the method include:

1) The assumption that the faecal index relationship is the same for forages selected by grazing animals as for forage fed in a conventional feeding trial (Streeter, 1969).
2) The regression varies between first growth and aftermath herbage (Greenhalgh & Corbett, 1960).
3) It estimates digestibility of a group of animals rather

than individuals (Van Dyne & Meyer, 1964).

4) The regression varies from year to year (Topps, 1962).

5) The regression varies for different cultivars of the same species of forage (Minson & Milford, 1967).

1.2.4 Protein degradation in the rumen as an index of nutritive value and its estimation.

Degradation of protein in the rumen is an important value to be used for the prediction of protein passing undegraded to the small intestine for the calculation of protein utilization and protein requirements of ruminants (Raab et al., 1983). Chalmers and Synge (1954) reported an inverse relationship between the nutritive value of feed protein and the extent of its degradation in the rumen.

1.2.4.1 Estimation of protein degradation.

1.2.4.1.1 Protein solubility in mineral buffers.

The extent of dietary protein degradation in the rumen has been related to its solubility by several researchers (Sherrod & Tillman, 1962; Evans & Biddle, 1971; Aitchison, 1976) and attempts have been made to estimate protein degradation from solubility tests (Peter et al., 1973; Wohlt et al., 1973; Crooker et al., 1978; Chamberlain & Thomas, 1979; Krishnamoorthy et al., 1982). Aii and Stobbs

(1980) determined the solubility of some tropical grasses and legumes in Burrough's mineral mixture and found that the solubility varied between grasses with lowest values found for Digitaria decumbens, Panicum maximum and Setaria anceps and the highest protein solubility found in Panicum coloratum, Bracharia mutica and Chloris gayana. With the legumes Desmodium intortum and Desmodium uncinatum had the lowest solubilities and Macroptilum uniflorum, the highest. Abdalla et al. (1988) found no differences in solubility due to forage type or harvest type (Year 1 or 2) when he compared the solubility of Timothy, Brome and Orchard grasses and Fescue and combinations of Trefoil and grass or grass alone. Mineral solvents or buffers that have been suggested for the estimation of protein solubility include Wise Burrough's mineral mixture (Burrough's et al., 1950), McDougalls artificial saliva (Peter et al., 1973), bicarbonate phosphate buffer, autoclaved rumen fluid, NaCl and borate phosphate buffer (Krishnamoorthy et al., 1982). Broderick & Craig (1980) however noted that techniques such as protein-solubility may be inaccurate because they tend to measure the properties of only the rapidly degraded fractions and not those of the protein as a whole.

1.2.4.1.2 Use of commercial proteases.

Poos et al. (1980) reported the use of five commercial proteolytic enzymes (bacterial protein, papain, ficin,

bromelain and fungal protease) in predicting rumen degradation and percent by-pass of various protein sources. They noted that fungal protease gave the highest correlation across all incubation times (1 - 24 hours). Chamberlain & Thomas (1979) used a mixture of artificial saliva and a mixed protease (Streptomyces griseus) and protein breakdown was measured as a proportion of N not precipitated with 1.2 M trichloroacetic acid.

1.2.4.1.3 Use of duodenally cannulated animals and digesta markers (Faichney, 1975; MacRae, 1975).

These techniques have been used to obtain measurements of protein flow into the abomasum. Used in conjunction with microbial markers such as RNA or DAPA (Ling & Buttery, 1978) or isotopes such as ^{35}S, ^{32}P or ^{15}N (Pilgrim et al., 1970; Walker & Nader, 1975; McMeninam et al., 1976; Van Nevel & Demeyer, 1977), determinations of microbial protein synthesis can be obtained. A flow of true protein nitrogen and the proportion of ingested nitrogen degraded in the rumen can then be obtained.

1.2.4.1.4 Use of mathematical models.

In an attempt to recognize the importance of rumen dynamics and associated factors such as rate of passage, rate of degradation and lag time before degradation begins,

mathematical models have been employed to predict dietary protein degradation in the rumen. Prominent are:

1) The model by Ørskov and McDonald (Ørskov & McDonald, 1979) applied basically to the use of polyester bags to incubate feed protein in the rumen of a fistulated animal (In situ technique) (Ørskov & Mehrez, 1977; Nocek, 1985).
2) The model by Broderick and Craig (Broderick & Craig, 1980) to interpret data from in vitro incubations conducted using ratios of protein to ruminal fluid similar to those expected in vivo.

Both models are similar in their assumptions of the heterogeneity of feed protein and first order kinetics for degradation and passage of protein from the rumen.

Thus in the model proposed by Ørskov and McDonald the amount of protein (p) degraded at time (t) is given by the exponential equation

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

where a is interpreted as the rapidly soluble protein fraction, b the amount which in time will degrade and c the fractional-rate constant at which the fraction described by b will be degraded per hour. The equation is normally constrained so that a + b cannot exceed 100%. The constants in the exponential equation are then determined by curve fitting (Ørskov, 1982) or an iterative least square procedure.

1.2.4.1.5 Other techniques for estimating protein degradation in the rumen.

Other methods employed include the prediction of protein degradation from the release of ammonia (NH_3) (Raab et al., 1983; Chamberlain & Thomas, 1979) from the incubation of a feedstuff with rumen fluid in vitro. A colorimetric method (Mahadevan et al., 1979) where the protein is converted into a highly colored diazotized derivative is also employed. The derivative is subsequently incubated in vitro with rumen microorganisms and the amount of the undigested precipitable diazo-protein determined.

1.3 Growth and nutritive value of experimental forages.

1.3.1 Sainfoin.

1.3.1.1 Growth characteristics.

Little research effort has been devoted to the growing of sainfoin. A survey of the few references available reveal the following:

a) It is a deep rooting perennial well adapted to drought conditions and frost tolerant.
b) It seems to prefer calcaerous soils (Baker et al., 1952).
c) It is a crop of modest requirements and does not respond to fertilization with phosphorus (Roath & Graham, 1968).

1.3.1.2 Nutritive value of sainfoin.

1.3.1.2.1 Yield and leaf to stem ratios.

The poor establishment and low yields of sainfoin (Wilman & Asiedu, 1983) in comparison to other forage legumes may account for the low research interest shown in its growing. Varga (1968), however, showed that leafier varieties with improved after growth capacities were attainable through vigorous breeding programs.

Baker (1952) cut sainfoin, grown under dryland conditions, at different physiological stages of growth and reported mean dry matter yields of 9,13 t/ha*. When the first full flowering cut was made into hay, yields of 7,25 t/ha* were obtained.

Leaf:stem ratios ranging from 1,17 to 0,70 were obtained for the first and subsequent re-cuts for the pre-flowering stage; 0,74 to 0,64 for the early flower stage and 1,98 to 0,52 for the full flower stage. Wilman and Asiedu (1983) in a study with sainfoin, red clover, lucerne and ryegrass under dryland conditions noted dry matter yields (t/ha) of 1,017; 1,504 ; 2,030 and 3,899 respectively for three primary growth and four regrowth periods. The percentage of green leaf in dry matter were 79,3; 84,2; 63,2 and 54,8 in the same order. Mean dry matter yields (t/ha*) of 6,73 when

* computed from t/acre by multiplying by 2,5

cut as pasture and 8,68 when sainfoin was cut as hay were obtained in Reno, Nevada (Jensen & Sharp, 1968). Hanna and Smoliak (1968) recorded the following results from several hay tests in Canada: dry matter yields (t/ha*) for different cultivars under dry land conditions ranged from 3,48 to 7,10 (compared with 10,70 for lucerne) in Saskatchewan; 4,95 to 7,55 (8,40 for lucerne) in Lethbridge (irrigated); 4,95 to 7,08 (9,08 for lucerne) also in Lethbridge (dryland conditions); 9,50 to 13,25 (13,38 for lucerne) in Winnipeg and 1,13 to 4,20 (5,60 for lucerne) in Melfort. In these tests Eski and some Russian strains provided the most promise. The authors noted the following results for a dryland grazing test (Table 1.6):

Table 1.6 Relative yields and apparent consumption by sheep in dryland grazing test, Lethbridge, 1968.

	Yield as % of alfalfa	Apparent %	Consumption lbs DM
Alfalfa	100	61	494
Sainfoin	108	83	718
Alfalfa + CWG[a]	100	55	445
Sainfoin + CWG	98	61	476

a - crested wheatgrass

Comparing data on different sainfoin cultivars and other common legume fodder crops, Carleton et al. (1968) drew the following conclusions:

i) Eski sainfoin has yielded less than, as much as, or more than alfalfa (lucerne) depending upon location and year

* computed from t/acre by multiplying by 2,5.

of production.

ii) Eski has been more productive than all other one-cut sainfoin varieties and lines tested and equal in yield to one multi-cut type sainfoin.

iii) Sainfoin yields generally more in the first cutting and less in the second cutting than alfalfa.

iv) Sainfoin recovers more slowly following cutting than alfalfa. Frequent cutting affects sainfoin more adversely than alfalfa due to an increased loss of stand.

v) Yields of sainfoin in the third year after seeding may be reduced because of a decrease in stand.

1.3.1.2.2 Chemical composition, digestibility, voluntary intake and animal performance on Sainfoin.

Baker (1952) recorded the following chemical composition of sainfoin (Table 1.7).

Table 1.7 Average composition of sainfoin at different growth stages.

	Preflowering		Early flower		Full flower	
	1949	1950	1949	1950	1949	1950
Dry matter(%)	24,5	20,2	25,5	20,6	27,3	23,1
	Percentage composition of dry matter					
Crude protein	20,4	21,5	18,7	20,2	17,4	17,5
Ether extract	2,4	2,8	2,5	2,6	2,5	2,4
Crude fibre	15,1	18,2	20,6	21,2	22,4	24,9
N-free extract	56,4	50,2	52,4	49,3	51,8	47,7
Total ash	5,7	7,3	5,8	6,7	5,9	7,1
Silica	0,1	0,2	0,1	0,1	0,2	0,1
Silica-free ash	5,6	7,1	5,7	6,6	5,7	7,0
CaO	1,88	2,13	2,05	2,05	2,13	2,15
P_2O_5	0,66	0,61	0,62	0,62	0,53	0,57
K_2O	1,11	1,76	0,95	1,53	0,87	1,61
MgO	0,49	0,45	0,46	0,44	0,50	0,41
Chlorides as NaCl	0,46	0,71	0,37	0,64	0,32	0,65
True protein	17,6	18,7	15,4	17,6	15,1	15,6
"Amides"	2,8	2,8	3,3	2,6	2,3	1,9

Davis (1968) recorded crude protein content of sainfoin leaf of 11 varieties from the U.S.S.R., ranging from 15,1% to 17,7% (mean 16,3%). Wilman and Asiedu (1983) obtained a nitrogen content (mean of two primary growth and two first regrowth periods of age 8 weeks) of 3,43% compared to red clover (4,83%), lucerne (4,52%) and ryegrass (3,15%).

Terry and Tilley (1964) noted that in contrast to lucerne, the in vitro digestibility of the leaflets and petioles of sainfoin were considerably less than those of lucerne leaves and that sainfoin stems were much more digestible than those of lucerne of a similar whole plant digestibility. Their results showed in vitro dry matter digestibilities of 70%; 71%; 72% and 74% for Cotswold common, Giant, Local Russian and Turkish Anatolian cultivars of sainfoin. Wilman & Asiedu (1983) reported in vitro dry matter digestibility of 63,2% for sainfoin in contrast to 69,1%; 67,2% and 67,7% for red clover, lucerne and ryegrass respectively. The digestibilities for sainfoin 65,2% (leaf) and 64,7% (stem) were in contrast to 75% for lucerne leaf and 60,4% for stem. Meissner et al. (1989) reported an in vitro digestibility of organic matter of material from oesophageal fistulae for sainfoin of 49,9% (November, 1986) and 49,5% (June, 1987) and voluntary organic matter intakes per metabolic livemass of 37,5g and 37,8g for the two periods. Hanna and Smoliak (1968) reported higher apparent consumption of sainfoin and a mixture of sainfoin and crested wheatgrass than lucerne and its mixture with the same grass (Table 1.6). In a study with young sheep grazing pure species plots grown under high soil fertility conditions, Barry (1984) reported that with the exception of Huia white clover, there were higher livemass gains on Fakir sainfoin compared to Maku lotus, Wairau lucerne, Hamua red clover and Ruanui ryegrass.

1.3.1.2.3 Condensed tannins and nutritive value of sainfoin.

Condensed tannins are polymeric flavanols and confer both beneficial and detrimental effects depending upon tannin molecular weight and reactivity with proteins (Barry, 1984). Legumes containing substantial concentrations of condensed tannins in leaf and stem tissue do not cause bloat due to precipitation of soluble plant proteins in the rumen. Another consequence thereof is the higher availability of the protein postruminally. High molecular weight (17000 - 28000) condensed tannins (6% of DM) occur in the leaves and stems of sainfoin (Barry, 1984). Because of the higher molecular weight of the tannins in sainfoin, rumen carbohydrate digestion is not so depressed but the tannins are not so efficient at increasing amino acid supply in the lower digestive tract as the low molecular weight tannins found in Lotus spp. and other plants (Barry, 1984).

1.3.2 Sheep's Burnet.

There appears to be very little scientific information on this promising herb. Information gleaned from New Zealand farmer information leaflets and John Fair's Guide to Profitable Pastures (Fair, 1989) gives the following picture about the growth and nutritive value:

i) Even though its cultivation dates back to the turn of the century in this country, it has only received attention recently when it came into the country as a

contaminant of imported sainfoin seed.

ii) It is a deep-rooting (tap root up to six meters long) herb with a reputation for survival and continued production over a wide range of low soil fertility, cold and dry conditions. It responds vigorously, however, to water and grows best in 500 - 600 mm rainfall regions but can survive where rainfall is as low as 300 mm annually. It tolerates a pH range of 5 - 8. The most productive periods are autumn/winter and early spring but it will continue to give foggage in summer.

iii) It has a long establishment period of about 12 - 18 months.

iv) It is an aggressive competitor for soil moisture and seems to suppress and smother weeds.

v) It can be mixed with hardy grasses such as perennial wheatgrass, Brome or Tall oat grass or planted in conjunction with Lotus corniculatus or sainfoin.

vi) It has a further important role to play in soil conservation (Fisher et al., 1987).

vii) It produces a copious amount of seed and germinates profusely from self sown seeds.

1.3.3 Lucerne.

1.3.3.1 Growth characteristics.

Lucerne is adapted to a wide range of environmental

conditions. Its strong tap root system enables it to draw moisture from great depths resulting in good production on soils with a deep water table and from deep soils during droughts (Fair, 1989).

1.3.3.2 Nutritive value of lucerne.

1.3.3.2.1 Yield and leaf to stem ratios.

A lot of research work has been done on yields of lucerne. A few well chosen examples, however, would give a good overview of the yields of lucerne pasture. Table 1.8 shows yields of lucerne at different physiological stages of growth in a study at Wairakei Experimental station, Taupo, New Zealand.

Table 1.8 Yields of lucerne pasture at different stages of growth (Joyce et al., 1973).

	EV	LV	BF	FL
Yield (kg/ha)				
Dry matter	2498	3469	4159	4650
Digestible organic matter	1631	2184	2392	2607
Crude protein	744	917	1030	1028
Digestible crude protein	600	709	796	771

EV - Early vegetative
LV - Late vegetative
BF - Before flowering
FL - Flowering

Willman and Asiedu (1983) reported dry matter yields (t/ha) of 2,03 for three primary growth and four regrowth periods under dryland conditions and green leaf expressed as a percentage of dry matter of 60,7 for three primary growth and four regrowth periods at Aberystwyth, Wales. Rethman et al. (1986) reported yields (t DM/ha) ranging from 3,75 to 7,01 under dryland conditions at different espacement at the Nooitgedacht Research station, Ermelo, in the Eastern Highveld region of South Africa.

1.3.3.2.2 Chemical composition, digestibility, voluntary intake and animal performance on lucerne.

Table 1.9 shows the chemical composition of lucerne and digestibility of lucerne at different physiological stages of growth.

Table 1.9 Chemical composition and digestibility of lucerne (Joyce et al., 1973).

	EV	LV	BF	FL
% Crude protein	29,8	26,4	24,8	22,1
% Acid detergent fibre	28,2	29,7	33,3	31,4
% Lignin	4,25	5,85	6,5	6,40
% Soluble sugars	5,58	4,85	4,54	5,81
% Ash	14,5	12,3	12,7	10,5
Caloric value (kcal/g)	4,165	4,310	4,110	4,225
% Digestibility				
Organic matter	76,4	71,8	65,9	62,5
Crude protein	80,7	77,4	77,3	74,9
Gross energy	72,1	69,1	61,8	59,9

Terry and Tilley (1964) reported dry matter digestibility of 75% (whole plant), 81% (leaf) and 69% (stem) for young lucerne. The corresponding values for mature lucerne were 66%, 78% and 55% respectively. Wilman and Asiedu (1983) reported a nitrogen content (% of DM) of 4,52 and *in vitro* dry matter digestibility of 67,1% for 8 week old lucerne (mean of two primary and four regrowth periods) and N content of 4,68 (green leaf) and 1,96 (stem) for two primary growth and two first regrowth periods. The corresponding dry matter digestibility for green leaf and stem were 75,0% and 60,4% respectively. Joyce *et al.* (1973) reported the following figures for intake and livemass gain (Table 1.10).

Table 1.10 Growth rate and intake data of hoggets fed lucerne (Joyce *et al.*, 1973).

	Fed *ad libitum*				Fed Maintenance			
	EV	LV	BF	FL	EV	LV	BF	FL
Livemass gain (g/day)	91	85	48	36	16	3	13	16
Wool growth (g/day)	11	12	5	7	5	5	3	3
Dry matter intake (g/day)	724	770	593	571	434	418	441	492
Digestible organic matter intake (g/day)	484	488	375	310	288	265	251	271
Carcass weight (kg)	11,3	11,1	8,8	8,59	8,85	8,13	7,75	8,13
Efficiency of livemass gain (g DM/g LWG)	8,2	9,6	18,4	18,6	-	-	-	-

Meissner *et al.* (1989) working at Hatfield Experimental Farm, Pretoria, recorded organic matter digestibilities (*in*

vitro) of 68,7; 64,3; 63,6; 59,2 (material from oesophageal fistulae) and organic matter intakes (g/kg $W^{0.75}$/day) in mature wethers of 29,8; 33,6; 21,5 and 28,6 in October 1986, November 1987, December 1987 and January 1988.

Cruishank et al. (1985) reported an organic matter intake (g/kg LW*/day) by lambs of 36,5 (DOMI of 31,2). Corbett and Pickering (1979) and Corbett (1979) reported organic matter intakes in lambs of 416 g/day (42g/kg $LW^{0.75}$) and 616 g/day (50 g/kg $LW^{0.75}$/day) respectively. Using cannulated lambs Corbett and Pickering (1979) reported the digestibility of non-ammonia nitrogen postruminally of 70% and 69% for lucerne grazed in February to April and October to December respectively. Corbett (1979) reported a disappearance of non-ammonia nitrogen as a fraction of nitrogen intake of 56,7% and 57,5% for lucerne grazed in February to April and October to December respectively.

* livemass